An Agent-Based Approach to the Limits of Economic Planning

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Abstract

Mises' and Hayek's arguments against central economic planning have long been taken as definitive proof that a centrally planned economy managed by the government would be impossible. Today, however, the exponential rise in the capacities of AI has opened up the possibility that supercomputers could have what it takes to plan the national economy. The 'economic calculation debate' has thus reignited. Arguably, this is because neither Mises nor Hayek have given a clear and conclusive argument why central planning of the economy is impossible *in principle*. The paper frames the problem of economic planning as an agent-environment interaction, offering a taxonomy of the different sets of agents at play a) in a market economy and b) in a centrally planned economy equipped with the most sophisticated AI technology. The argument is that public institutions as planning bodies cannot replace the market order, no matter the AI technology behind them, for the elimination of the market entails the elimination of crucial kinds of agents that cannot be recreated or emulated through AI or careful social planning: the proactive action of entrepreneurs driving market allocation.

Keywords: Calculation Debate, Knowledge Problem, Lange-Lerner Model, Artificial Intelligence, Agency

1. Introduction

Mises (1963; 1996) and Hayek (1945; 2014) have crafted compelling arguments against central economic planning. What is variously referred to as the 'Mises-Hayek thesis', the 'calculation problem', or the 'knowledge problem' is a family of arguments against economic planning (Yeager 1994; Polanyi 2013; Kiesling 2015; Gmeiner and Harper 2022). The claim is the impossibility for a central planner to realize the optimal distribution of goods in society as to meet the preferences of all economic actors. Consequently, it is impossible for a government, or any other planning authority, to achieve what the market order already accomplishes spontaneously in a free-market economy. However, Mises and Hayek have not offered clear enough reasons why central economic planning is impossible *in principle* to defuse the attempts to employ AI technology to solve the issue. A plausible proposal is that entrepreneurs are the agents crucially distinguishing a market economy from a planned economy.

The core of the problem is that the huge amount of information needed to plan the economy is never available to a single economic actor. Knowledge about people's preferences, needs, opportunities for innovation, availability to work, and so on, is dispersed in society and cannot be retrieved by the central planner. Moreover, this information is constantly changing with the evolving context of economic activities.

> The economic problem is thus not merely a problem of how to allocate 'given' resources – if 'given' is taken to mean *given to a single mind* which deliberately solves the problem set by these 'data'. It is rather a problem of how to secure the best use of resources known to any of the members of society, for ends whose relative importance only these individuals know. Or, to put it briefly, it is a problem of the utilization of knowledge not given to anyone in its totality. (Hayek 1945: 519-520, emphasis mine)

The market order, on the other hand, can operationalize this knowledge because market competition does not require any economic actor to know all the salient economic facts across society (Hayek 2016). The market solves the economic problem through the 'price system', i.e. the distributed communication system that signals variations in the availability and demand of certain resources, assets, or products as a result of economic actions and preferences (Hayek 1945; Mises 1996).

1.2 The Price System

There are two phases of the allocation of resources that cannot be adequately emulated by the central planner:

- The central planner cannot *access and collect* all the necessary economic knowledge 'in the absence of market prices for the factors of production' (Mises 1963: 705).
- The central planner cannot *compute* all the necessary economic knowledge in such a way as to generate one correct and consistent allocation of resources, even 'if all data were given to a single mind' (Hayek 1945).

The price system accomplishes both at once, as the signaling action performed by changing prices causes simultaneous changes in the allocation of resources (Kirzner, 1984). In the same vein, economic knowledge gives shape to the overall states of the economy and reconfigures the array of available opportunities, resources, preferences, and so on from moment to moment. In this sense, the conceptual tool of

'market equilibrium' should not be interpreted as the goal of the economy, but as a theoretical fiction to understand the tendency of producers to quell consumers' demand (Kirzner 1997). Thus, there is no such thing as a static corpus of economic knowledge that one could manipulate to discover an optimal distribution of resources, for 'economic data are forever changing, so that the static nature of economic activity is only a theoretical assumption corresponding to no real state of affairs' (Mises 1963: 109).

The price system must encapsulate information necessary to everyone is just a priori impossible to determine, as one cannot predict which factors will become relevant in any given transaction in the real economy (Felin et al. 2014; Kirzner 1982; Moreno-Casas 2022). This includes information about available financial assets, the location of raw materials, the distribution and availability of production facilities, all the way to more qualitative knowledge such as personal preferences, inclinations, know-how, individual ability to sell products or set prices, personal acquaintances. As an example, the central planner would not only need to know how much money Sarah has in her bank account and the fact that she needs a car to drive to work every day: in order to find the most efficient allocation, the planner would also need to know that the local mechanic is her uncle and would be willing to treat her to a discount just because it is her asking.

Economic knowledge is particularly tricky to gather and compute not only because the range of information to be collected is huge and changing. Hayek stresses the difference between economic *data* and economic *knowledge*, two kinds of economic information that are equally handled by the price system(Hayek 1963; 1982; 2014). Essentially, economic data refers to all the econometric indicators normally at the disposal of the economist or the central planner, e.g. income, assets, credit score, investment history, or GDP and the like. Economic knowledge refers instead to information that is both:

- *Situated*, meaning that it is essential that it is held by the relevant economic actor(s) and takes place in a certain context (Kirzner 1973; 1984).
- *Tacit*, meaning that it can be inarticulate, implicit, subjective, or otherwise radically qualitative – think of the practical knowledge I have about my own abilities or preferences, even for things and activities I do not have a conscious preference for (Polanyi 2013; Kiesling 2015).

