Technological Forecasting & Social Change 80 (2013) 1557–1562

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

Long-term GDP forecasts and the prospects for growth

Theodore Modis *,1

Growth Dynamics, Via Selva 8, 6900 Massagno, Lugano, Switzerland

ARTICLE INFO

Article history:
Received 13 August 2012
Received in revised form 4 February 2013
Accepted 20 February 2013
Available online 13 March 2013

Keywords:
Logistic growth
Natural growth
S-curve
GDP
Inflation
Saturation
Logistic versus exponential

ABSTRACT

The growth of GDP is considered as a natural-growth process amenable to description by the logistic-growth equation. The S-shaped logistic pattern provides good descriptions and forecasts for both nominal and real GDP per capita in the US over the last 80 years. This enables the calculation of a long-term forecast for inflation, which is to enter a declining trend not so far in the future. The two logistics are well advanced, more so for nominal GDP. The assumption for logistic growth works even better for Japan whose nominal GDP per capita has already completed tracing out an entire logistic trajectory. The economic woes of industrialized countries could be attributed to the saturation of growth there, as if a niche in nature had been filled to capacity. In contrast, GDP growth in China and India is in the very early stages of logistic growth still indistinguishable from exponential patterns. The ceiling of these logistics can be anywhere between 5 and 10 times today's levels.

1. Introduction

The growth of Gross Domestic Product (GDP) is considered to be an essential ingredient of a healthy economy. A plethora of near-future forecasts typically projects a constant percentage over several years in the future invariably promising growth [1]. But longer-range forecasts are also often based on more or less exponentially growing patterns [2]. And yet there have been voices advocating that days of diminishing growth are approaching. These voices began in 1972 with the publication of *The Limits to Growth* by the Club of Rome [3]. But they increased in numbers recently with such works as Tim Jackson's *Prosperity Without Growth* [4], Serge Latouche's *Farewell to Growth* [5], and Peter Victor's *Managing Without Growth: Slower by Design, Not Disaster* [6]. Richard Heinberg has a rather extensive compilation of publications on this subject in his book *The End of Growth* [7].

Complementary to the works mentioned, which are generally based on economic arguments, I want to address in this article the growth of GDP as a natural-growth process. Growth in competition is an appropriate eyepiece here because there is abundant competition in the processes that contribute to the formation of GDP and the issue of limited resources cannot be denied. Competition and limited resources are the ingredients of logistic growth that describes growth in competition of species populating ecological niches. But my ultimate argument for using a logistic approach is an a posteriori one, namely the goodness of the way logistic growth describes the evolution of GDP over almost a century.

Logistic growth implies a cap, a final ceiling, in sharp contradiction to forecasts based on linear and exponential patterns, which are unlimited. I will present actual data on GDP growth demonstrating that such a cap is altogether realistic. Once at the ceiling there can be no more growth, none unless catastrophes and disasters of unseen-before magnitude create new niches for growth or the "species" undergoes a major mutation effectively transforming itself into a different species, e.g. through war and conquest of new territory.

* Tel.: +41 91 9212054; fax: +41 801 6506643.
E-mail address: tmodis@yahoo.com.

[1] Theodore Modis is the founder of Growth Dynamics, an organization specializing in strategic forecasting and management consulting: http://www.growth-dynamics.com.

0040-1625/$ – see front matter
http://dx.doi.org/10.1016/j.techfore.2013.02.010

2. Logistic-growth fits on the US GDP

The historical data on the US GDP per capita come from the US Department of Commerce, Bureau of Economic Analysis, and the US Census Bureau [8]. They consist of yearly data points up to and including reliable estimates for year 2012. The logistic equation used is Eq. (1). The fitting procedure involved the minimization of a Chi Square using EXCEL's solver.

$$X(t) = \frac{M}{1 + e^{-\alpha(t-t_o)}} + C \tag{1}$$

where M is the ceiling level of the logistic S-shaped pattern, α the steepness of the curve, t_o the midpoint of the entire growth process, and C an eventual pedestal (positive or negative) on which the logistic may be sitting, often associated with missing early data.

