Univerzitet Crne Gore
EKONOMSKI FAKULTET PODGORICA

UCG
Univerzitet Crne Gore

Broj:01/1087

Podgorica, 23.04.2024.godine

UNIVERZITET CRNE GORE
-Odboru za doktorske studije i Senatu-

PODGORICA

Predmet: Materijal za sjednicu Odbora i Senata

Poštovani,

U skladu sa članom 41, stav 4 Pravila doktorskih studija, dostavljamo Vam materijal za narednu sjednicu Odbora za doktorske studije, odnoso Senata Univerziteta Crne Gore i to:

- dopunu Odluke o imenovanju Komisije za ocjenu doktorske disertacije mr Damira Sindika sa propratnom dokumentacijom.

DEKAN
Prof.dr Mijat Jocović

Univerzitet Crne Gore
Ekonomski fakultet Podgorica
Adresa: **Jovana Tomaševića 37**
81000 Podgorica - Crna Gora
Telefon: **+382 20 241 757** / Fax: **+382 20 244 588**
E-mail: **ekonomija@ac.me** / Web: **www.ekonomija.ac.me**
Žiro-račun: **510-131-35** / PIB: **02016702** / PDV: **30/31-03951-6**

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UNIVERZITET CRNE GORE
EKONOMSKI FAKULTET PODGORICA
DOKTORSKE STUDIJE
Br. 01/ 1088
Podgorica, 23.04.2024.god.

Na osnovu čl. 64. Statuta Univerziteta Crne Gore, člana 41. Pravila doktorskih studija, Vijeće Ekonomskog fakulteta je na sjednici održanoj 23.04.2024.godine donijelo

O D L U K U

1. Vrši se izmjena sastava Komisije za ocjenu doktorske disertacije **„Nelinearna dinamička analiza disekvilibrijuma i haosa u agregatima raspoloživog dohotka, imetka i potrošnje u makroekonomiji Evropske unije“** doktoranda **mr Damira Sindika.**
2. Komisija za ocjenu doktorske disertacije **„Nelinearna dinamička analiza disekvilibrijuma i haosa u agregatima raspoloživog dohotka, imetka i potrošnje u makroekonomiji Evropske unije“** doktoranda **mr Damira Sindika** biće u sastavu:
   - Prof. dr Vladimir Kašćelan, redovni profesor, Ekonomski fakultet Podgorica, Univerzitet Crne Gore, prvi mentor;
   - Prof. dr Ljiljana Kašćelan, redovni profesor, Ekonomski fakultet Podgorica, Univerzitet Crne Gore, drugi mentor;
   - Prof. dr Josip Tica, redovni profesor, Ekonomski fakultet u Zagrebu, Sveučilište u Zagrebu, Republika Hrvatska, član.
   - Prof. dr Maja Baćović, redovni profesor, Ekonomski fakultet Podgorica, Univerzitet Crne Gore, član;
   - Doc. dr Saša Vujošević, docent, Ekonomski fakultet Podgorica, Univerzitet Crne Gore, član.
3. Odluka se dostavlja Centru za doktorske studije UCG na dalji postupak.

O B R A Z L O Ž E NJ E

Komisija za doktorske studije je, u skladu sa čl. 41, stav 4 Pravila doktorskih studija koji predviđa da ukoliko doktorand ima dva mentora komisija mora da ima 5 članova, predložila Vijeću fakulteta da donese Odluku kojom predlaže Senatu UCG formiranje novog sastava Komisije za ocjenu doktorske disertacije **„Nelinearna dinamička analiza disekvilibrijuma i haosa u agregatima raspoloživog dohotka, imetka i potrošnje u makroekonomiji Evropske unije“** doktoranda **mr Damira Sindika**.
Na osnovu izloženog odlučeno je kao u dispozitivu.

DEKAN
Prof.dr Mijat Jocović

DOSTAVLJENO:
-a/a
-referentu doktorskih studija,
-Centru za doktorske studije.
-Senatu UCG.

Prof. Dr Maja Baćović

Mjesto i datum rođenja: Podgorica, Crna Gora, 1976.
Adresa: Jovana Tomaševića 37, Podgorica, Crna Gora
Telefon/Fax: +382 20 241 138
e-mail: majab@t-com.me , majab@ac.me
ORCID ID: https://orcid.org/0000-0002-8865-3924
Web of Science ResearcherID: R-1533-2019

Obrazovanje

- Doktorske studije, Ekonomski fakultet, Univerzitet Crne Gore (2002-2005)
- Postdiplomske studije "Preduzetnička ekonomija", Ekonomski fakultet, Univerzitet Crne Gore (1998-2001)
- Ekonomski fakultet, Univerzitet Crne Gore (1994-1998)
- Gimnazija "Slobodan Škerović", Podgorica (1990-94)

Radno iskustvo:

- Univerzitet Crne Gore, Ekonomski fakultet, Podgorica
  - Redovni professor (Makroekonomija), 2022-
  - Vanredni profesor za oblast Makroekonomija (2017-2021)
  - Prorektor UCG (2015-2017)
  - Član Senata Univerziteta Crne Gore (2013-2014; 2015-2017)
  - V.D. Dekana Ekonomskog fakulteta (novembar 2014-februar 2015, februar-april 2016)
  - Prodekan za međunarodnu saradnju i nauku (oktobar 2013-novembar 2014)
  - Prodekan za međunarodnu saradnju, nauku i nastavu (decembar 2012-septembar 2013)
  - Vanredni profesor na predmetima: Ekonomska statistika i Makroekonomija za preduzetnike (2011-2017)
  - Docent na predmetima: Ekonomska statistika, Makroekonomija za preduzetnike, Monetarna statistika, Demografska analiza (2006-2011)
  - Asistent/saradnik, 2000-2006.

Priznanje za doprinos naučno-istraživačkom i stručnom radu za 2021. godinu na Ekonomskom fakultetu u Podgorici.

Profesionalni angažmani:

- Član odbora direktora Klinickog centra Crne Gore (2017-2021)
- Član Savjeta za konkurentnost Vlade Crne Gore (2017-2020)
- Član Odbora direktora "Jadransko brodogradilište Bijela", a.d, Bijela (2014-2015)

- Predsjednik Savjeta statističkog sistema Crne Gore (2006-2011), član Savjeta (2011-2013), Član Savjeta (2021-2022)
- Predsjednik Odbora direktora Montenegroberze a.d (2006-2008)
- Institut za strateške studije i prognoze (istraživač i analitičar) (1999-2007)
- USAID funded Economic reform project in Montenegro (2001-2003)

Nagrade

- Nagrada za doprinos naučno-istraživačkom i stručnom radu za 2021. godinu na Ekonomskom fakultetu u Podgorici
- Godišnje nagrade za rezultate ostvarene tokom studiranja

Ostale aktivnosti

- Koordinator Ekonomskog seminara (2022-), https://www.linkedin.com/posts/faculty-of-economics-podgorica_u-cilju-promocije-rezultata-pove%C4%87anja-kvaliteta-activity-6979024421852180480-HE0h?utm_source=share&utm_medium=member_desktop
- "The Age of STEM", predavanje po pozivu na Universita di Pavia (https://www.collegiovolta.org/news-events/age-stem-education-2023)

Akademska mobilnost

- Universite Cote DAzur, Nice, France, jun 2023.
- Univerzitet u Beogradu, Ekonomski fakultet, Oktobar 2023
- Universidad de Huelva, Huelva, Spain, November 2023
- University of Grenoble - IUT Valence, December 2023
- SGH Warshaw School of Economics, April 2024

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2. Baćović, Maja (2020): "**Economy of Montenegro from XIX to XXI century - an overview**", GlobeEdit, ISBN: 978-620-0-61206-9
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4. Baćović, Maja (2003): "**Sistem nacionalnih racuna**", ISSP, Podgorica, ISBN: 86-84299-09-4

Poglavlje u monografiji:

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2. **Baćović, Maja** (2010):„**Demografski problemi i njihove imlikacije – kvalitet ljudskog činioca u razvoju"**, u monografiji „Crna Gora u XXI vijeku – u eri kompetitivnosti, Ekonomski razvoj", Crnogorska akademija nauka i umjetnosti – CANU, posebna izdanja (monografije i studije), knjiga 73, sveska 3, Podgorica, ISBN: 978-86-7215-242-5, strane: 185-199
3. **Baćović, Maja** (2010):„**Tržište rada u Crnoj Gori"**, u monografiji „Crna Gora u XXI vijeku – u eri kompetitivnosti, Ekonomski razvoj", Crnogorska akademija nauka i umjetnosti – CANU, posebna izdanja (monografije i studije), knjiga 73, sveska 3, Podgorica, ISBN: 978-86-7215-242-5, strane: 331-357

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4. Andrijašević, Živko, **Baćović, Maja**. (2022). **Economic development of Montenegro from 1918 to 1990: the impact of political status and economic development model,** *Journal of Southeast European and Black Sea Studies*, 22(2) pp. 207-224. Print ISSN:1468-3857, Online ISSN:1743-9639 DOI: https://doi.org/10.1080/14683857.2021.2018157
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25. Baćović, M., Backovic, T., Milovic, N. (2022). **Research and innovation performance of Western Balkan countries,** IFKAD 2022: Knowledge Drivers for Resilience and Transformation, Lugano, Switzerland, ISBN: 978-88-96687-15-4 (e-book). pp. 457-474.
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35. Maja Baćović (2024). **Demografske promjene, produktivnost rada, i budućnost tržišta rada i fiskalne politike u Crnoj Gori,** konferencija "*Budućnost tržišta rada i fiskalne politike u Crnoj Gori"*, Crnogorska akademija nauka i umjetnosti (CANU), Podgorica, Februar 2024. (zbornik u pripremi)
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37. Maja Baćović: «**Preduzetništvo i nezaposlenost u Crnoj Gori»,** konferencija «Zapošljavanje kroz prizmu preduzetništva», Ekonomski fakultet, Podgorica, 2012. **ISBN: 978-86-80133-63-8,** pages: 229-238
38. Maja Baćović: «**Stanovništvo i ekonomski razvoj Crne Gore u XXI vijeku»,** u zborniku: Stanovništvo i razvoj», IDN, Beograd, 2012. **ISBN:** 978-86-7093-140-4, strane: 29-39
39. Maja Baćović: »**Determinante rasta produktivnosti i dohotka sa osvrtom na mala i srednja preduzeća»,** konferencija «Ekonomski razvoj kroz prizmu preduzetništva», Ekonomski fakultet, Podgorica, 2011. **ISBN**: 978-86-80133-56-0**,** strane: 177-187
40. Maja Baćović: «**Ekonomski rast na Balkanu: uslovljen rastom efikasnosti i/ili članstvom u EU?»,** u zborniku: «Balkan i EU», Institut društvenih nauka-IDN, Beograd, 2011, ISBN: 978-86-7093-137-4, strane: 112-122
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43. Maja Baćović: »**Mala otvorena ekonomija i globalna finansijska kriza«,** u zborniku: «Kriza i globalizacija», Institut društvenih nauka-IDN, Beograd, 2009, ISBN: 978-86-7093-133-9, pages: 136-145
44. Maja Baćović: »**Socioloske odrednice nastanka i razvoja kapitalizma**«, u zborniku "Ekonomija i sociologija", Institut društvenih nauka-IDN, Beograd, 2007, ISBN: 978-86-7093-117-6, ştrane: 181-188
45. Maja Baćović: **Tržište kapitala-ogledalo tržišne ekonomije“,** Miločerski ekonomski forum, SECG i SES, Miločer, 2008, SBN: 978-86-907245-3-6, strane: 409-416
46. Maja Baćović: „**Teorija racionalnih očekivanja: da li se može empirijski potvrditi u ekonomiji Crne Gore“,** „Preduzetnička ekonomija“, Vol. XV/I, Podgorica (2006) (ISSN: 1451-6659)
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57. Maja Baćović: «**Humani kapital i ekonomski razvoj: kvantifikacija humanog kapitala i uticaj investicija u humani kapital na ekonomsku efikasnost**», «Preduzetnička ekonomija», Vol. 2, Podgorica (2003) (**ISSN: 1451**-6659)
58. Maja Baćović: «**Konvertibilnost novca – preduslov ostvarivanja ekonomskih sloboda pojedinaca i ekonomskog rasta i razvoja**», «Preduzetnička ekonomija», Vol. 1, Podgorica (2002)
59. Maja Baćović: »**Slobodna međunarodna razmjena i ekonomske slobode**«, u zborniku "Politika i slobode", IDN, Beograd, 2003, ISBN: 86-7093-103-6
60. Maja Baćović: «**MVP-uticaj na ekonomski razvoj**», Miločerski ekonomski forum, SECG i SES, Budva, 2002
61. Maja Baćović: «**Reforma statističkog sistema u Crnoj Gori – preduslov za uključivanje u svetske ekonomske tokove**», Ekonomist (SEJ), Vol 34, Beograd (2001), (ISSN: 0354-5253)
62. Maja Baćović: «**Ekonomsko obrazovanje u računovodstvu, reviziji i finansijama**», SRRCG, Računovodstvo i finansije, br.10 (oktobar 2001)
63. Maja Baćović: «**Obračun agregata proizvodnje i dohotka u SNA sistemu nacionalnih računa**», Računovodstvo i finansije, br.8 (avgust 2001)
64. Maja Baćović: «**Uticaj medjunarodnog kretanja kapitala na ostvarivanje eksterne ravnoteže u privredi**», savjetovanje SECG i SES, Miločer (septembar 2001)
65. Maja Baćović: «**Turbo kapitalizam – globalni proces i njegove implikacije u zemljama u tranziciji**», u zborniku "Globalizacija i tranzicija", IDN, Beograd (jun 2001), ISBN: 86-7093-097-8

66. Maja Baćović: «**Globalizacija i stepen siromastva u svijetu**», Globalizacija (zbornik radova), Ekonomski fakultet, Podgorica (novembar 2000)
67. Maja Baćović: »**Opšta obilježja ESA 1995. i nove statističke institucije u Crnoj Gori**«, PMB 2000, Ekonomski fakultet, Podgorica, 2000
68. Maja Baćović: «**Direktno vs. Indirektno finansiranje institucija visokog obrazovanja**», Ekonomski fakultet, Podgorica (septembar 2000)
69. Maja Baćović: "**Vidovi i efekti postojanja korupcije**", u zborniku "Sistem i korupcija", IDN, Beograd, 2000, ISBN: 86-7093-093-5
70. Maja Baćović, Zoran Djikanovic: "**Proces privatizacije u Crnoj Gori**", NDEJ, Beograd (Zbornik radova) (mart 2000)
71. Maja Baćović: "**Institucionalni okvir za rad privatizacionih fondova u Crnoj Gori**", SEJ, Miločer, Budva (zbornik radova) (septembar 1999)

Projekti (publikovani rezultati istraživanja):

1. Ministarstvo za ljudska i manjinska prava Crne Gore i UN Woman, projekat: Jačanje ekonomskih i socijalnih prava žena u Crnoj Gori, izrada publikacije: "Žene i muškarci u Crnoj Gori – 2012."
2. UNDP: Human Development Report for Montenegro, 2011.
3. CANU: Crna Gora u XXI vijeku – u eri konkurentnosti, podprojekat: Ekonomski razvoj 2009-2010
1. Rad na temu: **Demografski problemi i njihove implikacije – kvalitet ljudskog činioca u razvoju**
2. Rad na temu: **Tržište rada u Crnoj Gori**
4. ISSP: Agenda ekonomskih reformi za Crnu Goru - 2007-2011.
5. Vlada Crne Gore: Prostorni plan RCG do 2020 godine (2007)
6. Vlada R. Crne Gore: Agenda ekonomskih reformi za Crnu Goru-izvještaj i preporuke (2005)
7. Human Development Report for Montenegro, ISSP and UNDP (2005), Koordinator izrade Izvještaja i autor dijela teksta
8. Transition report for Montenegro, ISSP (2004)
9. Vlada R. Crne Gore: Agenda ekonomskih reformi - 2002-2006. (2002)

Ostali projekti:

1. *Promovisanje internacionalizacije visokoškolskih ustanova u Crnoj Gori kroz izgradnju kapaciteta za studijske programe na engleskom jeziku (* ME-Study in English), 2024- (clan tima)
2. Projekat međunarodne naučne saradnje: „Uticaj deviznog kursa na spoljnotrgovinsku neravnotežu u uslovima krize – održivi razvoj novih zemalja članica EU i Zapadnog balkana", br. 451-03-02263/2018-09/15, Ekonomski fakultet, Univerzitet u Beogradu i Ekonomski fakultet UCG (2020-2021)
3. Rukovodilac medjunarodnog projekta DEVCORE (2015-2017)

4. Rukovodilac medjunarodnog bilateralnog projekta (naucna saradnja izmedju Crne Gore i Austrije) u partnerstvu sa Vienna University for Economics and Business, "Razvoj istrazivackih kapaciteta na ekonomskim fakultetima" (2015-2016)
5. Reforma statističkog sistema Crne Gore (2003)
6. Program obuke za brokere, dilere i investicione menadžere, Komisija za HOV Crne Gore, predavač (2007)
7. Škola statistike, predavač (2006-2010)

Učešće na međunarodnim konferencijama

1. IFKAD 2023, Matera, Italy (www.ifkad.org)
2. MICEB 2023, Budva, MN (www.miceb.me)
3. ICED 2022 (International Conference on the Economics of the Decoupling), Zagreb, Croatia, https://iced.net.efzg.hr/
4. *IFKAD 2022,* Lugano, Švajcarska, https://www.ifkad.org/event/ifkad-2022/
5. 12th SCF international conference: "*Contemporary issues in social sciences*", Antalya, Turska, Oktobar 2021
6. *11th Economics & Finance Conference,* Rome, maj 2019
7. *7th REDETE conference*. Banja Luka, University of Banja Luka, Faculty of Economics , oktobar 2019
8. DEVCORE workshop on Learning Outcomes, Atina, Grčka, jun 2015.
9. DEVCORE workshop on Learning Outcomes, Kopenhagen, Danska, april 2015.
10. Horasis, Global China Business meeting, Lake Como, Italy, October 2014.
11. Eduniversal World convention, Istanbul, Turska (Oktobar 2014.)
12. Crnogorska akademija nauka i umjetnosti (CANU), Centar mladih naučnika: "Glavni trendovi u istraživanju mladih naučnika u savremenoj nauci: promjena paradigme od atoma ka bitima", II interdisciplinarna medjunarodna konferencija, Podgorica, septembar 2014.
13. Horasis, Global Russia Business Meeting, Valensia, Spain (April 2014)
14. Horasis, Global China Business meeting, Hague, Netherlands, November 2013.
15. Montenegrin Academy of Arts and Sciences, Centre of Young Scientists: Regional Conference on Status of Young Scientists and Science in the region, Podgorica, October 17-18, 2013.
16. Eduniversal World convention, Bangalore, India (9-12. oktobar 2013)
17. DIEM 2013, Dubrovnik, Hrvatska (Septembar 2013)
18. PRME samit, CEEMAN, Bled, Slovenija (Septembar 2013)
19. OEAD: Conference on Higher education cooperation in Central, Eastern and South Eastern Europe, Vienna, July 3-5, 2013.
20. Development in Economic Theory and Policy, Bilbao, Spanija, 27-28.jun 2013.
21. Global China Business Meeting, Horasis, Riga, Latvia, November 25-27, 2012
22. "Ukraine and Montenegro: Present and Perspectives", conference organized by National Academy of Science of Ukraine, National Academy of Pedagogical Sciences of Ukraine and Montenegrin Academy of Sciences and Arts, Kiev, 16-19 October 2012.

23. Učešće na sastanku Svjetskog ekonomskog foruma: „World Economic Forum's Annual Meeting of the New Champions, Dalian, People's Republic of China, 13-16 September 2011", nakon selekcije organizatora (50 mladih naučnika iz svijeta) a na bazi nominacije Crnogorske akademije nauka I umjetnosti (2011)
24. Third International Conference on overcoming regional disparities, Cetinje, Montenegro (organized by: Montenegro Ministry of Economy, UNDP and GIZ), June 2012
25. World Conference on RESEARCH INTEGRITY: Gulbenkian Foundation, Lisbon, Portugal, 16 - 19 September 2007
26. II International symposium on Economic Theory, Policy and Applications, Athens, Greece, August 2007
27. "Europe and Latin America", CLADEA 2006 (September 10-13), Montpellier, France
28. Bruno Leoni Institute: Second Misses Seminar, Sestri Levante, Italy (2005)
29. EEA/ Eastern Economic Association Annual Meeting, Washington, DC, USA (2004)
30. ASSA/ American Economic Association Annual Meeting, San Diego, CA, USA (2004)
31. World bank: "Reforms in SEE countries", Budapest, Hungary (2003)
32. "Economic Perspectives of Former Yugoslavia states", Cavtat, Croatia (2003)
33. "Investment opportunities in Serbia and Montenegro", Brussels and Luxemburg (2003)
34. Ronald Coase Institute Fellow, ISNIE - «New Institutional Economics», University of Tuebingen, Tuebingen, Germany (september 2000)
35. "Corporate Governance", OECD, Zagreb, Croatia (2002)
36. "Economic Assesment of FRY", OECD, Paris, France (2002)
37. OECD: International accounting standards, Zagreb, Croatia (2002)
38. OECD: International accounting standards, Istanbul, Turkey (2001)
39. OECD: International accounting standards, Sarajevo, Bosnia and Herzegovina (2001)
40. USAID-«Capital Market Regulation», Dubrovnik, Croatia (2000)
41. USAID-"Reform of the pension system", Ljubljana, Slovenia (1999)
42. USAID-"Reform of the pension system", Budapest (1998)

Specijalizacije i treninzi

U trajanju dužem od 1 mjeseca

1. JFDP stipendija: University of Delaware (USA), Department for Economics, akademska godina 2003/04
2. British Trust stipendija: University of Greenwich, London (UK), Department for Economics, akademska godina 2000/01 (ljetnji semester)
3. "Economic indicators", BLS, Washington, Washington DC, USA (August-September 1999)

U trajanju od 1-4 nedelje

1. Univerzitet u Lubljani, studijska posjeta, jul 2017
2. WU – Vienna University for Economics and Business, istraživački boravak, decembar 2015.
3. WU – Vienna University for Economics and Business, istraživački boravak, mart 2015.
4. Vienna Institute for International Economics (WIIW) and Joint Vienna Institute (JVI): Public Governance and Structural Reforms, Vienna, Austria (April 2013)
5. Vienna Institute for International Economics (WIIW) and Joint Vienna Institute (JVI): Public Private Partnership, Vienna, Austria (September 2009)
6. 4th Balkan Summer School on Survey Methodology, Durres, Albania, August 31-September 4, 2009, organized by Instat, Albania and Statistics Sweden, Balkan Project Office
7. European Commission, Joint Research Centre, Institute for Prospective Technological Studies: Workshop on the development of ERAWATCH: ERA and neighborhood countries, Seville, Spain (November 2009)
8. UNESCO workshop on Science, Technology and Innovation Indicators: Trends and Challenges, Skopje, March 2007
9. Vienna Institute for International Economics (WIIW) and Joint Vienna Institute (JVI): Foreign Investment Policies, Vienna, Austria (October 2005)
10. "Financial Management", Training for faculty members, USAID, Mostar, Bosnia&Herzegovina (july-august 2002)
11. International Management Teachers Academy, CEEMAN, Bled, Slovenia (May 2002)
12. Training for trainers, BLS, Washington, DC, USA (September 1999)
13. IAS stipendija, Comparative economic and political systems, Prague, Czech Republic (july 1999)
14. G-17 fellow, Summer school of economic policy, Belgrade (June 1998)

Radna praksa (internship)

1. International Law Institute: Post-privatization: Managing the Challenge, Washington, D.C (jun 2004)

Strani jezici

Engleski (aktivno)

Članstvo:

1. Odbor za ekonomska istraživanja, Crnogorska akademija nauka i umjetnosti (2010-2017)
2. Centar mladih naučnika, Crnogorska akademija nauka i umjetnosti (2010-2016)
3. Član Saveza ekonomista Crne Gore (2000-2007)

Univerzitet Crne Gore
adresa / address_Cetinjska br. 2
81000 Podgorica, Crna Gora
telefon / phone_00382 20 414 255
fax_00382 20 414 230
mail_rektorat@ucg.ac.me
web_www.ucg.ac.me
University of Montenegro

Broj / Ref 03- 813

Datum / Date 15.04 20 22

Crna Gora
UNIVERZITET CRNE GORE
EKONOMSKI FAKULTET
Broj 01-1113
Podgorica, 20.04.22 god.

Na osnovu člana 72 stav 2 Zakona o visokom obrazovanju („Službeni list Crne Gore", br. 44/14, 47/15, 40/16, 42/17, 71/17, 55/18, 3/19, 17/19, 47/19, 72/19 i 74/20 i 104/21) i člana 32 stav 1 tačka 9 Statuta Univerziteta Crne Gore, Senat Univerziteta Crne Gore, na sjednici održanoj 15.04.2022. godine, donio je

O D L U K U
O IZBORU U ZVANJE

Dr MAJA BAĆOVIĆ bira se u akademsko zvanje **redovni profesor Univerziteta Crne Gore iz oblasti Ekonomska analiza i politika na Ekonomskom fakultetu Univerziteta Crne Gore**, na neodređeno vrijeme.

SENAT UNIVERZITETA CRNE GORE
PREDSJEDNIK
Prof. dr Vladimir Božović, rektor

DR SAŠA VUJOŠEVIĆ

BIOGRAFIJA

Rođen je 20.03.1967. godine u Beogradu. Osnovnu i srednju školu je završio u Podgorici, gdje je i diplomirao na Prirodno-matematičkom fakultetu u Podgorici, na odsjeku za Matematiku 1993. godine sa prosjekom 9,47. Postiplomske studije je završio na Matematičkom fakultetu u Beogradu sa prosjekom 9,83, gdje je 2000. godine, odbranio magistarski rad „Računarsko prepoznavanje srpske ćirilice".

Doktorsku disertaciju pod nazivom „Sigurnost elektronskih transakcija u elektronskom bankarstvu" odbranio je na Ekonomskom fakultetu u Podgorici, 8. decembra 2010. godine.

Radi stručnog usavršavanja, boravio jesam na specijalizaciji na Katz School of Business, Pittsburgh, Pennsylvania, USA, 2005. godine.

U zvanje docenta izabran je 13.06.2013. godine, a 2019. godine reizabran u isto zvanje.

Važniji radovi

- Vukićević, Ž. K., Popivoda, G., **Vujošević, S**., Škrekovski, R., & Dimitrov, D. (2023). The σ-Irregularity of chemical trees. *Match*, *91*(1), 267–282. https://doi.org/10.46793/match.91-1.267k
- **Vujošević, S.,** Popivoda, G., Vukićević, Ž. K., Furtula, B., & Škrekovski, R. (2021). Arithmetic–geometric index and its relations with geometric–arithmetic index. Applied Mathematics and Computation, 391, 125706. https://doi.org/10.1016/j.amc.2020.125706
- Vukićević, Ž. K., **Vujošević, S.**, & Popivoda, G. (2021). Unicyclic graphs with extremal values of arithmetic–geometric index. Discrete Applied Mathematics, 302, 67–75. https://doi.org/10.1016/j.dam.2021.06.009
- **Vujošević, S.** (2022). Computation of edge Pi index, vertex Pi index and Szeged index of some cactus chains. Mathematica Montisnigri, 54, 14–24. https://doi.org/10.20948/mathmontis-2022-54-2
- **Vujošević, S**., Poljašević, J., Lakićević, M. (2022). Application of graph theory for the purpose of diversifying the portfolio of stocks on the Banja Luka stock exchange. DOI: 10.7251/FIN2202003V

- Lalević Filipović, A., Brkan Vejzović, A., Novović Burić, M., **Vujošević, S**. *(corresponding author)*, (2018), *A VAR analysis of the effect of macroeconomic variables on non-performing loans in Western Balkan Countries,* International Journal of Scholarly Papers, Transformations in Business &Economics (TIBE), Vol 17. No 2A(44A), ISSN 1648 – 4460, pp. 511-524
- Cerović Smolović, J., Lipovina-Božović, . & **Vujošević S**,. (2017), *GARCH models in value at risk estimation: empirical evidence from the Montenegrin stock exchange*, Economic Research-Ekonomska Istraživanja, Vol. 30 Issue 1, ISSN: 1331-677X (Print) 1848-9664 (Online)pp. 477-498
- Ćetković, J., Lakić, S., Lazarevska, M., Žarković M., **Vujošević, S.,** Cvijović, J., and Gogić M., *Assessment of the Real Estate Market Value in the European Market by Artificial Neural Networks Application*, Complexity, Special Issues: Artificial

Neural Networks and Fuzzy Neural Networks for Solving Civil Engineering Problems, ISSN: 1099-0526 (Online), pp. 1-10

- Novović Burić M., Kašćelan V, **Vujošević S**., (2015), *Bancassurance concept from the perspective of Montenegrin market*, Economic Review – Journal of Economics and Business, Vol. XII, Issue 2, ISSN 1512-8962, pp.62-73
- Cerović, J., Lipovina-Božović, M., **Vujošević, S.** (2015). "A Comparative Analysis of Value at Risk Measurementon Emerging Stock Markets: Case of Montenegro", Business Systems Research, Vol. 6, No.1, ISSN: 1847-9375, pp. 36-55Lipovina-Božović, M; Cerović, J; **Vujošević, S**, 2015. Forecasting inflation in Montenegro using univariate time series models, Business and Economic Horizons, Vol.11, Issue1, pp.51-63.

Univerzitet Crne Gore
adresa / address_Cetinjska br. 2
81000 Podgorica, Crna Gora
telefon / phone_00382 20 414 255
fax_00382 20 414 230
mail_rektorat@ucg.ac.me
web_www.ucg.ac.me
University of Montenegro

Broj / Ref 03-1688

Datum / Date 04.06.2019

Univerzitet Crne Gore
UNIVERZITET CRNE GORE
EKONOMSKI FAKULTET
Broj 01- 1302
Podgorica, 12/06/2019 god.

