

REPORT DOCUMENTATION PAGE			Form Approved OMB NO. 0704-0188		
The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA, 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.					
1. REPORT DATE (DD-MM-YYYY) 29-11-2017		2. REPORT TYPE Final Report		3. DATES COVERED (From - To) 15-Mar-2012 - 31-Oct-2017	
4. TITLE AND SUBTITLE Final Report: Energy and Environmental Drivers of Stress and Conflict in Multi-scale Models of Human Social Behavior			5a. CONTRACT NUMBER W911NF-12-1-0097		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER 611103		
6. AUTHORS			5d. PROJECT NUMBER		
			5e. TASK NUMBER		
			5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAMES AND ADDRESSES Santa Fe Institute of Science 1399 Hyde Park Road Santa Fe, NM 87501 -8943			8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS (ES) U.S. Army Research Office P.O. Box 12211 Research Triangle Park, NC 27709-2211			10. SPONSOR/MONITOR'S ACRONYM(S) ARO		
			11. SPONSOR/MONITOR'S REPORT NUMBER(S) 61112-LS.14		
12. DISTRIBUTION AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.					
13. SUPPLEMENTARY NOTES The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Luis Bettencourt
a. REPORT UU	b. ABSTRACT UU	c. THIS PAGE UU			19b. TELEPHONE NUMBER 505-946-2789

RPPR Final Report
as of 08-Feb-2018

Agency Code:

Proposal Number: 61112LS

Agreement Number: W911NF-12-1-0097

INVESTIGATOR(S):

Name: Luis M. A. Bettencourt
Email: lmbettencourt@gmail.com
Phone Number: 50594627890000
Principal: Y

Organization: **Santa Fe Institute of Science**

Address: 1399 Hyde Park Road, Santa Fe, NM 875018943

Country: USA

DUNS Number: 178044996

EIN: 850325494

Report Date: 31-Jan-2018

Date Received: 29-Nov-2017

Final Report for Period Beginning 15-Mar-2012 and Ending 31-Oct-2017

Title: Energy and Environmental Drivers of Stress and Conflict in Multi-scale Models of Human Social Behavior

Begin Performance Period: 15-Mar-2012

End Performance Period: 31-Oct-2017

Report Term: 0-Other

Submitted By: Luis Bettencourt

Email: lmbettencourt@gmail.com

Phone: (505) 946-27890000

Distribution Statement: 1-Approved for public release; distribution is unlimited.

STEM Degrees:

STEM Participants:

Major Goals: Nothing to Report

Accomplishments: Nothing to Report

Training Opportunities: Nothing to Report

Results Dissemination: Nothing to Report

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: PD/PI

Participant: Luis Bettencourt

Person Months Worked: 1.00

Project Contribution:

International Collaboration:

International Travel:

National Academy Member: N

Other Collaborators:

Funding Support:

ARTICLES:

RPPR Final Report as of 08-Feb-2018

Publication Type: Journal Article Peer Reviewed: N **Publication Status:** 1-Published

Journal: Scientific Reports

Publication Identifier Type:

Publication Identifier:

Volume: 0

Issue: 0

First Page #: 0

Date Submitted:

Date Published:

Publication Location:

Article Title: Professional Diversity and the Productivity of Cities

Authors:

Keywords: statistical physics, theoretical ecology, sustainability, socioeconomic scenarios

Abstract: Attempts to understand the relationship between diversity, productivity and scale have remained limited due to the scheme-dependent nature of the taxonomies describing complex systems. We analyze the diversity of US metropolitan areas in terms of profession diversity and employment to show how this frequency distribution takes a universal scale-invariant form, common to all cities, in the limit of infinite resolution of occupational taxonomies. We show that this limit is obtained under general conditions that follow from the analysis of the variation of the occupational frequency across taxonomies at different resolutions in a way analogous to finite-size scaling in statistical physical systems. We propose a theoretical framework that derives the form and parameters of the limiting distribution of professions based on the appearance, in urban social networks, of new occupations as the result of specialization and coordination of labor. By deriving classification scheme-independent meas

Distribution Statement: 1-Approved for public release; distribution is unlimited.

