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Last Days of Linearity in Business Analytics: Useful Analysis Based on Programming Tools

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Abstract

Modern tools, especially in the conditions of availability of computer calculations, no longer need simplification in the form of linearity in modeling business processes. Using the example of the interaction of strategies, Fama - French analysis, neural networks and other tools, the appropriateness of transforming the methodology in the direction of nonlinearity is shown. The method of simulating physical forces in economic processes is included in this analysis. A range of Python and R packages are used.

Keywords: strategies interaction, Fama – French, econophysics, nonlinearity

JEL: C45, C53, D22

Introduction

Linearity has always been an attempt to simplify economic and mathematical models. Students of economics as a rule remember lectures on macroeconomics when, somewhere at the very beginning, the lecturer drew two intersecting lines of supply and demand. And then, over a long period of time, these lines became fat, took the waved form, or changed the direction of their convexity.

It would be interesting to immediately plunge into the world of reality, ignoring a whole series of incredible assumptions. Of course, no one is going to reject such linear models as Fama-French analysis and the wonderful toolkit taken from game theory. However, there is a serious temptation to stray from the traditional path from time to time. In our research, we take several important steps:

1. Based on the interaction of strategies, we test the possibilities for approximating the life cycle process of goods using linear models. In this way we apply several of the most famous strategies from the Axelrod tournament supplementing the toolkit of Google Books Ngram Viewer.
2. Next we choose several dozen completely different companies representing the stock markets of the world. These can

be IT, telecommunications and others. Some Python packages allow us to read market data of these companies, for example, from the Yahoo Finance website based on a regular ticker. For these companies, we propose the Fama-French 5-factor model to identify strategy. We test when such an analysis works, and when we need to abandon linearity.

3. If the Fama-French model does not work in certain cases, then we apply the same matrix of factors, supplementing our analysis with the ability to build neural networks based on hidden layers and manipulating the number of neurons.
4. In comparison with neural networks, methods of Econophysics look more obvious and maximally applicable. The question arises as to what exactly to choose as analogues of the main interactions presented in physics.
5. If the approaches proposed by us work, then the question of the inadmissibility of further deterioration of economic models by linearity receives a positive answer.

Review

In 1965, Gordon Moore made a game changing prediction that announced our modern digital revolution. He postulated that the number of transistors on a microchip doubles every two years, and the cost of computers halves. His prediction could be extrapolated to imply that the overall processing powers for computers will double every two years (Moor, 1964, 1965). It was perhaps the most painful blow to the formalized linearity of business processes in modern history.

Game theory methods could be chosen as very helpful instruments for different types of interaction analysis. Robert Axelrod has proposed a tournament on the basis of The Prisoner's Dilemma (1980). This prompted the analysis of hundreds of different strategies. In the modern version of this game, manipulating the Python code allows us to perform such calculations quickly and efficiently. Having knowledge about the state and main features of concrete personality, firm, institution, technology it could be useful using the Axelrod code to predict the result of such imaginable competition. In this way, different periods of the company's operation or the technology's life can be defined as a change in strategy.

Further, we intend to reveal the presence or absence of a long-term strategy based on the 5-factor model of Fama-French (maximum possible period, factors for developed or emerging markets) (Fama & French, 2015).

If the approach based on the 5-factor model of Fama-French does not show a result (the necessary criteria are not met, first of all Fisher - criterion), it could be possible modeling based on neural networks, rejecting linearity (Tronto et al., 2008).

Currently a considerable number of scholars have applied physics concepts and methods to understand economic phenomena. Notably, the distribution of returns in financial markets is studied the most intensively in that way, the distribution of income and wealth, the distribution of economic shocks and growth rate variations and the distribution of firm sizes and growth rates (Stanley et al. 1996). We would like to draw attention to the Theory of Monads proposed by Mykola Rudenko (Логвиненко & Мазуренко, 2019) and Newtonian Microeconomics published by Mattie Estola, which states that physical tools may help investigate economic problems. According to Estola (2017, p. 7), "the economic forces acting upon economic quantities are defined, and these forces explain the observed changes in economic quantities".

Method

First we go to the technology analysis. Using Google Books Ngram Viewer, we can assess the interest in studying (analyzing) concrete technology. For comparison, we analyze such goods as ‘gramophone,’ ‘pager,’ and ‘recorder.’ Along the curve of a specific technology, we try to identify the behavior strategy of the owner accompanying the specific moment. Next stage focuses on the problems of building a company's strategy based on the Fama-French model.