Faced with the dilemma of studying the nominal GDP expressed in current dollars or the real GDP – i.e. corrected for inflation – expressed in constant (chained) dollars, I decided to study them both. Furthermore, I chose to look at GDP *per capita*, because the growth of population may mask or modulate the growth of GDP. To my surprise both sets of data resulted in excellent logistic fits. Fig. 1 shows nominal GDP per capita and Fig. 2 shows real GDP per capita. The lower graphs show the rate of change in annual increments, i.e. the life cycle of each process; they are derived from the curves at the top of Figs. 1 and 2. The emerging images indicate that the inflection points – centers of the life-cycle curves – are behind us, particularly for nominal, and that there is about a 7-year lead by nominal GDP.

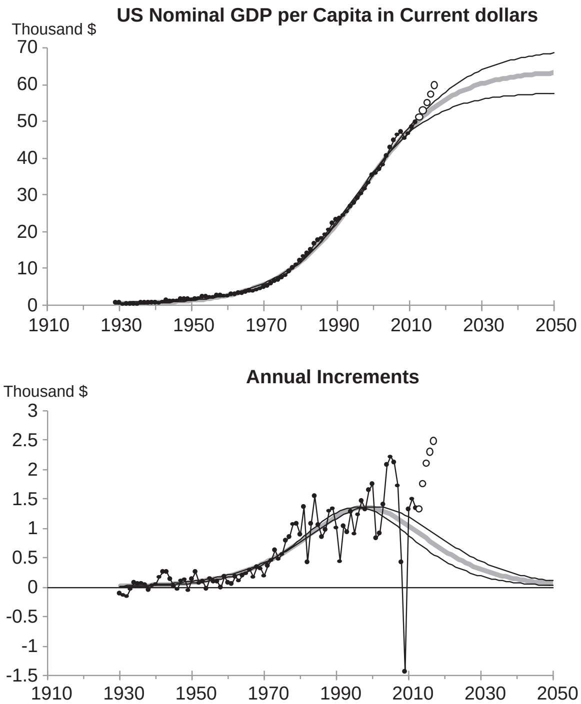


Fig. 1. Above, nominal GDP per capita (black dots) and logistic fit (thick gray line). Below, the rate of growth in annual increments. The open circles are IMF forecasts. The thin black lines delimit 90% confidence-level bands.

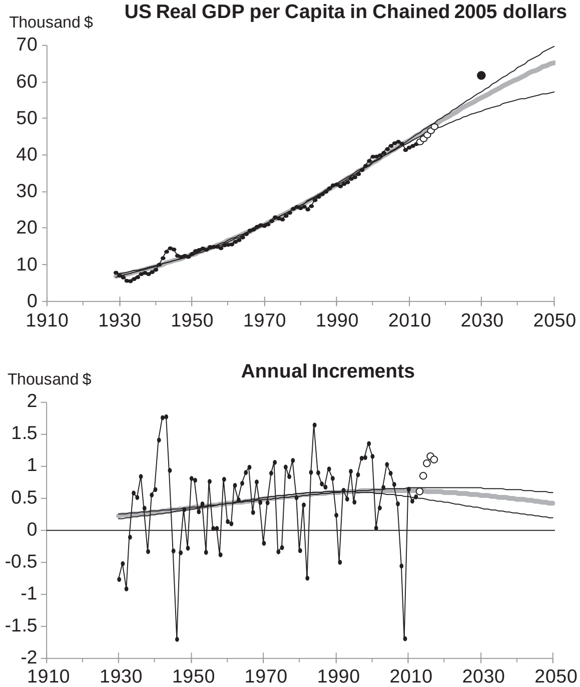


Fig. 2. Above, real GDP per capita (black dots) and logistic fit (thick gray line). Below, the rate of growth in annual increments. The open circles are IMF forecasts. The thin black lines delimit 90% confidence-level bands. The big black dot is a long-term forecast by Agnus Maddison [11].

The goodness of the fits can be visually appreciated by the way the data points closely follow the logistic patterns (thick gray lines) over 80 years despite many world-shaking events and varying inflation over this period of time. The fit parameters are tabulated in Table 1.

A further surprise was that whereas the nominal GDP nears completion of the growth process, the curve was 77.6% completed by the end of 2012, the real GDP has still considerable remaining growth potential, its curve was only 55.2% completed. The respective midpoints – inflection points of the logistics – were in mid 1998 for nominal GDP and late 2005 for real GDP. Thin black lines delimit 90% confidence-level bands, in other words, where we should expect future GDP values to fall nine times out of ten. Such bands were established using look-up tables in Reference [9] and taking into account the error per data point (approximated here by the mean absolute deviation). The 90% confidence-level intervals for the two inflection points are 1995–2000 and 1991–2020 respectively.