Na osnovu člana 72 stav 2 Zakona o visokom obrazovanju („Službeni list Crne Gore" br. 44/14, 47/15,40/16,42/17,71/17 55/18 i 3/19) i člana 32 stav 1 tačka 9 Statuta Univerziteta Crne Gore, Senat Univerziteta Crne Gore, na sjednici održanoj 04. juna 2019.godine, donio je

O D L U K U
O IZBORU U ZVANJE

Dr SAŠA VUJOŠEVIĆ bira se u akademsko zvanje **docent Univerziteta Crne Gore za oblast Kvantitativna i informatička ekonomija na Ekonomskom fakultetu Univerziteta Crne Gore** (Finansijska i aktuarska matematika, Statistika u turizmu, Softversko modeliranje u ekonomiji i Matematika za biznis), na period od pet godina.

SENAT UNIVERZITETA CRNE GORE
PREDSJEDNIK

Prof.dr Danilo Nikolić, rektor

Broj:01/372

Podgorica, 03.04.2024.godine

UNIVERZITET CRNE GORE
-Odboru za doktorske studije i Senatu-

PODGORICA

Predmet: Materijal za sjednicu Odbora i Senata

Poštovani,

U skladu sa članom 38. Pravila doktorskih studija, dostavljamo Vam materijal za narednu sjednicu Odbora za doktorske studije, odnoso Senata Univerziteta Crne Gore i to:

-Ispunjenost uslova doktoranda (obrazac D2) sa propratnom dokumentacijom za mr Damira Sindika.

DEKAN

Prof.dr Mijat Jocović

Univerzitet Crne Gore
Ekonomski fakultet Podgorica
Adresa: **Jovana Tomaševića 37**
81000 Podgorica - Crna Gora
Telefon: **+382 20 241 757** / Fax: **+382 20 244 588**
E-mail: **ekonomija@ac.me** / Web: **www.ekonomija.ac.me**
Žiro-račun: **510-131-35** / PIB: **02016702** / PDV: **30/31-03951-6**

UNIVERZITET CRNE GORE
EKONOMSKI FAKULTET PODGORICA
DOKTORSKE STUDIJE
Br. 01/ 332
Podgorica, 03.04.2024.god.

Na osnovu čl. 64. Statuta Univerziteta Crne Gore, člana 41. Pravila doktorskih studija, Vijeće Ekonomskog fakulteta je na sjednici održanoj 03.04.2024.godine donijelo

O D L U K U

1. Utvrđuje se da su ispunjeni uslovi iz Pravila doktorskih studija za dalji rad na doktorskoj disertaciji **„Nelinearna dinamička analiza disekvilibrijuma i haosa u agregatima raspoloživog dohotka, imetka i potrošnje u makroekonomiji Evropske unije“** doktoranda **mr Damira Sindika** .
2. Predlaže se Odboru za doktorske studije i Senatu UCG da formira Komisiju za ocjenu doktorske disertacije **„Nelinearna dinamička analiza disekvilibrijuma i haosa u agregatima raspoloživog dohotka, imetka i potrošnje u makroekonomiji Evropske unije“** doktoranda **mr Damira Sindika** u sastavu:
   - Prof. dr Vladimir Kašćelan, redovni profesor, Ekonomski fakultet Podgorica, Univerzitet Crne Gore, prvi mentor;
   - Prof. dr Ljiljana Kašćelan, redovni profesor, Ekonomski fakultet Podgorica, Univerzitet Crne Gore, drugi mentor;
   - Prof. dr Josip Tica, redovni profesor, Ekonomski fakultet u Zagrebu, Sveučilište u Zagrebu, Republika Hrvatska, član.
3. Odluka se dostavlja Centru za doktorske studije UCG na dalji postupak.

O B R A Z L O Ž E N J E

Doktorand **mr Damira Sindik** je uradio doktorsku disertaciju **„Nelinearna dinamička analiza disekvilibrijuma i haosa u agregatima raspoloživog dohotka, imetka i potrošnje u makroekonomiji Evropske unije“,** nakon čega je Komisiji za doktorske studije podnio zahtjev za formiranje Komisije za ocjenu doktorske disertacije.
Komisija za doktorske studije je, nakon razmatranja dokumentacije, predložila Vijeću fakulteta da donese Odluku kojom predlaže Senatu UCG formiranje Komisije za ocjenu doktorske disertacije **„Nelinearna dinamička analiza disekvilibrijuma i haosa u agregatima raspoloživog dohotka, imetka i potrošnje u makroekonomiji Evropske unije“** doktoranda **mr Damira Sindika**.
Na osnovu izloženog odlučeno je kao u dispozitivu.

DEKAN

Prof.dr Mijat Jocović

DOSTAVLJENO:
-a/a
-referentu doktorskih studija,
-Centru za doktorske studije.
-Senatu UCG.

UNIVERZITET CRNE GORE
EKONOMSKI FAKULTET

Komisiji za doktorske studije

Predmet: Saglasnost mentora sa tekstom disertacije doktoranda

Ovom izjavom dajemo svoju saglasnost na tekst doktorske disertacije doktoranda Damira V. Sindika, koji je doktorand predao Studentskoj sluzbi Ekonomskog fakulteta.

Podgorica, 04. mart 2024.

Mentori

1. Prof. dr Vladimir Kašćelan

2. Prof. dr Ljiljana Kašćelan

Univerzitet Crne Gore
Ekonomski fakultet Podgorica
Adresa: **Jovana Tomaševića 37**
81000 Podgorica - Crna Gora
Telefon: **+382 20 241 757** / Fax: **+382 20 244 588**
E-mail: **ekonomija@ac.me** / Web: **www.ekonomija.ac.me**
Žiro-račun: **510-131-35** / PIB: **02016702** / PDV: **30/31-03951-6**

ISPUNJENOST USLOVA DOKTORANDA

OPŠTI PODACI O DOKTORANDU			
Titula, ime, ime roditelja, prezime	M.Sc. Damir V. Sindik		
Fakultet	Ekonomski Fakultet Podgorica		
Studijski program	Doktorske studije Ekonomije		
Broj indeksa	D 4/16		
NAZIV DOKTORSKE DISERTACIJE			
Na službenom jeziku	Nelinearna dinamička analiza disekvilibrijuma i haosa u agregatima raspoloživog dohotka, imetka i potrošnje u makroekonomiji Evropske unije		
Na engleskom jeziku	Nonlinear dynamical analysis of disequilibrium and chaos in aggregates of disposable income, wealth and consumption in EU macroeconomics		
Naučna oblast	Primijenjena Matematika u Ekonomiji		
MENTOR/MENTORI			
Prvi mentor	Prof. dr Vladimir Kašćelan	Ekonomski Fakultet, Univerzitet Crne Gore, Crna Gora	Matematička ekonomija i Finansije – Finansijska i aktuarska matematika
Drugi mentor	Prof. dr Ljiljana Kašćelan	Ekonomski Fakultet, Univerzitet Crne Gore, Crna Gora	Poslovna inteligencija – Analitika poslovnih podataka – Data mining
KOMISIJA ZA PREGLED I OCJENU DOKTORSKE DISERTACIJE			
Prof. dr Vladimir Kašćelan		Ekonomski Fakultet, Univerzitet Crne Gore, Crna Gora	Matematička ekonomija i Finansije – Finansijska i aktuarska matematika
Prof. dr Ljiljana Kašćelan		Ekonomski Fakultet, Univerzitet Crne Gore, Crna Gora	Poslovna inteligencija – Analitika poslovnih podataka – Data mining
Prof. dr Josip Tica		Ekonomski fakultet u Zagrebu, Sveučilište u Zagrebu, Hrvatska	Makroekonomija i gospodarski razvoj

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Univerzitet Crne Gore
Ekonomski fakultet Podgorica
Adresa: **Jovana Tomaševića 37**
81000 Podgorica - Crna Gora
Telefon: **+382 20 241 757** / Fax: **+382 20 244 588**
E-mail: **ekonomija@ac.me** / Web: **www.ekonomija.ac.me**
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Simulation of disequilibrium and chaos in aggregates of disposable income, wealth, and consumption in EU macroeconomics using nonlinear dynamic analysis

Damir V Sindik, Vladimir Kašćelan and Ljiljana Kašćelan

Abstract

Economic disequilibrium theory (DT) more realistically represents modern macroeconomic systems than general equilibrium theory. DT coupled with applied mathematical economics and nonlinear dynamical analysis generates multi-dimensional phase spaces. Interdependencies of endogenous variables in state space create a flow of different and "parallel economic realities," which depend on the initial conditions. By modeling variable changes using the nonlinear least squares (NLLS) method, we define the first-order nonlinear ordinary differential equation (NODE) system. The NODE system is impossible to solve analytically. The numerical solution and visualization requires the MATLAB software package, combined with its specialized applications pplane (two-dimensional (2D)) and MATCONT (three-dimensional (3D)). By analyzing the evolution of flow operators, we can predict the future qualitative behavior of the entire system, determine the model-optimal values, and perform inverse modeling for variables. The obtained data advocate better and more stable macroeconomic paths that economic policymakers can pursue. The proposed methodology's boundaries have strong links to chaos theory. Chaotic behavior can arise after a certain number of periods. We found very high computation accuracy, transformation of discrete variables to continuous functions, and the implementation of high-order polynomial data fitting offset its effects in part and to some reasonable degree.

Keywords

Disequilibrium theory, nonlinear dynamic analysis, chaos theory, simulation of EU macroeconomic, long-term prediction

1. Introduction

Nonlinear dynamic analysis (NDA) is mainly present in the natural sciences. It studies how individual parts affect the entire system, e.g., local laminate and/or turbulent flow in fluid dynamics. Numerous applications and examples are present in electronics, fluid dynamics, thermodynamics, chemistry, biology, physics, and many other related scientific fields.[1–4] NDA's possible applications in the social sciences definitely exist. Macroeconomics is one such an example. Exerted by its smallest constituent parts (people), many interactions happen in the economy. Macroeconomics is studying the aggregate effects of a huge number of such interactions.[5–7]

Similarly, the interactions of singular atoms and/or molecules have an overall influence on a river's flow. Finding those interconnections and explaining them completely—in both cases, in today's science is still impossible and unknown. However, bigger clusters, or groups of basic system constituents, can exert enough influence on the aggregate behavior of the system. The nature, size, and influence of those groups in macroeconomics are at the center of this research.

Aggregates of total disposable income, wealth, and consumption are constituent pillars of any economy. Macroeconomics reflects their interdependency furtherly inter-tangled with socio-economic parameters such as referent interest rates, tax rates, price, and quantity of produced goods/services, supply, and demand. A basic human

Faculty of Economics Podgorica, University of Montenegro, Montenegro

Corresponding author:
Damir V Sindik, Faculty of Economics Podgorica, University of Montenegro, Kralja Nikole 122/21, 81000 Podgorica, Montenegro.
Email: sindikdamir@gmail.com

need is to have means for consumption. Certain incomes must back consumption. As prices and human needs vary with time, some products and services might not be in accordance with income. If a person cannot provide enough funds by actual income, it must finance consumption from alternative channels. In such a case, savings or some other in time-accumulated wealth complementary supports actual or future consumption. Very often, some individuals or families cannot take a loan from financial institutions because of their low credit rating.

The change in aggregates of total disposable income, wealth, and consumption is not discrete, but rather continual. Accordingly, we define continuous functions for the involved variables. In addition, there exists a certain degree of inherent ''inertia'' in variable(s) time-evolution resembling physical ''flow,'' which is known in economic literature as *stickiness*. The NDA is studying and analyzing such flows. We will implement NDA on aggregates of total disposable income, wealth, and consumption for two-dimensional (2D) and three-dimensional (3D) systems.

The initial motivation and idea was to try to find some substantially small dilatation that would affect the system as a whole. Knowing and understanding, that such a demanding task could not be achieved by our part and today's technology, we reformulated the research goal to find in one area of European Union (EU) macroeconomics reasons why, where, and how small fluctuations in Y_H, W_H, and C_H affect each other.

Disequilibrium theory (DT) inherently describes nonlinear systems, with in-time nonlinearly changing equilibriums. We implement the NDA, econometric nonlinear least squares (NLLS) method, and DT macroeconomic foundations to create model equations. In systems that are highly nonlinear almost regularly, incur the ''birth'' of chaos. Presented, discussed, and analyzed is the qualitative and quantitative impact of chaos on macroeconomic aggregates. A prediction window, without chaos, depends on the state of the system and initial conditions. The Lyapunov Exponent (LE) depends on the initial conditions. Besides the interest of finding nonlinear ordinary differential equation (NODE) system solutions, we are interested in discovering what are their properties and states. Connecting the presented research methodology to real EU macroeconomic data, our goal became to determine their qualitative and quantitative interdependency. Sometimes, system behavior in ''one part'' of nonlinear dynamical system (NDS) phase plane has only intrinsically mathematical value, but it does not have any macroeconomic meaning. The phase planes generated by NDA are inherently responsive to initial conditions, and accordingly, it is possible to get different solution paths with the same model. The change in initial conditions can affect the qualitative behavior of the whole system. As mentioned, it can be a starting point for a different, but possible macroeconomic reality. Discovered NDS equilibrium curves (ECs) and/or equilibrium points (EPs) offer detailed and in-depth system insight.[8,9]

The remainder of this paper is organized as follows. In section 2, we describe DT foundations; we define models and corresponding econometric links to NDA. In section 3, we elaborate the methodology we use, while in section 4 is the discussion of the results. Section 5 rounds up the conclusions, and suggests future research paths.

2. Theoretical foundations

2.1. DT, econometrics, and NDA

DT is a relatively new concept in economics. Based on non-Walrasian approach, DT is contemplated in the early works of Patinkin,[10–12] Robert W Clower,[13] and Axel Leijonhufvud.[14] Followed by more in-depth works of Solow and Stiglitz,[15] and on a similar theoretical route, Barro and Grossman.[16–21] Chiarella et al.[22–25] using advanced and rigorous macroeconomic theoretical interpretations developed DT into a modern contemporary economic theory. The early work of Chiarella and Flaschel[24] on DT started in the mid-1980s.[22] From its relatively modest and unnoticed origins, DT has evolved as an advancement of the Keynes–Metzler–Goodwin (KMG) model, toward a standalone theory with its own postulates. The ''working KMG model'' represents a format of encapsulated Keynesian monetary growth analysis, the Rose effect (The destabilizing/stabilizing role of real wage changes depends on wage and price flexibilities, and marginal propensities to consume and invest.[22]), the Pigou effect (Real money or wealth holdings change with inflation: the real balance effect leads to economic expansion via consumption demand if wage and price deflation occurs.[22]), the Hicksian (IS-LM) representation of Keynes-components, and so on.[22]

Chiarella et al. have defined and theoretically developed many-dimensional models, e.g., 9D KMG model and its sub dynamic 5D KMG-based model, in addition, in intensive form 22D and 39D models.[22] Many dimensions in models relate to variables that coexist in real macroeconomic systems. After defining equational and logical interactions between variables, and additionally by encompassing reasonably many variables in models, the resulting mathematical interpretation accurately represents a real macroeconomic system. Multi-dimensional DT models ''depict'' a much more realistic ''macroeconomic picture,'' than it is the case with greatly reduced and overly simplified models. DT and NDA are important for economics as they provide an improved technique to reflect the reality of complex system(s) into modeling equations. Compared to, e.g., Dynamic Stochastic General Equilibrium (DSGE) models, DT and NDA offer a complete flow dependence analysis, and not ''only'' on previously and recursively calculated values. In addition,

linearization is not required as all calculations and analyses are performed in a nonlinear environment (reality based). Furthermore, in NDA, for the same set of model equations, we can create a ''parallel economic reality'' by just changing the initial conditions, without the need to estimate the system again (There are even more advantages when comparing NDA to other methods, but it is beyond the scope and aim of this paper to elaborate them all.).

The drawbacks of DT are (1) relative analytical and numerical complexity for analysis and, consequently, for synthesis and (2) DT sui generis postulates agree with some earlier pre-established economic theories. Today's computing power, specialized applications, and NDA with relative ease overcome the former drawback. In addition, the ''birth'' of chaotic behavior in such systems is relatively common. The later ''drawback'' is subjective and relative. Due to researcher's way of reasoning and personal opinion(s), especially in social sciences, inherently and per se, some proposed theories have always-subjective parts innate from the creator. Related to real and practical problems, and by the force of argument and proof, one can confirm or refute corresponding theories.

DT assumes that in the basic structure of the economy, there inherently exist an interdependency and interaction between workers, asset holders, firms, government, prices, expectations, stocks, and growth. Some mentioned categories are a product of irrational behavior, and we tie these to the concept of ''free will.'' The process of thought, rationality and/or emotions, correlates with the abstract term of ''free will,'' and it is inherently associated with human beings. Accordingly, to some degree, there is always the exertion of ''free will'' in every institutional entity (e.g., policy decision-maker), because at its core there is always a person. In addition, it is impossible to know, or determine when some individual or family will file for a loan, sell a house, buy a car, or may get ill—due to poor lifestyle, and accordingly, to need more funds for medical treatments, and so on. We can only observe the aggregate, macroeconomic, values. Consequently, there exists an emerging pattern of behavior on a large scale. In the case of DT, it is a macroeconomic scale with minor microeconomic foundations. Chiarella et al.[22] based DT on the Australian economy. Contrary, in this research, we will study EU macroeconomics. Despite some similarities, the concept of EU macroeconomics is different from that in Australia. The EU now has 27 different economies (Here conducted research, is on the EU28. It includes Great Britain (GB) before formal ''Brexit,'' up to 2019.), jurisdictions, and political entities. The starting equations of the original DT were recombined to adjust EU specifics.

The EU modification of the original DT[22] primarily consists of integrating workers and asset holders, due to their very similar logical and economic interdependency, into one category: households. Household's category encompasses workers paid by salary and/or wage, and asset owners who have some additional source of income (beside salary). Asset owners' additional source of income derive from the following: real estates in ownership; dwelling profits earned by the renters who own real estates; collected interests on deposits; production or service profits earned by worker's engagement; capital gains; and so on.

Originally in DT asset holders were individuals or Small Private Business Enterprises (small and medium-sized enterprises (SMEs)) that can earn profit by selling their products and/or service, renting small privately owned holdings in real estate capital, gains from stocks and/or bonds, extra work engagement, dividend profit from share ownership, and so on. The characteristics that these categories have in DT are present in reality for EU28, and their corresponding definitions are in the *European system of accounts ESA 2010* (The document that is defining the category and types of Households, in the EU, is presented and explained in *the European system of accounts ESA 2010*, accessible on the web link: https://ec.europa.eu/eurostat/documents/3859598/5925693/KS-02-13-269-EN.PDF/44cd9d01-bc64-40e5-bd40-d17df0c69334.).

The EU acts as single economy concerning the free flow of people, goods, services, and capital. The population of the EU has its sui generis compared to the original DT equations.[22–25] In practice, e.g., EU citizens have a preference in *domestic* cash deposits (short-term agreed maturity deposits) and shareholdings, rather than, e.g., investments in domestic and foreign bonds. The term *domestic EU* refers to all individuals and business entities that have their seat in EU jurisdictional territory—all the countries and companies that are subject to EU laws. Such specifics created the need to transform the original DT equations to their adapted EU form.

The starting and original DT equations for households (The household category considers workers and asset holders with all their possessions and obligations.[22]) are, for workers:[22]

$$Y_{\omega}^{D_n} = (1-\tau_w)\left[\omega L^d + \omega(L-L^{\omega}) + \omega^r \alpha_l L_2\right] + (1-\tau_c) r B_{\omega} \tag{1}$$

$$L^{\omega} = L_f^{\omega} + L_g^{\omega} \tag{2}$$

$$L^d = L_f^d + L_g^d = L_f^d + L_g^{\omega} \tag{3}$$

$$C_{\omega}^{on} = c_{\omega 1} Y_{\omega}^{Dn} + c_{\omega 2} W_{\omega}^n \tag{4}$$

$$W_{\omega}^n = M_{\omega} + B_{\omega} \tag{5}$$

$$L_g^d = L_g^{\omega} \tag{6}$$

In addition, for asset holders:[22]

$$Y_c^{D_n} = (1-\tau_c)\left[\rho^e p_y K + rB_c + B_1^l + p_h C_\omega^h - p_y \delta_h K_h\right] + e\left(1-\tau_c^*\right)B_2^l \tag{7}$$

$$C_c^{on} = c_{c1} Y_c^{Dn} + c_{c2} W_c^n \tag{8}$$

$$W_c^n = M_c + B_c + p_b B_1^l + p_e E + e p_b^* B_2^{l*} + p_y K_h \tag{9}$$

$$p_b^* = \frac{1}{r_l^*} \tag{10}$$

Combining the Equations from (1) to (10), based on their economical and mathematical meaning, we obtain a system of equations that encompasses together workers and asset holders, further addressed by households. In Equations (1)–(10)[22] (Chapter VII p. 289,[22] consists of more than a 100 equations. This research relates to households. Therefore, we reduced the number of equations.), Y_ω^{Dn} and Y_c^{Dn} are the nominal disposable income of workers and asset holders; τ_ω is the tax rate on wages, pensions, and unemployment benefits; ω is the nominal wage before tax; L^{d} is the total employment of the employed; L is the labor supply; L^ω is the total active work force; ω^{r} is the pension rate; α_1 is the participation rate of the potential work force; L_2 is the population aged 66 years and more; τ_c is the tax rate on profit, rent, and interest; r is the nominal short-term (Short-term considers rates up to 1 year of maturity.) domestic interest rate (price of bonds $p_b = 1$); r_l^* is the nominal short-term domestic interest rate; L_f^ω is the work force of firms; L_g^ω is the total government employment (equals public work force); C_ω^{on}, C_c^{on} are the total nominal equilibrium consumption of workers and asset holders; $c_{\omega 1}$ is the propensity to consume goods of workers out of income; $c_{\omega 2}$ is the propensity to consume goods of workers out of wealth; W_ω^n, W_c^n are the nominal wealth of workers and asset holders; M_ω, M_c are the money holdings of workers and asset holders; B_ω, B_c are the short-term debt held by workers and asset holders; ρ^e is the expected short-run rate of profit of firms; p_y is the price level of domestic goods net of value added tax; K is the capital stock; B^l is the stock of domestic long-term bonds, of which B_1^l are held by domestic asset holders, and B_1^{l*} by foreigners; B_2^l is the foreign bonds held by domestic asset holders; c_{c1} is the propensity to consume goods of asset holders out of income; c_{c2} is the propensity to consume goods of asset holders out of wealth; p_h is the rent per unit of dwelling; C_ω^h is the real (equilibrium) dwelling services consumption of workers; δ_h is the depreciation rate of the capital stock of households; K_h is the capital stock in the housing sector (weighted average); e is the exchange rate (units of domestic currency Australian dollar (A$) per unit of foreign currency: A$/$); p_b, p_b^* are the price of bonds domestic and foreign; p_e is the price of equities; E is the equities. Names and markings, for all terms, are identical, as presented in Chiarella et al.[22] All the calculations and values in this research were in euro (EUR). The Australian dollar (A$) currency is mentioned here only to correctly represent the original work of Chiarella et al.

2.2. The model foundations

To represent more realistically EU macroeconomics, a combination of Equations (1)–(10) defines Equations (11) and (12). Depreciation of housing capital and the rate of change is (1) included in the EU housing price index (HPI_H) and (2) research uses net value of capital for household housing stock (K_{hH}).[22] Comparative to owning bonds EU citizen prefer savings and stock ownership. Accordingly, Equations (1)–(10) adapt to substitute the short-term bond coupon with savings on a yearly interest payment. The coupon from bond net yield equivalents to 1-year maturity cash deposit payment, and/or equities yearly dividend payment. In the transition or intermediate formulas (11) and (12), we used EU gross wage data from Eurostat for employed, unemployed, and pensioners. By incorporating coefficients to average gross workers salary, we obtain a more flexible and detailed analytical window (This paper is a part of a wider research framework, which is testing the impact of different coefficients on various endogenous variables. We study hyper-chaotic behavior in 4D and 7D systems, using NDA, among others for harmonized indices of consumer price (HICP), r_{1_10}, and Y_H.).

In addition, there are coefficients for EU population size, employed, unemployed, and pensioners. Using coefficients, we adjust the amounts of net and gross average EU wages by age, population, and legal entitlement. As mentioned, it provides the opportunity to isolate the term of gross wage. Transition, or intermediate formulas, are (Presented equations are intermediary step. For more details on the original equations, see Chiarella et al.[26])

$$Y_H^{Int} = \{[(1-\tau_\omega)\alpha_l + \alpha_{GU}\alpha_U]L_1 + \alpha_{GR}\alpha_r L_2\}\omega_G + (1-\tau_c) r_{KH_{AV}} B_{KH_{AV}} \tag{11}$$

$$W_H^{Int} = M_H + B_H + \frac{B_1^L}{r^L} + e\frac{B_2^L}{r_L^*} + p_e E + HPI_H K_{hH} \tag{12}$$

$L^\omega = \alpha_L L_1$; $L^r = \alpha_r L_2$; $L^U = \alpha_u L_1$; $\omega^r = \alpha_{GR}\omega_G$; $\omega^U = \alpha_{GU}\omega_G$; $p_e E = \sum_{i=1}^n p_{Ei} E_i$ (The value $p_e E$ represents the total sum of all equites in a household portfolio, with a mark-to-market value. There were n stocks in this portfolio.), where $i = 1,\ldots,n$.

$$P = \sum_{t=1}^{n} \frac{I}{(1+i)^t} + \frac{F}{(1+i)^n} \tag{13}$$

In Equation (13), the terms have the following meaning: P is the price of bond; n is the number of payment periods (number of years divided by 2); I is the half year

payment (coupon); i is the discount rate; F is the face value of bond; t is the time entitled coupon payment. When t and n are equal to one, we have a yearly bond payment. Consequently, I represent a yearly payment of one coupon instead of two, and it is adequate to the income equivalent for a yearly interest payment on timed savings. Furthermore, we neglect the second term in Equation (13) because it represents the face value of the bond in the final payment, or in a case of timed deposit fund(s) withdrawal.[27]

In Equations (11) and (12), we include the income generated by short-term investments in domicile and foreign bonds to create Equations (14)–(16). Foreign bonds have the meaning of debt assets emitted outside the EU28 legal residency of the bond issuer. For the EU28 population, the final two terms in Equation (14) are much smaller than equity investments, but for completeness and precision of this research, they are accounted in total disposable income:

$$Y_H = \{[(1-\tau_\omega)\alpha_I + \alpha_{GU}\alpha_U]L_1 + \alpha_{GR}\alpha_r L_2\}\omega_G + (1-\tau_c)[r_{KH_{AV}}B_{KH_{AV}} + P^*_G r^*_{kH} + P_G r_{kH}] \quad (14)$$

$$W_H = M_H + B_H + B^L_1 + B^L_2 + E_H + H_{PI}K_{hH} \quad (15)$$

$$C_H = c_{\omega 1}Y_H + c_{\omega 2}W_H \quad (16)$$

In Equations (14)–(16), P^*_G represents the income from foreign bonds collected by the EU population; r^*_{kH} represents the average interest rate for investments in foreign short-term agreed maturity deposits or equivalently in foreign bonds (by EU population standpoint); P^r_G represents the income from domestic bonds by EU population; r_{kH} represents the average interest rate for investments in domestic short-term agreed maturity time deposits or equivalently in domestic bonds (by EU population). Equations (14)–(16) form the basis of the research. For EU28 (Furthermore, when mentioning the European Union (EU), we will refer to the EU28 composition of 1 July 2013 for the Republic of Croatia's ascension to the EU. The UK referendum on leaving the EU (''Brexit''), and its impact on calculations and conclusions, we also include and consider.) households, final mentioned system of equations corresponds to the categories of total net disposable: income (Y_H), wealth (W_H), and consumption (C_H). In the index of Y_H, W_H, and C_H variables, the capital letter ''H'' represents the households, while a small letter ''h'' represents the housing and/or real estates in possession.

Total disposable consumption (C_H) is a linear combination of total disposable wealth and income by coefficients $c_{\omega 1}$ and $c_{\omega 2}$. The sum of coefficients $c_{\omega 1}$ and $c_{\omega 2}$ is equal to 1, because of logic is similar to ''macroeconomic communicating vessels.'' Periods without crisis transfer earned income into wealth and/or consumption, and in time of crisis, wealth transfers back to income for consumption. Financial ''spill off'' is always present in life, and cycles between mentioned categories. In addition, they represent a closed unit circle in their net value. Chiarella et al.[22] defined coefficients as ''consumption function on a simple linear life cycle approach, which adds workers' wealth as an argument and determinant of their total consumption in nominal terms (but not yet the rate of interest, however measured)''. Chiarella et al. did not exactly determine the empirical values of the coefficients. They tested various coefficient values that are both hypothetical and theoretically possible. In our work, we try to incrementally contribute to Chiarella et al.[22] by implementing DT on real data, and among other, correspondingly to determine the values of coefficients in matter.

Keynes consumption function[28] (KCF or CF), is also known as simple consumption function (SCF),[11] has the analytical expression $C = C_{KCF} = a + bY$, where a represents the subsistence level of consumption, b represents the marginal propensity to consume (MPC), C is the consumption, and Y is the income. Let us have in mind that CF, or SCF, intersects the line with a slope of 45° at one point—we will name that point ''T.'' At point T, the average propensity to consume (APC) is equal to one. APC was always slightly lower than MPC. To the left of T, APC is greater than one, and to the right of T, APC is less than one. The meaning is that, to the left of T, consumption is greater than income, and to the right the consumption is less than income. Keynes stated that, at low incomes, people spend a high proportion of their income, and practically APC could be one. People spend everything they have, as with low incomes they are unable to have savings, because of spending everything they earn on essential goods. However, as income rises, people can afford to save a certain part of their income, although high-income owners have significantly lower APC!

Keynes called a ''fundamental psychological law'' that people do not spend all the income, but save some part. All aforementioned is a theoretical standpoint for a postulate that is almost one century old. Naturally, it has evolved in time. In representing more realistically the first bi-decade of 21st century in EU macroeconomics, and using historical–economical knowledge, we expand and modify the CF.

If we adopt the approach that the ratio between income and wealth is $(c_{\omega 1} + c_{\omega 2}) > 1$, we would agree with GR Holden[29] principle that the consumption C is greater than income Y (MPC > 1). We know that in macroeconomics long-term, it would be an economic ''perpetuum mobile.'' The meaning is that, people cannot sustain long-term consumption without income-backed funds, or by necessity, they should spend a certain amount of in time-accumulated wealth (supposedly, they have such wealth).