Generally the 5-factor Fama – French model could be presented in a form:

$R_{it} - RF_t = a_i + b_i (RM_t - RF_t) + s_i SMB_t + h_i HML_t + r_i RMW_t + c_i CMA_t + e_{it}$ (1)

Where R_{it} is the return of one of portfolio i in month t; RF_t is the risk free return; RM_t is the return on the value-weight market portfolio; SMB_t is the return on a diversified portfolio of small stocks minus the return on a diversified portfolio of big stocks (i.e. the size effect); HML_t is the return spread of cheap minus expensive stocks (i.e. the value effect); RMW_t is the return spread of the most profitable firms minus the least profitable; CMA_t is the return spread of firms that invest conservatively minus aggressively; a_i, b_i, s_i, h_i, r_i, c_i – some coefficients; e_{it} is a zero-mean residual.

A modification of the approach based on neural networks used in this study is an attempt to simulate some changes on the market by adding a hidden layer with an increased number of neurons (factors). As the object of such analysis, the Fama-French matrix of factors and the adjusted price of shares of the analyzed company are chosen.

We get all the data for calculations from the web sites: yahoo.finance, investing.com, and focus-economics.com based on the tickers of the respective companies and the corresponding Python and R packages. In most cases, the maximum possible period for analysis is chosen, based on the time the company has been on the stock market.

Research

Interaction of strategies

First, we will show the inappropriateness of a linear approach based on the interaction of strategies. A list of the simplest business strategies can be found, for example, in the Axelrod tournament documentation (Table 1).

Understanding in general how the company behaves at different stages of the product life cycle, we can assign a specific type of strategy to each of these stages. Of course, here we make assumptions about the rationality of the player.

The simplest version of the life of the product could be obtained with the help of such a tool as Google Books Ngram Viewer (a graph showing how those phrases have occurred in a corpus of books over the selected years). It is proposed for analysis gramophone, pager and recorder.

Table 1. The sample of Axelrod strategies

Strategy	Description
Anticycler	A player that follows a sequence of plays that contains no cycles: CDD CD CCD CCCD CCCCD ...
BushMosteller	The probability of playing C or D will be updated using a stimulus which represents a win or a loss of value based on its previous play's payoff in the specified probability.
Collective.Strategy	'It always cooperates in the first move and defects in the second move. If the opponent also cooperates in the first move and defects in the second move, CS will cooperate until the opponent defects. Otherwise, CS will always defect
Grumpy	A player that defects after a certain level of grumpiness. Grumpiness increases when the opponent defects and decreases when the opponent co-operates.
LookerUp	This strategy uses a Lookup Table to decide its next action.
MemoryOnePlayer	Uses a four-vector for strategies based on the last round of play
Stalker	This is a strategy which is only influenced by the score.
TrickyCooperator	A Cooperator that is trying to be tricky.
WinStayLoseShift	a strategy that shifts if the highest payoff was not earned in the previous round

Source: https://axelrod.readthedocs.io/en/stable/

We don’t observe in reality any linear character of technology and as a result of the company that owns it.

Let's analyze the case of the gramophone (Fig. 1). At the very beginning of the emergence of technology, the strategy of Schumpeter's entrepreneur (creating disturbance in the market) is necessary. It is possible to implement such strategies as Tricky Cooperator, Stalker, Anticycler and others. Next comes the planning and encouragement stage and the time for such strategies as LookerUp, Calculator, and BushMosteller.

At the time of saturation of the market, not everyone manages to switch to new technologies; efforts are being made to revive outdated technologies. Therefore, a certain waviness of the curve appears. This focus on one's own experience and beliefs is realized, for example, with the help of strategies One Memory Player, Average Copier, etc. If the manufacturer or owner cannot continue to abandon outdated approaches, goods and services, he has no choice but to accept everything and everyone. The best reflection of this behavior is the Cooperator strategy (choice for next stage). Interestingly, a real Tricky Cooperator may appear later, which will bring the old technology back to life in the short term and the same buyers (also Tricky Cooperator) will purchase this technology.