Table 1
Results for the logistic fits on nominal and real US GDP per capita.

	M	α	t_o	C	Mean abs. dev.
Nominal	63.40584	0.085912	1997.522	0.430336	7.9%
Real	85.00400	0.029035	2004.832	−1.63077	2.9%

The open circles shown for the period 2013–2017 are forecasts by the International Monetary Fund (IMF) made in traditional economists' ways, most frequently consisting of linear and exponential extrapolations [10]. For nominal GDP they indicate a more optimistic trend progressively deviating from the logistic course (outside the 90% confidence-level band). The big black dot in Fig. 2 is a long-term forecast by Agnus Maddison [11].

There is a rather limited amount of growth potential ahead of us in nominal GDP but a significant amount of growth potential in real GDP, which economists prefer to talk about more often than not. But what good is it for us to know that “somewhere” there is much growth while all we see in everyday life in current dollars is little growth? The real GDP seems to have little relevance to the people on the streets. Apparently inflation has “eaten up” all our growth potential. But given that both nominal and real GDP constitute natural-growth processes – i.e. follow logistic trajectories – inflation, which is linking these two must also have some *natural* origin rather than its usual attribution to frivolous human behavior!

In fact, the decline of nominal GDP's rate of growth in *percentage terms* began already in the late 1970s, as can be seen in Fig. 3. The data fluctuate considerably particularly during early 20th century because of the small absolute values of GDP (which is in the denominator). Nevertheless, the thick gray line, derived from the logistic curve in Fig. 1, provides a good description for what happened during the last 80 years. The trend indicated by the IMF forecasts seems to be in sharp disagreement.

3. Inflation

From the logistic curves for nominal and real GDP we can extract an overall trend for inflation, shown in Fig. 4. The thick gray line is not a fit to the data here. It is calculated from the ratio of the gray logistic curves in Figs. 1 and 2, and seems to be a fair description of the trend of the consumer price index over the past 80 years. It provides a long-term forecast for inflation — something of a Holy Grail quest for economists. It heralds deflationary times in the future.

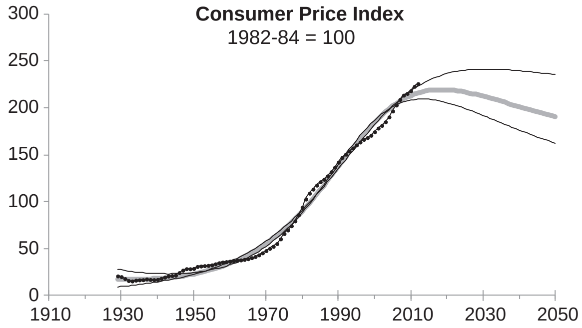


Fig. 4. The black dots are the actual numbers for the consumer price index (1982–84 = 100). The thick gray line indicating the inflation trend is not a fit to the data. It is calculated from the logistic curves in Figs. 1 and 2. The thin black lines delimit an uncertainty range resulting from the bands defined by the thin black lines in Figs. 1 and 2.

4. GDP growth in other parts of the world

It is of interest to also examine the long-term prospects of GDP growth from a logistic point of view in other parts of the world. Fig. 5 shows that the nominal GDP per capita in Japan has completed its logistic curve twenty years ago! No uncertainties around this logistic fit. The fit parameters are given in Table 2.

There has been no growth in Japan for twenty years and the traditional forecast from IMF for years 2013–2017 – shown here with the open circles – does not contradict our logistic description unless its rising trend continues well beyond 2017.

However in developing countries the story is different. Figs. 6 and 7 show the nominal GDP per capita and logistic fits for China and India respectively. The data come from EconStats [12]. Both growth processes are in the very early stages of logistic growth, a region where it is difficult to

