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How computer science has contributed to the social sciences and how it can give a new form to policymaking

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ABSTRACT

In the 40s and 50s of last century, the presence of new mathematical tools–first of all, game theory–combined with the first steps of cybernetics and neural calculus, created a new wave of expectations towards the nascent computer science, with the social sciences in the front row.
The precondition, however, was that of the availability both of computing power and of the tools to program it, with the possibility of applying statistics, and its evolution in the economic field–namely econometrics–to analyze large-scale socio-economic phenomena.
Computers made easy the solution of models with many equations and many variables, with the perspective of forecasting and planning, with simulation. The improvement of the techniques was extraordinary, but still insufficient for practical use. The main obstacle to the centralized planning activity in the communist countries was the lack of computing power over the years of the most important efforts for the effective use of planning in real life.
Making a jump to recent years, the new form that the social sciences and economics most recently draw from the computer science, in particular, object-oriented techniques, is the construction of artificial worlds populated by agents, to explain the emergence of macro effects through their behavior.
Finally, artificial intelligence algorithms and cognitive science are introducing a new revolution in perspective of policymaking, also with new capabilities in planning.

THE DAWN OF INFORMATION TECHNOLOGY

The magic moment is that of the mid-1940s of the last century, when great minds like John von Neumann, Oskar Morgenstern (who worked closely with von Neumann on economics) and John Nash (who, in spite of working alone, certainly influenced that era), led to an exceptional joint emergence of high expectations: that of the new calculation tools, that of a new language for the social sciences (game theory), and the focusing of the concept of complexity (Hanappi, 2015; Moscati, 2011). With them, Wiener and the cybernetics.

AFTER THE DAWN, THE 60S OF THE LAST CENTURY

With Gigerenzer (2001), we know that towards the end of the 60s of the last Century, calculation breaks into the social sciences, with the great novelty of simulation.

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Mental experiments, from physics to political science, have been a research tool in situations where it was not possible to obtain data, such as historical counterfactual scenarios. The computer has created a new kind of mental experiment: computer simulation. The world resource model of Jay Forrester's Club of Rome is one of the best-known social science simulations.

The famous computerized tournament organized by Robert Axelrod to play the so-called prisoner's dilemma demonstrated the success of a simple social heuristic called tit-for-tat. That initiative became the model for numerous simulations on game theory, also for the science of politics. Simulations force researchers to precisely specify their ideas and become a tool to discover new implications of those ideas. Always with Gigerenzer: in some fields, that of defining precisely assumptions has become a requirement for a theory. What it is not possible to simulate, does not deserve to be called theory. On strategic games in decision theory, see, for example, Bassetti and Luvison (2018).

Another presence of information technology influences the social sciences in the same period: the automated statistical calculation. To remember a name, we had SPSS (Statistical Package for the Social Sciences), created in 1968. Since that time, the social sciences have seen the explosion of the use of statistical methods needing a lot of calculation, including the factor analysis, cluster analysis, variance analysis, and multiple regression. It was an enormous leap forward, even if for the econometrics, in the same years, the statistical subroutines realized by IBM were already used in Fortran; in 1970 came the IMLS (International Mathematics and Statistics Library) or ISML as it was initially called that library of functions.

The availability of computing power, even if negligible today, and of the tools to program it, made it possible to apply statistics, and its evolution in the economic field, namely econometrics, to understand socio-economic phenomena.

At the same time, we had tools managing models with many equations and many variables, with the perspective of forecasting and planning. The strictly operational economic planning, unfortunately, had its moments of most active attention before the significant development of the automatic calculation and was significantly constrained by the lack of this kind of tools.

THE FIRST BIG MODELS, THE SIGNIFICANT ITALIAN EXPERIENCE

The M1 BI model–the first model of the Bank of Italy–was built starting in 1968. It has been referenced in the Bank of Italy's Annual Report for 1971 and published since 1970 (Bank of Italy, 1970). In Draghi (2009), we read that the model received a decisive boost by Guido Carli, as Governor of the Italian Central Bank, and the advice of great scholars such as Franco Modigliani. From other sources, more personal, I remind Bruno de Finetti among the great consultants and the work of Paolo Savona and of the future Governor Paolo Baffi. The model contained 122 equations in 122 variables and was at the limits of the processing capacity for the time.

In 1976, the Confindustria Study Center, on the advice of the president of the industrial association (Carli, also in this case), created its econometric model of the Italian economy. The construction started with the work of Massimo Tivegna, in collaboration with the Wharton Econometric Forecasting Associates / Stanford Research Institute and with CNUCE-CNR of Pisa.

