ARTIFICIAL INTELLIGENCE TO OPTIMIZE COUNTRIES' MACROECONOMICAND ENVIRONMENTAL PROGRAMS

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ABSTRACT

We present how artificial intelligence can be used to optimize countries' macroeconomic and environmental programs for a given period. Weuse an automaton that manages possible changes to a country's membership of country unions, an Expert System based on macroeconomic and environmental rules, and an optimizer of rules, scenarios, and programs. This approach can be applied to any country by using its historical data and by quantifying parameters suitable for that country: name of the country, population, cash, situation in relation to country's unions, constraints (in particular limit values that must be respected by the programs), and macroeconomic and environmental rules parameters. As example, we apply the presented process to examples of France' programs. We put forward optimizations of four macroeconomic and environmental scenarios, and seven macroeconomic and environmental programs for France from 2022–2026 in line with different objectives. We then quantify the significant improvements obtained with their optimizations.

KEYWORDS

Artificial intelligence,Expert systems, Information systems,Optimization,Macroeconomics

1. INTRODUCTION

The main objectiveof this workis to answer the following question: "Could artificial intelligence be employed to optimize countries' macroeconomic and environmental programs proposed by economists, environmental experts, and politicians?".

Version of 2016 of the Artificial Intelligence Software We Developed

With the 2016 version of thesoftware it was only possible to make four-year simulations of country macroeconomic programs. It was not possible to optimize these programs. A study of the French government's macroeconomic program with this software has concluded that the alternative for France for the period 2015-2018 was "Revolution or Moderate Anti-austerity"[1].

Triptych of Artificial Intelligence of Collaborative Components

This triptych iscomposed of an Automaton, an Expert System, and an Optimizer(Figure 1). Its use is illustrated with studies of France' Macroeconomic and Environmental Programs.
The automaton manages possible changes to a country's membership of country unions. The Expert System calculates the scenarios parameters (which are program projects), and the macroeconomic and environmental programs parameters. The optimizer optimizes the parameters of rules, scenarios, and programs.

DOI: 10.5121/ijaia.2022.13502

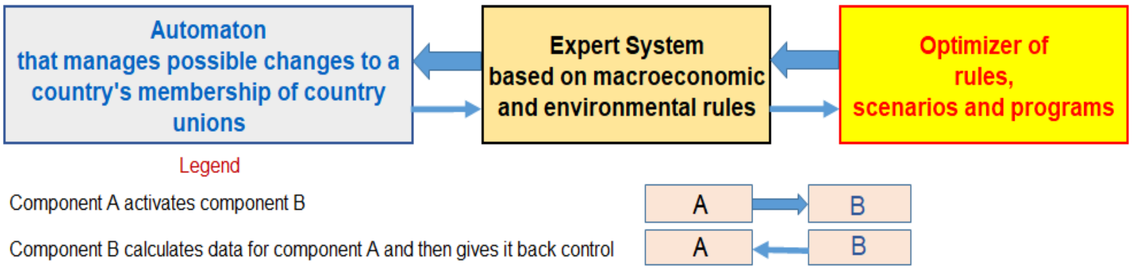


Figure 1. The triptych of artificial intelligence collaborative components used.

2. PRESENTATION OF THE "ARTIFICIAL INTELLIGENCE SOFTWARE TO OPTIMIZE COUNTRY'S PROGRAMS" (AISP)

Main AISP inputs and outputs arein Figure 2.A synopsis of AISP features is in Table 1.Historical macroeconomic and environmental statistical data of a country from any number of years are stored in a database. A statistical database of France from 2011 to 2021 has been created.

Rules are recorded in anExpert System.Programs for a country for a given period are evaluated in the context of hypotheses, constraints, and objectives, and by an evaluation function (an objective function).Each scenario and program is defined with more than 140 parameters for each year studied, and 90 global parameters.The software automatically optimizes the rules of the Expert System and scenarios and programs for a period of one to five years in line with the chosen objectives.

