# Chapter 24

# Branching out into the Universe

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Work on diffusion models started at IIASA in 1974 when we were searching for a solution to the problem of putting some internal logic into the dynamics of energy markets (Marchetti, 1975). The problem was formally solved by using multiple competition dressed in logistics which are the simplest coder for the simplest diffusion process, the epidemic one.

The immensely complex phenomenon of using energy in various forms with all the interfacing of economics, technologies, and politics, and over a period of more than 100 years, showed up as a crystalline substitution, i.e., a multiple diffusion process (*Figure 24.1*). The result was a philosophical shock to me, because it robbed the process of its contemporaneity. A single set of equations, each with an input of only two parameters, was capable of describing the whole process even 100 years or more ago. In addition the description did not require the notion of money or other economic paraphernalia. Everything could be reduced to the timing and speed of the introduction of each new competitor. All the rest was a consequence, even 100 years later. Apart from the isolation resulting from the effects of daily affairs, the system showed an incredible long-term self-consistency, in spite of the continuously changing technical, economic, and political substrate. The

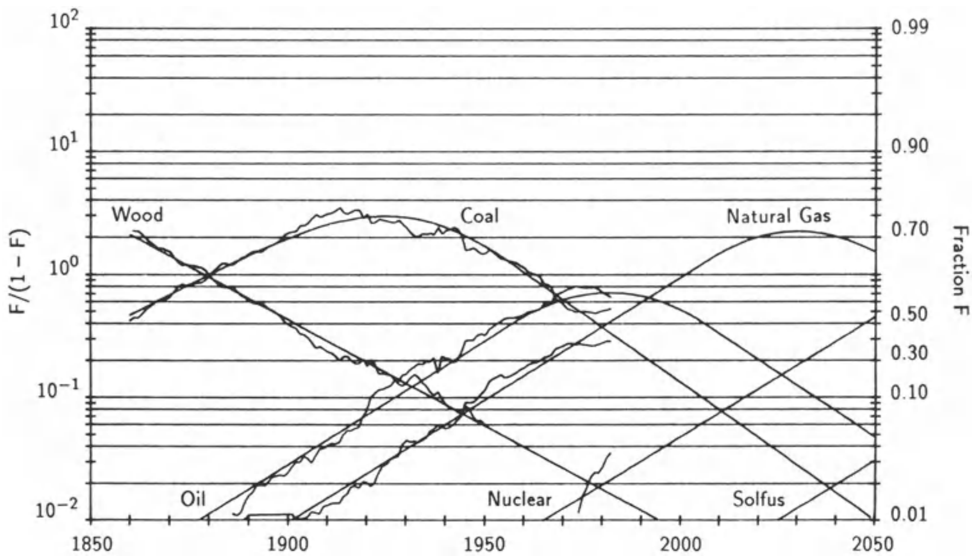


**Figure 24.1**. World primary energy substitution, in fractional shares of primary energy consumption by source. (Source: Marchetti and Nakićenović, 1979.)

precision of the match discouraged any thoughts that it was a pure coincidence. The next step was in fact the initial branching out into a whole set of cases of primary energy substitution, from single countries to electricity production, to single industries.

Altogether we collected about 300 cases (Marchetti and Nakićenović, 1979), showing that the multiple diffusion process was an unsinkable descriptor of the dynamics of the real world in the energy area. The first branching out from energy proper started here, where we were using proxies, like the number of diesel versus steam locomotives to pattern the substitution of oil versus coal for railway transport, or the amount of coal extracted using various technologies, to pattern the competition between these technologies. Everything worked very well, and the suspicion was that the methodology could be of very broad significance.

Our ancestors operated in the thirties under the spur of the work of Volterra in Italy and Lotka in the USA. Both gentlemen were dealing with biological systems, but there was an overspill of interest for people working in the area of economics and sociology. A number of papers appeared, some with penetrating insights into the possibility of using logistic analysis to map social processes. I still wonder what inhibited an explosion of research at that time. Certainly multiple competition or diffusion was not under control or even in the minds of these precursors. Nor was the strong effect of Kondratieff cycles in single penetration logistics. Nor the frantic hunt around the asymptote for certain economic systems.