1.3 AI Enters the Picture

At a certain point in the debate, the supporters of central planning have turned to AI and, more generally, to computational techniques to advance solutions to the calculation problem once and for all. As Oskar Lange, the founding father of so-called 'market socialism', puts it:

> Let us put the simultaneous equations on an electronic computer and we shall obtain the solution in less than a second. The market process with its cumbersome *tatonnements* appears old-fashioned. Indeed, it may be considered as a computing device of the preelectronic age. (Lange 2002: 1)

Admiring the rising success of new technologies, the supporters of planned economies started designing models to replace human bureaucrats and social engineering with data harvesting and manipulation. These ideas have been interchangeably named 'technosocialism', 'cybersocialism', or 'digital socialism' (Boettke & Candela 2023; Limas 2018; Morozov 2019). Based on the work of Stafford

Beer and other founding fathers of the field of cybernetics, Salvador Allende's Chile was the first to launch a computerized system – called CyberSyn in 1972 – to run the national economy. However, the program was scrapped prematurely as a result of the 1973 coup (Beer 1959; Medina 2011; Wiener 2019). Since then, attempts to achieve technosocialism have materialized only as theoretical contributions.

The rationale that supercomputers first, and AI proper after that, could be used to manage the complexity of the economy better than the spontaneous order of the market is simple enough.[1] Lange, as shown in section 3, proposed to emulate the elaboration of prices in the economy through a trial-and-error process. Trial and error of a whole national economy can be cumbersome, costly, and dangerous, however. Hence the idea of testing various possible allocations of resources and production solutions virtually, by exploiting a computational power orders of magnitude greater than those of functionaries working with paper and pen.

To sum up, the supporters of economic planning frame the problem as a quest to find the best optimizing algorithm that computes the best allocation of resources out of hte available economic data. Given the possibility to gather all the necessary economic knowledge about those variables, and given enough computational power, the problem looks tractable in principle. However, the issue with economic planning is deeper than that, because the workings of the market order are not a form of optimizing algorithm nor there is anything to optimize in the first place (Felin et al. 2014; Carissimo and Korecki 2023). Rather, as Hayek had already pointed out, the market works as a spontaneous order that operates through *evolutionary* processes with no real convergence to an optimum (Hayek 1982, 2014b; Mirowski and Somefun 1998).

1.4 The Argument

This analysis of the Mises-Hayek thesis reflects both on economic knowledge and on the structure to convey it. To reiterate, that economic planning is *impossible* due to some of the above reasons can potentially mean two things. The 'impossibility' can either refer to an empirical fact, implying that we might find ways to collect and manage all the information needed for economic planning in the future (e.g. through AI techniques), or to a conceptual impossibility, meaning that the economic system is just not something that can be planned centrally.

In the former interpretation, the economic problem might be solved in the future through some technological breakthrough, e.g. quantum computing or General AI. Indeed, this is the route paved by some of the first responders to Mises and Hayek. Lange (1936) contended that

> they do not deny the theoretical possibility of a rational allocation of resources in a socialist economy, they only doubt the possibility of a satisfactory practical solution of the problem' (1936: 56).

While his claim is debated by some commentators like Kirzner (1984),[2] plausibly Mises and Hayek did not insist properly on the scope of their arguments. Thus, much

[1] The supporters of economic planning are motivated by the contention that careful governmental intervention may allocate resources in the economy in a more efficient and fairer way, enabling politicians to prevent corruption and inequality. Moreover, an economy under governmental control may be steered to pursue political values or macroeconomic goals, such as diverting resources toward the construction of essential infrastructure or to tackle national emergencies (Cockshott & Cottrell 1993; Cohen 2009).

[2] Lange himself gives two proofs of his claim. Robbins, echoing some of Mises' remarks, comments: 'On paper we can conceive this problem to be solved by a series of mathematical

room for maneuver has opened to subsequent proponents of central planning that tried to solve the practical impossibility through the wonders of AI.

Before addressing the main issue, some clarificatory remarks are in order. The claim of socialist economists and philosophers against the Hayek-Mises thesis does not concern the government's ability to steer partial aspects of the economy through economic policies, such as price regulations or demand stimulations (Cockshott, 2007; Mises, 1963). Rather, the focus of central economic planning lies in the works of Soviet economists or foreign admirers of the USSR, who sought to develop alternative economic systems where property rights, the price system, and free market transactions would be abolished (Barone, 1963; Kantorovich, 1960). In that literature, governmental plans would replace the market order in all its functions, allegedly with greater efficiency and fairness for all. Hence, the Mises-Hayek thesis examined here is not a reason against forms of state intervention in the market economy to manipulate the outcome of particular market configurations. Economic planning, to the contrary, must span over all kinds of products and resources available in society, and concern all kinds of needs and preferences of economic actors.

As a consequence of the fact that economic planning is supposed to replace the market economy, either by the means of social engineering or modern AI technology, such planning is supposed to serve ideally all the *particular* preferences of all the economic actors. Hence, it is not sufficient to show that the planner may plan the production of 500 cars of such and such varieties and kinds to meet the needs that a town of 1000 people might have. Production must be coordinated in a way that gives each of those 1000 people the car of the exact type that they would have chosen to buy in a free market, or whatever else they would have chosen to buy instead.

Finally, the paper addresses the most classic models of *central* economic planning, where economic plans are enacted ultimately by one single central planning body. There have been lately some proposals to overcome the limitations of these socialist models by relaxing one of the core tenets of socialist economic planning, namely centralization – that is, by realizing decentralized forms of AI-assisted economic planning, which sometimes goes by the name of 'democratic economic planning' (Saros 2014, Morozov 2019; Nieto 2021). These later attempts do not automatically reject all of the claims of the Mises-Hayek thesis and should be treated in a separate paper.[3]

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calculations […] But in practice this solution is quite unworkable' (Robbins 1934: 151). The second source is from Hayek himself – although Lange omitted the nuance of the second sentence of the following quotation, where Hayek is responding to Taylor's (1929) and Crosby Roper's (1929) proposed solution to the calculation problem: 'Now it must be admitted that this is not an impossibility in the sense that it is logically contradictory. But to argue that a determination of prices by such a procedure being logically conceivable in any way invalidates the contention that it is not a possible solution, only proves that the real nature of the problem has not been perceived' (Hayek 1963: 207-208). For Hayek's own response to Lange, see also Hayek (1982).