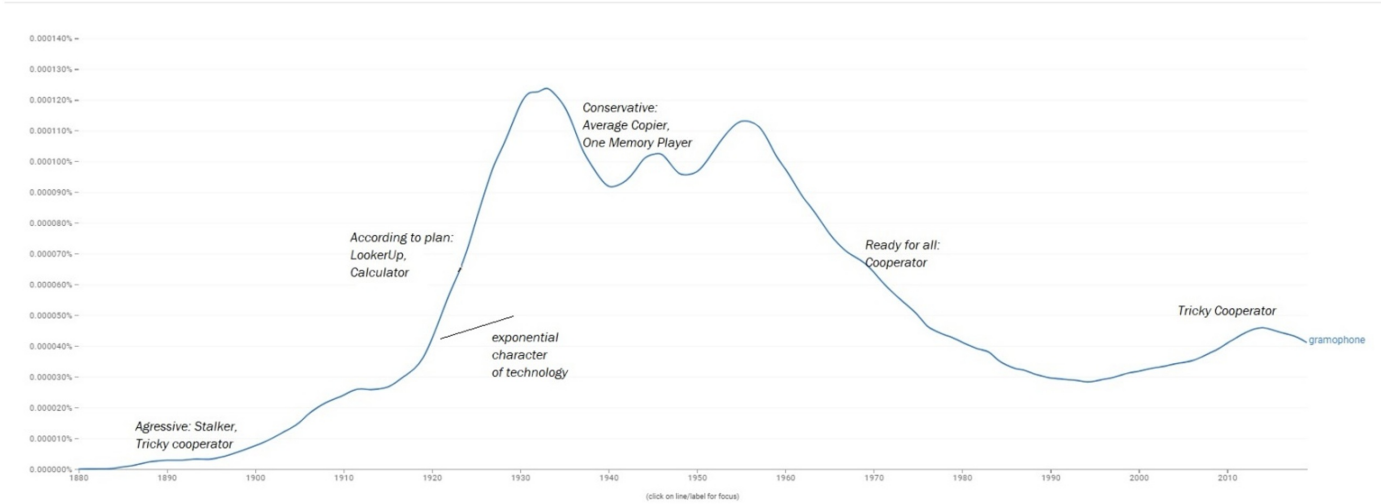

Figure 1. Strategies change for technology ‘gramophone’ owner

Source: https://books.google.com/ngrams/ and own accommodation

Different strategies on different stages of technology life cannot be represented by a linear function based on the definition of linearity. The biggest mistake is to think that a company has one strategy for all occasions. And this means that there cannot be linearity at all.