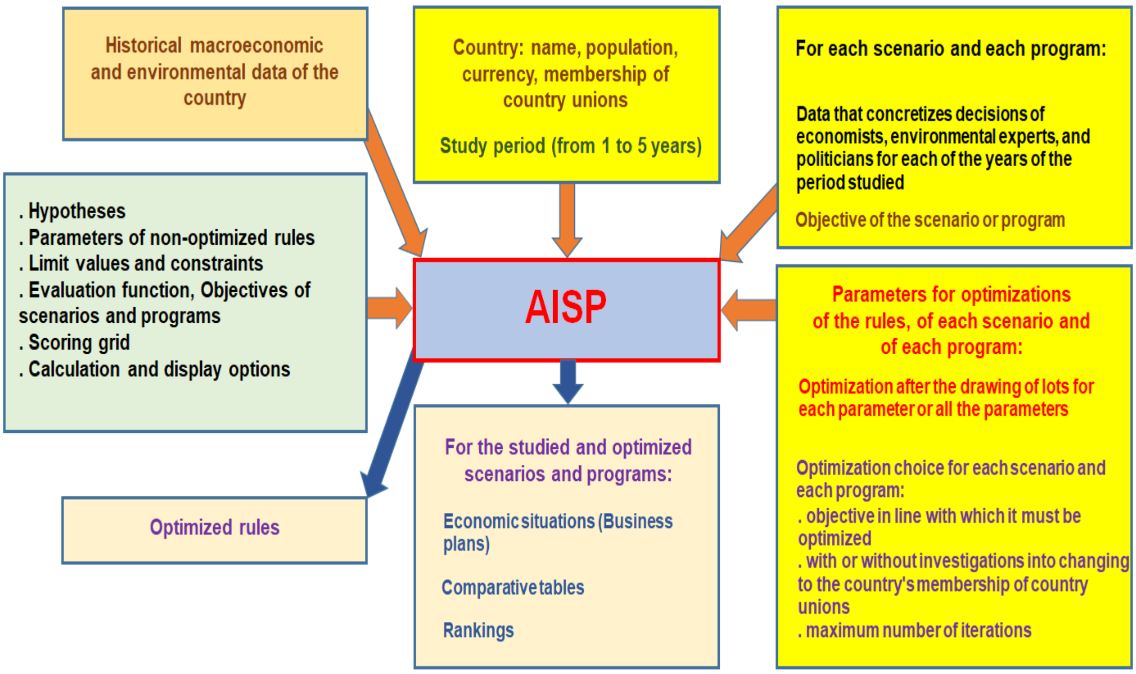


Figure 2.Main AISP inputs and outputs.

Table 1. Synopsis of AISP features.

Constraints on rules optimization rules parameters	1 084
Constraints on the parameters of program optimization rules	150
Constraints on program data	80
Automaton that manages possible changes to a country's membership of country unions	
4 main states	
12 secondary states	
Expert System based on macroeconomic and environmental rules	
Rules	50
Parameters of the rule optimization rules	544
Parameters of the program optimization rules	210

AISP was developed with Microsoft Visual Basic for Applications (VBA) Excel 365, 2019 version (64 bits) on a PC whose Intel Core I7 processor has a speed of 2.9 Giga Hertz.

3. Automaton that Manages Possible Changes to a Country's Membership of Country Unions

The automaton is depicted in Figure 3. It can be used for country's unions such as European unions. It can also be used for any country's union other than Commercial Zones, Free movement areas and Monetary Zones, for exampleNATO.

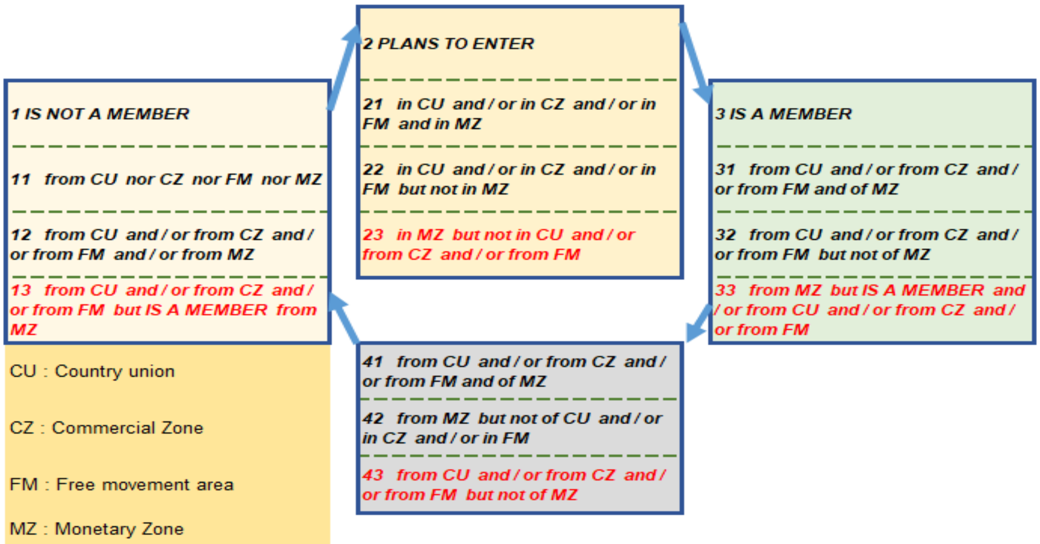


Figure 3.Automaton that manages possible changes to a country's membership of country unions.

This automaton is used during interactive simulations of non-optimized scenarios and programs, and optimizations of scenarios and programs.