[3] Whilst Mises and Hayek are vocal supporters of free markets and capitalism in general, the paper wishes to remain silent on the sustainability or morality of capitalism as a system. The argument just substantiates the Mises-Hayek thesis toward a conceptual impossibility of economic planning regardless of any advance in AI technology. This entails the impossibility of replacing the decentralized operation of the price system with known technological means. However, capitalism as a whole still has to put up with new developments that Mises and Hayek hardly could have imagined in their time. These include the issues related to climate change, as well as the birth of multinational corporations so big and efficient to have the potentiality to hijack portions of political power away from governments. Thanks to an anonymous reviewer for prompting these remarks.

The following approach supports the claim that economic planning is *conceptually* impossible. The bottom line is that we should understand the problem of economic planning as an interaction between different kinds of agents with different levels of agency. To solve the economic problem and replace the market order, the central planner must have the relevant agential capacities. As a result, the central planner must not only surround itself with amazing AI technology: it must constitute or support a system of suitable agents to display the needed capacities. The argument, therefore, is that there is no central planner that can be in this position, because neither AI nor collective action can provide the right kind of agency. Rather, market allocation must be orchestrated by individual entrepreneurs, as they possess a 'proactive' level of agency. It is entrepreneurs, in fact, who can uncover and update the consumers' preferences and the investments of producers, while navigating the complex development of the economy by providing innovation. This idea applies to both the 'analogical' and the 'digital' proposed approaches to economic planning. In short, the adoption of the most advanced AI systems cannot improve the models of planned economies substantially enough to overcome the Mises-Hayek thesis.

2. Agency and the Economy

Much of the calculation debate has been spent on either the nature of economic knowledge or, more rarely, on the complex character of the economic system.[4] While there is truth to these approaches, a *conceptual* impossibility of economic planning must be proven by showing that the agents involved in planned economies do not have the necessary agential capacities to solve the economic problem. Only such an ontological approach can conclusively state that central planning is out of reach no matter how sophisticated the AI systems at the disposal of the planning authorities. This section will thus introduce an ontological treatment of agency suitable to *collective* agents such as public agencies and *AI* agents. By highlighting the different agents in a market economy and in a planned economy, the paper will be in a position to discuss the classic models of AI-assisted economic planning.

2.1 The Concept of Agency

Economists routinely speak of 'agents' or 'actors' to conceptualize economic phenomena. Yet, their use of the terms is usually quite loose in the sense that economic actors are just framed as the simplified subjects of economic decisions, e.g. the *homo oeconomicus* of neoclassical microeconomics (Simon 1957; Sen 1977). It makes no difference that economic actors may enter the market with different capacities, in different contexts, or even as different entities. For example, neoclassical economics defines microeconomic buyers and sellers and macroeconomic firms or governmental agencies as rational constrained maximizers. By adopting a stronger take on agency and trying to import real-world agents into the market economy, economic models may appreciate different levels of agency – including the different perspectives and roles that individual entrepreneurs and the central government have in the economy. In fact, those who treat the Mises-Hayek thesis as an empirical claim must assume that the market participants and the central planner are essentially the same agents with the same capacities, just situated from different points of view.

[4] See, for instance, Boettke and Candela 2023; Gmeiner and Harper 2022; Felin et al. 2014; Lambert and Fegley 2023; Yeager 1994; Kiesling 2015.

An agent is an entity capable of performing actions, as opposed to merely making things happen. This is the difference running between, e.g., Jenny throwing an apple at Mary and a tree hitting Isaac on the head with a falling apple. Agency entails two essential features:

- It is (at least broadly) intentional, meaning that it can develop internal states that are directed toward the realization of the event that is the outcome, or goal, of the action.
- It is autonomous in the interaction with its environment, i.e. can perform actions without external intervention of other systems.

These features are the minimal requirements for something to count as an agent. For instance, even something as simple as a thermostat can autonomously interact with its environment to realize an increase in the room's temperature at the right conditions.

2.2 Agential Structure and Agential Dispositions

This is a deflationary account of agency, as it accommodates as agents many more entities than are usually found in the literature. In fact, much of it has traditionally focused on fully capable human agents, well-structured social institutions, or sometimes non-human animals. If anything can be treated as an agent, provided it can autonomously show directedness in the above sense, several kinds of agents appear. They can be organized based on two factors: their structure and their agential dispositions.

The agent's structure comprises the characteristics of its inner makeup – its attributes as a substance, if you will:

- *Natural systems*, whose individuality and agency rest on biological processes (Barandiaran et al. 2009).
- *Collective systems*, groups of people (or other organisms) that can perform actions as distinct from the actions of their members (Bratman, 1999; Searle, 2002; Tuomela, 2007). For instance, a couple moving a couch across the room: assuming the couch is heavy enough, no single member of the couple can be said to be moving the couch herself.
- *Automated systems*, artificially designed so that their elements are arranged to perform certain actions.

Agential dispositions express what a certain agent can or cannot possibly do. Much like normal dispositions (e.g. a glass' disposition to break under certain conditions), agential dispositions are defined and delimited by the nature of the agent's structure:

- *Active*, displaying the mere ability to act autonomously in the environment and point to some end-state triggered by certain surrounding conditions. As explained by List and Pettit (2011), the minimal conditions for something to be an agent may be: a) the ability to detect the surrounding environment, b) the ability to represent how things should be in the surroundings, c) the ability to act in the environment based on (a) and (b).
- *Reactive*, displaying the ability to determine the course of action to reach a given goal. List and Pettit (2011) call this ability a basic form of 'rationality', amounting to the development of *second-order* internal states.

- *Proactive*, displaying the ability to generate new goals to pursue, effectively showing a sort of *will*. The difference between reactive agency and proactive agency lies in what Ezenkwu and Starkey call, respectively, 'low-' and 'high-level autonomy': the latter is the proactive ability to pursue goals that are 'not explicitly defined in the environment' (2019: 340). On the other hand, agents with low-level autonomy cannot freely choose the goals they strive to achieve.