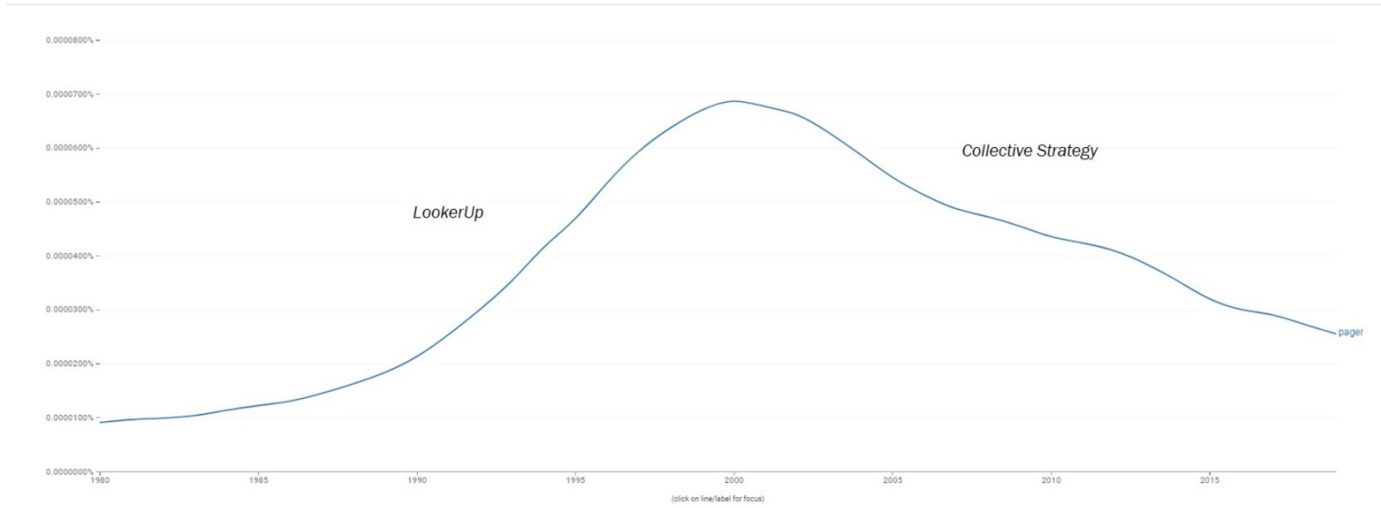

Figure 2. Strategies change for technology ‘pager’ owner

Source: https://books.google.com/ngrams/ and own accommodation

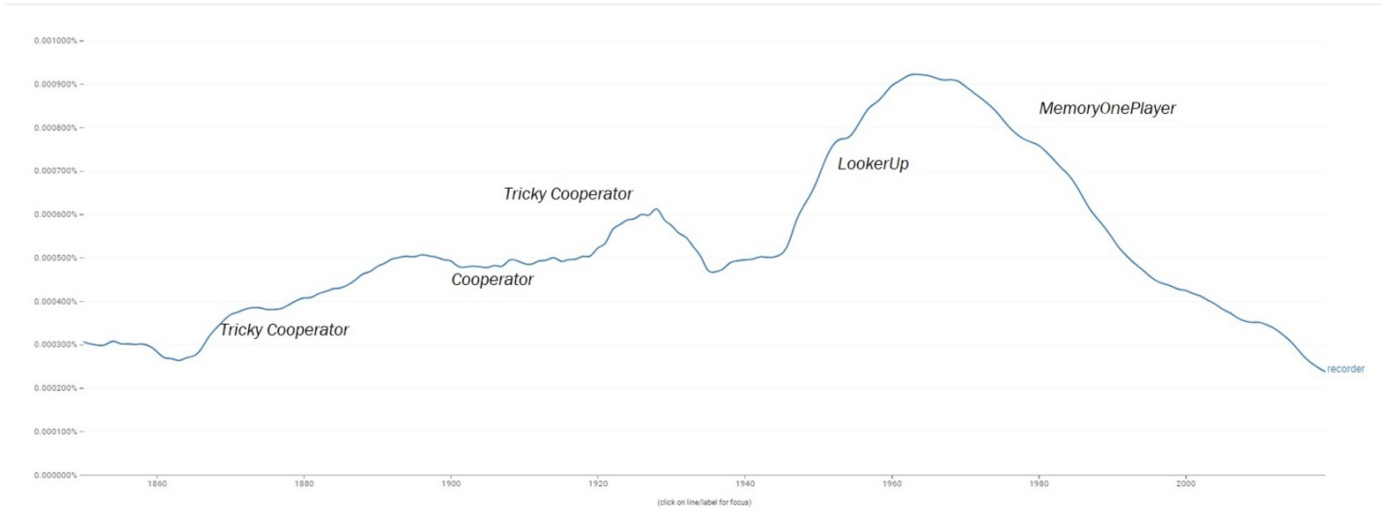

Figure 3. Strategies change for technology 'recorder' owner

Source: https://books.google.com/ngrams/ and own accommodation. Notes: recorder Unexpected waves could be explained by paying attention to own history disregarding real situation in the market.

The same manipulation with strategies could be done with 'recorder' and 'pager'. Obviously all these cases are a little different (Fig. 2, Fig. 3). In some cases, the interaction of strategies can take completely unexpected forms.

Fama – French model as reflection of the linear character of changes

Do we have in modern world sufficient basement for the type of linearity proposed by 5-factor Fama-French model? Perhaps the explanation is the specificity of the factors involved in such a model?

Hypothesis:

Fama - French factors are focused on the company's reputation and its reflection on the stock market opinion. This is about growth stock or value stock, greater or lesser risk compared to the average in the market, the level of capitalization, etc. But if the role of the stock market as an estimator can be questioned, the model stops working.