Always in those years, the Modellaccio of Ancona was producing significant results, with Giorgiò Fuà and people from the Centro Scientifico IBM of Pisa (at the time: Carlo Bianchi, Giorgio Calzolari, and Paolo Corsi), and many other names. The Modellaccio was also used by the CGIL (the most relevant left-wing union at that time) to have the capability of analyzing the Italian economy in line with current economic researches. Other models were those of Sylos Labini and the one that originated the Prometeia group. The Turin Model also lived for a few years.

That has been an extraordinary situation in Italy: the best minds of economics committed to the national problems, employing by the new tools of information technology. See Binotti and Ghiani (2006) on the subject.

ECONOMIC PLANNING AND INPUT-OUTPUT MODELS

In a parallel way–always thanks to the new computing facilities–the input-output models were arising, as reasoning tools both for the economic programs in many western countries and the planning in the communist countries (Tretyakova and Birman, 1976). The roots of these models are in the *Tableau économique* by François Quesnay, dated 1758, but already published in various versions in previous years. In Figure 1, we see a table taken from an anastatic reprint.

The theoretical basis of input-output tables of inter-industrial flows of goods and services is in the work of Wassily Leontief; among all the possible references, see Leontief (1966). In Italy, the distinguished scholar Vera Cao-Pinna published her work (Cao-Pinna, 1958) in the same years, with a 23-sector table. It is fascinating that into the cover pages of the book, it is specified: "by the Fiat Statistical Service and Economic Studies and the Fiat Central Mechanized Calculation Service." The production of the so-called direct and indirect final demand activation coefficients requires the determination of the Inverse Matrix Coefficients. In this case a 23 x 23 matrix, whose determination occurred through a mechanized, non-electronic computational structure. Of course, the real development is only with electronic computing and mainly with modern computers. Consider that a contemporary table of the U.S. Bureau of Economic Analysis has 405 sectors.

CENTRAL PLANNING

In countries with a market economy, the knowledge given by input-output tables is useful to understand the direct and indirect effects of economic policies. In that perspective, an analysis, if not at 23 sectors, but with 100 or slightly more, is already important. Instead, if we follow the paradigm of central planning, and we use the table to drive an economy, microdata becomes essential. In this case, the calculation power is crucial, but not sufficient. To plan an economy in its details, we need the data and the decentralization of their collection and utilization.

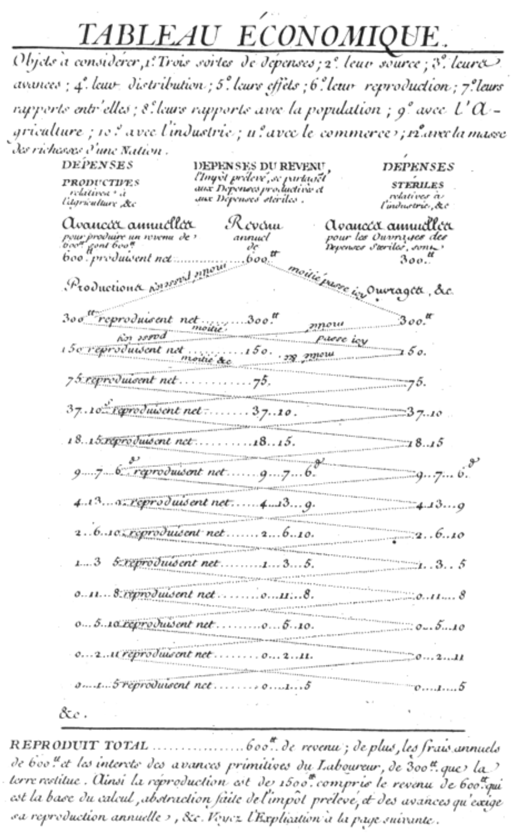

Figure 1 – A page of the *Tableau économique* by François Quesnay, 1758.

In Gerovitch (2008), we read some passages that outline the critical links among information technology, planning economics, and economic reality:

> In October 1961, just in time for the opening of the Twenty-Second Congress of the Communist Party, the Cybernetics Council of the Soviet Academy of Sciences published a volume appropriately entitled, *Cybernetics in the Service of Communism*. This book outlined the great potential benefits of applying computers and cybernetic models in a wide range of fields, from biology and medicine to production control, transportation, and economics. In particular, the entire Soviet economy was interpreted as "a complex cybernetic system, which incorporates an enormous number of various interconnected control loops." Soviet cyberneticians proposed to optimize the functioning of this system by creating a large number of regional computer centers to collect, process, and redistribute economic data for efficient planning and management. Connecting all these centers into a nationwide network would lead to the creation of 'a single automated system of control of the national economy.

