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Yaneer Bar-Yam, Marco Lagi

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New England Complex Systems Institute - Camb
24 Mt. Auburn St.

Cambridge, MA 02138 -6042

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14. ABSTRACT
Price and value are not synonymous, they are related concepts. Value is determined by desire of an individual for a good, price is determined by collective agreements on transactions to transfer that good. Such a shift between scales is at the heart of complex systems research, which quantifies the emergence of larger scale phenomena from smaller scale interactions. Attempts have been made toward formalizing theories of price formation, but none of them so far was able to reproduce historical economic data in a quantitative way.

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non-equilibrium economics, commodity prices, futures markets, bandwagon effects, quantitative modeling, modeling validation

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a. REPORT	b. ABSTRACT	c. THIS PAGE			Yaneer Bar-Yam
UU	UU	UU	UU		19b. TELEPHONE NUMBER: 617-547-4100

Report Title

Economics of Collective Value: Final Report

ABSTRACT

Price and value are not synonymous, they are related concepts. Value is determined by desire of an individual for a good, price is determined by collective agreements on transactions to transfer that good. Such a shift between scales is at the heart of complex systems research, which quantifies the emergence of larger scale phenomena from smaller scale interactions. Attempts have been made toward formalizing theories of price formation, but none of them so far was able to reproduce historical economic data in a quantitative way.

In this work, for the first time we were able to build a theoretical framework that quantitatively reproduces the complex dynamics of economic agents, and the resulting price behavior of commodity markets. We modeled mathematically the mechanisms that underlie collective social behaviors, such as bandwagon effects, and found evidence of their destabilizing force on the markets in the aftermath of the financial crisis. We demonstrated how an unregulated economic activity, derived from the concept of a self-correcting stable economy, does not achieve market efficiency. Our framework, introducing the perspective of complex systems into theories of price formation, provides a new scientific basis for economic systems.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received	Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received	Paper
2012/04/09 1˙ 5	Marco Lagi, Yavni Bar-Yam, Karla Z. Bertrand, Yaneer Bar-Yam. The Food Crises: A quantitative model of food prices including speculators and ethanol conversion, arXiv:1109.4859v1, (09 2011): 0. doi:
2012/04/09 1˙ 3	Marco Lagi, Yavni Bar-Yam, Karla Z. Bertrand, Yaneer Bar-Yam. UPDATE February 2012 - The Food Crises: Predictive validation of a quantitative model of food prices including speculators and ethanol conversion, arXiv:1203.1313v2, (03 2012): 0. doi:

TOTAL: 2

Number of Papers published in non peer-reviewed journals:

(c) Presentations

The following papers were presented by invitation.

1. World Economic Forum--Davos, Switzerland--January 25-29, 2012
Two Presentations:
a) "Mercurial Markets"
b) "The Food Crises and Prices"

2. Food, Conflict, and Fragility Workshop--Washington, DC--March 26, 2012--Hosted by: USAID and Woodrow Wilson International Center for Scholars, Environmental Change and Security Program
One Presentation:
"Economics of Food Crises"

3. Strategic Multi-Layered Assessment Conference--Bethesda, MD--November 30, 2011
One Presentation:
"From Global to Local: Security for all Scales and all Modes"

Number of Presentations: 4.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Paper

TOTAL:

Patents Submitted

Patents Awarded

Awards

Research funded by this award was included in Wired Magazine's "Top Scientific Discoveries of 2011" accessible at:
http://www.wired.com/wiredscience/2011/12/top-discoveries-2011/?pid=2729

Graduate Students

NAME	PERCENT_SUPPORTED	Discipline
Vedant Misra	0.60	
Blake Stacey	0.30	
FTE Equivalent:	**0.90**	
Total Number:	**2**	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
Marco Lagi	0.60
Anzi Hu	0.30
Andreas Gros	0.18
Amac Herdagdelen	0.15
Dion Harmon	0.02
FTE Equivalent:	**1.25**
Total Number:	**5**

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Yaneer Bar-Yam	0.12	No
Richard N. Cooper	0.07	No
FTE Equivalent:	**0.19**	
Total Number:	**2**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period:	0.00
The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:.....	0.00
The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:.....	0.00
Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):	0.00
Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:	0.00
The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense	0.00
The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:	0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME
Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED
Karla Bertrand	0.27
Shlomiya Bar-Yam	0.27
FTE Equivalent:	**0.54**
Total Number:	**2**

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

See Attachment

Technology Transfer

Economics of Collective Value: Final Report

Marco Lagi and Yaneer Bar-Yam

New England Complex Systems Institute

238 Main St. Suite 319 Cambridge MA 02142, USA

(Dated: March 30, 2012)

Abstract

Price and value are not synonymous, they are related concepts. Value is determined by desire of an individual for a good, price is determined by collective agreements on transactions to transfer that good. Such a shift between scales is at the heart of complex systems research, which quantifies the emergence of larger scale phenomena from smaller scale interactions. Attempts have been made toward formalizing theories of price formation, but none of them so far was able to reproduce historical economic data in a quantitative way.