4. Expert System Based on Macroeconomic and Environmental Rules

The proposed simplified macroeconomic model of a country (Figure 4) represents classical macroeconomic aggregatesand mechanismstranslated with 50 rules (defined with 543 parameters), governed by macroeconomics lawsdefined by economists and environmental experts including Nobel laureates.

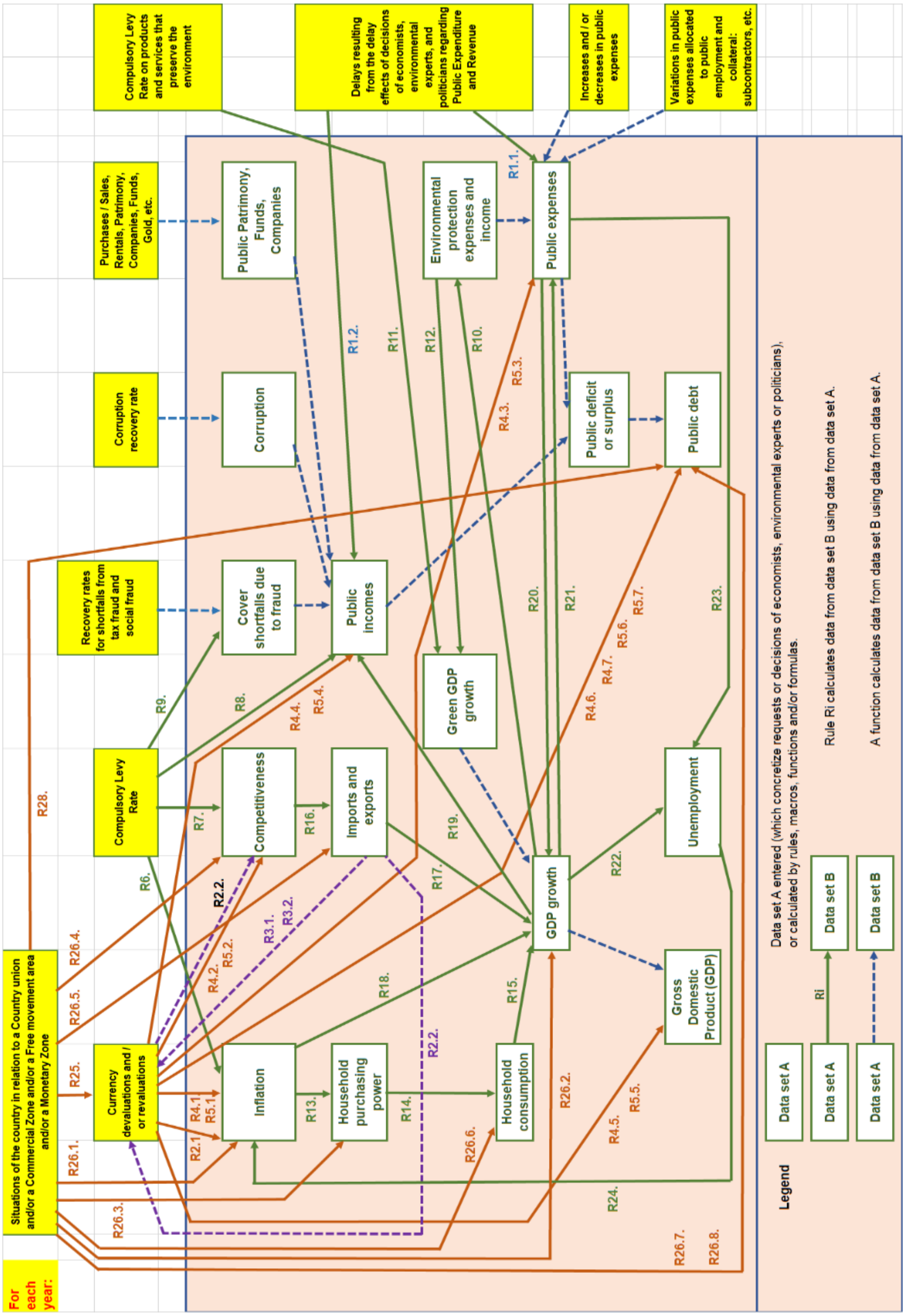


Figure 4. Macroeconomic and environmental model of a country

The Expert System makes it possible for calculating on one hand, data for an historical period and, and on the other hand, scenario and program data for a country for a given period. Few of the rules are shown below.

4.1. R10. Environmental Protection Expenditure: Impact of GDP Growth

We tried to take into account the conclusions of think tanks such as the Club of Rome reflections, the "Meadows Reports" [2] [3], the "Brundtland Report" [4], and studies by the economist Nicholas Stern [5] and the OECD [6] [7] and historical data for France for the period 2011-2021.The reflections of the Rome Club and the "Meadows report" had led to the conclusion that in order to preserve the environment there should be no growth. These studies concluded that the costs of the consequences of environmental degradation were between 1% and 5% of GDP depending on the disaster mentioned. The OECD claims that *"the cost of inaction on climate change would be higher than the cost of action"* [6] [7].We present only one environmental rule about the impact of GDP growth on environmental protection expenditure.