2.3 A Taxonomy of Agents

These two dimensions capture important operational insights on the notion of agency. One can evaluate what an agent can or cannot do in a certain environment – for instance, in the context of a national economy – based on the observation of its behavior, i.e. assessing its agential dispositions. At the same time, though, any agent's level of agency is bounded by its structure, so that one cannot possibly expect a certain behavior by an agent whose nature does not allow for the relative dispositions to arise. Hence, the agent's structure acts as the condition of possibility for the agent's level of agency.

	ACTIVE	REACTIVE	PROACTIVE
NATURAL	Biochemicals	Viruses	Organisms
COLLECTIVE	Mobs	Organizations	Corporate Persons
AUTOMATED	Agentic Artifacts	Artificial Intelligence (AI)	Artificial Persons (AGI)

Table 1: Taxonomy of agents (Martinelli, 2023).

An example of an active automated agent would be a speeding radar. The radar can, without external intervention, develop internal states that are directed to the realization of a new state of affairs (namely, issuing a fine ticket to speeding cars). It can do so when the right circumstances take place (a passing car drives faster than the pre-set limit), but it has no control on how the fine is issued or on whether special circumstances should waive the fine or alter the speed limit. Reactive agents, as said, can autonomously direct their goal's pursuit in response to changes in the environment. A chess-playing machine, i.e. a reactive automated agent, can pursue the goal of winning the match in different ways depending on the opponent's moves and strategy. Proactive agents, such as human people, are not only capable of navigating the environment to pursue a pre-determined goal but can make spontaneous resolutions to identify new goals for themselves, e.g. abruptly walking away from their office to go take a walk by the lake.

3. Models of Central Planning

With a working theory of agency in place, the problem of economic planning can be framed in terms of agent-environment interactions. The market order, which the supporters of planned economies seek to overwrite, elaborates allocations of products and resources through the combination of several different agents with different arrays of agential dispositions. For a planned economy to do the same, a certain planning model ought to provide the same agential dispositions. Therefore, the two main models that have been proposed to plan the economy with the aid of AI systems – the Lange-Lerner model in its latter formulations, and the Cockshott-

Cottrell model – must stand in comparison with an agential reading of the market economy.

This comparison will provide an argument against planned economies in section 4. They lack the proactive agents, namely the entrepreneurs, that are considered to be the real driving force pushing the market toward the correct allocation of products and resources (Kirzner 1973a, 1973b, 1997). Central economic planning, to the contrary, cannot tolerate the presence of self-interested entrepreneurs deviating from the collective plan.

3.1 The Free Market Economy

Consider the following proposal of how the market order enacts the price system described by Mises and Hayek.

	ACTIVE	REACTIVE	PROACTIVE
NATURAL	Buyers/Sellers	Employees/Managers	Entrepreneurs
COLLECTIVE	Market(s)	Firms/Governmental Agencies	
AUTOMATED	Algorithmic Software	AI Traders	

Table 2: Agents at play in a market economy.[5]

The above conceptualization is of course a simplification of how the economy in its entirety works, an approximation tailored to visualize the formation of market allocation in particular. Moreover, of course all human beings involved in the processes of the economy always retain their original capacity for proactive agency. However, *in their economic function*, economic actors may only need to display lower agential dispositions depending on the task at hand. Human economic actors, for instance, merely behave as 'active agents' as they buy and sell goods and services, thereby prompting signals to the overall price system in response to certain local conditions (e.g. certain availabilities, certain preferences, and relative prices of substitute goods). Similarly, employees and managers alike act *reactively* relative to their economic function, as they strive to realize a goal imposed externally to them (from their boss, their company, or the company's shareholders). The human economic actors that, economically speaking, express their proactive agency in pursuing new goals and values in unpredictable environments are entrepreneurs. They are, as a result, the real driving force of innovation and market allocation.

Moving to the artificial agents involved in the market economy: 1) active mobs, i.e. local market configurations that under certain conditions express certain aggregate effects (such as a raise in price of gasoline as a response to widespread higher demand); and 2) reactive organizations, i.e. firms and governmental agencies, which pursue goals that result respectively from the aggregation of their shareholders and of politicians, bureaucrats, or popular voting. Automated agents such as ADMs and AI systems may be found acting in the market economy as algorithms that assist or automate certain processes of economic decision-making or the organization of supply chains. These may include data-manipulation algorithms in big companies, or AI traders buying and selling stocks by adapting to market conditions.

[5] Combinations of these agents, such as systems of AI machines working in parallel, or hybrid decision-makers composed of human équipes and AI recommendation systems, can be reduced to the simpler categories of collective agents and automated agents.

3.2 Lange-Lerner Model

The Lange-Lerner model, developed by Oskar Lange and Abba Lerner, has arguably been the single most influential model for a planned economy throughout the Cold War (Lange 1936; Lerner 1938). The model is the foundation of 'market socialism', as it tries to recreate the trial-and-error processes that bring the market to the perfect allocation of products and resources, while substituting the price system with a sophisticated algorithm to centralize control.

Lange and Lerner echo the Italian economist Enrico Barone (1963), who reinterpreted Walras' (1965) and Pareto's (2014) classic works on the formalization of market equilibrium to describe the abstract functioning of a central planned economy. The idea is that the market clears thanks to the price system's tendency to equalize supply and demand for any given product and resource in the economy through trial-and-error adjustments of relative quantities. Buyers and sellers bid on prices and experience shortages and surpluses that are progressively corrected by market competition with the adjustment of relative prices. As Vilfredo Pareto had argued, This process may be described abstractly as a huge system of differential equations, matching available production functions to consumers' preferences (2014). Pareto himself warned against the idea that all the necessary information conveyed by such equations is ever consistently located anywhere in the economy. This is similar to what Hayek had later contended in formulating the knowledge problem:

> It is an impermissible falsification of the sequence of cause and effect to claim that the 'data' presumed (though not known) by the theorist are also known to [the planner]. (Hayek 1982: 2)

Many supporters of economic planning just assumed the neoclassical tenet that all the economic information dispersed in the economy may be captured by the economist's models. Hence, they assumed that new computational techniques could be harnessed to gather and compute all the knowledge necessary to plan the economy.