> Yet the grandiose plans of Soviet cyberneticians to reach optimal planning and management of the national economy by building a nationwide network of computer centers never came to fruition. Western analysts have commented on the technological obstacles to the development of Soviet computer networks, such as the lack of reliable peripherals and modems, poor quality of telephone lines, and weak software industry.

The great computerized economic plan did not turn into a reality due to a sequence of complex contrasts between the decision-makers much more than for technological problems. The main issue was the design to create a perfect top-down system, forgetting the necessity of proceeding by trial and errors, adaptations, and learning, which characterizes the development of any wide-ranging computerized system. In Gerovitch (2004, last chapter) we have an in-depth analysis of the complex links between economic problems, power considerations, bureaucratic resistances, and cybernetic perspective, with continuous references to Berg (1961)[2].

AGENT-BASED SIMULATION, ALSO FOR PLANNING

More recently, starting about 30 years ago, we had Agent-Based Models (ABMs), that can also be used to implement experiments and trial and errors learning processes.

This methodology allows the construction of artificial worlds populated by agents, which interactively explain the emergence of macro-type effects with their behavior. Considering the random components in the actions of those agents, it is also a sort of social extension both of Monte Carlo methodology and Discrete Event Simulation (DES); in each case, adding cognitive abilities and decision making into the agents.

[2] About the title: in Gerovitch (2008) we have "*Cybernetics in the Service of Communism*"; in Gerovitch (2004), "*Cybernetics–in the Service of Communism*" with a note explaining that «The gist of the dash in this title was "must be put»." The translator of the Office of Technical Services, U. S. Department of Commerce used "*Cybernetics at the Service of Communism*."

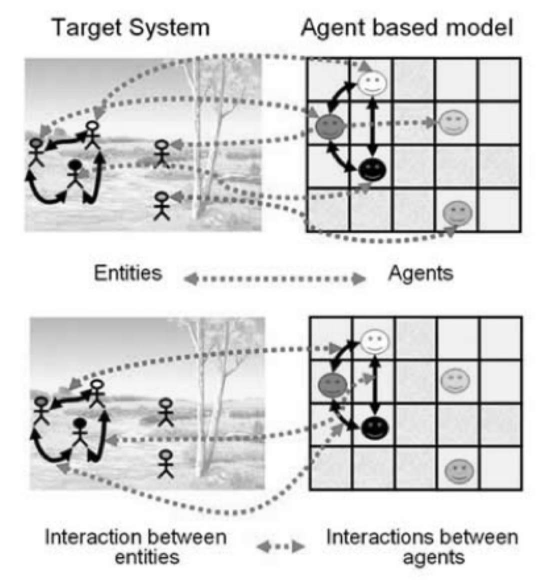

Figure 2 – ABMs in two pictures: the image is due to Bruce Edmonds, http://bruce.edmonds.name.

Paraphrasing and integrating an excellent Wikipedia entry:[3] ABMs are computational models to simulate the actions and interactions of autonomous agents. Agents are individuals or collective entities such as organizations or groups to assess their effects on the system as a whole. They combine elements of game theory, complex systems, emergence, computational sociology, multi-agent systems, and evolutionary programming. Monte Carlo methods are used to introduce randomness. In particular, in the field of ecology, ABMs are also called individuals-based models (IBM), and individuals can be simpler than fully autonomous agents as within ABMs. Recent literature on IBM-based, ABM, and multi-agent systems, shows their use on vast scientific domains, including biology, ecology, and social sciences. Agent-based modeling is related, but distinct from the concept of multi-agent systems or multi-agent simulation (MAS, for Multi-Agent Systems). Building an ABM we want to know the effect of the collective behavior that emerges from agents who obey more or less complex rules, typically in natural systems. Instead, the purpose of a MAS is to design agents to solve specific problems, mainly in an engineering perspective.

A self-explanatory image of an agent-based simulation framework–and of the role of the scholar who constructs it–is that of Figure 2, due to Bruce Edmonds: on the left, we have the real agents,

[3] https://en.wikipedia.org/wiki/Agent-based_model

including the observers within the simulation, on the right the agents artificial and their interactions, which exclude observers.

The first generalized program for agent-based simulation has been Swarm, presented in the mid-1990s by scholars working at the Santa Fe Institute; see Minar et al. (1996).