Alternatively, for $(c_{\omega 1} + c_{\omega 2}) < 1$, we would support JM Keynes principle that the consumption C is lower than income Y (MPC < 1), and that the remaining part of income continuously goes into savings. Again, it does not

reflect today's reality, as many families and people struggle to keep up the peace with their short and long-term consumption, wishes, and/or obligations (We present a couple of examples to get an overall impression of the practical implementation of CF. For the following values a = 500€ (fixed consumption in a period, e.g., monthly gas, electricity, car fuel, water, and municipality services), b = 0.7 (or, meaning someone spends 70% of its income), Y = 2.000€ (income), and C (consumption) has the calculated value of C = 500€ + 0.7 × 2.000€ = 500€ + 1.400€ = 1.900€. There is a need to spend almost all income on living costs, only 5% is possible to channel into savings, or investment. As mentioned it is (even) a relatively positive scenario. The other case would be if the income, all else being equal, is, e.g., Y = 1.000€. The aggregate consumption should be C = 1.200€, which is 20% more than the actual income! Human beings have a natural will and instinct for self-preservation. Accordingly, the difference in income one must (!) substitute by other means than wage/salary. Academics today argue that there is a steady and consistent worldwide trend of middle class ''economic disintegration'' as opposed to the economic expansion of the 1940s and 1950s. Recently, various studies have evidenced this.

Methodologically, we state that $(c_{\omega 1} + c_{\omega 2}) = 1$. Further suggesting the channel of total disposable wealth (W_H) (In our work, we define W (wealth) as an economically complex variable, see Equation (15) and related terms for a detailed explanation.) complements Keynes CF to unity. Keynes explicitly stated that the difference between consumption and income, related to the CF analytical form or b value, transfers to savings. Hence, the amount of savings should be equal to $(1-b)W = c_1 W$. Furthermore, $C = a + bY + c_1 W_{(H)} = a + bY + (1-b)W_{(H)}$. In sum, $b + c_1 = b + (1-b) = 1$, same as in our methodological approach. In addition, we could arrive at the same conclusions using the substitution $f = c_{\omega 1} a$ = const. Consequently, we have $C = C_{KCF} + c_{\omega 2} W_H = (c_{\omega 1} a + c_{\omega 1} Y) + c_{\omega 2} W_H = f + c_{\omega 1} Y + c_{\omega 2} W_H \approx c_{\omega 1} Y_H + c_{\omega 2} W_H$ {it is valid that $(c_{\omega 1} Y_H + c_{\omega 2} W_H) \gg f = c_{\omega 1} a\} = c_{\omega 1} Y_H + (1-c_{\omega 1}) W_H$, which further and again implies $\Longrightarrow$ $c_{\omega 1} + c_{\omega 2} = 1$, exactly at the point T!

We have merged EU workers and asset holders from Chiarella et al.,[25] and accordingly, there are savings by both categories. However, in the final 10–15 years, the point T in the CF intersection is (unfortunately) a much more realistic living standard ''scenario'' for the majority of the EU-wide population. The EU28 level of savings fell from 12.80% in 2009 to 10.67% in 2019 (Source: https://ec.europa.eu/eurostat/databrowser/view/tec00131/default/table).

Unemployment social security benefits in the EU generally last up to 1 year. Expectation is that one should be able to find employment within a year. Discrepancies exist in relation to how long unemployment benefit(s) last in the EU28. Therefore, we use the average value. The ratio of average wealth to 1-year average consumption is equal to 6.85 times, correspondingly coefficients $c_{\omega 1}$ and $c_{\omega 2}$ have values $c_{\omega 1}$ = 0.8726 and $c_{\omega 2}$ = 0.1274. On average, an unemployed EU citizen without income and a social security benefit can ''survive'' around 7 years, under the assumption that they worked throughout their life, earned some savings, have certain investments, and own real estate(s).

It is critical to note here, that not all EU citizens have the latter qualifications regarding the diversity and wealth possession. Considering the average rate of intertemporal wealth exchange, we have a significantly precise estimate in matter. Intertemporal wealth exchange indicates that younger workers have less accumulated wealth but have decent disposable income. In addition, they have high personal and professional mobility, i.e., more diverse career prospects in case of sudden unemployment. This is due to physical strength and/or knowledge of new IT solutions, which are essential and extensively used in the modern workplace. Middle-aged workers have average wealth, characterized by some savings and partly paid-for real estate, while the oldest workers have the most accumulated wealth, often including savings, investments, and real estate. ''Household'' can have various definitions. By the Eurostat statistic definition, we use the most commonly present.[5] EU28 households have, on average, two employed household members, and this is valid for families with or without children. The average household has three or four members. In addition, 87% of families with children have one or two children living with their parents.[5] In determining gross and net household salary (wage), we use the weighted income average of both employed household members.

Naturally, a household will avoid a situation where it is necessary to sell their apartment/house to cover everyday costs of living. However, in our research, we investigated household *resilience*, or a household's ability to ''survive'' when using all available means to cover living costs. Conversely, the main question arises what are the dynamics—qualitative and quantitative, between Y_H, W_H, and C_H?

3. Methods

Data used in the research originate from two main EU data sources: Eurostat and the European Central Bank (ECB) Storage Data Warehouse (SDW). SDW is the public name for the ECB statistical database, and both databases are public and free of charge.

The methodology implemented in the research consists of several procedures. First, we define the polynomial form of all variables in Equations (1)–(16) by fitting the observed data using the *Vandermonde coefficient matrix*

method. Combining the obtained polynomial expressions for exogenous variables in Equations (1)–(16), we obtain the final polynomial expressions for endogenous variables. After forming the final polynomial forms for Y_H, W_H, and C_H, we expand the initial data set using the obtained polynomial functions to define additional endogenous variable values. At that point, we perform an econometric method of NLLS on the newly generated and expanded endogenous variable sets. Simultaneously, we define the first-order derivative regressions for the involved variables. We define regressions independently of each other, and there are various combinations for 2D and 3D systems.

The following polynomial functions (Polynomial expressions for endogenous variables are of 28th, 14th, and 7th degree and have all terms, similarly, for all exogenous variables. All coefficients in such expressions have at least 54 (or more) digits, due to double precision calculation. We use double precision to study the effects of how a small change/perturbation in some parts can affect the system as a whole. Accordingly, they are very hard to present in this paper space wise. On demand, here used research material we will gladly provide to interested researchers.) are used to calculate the variables:

$$x(t_s) = Y_H(t_s) = \sum_{\alpha=1}^{r} P_{1\alpha}^{(\gamma)}(t_s) \tag{17}$$

$$y(t_s) = W_H(t_s) = \sum_{\beta=1}^{d} P_{2\beta}^{(\delta)}(t_s) \tag{18}$$

$$\begin{aligned} z(t_s) &= C_H(t_s) = c_{\omega 1} Y_H(t_s) + c_{\omega 2} W_H(t_s) \\ &= c_{\omega 1} \sum_{\alpha=1}^{r} P_{1\alpha}^{(\gamma)}(t_s) + c_{\omega 2} \sum_{\beta=1}^{d} P_{2\beta}^{(\delta)}(t_s) \end{aligned} \tag{19}$$

In indices (17)–(19), s is the number of newly defined time intervals (extension of the original time interval), and $s = 132$ (the number of months in 11 years); α and β represent the number of exogenous variables included in the model, $r = 16$ and $d = 7$, respectively; γ and δ represent the highest order of best polynomial fit for Equations (17) and (18), respectively, where $\gamma = 28$ and $\delta = 7$. The corresponding derivatives in time for Equations (17) and (18) are Equations (20) and (21). The linear combination of Equations (20) and (21) defines Equation (22).

$$\dot{x} = \dot{Y}_H = \sum_{\alpha=1}^{r} P_{1\alpha}^{(\gamma-1)}(t_s) \tag{20}$$

$$\dot{y} = \dot{W}_H = \sum_{\beta=1}^{d} P_{2\beta}^{(\delta-1)}(t_s) \tag{21}$$

$$\dot{z} = c_{\omega 1} \sum_{\alpha=1}^{r} P_{1\alpha}^{(\gamma-1)}(t_s) + c_{\omega 2} \sum_{\beta=1}^{d} P_{2\beta}^{(\delta-1)}(t_s) \tag{22}$$

Table 1. Change of one coefficient and affected variables.

Coefficient	Affects
a	Income—by the change of wealth
b	Income—by the change in consumption
c	Wealth—by the change in income
d	Consumption—by the change of income
e	Consumption—by the change of wealth

For pragmatic reasons, we will not present polynomial expressions for total disposable income (Y_H), total disposable wealth (W_H), and total disposable consumption (C_H) in detail. The new (expanded) endogenous variable set(s) now has 132 steps corresponding to 132 periods, or 11 years (2005–2015) multiplied by 12 months.[30,31]

EViews software[32–34] is implemented on the new expanded set to define NODE systems[35] using the NLLS method.[36–40]

The obtained system is:

$$\begin{aligned} \dot{x} = {} & ay + bz + 13.5253578245x^2 - 0.690104080865z^2 \\ & - 0.138525496665x^2y + 0.196119583397z^2x \end{aligned} \tag{23}$$

$$\begin{aligned} \dot{y} = {} & cx + 20.9011379499x^2 + 4.8792373844z^2 \\ & - 0.00287830380623y^2z \end{aligned} \tag{24}$$

$$\begin{aligned} \dot{z} = {} & dx + ey + 0.021147547x^2y - 0.00209020475075y^2x \\ & + 0.436778879943xy \end{aligned} \tag{25}$$

Substituted system parameters in Equations (23)–(25) are as follows:

$$a = 8.45687126471, b = -53.1264586317, c = -337.85774025,$$
$$d = -48.0284342842, \text{ and } e = 0.459277371024$$

The starting point or initial condition for Equations (23)–(25) is $(x_0(0)–y_0(0)–z_0(0))$, where $x_0 = 3.4823$, $y_0 = 135.3687$, and $z_0 = 20.28491923073593$. The initial point in an NODE system analysis corresponds to the value of endogenous variables at the end of the first period/year. It is clear and obvious that real-life macroeconomic variables need some time to progress, to have a finite value in matter. In all calculations related to this research, we consider, with synchronicity, the mentioned one-time period lag. The abovementioned does not affect the qualitative and quantitative behavior of NODE systems and/or NDA conclusions due to its relative nature.

In Table 1, we can see variable interdependencies in systems (23)–(25) for one parameter/coefficient change.

There are situations when two coefficients change simultaneously, e.g., the change of coefficients d and e

reflect how the change in income and wealth influence consumption. There are numerous similar combinations in Equations (23)–(25); however, we only present coefficients d and/or e change interdependencies. All values are in trillions of euro (€). Other coefficients in Equation (23) represent the speed of change, how fast the disposable income absolute (squared) value change affects its own final value (x^2), and how the absolute change of disposable consumption affects disposable income (z^2). Equations (24) and (25) similarly match their corresponding macroeconomic meaning. We implemented the model derivation process by starting with all combinations of exogenous variables and their corresponding coefficients up to the fourth degree. We removed insignificant high p-value coefficients and repeated the regression process until statistical and NDA standards were met.[36,37]

We form the presented 2D systems by combining endogenous variable values for Y_H, W_H, and C_H in regressions. The combinations are Y_H–W_H, Y_H–C_H, and W_H–C_H. The first model, a system in 2D, for Y_H–W_H is:

$$\begin{aligned}\dot{x} = {} & 6.60849150292y - 0.0387159096202y^2 + 0.901965701492x^2y \\ & - 4.7914410614e-05y^2 + 0.0345166029752y^2x \\ & - 4.81428296836xy - 0.00707981334326x^2y^2 \\ & + 1.30400617517e-06x^3y^3 - 0.289160634084x^4\end{aligned} \tag{26}$$

$$\begin{aligned}\dot{y} = {} & -789.360304346y - 7278.75059057x^2 + 2.00654476396y^2 \\ & + 1895.0078082x^3 + 0.0116097917941y^3 - 142.108117291x^2y \\ & - 4.24755739138y^2x + 840.915109404xy + 0.818695258119x^2y^2 \\ & - 0.00012009371033x^3y^3 - 80.9908881783x^4\end{aligned} \tag{27}$$

High R-squared values may indicate ''spurious regression'' results. That is not the case here.

We tested for stationarity and variable(s) residuals for all 2D and 3D systems. Results are obtained by implementing the unity root test using the Augmented Dickey–Fuller (ADF) test with level, the first difference or second difference when required, both intercept and/or trend options variations, and with the Schwartz Information Criterion on 12 lags or using the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test (whichever was possible to perform from that level and up). In almost all cases, the ADF test's results present nonstationarity of residuals. However, KPSS test results indicate stationarity of all residuals. Thus, the overall conclusion is that the residuals for 2D and 3D systems are trend-stationary. Hence, the absence of spuriousness in regression results, and the confirmation of regression(s) expressions.

In addition, we performed autocorrelation (AC) and partial autocorrelation (PAC) tests for all variables and residuals, obtaining the same results. There is no significant AC, except for the first lag, and even then, it is less than one (For every equation and system presented, we can provide to interested readers tables (screenshots), other related scientific materials, including all the histograms, AC and PAC values, coefficients and residuals diagnostic, and so on, as a proof of unbiased and consistent estimation of equation/system coefficients. For reasons of rationality, we do not present them in this paper.). The relatively high goodness of fit for dependent variables is due to this study's use of high-order polynomial fit, as opposed to linear and quadratic combinations of independent variables—with or without lag. In addition, with very high polynomial coefficient precision, we obtain very close values for dependent variables. This always generates regressions with high R^2 values.

p-values in regressions are all zero because we dropped out all nonzero p-value coefficients. We based our decision on the already existing goodness of fit, and on the desire to scale down the model's complexity. We compared the two regressions for goodness of fit, with all p-values that have a statistical acceptance level under 5%, contrary to using only zero p-value coefficients. The goodness of fit was almost identical in both cases, and we therefore decided to make regression expressions less complicated for NDA.

Table 2 presents the EViews regression screenshot output for Equations (26) and (27). We observe a relatively high R-squared value of 0.914573. Comparing the obtained R-squared value to econometric applied research results (usually ranging from 0.35 to 0.65), those values indicate excellent results.[22,39,40]

The eventual existence of multicollinearity is of no importance in this research because we do not use regressions to analyze the influence of regressors on dependent variables, but only variables' mutual relationships in NDA. In addition, multicollinearity does not reduce the predictive strength of the model, but rather affects only the regression calculations for individual regressor parameters. This is a consequence of this study's methodology, and does not suggest a problem in regression definition. There exists a strong macroeconomic positive correlation between Y_H and W_H as households translate income into wealth and/or consumption increase. By wealth, we mean real estate, savings, investments, and so on. Low income means less wealth and consumption.

The central point in this research and methodology is to explain, as well as possible, the changes of endogenous variables, with those same variables. This implies that we should have an excellent variable derivatives fit with combinations of those same variables. All said, this is valid only for macroeconomic variables that do have an intrinsic and ''natural'' correlation, and in this study, income wealth and consumption have a strong economic relationship.

Classical econometric norms for regressions are of secondary importance in this methodology because we will analyze systems only by NDA. In essence, for this research, econometric rules that are usually strict and

Table 2. EViews NLLS regression results for Equations (26) and (27).

System: Y_H_W_ H_OMEGA12				
Estimation method: nonlinear least squares				
Date: 31 May 2020. Time: 17:25				
Sample: 2005M01 2015M12				
Included observations: 132				
Total system (balanced) observations 264				
	Coefficient	Standard error	*t*-Statistic	Probability
C(13)	6.608492	0.849645	7.777944	0
C(15)	− 0.03872	0.004555	− 8.49904	0
C(17)	− 4.79E − 05	8.66E − 06	− 5.53031	0
C(18)	0.901966	0.13706	6.580788	0
C(19)	0.034517	0.004869	7.089551	0
C(110)	− 4.81428	0.688178	− 6.99569	0
C(111)	− 0.00708	0.001061	− 6.67222	0
C(112)	1.30E − 06	2.08E − 07	6.284052	0
C(113)	− 0.28916	0.052133	− 5.54658	0
C(23)	− 789.36	56.35737	− 14.0063	0
C(24)	− 7278.75	734.2353	− 9.91338	0
C(25)	2.006545	0.38556	5.204228	0
C(26)	1895.008	168.2991	11.25976	0
C(27)	0.01161	0.001293	8.97697	0
C(28)	− 142.108	10.45801	− 13.5884	0
C(29)	− 4.24756	0.296242	− 14.3381	0
C(210)	840.9151	59.11406	14.2253	0
C(211)	0.818695	0.061603	13.28992	0
C(212)	− 0.00012	9.93E − 06	− 12.0885	0
C(213)	− 80.9909	8.90979	− 9.0901	0
Determinant residual covariance		0.001427		
Equation: X_DOT = C(13) × Y + C(15) × Y^2 + C(17) × Y^3 + C(18) × X^2 × Y + C(19) × Y^2 × X + C(110) × X × Y + C(111) × X^2 × Y^2 + C(112) × X^3 × Y^3 + C(113) × X^4				
Observations: 132				
R-squared	0.853453	Mean dependent variable		0.172275
Adjusted *R*-squared	0.843921	S.D. dependent variable		0.153112
SE of regression	0.06049	Sum squared residual		0.45006
Durbin–Watson statistic	0.114087			
Equation: Y_DOT = C(23) × Y + C(24) × X^2 + C(25) × Y^2 + C(26) × X^3 + C(27) × Y^3 + C(28) × X^2 × Y + C(29) × Y^2 × X + C(210) × X × Y + C(211) × X^2 × Y^2 + C(212) × X^3 × Y^3 + C(213) × X^4				
Observations: 132				
R-squared	0.914573	Mean dependent variable		2.237997
Adjusted *R*-squared	0.907513	SD dependent variable		6.888352
SE of regression	2.094865	Sum squared residual		531.0035
Durbin–Watson statistic	0.104113			

SE: standard error; SD: standard deviation; NLLS: nonlinear least squares.

binding for regressions have much less impact as the scientific analysis will perform NDA in phase space. Coefficient analysis with the covariance ellipses method indicates the absence of correlation in most cases, and for all significant coefficients (Figure 1).

By value regression, the highest (''heaviest'') coefficients have no correlation. Some correlations arise with less significant coefficients. The highest coefficient determines the regression main curve behavior, while the other coefficients determine fine-tuning to final values.

NLLS considers combinations of multiple variables on different exponents, and not solely the lagged values/errors of independent variables. In addition, adjusted *R*-squared equals 0.843921 and 0.907513, and is near *R*-squared values. Adjusted *R*-squared is a regression link to degrees of freedom of the initial sample, and it penalizes the model

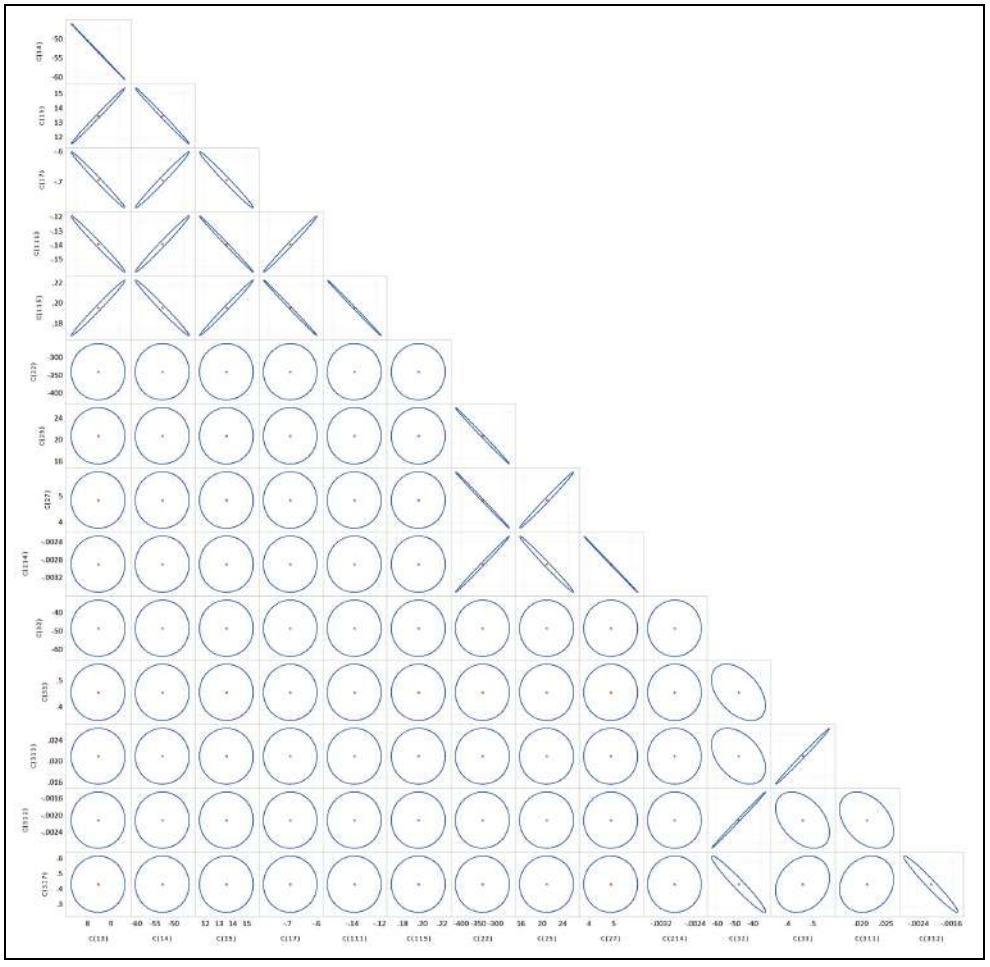

Figure 1. Covariance ellipse coefficient analysis for Equations (26) and (27) present acceptable presence of correlation.

for using insignificant independent variables. Small differences between *R*-squared and adjusted *R*-squared confirm the overall results. Standard errors (SEs) of regression are shown in Figure 2 (blue line), and are within acceptable boundaries of statistical error. That is, SE is equal to 2.094865, and is frequently less than 3% (Figure 2(b)).

It is important to note that, at the edges of the presented interval, modeled variables have some distortions due to the correlation of the degrees of freedom of initial data sets for all variables included in Equations (1)–(13), and the degree of Vandermonde matrix highest coefficient in polynomial fits. This does not cause any inconsistencies in the analysis and conclusions of evolutional operators in NDA because the evolution operator flow has inherent ''inertia'' or value stickiness.

Durbin–Watson (DW) statistic value is near zero (DW = 0.104113), and it clearly indicates the existence of a strong positive AC. Numerically, if possible, NLLS will always try to estimate up to the dependent variable value, and not overshoot it.[39,40] We estimate the derivative (change) of endogenous variables with positive and negative sign values. In the correlation matrix, it always induces a strong first lag correlation, but still less than one. Other lag values were less than one. Variables that have certain macroeconomics connection must show some degree of AC. In this study, positive AC is better and more ''desirable'' than negative AC. Conversely, residuals are mainly of the same sign and on the same ''side'' of estimation curve (estimated values are less than the observed/real values).[32,40]

Furthermore, for 3D systems (23)–(25), we have acceptable *R*-squared values, of 0.823086, 0.626367, and 0.675471, respectively. In addition, we have DW close in value between all three variables in the 3D system. DW values in 3D systems are similar to the case of all 2D systems with the same explanations.

We tested and confirmed that Y_H is nonstationary, and its residuals are stationary. Variables W_H and C_H are stationary, and their residuals are trend-stationary. The premise of the original model in Equation (16) by Chiarella et al. has in its definition a strong linear bond between endogenous variables. In addition, it does not represent a

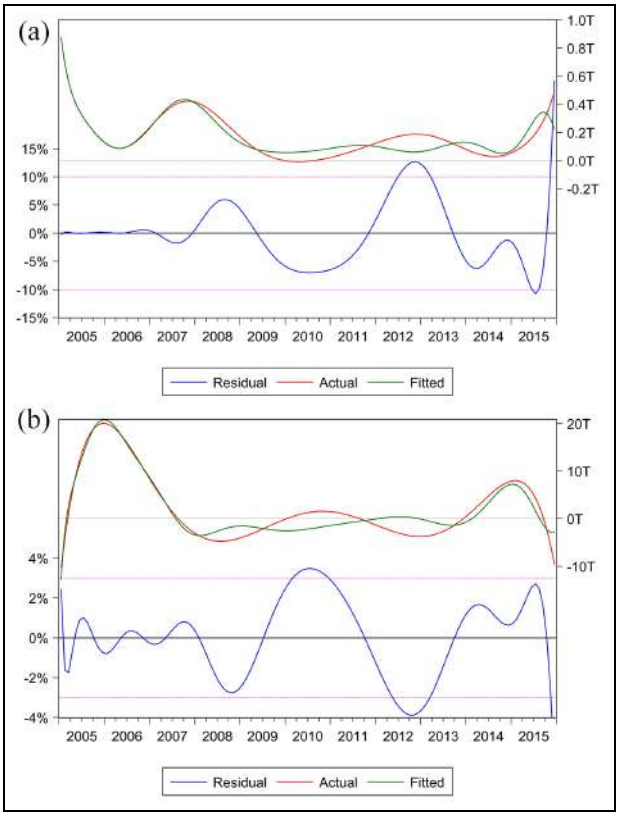

Figure 2. Actual (red) and fitted (green) values, in trillions of euro, of dependent/endogenous variables change (derivative). Right axis: (a) for $\dot{x}$ is the total disposable income of EU population (Y_H); (b) for $\dot{y}$ is the total wealth of EU population (W_H). Residual values (blue) are in percentage and use left axis in (a) and (b). Pink dotted lines on graphs represent 10% and 3% margin, for residual error for $\dot{x}$ and $\dot{y}$, respectively.

problem related to obtained DW value, as we have a very high goodness of fit for all variables using polynomial representation, acceptable positive AC due to not overshooting values of dependent variables, and using NLLS on a relatively wide set of expanded data with double precision calculations.[22,39,40]

In addition, we define 2D system for Y_H–C_H:

$$\begin{aligned}\dot{x} = {} & 55.8703026552y - 11.562928349x^2 - 2.63682532924y^2 \\ & + 7.5099444639x^2y + 1.70702523514y^2x - 34.8573222842xy \\ & - 0.369944451525x^2y^2 + 0.000423242850597x^3y^3 \\ & - 0.282277778999x^4\end{aligned} \tag{28}$$

$$\begin{aligned}\dot{y} = {} & -909.309174717x - 389.865490323y + 14.4613766406y^2 \\ & - 63.3218370705x^2y - 17.8606213969y^2x + 422.923220009xy \\ & + 3.24101958971x^2y^2 - 0.00374050131696x^3y^3 \\ & + 2.91957946299x^4 + 0.00670249001496y^4\end{aligned} \tag{29}$$

In addition, for W_H–C_H:

$$\begin{aligned}\dot{x} = {} & -2199.5782845x + 19.3111629818x^2 + 207.78679052y^2 \\ & - 1.93967939814x^2y - 8.62819668047y^2x + 205.425861465xy \\ & + 0.0715240896809x^2y^2 - 2.09639243177e-06x^3y^3\end{aligned} \tag{30}$$

$$\begin{aligned}\dot{y} = {} & -101.273616489x + 572.743353146y - 53.6369547603y^2 \\ & + 0.00470259716494x^3 - 0.0949084413257x^2y \\ & + 0.338166544961y^2x + 10.0365059692xy \\ & + 0.00018293223347x^2y^2\end{aligned} \tag{31}$$

The data points that were missing were determined by extrapolation and/or interpolation using the modified Akima method,[41] with a function called *makima* in MATLAB. *Makima* methodological basis considers a priori and a posteriori data values, when determining the missing values. All 2D systems and a 3D system were defined completely independently. For analyzing 2D systems, we use *pplane9*,[42–44] and for 3D system with a specialized application MATCONT ver. 7p1 for MATLAB® ver. R2018b.[45,46]

Using applied numerical, graphical, and bifurcation examination of the discovered equilibriums and singularities, we perform a deduction analysis for significant EU macroeconomic variables.

By induction and synthesis, we will try predicting the qualitative and quantitative system evolution.[5,8,45,47,48] Using NDA, we define phase portraits, solutions, and parameter spaces for the known past period from 2005 to 2015, which represents 11 years of most constitutionally stable EU. Subsequently, from the model standpoint, we compare obtained results of flow to a ''relative future'' for years 2016–2019 performing a precision-level inspection.

Data for 2020/2021 were not included in this research. Statistically speaking, it is more a *Black Swan* type event (influenced by COVID-19 pandemics), than it is a ''normal'' macroeconomic system behavior. If the previous methodology is adequate, and satisfies the broadly posed scientific criterion on statistical (marginal) error, we can further make predictions about variable values true future. We isolate variables of interest and determine their optimal NDA (calculated) values, with the aim of recommending in future better, e.g., monetary and/or fiscal policies.

The NDA discovered that the number of potential consistent and reliable periods for prediction is around 21 periods (exactly 20.74). Universal and uniquely accepted definition of chaos does not exist, but the postulates that everyone will agree on the state: ''Chaos is aperiodic long-term behavior in a deterministic system that exhibits sensitive dependence on initial conditions.''[9] Numerical solutions for the NODE system of Equations (20) and (22) are in phase space.