Lange and Lerner developed a model to solve this system of equations without relying on the spontaneous order of the market. The idea is that the Central Planning Board should start with delineating a set of production goals that are supposed to capture the needs and preferences of the people. Lange is vacuous on how the government should keep track of the dynamic, subjective, and often contradictory preferences of individual economic actors. With a collective plan in place, the government shall distribute the resources and assets available in society to the (nationalized) enterprises that make up the various sectors of the economy. Each industry is run ultimately by public managers whose task is to realize their part of the collective production plan while minimizing the costs of production. After every production cycle, each industry is supposed to communicate their shortages and surpluses, and request/give off resources and assets from/to industries in other sectors of the economy. Over time, the economy may thus reach equilibrium, i.e. a perfect alignment with the production plan and, therefore, the people's preferences.

Lange himself, as said, later realized that this model lends itself to automatization through digital means (Lange 2002). This is because the execution of the production plan is already *algorithmic* in some sense. Production plants have to react by registering their inputs, comply with the outputs set by the Central Planning Board, and then influence the supply and demand for resources and assets of correlated plants. The overall trail-and-error progression toward the state of equilibrium is obtained by the aggregate decisions of public managers taking care of

smaller portions of the collective plan. As a result of the alleged computational nature of the economic problem, which is solved in analogue terms by market institutions, 'mathematical programming turns out to be an essential instrument of *optimal* long-term economic planning' (Lange 2002: 4).

The way in which public industries in the Lange-Lerner model compute the perfect allocation of products and resources resembles many aspects of modern-day neural networks. Neural networks are popular AI models that exploit the capacity of parallel computation by millions of smaller functional unites, called 'nodes' of the networks or 'neurons' (Fodor & Pylyshyn 1988; Smolensky 1987). Each node is tasked with relatively simple logical operations, and it is programmed to fire in response to the connection with few neighboring nodes. Neural networks are then usually trained with massive amounts of data to recognize patterns of node activations that are likely to produce expected outputs in relation to certain inputs (Feldman & Ballard 1982). As a result, the system can reliably produce outputs constrained to satisfy certain requirements by learning to modify the relative weight of the connections between the nodes.

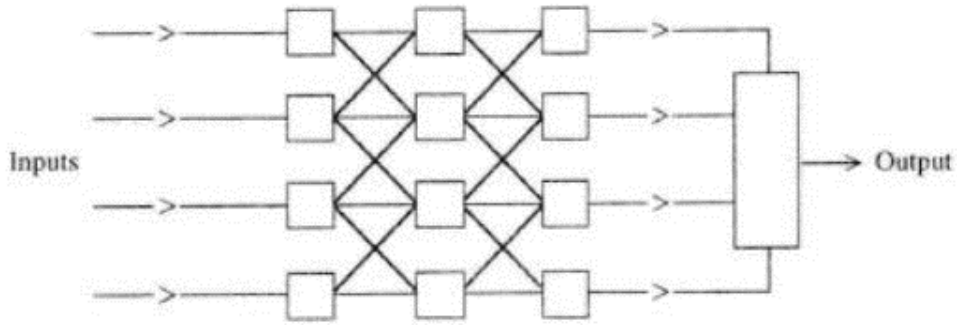

Figure 1: model of a basic neural network (Smith & Reisman 1997)

Similarly, public industries in the Lange-Lerner model need not actively work to implement the whole collective plan: they need to take care of their smaller share of the plan and communicate with the neighboring plants the resulting shortages and surpluses. We can think of public managers as adjusting the weight of the connections between their plants by modulating the flow of resources or byproducts going from one to the other.

As suggested by Lange, the corrections of shortages and surpluses need not take place in the real world, try after try, anymore. Neural networks and similar AI systems may simulate the state of the economy over and over again, replaying iterations hundreds of times per second in search of an acceptable production plan to execute in the planned economy. And, given the parallels between the Lange-Lerner framework and neural networks, it is conceivable that not human bureaucrats in the Central Planning Board but a sophisticated neural network system could automatically tilt the economy toward constant clearing (Cockshott 1988; Cockshott and Cottrell 1999).

3.3 Cockshott-Cottrell Model

The other classic model of an AI-assisted planned economy is the Cockshott-Cottrell model (Cockshott & Cottrell 1993). As they distance themselves from the foundations of the Lange-Lerner model (Cottrell & Cockshott 1993), they attempt to seize further the potential of real-time data analysis and neural networks (Cockshott 1988; Cockshott & Cottrell 2007).

The starting point of the Cockshott-Cottrell model is the Marxian idea of expressing the economic value of all economic items in terms of labor hours (Marx, 1999).[6] All resources and products would be assigned an index corresponding to how many hours they took to produce, which is of course sensitive to technological progress in production techniques. At the same time, workers would be granted labor certificates for every hour spent producing goods and services in the economy (Cockshott 2007; Cockshott & Cottrell 1999).

Similar to the Lange-Lerner model, the government would distribute a random allocation of resources and production goals to all industries in the economy, and their public managers would be tasked with meeting their portions of the plan while minimizing the costs (i.e. finding the least labor-intensive combinations of inputs and production techniques available). AI systems may exploit the neural-network shape of the planned economy to simulate various possible allocations and policies and adjust the connections between the production plans accordingly in full automation. At the same time, after every production cycle, the workers may purchase the resulting goods of their liking with their labor certificates. The Central Planning Board would thus have a way to get feedback from the public and learn the revealed preferences of the citizens (Cockshott and Cottrell 1993, 1999). These adjustments may be directly fed into a machine learning system, which could help the government to update the collective plan to align with people's preferences.