FROM ARTIFICIAL INTELLIGENCE AND ABMS BACK TO THE MARKETS AND THE ECONOMIC PLANNING, VIA CHESS GAMES

Kasparov (2018) offers us a fulminating *incipit*:

> The recent world chess championship saw Magnus Carlsen defend his title against Fabiano Caruana. But it was not a contest between the two strongest chess players on the planet, only the strongest humans. Soon after I lost my rematch against IBM's Deep Blue in 1997[4], the short window of human-machine chess competition slammed shut forever. Unlike humans, machines keep getting faster, and today a smartphone chess app can be stronger than Deep Blue. But as we see with the AlphaZero system (…), machine dominance has not ended the historical role of chess as a laboratory of cognition.

AlphaZero (Silver et al., 2018) is a computing system capable of learning without outside help: this is the key to everything. The system at the beginning knew only the rules of chess, without integrated human strategies. In a few hours, it played more games against itself than the total of the recorded matches in the history of human chess. It became strong enough to defeat Stockfish, i.e., the program previously considered the best chess electronic player. It won–in the first match of which we had news in December 2017–28 games, drawing 72, never losing. In April 2019 the announcement of a new confrontation in which AlphaZero, out of 1000 matches, won 155, lost 6, drawing the rest. Meanwhile, in May 2019, Stockfish is back to win the world championship for programs (AlphaZero does not participate).

Again, with Kasparov, chess represents the *Drosophila melanogaster* (the fruit fly, considered a model organism for genetic research) of artificial intelligence. The traditional criticism is that

[4] In 1996 the winner was Kasparov; after the computer's victory in 1997, there were many suspicions of manipulating computer responses; these are very distant times, given the current results of the machines.

the machine uses methods of analysis and decision different from those of the human brain. This is no longer a valid consideration. AlphaZero has independently learned and selected the best choices and, as Kasparov notes: « (…) AlphaZero prioritizes piece activity over material, preferring positions that to my eye looked risky and aggressive. Programs usually reflect priorities and prejudices of programmers, but because AlphaZero programs itself, I would say that its style reflects the truth.»

Indeed, it is the *Drosophila*. We cannot imagine, at least over the next few decades, that a system with self-learning, after having assimilated–by breaking down the concepts–all the texts of philosophy, gives us the fundamental answer. Most likely, it will be able to find the inconsistencies and contradictions within many systems of reasoning. Economics is a research field simpler than philosophy. Sure, it is complex; i.e., we cannot linearly analyze its phenomena (if not at the price of excessive simplifications). Anyway, in that field, machine intelligence can instead produce surprising suggestions, very promptly.

How Amazon delivers us not routinary items in just a few hours? It feeds its warehouses, mostly decentralized, based on forecasts and we know that it does so using relatively soft artificial intelligence. An interesting article by the Economist (2019), as always without a signature, proposes another significant *incipit*: «Amazon's six-page memos are famous. Executives must write one every year, laying out their business plan. Less well known is that these missives must always answer one question in particular: how are you planning to use machine learning? Responses like "not much" are, according to Amazon managers, discouraged.»

A so huge buyer decision on how much to buy is not far from deciding how much to produce; moreover, choosing selling prices for that production is very close to planning the economy. The same is for oligopolies such as Walmart, Alibaba, JD.com.

From "Il ministro della produzione nello stato collettivista" of Enrico Barone–one of the "three of Lausanne", less quoted than Léon Walras and Vilfredo Pareto, but also to be carefully studied–we read (Barone, 1908b, p. 410, Italian version; here we quote from the Barone, 2012, the published translation, p. 110):

> The determination of the coefficients economically most advantageous can only be done in an *experimental way*: and not on a *small scale*, as could be done in a laboratory; but with

experiments on a *very large scale*, because often the advantage of the variation has its origin precisely in a new and greater dimension of the undertaking. Experiments may be successful in the sense that they may lead to a lower cost combination of factors; or they may be unsuccessful, in which case that particular organization may not be copied and repeated and others will be preferred, which *experimentally* have given a better result.

The Ministry of Production could not do without these experiments for the determination of the *economically* most advantageous technical coefficients if it would realize the condition of the minimum cost of production which is *essential* for the attainment of the maximum collective welfare.

It is on this account that the equations of the equilibrium with the maximum collective welfare are not soluble *a priori*, on paper.

Some collectivist writers, bewailing the continual destruction of firms (those with higher costs) by free competition, think that the creation of enterprises to be destroyed later can be avoided, and hope that with *organized* production it is possible to avoid the dissipation and destruction of wealth which such *experiments* involve, and which they believe to be the peculiar property of "anarchist" production. Thereby these writers simply show that they have no clear idea of what production really is, and that they are not even disposed to probe a little deeper into the problem which will concern the Ministry which will be established for the purpose in the Collectivist State.