Acknowledged Federal Support:

Publication Type: Journal Article Peer Reviewed: N **Publication Status:** 1-Published

Journal: Big Data

Publication Identifier Type:

Publication Identifier:

Volume: 0

Issue: 0

First Page #: 0

Date Submitted:

Date Published:

Publication Location:

Article Title: The Uses of Big Data in Cities

Authors:

Keywords: Socioeconomic scenarios, sustainability, theoretical ecology, statistical physics

Abstract: There is much enthusiasm currently about the possibilities created by new and more extensive sources of data to better understand and manage cities. Here, I explore how big data can be useful in urban planning by formalizing the planning process as a general computational problem. I show that, under general conditions, new sources of data coordinated with urban policy can be applied following fundamental principles of engineering to achieve new solutions to important age-old urban problems. I also show that comprehensive urban planning is computationally intractable (i.e., practically impossible) in large cities, regardless of the amounts of data available. This dilemma between the need for planning and coordination and its impossibility in detail is resolved by the recognition that cities are first and foremost self-organizing social networks embedded in space and enabled by urban infrastructure and services. As such, the primary role of big data in cities is to facilitate information

Distribution Statement: 1-Approved for public release; distribution is unlimited.

Acknowledged Federal Support:

RPPR Final Report as of 08-Feb-2018

Publication Type: Journal Article Peer Reviewed: N **Publication Status:** 1-Published

Journal: Journal of the Royal Society Interface

Publication Identifier Type: Publication Identifier:

Volume: 0 Issue: 0 First Page #: 0

Date Submitted: Date Published:

Publication Location:

Article Title: The Scaling of Human Interactions with City Size

Authors:

Keywords: networks, mobile phone data, human interactions, urban scaling, epidemiology

Abstract: The size of cities is known to play a fundamental role in social and economic life. Yet, its relation to the structure of the underlying network of human interactions has not been investigated empirically in detail. In this paper, we map society-wide communication networks to the urban areas of two European countries. We show that both the total number of contacts and the total communication activity grow superlinearly with city population size, according to well-defined scaling relations and resulting from a multiplicative increase that affects most citizens. Perhaps surprisingly, however, the probability that an individual's contacts are also connected with each other remains largely unaffected. These empirical results predict a systematic and scale-invariant acceleration of interaction-based spreading phenomena as cities get bigger, which is numerically confirmed by applying epidemiological models to the studied networks. Our findings should provide a microscopic basis towards under

Distribution Statement: 1-Approved for public release; distribution is unlimited.

Acknowledged Federal Support:

Publication Type: Journal Article Peer Reviewed: N **Publication Status:** 1-Published

Journal: PLoS ONE 2010

Publication Identifier Type: Publication Identifier:

Volume: 0 Issue: 0 First Page #: 0

Date Submitted: Date Published:

Publication Location:

Article Title: Determinants of the Pace of Global Innovation in Energy Technologies

Authors:

Keywords: climate change, innovations in energy technologies

Abstract: Understanding the factors driving innovation in energy technologies is of critical importance to mitigating climate change and addressing other energy-related global challenges. Low levels of innovation, measured in terms of energy patent filings, were noted in the 1980s and 90s as an issue of concern and were attributed to limited investment in public and private research and development (R&D). Here we build a comprehensive global database of energy patents covering the period 1970–2009, which is unique in its temporal and geographical scope. Analysis of the data reveals a recent, marked departure from historical trends. A sharp increase in rates of patenting has occurred over the last decade, particularly in renewable technologies, despite continued low levels of R&D funding. To solve the puzzle of fast innovation despite modest R& increases, we develop a model that explains the nonlinear response observed in the empirical data of technological innovation to various types of investme

Distribution Statement: 1-Approved for public release; distribution is unlimited.

Acknowledged Federal Support:

Nothing to Report