The real novelty of the Cockshott-Cottrell model is that the formulation of collective plans may be automatically supplied with real data on people's preferences. This idea was embryonically implemented into Allende's CyberSyn project, with periodic anonymous sampling of requests and needs from the public for the machine to adjust production plans accordingly (Medina 2011). With today's data-tracking capabilities and big-data analysis techniques, even more sophisticated ways for the planning authorities to predict people's preferences are conceivable. For instance, online purchase history data collected by the government and Google search queries analytics may give machine learning models a way to predict the aggregate demand for any item of the economy, and the relative need for resources and by-products (Limas 2018).

3.4 Planned Economies

The following is a representation of the agents at stake in the models outlined above.

	ACTIVE	REACTIVE	PROACTIVE
NATURAL	Buyers/Sellers	Public Managers	
COLLECTIVE		Government Agencies / Public Companies	
AUTOMATED	ADMs	AI Planners	

Table 2: Agents at play in a planned economy.

The Cockshott-Cottrell model retains a role for individual consumers (the workers with their labor certificates) and sellers, framed as active agents. ADMs may be used for technical or administrative tasks, or as algorithms to simplify predictions based on big-data analysis. What the two models have in common is a strong reliance on reactive agents, in the form of the production plants' managers, the nationalized firms

[6] For a critical discussion on this idea, see Mises (1996), ch. 36 and ch. 46.

executing the plan, the governmental agencies formulating or condoning the plan, and of course the AI models used to implement the formulation and execution of the collective plan. There is an absence of agents with the ability to advance innovative goals proactively, outside of the predetermined collective plan.

Gmeiner and Harper (2022) advance a template for an algorithm that may generally be used to plan the economy in ways compatible with how the main models in the literature propose to use AI to operationalize their systems.

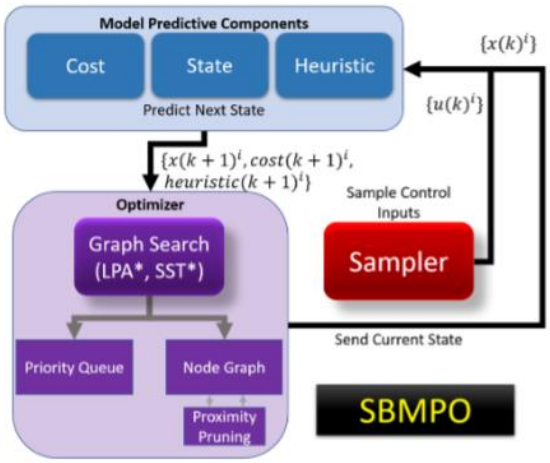

Figure 2: scheme of a SMBPO (Sample-Based Model Predictive Optimization) algorithm (Gmeiner and Harper 2022: 10)

For absolving the tasks required to plan the economy under both the Lange-Lerner model and the Cockshott-Cottrell model, the AI technology employed by the Central Planning Board would need to display at least three functionalities:

1. A sampler, tasked with proposing new policies, i.e. new configurations of current resources and assets available in society, under constraints such as available production techniques, technology, and pre-set goals and values.
2. A predictor, tasked with evaluating each possible policy and thereby estimate the following state of the economy.
3. An optimizer, tasked with ranking the feasible policies through the available predictions, according to pre-set goals and values and to other constraints, such as costs minimization.
4. As said, the Cockshott-Cottrell model prompt us to imagine a fourth functionality, namely the automatization of the formulation of the economic plan, through either analogue (workers buying items with their labor certificates) or digital (big-data analysis and real-time data tracking) feedback loops.

Importantly, none of these steps requires the ability on the part of the AI system to impose new goals outside of those pre-set by the Central Planning Board or implicit in the data fed to the system. Moreover, these systems cannot accept innovation insofar as it means deviating from the initially specified objectives. Temporary inefficiency in allocation may be tolerated by the optimizer, but only in the measure it may still count as a temporary cost to serve the fixed collective goal. To the contrary, the market order produces innovation to deal with the dynamic evolution of the

economy precisely by pursuing new goals that deviate from the collective tendency toward equilibrium (e.g. the private profit of individual entrepreneurs).[7]

4. Entrepreneurial Proactivity and Reactive Planning

The core ontological difference between the market economy and how planned economies may be conceived lays in the lack of proactive agency. In the market, it is individual entrepreneurs who bring about new ideas, products, and production techniques to keep the allocation of resources up to speed with the complex preferences of the consumers and the advances of technology. They do so precisely by exercising the characteristic human ability to navigate complex systems by creating new goals that were not implicit in their environment. This is the main argument to claim that economic planning is impossible in principle even with the best foreseeable AI technology. The role of predictive algorithms and public managers that economic planning models use to give flexibility to the collective plan does not live up to the requirements of proactive agency, thereby leaving the planned economy without any viable way to grapple with the dynamic possibilities of the economy.

4.1 Entrepreneurs as the Driving Force of the Market

The argument that central planning lacks the capacity for innovation that entrepreneurs bring to the market is already present in the literature. It was introduced in a second wave of support to the original Mises-Hayek thesis by Don Lavoie (1990) and Israel Kirzner (1984). The ontological angle that the paper takes with respect to this conclusion, and its apport to the calculation debate, is arguably different. Arguably, others in the debate have thus far failed to highlight why entrepreneurs *not only* are crucial to market allocation, *but also why* the role of entrepreneurs cannot be planned or automated. The answer is that entrepreneurs must be proactive agents, and only individual, human economic actors may be proactive. By eliminating free individual entrepreneurs from the picture, there is no more proactivity allowing society to keep the pace of the complexity of the economy. Before moving on, a reflection on entrepreneurship is in order.

The standard view of the entrepreneur used by the Austrian arguments against economic planning is implicitly found in Mises, but has been greatly developed by Israel Kirzner – and, to some extent, by Joseph Schumpeter (Kirzner, 1973a, 1982, 1997; Mises 1996; Schumpeter 1934, 2011).[8] To be an entrepreneur means to set

[7] One may argue that the success of these models is not prevented, but should just wait for the invention of AGI, which would confer proactive agency to AI systems. While AGI is not yet foreseeable given the current knowledge about AI, as all current models point to the elaboration of pre-set values and functions, it is reasonable to assume that AGI is not possible in principle. This is due to limitations to our ability to model the complexity of the human mind and intelligence (Landgrebe & Smith 2022). Moreover, automated agents in general, as argued below, depend on the attitudes of other agents, e.g. their human developers and/or users, to formulate their own attitudes and goals, thereby preventing the formation of a literal AI will (Popa 2021).