My exploration was, however, prudent, choosing contiguous subjects. Having a loose consulting contract with FIAT, I was asked to peep into the car system. The original stimulus was to see if technological innovations or promotional campaigns had an effect on sales and on the ownership of cars. The first case that I studied was Italy where I looked at cars in circulation, a statistic more easily available than the one on sales (see, for instance, Marchetti, 1983). I was again philosophically shocked. The diffusion runs with an astonishing stability and precision, insensitive to any initiative coming from the industry or sudden changes in economics and politics on the outside. The first and second oil shock did not produce the tiniest dent, not to speak of promotional campaigns into which the car industry sinks fortunes.

Sponsors and colleagues were equally upset. The faith in pretty girls had deep emotional roots. *Obviously* all the *mise en scène* had the purpose of beating competition, and not really to increase the ownership of cars. That was the explanation of my results. So I went to see the evolution in time of market shares between the main car producers in the USA and Japan. The results confirm that *obviously* all the fuss was not about beating the competitor, but to keep him at bay.

My personal interpretation, based on hundreds of evident examples, is that people talk and the system does its business. The French have a delicious fable written down by Lafontaine, *La Mouche Cochère*, where a fly by actively flying up and down helps a pair of oxen to pull a heavy cart. And it is also very tired and self-satisfied at the end. A great deal of the talk of *decision makers* seems to fit this description very well. I wonder how many ponderous decisions had to be taken to keep the curves of *Figure 24.1* in such good shape.

The philosophical breakthrough in the application of these diffusion equations came when a friend of mine, president of the Italian Marketing Association, asked me to prepare an innovative paper for a conference on innovation which he had organized in Turin in 1979 (Marchetti, 1980). I had on my desk

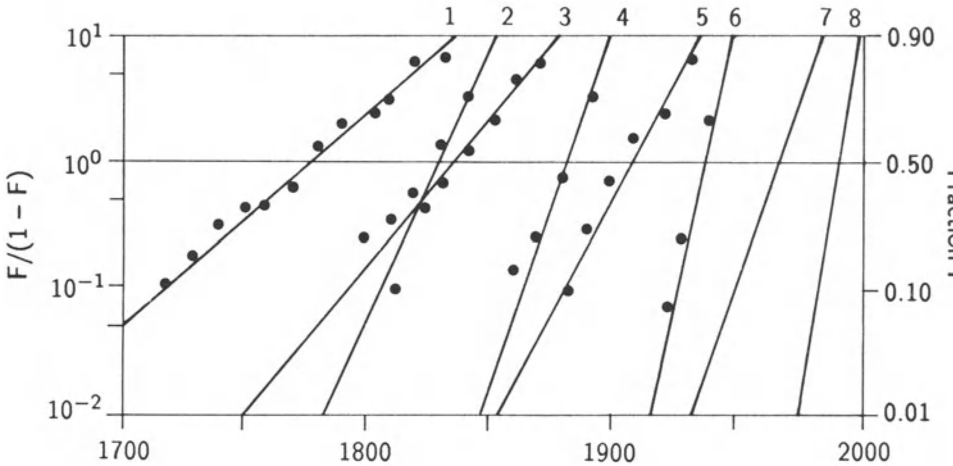


**Figure 24.2.** Invention and innovation waves, the secular set: The first three waves of the series are historical. We live in the fourth. Odd numbers indicate invention waves and even ones innovation waves (number 8 indicates the fourth innovation wave). (Source: Marchetti, 1980.)

the Mensch book on innovation, "*Das Technologische Patt*", with statistics on basic inventions and innovations dating back to 1800 (Mensch, 1975). The quality of these statistics comes from a homogeneous definition for the *dates* when inventions and innovations appeared.