In this work, for the first time we were able to build a theoretical framework that quantitatively reproduces the complex dynamics of economic agents, and the resulting price behavior of commodity markets. We modeled mathematically the mechanisms that underlie collective social behaviors, such as bandwagon effects, and found evidence of their destabilizing force on the markets in the aftermath of the financial crisis. We demonstrated how an unregulated economic activity, derived from the concept of a self-correcting stable economy, does not achieve market efficiency. Our framework, introducing the perspective of complex systems into theories of price formation, provides a new scientific basis for economic systems.

Classical equilibrium economics models the dynamics of economic markets as a balance of supply and demand. However, demand by investors manifests herding behavior. Bandwagon effects and trend following cause the bubbles and panics that undermine the relationship of fundamental value and price, pushing prices away from the equilibrium established by the collective agreement of individual values. All of these played a crucial role in the 2007-2008 financial crisis and its aftermath, which included a worldwide recession with high rates of unemployment and foreclosure, shortages of food in many developing countries and sharp peaks in commodity prices. These in particular had a dramatic impact not just on low-income individuals, but on overall global security and stability. By the end of 2010, food prices had soared to double the values of a mere five years before, triggering riots worldwide and the violent protests known as the Arab Spring [1].

Equilibrium economics is not able to explain the huge spikes in prices that occurred in 2008 across many commodity markets, since they are not consistent with a decreased demand due to a global recession. Only a non-equilibrium framework can account for the departure from supply-demand determined prices. The dynamics of complex systems includes collective behaviors such as fads and panics, and cascading failures that propagate within and across subsystem boundaries. Complex systems research is therefore necessary for a new scientific basis for economic systems.

We started by examining the case of food prices. A variety of factors were proposed to explain their behavior: increased oil prices, shortages of grain due to adverse weather, rising meat consumption in China and India, currency exchange rates, conversion of corn to ethanol, investor speculation. We examined each of these factors in depth, and combining the analysis with a non-equilibrium approach we determined that only two were significant: ethanol conversion and speculation [2]. To confirm our analysis, for the first time we built a non-equilibrium model of food prices that quantitatively matched food price data from Jan 2004 to Mar 2011 (Fig. 1). Ethanol production accounts for the underlying trend of slow price growth, while financial speculation in the commodity markets is responsible for the sudden price spikes in 2008 and 2011. We successfully characterized trend following as well as dependencies of different investment markets, capturing the assets shifts between commodities, equities and bonds to take advantage of increased expected returns.

Without any modification to its assumptions or formulation, we were also able to extend the food prices model for 10 more months, to Jan 2012 [3]. By simply extending its original

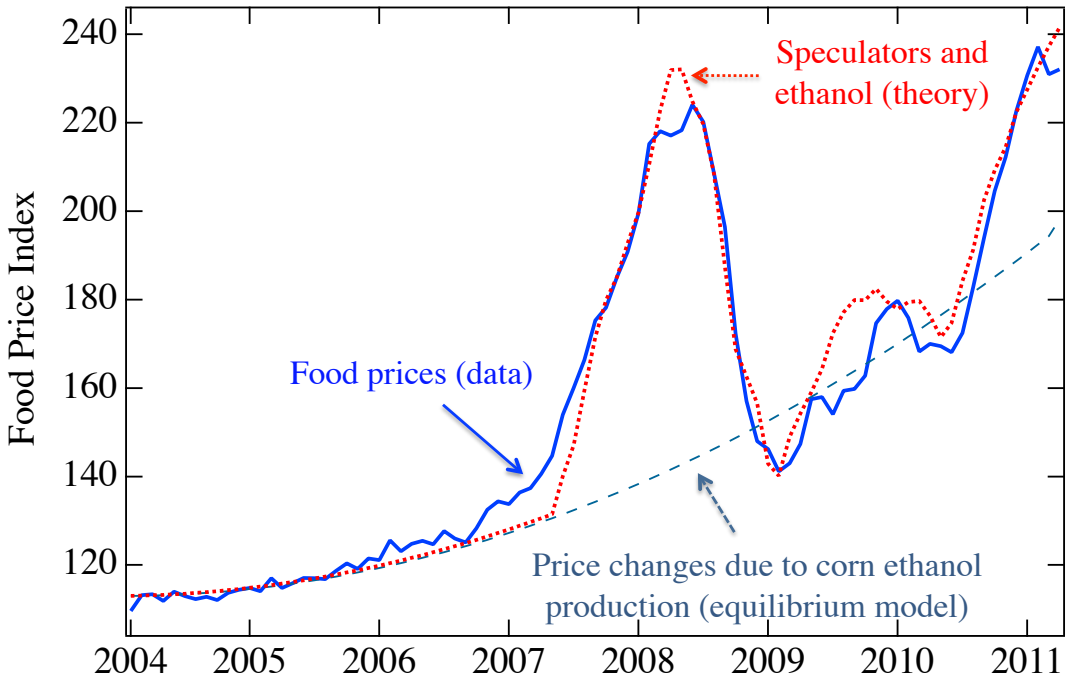

FIG. 1: **Food prices and model simulations** - The FAO Food Price Index (blue solid line) [11], the ethanol supply and demand model (blue dashed line), where dominant supply shocks are due to the conversion of corn to ethanol so that price changes are proportional to ethanol production (see [2], Appendix C) and the results of the speculator and ethanol model (red dotted line), that adds speculator trend following and switching among investment markets, including commodities, equities and bonds (see [2], Appendices D and E).

dynamics, the model proved to be robust, and consistent with the ongoing behavior of food prices (Fig. 2), even capturing a change in their direction at the right moment in time. The agreement of the fit with the FAO Food Price Index is still strikingly quantitatively accurate, validating both the descriptive and predictive abilities of the model.