In the proposed model attention is paid to market data and not accounting statements. Modern approaches require a combination of these characteristics. We can find a lot of this type research of bankruptcy prediction modelling. It could be accepted that profitability (wide range of indicators: EBT, EBITDA, NOPAT, NI, etc.) as a result of the accountant's creativity (with small acceptations not unified in frames of IFRS) and cannot be considered as a reflection of financial health of enterprise. But on the other hand the historical foundation of the firm and therefore the accumulated reputation, clientele, dynamics of assets, etc. expressed in specific indicators, sometimes with a revaluation are not taken into account.

Let us imagine that the stock market is not a priority for the company (perhaps more attention to public orders, banking services, sufficient own operating flows, the commitment of shareholders: the agreed delay of dividends for a long period of time) or is in a state of development, reform, stagnation... Let's imagine a (significantly different from the American)

continental model of a corporation where the bank plays the most serious role, not the small investor. If there is access to management accounting, the role of auditing in the stock market becomes secondary. This is the case when the stock market does not give sufficient answers about the status quo of the company. The same situation exists with regard to goods (technology), when we are dealing with a monopoly. In such situations, it is better for the market to remain silent about his point of view.

Table 2. Fama – French modeling examples

Item	Adj R^2	Probability(F)	Mkt – RF*	SMB*	HML*	RMW*	CMA*
Working model							
AAPL	0.37	6.8e-27	1.26	-	-0.56	-	-0.77
MSFT	0.4	3.15e-48	1.08	-0.31	-0.46	-	-0.69
AMZN	0.31	1.08e-24	1.43	-0.65	-0.74	-	-0.81
7040.SR	0.07	0.01	-	-	-7.38	-	12.12
6857.T	0.24	5.73e-07	1.22	-	1.33	-	-1.35
LBW.WA	0.25	0.00	-	-	1.78	-	3.43
Working partly (only Mkt-RF as a significant factor)							
TSLA, EPAM, BKNG, 6952.T, ANY.BD, AVST.L, ^CMC200, FORTUM.HE, YASKY, and others							
Not working model (probability of F – criterion bigger than 0.05)							
IFI.WA, JAZEERA.KW, 3333.HK, 4751.T, 4716.T, MRNA, APH.JO, CZG.PR, ABL.OL and others							

*Notes: * - β – coefficient of the model. In block 'working model' only factors with probability smaller than 5%. For model realization it was used the proper Python coding.*

As we see IT – companies (EPAM, IFI.WA), crypto – currencies (^CMC200), North European companies (specific budget model), Chinese business, etc. are not a proper object for such modeling. If we have to limit ourselves only to this approach, then the question of the existence of strategies of such companies would receive a negative answer. But for companies that have been on the market for decades, this is impossible. There are also problems with companies that are approaching bankruptcy (Evergrande (3333.HK)). Let's just imagine how difficult it is for emerging markets to build a single linear model (Mexico, Brazil, CEE, and others). Even in our small sample, it is revealed that for the model success mainly it should be a risky aggressive business with an emphasis on the future (growth stock).