In order to make these statistics treatable with our diffusion equations, I then made the hypothesis that an innovation can be considered as an object, a product, like a car, generated in response to market demand. The set of innovations would progressively fill the market, like cars. The thread was thin but it held. Not only innovations, but also invention waves fit the model very well. This was the first hint of the fractal nature of the social and economic system we shall talk about later on.

The analysis of the inventions and innovations waves *à la* Mensch revealed internal regularities that led me to find some arithmetic rules to calculate the ones that followed. The result of this exercise is reported in *Figure 24.2*. That the system regulates so precisely such fancy action like inventing and innovating was really an unexpected result.

But also entrepreneurship is equally regulated. For instance, an analysis of the opening of firms producing cars and of firms quitting the market follow perfect (cumulative) logistics. Nitety-nine percent of the firms did quit, and that gives a glimpse of what could be defined as the *Holocaust of the enterpreneurs.*

The chart of *Figure 24.2* reveals also another detail in the behavior of the system: that the centerpoints of the innovation waves are spaced at 55 year intervals, the distance of one Kondratieff long cycle. It puts the mechanisms into a Schumpeterian vision of markets progressively saturated leading to recession. Innovation and entrepreneurship reopen the game into a new spurt of activity. A completely different approach was taken by Stewart (1982) of Nutevco who measured the deviations of primary energy consumption and electricity consumption from the secular trends. Also his analysis shows in crisp form the pulsations of the global activity. With a periodicity of 55 years.

Faith and daring come with success and at this point all inhibitions were removed. After all experimenting was cheap, and failures could find their way to the paper basket. Only a short sampling can be taken out of the 3000 odd examples which Nakićenović, Grübler, and I have collected. I must honestly say that being beyond my career I was always the most daring. I did not have much to lose and have no professional peers to keep me in line. Much stimulation comes when critics start gnawing at the borders to check the consistency of the stuff. One of the first observations was that the model only operates for Western countries during the last century or so. It was true that all our examples fell into this time slot, but the obvious reason was the availability of sound statistics.

But a number of things are well recorded from a deeper past, so I analyzed the diffusion wave of the construction of gothic cathedrals. Their cumulative number in terms of *first stones* is reported in *Figure 24.3*. The regularity of the process, over such a long period of time, with economic revolutions, wars and plagues, is really astonishing. In my view it is a milestone in revealing the deep regulatory feedbacks of the social system. This self-regulation is pervasive. In a completely different field we can observe, e.g., the perfect resilience of the air transport system growth to the oil price shocks of 1974 and 1979. The immunity was acquired through a complex and painful *internal* reorganization of the air companies. Going to centralized economies does not change the situation either, as much work done by Grübler (see, for instance, Chapter 19) shows.

At this point the concept started taking shape, i.e., the diffusion process is really at the cultural level and *paradigms* are generated and selected somewhere, and then move into the heads of people to become finally *action.* Hägerstrand's field measures of the mechanisms of this diffusion through very