[8] Kirzner's and Schumpeter's classic takes on entrepreneurship indeed are different in some respects. However, as Kirzner points out, they refer for the most part to different features of entrepreneurship (1999). In particular, Kirzner's stress on the equilibrating role of entrepreneurs (as opposed to Schumpeter's transformative and disruptive view of 'creative destruction') is more suitable to understand the role of entrepreneurship in economic

goals in order to realize profits (monetary or otherwise) against a background of uncertainty. Such is potentially the condition of any acting man in the economy, from the CEO of Microsoft to the customer trying out a new supermarket to save himself a couple dollars on cheese.

> The driving force of the market process is provided neither by the consumers nor by the owners of the means of productions – land, capital goods, and labor – but by the promoting and speculating entrepreneurs [...] Profit-seeking speculation is the driving force of the market as it is the driving force of production. (Mises 1996: 328-329)

As they pursue their interest by interacting with others and the circumstances of their particular environment, entrepreneurs buy and sell trying to gain more in value than what they got in exchange. Again, such profit might be merely monetary or 'spiritual' in terms of personal satisfaction or self-fulfillment (Schumpeter 1934; Mises 1996). They plan out the use of their own resources to try and capture the interests and goals of other actors, so that economic transactions are perceived as advantageous for both parties. For instance, when Sarah sells her pen for 5$, that is because she values 5$ more than her pen and someone else, for personal reasons, values her pen more than 5$. As Kirzner describes at large, this puts entrepreneurs in the position to shape the economy around them, as 'the entrepreneur's role is to decide what resources should be used, and/or what goods and services should be produced' (Kirzner 1973a: 17). They move from the signals of the price system and ultimately send back new signals that slightly modify the prices for everybody with each new move they make. (Kirzner 1973a; 1973b; 1997). By doing so, they not only serve people's preferences that are unmet or even unarticulated, but they can even generate new preferences consumers were unaware of. Their pollinating function adjusts prices toward an ideally better allocation of resources, as more personal preferences are met more closely; as a result, they distribute economic knowledge in the system and represent the driving force of the market (Kirzner 1984; 1997).

4.2 The Indispensability of Proactive Agents

Economic actors, as said, may assume different roles as they perform various economic activities: consumer, producer, speculator, shareholder, and so on (Mises 1996; Kirzner 1973a). However, on a deeper level, entrepreneurship is the fundamental feature of all economic actions: 'in any real and living economy every actor is always an entrepreneur' (Mises 1996: 252). This is an important remark because it highlights the necessity for the economy to guarantee a central decisional role to individual biological agents. Humans are in fact the only agents capable of proactive agency, which is a requirement for entrepreneurial activity. And entrepreneurial activity is indeed crucial to the functioning of the economy in ways that cannot be planned away.

The entrepreneur's general aim is to gain profit by being *alert* to the discrepancies between prices and economic valuations and preferences in society. Each entrepreneur acts in any particular context by creating new proxy goals to make profit. For instance, an individual may perceive that the best investment opportunity is to invest in gold to curb an upcoming wave of inflation, or that he should sell his house in the countryside to buy a flat in downtown London and rent it, or that he should launch on the market a new device to remotely control washing machines to

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calculation. Hence, the paper does not delve further into the specific differences between Kirzner's and Schumpeter's views.

quell an unspoken demand in local households. None of these goals are neither intrinsic to his function as a man or entrepreneur, nor implicitly defined in the environment. By setting up new goals as they navigate their environment, they redefine the parameters that are relevant to understand the situation and to estimate whether their plan is going to fruition (Felin et al. 2014). For instance, when an entrepreneur sets himself the goal to buy a stock of copper from abroad, the state of cargo ship traffic in the Suez Canal becomes relevant to his environment, out of an act of his will and not because of anything intrinsically relevant to it. With their activity, entrepreneurs effectively discover alternative uses of available resources that could have not been predicted beforehand (Kirzner 1973b). They thus bring in information that was not already available, thereby enlarging the set of possibilities in the economy (as opposed to simply uncovering possibilities that were implicit in their market context) (Schumpeter 2011). In other words, they follow their purpose to the discovery of 'unknown unknowns' that could not have been mapped by anyone a priori (Knight 1921).

To the contrary, artificial agents both of the collective and of the automated kind are at best reactive. In fact, their attitudes, decisions, and intentions are always derived from the aggregation of other agents' attitudes – be it the groups' members or the AI system's developers or users. An order featuring only collective and automated agents in positions of decisional power is bound to lack the entrepreneurial activity needed to keep up with the dynamic, complex transformation of the economic system.

The goals and values of collective agents are always inscribed in the institutional rules aggregating individual contributions (List & Pettit 2011). The government, as an organization, puts up rules and procedures that constrain the behavior of its members in order to guide the creation of collective intentions (Little 2020; Searle 2002; Tuomela 2007). The resulting collective goals are ultimately selected by the members of the government – either parliamentarians, a dictator and his entourage, or the people through direct democracy, depending on the form of government. They may amount to realize some distribution of resources, perform public investments, disincentivize drug use, founding a colony, or waging war. The government as a collective agent is therefore only reactive, as it can autonomously enact certain goals (e.g. once a law has passed it can be enforced unbeknownst and even against the second thoughts of the people that actually passed it) without actually creating and setting them in the first place.