Example of neural network

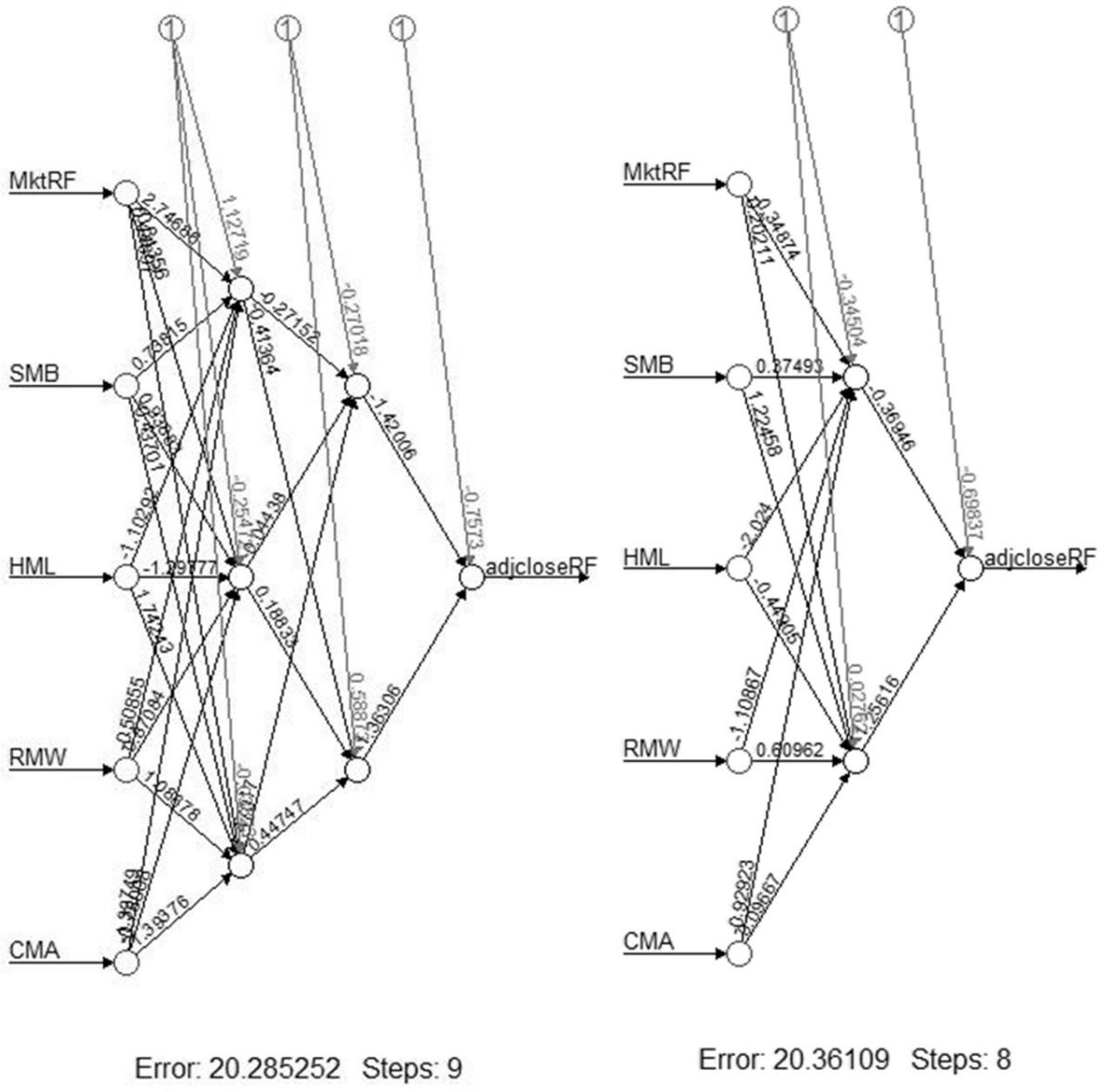

Figure 4. Neural networks for IFI.WA and JAZEERA.KW

At the same time, if the model of the interaction of the market price and the factors of the Fama-French model is based on neural networks, the level of confidence of such models is quite high. The cases of two companies with two and one hidden layers, respectively, are shown below.

Notes: IFI.WA (left): used in the model err.fct='sse', threshold=0.01, algorithm = "slr". Model accuracy = 0.6450816; JAZEERA.KW (right): model accuracy = 0.5787362. It was used a proper packages of R.

Although the analysis of the impact of individual factors has become too complicated, the question of the existence of a non-linear strategy has received a positive answer. In addition, such models have become a good price prediction tool.

Econophysics: economic forces in the market

New times, maybe even new human need some new a multidisciplinary view of the economy. It happened before and it happens today. The models developed in physics were used and are applied in modeling economic processes. Unfortunately, this approach has not always been understood.

Promising interdisciplinary works of Benoit Mandelbrot, Adolphe Quatelet and Louis Bachelier were almost completely neglected by neoclassical economists until the rise of econophysics in the 1990s gave them renewed interest.

In general, the approach of econophysics can be adequately applied in a broader sense. The profit or close determination of the result of business could be presented by the interaction of 5 forces: stock and banking markets, shadow market, budget and entrepreneurial skills. The deeper approach involves vibrational business interactions such as accounting manipulations, fraud behavior in stock and banking market. We divide the business environment into 4 Edgeworth boxes.

Econophysics practically originated in the 1990s. We owe this to two extraordinary individuals who had the scientific courage to allow physics students to use economic statistics in their master's theses. Eugene Stanley in Boston and Imre Kondor in Budapest made the most tangible steps in this worldview transformation.

The methodological tools for this range research are computer-based simulation models. An example of such an analysis is the determination of the Gini index based on agents' interactions.