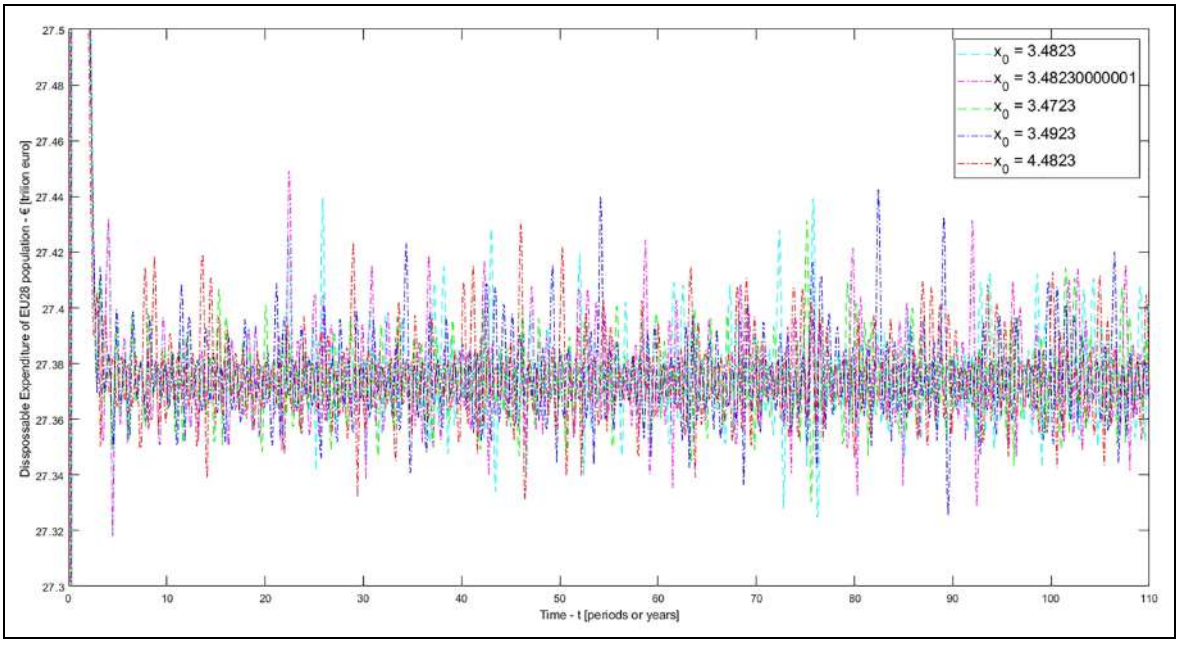

Figure 3. Change in the initial value of total disposable income Y_H (x_0) (trillion €), and its impact on C_H. The exact change in value for initial conditions is presented in figure's legend.

Used NDA methodology has means to discover and interpret core macroeconomic dynamics. Correspondingly, the main purpose is to discover or detect the underlying and hidden (deeper) dynamics that arise by discovering singularities and bifurcation continuation, and not ''only'' by finding solutions/equilibriums for the system. When a singularity arises in 3D, we continue it numerically. In the case of 2D systems, we analyze the relationship between trajectories, observed, and simulated results. The importance of obtained results has ground in the discovery of deeper and hidden systems dynamic—connected to their economic meaning, in contrast to the general equilibrium approach. Usually, the system of NODEs is impossible to solve analytically. Therefore, we use simulation(s) to determine qualitative and quantitative behavior, without actually solving them.

We look for chaos in C_H because it is a resulting time series of two endogenous variables, and the final aim of the interaction of two endogenous variables. In addition, it represents a deterministic variable from the rest of the model. Correspondingly, by determining the presence, or absence, of chaos, it is important to know the window of reliable prediction for 3D systems. As mentioned, it is irrelevant for Y_H and W_H, so we do not inspect for chaos in those variables.

Furthermore, we check for sensitive dependence on initial conditions to prove or disprove the birth of chaos in endogenous, and deterministic C_H time series.

The change of C_H depends on small changes in initial conditions of Y_H, presented in Figures 3 and 4. According to the cited ''definition'' of chaos, we clearly see that there is a resemblance of an aperiodic long-term behavior. In Figure 3, we present 110 periods (years). The period of 110 years has no macroeconomic meaning, but it has a mathematical meaning to show long-term aperiodicity. We could have picked any relatively significant number (e.g., 500 and 1.000). Conclusively, there is no periodic component, and it is completely stochastic. In making the final statement, we need to be very cautious because sometimes after billions, trillions, or even more, iterations and calculations there may arise periodicity. In that regard, we will perform more tests that are rigorous.

In addition, the system is deterministic, with no random component(s) inserted in the system (model) at any time. Furthermore, the system clearly exhibits a very dependable behavior to small changes in initial conditions. For insignificant dilatations in the initial conditions, we get chaotic behavior of the system after the mentioned period. On the difference between the two initial conditions presented in Figure 4, on average, it is less than 0.00321669%, and we treat it as insignificant by macroeconomic statistical standards.

The mentioned difference coincides with the a priori defined precision in the process of numerical solving of the NODE system. We could set a more rigorous tolerance condition(s) for solving the NODE system, but as a consequence, we would have unreasonably longer times for numerically solving the system, and would need much more computation power. Important to note is that, when we perform NODE MATCONT analysis, there is a transition (transient) period at the start of computation of around

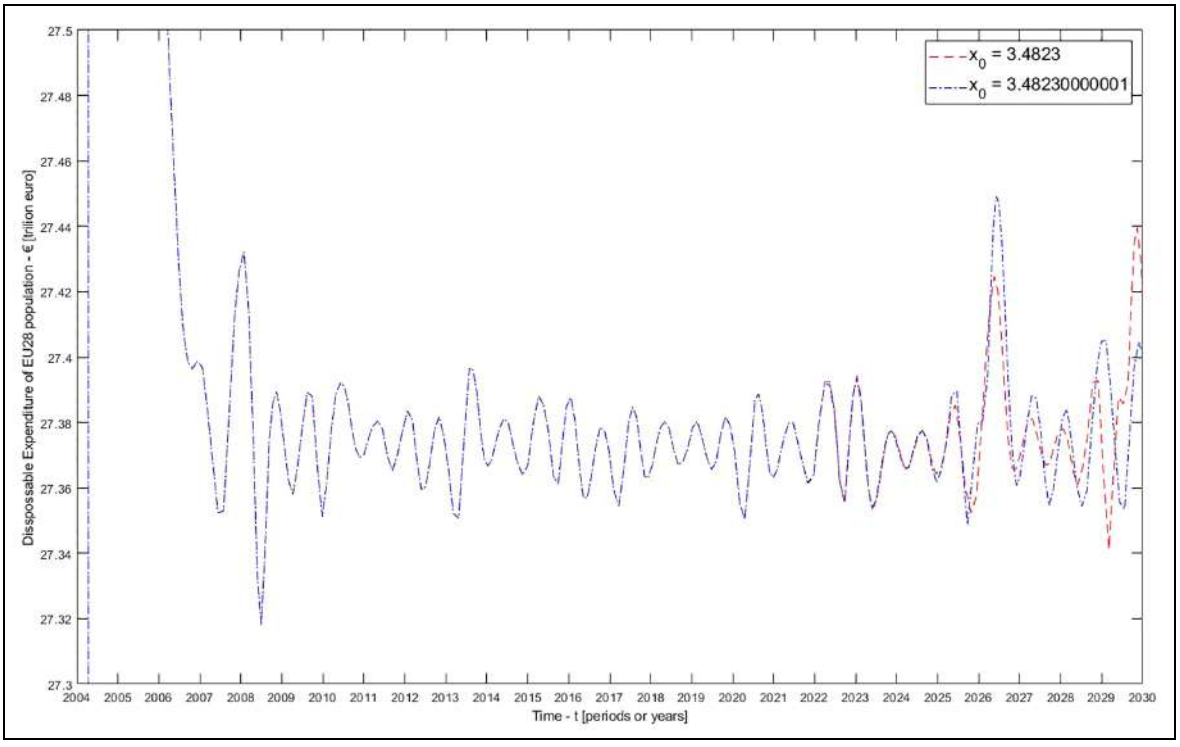

Figure 4. Zoomed in, the difference in initial value change for total disposable income Y_H, and its impact on C_H. The value change for Y_H (x_0) is presented in figure's legend.

2.5–3 periods (exactly 2.812), after which the numerical integration settles at stable values.

We rigorously tested the presence of chaos by implementing the Gottwald–Melbourne ''0–1 test''[49,50] (further in the paper marked as ''0–1 Chaos test''), the LE Jacobian method,[51] and the activation function with neural network (AFNN) test that approximates a chaotic map.[52–54]

The system defined by Equations (23)–(25) for C_H values numerical settles, as mentioned, after 3 periods or 97 iterations around a mean value of 27.3835 (trillion euro). By continuation in MATCONT, we discovered that for small changes in initial conditions, the resulting two trajectories in phase space differ from each other chaotically (Figures 3 and 4). Every solution curve converged to a strange attractor in the form of limit cycle (LC) after 21 periods (Figure 5).

The LE Jacobian method[51] is presented in Figure 6.

LE only cannot definitely determine the existence of chaos. Accordingly, we performed additional rigorous tests. The AFNN[52–54] gave us the following results for C_H value: $H = 0$, p-value = 1, $\lambda = 0.0023$, where positive LE indicates the onset of chaos, and AFNN = (1, 1, 1), confidence interval (CI) = 0.0022.

Hypothesis $H = 0$ means, ''Do not reject the null hypothesis of Chaos at significance-level CI (0.0022).''[54] The standard level of CI is equal to 0.0022, meaning that CI is not satisfied for 0.22% of all sample data. Chaotic behavior is certain, as probability p is equal to one.

For neural network (NN), the initial order we chose was (L, m, q)[53] = (5, 6, 5). However, it was automatically ''downgraded'' after the computation to (1, 1, 1). NN did not need many layers to define AF with chaotic characteristic, as it is an obvious case from NN standpoint.

In addition, we conducted the ''0–1 Chaos test'' on 1089 data points obtained from the C_H difference for two different initial conditions for x_0 (time series in Figure 5), with the result equal to 0.9872. Values for both x_0 initial conditions were presented in Figure 4 legend. In the ''0–1 Chaos test,'' if the result of the analyzed time series is near zero, it means nonchaotic data. Contrary, if the result is near one, the time series is chaotic. In all tests, we took special care not to over or under sample time series, as it might result in wrong conclusions. Sometimes, transient(s) last for 100 iterations. The aperiodic behavior starts to be obvious only after a few thousands of iterations. We carefully observed to maintain a constant balance between the usage of different methods and data samples, as it represented a supplementary challenge in this research. A strange attractor for C_H is presented in Figure 7.

For $\lambda < 0$, the orbit attracts to a stable fixed LC. A negative LE is characteristic of dissipative or nonconservative system. Such a system exhibits asymptotic stability. The more negative the exponent, the greater the stability. Super-stable fixed points and super-stable periodic points have a $\lambda \to -\infty$.[54]

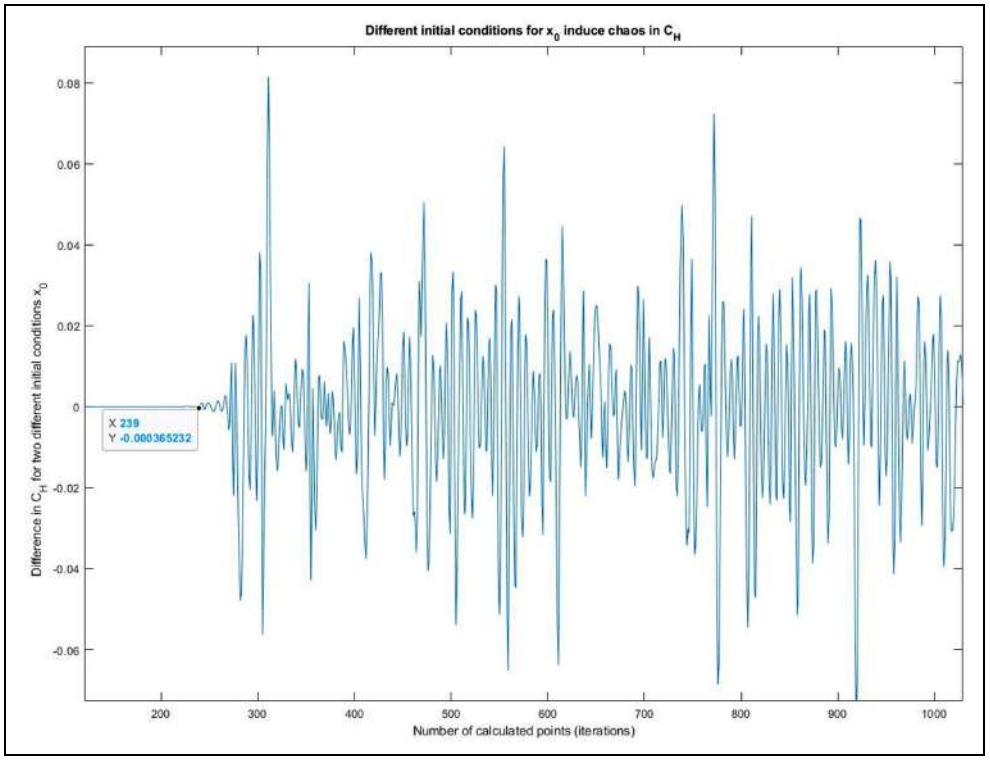

Figure 5. Different initial conditions for x_0 induce chaos in C_H. Difference between 1.089 data points for C_H values for two different initial conditions x_0 (values shown in Figure 4 legend). After 239 iterations or 20.74 periods, the difference starts from 0.000365232 trillion euro (365.23 million euro) and up.

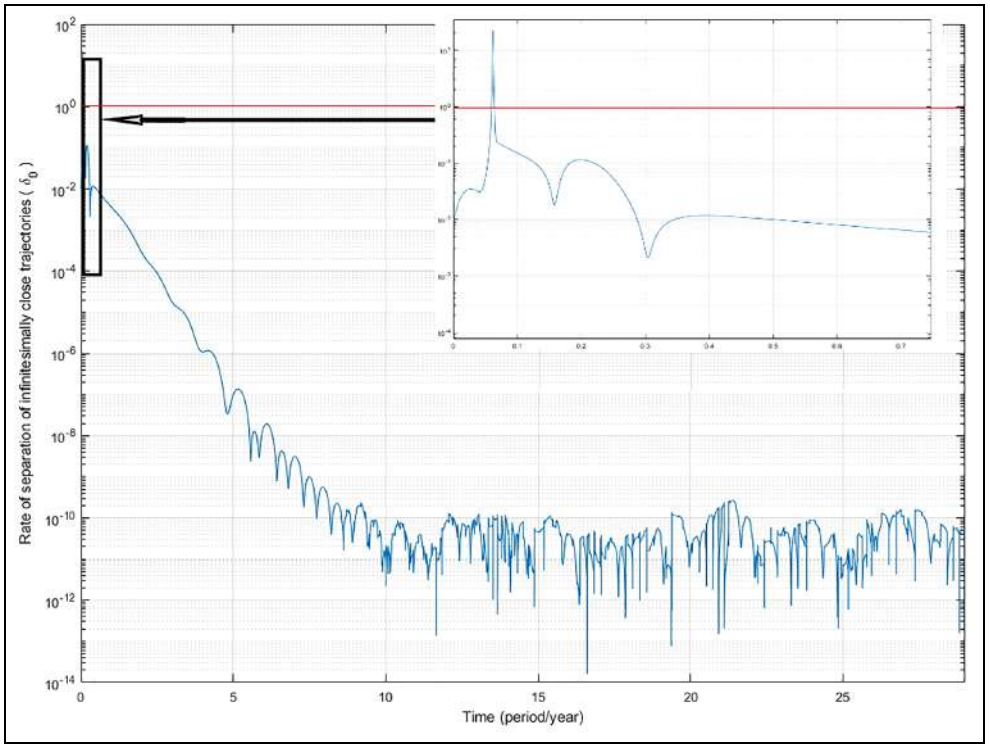

Figure 6. LE for Y_H, W_H, and C_H system. The rate of separation of infinitesimally close trajectories δ_0 consequently shrinks the volume in phase space exponentially fast.

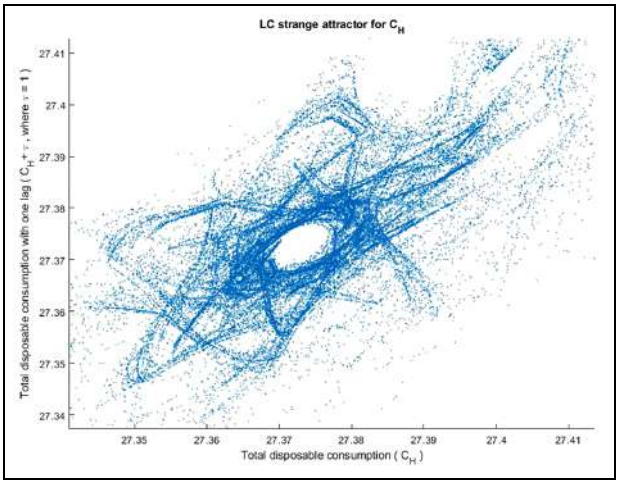

Figure 7. Strange attractor for C_H solution curves in phase space. Super-stable LC emerges as $t \to \infty$ (*Poincaré – Bendixson Theorem*). Planar projection of 3D attractor after 46.033 calculated points (5.008 periods/years). The system is dissipative and volume contract under the flow in phase space,[9] as is visible from the other two (remaining) planar projections/calculations.

We note again, that λ depends on x_0. However, it has the same qualitative behavior for all x_0 in the basin of attraction for a given attractor. The number of prediction periods differs slightly from earlier stated because LE calculation depends on initial conditions and calculation steps. The dips in Figure 6 should drop down to $\lambda = -\infty$ because a super-stable cycle is guaranteed to occur somewhere near the middle of each dip, and such cycles have $\lambda = -\infty$.

This part of the spike was too narrow to be resolved in Figure 6.[9] The step of integration is 0.001 to avoid over or under sampling. LE is not a uniform indicator of chaotic behavior. After more than 100 iterations, it is still uncertain whether LE is in chaos ($\lambda > 0$) or was a transient. For mentioned reason, we couple LE with AFNN, and the ''0–1'' chaos testing method.

Although we found chaotic behavior, from the macroeconomic standpoint, it has no practical impact. On several system points and parameter values, we discovered ''hints'' of chaos, but for the same later mentioned reason, we did not inspect it in detail.

To find a balance between macroeconomic useful results, and only mathematically interesting ones, is a true challenge. We do not state that the difference from 365 million to 850 billion euros does not make a very significant difference, but it is not enough to disorder the EU macroeconomic system into chaos.

4. Results and discussion

4.1. Analysis and results for 2D systems

In this section, we will analyze 2D systems to determine an eventual discrepancy between observed data and system flow values. By performing NDA, we determine in phase space what are attracting or repelling points/curves, further defining qualitatively and quantitatively macroeconomic behavior interdependency between endogenous variables. In addition, coherent and independently obtained results for 2D and 3D systems have a mutually conclusion-supporting value and meaning.

One of the most important tasks is to discover in phase plane the existence of focal sink(s) or stable node(s), as they show the tendency of the system flow to converge on those singularities. In economic terms, this means that the values of endogenous variables will converge on those values (singularities), even though they are not optimal or desired by broadly posed standards. It depicts an ''economic flow imminence'' in reaching those points when we consider all variable interdependencies! In reality, it describes which values the system ''should have'' to be stable and flow consistent. Macroeconomics and real life are continual. If some structural breaks arose, they would be always artificial, contrary to the continuous flow, and subjectively human in origin.

Using the *pplane9* application for MATLAB, we analyze 2D systems. For 2D systems, we will not present a bifurcation analysis. We focus on 2D analysis to discover the overall system flow, eventual existence of converging points, and corresponding trajectories. Created through numerically solving the systems of Equations (26) and (27) we obtain, for instance, the Y_H–W_H 2D system graphical solution, to determine stable and unstable manifolds, and to discover the discrepancy between the observed and solution-generated values. Generally, this is valid for Figures 8–11, and partially for Figure 9, which is only for idea-illustration purposes.

In addition, we use simplified 2D models (26)–(31) to define the flow of the system and to determine singularities. Based on the determined singularities from the original model (14)–(16), tax rates and wages correspond to these singularities.

4.1.1. Y_H–W_H variables, 2D system. Based on a 2D simulation of macroeconomic variables in Equations (26) and (27), we determine the system solution(s) and singularity discovery. The phase plane NDA for Y_H–W_H is presented in Figure 8.[8,9,43] There are two scales on the x-axis: the upper for years and the lower for Y_H value (EUR in trillions). On the y-axis, we have a value in trillions of euros for W_H. The purple triangles on the graph mark values obtained by polynomial expressions, and represent ordered pairs of endogenous variables (Y_H–W_H). Military green diamonds with cross marks the observed/original data values from Eurostat and ECB (SDW). This marks the correspondence with the years 2005–2014. The black circle with a star in the middle is the value for 2015, and it is marked with letter ''E.''

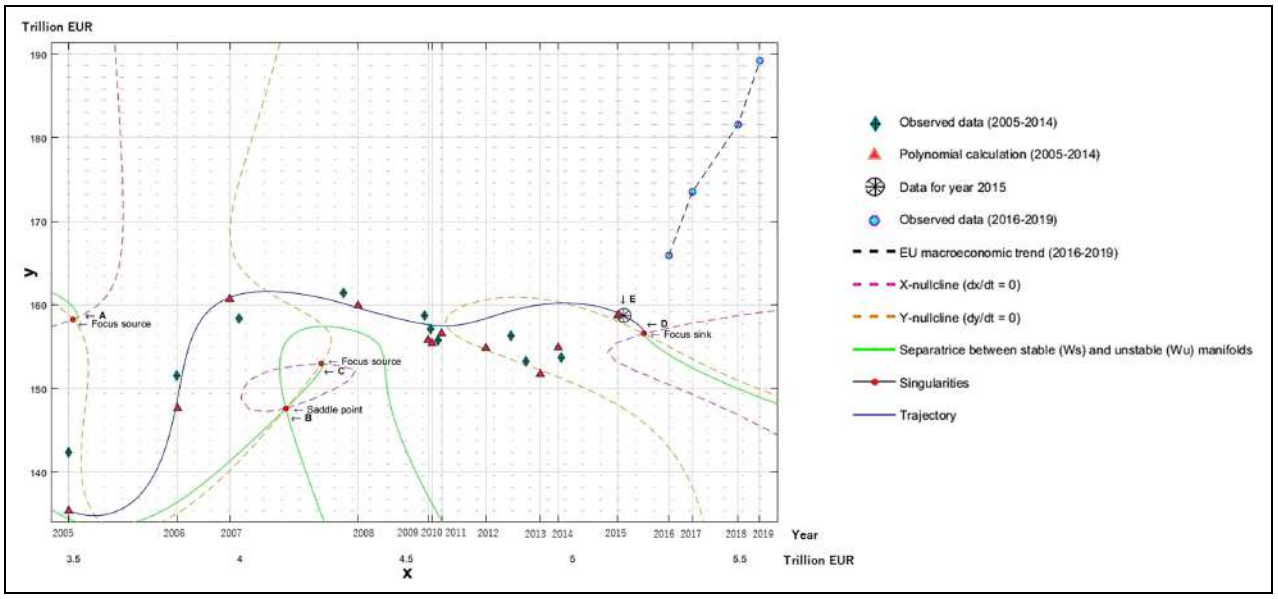

Figure 8. Interdependency in the phase plane for Y_H and W_H with characteristic data points and trajectory.

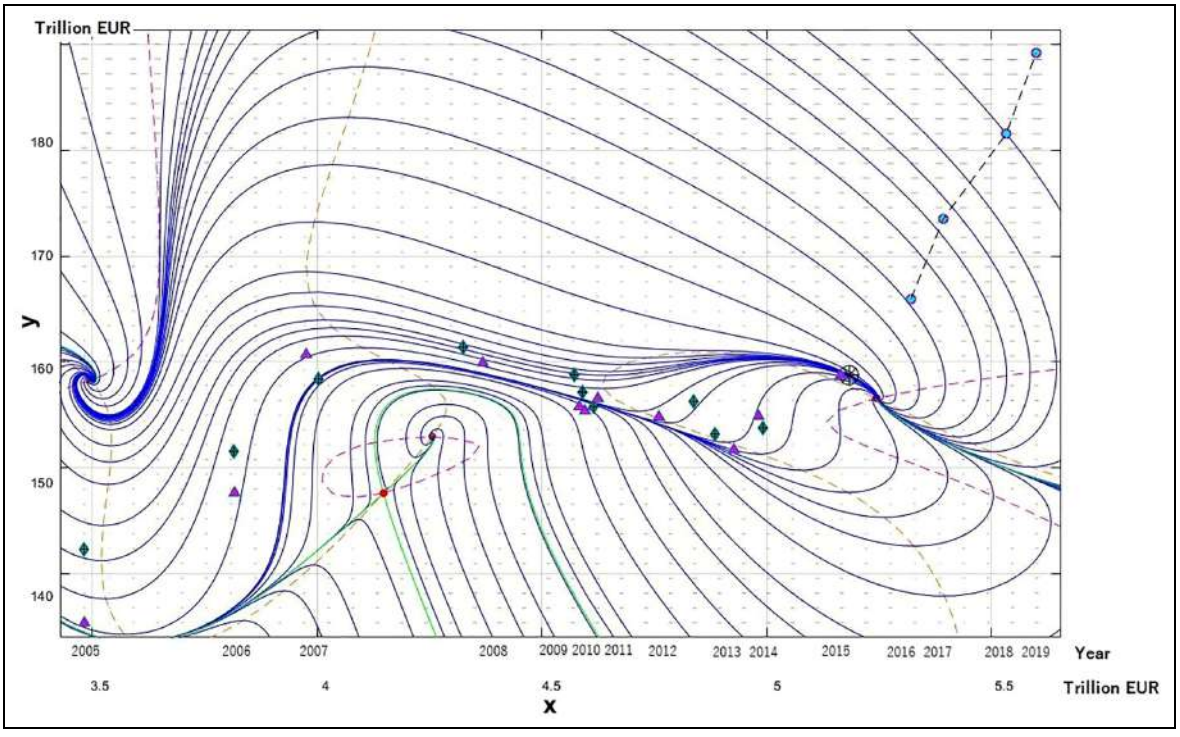

Figure 9. Similar to weather maps, macroeconomic trajectory depends on initial conditions. Presented methodology can become a standard proposition for analyzing systems in economics. The computational power, application diversity, and elaborate mathematical foundations make this approach very feasible.

The red dots represent the EPs. The cyan filled circles represent observed/original data for 2016 through 2019. The dashed black line connecting azure points from 2016 through 2019, and it represents a real EU macroeconomic trend.

The following EPs were calculated, and marked in notation (Y_H–W_H): (3.4954–158.2489) focus source (point A); (4.1475–147.6098) saddle point (point B); (4.2561–152.9631) focus source (point C); (5.2440–156.5716) the focus sink (point D).[8,9,55,56]

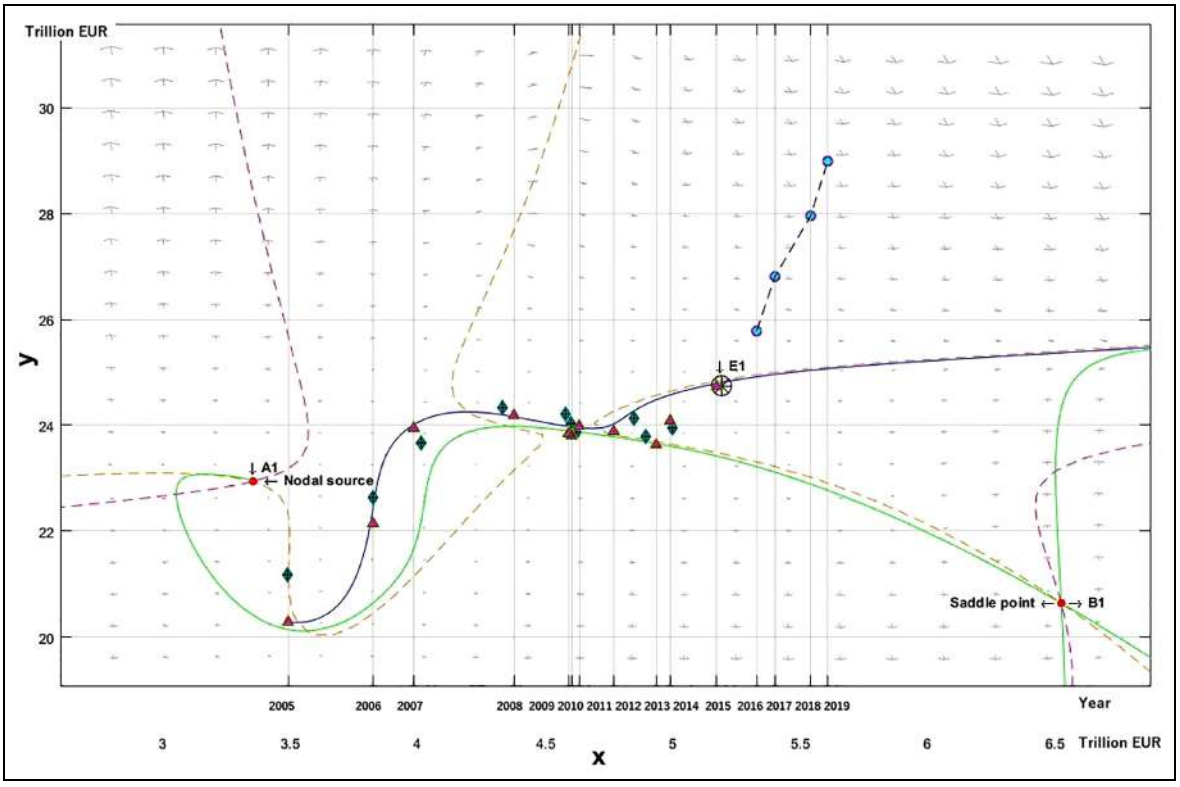

Figure 10. Interdependency in the phase plane for Y_H and C_H with characteristic data points and trajectory.