For France for the 2011-2021 period, we have initialized parameters of the non-optimized rule R10 with a weak impact of the growth of the GDP on the expenditure of protection of the environment because it is what emerges from the analysis of the historical data (see Table 2). The optimization of this rule, which aims to minimize the gap between the statistical historical data and the calculated historical data, founds that the impact of GDP growth on environmental protection expenditure is 75% lower than the impact we had initialized when GDP falls by 1%, but increases by 21% when GDP rises by 1% (see Table 3).

Table 2. R10. non-optimized. Environmental protection expenditure: impact of GDP growth.

R10. non-optimized. Environmental protection expenditure: impact of GDP growth			
A decrease in the growth of GDP	*-1.00%*	has an impact on environmental protection expenses of	*-0.30000%*
An increase in GDP growth	*1.00%*	has an impact on environmental protection expenses of	*0.30000%*

Table 3. R10. optimized. Environmental protection expenditure: impact of GDP growth.

R10. optimized. Environmental protection expenditure: impact of GDP growth			
A decrease in the growth of GDP	*-1.00%*	has an impact on environmental protection expenses of	*-0.08428%*
An increase in GDP growth	*1.00%*	has an impact on environmental protection expenses of	*0.39869%*

4.2. R18. GDP Growth: Impact of Inflation

The impact of inflation on GDP growth have been the subject of numerous studies by economists. The 3 cases generally considered are:

1st case: Inflation is less than a minimum threshold Im(deflation).Deflation is considered by many economists, including Keynesian economists[8], to be a worrying indicator because deflation has a negative impact on GDP growth. A deflationary spiral may be initiated, a process which has a negative impact on the economy.

2nd case: Inflation is between thethreshold Imand a threshold IM. Many economists consider that in this case inflation has a positive impact on GDP growth.

3rd case: Inflation is greater than the IM threshold. Beyond this threshold, many economists consider that in this case inflation has a negative impact on GDP growth.
The main problem is to fix the values of the thresholds Im and IM.

The main objective of the European Central Bank, as defined by Article 127 of the Treaty on the Functioning of the European Union, is to ensure price stability. Since 2003, this objective has resulted in a search for an inflation rate "close to, but less than 2%" (IM) per year.Since July 8, 2021, a change of strategy: its inflation target is still set at 2%, but is now symmetrical, the 2% threshold being understood as a medium-term objective.

Considering the current evolution of the inflation in 2022, we fixed the values of the thresholds Im and IM respectively to 0% and 4% and we modeled the 3 cases for the French economy in the current circumstancesin the non-optimized rule R28 (see Table 4).

For the France for this period, the optimization of rule R18 hardly changed the Im threshold which increased very slightly from 0.00% to 0.01%, but reduced the IM threshold from 4.00% to 3.00% (Table 5). The values of the inflation impact parameters on growth have all been reduced except for the impact parameter when inflation is between Im and (IM+Im)/2.

Table 4. R18. non-optimized. GDP growth: impact of inflation

R18. non-optimized. GDP growth: impact of Inflation					
If inflation is at or below the threshold Im		***0.00%***			
a decrease in Inflation	***-1.00%***	**below the threshold Im**	**has a negative impact on GDP growth of**		***-1.00000%***
If inflation is between the Im threshold		**0.00%**	***and IM threshold***	***4.00%***	
If inflation is lower (IM + Im) / 2 =	**2.00%**	**and less than (IM+Im)/2 of**	***1.00%***	**effect on growth of**	**1.00000%**
If inflation is higher (IM + Im) / 2 =	**2.00%**	**and greater than (IM+Im)/2 of**	***1.00%***	**effect on growth of**	**0.50000%**
If inflation is at or above the threshold IM		**4.00%**			
an increase in Inflation	***1.00%***	**above the threshold IM**	**has a negative impact on GDP growth of**		**-0.10000%**

Table 5. R18. optimized. GDP growth: impact of inflation

R18. optimized. GDP growth: impact of Inflation					
If inflation is at or below the threshold Im		***0.01%***			
a decrease in Inflation	***-1.00%***	**below the threshold Im**	**has a negative impact on GDP growth of**		***-0.00201%***
If inflation is between the Im threshold		**0.01%**	***and IM threshold***	***3.00%***	
If inflation is lower (IM + Im) / 2 =	**1.51%**	**and less than (IM+Im)/2 of**	***1.00%***	**effect on growth of**	**1.00000%**
If inflation is higher (IM + Im) / 2 =	**1.51%**	**and greater than (IM+Im)/2 of**	***1.00%***	**effect on growth of**	**-0.19983%**
If inflation is at or above the threshold IM		**3.00%**			
an increase in Inflation	***1.00%***	**above the threshold IM**	**has a negative impact on GDP growth of**		***-0.45599%***