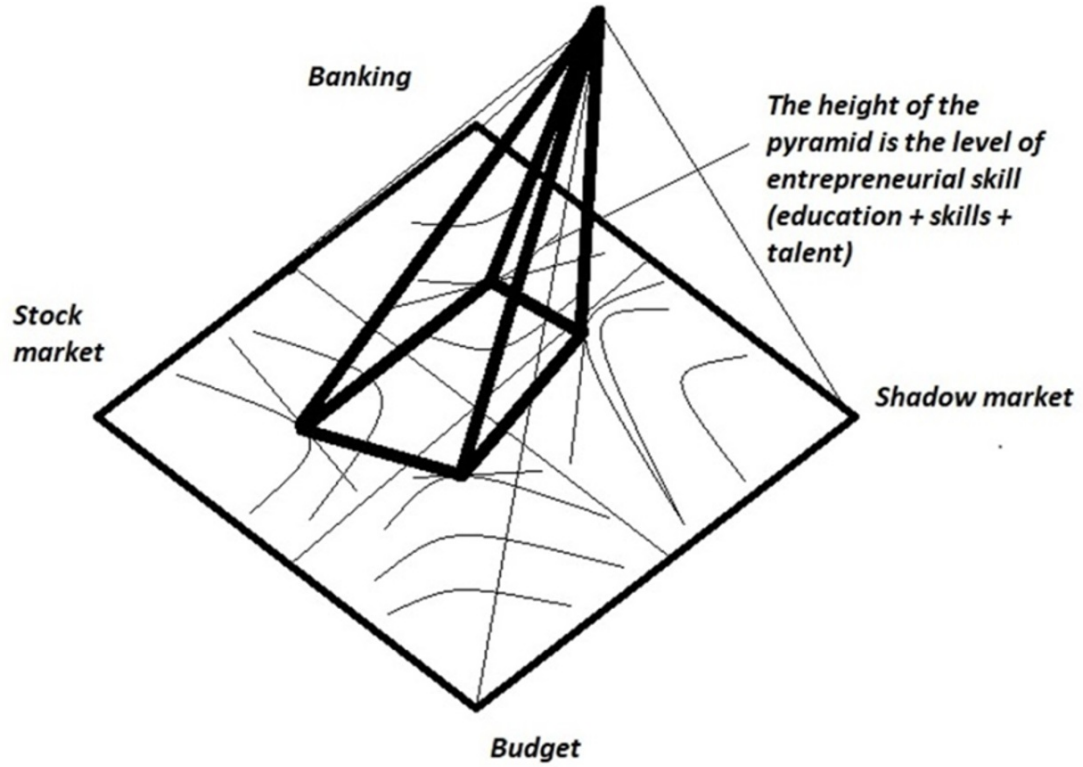

Figure 5. Economic forces that determine entrepreneurial success

The resources of the stock market, the bank, the shadow market and the budget interact with the entrepreneurial flair in the respective boxes (Fig. 5). Accordingly, we have 8 different maps of indifference curves and 4 budget lines. Next we

look for equilibrium positions based on them. Interestingly, high business profitability is possible with different levels of involvement of each of these forces. Unfortunately, marginal cases of this model are now represented in the economies of Ukraine, as well as China or India.

What about institutions interaction? A collaboration of economists and physicists has showed that “too much risk sharing in a network of institutions can decrease stability” [Buchanan, 2013].

Do we believe in “string theory” analogy in economics? If it is possible to explain by one theory the electromagnetic, gravitational, weak and strong nuclear reactions, then why there can’t be single economic theory that unifies the approaches in the field of hundreds of economic theories. We hope for.

Not only on the basis of accessible and accurately prepared stock market statistics, but also in a more extensive version of the interaction of major economic forces on entrepreneurial activity, the tools of econophysics are becoming increasingly popular. Let's focus our attention only on two main forces - the stock market and the banking sector (shown in the figures below as separate blocks, at the same time lacking a stable support in times of crisis) (Fig. 6).