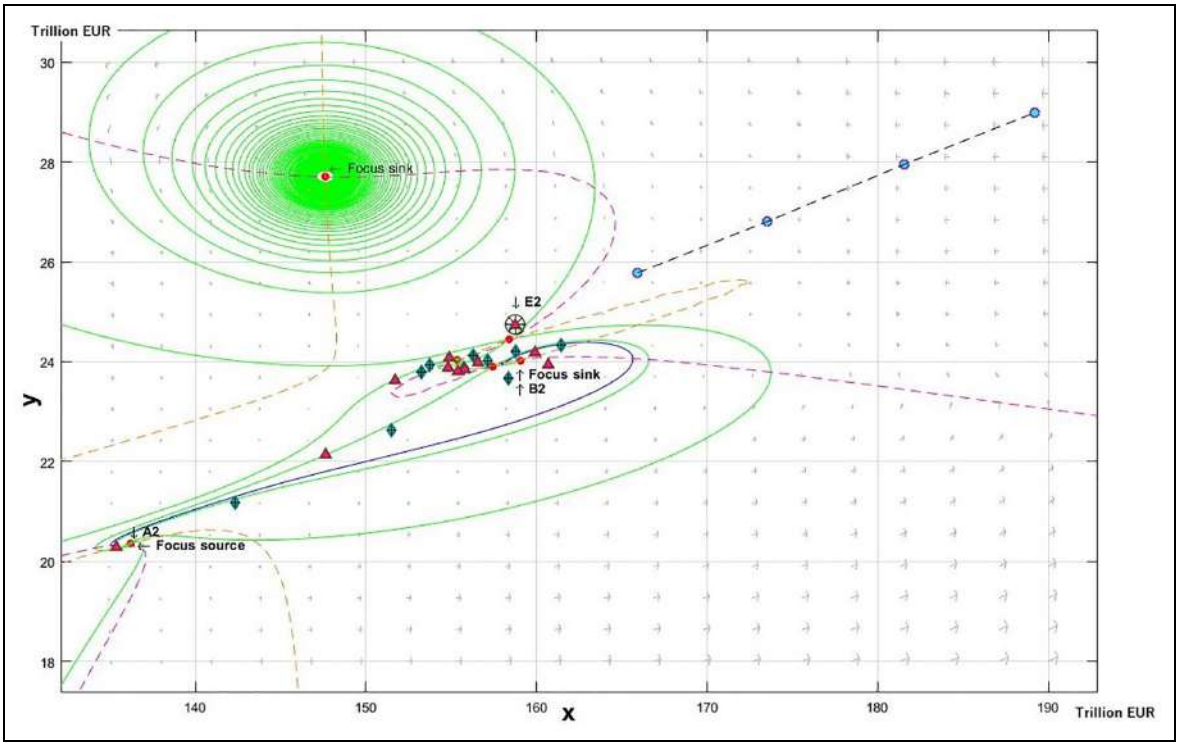

Figure 11. Interdependency in the phase plane for W_H and C_H with characteristic data points and trajectory.

There are two more calculated EPs: (−0.0001–0.0000) saddle point (trivial point) and (5.0693–65.6318) saddle point (which is outside of the ''real'' macroeconomic area for model interpretation).

The magenta dashed line represents x-nullcline ($\dot{x} = 0$), while the orange dashed line represents y-nullcline ($\dot{y} = 0$). On the phase plane, the light-green solid lines represent the separation between the stable (W^s) and unstable (W^u) manifolds. There exists another separation between them, but we do not consider and present it on a graph, as it is (as well) out of the area of possible macroeconomic values. These separation lines NDA defines as *separatrice*. The blue line represents the trajectory in the phase plane, and it starts at real/observed value for 2005 with initial conditions (x_0–y_0) = (Y_{H0}–W_{H0}) = (3.4823–135.3687). We will use the same notations in sections 4.1.1–4.1.3.

The main idea of 2D analysis is directly analog to the phase planes, viewed daily by billions of people in the world, in the form of weather forecasts. The EP marked with ''D'' is a focal sink. This means that all trajectories for initial conditions chosen on stable manifolds W^s (above the green solid line) will converge on those EP, in all related periods. Therefore, we can say that the relative past and future values, from a macroeconomic model standpoint, will converge to point ''D.''

The idea of ''relative past'' is for the years from 2005 to 2015, and ''relative future'' is for years 2016 to 2019. Therefore, we can test our system results/conclusions from the first to the second period.

Point ''D'' is a ''value attracting point'' for the complete stable manifold W^S. Meaning in economic terms, when we consider all endogenous variables interdependencies, the value for Y_H and W_H will settle at point ''D'' for any arbitrary combination of income-wealth values in W^S. There exists an unstable manifold, but it has no significance for macroeconomic research. Regarding the final conclusion, the quantity of produced goods in a real economy cannot be negative. It can be either zero, or some other finite value. The value of point ''D'' is (Y_H–W_H) = (5.2440–156.5716).

Figure 9 illustrates the advantages of using the NDA in contrast to contemporary economic methods and theories. NDA makes it possible to use the same system of equations, with different initial conditions, to determine alternative system behavior and ''realities.'' In econometrics, if we change a few values in a time series, especially the first and/or final ones, we must define a new regression. In NDA with a polynomial data fit (as presented here), we just change the initial point in flow, and all subsequent values will follow system solutions (trajectories).

After defining the system flow and the discovery of singularities, we can inverse model the variable data to find their corresponding policy value(s). Regarding policies of interest, two of the most important exogenous variables are the tax rate on wages ($\tilde{\tau}_\omega$) and nominal gross wage before income tax ($\tilde{\omega}_g$). Accordingly, we will define their matching equations.

Formulas for tax rate on wages ($\tilde{\tau}_\omega$) and nominal gross wage before income tax ($\tilde{\omega}_g$) from Equation (14):

$$\tilde{\tau}_\omega = \frac{\omega_G(L_1(\alpha_l + \alpha_{GU}\alpha_U) + \alpha_{GR}\alpha_r L_2) - Y_H - (1-\tau_c)\left[r_{KH_{AV}}B_{KH_{AV}} + P^*_G r^*_{kH} + P_G r_{kH}\right]}{L_1\alpha_l\omega_g} \quad (32)$$

$$\tilde{\omega}_g = \frac{Y_H + (\tau_c - 1)\left[r_{KH_{AV}}B_{KH_{AV}} + P^*_G r^*_{kH} + P_G r_{kH}\right]}{L_1(\alpha_{GU}\alpha_U - \alpha_l(\tau_\omega - 1)) + L_2\alpha_{GR}\alpha_r} \quad (33)$$

It is important to note, that $\tilde{\tau}_\omega$ and $\tilde{\omega}_g$ were obtained from Equations (32) and (33) by reading graph values for Y_H–W_H–C_H in related points of interest. NDA calculations define all graphs. Correspondingly, for any point on the graph, there exists a double precision value in the MATLAB workspace. The values for τ_ω and ω_g were acquired from Eurostat DB and ECB SDW. Using inverse modeling with Equations (32) and (33), we find discrepancies between model converging and observed values. For example, there are different reasons why the HPI is elevated throughout Europe. Especially in the last decade, it has become much harder to own a house or an apartment. For the EU, a reason is that ''Brexit'' imposed overpricing in new and existing real estate. Relatively cheap money has been infused into the EU macroeconomic system (for almost a decade after 2008 global financial crisis) sustained long-term inflation in the housing market, residential and ownership laws changed for EU and UK citizens, new ''tariffs,'' and so on.

Our research concludes that the HPI (H_{PI}) in the EU is on average 1.4051% more elevated than it should be (as defined by the model's flow). This value does not seem too high, but when compounded annually, with already high prices for real estate and soaring interest rates on mortgage loans, we observe a significant increase in living costs. In addition, we concluded that the converging values for tax on gross wage/salary should decrease by 3.81% while the gross wage/salary should increase by 1.19%. Again, this decrease/increase does not seem too much, but in time, its compounded effects gain momentum.

Interestingly, the value of wealth (W_H) tends to decrease toward EP ''D.'' There is a need to substitute, by other means, the ''missing'' amount of disposable income (Y_H). Therefore, it is possible to transfer some of the wealth to income to finance consumption. This, in fact, happened in times of different economic crisis that struck the EU. Some of them are World Financial crisis in 2008, the EU

Table 3. Difference between observed values for Y_H and C_H and their model-expected convergent values.

Year	$Y_{H–2016–2019}$ (%)	$C_{H–2016–2019}$ (%)
2016	0.0062	7.33
2017	0.1338	11.62
2018	0.4583	16.39
2019	0.6699	20.69

The percentage shows how elevated is the real value for C_H.

sovereign debt crisis in 2011/2012, the EU migrant crisis in 2015, Brexit in 2016, EU member states constitutional disagreements in 2018/2019, and so on.[57]

One of the main reasons for greater disposable income and wealth at disposal for the EU population from 2016 to 2019 is the ECB Asset Purchase Program (APP), which comes in different forms and under variate conditions over time. Under the premise of money multiplication, which is in the case of financial institutions around 1:10, the ECB APP (More information can be found on the web link: https://www.ecb.europa.eu/mopo/implement/app/html/index.en.html) originally ''injected'' into the EU economy around 3.2 trillion euro. Under Basel III, minimum Tier 1 capital ratio is 10.5%, by dividing the bank's Tier 1 capital by its total risk-weighted assets (RWAs). The meaning is that the EU economy ''absorbed'' around 32 trillion of euro in just a few years! Huge amounts of money, rapidly and indirectly, find their way into financial institutions balance sheet consolidation, loans to EU population, and SMEs.

Correspondingly, it increased the EU population's total disposable income and wealth, practically, in the exact amount as shown in Figure 8 (upper-right corner). The presented way of financing and spending is unsustainable in the long term and must change. Potentially, the main negative effects are higher inflation and a weaker euro compared to the US dollar. On the positive side, compared to 2008 and the US The Federal Reserve (FED) Troubled Asset Relief Program (TARP), is that most ECB APP funds have found their way to real economy (people and SMEs), and not prevalently in the stabilization of financial institutions' balance sheets.

4.1.2. Y_H–C_H variables, 2D system. Y_H–C_H system presents a significant discrepancy in results between system flow and observed values. We will show to which extent the living standard of the EU population is significantly unfounded in a real economy. Mentioned incorporates the main importance of simulated results. The NDA phase plane for Y_H–C_H variables is presented in Figure 10.

There are two more calculated points of interest: (0.0000–0.0000) focus sink (trivial point) and saddle point (−10.4917–5.0752). Both are out of the real macroeconomic area for model interpretation.

The trajectory approaches the upper-right y-nullcline. As mentioned, it represents a qualitative conclusion that the values C_H and Y_H in the future are asymptotically approaching (by trajectory) the y-nullcline, which represents a zero-change for C_H in the phase plane. As mentioned, it is only possible if variables preserve a constant ratio, in this particular case, the ratio between income and consumption ($C_H(t)/Y_H(t) \approx$ const.). Consequently, any change in consumption, e.g., rise or fall, the income will follow with the same sign. Therefore, both are stable, with a constant ratio, and positively correlated with every point after 2015.

Vectors in vector fields do not change direction and intensity ''at'' nullcline (in this particular case, the y-nullcline). This is only possible if tangent vectors to trajectory, which is approaching asymptotically to nullcline, conserve at every curve point a constant ratio ($C_H(t)/Y_H(t) \approx$ const.) as $t \to \infty$. Aforementioned ''at'' is under quotation marks because the trajectory never reaches the nullcline. In macroeconomic terms, it means that the ratio of future consumption and total disposable income is nearly constant, which further implies a conserved living standard in the near future for the EU population. Although, in reality, we have exchange between Y_H and W_H as part of wealth transfer to consumption (C_H) through increased income (as we present in the next section). Note, the difference in value between y-nullcline and observed data is shown in Table 3. Macroeconomic meaning is that, even without real income increase, there is a possibility for higher consumption at the expense of accumulated wealth and/or institutionally infused money into the economy.

Table 3 presents the percentage difference from the actual value of Y_H and C_H to their flow-defined convergent value. Obviously, the disposable consumption of the EU population is significantly greater than the macroeconomic model (flow) expects. Reasons for consideration were related to ECB APP.

4.1.3. W_H–C_H variables, 2D system. The importance of this analysis is to present the difference between wealth and disposable consumption at the marginal propensity (MP) of wages/salaries. MP for salaries and/or wages in EU macroeconomics is not literally equal to zero, but instead it is very close to zero (as shown in Table 3 for $Y_{H–2016–2019}$).

The NDA phase plane for W_H–C_H variables is presented in Figure 11. Dynamics of W_H–C_H system are very complex, and we will not analyze them in detail (regarding NDA). Point ''B2'' is the converging EP, and is marked on graph with a red dot and pointing arrow (center of Figure 11).

Table 4. Difference between model-defined values for W_{B2} and C_{B2} and their observed data.

Year	$W_{H\text{-}B2}$ (%)	$C_{H\text{-}B2}$ (%)
2016	4.31	7.33
2017	9.10	11.62
2018	14.14	16.39
2019	18.95	20.69

The percentage shows how elevated are variables' real values compared to the model converging point.

The increase in spending was possible because of APP indirect channels ''spill off'' to the EU population, and additionally from wealth transfers to consumption. This implies that to offset income stagnation or lowered purchasing power parity (PPP), the EU population needed to spend some of its time-accumulated wealth, e.g., savings, equities, and real estate.

The real macroeconomic value trajectory is in the stable manifold (W^s), and we already explained that the discrepancies mainly arise from ECB APP infused funds. In Table 4, we quantitatively present those differences.

We cannot analyze the value of tax and wage convergence directly from Figure 11, due to the 2D system representations. The point of NDA is to analyze the system behavior without actually solving the system in an analytical form. If we lack clarity from NDA generated phase planes, we lose the edge and analytical advantage point. Due to the dense grouping of points in the center of Figure 11 and other corresponding manifold dynamics, we are unable uniformly interpret the system. In addition, qualitative and quantitative analyses have its basis in the selection of relevant values, further calculations, flow analysis, and so on, we could not determine with a certain level of confidence, due to not enough clear representation(s).

The solution lies in using all three variables (3D model). This represents the limits of 2D analysis.[8,32]

4.2. Analysis and results for 3D system

The purpose of 3D analysis is to determine the qualitative and quantitative system behavior by considering all interdependencies between macroeconomically close and intrinsically correlated variables. The results of 3D NDA are equilibrium solutions, bifurcation curves, singularities, and so on, and together they define the system flow. In macroeconomic terms, it means that we discover time-dependent equilibriums for endogenous variables with their corresponding stable or unstable state, points that indicate qualitative changes in the behavior of macroeconomic variables such as stagflation, growth, stagnation, and recession. These results are important as they uncover hidden layers of macroeconomic behavior, and most importantly, their causes.

To obtain results, we will first perform the codim 0 bifurcation of parameters. The meaning is that to find the system solution curve (equilibrium), we must analyze its dynamic in 3D, and determine whether it consists of stable or unstable parts. In the same step, if we have found singularities, we target them as present structural breaks and future starting points for continuation and/or bifurcation analysis. Continuation's economic meaning is that we inspect what has, or what could, happened to some characteristic point beyond the reality period (in past or future) coupled with different values than those observed for, e.g., income, wealth, or consumption. In addition, we can change the main ratio of involved variables in Equation (25) by performing codim 1 bifurcation with (only) parameter d change, or codim 2 bifurcation by simultaneously changing parameters d and e. We can perform continuation of singularities, or characteristic points at any codim level. Theoretically, we can ''continue'' any significant point that does not yield a trivial singular value, and for a reasonably small number of parameter sweeps or iterations. The economic meaning of bifurcation is to calculate various values for the dependent endogenous variable C_H as a representation of different macroeconomic scenarios. By changing the ratio between descriptive variables Y_H and W_H, in the dependent variable C_H, we create an ever-changing macroeconomic scenario within the boundaries of the overall system flow.

For instance, we can analyze what could happen to all variables in the system, and the whole system, by changing the values and/or ratios of only income in consumption, or with wealth moving at slower/faster pace than income but keeping the same overall ratio in consumption. Values for variables cannot be completely arbitrary, as they must follow the overall system dynamics (flow). Similar to 2D systems, we use simplified 3D models as in Equations (23)–(25) to define the flow of the system and to determine singularities. Based on the determined singularities from the original model (14)–(16), tax rates and weights correspond to these singularities. The main policies that can be influenced by the ECB, and related EU institutions, are monetary policies. In today's macroeconomic environment, an overall theoretical and practical premise exists, and it holds that by changing or ''steering'' the monetary policy, fiscal policy will follow and adjust. Monetary policy is central to the eurozone countries, which are part of the European System of Central Banks. Contrary to this, fiscal policy is driven domestically in each member country, and there is no true EU-wide harmonization on the matter. For example, wage tax in EU27 countries in 2021 had values ranging from 18.1% in Cyprus to 46.2% in Germany (https://ec.europa.eu/eurostat/cache/metadata/en/earn_net_esms.htm for metadata, and https://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do for data). By changing the parameters d and/or e, we change the solution(s) of the entire NODE system. Changes in NODE

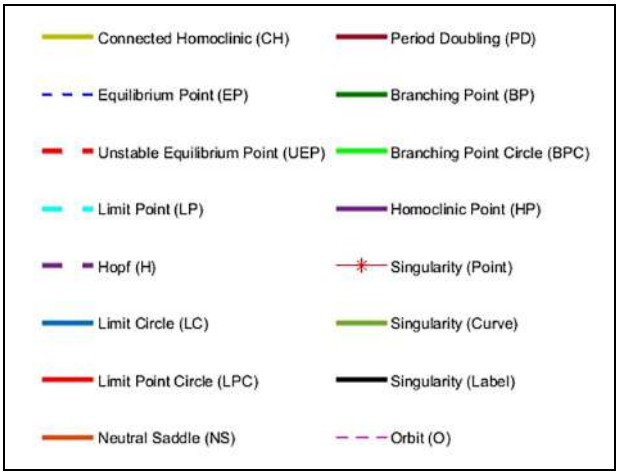

Figure 12. Legend in color for markings and symbols on all 3D MATCONT figures.

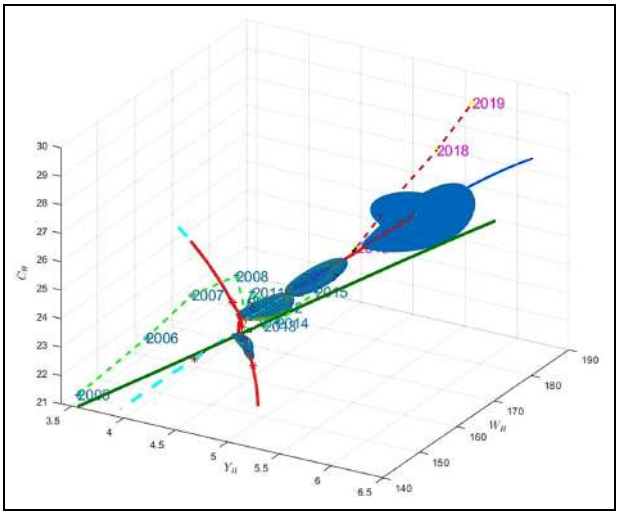

Figure 13. Multiple bifurcations for Y_H–W_H–C_H system in one 3D diagram for codim 0, 1, and 2. Legend specifics are only for Figures 13 and 14: light-green dashed line and blue year numbers represent "relative past," while red dashed line and pink year numbers represent "relative future" (from model standpoint).

coefficients induce millions, billions, or even trillions of numerical solutions for the NODE system. Furthermore, changing the parameter d down in value (it is analogously valid for the rise of the parameter), we affect the monetary policy change as the policy value must go up, because of the minus sign in front of the coefficient. Considering the reverse but proportional correlation, we simulate what will happen to the model or EU macroeconomics, when we reduce the influence of income in consumption. Meaning in economic terms, lowering the income of people will simultaneously change consumption and/or the wealth. In addition, to substitute the missing part of their income, people will use wealth (15) to preserve their living standard. To help its people, EU institutions will try to create or adjust monetary policies. Results from newly obtained $\tilde{\tau}_\omega$ and $\tilde{\omega}_g$ were compared to observed data, to recommend to policymakers what policies should go up or down in value and/or duration. The legend for all 3D MATCONT figures is presented in Figure 12.

The 3D system consists of variables Y_H–W_H–C_H, and we will analyze it by MATCONT application using codim 0, 1, and 2 parameter bifurcations on singularities that coincide with macroeconomic points.[8,9,43,45] The marked years on the graph correspond to real values. The EC in blue is stable, and in red is unstable. Here, we will analyze the system (23)–(25). Figure 13 presents in one figure all relevant bifurcations, while Figure 14 is its planar projection. The number of bifurcations for such a system is theoretically unlimited, and the ones we here present/study are of direct interest to real data macroeconomic analysis[8] (p. 62). All values are in trillions of euros (€). Presented diagrams in Figures 13 and 14 provide an overall overview of the system characteristics. Those diagrams will be broken down to three combined codim 0, 1, and 2 bifurcation diagrams (In applied NDA research, we should always have in mind that ''Equivalently, the codimension (codim for short) is the number of independent conditions determining the bifurcation. This is the most practical definition of the codimension. It makes clear that the codimension of a certain bifurcation is the same in all generic systems depending on sufficient parameters.'' Kuznetsov[8] (p. 62).).

After we obtain income and wealth values from solutions and figures, we can put them in starting equations to define the new corresponding value of consumption. In addition, we can put values for income, wealth, and consumption, determined through solutions and figures, in particularly isolated equations for exogenous variables to define what their flow-defined value should be (We define Equations (35) and (36) for the tax rate on wages ($\tilde{\tau}_\omega$), and nominal gross wage before income tax ($\tilde{\omega}_g$), although we can implement it for any exogenous variable in Equations (14) and (15).). For the aforementioned purpose, we obtain the following equations by substitution of Equations (14) and (15) in Equation (16) (we obtained Equations (34)–(36) by MATLAB® R2018b Symbolic Toolbox.):

$$C_H = C_{\omega_2}\left(M_H + B_H + B_1^L + B_2^L + E_H + H_{PI}K_{hH}\right) \sigma_1\left(\frac{C_{\omega_2}W_H + \frac{\sigma_1\left(\frac{C_{\omega_2}W_H + C_{\omega_1}Y_H}{W_H} - 1\right)}{\frac{Y_H}{W_H} - 1}}{W_H} - 1\right) + \frac{}{\frac{\sigma_1}{W_H} - 1} \tag{34}$$

where:

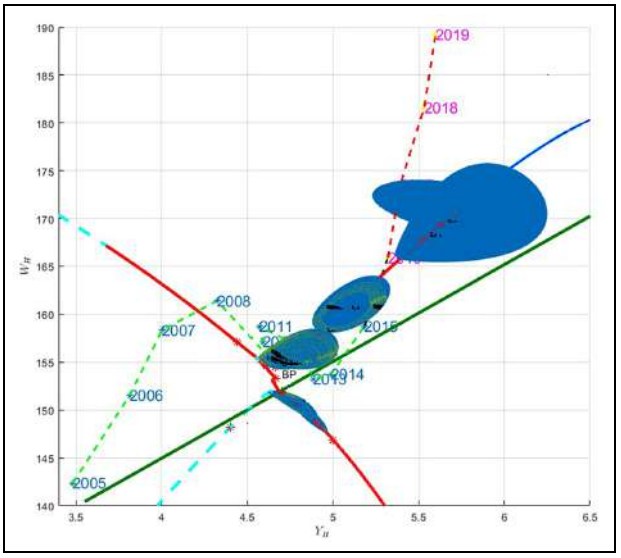

Figure 14. Zoomed part of Y_H–W_H projection from different angles in Figure 13. The actual difference from real and model-defined values is less than it is seen in Figure 14 because the figure is a planar Y_H–W_H projection of a 3D system curve (both stay closer in space).

$$\sigma_1 = \omega_g\left(L_1\left(\alpha_u\alpha_{gu} - \alpha_l(\tau_\omega - 1)\right) + L_2\alpha_r\alpha_{gr}\right) - (\tau_c - 1)(r_{KH_{AV}}B_{KH_{AV}} + P_G^*r_{kH}^* + P_Gr_{kH})$$

By solving Equation (34) for $\tilde{\tau}_\omega$ and $\tilde{\omega}_g$, we get Equations (35) and (36), respectively:

$$\tilde{\tau}_\omega = \frac{\left(1 - \frac{\sigma_3}{W_H}\right)\left(\sigma_2 - \frac{\sigma_1\left(\omega_g\left(L_1\left(\alpha_l + \alpha_u\alpha_{gu}\right) + L_2\alpha_r\alpha_{gr}\right) - (\tau_c - 1)\left(r_{KH_{AV}}B_{KH_{AV}} + P_G^*r_{kH}^* + P_Gr_{kH}\right)\right)}{\frac{\sigma_3}{W_H} - 1}\right)}{L_1\alpha_l\omega_g\sigma_1} \quad (35)$$

In addition,

$$\tilde{\omega}_g = \frac{\left(\frac{\sigma_3}{W_H} - 1\right)\left(\sigma_2 + \frac{\sigma_1(\tau_c - 1)\left(r_{KH_{AV}}B_{KH_{AV}} + P_G^*r_{kH}^* + P_Gr_{kH}\right)}{\frac{\sigma_3}{W_H} - 1}\right)}{\sigma_1\left(L_1\left(\alpha_u\alpha_{gu} - \alpha_l(\tau_\omega - 1)\right) + L_2\alpha_r\alpha_{gr}\right)} \quad (36)$$

where:

$$\sigma_1 = \frac{C_{\omega_2}W_H + \sigma_2}{W_H} - 1$$

$$\sigma_3\left(\frac{C_{\omega_2}W_H + \frac{\sigma_3\left(\frac{C_{\omega_2}W_H + C_{\omega_1}Y_H}{W_H} - 1\right)}{\frac{Y_H}{W_H} - 1}}{W_H} - 1\right)$$

$$\sigma_2 = \frac{}{\frac{\sigma_3}{W_H} - 1}$$

$$\sigma_3 = \omega_g\left(L_1\left(\alpha_u\alpha_{gu} - \alpha_l(\tau_\omega - 1)\right) + L_2\alpha_r\alpha_{gr}\right) - (\tau_c - 1)\left(r_{KH_{AV}}B_{KH_{AV}} + P_G^*r_{kH}^* + P_Gr_{kH}\right)$$

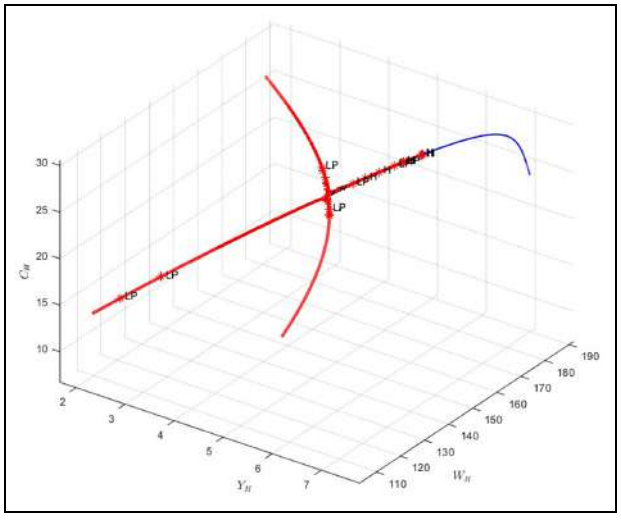

Figure 15. Codim 0 equilibrium points and curves in phase space.

We will use expressions (35) and (36) for inverse modeling of EU macroeconomic, fiscal, and monetary policies.

4.3. Codim 0, 1, and 2 parameter bifurcations

In NODE analysis, the first goal is to find singularities such as EPs and/or curves. In Figure 15, we present EC defined by continuation in $\mathbb{Z}_+$ and $\mathbb{Z}_-$. The first two limit points (LPs) located at the bottom left in Figure 15, which we define through continuation in $\mathbb{Z}_-$ time, and have only a theoretical value. Continuation of bifurcation characteristic points in $\mathbb{Z}_+$ corresponds to observed data. The solutions and continuations for codim 0 (equilibrium), codim 1 (parameter d bifurcations), and codim 2 (parameters d and e bifurcations) are all based on Equation (25).[8,9,58]

Figure 16 represents a projection on the x–y plane of codim 0 (equilibrium) and codim 1 (parameter d bifurcation) points and curves.

The LP mark on the graph is an LP bifurcation. LPs have many names in NDA literature. One of the widely known and used names is saddle-node bifurcation. The mark H corresponds to the Hopf (Andronov–Hopf) bifurcation[8] (p. 78). Generally, and depending on the type of LP or H, we can have in economic terms, an opposite change in trend coupled with the same converging value (LP) or slow (“stagnating”) growth, or recession (H). Sometimes, we can have an exploding series characterized

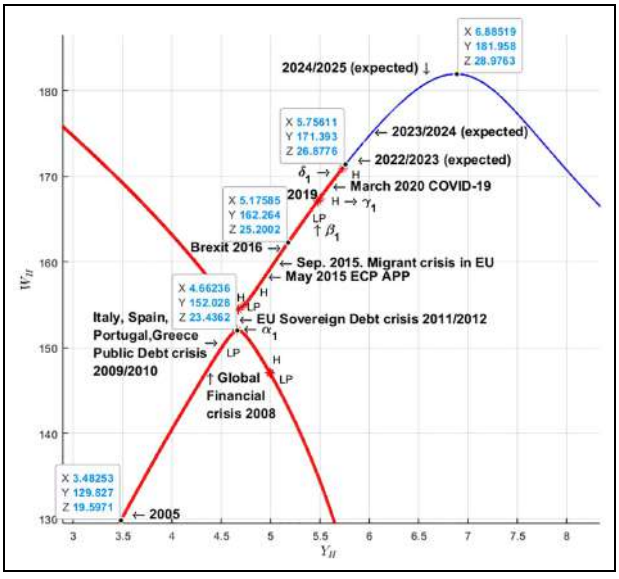

Figure 16. Projection on *x*–*y* plane of codim 0 (equilibrium) and codim 1 (parameter *d*) bifurcation points and curves. It is impossible to name and present, in one small figure, all the EU tumulus events in the last two decades; accordingly, we marked only the most significant (with the biggest impact). Due to the text–image ratio, some arrows point in an approximate direction or location on the graph.

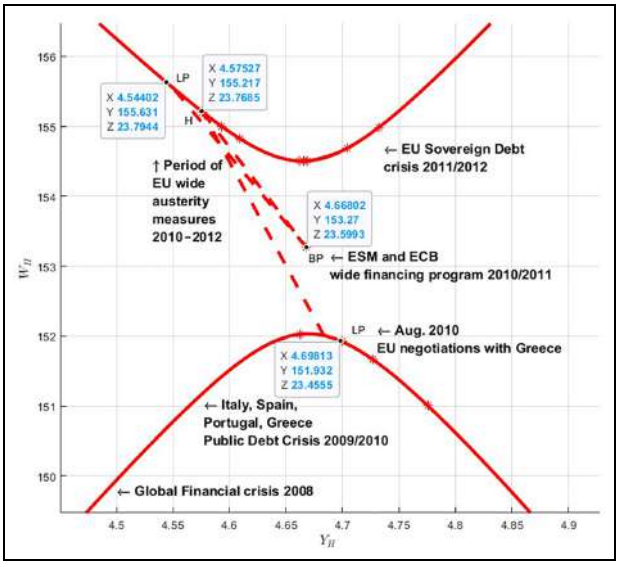

Figure 17. Codim 0, 1, and 2 bifurcations of parameter *d* and/or e, zoomed central part in Figure 16. Due to the text–image ratio, some arrows point in an approximate direction or location on the graph.

by an exponential increase of Hopf period, and positive λ as time increases. The meaning is that there could be hyperinflation, and consequently stagnation, in the economy.