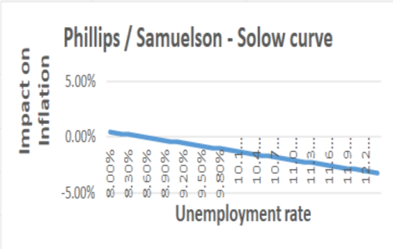
4.3. R24. Inflation: Unemployment Impact (Extension of Phillips' law by Paul Antony Samuelson and Robert Merton Solow)

Phillips' law states that there is an inverse relationship between the unemployment rate and the nominal wage growth rate [9]. Paul Antony Samuelson and Robert Merton Solow, Nobel laureates in economics in 1970 and 1987, extended Phillips' law to a relationship between the unemployment rate and the inflation rate [10]. This extension states that there is an inverse relationship between the unemployment rate and the inflation rate.

These economists thus highlighted the dilemma between inflation and unemployment according to which governments should choose slightly higher inflation to bring down unemployment, and, conversely, accept more unemployment in order to overcome inflation.We have hypothesized that for France to the 2011-2021 period the curve that represents the relationship between the unemployment rate and the inflation rate should be represented by a right segment. The equation for this line was defined in the R24 rule depicted in Table 6.For the sake of brevity only the optimized rule is depicted. Note that the optimization does not modify the parameter of the coefficient aL (keeping its value 2.11) but reduces from 1.00 to 0.66 the coefficient of the parameter bL of the equation on the right which models the rule of the extension of Phillips' Law by Paul Antony Samuelson and Robert Merton Solow.

Table 6. R24. optimized. Inflation: Unemployment impact (extension of the law of Phillips by Samuelson and Solow).

R24. optimized. Inflation: Unemployment impact (extension of the law of Phillips by Samuelson and Solow)				
Choice 1 : Modeling of the relationship "Unemployment rate / Impact on inflation" on the period 2022-2026 with a straight line				
Choice 2 : Modeling of the relationship "Unemployment rate / Impact on inflation" on the period 2022-2026 with a hyperbola				
Choice: 1				
Choice 1 : Modeling of the relationship "Unemployment rate / Impact on inflation" on the period 2022-2026 with the straight line of equation:				
Impact on Inflation =	aL	x Unemployment rate +	bL	
Entered values of the parameters	-0.40		10.95%	
Parameter multipliers	2.11		0.66	
Parameter Values	-0.84		7.25%	
Choice 2 : Modeling of the relationship "Unemployment rate / Impact on inflation" on the period 2022-2026 with the hyperbola of equation:				
	Impact on Inflation (YP)			
	Unemployment rate (XP)			
	YP = (aP.XP + bP) / (cP.XP + dP)			
Parameters	aP	bP	cP	dP
Entered values of the parameters	0.00	18.00%	72.00	100.00%
Parameter multipliers	1.00	1.00	1.00	1.00
Parameter Values	0.00	18.00%	72.00	100.00%



4.4. R25. Revaluation / Devaluation of the Currency According to the Situation of the Current Year and the Situation of the Previous Year Relative to Country's Unions

Several rules manage impacts of changes to a country's membership of country unions. For sake of brevity, we do not present the rule which manages impacts of changes to a country's membership of country unions on monetary devaluations and revaluations.

4.5. Automatic Year-to-Year Propagation of Calculated Historical Data and of Calculated Scenarios and Programs Data

The data of the rules for a year N + 1 are calculated from the statistical historical data (method 1),or from the data calculated for year N (method 2).We use the second method because it better reflects the propagation of the cumulative gaps between the data calculated from year to year.The data of a scenario or a program of the first year N of the period of study are calculated from the historical data of the year N - 1. The data of a scenario or a program of the others years N + i of the study period are calculated from the data calculated for this scenario or program for year N + i - 1.

5. Optimizer of Rules, Scenarios and Programs

5.1. Goal of Rule Optimization. Goal of Scenarios and Programs Optimizations

The goal of the optimization of the (set of) rules is to minimize (up to 0%) the gap between statistical historical macroeconomic and environmental data and calculated historical data with these rules in line with a chosen objective.
The goal of the optimizations of a scenario or a program is tomaximize its financial score in line witha chosen objectiveup to a fixed threshold. We have chosen 10 as the value of this threshold.

5.2. Numbers of Possible Solutions to Optimize Rules, Scenarios and Programs

The number of possible solutions to study the rules is equal to the product of the possible values of their 218 optimizable parameters. Studying allthese solutions would require executing24.37 x 10^{316}instructionsand therefore 3.49 x 10^{283} years of computation with the PC we used.