Moreover, the model predicts that higher than equilibrium commodity prices would lead to an increase in inventories, after a time lag that depends on the future contracts maturation. In particular, when food prices rise above equilibrium grain stocks accumulate, while at the same time people cannot afford to buy food and go hungry. Experimental evidence of an increase in world grain inventories in 2009 is further validation of our model.

This research was reviewed by leading experts, including C. Peter Timmer (Professor of Development Studies Emeritus, Harvard University), Jeffrey C. Fuhrer (Executive Vice President and Senior Policy Advisor, Federal Reserve Bank of Boston), Richard N. Cooper (Professor of International Economics, Harvard University) and Thomas C. Schelling (Dis-

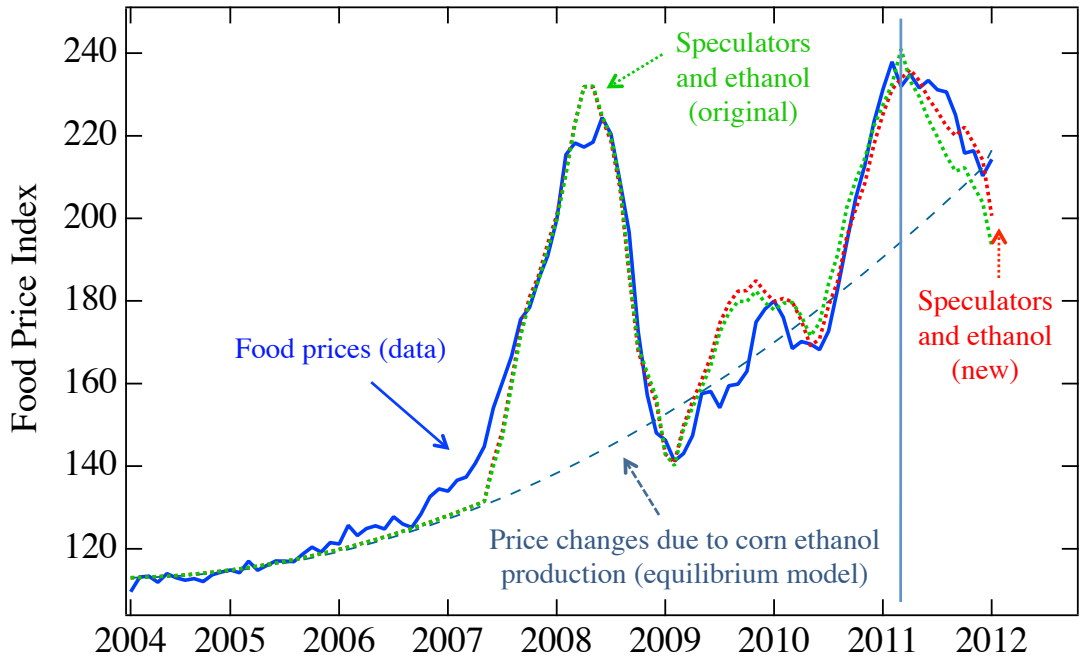

FIG. 2: **Food prices and model simulations** - The FAO Food Price Index (blue solid line) [11], the ethanol supply and demand model (blue dashed line, see [2], Appendix C) and the results of the speculator and ethanol model (green and red dotted lines), that adds speculator trend following and switching among investment markets, including commodities, equities and bonds (see [2], Appendices D and E). The green curve is the fit extended to the present with the original parameter values, the red curve is the fit with new optimized parameters. The vertical blue bar marks the end of the original fit in March 2011.

tinguished Professor of Economics Emeritus, University of Maryland). It was included in the top 10 scientific discoveries of 2011 by Wired Magazine [4]. It was widely covered by the media, including The New York Times [5], TIME Magazine [6], The Guardian [7], Fast Company [8] and Scientific American [9] to mention a few. It was presented at the World Economic Forum, and it is now considered a fundamental contribution to the literature. It initiated collaborations between the New England Complex Systems Institute and humanitarian organizations including the World Food Programme and USAID.

The fundamental nature of the model allowed us to study not only the dependencies coupling different markets (commodity, equity and credit market), but also the price behavior of various commodities like food, crude oil and metals and their mutual interactions [10]. These are the initial steps towards a new scientific basis for economic systems that will quantitatively reproduce the complex dynamics of economic agents and price behavior, and better inform economic and social policy decisions.

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