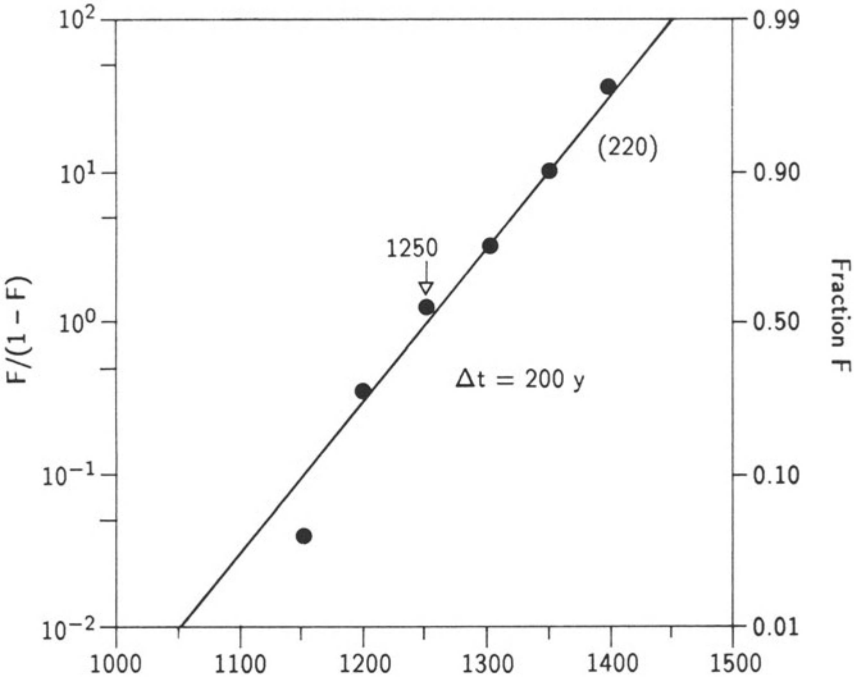


**Figure 24.3.** Building gothic cathedrals (an incredible burden to the populations of the Middle Ages) analyzed as a diffusion process. The chart gives the cumulative number of *first stones* for what will in time become a cathedral. The dates are well documented. (Source: Marchetti, 1986.)

stable social networks made by sets of about 100 people, gives a hint about the causes of the stability of the process.

These friendly gangs, as they emerge from anthropological studies, already existed in the neolithic age. Fast travel and telecommunication gives them larger territories without changing the structure and timing of their interactions very much. This communication by internal lines neatly explains why the information pouring by the media does not seem to dent the rates of a diffusion process, even over a span of 100 years.

Speaking of media, a couple of years ago I did some research for the CEE on nuclear energy and the social system (Marchetti, 1988). Measuring the opinion of people is a hard task because people rarely know the deeper meaning of their actions, and sometimes lie about this. But the media act on strict feedback from their customers, and try desperately to match what the customers want to hear. So I started measuring the media in order to check public opinion. The hypothesis behind the use of the media as a proxy for public opinion may be right or wrong, but the result I want to show is that the coverage (cumulative number of articles or TV spots) follows exactly the scheme of a diffusion process. *Figure 24.4* reports the coverage of nuclear power by the media in the USA. Dailies and TV are much the same as they fish in the same pond of public opinion. The periodical press has a slightly higher time constant.