However, we cannot implement this uniformly, as every system has its own specifics. For instance, limited economic growth with stagnation at the end of some period is possible for certain variable values and singularity characteristics. However, in first place, it depends on the overall system conditions and solutions. A straightforward economic interpretation of the NDA does not exist. Researchers must consider several flow and singularity behaviors to interpret results.

Following the evolution of observed data on the equilibrium trajectory, and after a short quasi-linear rise, we arrive at the first LP. The position of this LP is at the ''top'' of the lower unstable (red) equilibrium curve. Analysis for each LP point, and the corresponding normal form coefficients would take too much time and space. Accordingly, we will limit the presentation to points and curves that have real macroeconomic value and correlation[8] (p. 103). From the starting point values (x_0–y_0–z_0) = (Y_H–W_H–C_H) = (3.4823–129.8–19.6) for 2005 (Figure 16), we begin the search for equilibrium. Then, considering the lower-left part of the diagram, we arrive at the top LP marked α_1 with values (4.662–152–23.44) for years 2009/2010. It has $a_{\alpha 1} = -1.373$, this means that the point is a nondegenerate node. At that point, higher order codimension (codim 2) appears as a Branching Point (BP) (see Figure 17) with coordinates (4.66802–153.27–23.5993). By zooming in on the part of Figure 16, we obtain Figure 17 which presents codim 1 (parameter *d*) bifurcation.

Codim 1 bifurcation directly shows how the change in income (Y_H) indirectly affects wealth (W_H), and directly consumption (C_H). In the years 2010/2011, there was a BP precisely when the EU was in a great sovereign debt crisis, and when the European Stability Mechanism (ESM) was started along with ECB financing programs. The crisis forced the ESM and ECB to implement extensive financial support in the EU. From 2009 to 2012, Y_H (Figure 17) oscillated from 4.698–4.575–4.668–4.544–4.669. This indicates that the EU was in an economic recession.

The BP point suggests that a structural break for income and wealth exists, and it could have further chaotic properties (although, not necessarily). In addition, it means that there is a switch in behavior toward income and wealth. Instead of going down following the lower-right curve, both simultaneously, go up following the upper-right curve. That is then valid in this system flow alone, and not in general. Then, we continue with the upper-right part of diagram, until point (5.001–159.3–24.67) for 2015.[8,9,59] The actual point value for Y_H = 4.9950099, and is used in all calculations. However, due to the graph's numerical resolution, the ''nearest'' point is 5.001. A small difference in coordinates emanates by passing from real to model-flow data compared to calculated values. All values are in

the precision span of up to 1%. This is more than satisfactory for macroeconomic analysis.

$LP_{\alpha 1}$ is an unstable point representing the results of spending on the already accumulated wealth of the EU population. Reference in time is shortly after the global financial crisis of 2008. After the period of ''saving spending,'' there is a significant decline in economic activity. The global financial crisis in 2008 affected the EU's financial and commercial sectors. Interestingly, in the future, the model predicts a stable downward trend after the years 2024/2025 (judging by the system flow). The ECB was monitoring the status of EU macroeconomics in 2011/2012. Consequently, acted using its famous ''whatever it takes'' statement (attitude) to reassure markets and the financial sector.

It was a European reaction to the ''financial crisis ripple effects'' of the global financial recession of 2008. It very profoundly affected EU macroeconomics. The problems started becoming ''visible'' in the summer of 2010, with several EU countries facing default, due to a high gross domestic product (GDP)/public debt ratio. Countries that were at the greatest risk were Greece, Italy, Portugal, and Spain. By mid-2011, the situation had reached its culmination point. Various efforts by EU leaders tried containing those countries' default, especially in the case of Greece. A series of negotiations had taken place between the EU's European Council leaders, the ECB, the International Monetary Fund (IMF), the World Bank (WB), and Greece. Credit Default Swaps (CDS) on Greece's public assets held mainly by the IMF and Goldman Sachs, made the negation, and the prospect of new loans very difficult.[57] After finding common ground, austerity measures were implemented in a few European countries, e.g., Greece, Italy, and Spain. When it seemed that the overall situation was starting to calm down, new deflationary and recessionary concerns were looming on the horizon. Austerity stopped the EU's development momentum, and endangered its inflation/unemployment targets.

This would certainly induce a downward trend, as shown in Figures 16 and 17 on the bottom-right part of diagram, if not for the ECB APP that caused the EU to recover and prosper. The situation in the EU again started to settle down from 2012 to 2014. However, then a new and severe migrant crisis hit the EU. It started in the summer of 2015 and lasted throughout the next few years, continuing even today. In addition, in the first half through to mid-2016, the prospects of ''Brexit'' were ''shaking'' EU markets (with high volatility, equity loss, etc.), and the overall stability of the bloc's economy was in some kind of ''surreal state.'' If the EU had faced only one of those challenges, the overall NDA 3D model calculated flow would be downward. In a relatively short period, the EU had faced several problems. ECB APP was around 3.2 trillion euros, and it had qualitatively changed the downward trend (More details on the web link: https://www.ecb.europa.eu/mopo/implement/app/html/index.en.html#pspp, accessed 26.04.2022.).

Furthermore, the trend started to go upward, and the ECB initiated low-interest rate loans to the financial sector to the value of up to 1.5 trillion euros. EU countries' sovereign debt crisis was only one of many problems that affected EU economics and politics.

At that time, the living costs of ordinary people increased because of inflation (HICP) (Definition from web link https://ec.europa.eu/eurostat/web/hicp, accessed 13.06.2021.). The HICP measures the weighted change in consumer prices for goods and services consumed by EU households over time. HICP was at an all-time high, in part due to ''cheap money'' being pumped into the system.[5] In the next 5 years, following the equilibrium curve, we arrive at (5.001–159.3–24.67) in 2015. All values from $Y_H = 5.001$ to 5.6 represent a ''relative prediction'' from 2016 to 2019.

After $Y_H = 5.6$ (Figure 16) all the following data represent the true future. $LP_{\beta 1}$ point has a positive quadratic normal form coefficient $a_{\beta 1} = 2.088$, which means that $LP_{\beta 1}$ is a nondegenerate node. This means that the equilibrium manifold near $LP_{\beta 1}$ looks more ''like a parabola.'' Interestingly, the period between $LP_{\alpha 1}$ and $LP_{\beta 1}$ implies that the wage tax (35) should be higher by 5%–15%, and for wage/salary (36) by 0.5%.

This is valid for the whole period studied, except for years 2017/2018 and 2019, where the EU should have decreased the tax burden to wages by -9.04% in 2017/2018 and by -10.71% in 2019. This was a consequence of ''artificial money supply increase'' in EU macroeconomics—to achieve targeted monetary policies by the ECB. Wage/salary changes of 0.5% are based on a year-to-year rate increase, and correlates with the ECB's efforts to offset a volatile HICP.

Higher taxes enable better social benefits and payouts for pensioners and the unemployed. The EU population that qualifies for pension (age 65 + years) is around 1.3 times greater than the working capable population, which represents a great labor policy strain.[8,45]

Following the upper-right curve in Figure 16, we encounter an unstable Hopf bifurcation point $H_{\gamma 1}$. It has the first Lyapunov coefficient $l_1 = 3.6342560$. There are two eigenvalues with Re $\lambda_{1,2} \approx 0$ (at parameter value). The critical frequencies are Im $\lambda_{1,2} \neq 0$, while the first Lyapunov coefficient is small and positive. The third eigenvalue is Re $\lambda_3 = 2.9364$ and Im $\lambda_3 = 0$. This signals that there is an unstable LC bifurcating from equilibrium.[8,45] This implies in macroeconomic terms that the values may ''oscillate'' around certain values producing long-term stagflation of income, wealth, and consumption.

Following the upper-right curve further, we arrive at the point where equilibrium changes from unstable to stable (the red to blue transition in Figure 16), at point (5.756–171.4–26.88). It coincides with a stable Hopf equilibrium

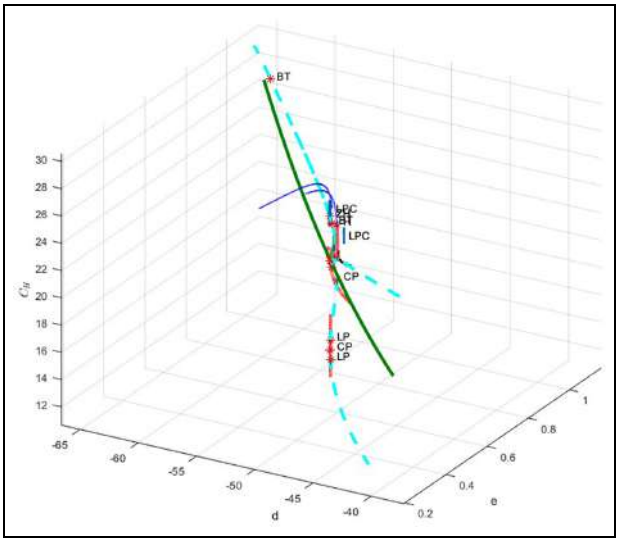

Figure 18. Bifurcation of parameter *d*, e, and C_H values.

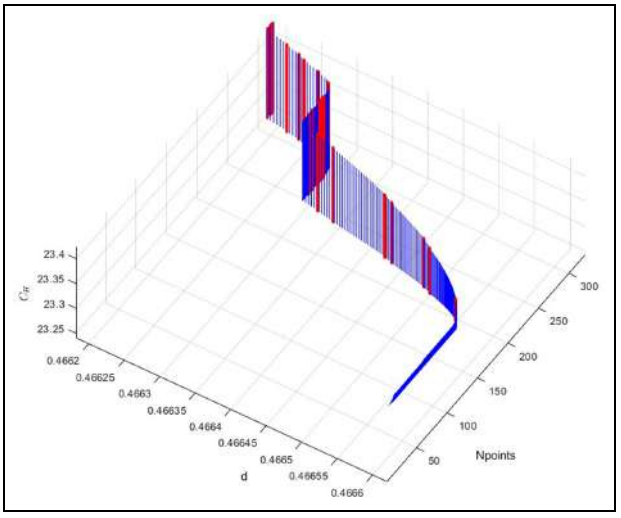

Figure 20. Bifurcation of parameter *d*, calculation–iteration points (*Npoints*), and C_H values.

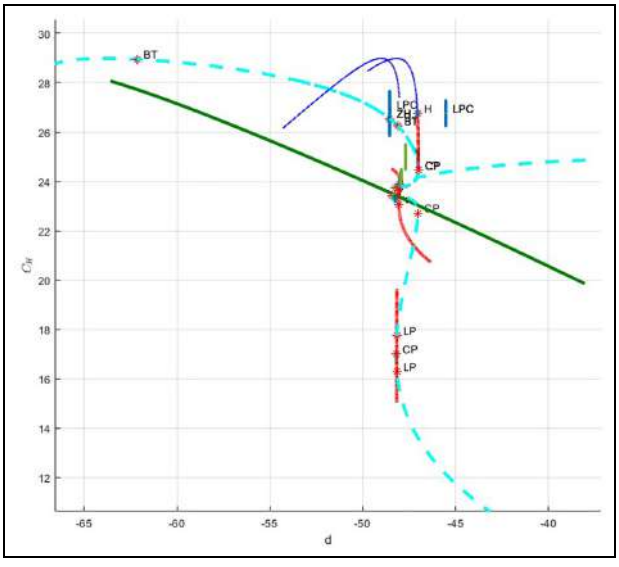

Figure 19. Bifurcation of parameter *d* and C_H values.

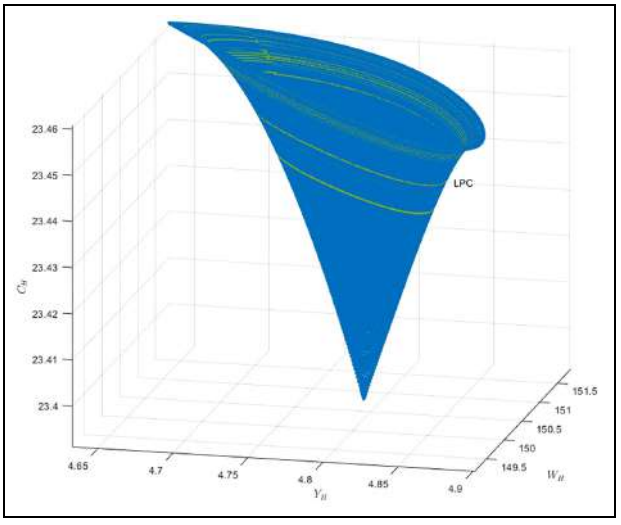

Figure 21. Bifurcation of parameter *d* with Y_H–W_H–C_H values, and the creation of multiple LPCs that correlate with Figure 20.

$H_{\delta 1}$, meaning that income, wealth, and consumption will steadily converge to a graph ''area'' with close values. Y_H gained an upward trend that should have reached a peak in 2021/2022. However, due to the COVID-19 pandemic, this did not happen, and it is now expected to reach it by 2024/2025, if geopolitical circumstances present today allow. After (6.885–182–28.98), there should be a ''stable'' decline in W_H due to unsynchronized EU monetary and fiscal policies.[5,57]

Bifurcation and continuation of parameter *d* and/or *e* in 3D phase space differ in appearance from what is familiar to many readers, e.g., logistic map. There are many singularities for systems (23)–(25). Even its small part is impossible to present in this paper. Although, to create an overall picture for the reader, we will present a few crucial and interesting bifurcations as illustration (Figures 18–23).

We ''just scratched the surface'' of the vast amount of analysis and conclusions that can be deduced by NDA in this research. As is obvious by the complexity of the bifurcations shown in Figures 18 and 19.

Referring to Figure 19, there is a similar (mirrored) picture for parameter *e* bifurcations. Here, presented limit point of cycles (LPCs) (Figure 21) are in 3D, and present how for a certain value of parameter *d* the system behaves. Contrary

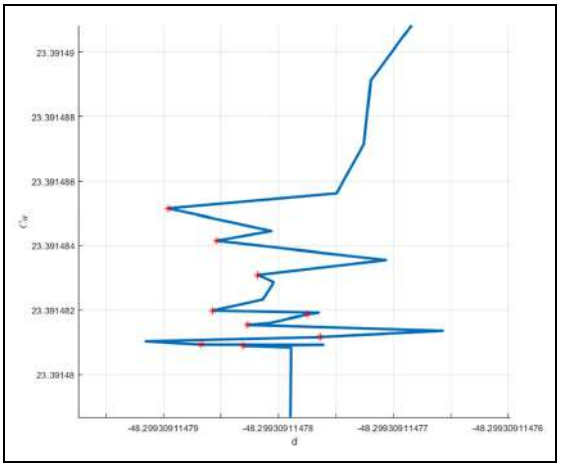

Figure 22. Bifurcation of parameter d and erratic C_H values. Red stars represent the bifurcation singularities.

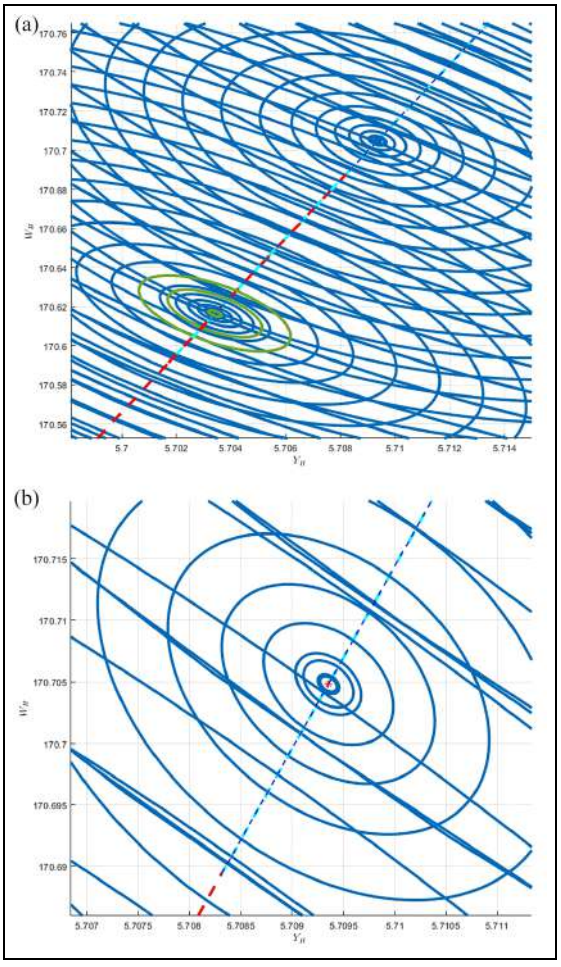

Figure 23. Zoomed in part of upper-right graph in Figures 13 and 14, where several LPCs and hundreds of LCs interact, collide and inter-tangle, and bifurcate. Note the values in parts of hundreds or thousands on y-axis, and in parts of thousands or tens of thousands on x-axis (respectively).

to Figure 20, presented here is the overall interdependency between Y_H, W_H, and C_H. For complete analysis, we should visualize variables and meditate bifurcations in 4D.

Figure 22 presents how a small perturbation of parameter d can affect the change in the dependent variable, in this study, total disposable consumption (C_H). In addition, the economic meaning is how the change in total disposable income directly influences the change in total disposable consumption, and indirectly in total disposable wealth.

Parameter d affects C_H in an erratic way for extremely small perturbations of one-euro order. Let us conduct the following thought experiment: suppose a person goes to the newspaper stand to buy a newspaper. While trying to take a euro coin from their pocket, the coin drops through the ventilation on the floor and is permanently lost. Is it possible that the described situation (according to Figure 22) triggers a ''butterfly effect'' in EU macroeconomics leading to chaos? The answer is of course not. Chaos in macroeconomics is practically impossible because there is too much ''free will,'' and the included variables do not follow strictly equational and/or rational behavior. In addition, a particular combination of parameter(s) and variable values should persist in time, and change according to bifurcation rules. This has extremely low terms of probability. Outside of numerical and mathematical values, the results from Figure 22 have no practical meaning.

Figure 23 presents a zoomed in region of the upper-right part of graph in Figures 13 and 14. Several LPCs and hundreds of LCs interact and exert the exchange of stability in bounded regions.

Between, and of singularities, we have the ''bouncing'' change of stability, where LCs disappear and/or are born. Local dynamics has interesting (purely) mathematical features and values. However, global dynamics has associations to the macroeconomic real business cycle (RBC) theory.

In Figure 24, we present codim 1 and 2 bifurcations for parameter d and/or e. Codim 1 bifurcation of parameter d indicates how the change in the value of Y_H indirectly affects W_H and directly C_H. Similarly, for codim 1, there exists indirect influence of W_H through parameter e bifurcation to Y_H, but mainly C_H. Codim 2 illustrates, among others, the EC ''jump'' from the lower to the upper part (as presented before in Figures 16 and 17).

Multiple LC curves arise at (4.795–151.1–23.43). The stability for some LCs, in this graph region, bounces back and forth, indicating a change of stability between stable and unstable LCs for specific parameter values. Due to the relatively small parameter changes, and small changes in endogenous variable values, the previously mentioned LC and LPC dynamics do not have a significant macroeconomic impact. Accordingly, we will not analyze it further. In macroeconomic terms, LPCs and LCs represent a

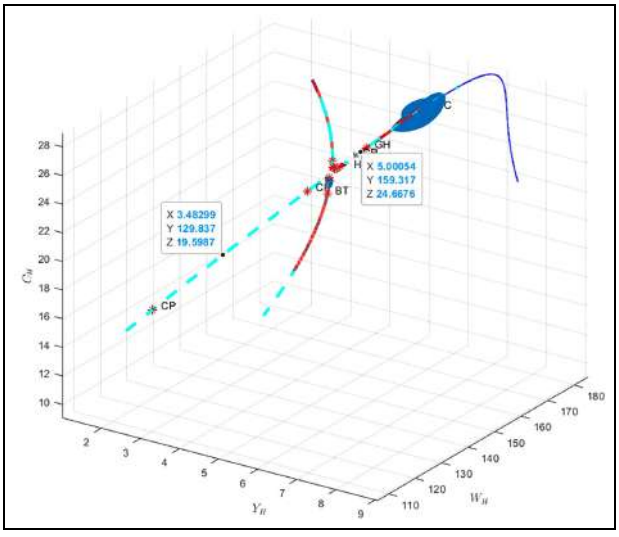

Figure 24. Codim 1 and 2 bifurcations (parameter *d* and/or e). Marked values correspond to the years 2005 and 2015.

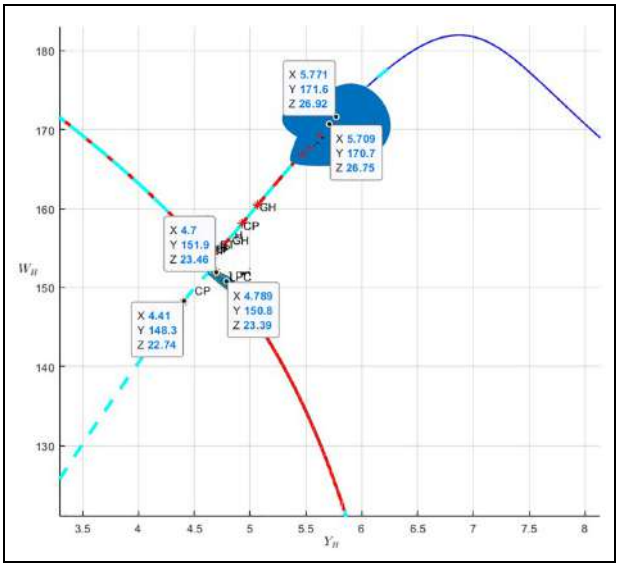

Figure 25. Codim 1 and 2 bifurcations of parameter *d* and/or e.

cyclical motion in the same region of the graph—back and forth, in economics popularly called ''stagnation.''

In Figure 25, we present Y_H and W_H planar projections for codim 1 and 2, as zoomed in part of Figure 24. Positive change of trend happens at LP (4.698–151.9–23.46). Subsequently, the system has avoided a macroeconomic recession that is, on the graph, represented by an LPC at (4.789–150.8–23.39) (Figure 25).

This LPC bifurcates from LC. There emanates multiple LPCs from this LC. In economic terms, it is a long-lasting ''trap'' for different values and changes of Y_H and W_H.[5] The first significant LPC has a period of T_1 = 13.95387

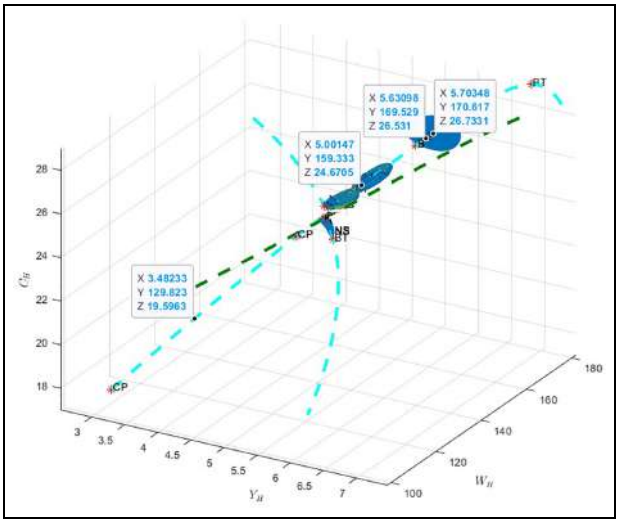

Figure 26. Codim 2 bifurcation of parameter *d* and e. Marked values, respectively, coincide with years 2005, 2015, 2019, and 2023/2024 (prediction).

periods/years (Figure 25). Nevertheless, the potential stagnation would not last that long, as the period is the circumference along the entire curve length. In practice, it would last half of the T_1 value, meaning around 6–7 years, which is still a relatively long period for having a stagnating economy. Other LPCs that emanate from the corresponding LC have differences in period change of order $\approx 10^{-4}$, and in macroeconomic terms, we assume it has an ''unchanged'' period. Any sudden change in variable values would interrupt the complete period path and will go in some other direction, which is especially possible in economics. Economics as a social science depends many times on voluntary decisions of a closed group of people or an individually ''tailored'' decision. Those decisions directly define the quality of life for hundreds of millions of people.

The red line, as stated above, represents an unstable equilibrium. The dashed red part is a graphical representation of the overlapping unstable equilibrium, and LP curve for different continuations of singularities. The green line marks LPCs, and the pastel blue marks LCs. The navy blue marks stable equilibrium(s), and it sometimes overlaps with different continuations. The purple marks the Hopf continuation equilibrium curve in higher parameter space (codim 2), where two parameters (*d* and *e*) are free for value sweep. Consequently, there is a susceptibility to the appearance of Hopf bifurcation.

The dark green dashed line in Figure 26 represents a curve where a BP appearance is possible. On the intersection of one similar curve and equilibrium point, we find a BP between two curves (see BP in Figure 17, and dashed green line in Figure 26).

Bogdanov–Takens (BT) coordinates are (4.6995544–151.92177–23.455451) and its normal form coefficient

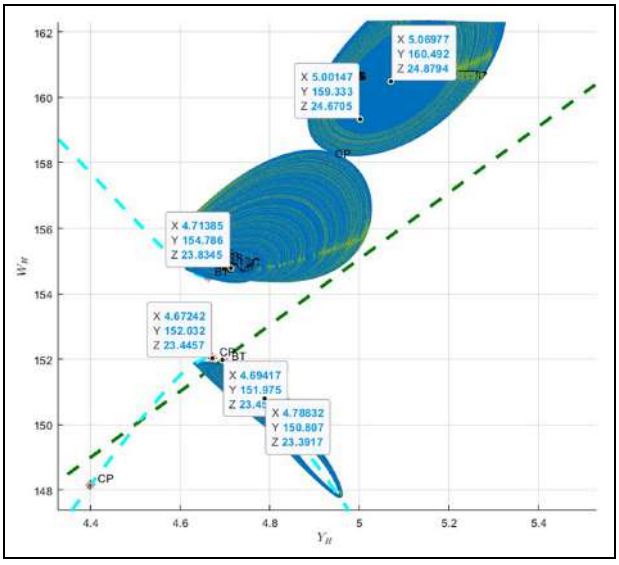

Figure 27. Zoomed in part of Figure 26 with projection on *x*–*y* plane, related to codim 2 bifurcation of parameters *d* and e.

c = (−2.10863423e−01, 3.25679947e–02), where nondegenerate conditions are relatively small in value, but still nonzero.[8,45]

Following the upper-right part of the diagram in Figure 27, we encounter a Generalized Hopf (Bautin) bifurcation point with coordinates (5.075–160.6–24.9), which emanate from the previously discovered Hopf.

BT bifurcation emanates in the lower-right part of diagram (Figures 25 and 26), where we had a nonsaddle equilibrium part that has undergone an Andronov–Hopf bifurcation that gives birth to LPCs. In addition, there is a Generalized Hopf (GH) point that has $\lambda_{1,2}$ = −0.0000 ± 0.4559i and λ_3 = 15.5401. The nondegeneracy condition coefficient is relatively small, but nonzero c = 2.8449421e−03, which implies a mildly parabola/ellipsoid-like form (around that point for nearby trajectories). This correlates to ''The bifurcation point separates branches of subcritical and supercritical Andronov–Hopf bifurcations in the parameter plain. For nearby parameter values, the system has two limit cycles that collide and disappear via a saddle-node bifurcation of periodic orbits.''[8] GH values correspond to the years 2015/2016. At the start of August 2015, underperforming data from the Chinese economy, and market index companies, shook the world's economy and markets. It quickly spread throughout the world, and in December 2015, major world markets and economies had the worst performance in years. This was particularly evident at the start of 2016. After the continuation of GH in two-parameter space (*d* and *e*), there appeared an LPC, which represents possible stagnation. Two such partially overlapping LPCs are located close together on the upper-right part of diagram (Figure 25), with coordinates (5.709–170.7–26.75) and (5.771–171.6–26.92). The final mentioned two points belong to the near future, approximately the years 2022 and 2023.

Even without the COVID-19 pandemic, the presented model shows a potentially real risk of stagnation in the near future. Even though relatively large amounts of money were ''injected'' into the EU economic system (by lasting ECB APP), we are at ''saturation point'' where nonfinancial and other institutions need it continuously to operate smoothly! Conversely, this does not contribute to a stable macroeconomic environment. Real economy production and services provided by SMEs need a stable and nonstagnating economic environment to operate ''smoothly.'' SMEs represent a lifeline to a great majority of the EU population, employing 83.9 million people in 2017, and accounting for 67% of all employment in the EU (Source: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20200514-1).

Following the real data path in 3D phase space, we discovered two Cusp points (CPs). CPs imply that there exists a structural break and/or sudden change in the curve direction (with hysteresis effect). The quantitative change of the parameters in question (*d* and *e*) was relatively small, and it has an average span of 1%–2% (up to 4% as a maximum). That suggests how ''fragile'' unstable (red) equilibriums are. In future predictions (2023/2024), parameter *d* changes up to 5.2% and *e* up to 17.95% (around the GH).

Furthermore, there different bifurcation points emanate with codim 2 bifurcations (Figures 25 and 26), but we will primarily analyze the ones that directly relate to observed economic data. That is, following the lower-left part of the diagram (back in time), we first encounter a CP, which has no significant impact on system flow. A similar conclusion is valid for the next CP with coordinates (4.672–152–23.45). In contrast, an important BP made possible a transition from the lower-left to the upper-right part of diagram (Figure 17). If the system flow followed the lower-right curve, we would encounter equilibrium LCs that bifurcate to LPCs, and then to neutral saddle-focus (NS). This has not been reached by values in reality, and accordingly, it will not be further analyzed.

On the upper-right curve, we encounter BT with coordinates (4.694–152–23.46). This BT exists between multiple CPs, even followed by CP, which indicates multiple structural breaks in the system flow.[8,9] In addition, this system has multiple stable and unstable invariant manifolds.

The first CP has coordinates (4.694–152–23.46) with a normal form coefficient c = 4.59143220e + 01 (Figure 27), and the second CP has coordinates (4.784–150.861–23.395) with c = 6.20242977e–02. This turbulent period with structural breaks coincides with the EU Sovereign debt crisis in the years 2011/2012. Furthermore, we encounter another BT, which after continuation and sweep of parameters caused a stable and unstable LPC. In macroeconomic terms, it means a possible and very significant stagnation–recession period. For specific values of parameters *d* and *e*, it

can induce a long-lasting economic downturn. As previously mentioned, it is valid under the assumptions that there exists an exact and specific combination of total disposable income and total wealth, in total consumption.