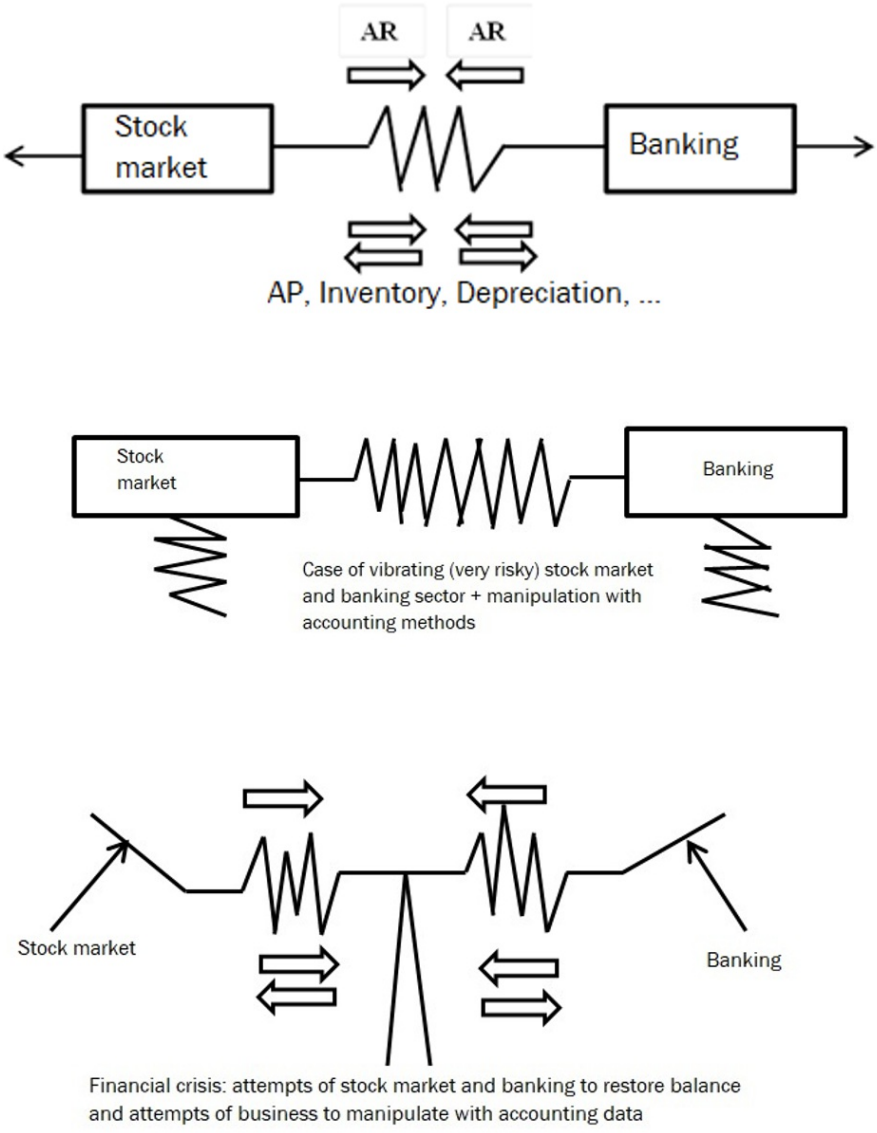

Figure 6. Vibrating and main economic forces

Source: own accommodation

Our attempt to bring economic forces into consideration clearly shows that linearity is possible only with stability in the market, absence of manipulative behavior on the part of institutions and businesses. In other cases, business (and therefore technology) behavior becomes non-linear.

Discussion

There is some simplification of the first model regarding the behavior of the technology in the market based on citations. At the same time, the modern digital society allows us to make assumptions about the significant correlation of possible sales volumes, price dynamics with interest in a specific author's certificate, and therefore also in citations, that is, interest in technology directly.

In the case of Fama-French analysis (actually linear regression), we can, improving the model, offer additional dummy variables or logarithmization. However, the authors do not consider this approach to be a solution to the problem of linearity.

There is a whole range of other approaches to what can be considered the main economic forces. The authors chose an approach based on the main market institutions. Based on the post-Washington Consensus descriptions with the same emphasis, this approach seems correct.

Conclusions

Based on the interaction of Axelrod's strategies, the inapplicability of the Fama-French analysis for the entire spectrum of business, and the appropriateness of the same approach with the use of neural networks, the transformation of the economic modeling process in the direction of non-linearity seems quite appropriate. We come to the same conclusion if we supplement the economic toolkit with the approaches of econophysics. Despite the ambiguity of the choice of economic forces, it is logical to conclude that such interactions require non-linearity.

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