The number of possible solutions to study each scenario or program is equal to the product of the possible values of all 70 parameters that can be optimized for each of them, 2.87 x 10^{73}. Studying allthese solutions would require executing2.87 x 10^{73} instructions, or 3.43 x 10^{56} years of computation for each scenario or program with the PC we used.

An exponential growth in the number of possible solutions to a problem, making the calculation of a result impossible, is called a "combinatorial explosion". This phenomenon falls under combinatorial optimization.

To optimize the rules, scenarios, and programs we need a combinatorial optimization method (a metaheuristic) that would make it possible to find "good" solutions (non-optimums) to optimization problems under constraint in reasonable computation times, if they exist.

Whether to optimize rules, scenarios or programs, the goal is to start from an initial solution, and arrive at an optimized final solution in "reasonable" computation times limited by predetermined maximum numbers (thresholds) of iterations or by the possible achievement of the optimal solution (if the goal of the objective function was reached).

We therefore had to implant the optimizer with a metaheuristic called single-solution-basedrather thana population-based metaheuristic. Single-solution metaheuristics start with a single initial solutionand gradually move away from it by building a trajectory in the research space to find a "good" solution. These methods are essentially the descent method, the Simulated Annealing algorithm, the Tabu search, the GRASP (Greedy Randomized Adaptive Search Procedure) method, the variable neighborhood search, the iterated local search, and their variants.Main single-solution metaheuristics are presented by Alain Billionnet [11]. Metaheuristics presentations are in the thesis by Ilhem Boussaid [12].

5.3. Choiceof the Simulated Annealing Algorithm to Optimize Rules, Scenarios and Programs

With the Descent Method the optimizations could remain trapped in the first local optimum encountered. The Tabu Search Method would use optimization search histories that would have to be managed at the expense of computation times. The GRASP method is a multi-departure metaheuristic, which is not the case for the optimizations we perform. The Variable Neighborhood Search is based on the fact that, at the initialization stage, a set of neighborhood structures is defined, which is not the case for the optimizations that we perform [13] [14]. The Iterated Local Search requires defining a perturbation function on the local optimum found at the current iteration, which we were not able to do.

For the optimizer, we have therefore retained the Combinatorial Optimization Method which is the Simulated Annealing algorithm with acceptance of thresholds of predetermined maximum numbers of iterations.We have made some adaptations to this algorithm.

The Simulated Annealing algorithm (SA)

SA has its origins in the formalism of statistical mechanics (Metropolis algorithm [15]). It was formalized by three IBM researchers, Kirkpatrick and al. [16], and independently by Cerny [17].

SA is inspired by the process of physical annealing used in metallurgy.SA is transposed into optimization to find the extreme a of a function: the objective function, assimilated to the energy of a material, is then minimized. The algorithm starts by generating an initial solution. With each new iteration, a solution is randomly generated in the N neighborhood of the current solution s.The solution is chosen if it has a performance greater than or equal to that of the current solution, that is to say, $f(s') \geq f(s)$. Otherwise, s' is accepted with a probability $e\Delta f/T$ (Metropolis rule).

5.4. Modalities to Search for Best Scenarios and Programs

The macroeconomic and environmental modalities are*:*the objectives of the scenarios and the programs; the research with or without investigations into the country changing its membership of country unions.

The modalities for optimizations of the scenarios, and of the programs are:the numbers of iterations requested; comparisons between the latest best solutions retained and the solutions in progress during the optimizations, either "after a random draw of each parameter", or "after random draws of all the parameters at the end of each iteration".

5.5. Algorithm for Optimizing the Objective Function of Rules and the Objective Function of Scenarios and Programs

The optimization of the rules is done by minimizing (with 0% as a goal) the gap between historical statistical macroeconomic and environmental calculated data with these rules.The goal of optimizing a scenario or a program is to maximize its financial score in line with a chosen objective chosen up to a threshold (set at 10).

For the optimizations the initial solutions are the values of the parameters of the non-optimized rules, and of the non-optimized scenarios and programs. For the re-optimizations the initial solutions are the values of the parameters found by their last optimizations.

At each iteration, a value of each parameter of the rules, of a scenario or of a program, is generated randomly in the vicinity of its current value by adding or subtracting a number. This number is calculated by multiplying a percentage randomly generated by the difference between the minimum and maximum values of this parameter recorded as constraints.

Case of a search for the best values of financial scores of scenarios and programs

The new value of anoptimized parameter is its old value plus the difference between its minimum and its maximum, multiplied by the value delivered by the “Rnd” VBA function which delivers a value within the range (0%; 100%). We use it twice.