ECB APP transitioned the EU macroeconomics to more ''calm waters'' represented by multiple LPCs at (5.001–159.3–24.67) in 2015, with a period of $T = 13.783886$ (Figure 27). However, in September 2015 and June 2016, the migrant crisis and ''Brexit'' struck the EU28 as creation of LPCs and LCs indicates.

The model values in 2016 indicate a recession, with LPCs that emanate at (5.07–160.5–24.88), and with a period of $T = 0.59230953$ (Figure 27). In addition, 2016 brought many political confrontations and different opinions on how to handle the EU migrant crisis. Every subtle change in macroeconomic data is visible in phase space. After a quasi-linear rise, we arrive at BT with coordinates (5.531–168–26.25), which correspond to the year 2018/2019 judging by Y_H, but not W_H! The final mentioned discrepancy arises because both parameters d and e affect the ratio of total disposable income and total wealth in total disposable consumption. In addition, they all follow the system flow. To follow the flow, variable values need to change according to NDA NODE solutions.

In addition, we encounter a Zero Hopf (ZH) with coordinate real part values (5.631–169.5–26.53) (Figure 27) which can lead to a localized chaos.[5,8,59] Consequently, the system starts drifting to unpredictability. Furthermore, we relate to the relatively near future in 2022/2023 with LPCs at (5.703–170.6–26.73) and a period of $T = 5.3838855$. This means that there is potential stagflation for around 2.5 years. Any intervention by the ECB, similar as it was with APP, can change or shift the course of any macroeconomic trend.[5,8,45] Although the value of EURO STOXX 50 in the last few years (from mid-2016) had a relatively stable growth, the share of the EU27 population at risk of poverty was 21.1% in 2019.

Small LPCs emanate on the lower-right part of the curve, with period $T = 0.1$ years. We did not analyze or consider them because those LPCs show a month and a half long ''stagnation'' in EU macroeconomics. This is not a stagnation, but rather a ''correction.'' Therefore, they are not significant in macroeconomic analysis. Although, the final mentioned LPCs have theoretical and inherent NDA value.

One of the biggest challenges in this research was finding a balance between the real macroeconomic usefulness of NDA, contrary to its numerical (mathematical) only interesting values.

5. Conclusion

We presented an incremental contribution to the implementation of NDA in the social sciences, specifically in macroeconomics.

Interested researchers can implement this methodology on any interconnected data series linked to a specific field of research. An additional value of this work is its two-line approach to analysis. One line of analysis sublimes the efforts for endogenous and exogenous variables to form an NODE system. The other line connects through NDA, postulates close-field variables (e.g., Y_H–W_H–C_H), and analyzes them with NDA computer-developed tools. Econometrics plays an intermediary role in connecting those two lines of analysis.

A great proportion of the financial funds injected into the EU macroeconomic system have gone to the EU population, and it is a remarkably positive outcome. In the future, the EU should conduct a very careful wage–tax policy, to remain stable and to ballast high amounts of accumulated public debt. ECB APP encouraged very significantly the European growth and development (*In varietate concordia* (English: United in diversity), the motto of the EU.).

The EU macroeconomics is an open economy, but it has many characteristics that positively resemble a closed economy. This is due to its significant population, accumulated knowledge, diversified financial investments across the EU, controlled business risk practice, education, the overall production capacity that is mainly oriented on inward economic growth, and so on. This is a foundation to a sure, stable, and secure future. Consequently, it guarantees the prospect of a better quality of life for all of its citizens.

The NDA discovered that there was a period of underspending on wages for the EU population in the period before the global financial crisis in 2008. In addition, it confirmed overspending on wages in the period from 2012 to 2019. This suggests that the EU was saving parts of the overall GDP in periods of well-being and spending more on a time of crisis. Conversely, the EU helped protect its citizens' living standards in a substantially long-lasting recession. We hope that our research will be of interest to readers, among other, to inspire them in expanding the present, or in developing new ideas or analysis paths.

Considering the data and knowledge from research, even without COVID-19 pandemics that hit hard the EU and the whole world, we discovered that at least for a couple of years, the EU stagnation was imminent. The COVID-19 pandemic has the status of an extraordinarily catastrophic event, in an economic and every other significant way! It is a global ''Black Swan'' event. Previous analysis shows us that for EU macroeconomics, a possible combination of economic recession and stagnation was very near. Although, model-expected stagnation would not be even close to the difficulties that have caused COVID-19 pandemics. EU programs like ''NextGenerationEU'' provide Europeans with a brightly paved path to the future.

The European way of life is truly one of Europe's unique and characteristic features. ECB harmonization and coordination, sustained by all EU members, even in times

of crisis, assure an effective implementation of monetary and fiscal policies.

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ORCID iD

Damir V Sindik https://orcid.org/0000-0002-5011-9048

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Author biographies

Damir V Sindik is a Head of Division for Payment Systems Oversight in Central bank of Montenegro, where he works for almost two decades. He graduated as Dipl. Ing. Electrotechnics in Electronics at the Faculty of Electrical Engineering at the University of Montenegro (UCG), obtained an MSc in Banking on the Faculty of Economics (UCG), and is a PhD candidate in final phase in Applied Mathematical Economics on the Faculty of Economics (UCG). He projected and implemented several national IT systems, and ORACLE databases. He participated in few national and European central-banking projects, research works, and operational analysis. His research interests are in the field of programing simulations of Complex systems, using NDA, Chaos theory, MATLAB Deep Learning data analysis, and Nonlinear econometrics.

Vladimir Kašćelan is a full-time professor at the Faculty of Economics at the University of Montenegro. He graduated in Mathematics at the Faculty of Natural Sciences and Mathematics (University of Montenegro), obtained MSc in Probability and Statistics from the Mathematical Faculty (University of Belgrade) and received his PhD at the Faculty of Economics (University of Montenegro). He teaches subjects in the field of Mathematical Economics, Financial and Actuarial Mathematics and Insurance. He is the author of several papers in international journals and conferences. He was CEO of the Central Security Depository (CSD) of Montenegro in the period November 2000 to February 2019 (https://scholar.google.com/citations?user=FqNEPZ0AAAAJ&hl=sr&oi=ao).

Ljiljana Kašćelan is a full-time professor at the Faculty of Economics at the University of Montenegro. She graduated in Computer Science at the Faculty of Natural Sciences and Mathematics, obtained an MSc in Computer Science from the Faculty of Electrical Engineering and a PhD in Business Intelligence from the Faculty of Economics (all at the University of Montenegro). She teaches courses in Business Informatics and Business Intelligence. Ljiljana is the author of several papers in international journals and conferences in the field of data mining and applications. Ljiljana Kašćelan is a member of the Euro Working Group on Decision Support Systems and a member of the Editorial Board of COMSIS Journal. She was a member of the University of Montenegro Senate from 2014 to 2019 (https://scholar.google.com/citations?user=M3E_M-cAAAAJ&hl=sr&oi=ao).

Biografija

Damir V. Sindik rođen je 28. oktobra 1975. godine u Kotoru, SFRJ. Magistrirao je na Ekonomskom fakultetu u Podgorici, na Univerzitetu Crne Gore (UCG), stekavši titulu akademski magistar ekonomije – bankarstva, sa najvećom ocjenom (10). Master teza mu je bila „Implikacije instrumenata Novog svjetskog poretka – Specifikacija CDS aranžmana". Diplomirao je na Elektrotehničkom fakultetu u Podgorici (UCG), kao Diplomirani Inženjer Elektrotehnike – Elektronike, takođe sa najvećom ocjenom.

Tokom dvadesetogodišnjeg rada u Centralnoj banci Crne Gore (CBCG) u Podgorici, radio je na poslovima vezanim za nadgledanja platnih sistema. Dizajnirao je i implementirao neke od nacionalnih IT sistema i ORACLE baza podataka, te učestvovao u pojedinim projektima evropskih centralnih banaka, istraživačkim radovima i operativnim analizama. Član je nacionalne radne grupe za implementaciju blockchain tehnologija u plaćanjima, uključujući Central Bank Digital Currency (CBDC) u saradnji sa jednom od vodećih svjetskih kompanija u navedenom domenu Ripple (USA).

Učesnik je projekata od nacionalnog značaja u saradnji sa World Bank (WB) i International Monetary Fund (IMF). Aktivni učesnik je brojnih seminara i skupova centralnih banaka, a neki od njih su: Swiss National Bank (SNB) – Academic Study Center Gerzensee, Bern, na temu modeliranja DSGE modela kroz Novokejnzijanske višedimenzione modele monetarne politike; European Central Bank (ECB), Frankfurt, vezano za moderne infrastrukture tržišta i platne sisteme; više seminara, kurseva i radionica u organizaciji Deutsche Bundesbank (DBB), Frankfurt, i Banca di Italia (BdI), Roma, vezano za različite vrste platnih sistema, digitalnog i elektronskog novca, platnih instrumenata; Bank of England (BoE), London, vezano za upravljanje poslovanjem u slučaju iznenadnih događaja i održavanja kontinuiteta poslovanja; Banque de France (BdF), Paris, povezano sa internom revizijom, poslovnom revizijom i upravljanjem rizicima; KPMG seminari, kursevi i radionice, oko upravljanja IT operativnim rizikom; Centralna banka Slovenije (BS), Ljubljana, na teme evropskih platnih i klirinških sistema; sertifikovani ORACLE DBA kursevi, i administracija različitih serverskih Windows i Linux platformi. Istraživački interesi obuhvataju programiranu-simulaciju kompleksnih sistema koristeći primijenjenu matematiku, teoriju haosa, analizu podataka pomoću MATLAB AI Deep Learning i primijenjenu nelinearnu ekonometriju.

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Sindik, D.V., Kašćelan, V., Kašćelan, L. (2023), Simulation of disequilibrium and chaos in aggregates of disposable income, wealth, and consumption in EU macroeconomics using nonlinear dynamic analysis. SAGE journals: Simulation, 99(2), pp.137-167. https://doi.org/10.1177/00375497221130100

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Kašćelan, V., Kašćelan, L., Sindik, D.V. (2023), EU insurance premiums and claims in conditions of economic crisis – NDA analysis; in: Kocović J., Mladenović, Z., Borićić, B. and Jovanović Gavrilović, B. : Challenges and insurance market's responses to the economic crisis, Monograph, Chapter 6, p. 93-112, Faculty of Economics Belgrade, ISBN: 978-86-403-1789-4 University of Belgrade, Faculty of Economics and Business Publishing Centre

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Papers in congresses, symposiums and seminars

International symposiums

Sindik, D.V., Kašćelan, V., Kašćelan, L. (2023). Interchange dynamics of world's green energy production and fossil fuels consumption. The 1st Montenegrin International Conference on Economics & Business (MICEB). Sustainable development: Transition to Green Economy. Book of Abstracts, p. 35. Budva, May 25-27, 2023.

Prof. dr Vladimir Kašćelan

Mjesto i datum rođenja: Cetinje, 10.09.1965.
e-mail: vladok@ucg.ac.me

Obrazovanje

Osnovnu i srednju školu završio na Cetinju sa diplomom Luča, kao jedan od najboljih učenika u svojoj generaciji. Studije matematike na PMF-u u Podgorici završio je 1989. godine, sa prosječnom ocjenom 9,63. Iste godine upisao je postdiplomske studije na Matematičkom fakultetu u Beogradu (smjer Verovatnoća i statistika). Poslije uspješno položenih ispita, sa prosječnom ocjenom 10, 1994. godine odbranio je magistarski rad «O srednjekvadratnom odstupanju ocjene kospektra višedimenzionalnog slučajnog procesa» (mentor Pavle Mladenović). Doktorsku disertaciju pod naslovom «Proračun cijena terminskih ugovora i hedžing strategije» (mentor Stojan Babić) odbranio je 1999. godine na Ekonomskom fakultetu u Podgorici. Usavršavao se na Univerzitetu „Lomonosov" u Moskvi, finansijsko-aktuarski centar.

Zvanje i predmeti

U zvanje redovni profesor Univerziteta Crna Gora za predmete Finansijska matematika i Rizik i osiguranje izabran je 27. maja 2010. godine. Od 1989. godine radi na Ekonomskom fakultetu u Podgorici kao asistent na predmetima Matematika i Finansijska matematika. Od 2000. godine, po izboru u zvanje docenta, držao je predavanja na predmetima: Matematika, Finansijska matematika i Teorija vjerovatnoće i primjene u ekonomiji, a na Poslovnoj školi, kasnije Visokoj školi za menadžment, predavanja na predmetima Privredna i finansijska matematika i Matematika za biznis. U zvanje vanrednog profesora za predmete: Finansijska matematika, Teorija vjerovatnoće i primjene u ekonomiji, Tržište novca i tržište kapitala i Rizik i osiguranje izabran je 2005. godine. Na postdiplomskim studijama je rukovodilac smjera Aktuarstvo, na kojem je uključen u izvođenje sljedećih disciplina: Finansijska matematika na finansijskom tržištu, Aktuarska matematika i Osiguranje i upravljanje rizikom.

Publikacije i radovi

Koautor je tri univerzitetska udžbenika: «Matematika za ekonomiste», «Privredna i finansijska matematika» i »Osiguranje i aktuarska matematika«, i autor nekoliko skripti iz Finansijske i Aktuarske matematike. Mentor je pri izradi dvije doktorske disertacije, 18 odbranjenih magistarskih radova i 67 diplomskih radova. Recenzet je radova u časopisima sa SCI liste i urednik međunarodne monografije. Objavio je oko 80 radova u međunarodnim, domaćim časopisima i na konferencijama.

Oženjen je i otac dvoje djece. Govori engleski, a služi se ruskim, italijanskim i francuskim jezikom.

Bibliografija

1. NAUČNOISTRAŽIVAČKA DJELATNOST

1.1 Monografija

1. Novović Burić, M., Lalević Filipović, A., Kašćelan, Lj., Kašćelan, V. (2021), Ipact of the COVID-19 Pandemic on the Montenegrin insurance market; in: Kocovic J., Jovanovic Gavrilovic, B., Boričić, B., Koprivica M. : Contemporary Challenges and Sustainability of the Insurance Industry, Monograph, Chapter 8, pp. 125-139, Faculty of Economics Belgrade, ISBN: 978-86-403-1693-4 Centar za izdavačku delatnost Ekonomskog fakulteta u Beogradu (CID)

2. Novović Burić, M., Lalević Filipović, A., Kašćelan, V., Kašćelan, Lj. (2020), Analysis of firms' participation in the financial market with a focus on the Montenegrin insurance market; in: Kocovic J, Rakonjac-Antic, T., Jovanovic Gavrilovic, B., Boričić, B : Insurance market after COVID -19, Monograph, Chapter 10, pp. 187-207, Faculty of Economics Belgrade, ISBN: 978-86-403-1644-6 Centar za izdavačku delatnost Ekonomskog fakulteta u Beogradu (CID)

3. Kašćelan, Lj., Lalević Filipović, A., Novović Burić, M., Kašćelan, V. (2020), IT technology application to accounting in Montenegrin companies – decision tree classification method in Drezgic, S., Zikovic, S., Tomljanovic, M.: Smart Governments, Regions and Cities, Monograph, Chapter 6, pp.105-121, ISBN: 978-953-7813-55-0 University of Rijeka, Faculty of Economics and Business

4. Novović Burić, M., Lipovina Božović, M., Kašćelan, V., Kašćelan, Lj., (2019), Application of Computer Methods in Evaluation of Citizens' Confidence in Montenegrin Insurance Companies, in: Kočović J., Tomašević M., Jovanović Gavrilović B., Boričić B., Petrović E. and Koprivica M. (ed.), Contemporary Trends in Insurance at the Beginning of the Fourth Industrial Revolution, Monograph, Chapter 16, pp. 265-284, ISBN: 978-86-403-1589-0, University of Belgrade, Faculty of Economics, Centar za izdavačku delatnost Ekonomskog fakulteta u Beogradu (CID)

5. Lj.Kašćelan, V.Kašćelan, M. Novović Burić (2018), A Decision Tree Analysis of Real Estate Insurance Customers in the Montenegrin Market in: Kočović J., Selimović J., Boričić B., Kašćelan V. And Rajić V. (ed.), Quantitative Models in Economics, Monograph, Chapter 16, pp. 289-304, ISBN 978-86-403-1561-6, University of Belgrade, Faculty of Economics, Centar za izdavačku delatnost Ekonomskog fakulteta u Beogradu (CID).

6. Kašćelan, V., Novović Burić, M., Cerovic Smolović J. (2018), Factor Analysis of Life Insurance Development in Montenegro, in: Kočović J., Jovanović Gavrilović B., Boričić B. and Radović Marković M (ed.), Insurance in the post-crisis era, Monograph, Chapter 12, pp. 205-218, ISBN: 978-86-403-1548-7, University of Belgrade, Faculty of Economics, Centar za izdavačku delatnost Ekonomskog fakulteta u Beogradu (CID)

7. Kašćelan, Lj., Kašćelan, V., Novović Burić, M. (2017), Data-driven Approach as an Alternative Method for Risk Assessment in the Montenegrin Automobile Insurance Market, in: Kočović J., Boričić B., Jovanović Gavrilović B., and Martin Balleer (ed.), Challenges and tendencies in contemporary insurance market, Monograph, Chapter 29, pp. 503-523, ISBN: 978-86-403-1522-7, University of Belgrade, Faculty of Economics, Centar za izdavačku delatnost Ekonomskog fakulteta u Beogradu (CID)

8. Kašćelan, V., Novović Burić, M. (2016), Risk management in financial services market, in: Kočović J., Jovanović Gavrilović B., Trifunović D. (ed.), Risk management in the financial services sector, Monograph, Chapter 3, pp. 47-64, ISBN: 978-86-403-1487-9, University of Belgrade, Faculty of Economics, , Centar za izdavačku delatnost Ekonomskog fakulteta u Beogradu (CID)

9. Novović Burić, M., Kašćelan, V. (2014), Risk management in insurance market of Montenegro, in: Kočović J., Jovanović Gavrilović B., Rajić V. (ed.), Risk measurement and control in insurance, Monograph, Chapter 4, pp. 63-77, ISBN: 978-86-403-1362-9, University of Belgrade, Faculty of Economics , Centar za izdavačku delatnost Ekonomskog fakulteta u Beogradu (CID)

10. Novović M., Kašćelan, V. (2013), Bancaasurance as a new channel of insurance sales in Montenegro, in: Kočović J., Jovanović Gavrilović B., Marković Radović M.(ed.), Product specifics on the markets of insurance and reinsurance, Monograph, Chapter 11, pp. 157-169, ISBN: 978-86-403-1309-4, University of Belgrade, Faculty of Economics, Centar za izdavačku delatnost Ekonomskog fakulteta u Beogradu (CID)

11. Monograph: Achieved Results and Prospects of Insurance Market Development in Modern World, Chapter 8 (Vladimir Kascelan, Milijana Novovic: The Development of Insurance Market in Montenegro), Ekonomski fakultet Beograd, Centar za izdavačku delatnost Ekonomskog fakulteta u Beogradu (CID), 2012., ISBN: 978-86-403-1222-6, 2012. str: 139-154

1.2 Radovi objavljeni u časopisima

1.2.1 Radovi u međunarodnim časopisima

1. Novović Burić, M, Kašćelan, Lj., Kašćelan V. (2021), »Economic and demographic determinants of premium reserve in Western Balkan countries during and after the crisis«, International Journal of Finance and Economics (early view, online version), https://doi.org/10.1002/ijfe.2466

2. Jelena Tomašević, Milijana Novović Burić, Ljiljana Kascelan, Vladimir Kascelan (2021), »Impact of premium reserve on life insurance investments in western Balkans«, Serbian Journal of Management, Article ID: 28022-174453 (accepted)

3. Milijana Novović Burić, Milan Raičević, Ljiljana Kascelan, Vladimir Kascelan (2021) »Socio–demographic Impacts on the Personal Savings Portfolio Choice - a Decision Tree Approach«, International Journal of Business Analytics (IJBAN), Article ID: 180420-090506 (accepted)

4. Milena Lipovina-Božović, Ljiljana Kašćelan, Vladimir Kašćelan. "A Support Vector Machine approach for predicting progress toward environmental sustainability from information and communication technology and human development", Environmental and Ecological Statistics, September 2019, Volume 26, Issue 3, pp 259–286. https://doi.org/10.1007/s10651-019-00427-2

5. Novović Burić, M., Kašćelan, V., Radović, M., Lalević Filipović, A. (2018), »Mechanisms of Protection from Interest Rate Risk with Reference to the Life Insurance Market in Montenegro«, Journal of Central Banking Theory and Practice, 1, Pint edition ISSN 1800-9581, Web edition, ISSN 2336-9205, pp. 17-42 , DOI: 10.2478/jcbtp-2018-0002

6. Jovanović M., Kašćelan Lj., Joksimović M., & Kašćelan, V. (2017). „Decision Tree Analysis of Wine Consumers' Preferences: Evidence from an Emerging Market", British Food Journal, 119(6), ISSN 0007-070X. DOI:10.1108/BFJ-11-2016-0568

7. Kašćelan, V., Kašćelan, L., & Novović Burić, M. (2016), »A nonparametric data mining approach for risk prediction in car insurance: a case study from the Montenegrin market« Economic Research-Ekonomska Istraživanja, 29(1), ISSN: 1331-677X (Print) 1848-9664 (Online), pp. 545–558, Journal homepage: http://www.tandfonline.com/loi/rero20 1 DOI:10.1080/1331677X.2016.1175729

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9. Jovanović, M., Kašćelan, L., Despotović, A., & Kašćelan, V. (2015), »The Impact of Agro-Economic Factors on GHG Emissions: Evidence from European Developing and Advanced Economies«. Sustainability, 7(12), 16290-16310. DOI:10.3390/su71215815

10. Kašćelan, L., & Kašćelan, V. (2015), »Component-Based Decision Trees: Empirical Testing on Data Sets of Account Holders in the Montenegrin Capital Market«. International Journal of Operations Research and Information Systems (IJORIS), 6(4), 1-18.

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15. Milijana Novović, Vladimir Kašćelan, Julija Cerović: "Performances of Insurance Market in Montenegro in Condition of Financial Crisis"," Economic Review: Journal of Economics and Business,, Volume IX , Issue 1, 2011, University of Tuzla, Faculty of Economics, ISSN:1512-8962, str:31-43

16. В.Кашчелан, М.Нововић: „Характеристики рынка страхования Черногории" Финансы, Но. 8, Министарство финансов Россиискои Федерации и Книжная редакция Финансы Москва, 2009, ISSN 0869-446X, 50-54

17. V.Kašćelan, B.Radulović "A Comparison of Technical Reserves of Insurance Companies From the Ex Yugoslavia Region" Journal of International Scientific Publications: Economy&Business, Vol 3 (2009), 924-939, ISSN 1313-2525

18. V.Kašćelan, B.Božović "Bond Yields and Yields Variations on Bonds in Montenegro" Management, number 52, Year XIV (2009), 73-80, ISSN 1820-0222, za englesko izdanje i ISSN 0354-8635 za naše izdanje

19. V.Kašćelan, B.Radulović „Osiguravajuće kompanije na finansijskom tržištu u regionu", Montenegrin Journal of Economics, Vol.4 no.7, July 2008, 5-15, ISSN 1800-5845

20. L.Jauković, V.Kašćelan „Nova regulativa solventnosti osiguravajućih kompanija u EU-Projekat Solventnost II", Montenegrin Journal of Economics, Vol.3 no.5, July 2007, 77-84, ISSN 1800-5845

21. V.Kašćelan, L.Jauković «Metode određivanja margine solventnosti osiguravajućih kompanija», Preduzetnička ekonomija Vol 11 (2006), 148-161, ISSN 1451-6659

22. V.Kašćelan, M.Novović «Komparativna analiza tržišta osiguranja u regionu», Preduzetnička ekonomija Vol 14 (2006), 37-50, ISSN 1451-6659

23. V.Kašćelan «Mjesto i uloga kastodi banke na tržištu kapitala», Preduzetnička ekonomija Vol 8 (2005), 52-60, ISSN 1451-6659

24. V.Kašćelan «Efektivna kamatna stopa na kredite i depozite- stvarna cijena kapitala», Preduzetnička ekonomija Vol 6 (2004), 6-14, ISSN 1451-6659

25. V.Kašćelan, M.Jovanović "Capital Market- Experience of Montenegro from the Central Depository Agency Prospective" Management, Vol 34 (2004), 39-43

26. V.Kašćelan "Probability Aspect of Optimal Stopping for Stock Options" Entrepreneurial Economy Vol 4 (2004)

27. V.Kašćelan "Estimation of Beta Coefficient and Stock Option Pricing" Mathematica Montisnigri Vol XIII (2001), 41-48

1.2.2 Radovi objavljeni u domaćim časopisima

1. V.Kašćelan, G.Mioljević „ Adekvatnost tablica smrtnosti u Crnoj Gori" Bankar br. 6, jun 2009, 80-87, ISSN 1800-7465

2. V.Kašćelan „Ugovorno saldiranje i garantni fond" Bankar, br.2, jul 2008., 32-37, ISSN 1800-7465

3. V.Kašćelan „PIN kodovi za vlasnike hartija od vrijednosti", Računovodstvo, Revizija i Finansije (RRF Magazin) broj 4-5 (2008), 33-34, ISSN 1800-718X

4. V.Kašćelan, R.Milutinović „Tržište zdravstvenog osiguranja u Crnoj Gori" Računovodstvo i revizija br. 3 (2008), 72-83, ISSN 1800-6159

5. V.Kašćelan, M.Novović «Osiguranje u svijetu sa osvrtom na Crnu Goru», Računovodstvo, revizija i finansije broj 6 (2006), 74-82, ISSN 86-84059-04-2

6. V.Kašćelan «Korporativne aktivnosti, pravila i neophodna dokumentacija pri registrovanju privrednih društava kod Centralne Depozitarne Agencije», Računovodstvo, revizija i finansije broj 7-8 (2005), 110-113, ISSN 86-84059-04-2

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8. V.Kašćelan "Zaštita akcionarskih prava na tržištu kapitala Crne Gore" Akcionar broj 5-6 (2004) 97-104

9. V.Kašćelan"Neting novčanih obaveza u CDA" Računovodstvo, revizija i finansije broj 9 (2002) 93-95

10. V.Kašćelan, M.Jovanović "Centralna Depozitarna Agencija- komponenta tržišta kapitala" Računovodstvo i finansije broj 4 (2001), 3-7

11. V.Kašćelan "Registracija akcionarskih društava kod Centralne Depozitarne Agencije" Računovodstveni savjetnik broj 7-8 (2001), 163-164

12. V.Kašćelan "Nužnost registrovanja kod Centralne Depozitarne Agencije" Računovodstvo i finansije broj 6-7 (2001), 335-337

13. V.Kašćelan "Veza masovne vaučerske privatizacije i Centralnog registra akcija" Računovodstvo i finansije broj 12 (2001) 180-181

14. V.Kašćelan "Opcije i optimalni momenti zaustavljanja" PMB (2000), 345-356

15. V.Kašćelan »O nekim problemima finansijske i aktuarske matematike«, Zbornik radova Ekonomskog fakulteta, Podgorica, 1995.

1.3 Radovi na kongresima , simpozijumima i seminarima

1.3.1.Međunarodni simpozijumi , kongresi i seminari

1. Kašćelan, V., Kašćelan, Lj., Novović Burić, M. (2020), "Regional Analysis Of Car Insurance In Montenegro Using Deep Learning Methods", Horizons, Macedonia, DOI 10.20544/HORIZONS.A.26.3.20.P07

2. Kašćelan, V., Novović-Burić, M.,Kašćelan, Lj. i Lipovina-Božović, M. (2019) "Analiza informisanosti i poverenja crnogorskih građana u industriju osiguranja primenom kompjuterskih

metoda". XVII Međunarodni simpozijum – Osiguranje na pragu IV industrijske revolucije, Zlatibor, maj 2019.

3. Novovic Burić M, Kašćelan, V. Lj.Kašćelan,(2018), "Limiting Factors of Real Estate Insurance Development In Montenegro - Decision Tree Analysis", SYMOPIS, Proceedings, ISBN 978-86-403-1567-8, University of Belgrade, Faculty of Economics, pp. 125-134

4. Kašćelan V., Kašćelan Lj., Novović-Burić M., Kalamperović E., (2015), »Alternative mechanisms for insurance risk transfer to the capital market«, Montenegrin International Conference for Entrepreneurial Development, MICED, Zbornik radova, ISBN 978-86-80133-72-0, str.88-96

5. Vladimir Kašćelan, Lidija Jauković, Milijana Novović: „Challenges of EU Accession from the point of Montenegrin Insurance Market Regulation", IX International Symposium „Supervision and Control of Insurance Companies' Operations", Udruženje aktuara Srbije, Zlatibor, maj 2011., ISBN: 978-86-403-1141-0, str: 68-85

6. Milijana Novovic, Vladimir Kašćelan, Julija Cerović, „Problemi poslovanja osiguravajućih kompanija u Crnoj Gori", VIII međunarodni simpozijum «Problemi poslovanja osiguravajućih kompanija u uslovima krize», Udruženje aktuara Srbije, Zlatibor, maj 2010, ISBN: 978-86-84309-26-8, str: 79-92.