AI agents too are reactive agents for the same reason. The goals of automated agents come from the source code written by the system's developers, was implicit in the training data's patterns, or is prompted by the end users (Popa 2021). In any case, AI systems only enjoy a low-level form of autonomy and cannot thus elaborate new goals of their own, as they are bound to execute their instructions (Ezenkwu and Starkey 2019). A software executing its code is bound to realize the goal inscribed in the code, no matter how sophisticated its adaptation to local circumstances may be. A deep-learning algorithm such as OpenAI's ChatGPT may perform very well across a wide range of applications but is ultimately bound to execute the functions crafted by the developers and work on the patterns found in the data set provided by the users (Landgrebe and Smith 2022; Floridi 2023). The difference between AI systems and other technological artifacts, from thermostats to photocell-powered gates, is just that they may enact their foundational goal, again, autonomously with respect to the circumstances they are faced with (List & Pettit 2011).

Various models in the calculation debate propose different technological solutions to support economic planning (Cockshott 1988). The machine learning

platforms suggested by Cockshott and Cottrell, for instance, make use of reinforcement learning techniques, which try to identify allocations of resources that optimize given objectives and constraints (Fernández-Villaverde 2020). The model's decisions may be supported by real-time feedback loops through data analysis of search engine queries or otherwise polling consumers' requests through data-tracking techniques (Limas 2018; Morozov 2019). Finally, the model decision's may be implemented through sensors and actuators capable of automatically increase the supply of goods or resources when an increase in demand is forecasted (Phelan 2020). Entrepreneurs in the market, as shown below, perform a different kind of function by identifying new directions for the economy and serving preferences that are yet to be articulated or uncovered.

4.3 Public Managers and Entrepreneurs

As argued, there can be no equilibrating allocation of resources without the proactive action of entrepreneurs. Individual proactive agents are indispensable to the economy, provided the aim is to realize all economic actor's own preferences. This argument against central planning is a conceptual impossibility: *only* entrepreneurs and *neither* collective agents such as the government *nor* automated agents such as AI systems are the *right kind* of agent to solve the economic problem.[9]

Hence, the problem of economic planning cannot be solved simply by enhancing the computational power or the data-tracking capabilities of the central planner. The creative power of entrepreneurs is key. There are structural limits to central planning, because it is *centralized* and thus perpetrated by non-biological, reactive agents. And there are reasons why non-biological agents cannot be proactive in the agential sense. Both AI systems and collective agents share a bounded form of autonomy that has roots in the source of their intentionality (Laukyte 2017; List 2021). Whereas proactive agents generate their intentional attitudes, such as goals and intentions, endogenously, non-biological agents have their attitudes prompted by external agents. In both cases of collective and automated agents, the source of agency is not original but is derived (Dretske 1975), thus impairing the full realization of proactive agential dispositions.

The indispensability of proactive individual entrepreneurs concerns both the realizability of the collective plan and the goals intended by the plan:

> if the planner does not know what it is that he is seeking to achieve, or does not know what resources are at his command, or what the efficacy of these resources is with respect to sought-after goals, then his plan – no matter how carefully formulated – is unlikely to result in the best possible outcome. (Kirzner 1984: 409)

[9] One might propose that an absolute form of dictatorship, where every single decision is directed by one man, may be proactive in the relevant sense. However, this objection does not take into account the impossibility for a single mind to manipulate the whole economy (Hayek 1976). To this apply all the classic considerations about the impossibility for a single agent to gather all the necessary information to plan the economy mentioned in the introduction. And in fact the need for *several* agents to manage all the steps toward the allocation of resources has been recognized by virtually all supporters of economic planning, in order to scale down the magnitude of the problem. Lange, Lerner, Cockshott, and Cottrell all acknowledge the need to decentralize at least the implementation of the economic plan through the coordination of several economic actors, i.e. workers and state-run industrial plants. Thus, my argument could sound as follows: only *several* entrepreneurs and neither collective agents such as the government nor automated agents such as AI systems are the *right kind* of agent to solve the economic problem.

When confronted with the role of the entrepreneur in the economy, Cockshott and Cottrell simply dismiss the idea that it is a market-specific institution as 'baseless' (1993: 14). Before them, Lange grossly misrepresented the importance of the creativity and situatedness of the entrepreneur, as he wrote that 'the administrators of a socialist economy will have exactly the same knowledge, or lack of knowledge, of the production functions as the capitalist entrepreneurs have' (Lange 1936: 55). Both underestimate the level of agency displayed by entrepreneurs in anticipating the preferences of consumers. And, indeed, they falsely equate entrepreneurs and the public managers of state-run companies, who are impaired by the rigidity imposed by the requirement to comply with the Central Planning Board's commands. Most likely, this underestimation is derived by the static foundations of Lange's understanding of the economy: as Hayek notes, Lange derives from Barone and Walras a conception of market equilibrium as an algorithmic process that may be recreated through different institutional supports (Hayek 1982). This conception, however, has prevented the supporters of *central* economic planning to properly address the role of entrepreneurship and innovation in the economy.

5. Conclusion

Lange, one of the first and most prominent responders to the Mises-Hayek thesis, tried to devise a model to mimic market allocation through central planning by emulating the trial-and-error path to market equilibrium. He wrote:

> on principle, [Robbins and Hayek] admit, the problem is soluble, but it is to be doubted whether in a socialist community it can be solved by a simple method of *trial and error*, as it is solved in the capitalist economy (Lange 1936: 56).

Arguably, this is not an adequate answer to the knowledge problem. For one should then ask: who is it that performs trials and errors to solve the problem?

Capitalism today is faced with criticisms and challenges beyond the technical feasibility of economic planning. These include, for instance, climate change and the fact that modern-day entrepreneurs may retain so much economic power to try and shape the economy around them through their own vision. However, the point made here is that the government, even in the face of known means and technology, may at best steer or nudge *partial* aspects of the economy. That is, the market's ability to allocate products and resources according to people's individual preferences is indispensable. The level of agency demonstrated by entrepreneurs in the market while aiding the dynamic evolution of the price system is a crucial feature of the economy that cannot be planned or emulated. And this fact is not going to be changed by whatever development of AI, or otherwise digital, data manipulation technology within the frame of our present understanding of the field.

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