Kernel of the algorithm of the optimization function that optimizes a parameter of a rule, a scenario or a program during an iteration:

We name:

Param: value of a parameter of a rule, a scenario or a program;
ParamMin: minimum value of a parameter (which was recorded as a constraint);
ParamMax: maximum value of a parameter (which was recorded as a constraint);
ParamRandom: value drawn randomly from a parameter;

Score: score of the set of rules (to be minimized to 0 the gap between historical statistical macroeconomic and environmental calculated data with these rules), or score of a scenario or a program (to be maximized up to a fixed threshold, for example 10);

ScoreNew: new score found;

CoeffParamRndVar: coefficient drawn at random (0%; 100%) multiplied by (ParamMax - ParamMin), result which is added to the current value of a parameter;

CoeffRndMinus1OrPlus1: coefficient equal to "+1" or to "-1" drawn at random which is multiplied by "CoeffParamRndVar x (ParamMax - ParamMin)", to search for a better value "to the left or to the right" of a parameter of a rule, scenario or program.

For each parameter of the rules, of a scenario or of a program

If 0 <= Rnd<= 0.5 ‘ FirstRnd draw
Then CoeffRndMinus1OrPlus1 = -1
Else 0.5 <Rnd<= 1
CoeffRndMinus1OrPlus1 = +1
End If

CoeffParamRndVar = Rnd‘ SecondRnd draw

ParamRandom = Param + (CoeffRndMinus1OrPlus1 x CoeffParamRndVar x (ParamMax - ParamMin))

If Optimization of the rules (therefore minimization of the Score)

```
 Then
        If ScoreNew< Score ‘ ScoreNew is calculated with ParamRandom
        Then Score = ScoreNew‘ Parameter values of the rules = New optimized parameter
                   values
                   Saving the values of new parameters of the rule
End If
End If

If Optimization of a scenario or a program (therefore maximization of the Score)
Then
        If ScoreNew> Score ‘ ScoreNew is calculated with ParamRandom
        Then Score = ScoreNew‘ Parameter values of the scenario or of the program = New
                                  optimized parameter values
        Saving the values of the new scenario or program parameters
End If
End If
End For
```

5.6. Rule Optimization Computation Times and Scenario and Program Optimization Computation Times

We have retained to choose a maximum number of iterations for each optimization, rather than setting deadlines. Thus, the executions of the optimizations are not interrupted by time limits.

We have made multiple settings to improve computation times.With the PC we used, using comparisons between the last best solution retained and the last solution found "after a random draw of each parameter" the Simulated Annealing algorithm allowed to optimizerules with 1,000 iterations in 12 hours and 47 minutes to optimize their 218 parameters, and each scenario and each program with 200 iterations to optimize their 70 parameters in 27 to 41 minutes.In total 18 hours and 52 minutes to optimize the rules, four scenarios, and seven programs. We consider that these optimizations were executed in "reasonable" times.

6. EXAMPLES OF HYPOTHESES

We have made the hypothesis that the rules applicable for France for 2011–2021 may be applicable to the study period from 2022 to 2026.The following fundamental hypotheses would likely lead to poorer results than those found by the study and are difficult to quantify: a major natural disaster; a world war more serious than that programmed with the hypothesis below concerning the current international situation (Table 7); variations in the price of petroleum greater than those programmed with the assumptions below in Table 8; a major pandemic more serious than that programmed with the hypothesis concerning COVID-19(quantified but not shown for brevity); a major deterioration of the environment; a major political crisis; an economic or financial crisis in the world.The hypotheses can be modified at any time and the data of non-optimized and optimized scenarios and programs are then instantaneously modified.

Hypothesis on the international situation on the France's gross domestic product (GDP).

Cabinet Astarès estimated that the war in Ukraine would significantly slow down growth in France in 2022 with an impact of one percentage point less [18]. We consider the hypothesis mentioned in Table 7 for 2022 to 2026.

Table 7. Hypothesis of the impact of the international situation on the France's GDP for the 2022 to 2026.

International situation. Impact on the Gross Domestic Product (GDP) of the country						
Consideration, YES = 1 or NO = 0, of the impact of the international situation on the GDP of the country's macroeconomic and environmental programs						1
Maximum severity of the international situation (% of countries concerned and gravity of the situation)	10.00	Hypothesis of decline in GDP in the event of maximum severity of the international situation for one month				-3%
A guerria outside the country's borders is considered an international situation of less gravity		2022	2023	2024	2025	2026
Duration of international tensions (in days)		299	180	0	0	0
Gravity of the international situation (% of countries concerned and gravity of the situation)		0.33	0.17	0.00	0.00	0.00
Potential impact of the international situation on the country's GDP		-1.00%	-0.31%	0.00%	0.00%	0.00%
Taken into account impact of the international situation on the country's GDP		-1.00%	-0.31%	0.00%	0.00%	0.00%

Hypothesis of the impact of the oil price on France's inflation. Many experts believe that if the price of a barrel of Brent is above $110, a 1% rise in its price generates a 1% rise in inflation in France, but that a fall in the price of oil does not generate a drop in inflation. Thus, for France, for 2022 to 2026, we have retained the assumptions in Table 8.