7. B.Božović V.Kašćelan „ Prinosi na obveznice u Crnoj Gori", SYMOPIS, 107-110, Ivanjica 2009, ISBN 978-86-80953-43-4

8. V.Kašćelan M.Novović „Isurance Market in Montenegro and Global Financial Crisis" The Seventh International Symposium on Insurance „Insurance and the Global Financial Crisis" , 128-144 (engleski jezik), / "Tržište osiguranja Crne Gore i globalna finansijska kriza" VII međunarodni simpozijum « Osiguranje i globalna finansijska kriza», 317-333 (naš jezik), Zlatibor 2009, ISBN 978-86-84309-22-0

9. V.Kašćelan, B.Radulović „A Comparison of Technical Reserves of Insurance Companies From the Ex Yugoslavia Region" the 8th International Symposium Economy&Business, 6, Sunny Beach, Bulgaria 2009, ISSN 1313-2525

10. V.Kašćelan M.Novović "Novi proizvodi na tržištu osiguranja Crne Gore" VI međunarodni simpozijum «Novi proizvodi na tržištu osiguranja», 26-43, Zlatibor 2008, ISBN 978-86-84309-21-3

11. L.Jauković V.Kašćelan " Mjerenje solventnosti osiguravajućih kompanija u zemljama bivše SFRJ", SYMOPIS, 193-196, Zlatibor 2007, ISBN 978-86-7680-124-4

12. V.Kašćelan L.Jauković " Kastodi servis kod penzijskih fondova" V međunarodni simpozijum «Strategije razvoja tržišta osiguranja u Srbiji », 163-168, Vrnjačka Banja 2007, ISBN 978-86-84309-17-6

13. L.Jauković V.Kašćelan „Regulation on Solvency of the Insurance Companies in EU with reflection on Montenegro" EURO XXII, 174, Prague 2007

14. Vladimir Kašćelan, Milijana Novović, "Tržište osiguranja u Crnoj Gori", IV Međunarodni simpozijum:"Savremeni trendovi u razvoju tržišta osiguranja", Udruženje aktuara Srbije, Vrnjacka Banja, 2006., ISBN: 978-86-403-0825-0, str.:38-49.

15. V.Kašćelan « Koncept kastodi banke na tržištu kapitala», SymOrg, 116, Zlatibor 2006, ISBN 86-7680-086-3

16. V.Kašćelan «On Solvency Measurement of Insurance Companies in Montenegro», EURO XXI 21st European Conference on Operational Research, 168, Reykjavik, Iceland 2006

17. V.Kašćelan "Fee Structures Comparisons of the CEECSD (Central and Eastern European Central Securities Depositories) Agencies" EURO XX, 20th European Conference on Operational Research- OR and the Management of Electronic Services, Rhodes, Greece 2004, 38

18. V.Kašćelan "Central Depository Agency- New Capital Market Institution in Montenegro" 6th Balkan Conference on Operational Research, Thessaloniki, Greece 2002, 161

1.3.2. Domaći kongresi, simpozijumi i seminari

1. V.Kašćelan "Uloga aktuarstva u razvoju tržišta osiguranja Crne Gore" Seminar „Tržište osiguranja u Crnoj Gori-aktuelno stanje i trendovi", Bečići 2009.

2. V.Kašćelan «Odnos kamata kod dva osnovna tipa investicionih zajmova», SYMOPIS 2005, 201-202, Vrnjačka Banja 2005, ISBN 86-403-0685-0

3. V.Kašćelan "Interna stopa prinosa kao efektivna kamatna stopa" SYMOPIS 2004, Iriški Venac, Fruška Gora 2004, 99-102

4. V.Kašćelan "Registracija promjene vlasništva u procesu privatizacije" SYMOPIS 2003, Herceg Novi 2003, 153-156

5. V.Kašćelan "O Centralnoj Depozitarnoj Agenciji" Seminar Instituta računovođa i revizora Crne Gore, Sutomore-Kolašin 2002, 238-239

6. V.Kašćelan "O teoremi pariteta call i put opcija" SYMOPIS 2001, Beograd 2001, 211-213

7. V.Kašćelan, M.Jovanović "Iskustva u radu Centralne Depozitarne Agencije- postupak registrovanja akcionarskih društava" IX Miločersko savjetovanje- Finansijska tržišta, Miločer 2001, 357-362

8. V.Kašćelan "Matematički aspekti forverdnih i fjučersnih ugovora" SYMOPIS 2000, Beograd 2000, 115-118

9. V.Kašćelan »Problematika proračuna cijena opcija«, Finansijska tržišta- V Miločersko savjetovanje, Miločer, 1997.

1.2 Recenziranje radova u međunarodnim časopisima:

1. Preduzetnička ekonomija- Entrepreneurial Economy
2. Economic Research-Ekonomska Istraživanja
3. Simulation: Transactions of the Society for Modeling and Simulation International
4. International Joural of Finance&Economics

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2 PEDAGOŠKA DJELATNOST

2.1. Univerzitetski udžbenik

1. V.Kašćelan, M.Novović »Osiguranje i aktuarska matematika« I izdanje, Univerzitet Crne Gore, Podgorica 2009., 206 str. ISBN 978-86-7664-066-9
2. B.Laković, V.Kašćelan, S.Vujošević Matematika za ekonomiste- Teorija i zadaci, III dopunjeno izdanje, Ekonomski fakultet, Podgorica 2003.
3. B.Laković, V.Kašćelan Privredna i finansijska matematika, II izdanje, Ekonomski fakultet Podgorica, 1997

2.2. Studijski priručnici

1. V.Kašćelan Osnove aktuarske matematike –skripta, Podgorica 2004.
2. V.Kašćelan Matematika za biznis- skripta, Podgorica 2003
3. Finansijska matematika I - Specijalističke studije na PMF-u
- hrestomatija, Podgorica 2003.
4. Teorija vjerovatnoće i primjene u ekonomiji– hrestomatija, Podgorica 2002.

2.3. Mentorstvo

1. Kod dvije doktorske disertacije
2. -18 magistarskih radova
3. -67 diplomskih radova

3 STRUČNA DJELATNOST

1. Projekat formiranja Centralne Depozitarne Agencije (CDA)- učešće u izradi Pravila, Uputstava, Cjenovnika i ostalih njenih pravnih akata- www.cda.cg.yu, Podgorica 2000-2018.
2. Projekat: Socio- ekonomski položaj zaposlenih u privatizovanim preduzećima u Crnoj Gori, EF-PKCG, Podgorica, 2006
3. Projekat Centralne banke Crne Gore za donošenje predloga Odluke i izrada Uputstva o jedinstvenom načinu obračuna i iskazivanja efektivne kamatne stope na kredite i depozite- Sl. List RCG br. 48, Podgorica 2003.
4. Projekat: Testiranje softvera za aukciju u procesu Masovne vaučerske privatizacije (MVP), Podgorica, 1999
5. Član Odbora direktora ECSDA- evropske asocijacije centralnih depozitarija za hartije od vrijednosti (2006-2018)
6. Direktor CDA (2000-2018)
7. Učešće (kao uvodničar, panelista i sl.) na brojnim seminarima u organizaciji berzi i depozitarnih agencija iz zemlje i inostranstva (2000-2018)
8. Rukovodilac Smjera Aktuarstvo na akademskim magistarskim studijama Ekonomskog fakulteta (2005-2018)
9. Član Odbora direktora Montenegroosiguranja a.d. Podgorica (2006-2007)
10. Osnivač i rukovodilac Centra za osiguranje i aktuarstvo Ekonomskog fakulteta (2007)
11. Osnivač prvog Udruženja aktuara Crne Gore (2007)
12. Član radne grupe za izradu Pravilnika o sticanju zvanja ovlašćenog aktuara, Agencija za nadzor osiguranja Crne Gore
13. Član programskog odbora i radnog predsjedništva međunarodnog simpozijuma iz osiguranja u organizaciji Ekonomskog fakulteta u Beogradu i Udruženja aktuara Srbije
14. Urednik monografije sa Symopisa 2018
15. Član komisije za licenciranje ovlašćenih aktuara u Crnoj Gori
16. Predavač na obuci za aktuare u Crnoj Gori u organizaciji ANO (predmeti: Finansijska matematika i Aktuarska matematika I)
17. Počasni član CAD (Crnogorskog aktuarskog društva)
18. Recenzent u Crnoj Gori i Srbiji za akreditaciju ustanova visokog obrazovanja

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УНИВЕРЗИТЕТ ЦРНЕ ГОРЕ
Ул. Цетињска бр. 2
П. фах 99
81000 ПОДГОРИЦА
ЦРНА ГОРА
Телефон: (020) 414-255
Факс: (020) 414-230
E-mail: rektor@ac.me

UNIVERSITY OF MONTENEGRO
Ul. Cetinjska br. 2
P.O. BOX 99
81 000 PODGORICA
MONTENEGRO
Phone: (+382) 20 414-255
Fax: (+382) 20 414-230
E-mail: rektor@ac.me

Број: 08-881
Датум, 27.05.2010 г.

Ref:
Date,

УНИВЕРЗИТЕТ ЦРНЕ ГОРЕ
ЕКОНОМСКИ ФАКУЛТЕТ
Број 01/858
10/06/ 2010 год.
ПОДГОРИЦА

Na osnovu člana 75 stav 2 Zakona o visokom obrazovanju (Sl.list RCG br. 60/03) i člana 18 Statuta Univerziteta Crne Gore, Senat Univerziteta Crne Gore, na sjednici održanoj 27.05.2010. godine, donio je

O D L U K U
O IZBORU U ZVANJE

Dr VLADIMIR KAŠĆELAN bira se u akademsko zvanje **redovni profesor** Univerziteta Crne Gore za predmete: Finansijska matematika i Rizik i osiguranje, na **Ekonomskom fakultetu**.

REKTOR

Prof.dr Predrag Miranović

Prof. dr Ljiljana Kašćelan- Biografija sa bibliografijom

1. Biografija

Rođena je 30.08.1968. godine u Beranama. Osnovnu školu i gimnaziju završila je u Beranama sa odličnim uspjehom i diplomom "Luča". Studije na Prirodno-matematičkom fakultetu - odsjek Matematika, smjer Računari, Univerziteta Crne Gore, započela je 1987. godine a diplomirala 1992. godine i stekla zvanje diplomirani matematičar. Poslijediplomske studije na Elektrotehničkom fakultetu u Podgorici, smjer Računarstvo, upisala je 1992. godine. U toku studija ostvarila je prosječnu ocjenu 10. Magistarski rad pod nazivom: "Automatsko generisanje operacija nad složenim objektima" odbranila je 1996. godine na Elektrotehničkom fakultetu u Podgorici. Doktorsku disertaciju pod nazivom "Model sistema za podršku odlučivanju u sanacionom menadžmentu zasnovan na data warehouse konceptu" odbranila je 2002. godine, na Ekonomskom fakultetu Univerziteta Crne Gore.

Za saradnika u nastavi na predmetu Informatika, na Ekonomskom fakultetu u Podgorici, Univerziteta Crne Gore, primljena je 1993. godine. U zvanje asistent za predmete Informatika i Baze podataka na Ekonomskom fakultetu u Podgorici, izabrana je 1997. godine. U zvanje docent izabrana je 2003. godine a u zvanje vanredni profesor 2008. godine. U zvanje redovni profesor izabrana je 2014 godine, za predmete Informatika, Baze podataka, Poslovna informatika i Sistemi poslovne inteligencije.

Tokom bavljenja pedagoškim radom na fakultetu, pored angažovanja u nastavnoj aktivnosti, bila je angažovana kao mentor za izradu značajnog broja magistarskih i diplomskih radova. Autor je udžbenika iz oblasti poslovnih informacionih tehnologija, čiji je izdavač Univerzitet Crne Gore.

Član je međunarodnog naučnog udruženja Euro Working Group on Decision Support Systems, kao i Upravnog i Uređivačkog odbora međunarodnog časopisa ComSis koji se nalazi na SCIe . Takođe, član je Senata Unverziteta Crne Gore.

2. Bibliografija (posljednjih 5 godina)

Članci u indeksiranim međunarodnim časopisima (SCIe, SSCI):

1. Rondović, B., Djuričković, T., & **Kašćelan, L.** (2019). Drivers of E-Business Diffusion in Tourism: A Decision Tree Approach. Journal of Theoretical and Applied Electronic Commerce Research, Vol. 14, 30-50. (Po 2018 latest Impact Factors (Clarivate Analytics | Journal Citation Reports | Thomson Reuters) časopis ima **IF 0,774**)

2. Biljana Rondović, **Ljiljana Kašćelan**, Vujica Lazović, Tamara Đuričković (2017): Discovering the determinants and predicting the degree of e-business diffusion using the decision tree method: evidence from Montenegro. Information Technology for Development, 12/2017 (Po 2018 latest Impact Factors (Clarivate Analytics | Journal Citation Reports | Thomson Reuters) časopis ima **IF 1,387**) **(1 citat)**

3. Jovanović M., **Kašćelan Lj.,** Joksimović M., & Kašćelan, V. (2017). „Decision Tree Analysis of Wine Consumers' Preferences: Evidence from an Emerging Market", *British Food Journal*, 119(6), ISSN 0007-070X. (Po 2018 latest Impact Factors (Clarivate Analytics | Journal Citation Reports | Thomson Reuters) časopis ima **IF 1,289**) **(2 citata)**

4. Kašćelan, V., **Kašćelan, L**., & Novović Burić, M. (2016). A nonparametric data mining approach for risk prediction in car insurance: a case study from the Montenegrin market. *Economic Research-Ekonomska Istraživanja*, *29*(1), 545-558. (Po 2018 latest Impact

Factors (Clarivate Analytics | Journal Citation Reports | Thomson Reuters) časopis ima **IF 1,137**) **(9 citata)**

5. **Kašćelan, L**., Kašćelan, V., & Jovanović, M. (2015). Hybrid support vector machine rule extraction method for discovering the preferences of stock market investors: Evidence from Montenegro. *Intelligent Automation & Soft Computing*, *21*(4), 503-522. (Po 2018 latest Impact Factors (Clarivate Analytics | Journal Citation Reports | Thomson Reuters) časopis ima **IF 0,652**) **(6 citata)**

6. Jovanović, M., **Kašćelan, L**., Despotović, A., & Kašćelan, V. (2015). The Impact of Agro-Economic Factors on GHG Emissions: Evidence from European Developing and Advanced Economies. *Sustainability*, *7*(12), 16290-16310. (Po 2018 latest Impact Factors (Clarivate Analytics | Journal Citation Reports | Thomson Reuters) časopis ima **IF 2,075**) **(8 citata)**

7. **Kašćelan, L**., Kašćelan, V., & Jovanović, M. (2014). Analysis of investors' preferences in the Montenegro stock market using data mining techniques. *Economic Research-Ekonomska Istraživanja*, *27*(1), 463-482. (Po 2018 latest Impact Factors (Clarivate Analytics | Journal Citation Reports | Thomson Reuters) časopis ima **IF 1,137**) **(4 citata)**

Knjige:

1. **Kašćelan Lj.**, »Informacione tehnologije za podršku poslovnom odlučivanju«, Univerzitet Crne Gore, 2016

Poglavlja u monografijama:

1. 1. **Lj.Kašćelan**, V.Kašćelan, M. Novović Burić (2018), A Decision Tree Analysis of Real Estate Insurance Customers in the Montenegrin Market", međunarodna monografija - *Quantitative models in Economics,* Faculty of Economics of the University of Belgrade

2. **Kašćelan, Lj.**, Kašćelan, V., Novović Burić, M. (2017): Data-driven Approach as an Alternative Method for Risk Assessment in the Montenegrin Automobile Insurance Market, međunarodna monografija - *Challenges and tendencies in contemporary insurance market*, Faculty of Economics of the University of Belgrade

Članci u ostalim indeksiranim međunarodnim časopisima:

1. Jovanovic, M., Joksimovic, M., **Kascelan, L**., & Despotovic, A. (2017). Consumer attitudes to organic foods: evidence from montenegrin market. *Poljoprivreda i Sumarstvo*, *63*(1), 223.

2. Jovanović, M., **Kašćelan, L**., Joksimović, M., & Despotović, A. (2015). Comparative analysis of agro-food trade in Montenegro and EU candidate countries. *Economics of Agriculture*, *62*(1), 155-162. (Emerging SCI indeksirani časopis)

3. **Kašćelan, L**., & Kašćelan, V. (2015). Component-Based Decision Trees: Empirical Testing on Data Sets of Account Holders in the Montenegrin Capital Market. *International Journal of Operations Research and Information Systems (IJORIS)*, *6*(4), 1-18.

4. Despotović, A., Joksimović, M., **Kašćelan, L.**, & Jovanović, M. (2015). Causes for depopulation of rural areas in the Municipality of Pljevlja. *Agriculture and Forestry*, *61*(4), 393-407.

5. **Kašćelan, L**., Kašćelan, V., & Novović-Burić, M. (2014). A Data Mining Approach for Risk Assessment in Car Insurance: Evidence from Montenegro. *International Journal of Business Intelligence Research (IJBIR)*, *5*(3), 11-28.

Indeksirani Conference Proceedings

1. **Kašćečan, L**., Lazović, V., Đuričković, T., & Biljana, R. (2018). Analysis of the Diffusion of E-services in Public Sector Using the Decision Tree Method. In *Proceedings of the ENTRENOVA-ENTerprise REsearch InNOVAtion Conference, Split, Croatia, 6-8 September 2018* (pp. 38-48). Zagreb: IRENET-Society for Advancing Innovation and Research in Economy. **ECONSTOR.EU**

2. Gazdić, T., & **Kašćelan, L**. (2013, May). Model of the business intelligence system for credit risk analysis. In *Information & Communication Technology Electronics & Microelectronics (MIPRO), 2013 36th International Convention on* (pp. 1155-1160). **IEEE**.

УНИВЕРЗИТЕТ ЦРНЕ ГОРЕ
Ул. Четињска бр. 2
П. фах 99
81000 ПОДГОРИЦА
ЦРНА ГОРА
Телефон: (020) 414-255
Факс: (020) 414-230
E-mail: rektor@ac.me

UNIVERSITY OF MONTENEGRO
Ul. Cetinjska br. 2
P.O. BOX 99
81 000 PODGORICA
MONTENEGRO
Phone: (+382) 20 414-255
Fax: (+382) 20 414-230
E-mail: rektor@ac.me

Број: 08-3128
Датум: 24. 12. 2014 г.

Ref:
Date:

Na osnovu člana 72 stav 2 Zakona o visokom obrazovanju (Službeni list Crne Gore br. 44/14) i člana 18 stav 1 tačka 3 Statuta Univerziteta Crne Gore, Senat Univerziteta Crne Gore, na sjednici održanoj 24. decembra 2014. godine, donio je

O D L U K U
O IZBORU U ZVANJE

DR LJILJANA KAŠĆELAN bira se u akademsko zvanje **redovni profesor** Univerziteta Crne Gore za predmete: Informatika i Baze podataka, na studijskom programu Ekonomija i Poslovna informatika i Sistemi poslovne inteligencije, na studijskom programu Menadžment, na Ekonomskom fakultetu.

REKTOR

Prof. Radmila Vojvodić

OSOBNE INFORMACIJE

Josip Tica

Trg J. F. Kennedyja 6, 10 000 Zagreb, Hrvatska

+38512383333

jtica@efzg.hr

www.efzg.unizg.hr/jtica

TRENUTNO ZVANJE I RADNO MJESTO

Redoviti profesor na Katedri za Makroekonomiju i gospodarski razvoj, Ekonomski fakultet Zagreb

RADNO ISKUSTVO

2016- Redoviti profesor na Ekonomskom fakultetu u Zagrebu, Katedra za Makroekonomiju i gospodarski razvoj

2011 - 2016 Izvanredni profesor na Ekonomskom fakultetu u Zagrebu, Katedra za Makroekonomiju i gospodarski razvoj

2006 - 2011 Docent na Ekonomskom fakultetu u Zagrebu, Katedra za Makroekonomiju i gospodarski razvoj

1999-2006 Asistent na Ekonomskom fakultetu u Zagrebu, Katedra za Makroekonomiju i gospodarski razvoj

OBRAZOVANJE

2000 - 2005 Doktor znanosti, Ekonomski fakultet Zagreb, Sveučilište u Zagrebu, Hrvatska

1999 - 2002 Magistar znanosti, PDS "Privredni razvoj", Ekonomski fakultet Zagreb, Sveučilište u Zagrebu

1994 - 1999 Prediplomski studij Poslovne ekonomije, Ekonomski fakultet, Sveučilište u Zagrebu

EDUKACIJE I STRUČNO USAVRŠAVANJE

2001 Razvoj financijskog sektora u zemljama u razvoju, NISIET, Hyderabad, India, stipendist ITEC-a.

Materinski jezik: Hrvatski

Ostali jezici

	RAZUMIJEVANJE		GOVOR		PISANJE
	Slušanje	Čitanje	Govorna interakcija	Govorna produkcija	
Engleski	C1				
Njemački	A1				

Stupnjevi: A1/2: Temeljni korisnik - B1/B2: Samostalni korisnik - C1/C2 Iskusni korisnik
Zajednički europski referentni okvir za jezike

Komunikacijske vještine: Dugodišnji rad sa studentima i kolegama na katedri i koautorima iz tri različite zemlje.

Organizacijske / rukovoditeljske vještine: Vodio timove veličine od 5 do 13 ljudi na istraživačkim i projektima izgradnje kapaciteta (*capacity building)* u vrijednosti od 100.000 do 1.000.000 HRK u trajanju od 15 mjeseci do 4 godine. Predsjedavao Upravnim vijećem Visoke poslovne škole Zagreb tijekom uspješnog procesa akreditacije.

Poslovne vještine: Iskusan programer u Stata-i, E-viewsu i RATS-u. Poznaje osnove HTML-a, Visual Basica, Gaussa i Matlaba. Dugogodišnje Iskustvo u Latexu.

Ostale vještine: *Vozačka dozvola*

Gostujući profesor
- Sveučilište u Pittsburghu, 2004/2005

Pozvana predavanja
- Fort Lewis College,
- Fort Heys University,
- Sveučilište u Pittsburghu

Projekti

Od 2002. do 2006. sudjelovao kao istraživač na projektu "Efikasnost nacionalnog gospodarskog rasta" (0067028) voditelja prof. dr. I. Družića.
Od 2007. do 2014. je sudjelovao kao istraživač na projektu Ministarstva znanosti, obrazovanja i športa "Analiza učinkovitosti gospodarskog rasta" (067-0671447-2494) voditelja prof. dr. I. Družića.
Od 2012. do 2013. bio je voditelj znanstveno-istraživačkog projekta Fonda za razvoj Sveučilišta u Zagrebu pod nazivom "Implementacija stohastičko-dinamičke ekonomske analize i nelinearne ekonometrijske analize u nastavnom i istraživačkom radu" financiranom u cijelosti u iznosu od 195.000 HRK.
Od 2014. do 2018. kao istraživač sudjeluje u projektu Hrvatske zaklade za znanost broj 5269 "Građanskopravna zaštita građana u financijskoj krizi/CitProtect" (http://citprotect.pravo.unizg.hr/).
Od 2014. do 2018. kao istraživač sudjeluje u projektu Hrvatske zaklade za znanost broj 7031 "Sustainability of Croatian Economic Policy and Development" (http://www.efzg.unizg.hr/default.aspx?id=22003).
Od 2015. do 2017. mentor je na projektu financiranog od strane Agencije za strukovno obrazovanje odraslih i European Stabilisation Funda broj HR.3.2.01 pod nazivom "Stvaranje preduvjeta za izgradnju računalnog makroekonomskog modela za Hrvatsku (SPIRITH)" financiranom u cijelosti u iznosu od 1.001.488,21 HRK.
Od 2020. voditelja projekta Hrvatske zaklade za znanost broj IP-2019-04-4500 „Analiza strukturnih čimbenika konvergencije Republike Hrvatske tijekom tranzicijskog procesa“ (https://convrh.net.efzg.hr/po%C4%8Detna-stranica) financiran u cijelosti u iznosu od 488.077,88 HRK.

Nagrade i priznanja	▪ FULBRIGHT, ITEC, CEEPUS stipendist
Javne i sveučilišne funkcije	▪ Od 2020. Zamjenik pročelnika Katedre za Makroekonomiju i razvoj ▪ Od 2013. do 2017. Član Odbora za javna priznanja u Skupštini Grada Zagreba u jednom mandatu ▪ Od 2012. do 2020. Vanjski član odbora za gospodarstvo Hrvatskog sabora u dva mandata.
Članstvo u stručnim udruženjima i tijelima	▪ Član Glavnog odbora Hrvatskog društva ekonomista
Stručni certifikati	▪
Uredništvo u časopisima (glavni, gostujući urednik, urednički odbor i sl.)	▪ Od 2019. - Glavni urednik - Ekonomski pregled Od 2011. – 2019. - Urednički odbor – Ekonomski pregled ▪ Od 2012. - Urednički odbor - Contemporary Economics ▪ Od 2017. - Urednički odbor - Croatian Review of Economic, Business and Social Statistics
Recenzije (časopisi, zbornici s konferencija itd)	▪ Ekonomski pregled, Financijska teorija i praksa, Društvena istraživanja, Zagreb International Review of Economics and Business, Empirical Economics, Revija za socijalnu politiku, Economic Change nad Restructuring, Ekonomska misao i praksa, Ekonomska istraživanja, Zbornik radova ekonomskog fakulteta u Mostaru, International Journal of Economic Sciences and Applied Research, Journal of Business and Economics Rijeka, Studies in Mathematical Science, Journal of Empirical Finance.
Istaknute konferencije (programski, organizacijski, znanstveni i drugi odbori)	▪ Godišnji skup ekonomista u Opatiji, duži niz godina. ▪ Znanstveni skup Kriza: preobrazba ili propast, (Urednici: Obadić, A., Šimurina, J., Tica, J.), Ekonomski fakultet, Zagreb, 23. studeni 2011., ISBN 978-953-6025-41-1
Osobni profili znanstvenika	ORCID: https://orcid.org/0000-0001-7937-1573 Google Scholar: https://scholar.google.hr/citations?user=eMQUfeoAAAAJ&hl=hr&authuser=1&oi=ao Popis radova: https://www.bib.irb.hr/pregled/znanstvenici/230573

ODABRANA BIBLIOGRAFIJA

Tica, J., Globan, T., Levaj, M. FDI in Croatia, in Foreign Direct Investment in the Successor States of Yugoslavia (editor: Deichmann, J.I.), Springer, 2020., str. 51-77., ISBN 978-3-030-55739-3

Tica, J., Globan, T., Arčabić, V.: The Mundell-Fleming Trilemma and the Global Financial Cycle: An Empirical Test of Competing Hypotheses, Romanian Journal of Economic Forecasting, Vol. 22, No. 3; str. 62-80, 2019. WoS, SSCI.

Tica, J., Šikić, L. Endogenous Convergence and International Technological Diffusion Channels. The South East European Journal of Economics and Business. Vol. 14., No. 2., 2019, str. 34.-53. WoS – ESCI.

Slišković, Tamara, Tica, J., The Importance of Distance In Hedonic Housing Price Model – The Case of Zagreb, Ekonomski pregled, 70, issue 5, p. 677-705, 2019. WoS – ESCI.

Arcabic, V., Tica, J., Lee, J. i Sonora, R.: Public Debt and Economic Growth Conundrum: Nonlinearity and Intertemporal Relationship, Studies in Nonlinear Dynamics & Econometrics, Vol. 22., Issue 1., Artical No. 0086., 2018. WoS, CC & SSCI

Dajcman, S., Tica, J.: The broad credit and bank capital channels of monetary policy transmission in the core and peripheral Euro Area, Zbornik radova Ekonomskog fakulteta u Rijeci : časopis za ekonomsku teoriju i praksu, Vol. 35, No. 2., 2017., str. 249-275. WoS, SSCI.

Raguž Krištić, I., Družić, I., Tica, J.: Impact of the Transition on the Total Factor Productivity in Croatia, Zbornik radova Ekonomskog fakulteta u Rijeci : časopis za ekonomsku teoriju i praksu, Vol. 34., No. 2., 2016. str. 271-308. WoS, SSCI.

Slišković, Tamara, Tica, J. Prostorna elastičnost traženih cijena stanova na stambenom tržištu grada Zagreba, Ekonomska misao i praksa, vol. , br. 1, 2016, str. 23-44. WoS – ESCI.

Tica, J., Kožić, I.: Forecasting Croatian Inbound Tourism Demand, Economic Research-

Ekonomska Istraživanja, , Vol. 28., No.1., 2015., str. 1046-1062. WoS, SSCI.

Sonora, J. R., Tica, J.: Harrod Balassa and Samuelson (Re)visit Eastern Europe, Cogent Economics and Finance, Vol.2., No.1., 2014., str. 1-17. WoS – ESCI.

Sonora, J. R., Tica, J.: Real Interest Parity in New Europe, Eastern European Economics, Vol.52., No.1., 2014., str. 35-56. WoS, CC & SSCI

Tica, J., Sorić, P.: Economic Integrations and Purchasing Power Parity, Economic Research-Ekonomska Istraživanja, Vol. 25., No.1., 2012., str. 4-20. WoS, SSCI.

Sonora, J. R., Tica, J.: Structural breaks and Purchasing Power Parity in the CEE and Post-War former Yugoslav States, Finance a úvěr-Czech Journal of Economics and Finance, Vol. 60., No.3, 2010. str. 213-225. WoS, CC & SSCI

Tica, J.: Tranzicijska ekonomika tečaja i hrvatsko gospodarstvo, Politička kultura, Zagreb, 2009., ISBN 978-953-258-037-2

Tica, J., Posedel, P.: Threshold Model of the Exchange Rate Pass-Through Effect, Eastern European Economics, Vol.47., No.6, 2009., str. 43-59. WoS, CC & SSCI

Tica, J., Jurčić, Lj.: A Relative Unit Labor Cost: Case of Accession Countries, Ekonomski pregled, 58, 2007, str. 655-679. WoS – ESCI.

Tica, J.: Long Span Unit Root Test of Purchasing Power Parity: The Case of Croatia, Ekonomski Pregled, 57, 12, 2006, str. 856-881. WoS – ESCI.

Tica, J.: Tranzicija hrvatskog stambenog tržišta, Politička kultura, Zagreb, 2002., ISBN 953-6213-49-4; UDK 351.778.56(497.5).

Sveučilište u Zagrebu

REPUBLIKA HRVATSKA

Na temelju članka 21. i 84. Statuta Sveučilišta u Zagrebu,
sukladno članku 93. Zakona o znanstvenoj djelatnosti i visokom obrazovanju,
na prijedlog Povjerenstva za utvrđivanje kriterija i potvrdu izbora u zvanje,

Senat Sveučilišta u Zagrebu potvrđuje da je

dr. sc. JOSIP TICA

izvanredni profesor
Ekonomskoga fakulteta Sveučilišta u Zagrebu
izabran na vrijeme od pet godina u znanstveno-nastavno zvanje i na radno mjesto

REDOVITOGA PROFESORA

u znanstvenom području društvenih znanosti,
znanstveno polje: ekonomija, znanstvena grana: opća ekonomija

Klasa: 640-03/16-07/116
Urbroj: 380-020/081-16-2
Zagreb, 19. srpnja 2016.

REKTOR

prof. dr. sc. Damir Boras