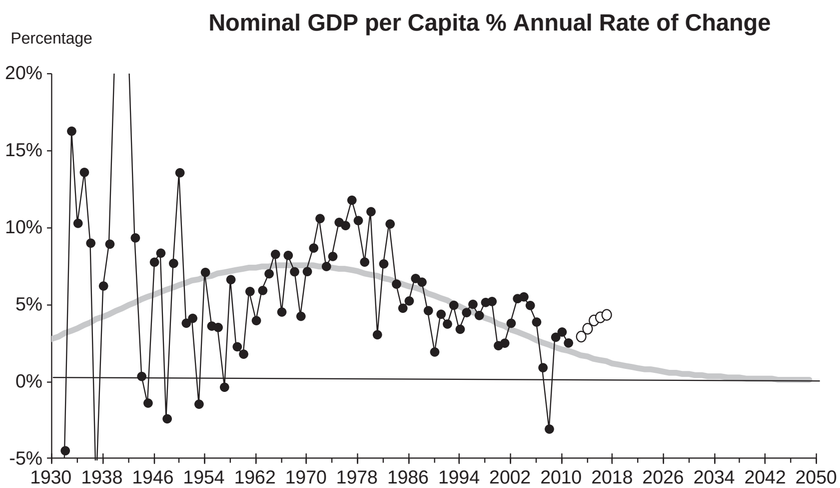


Fig. 3. Annual percent rate of growth of nominal GDP per capita (black dots) and of the logistic fit (thick gray line). The open circles are IMF forecasts.

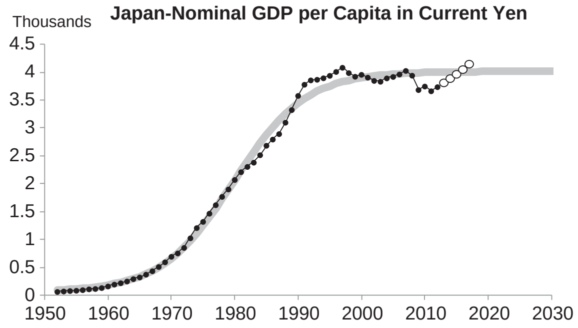


Fig. 5. Japanese nominal GDP per capita (black dots), IMF forecast (open circles) and logistic fit (thick gray line).

distinguish a logistic pattern from a simple exponential pattern. It is not realistic to try and establish uncertainties for the ceilings of the logistics in Figs. 6 and 7 because the patterns are still exponential for all practical purposes. Instead we can try to establish upper and lower limits for the ceilings of eventual logistics. The table in the Appendix A sets a lower limit as a factor of 5 on today's levels. Infant mortality and common sense can help us establish an upper limit. Infant mortality is usually taken between 5% and 10% of the final ceiling. A tree or a sunflower seedling of height less than 5% of its final size is vulnerable to herbivores or simply to be stepped on by a bigger animal. Assuming China's and India's natural-growth curves have advanced to at least beyond infant-mortality levels, their remaining growth potential should be at most about 10 times today's GDP levels.

5. Discussion

One cannot assume that a country's economy, its wealth, its prosperity, or the productivity of its people will be growing indefinitely. These are natural-growth processes and will eventually reach ceilings. This article focuses on GDP as a metric for economic growth because it is the most frequently quoted metric and data are readily available worldwide. Analyzing other indexes of national progress, such as GPI (General Progress Indicator), would probably lead to similar conclusions. In Japan the nominal GDP per capita has already reached its ceiling in the early 1990s and the country has had rates of growth around null ever since. In the US the annual GDP increments have already entered diminishing trends for both nominal and real GDP per capita, more evidently for the former; in percentage terms its rate of growth is expected to progressively diminish to 1.1% by 2020 and to 0.5% by 2030, see Fig. 3. All this should happen on the average, of course, as recessions and periods of growth come and go.

Considering that inflation is calculated from two natural-growth curves, it must also have a *natural* course to follow. In fact the CPI is forecasted to shortly enter a gentle downward trend, again on the average.

In view of a logistic analysis, as a niche becomes full the rate of growth progressively drops to zero. This is in general the case with the evolution of GDP in industrialized countries. Barring catastrophes and disasters of unseen magnitude one should not expect renewed growth rates in the industrialized world. In contrast, developing countries like China and India, where the logistic-growth process is still in its very early stages, should be expected to experience accelerating growth for decades.

A logistic description may not be appropriate for the evolution of GDP in some situations. For example, one could have thought that undergoing such major “mutations” as Germany's reunification in 1991 and the European monetary union in 1992 would invalidate a logistic description for the evolution of GDP in the countries involved. But apparently these mutations were not important enough. Most EU countries – including Germany – show only a minor glitch on the evolution of their GDP pattern around 1992; others like Belgium show no deviation whatsoever. Even Germany's reunification shows up as a minor deviation. In contrast, World War II breaks up the evolution of Germany's real-GDP-per-capita curve in order to place the country on an entirely different logistic curve after the war, see Fig. 8.