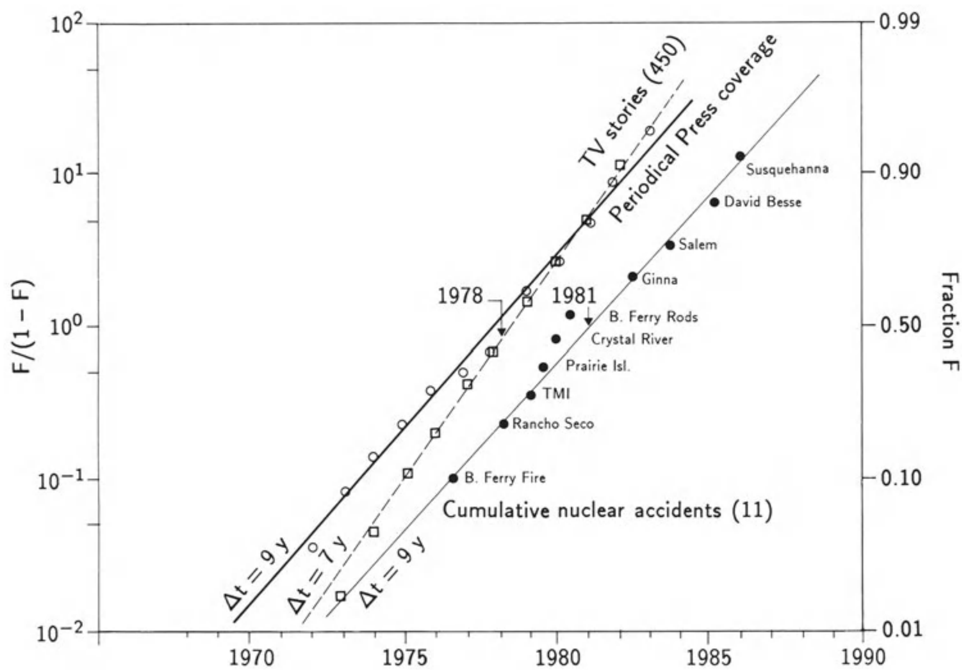


**Figure 24.4.** Media coverage of nuclear energy in the United States (measuring cumulative number of evening news reports in US TV networks and coverage index by US periodicals on nuclear power plants; data from Mazur, 1984). Also shown are the cumulative number of major US nuclear accidents. Observed is a parallel of the accident wave with the press wave *as if* opinion intensity preceded accident probability by a couple of years. The Three Mile Island accident, perceived as the worst, happened when coverage by the periodical press was at a maximum (F = 50%). (Source: Marchetti, 1988.)

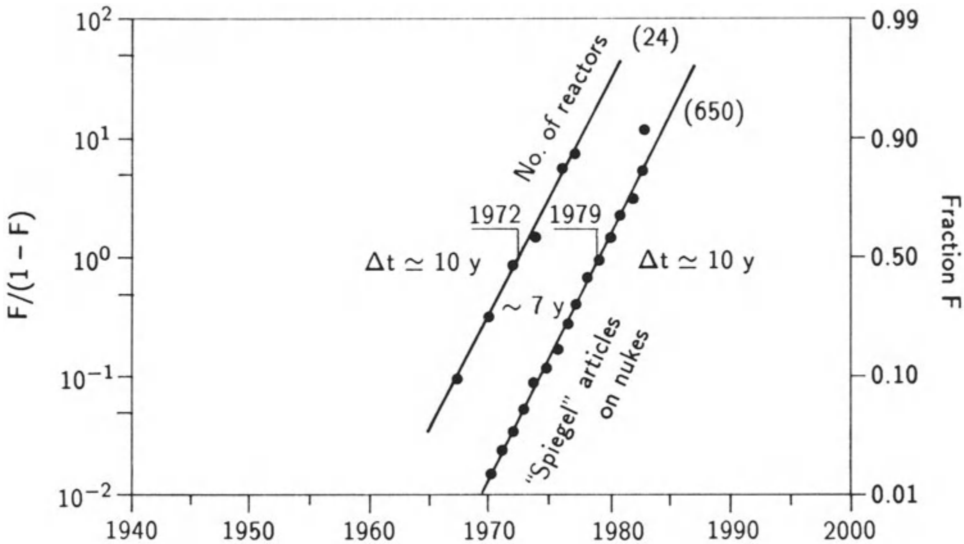


**Figure 24.5.** Media coverage on nuclear energy as represented by *Der Spiegel* is well correlated to the beginning of nuclear reactor construction in the FRG with a time lag of seven years. (Source: Marchetti, 1988.)

Also if one takes an individual journal, like *Der Spiegel*, one gets exactly the same result (*Figure 24.5*). The coverage is highly correlated with reactor construction start-ups both in the USA and the Federal Republic of Germany, if with many years delay time. Also accident waves are correlated with periodic press coverage. The Three Mile Island accident occurred when public attention, as measured by the periodical press, was at a maximum. This certainly does not establish a cause–effect relationship, but the time sequence proves invalid the reverse cause–effect, i.e., that the accident wave is the stimulus for press coverage.

The variety of subjects touched never ends, from the witch hunt of the Middle Ages, to the adoption of stamps in the Western hemisphere or the writing of papers on the greenhouse effects of $CO_2$. The same elementary mathematics neatly covers the fact.

At this point I have to draw some conclusions. As the economist Walt Rostow once said after listening to one of my presentations, *we may have struck a deeper level of truth*. The deeper level, as I see it now, is that our culture operates as the carrier of action paradigms at all levels of spatial and hierarchical integration. Humanity then operates as a gigantic quasifractal system, where the equation is always the diffusion equation but its parameters depend on the level of fractality.

If this is true, and everything we have done to date conveys that, a really deeper level of truth has been struck revealing the single and all-pervasive mechanism of the working of society. Studying primary energy substitution can lead very far indeed!

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