As a summary: Barone demonstrated, thanks to a rigorous mathematical analysis (which begins in: Barone, 1908a) that, without a price system that changes through trials and errors, determining as a consequence the production choices, the success of the *ministro della produzione dello stato collettivista* is impossible. I suggest to read the work of Barone, to find out what the level of economic research was at the beginning of the '900!

The same perspective of analysis, with the work of Mises (1920), generating the famous debate on the so-called *economic calculation problem*.

The great novelty is that, with artificial intelligence and ABMs, it is possible to simulate those processes of trial and errors, in a way that his unlucky minister could not even imagine. While AI is generating possible choices, ABMs can quite easily verify the consequences of those choices. The oligopolistic companies quoted above are doing something very close to this kind of operation. In Phillips and Rozworski (2019), we can find plenty of examples. The title of the book is strictly related to the perspective we analyze here: "*The People's Republic of Walmart: How the World's Biggest Corporations Are Laying the Foundation for Socialism*."

To conclude

As reported above (Gerovitch, 2008), very excellent ideas had been proposed in the Soviet Union system. Why failure? As we saw, it was not just a matter of hardware problems, but a profound controversy over the power and the organization planning. A key document is Berg (1961) that we have to analyze with the help both of Gerovitch (2004, Chapter 6) and of Malcolm (1963). The U. S. Department of Commerce translated the Berg's volume with the title "*Cybernetics at the service of communism*." Instead, Gerovitch (2004) uses "*Cybernetics–in the service of communism*" explaining in Note 16 of Chapter 6 that "The gist of the dash in this title was 'must be put'."

Currently, the entire construction of a cyber structure run by Artificial Intelligence is hypothetically possible, and the economic world is moving in a silent and accelerated way toward new structures, shaped by artificial intelligence. To conclude, from a quite recent interview to a very innovative economic thinker (Arthur, 2019, personal transcription):

> Arthur: (…) we're all familiar with the standard economy, which is an economy of I think 50 years ago, 100 years ago, an economy of factories and of vehicles and workers, etc. Now we have an economy that I vaguely see as under the surface. It's a digital economy or a virtual economy. I like to call it the autonomous economy. It's an economy of machines talking to machines, servers talking to servers, algorithms in conversation with other algorithms, making decisions. A lot of the economy, the decision-making, the control of production, the consumer choices and ordering things online is done on the Internet and done autonomously and increasingly done with this external intelligence I'm talking about. It's always on. It's not as if it's only on during working hours like shops are. It's always on. It's self-governing to quite a degree. It's decentralized. There's no central controller of this.
>
> Q: In a sense, it can set its own parameters or tune itself or allocate resources appropriately without human intervention. Is that part of the idea?

> Arthur: Yes, it is self-adjusting, self-organizing, self-healing. Everything is changing rapidly on the fly.
>
> Q: How important will rules about how we govern data and how we govern the intelligence systems themselves be as this autonomous economy evolves, matures and perhaps occupies more of the space that was occupied by the old traditional economy?
>
> Arthur: I think it's hard to overstate how important rules will be. I've studied a lot of technologies in the past, including railways, including early computers, including way back to printing. The pattern always is that the technology becomes available. Nobody quite knows what to do with it. Cars became available around maybe 1900, a bit before, a bit after, and they frightened horses. Nobody quite knew what to do about that. They didn't know what to do about an intersection. Traffic lights hadn't been quite thought of. Rules of the road weren't very clear.
>
> (…)
>
> Q: Yet we need to establish new rules for this new economy in the face of companies who have dominance that we haven't really seen historically. That suggests that there is a tension and actually quite a lot of friction in the process by which these new rules will evolve and one that will cause quite a lot of friction over the next couple of decades until we stabilize.
>
> Arthur: (…) I think we've seen a good deal of that already. The controlling factor isn't governments. They never quite know what to do about these huge tech companies. It's much more society. Something awful happens like Facebook might get used to sway an election in Europe or in the United States, maybe not their fault, and then society comes down like a ton of bricks and new regulations get passed. I don't see that there is an intelligent godlike way to govern all this. We're new territory all the time. As these big technologies come online, we're learning about different problems and really reacting to those rather than anticipating the problems in advance and doing something about it then.

We can summarize: a dream or a nightmare? With Arthur, in this «new territory,» we need new policies, the emergence of new policies. What a wonderful, or terrifying, new research field for social scientists.

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