Table 2
Results for the logistic fit on nominal GDP in Japan.

M	α	t_o	*C*	Mean abs. deviation
3.947866	0.1753931	1979.87	0.0665637	5.8%

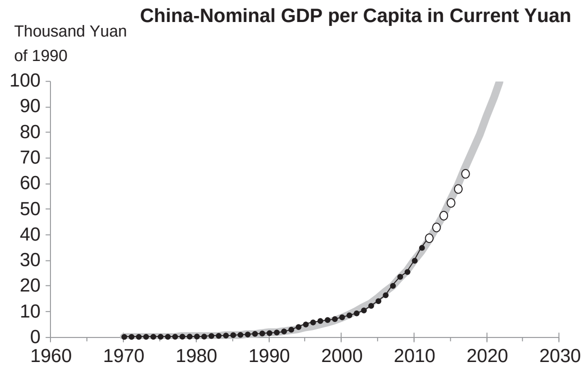


Fig. 6. Chinese nominal GDP per capita (black dots), IMF forecast (open circles) and logistic fit (thick gray line).

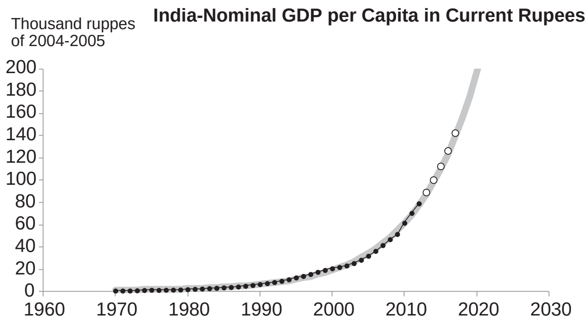


Fig. 7. Indian nominal GDP per capita (black dots), IMF forecast (open circles) and logistic fit (thick gray line).

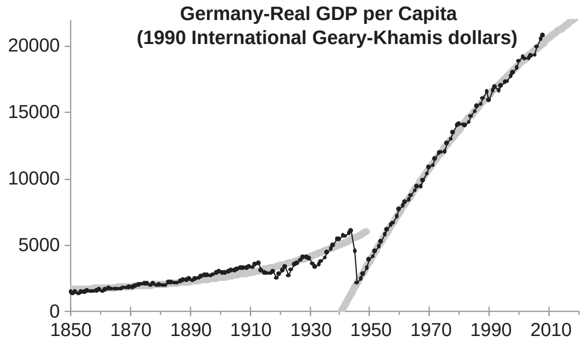


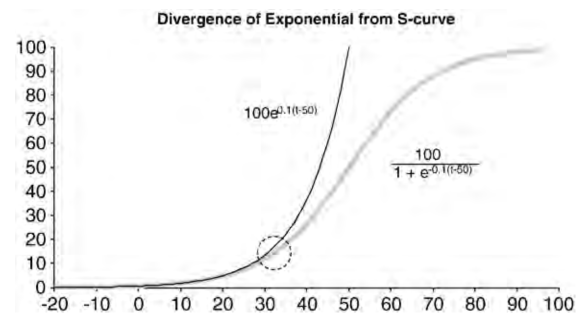
Fig. 8. German real GDP per capita (black dots) and logistic fits (thick gray lines). Data source: Agnus Maddison [11].

Most countries in the European Union are experiencing a saturation – i.e. they are approaching the ceiling of a logistic – comparable to that of the US and Japan and this could be one explanation of the West's lingering economic malaise. For these countries to find themselves back on steeply rising growth patterns a very fundamental change must take place. Probably nothing lesser than the acquisition of new territory or the complete revamping of their economy the way it happened in the US with the crash of 1929 would do the job. After all, as we can see in Fig. 1, events as important as World War II, which had such a profound effect on the evolution of Germany's GDP, produced only an insignificant glitch on the smooth evolution of America's GDP.

Appendix A. Distinguishing a logistic from an exponential

A logistic curve is indistinguishable from a simple exponential pattern in its very early stages. There has been controversy about the timing when a logistic curve unambiguously distinguishes itself from a simple exponential pattern [13]. In this appendix there is a quantification of this phenomenon.

Let us try to see at what time the S-curve deviates from the exponential pattern in a significant way, see Appendix Fig. 1. Appendix Table 1 quantifies the deviation between a logistic and the corresponding exponential pattern as a fraction of the Logistic's penetration level. By "corresponding" exponential I mean the limit of Eq. (1) as $t \to -\infty$ (with $C = 0$).



Appendix Fig. 1. The construction of a theoretical S-curve (gray line) and the exponential (thin black line) it reduces to as time goes backward. The big dotted circle points out the time when the deviation becomes important. The formulae used are shown in the graph.

Appendix Table 1
The deviation between exponential and logistic patterns as a function of how much the logistic has proceeded to completion.

Deviation	Penetration
11.1%	10.0%
12.2%	10.9%
13.5%	11.9%
15.0%	13.0%
16.5%	14.2%
18.3%	15.4%
20.2%	16.8%
22.3%	18.2%
24.7%	19.8%
27.3%	21.4%
30.1%	23.1%
33.3%	25.0%
36.8%	26.9%
40.7%	28.9%
44.9%	31.0%
49.7%	33.2%
54.9%	35.4%
60.7%	37.8%
67.0%	40.1%
74.1%	42.6%
81.9%	45.0%
90.5%	47.5%
100.0%	50.0%

In Appendix Table 1 we appreciate the size of the deviation between exponential and logistic patterns as a function of how much the logistic has proceeded to completion. Obviously beyond a certain point the difference becomes flagrant. When exactly this happens maybe subject to judgment so Appendix Table 1 is there to quantitatively help readers make up their mind. Most readers will agree that a 25% deviation between exponential and S-curve patterns is significant because it makes it clear that the two processes can no longer be confused. This happens when the logistic that corresponds to the exponential has reached about 20% of its ceiling level. In other words, the future ceiling that caps a growth process that just begins deviating from an exponential pattern in an unambiguous way is about 5 times this level.

References

[1] Free forecasts are provided by such organizations as the World Bank, the International Monetary Fund, and the European Commission. Forecasts for a fee are provided by such enterprises as Oxford Economics, Consensus Economics, and the Financial Forecast Center, 2012.
[2] For forecasts up to 2025 see The Conference Board www.conference-board.org/data/globaloutlook.cfm, and up to 2030 The Economist Intelligence Unit http://www.eiu.com/, US, Economy: long_term outlook, http://country.eiu.com/article.aspx?articleid=1299075914&Country=US&topic=Economy&subtopic=Long-term+outlook&subsubtopic=Summary.
[3] Donella H. Meadows, Dennis L. Meadows, Jorgen Randers, William W. Behrens III, The Limits to Growth, Universe Books, New York, 1972.
[4] Tim Jackson, Prosperity Without Growth, Earthscan, London, 2009.
[5] Serge Latouche, Farewell to Growth, Polity Press, Malden, MA, 2009.
[6] Peter Victor, Managing Without Growth: Slower by Design, Not Disaster, Edward Elgar, Cheltenham, UK, 2008.
[7] Richard Heinberg, The End of Growth, New Society Publishers, Gabriola Island, Canada, 2011.
[8] US Department of Commerce, Bureau of Economic Analysis, www.bea.gov/national/index.htm#gdp, and Population Estimates Program,

Population Division, U.S. Census Bureau http://www.census.gov/popest/data/national/totals/pre-1980/tables/popclockest.txt.
[9] A. Debecker, T. Modis, Determination of the uncertainties of S-curve logistic fits, Technol. Forecast. Soc. Chang. 46 (2) (1994) 153–173.
[10] International Monetary Fund, World Economic Outlook, www.imf.org/external/pubs/ft/weo/2012/01/index.htm.
[11] Agnus Maddison, The World Economy, OECD Development Centre Studies, Paris, 2004.
[12] EconStats: for India http://www.econstats.com/weo/CIND.htm, and for China http://www.econstats.com/weo/CCHN.htm.
[13] Theodore Modis, The singularity myth, Technol. Forecast. Soc. Chang. 73 (2) (2006).

Theodore Modis is a physicist, strategist, futurist, and international consultant. He is author/co-author to about one hundred articles in scientific and business journals and seven books. He has taught at Columbia University, the University of Geneva, at business schools INSEAD and IMD, and at the leadership school DUXX, in Monterrey, Mexico. He is the founder of Growth Dynamics, an organization specializing in strategic forecasting and management consulting: http://www.growth-dynamics.com.