Table 8. Hypothesis of the impact of the variations in the price of petroleum on the France's GDPfor 2022 to 2026.

Oil price. Impact on the Gross Domestic Product (GDP) of the country						
Consideration, YES = 1 or NO = 0, of the impact of the price of a barrel of Brent on the GDP of the country's macroeconomic and environmental programs						1
An increase in the price of the barrel of the Brent of	20.00%	generates a drop in GDP of				-0.10%
It is not modeled that a fall in the price of oil generates an increase in GDP.		2022	2023	2024	2025	2026
Price per barrel of Brent in $		115	110	100	90	90
Variations in the price of a barrel of Brent		47.44%	-4.35%	-9.09%	-10.00%	0.00%
Potential impact of variations in the price of a barrel of Brent on the country's GDP		-0.33%	-0.33%	0.00%	0.00%	0.00%
Impact taken into account of variations in the price of a barrel of Brent on the country's GDP		-0.33%	-0.33%	0.00%	0.00%	0.00%

Average rate of interest on debt repayment. Considering French debt repayment interest rates from 2011 to 2021, and the fact that rates rise, we assume that for France, for 2022 to 2026, the average rate of interest on debt repayment would be the one specified in Table 9.

Table 9. Interest of debt repayment of loans for 2022–2026 except in certain cases of change of the country situation.

Interest of debt repayment of loans during the period 2021 - 2025 except in certain cases of change of the country situation.		
For loans with a duration of	10	years
Average annual rate	2.00%	

Estimated exit fees for leaving the European Union, the Schengen area, and the Euro area. Considering the estimated cost for the United Kingdom of leaving the European Union ("Brexit"), we assume that for France, for 2022 to 2026, the estimated exit fees for leaving the European Union, the Schengen area, and the Euro area would be the one specified in Table 10.

Table 10. Exit fees for leaving the European Union, the Schengen area, and the Euro area.

Exit fees EU / EEA / Schengen / € Zo in Bn€					
	40	Billions of €			

7. Examples of Constraints

Let us recall (cf. Table 1in Section 2)that the rulesoptimization rules parameters must respect 1084 constraints,and parameters of program optimization rules must respect 150 constraints not presented in this article.Table 11 sets out examples of the 80 limit values that must be respected by the scenarios and programs for France in the current circumstances. The choices of the values of the limit values are very delicate.

Table 11. Limit values that must be respected by the scenarios and programs, which concretize decisions of economists, environmental experts, and politicians.

	Minimum and maximum values that they must respect each year.	Minimums	Maximums
	ECONOMIC UNION(S), MONETARY ZONE(S), COMMERCIAL ZONES(S), and FREE MOVEMENT AREA(S) Devaluations / re-evaluations of € if France :	11	43
Legend	*1 IS NOT A MEMBER*		
EU : European Union	*11 from EU nor EEA nor Schengen nor € Zo*	-20.00%	20.00%
	12 from EU and / or from EEA and / or from Schengen and / or from	-20.00%	20.00%
		-20.00%	20.00%
EEA : European Economic Area	*2 PLANS TO ENTER*		
	21 in EU and / or in EEA and / or in Schengen and in € Zo	-20.00%	20.00%
	22 in EU and / or in EEA and / or in Schengen but not in € Zo	-20.00%	20.00%
		-20.00%	20.00%
Schengen : European free movement area	*3 IS A MEMBER*		
	31 from EU and / or from EEA and / or from Schengen and of € Zo	-20.00%	20.00%
	32 from EU and / or from EEA and / or from Schengen but not of € Zo	-20.00%	20.00%
		-20.00%	20.00%
€ Zo : Eurozone	*4 PLANS TO EXIT*		
	41 from EU and / or from EEA and / or from Schengen and of € Zo	-20.00%	20.00%
	42 from € Zo but not of EU and / or in EEA and / or in Schengen	-20.00%	20.00%
		-20.00%	20.00%
	Compulsory Levy Rate (CLR) - Variation		
	HOUSEHOLDS: Taxes	-5.00%	5.00%
	HOUSEHOLDS: Levies	-5.00%	5.00%
	HOUSEHOLDS: Contributions	-5.00%	5.00%
	COMPANIES: Taxes	-5.00%	5.00%
	COMPANIES: Levies	-5.00%	5.00%
	COMPANIES: Contributions	-5.00%	5.00%
	Variation CLR on products & services that preserve the environment	-10.00%	10.00%
	Public expenses. Rate variation:		
	Variation in environmental protection decided by economists, environmental experts, and politicians + resulting from growth	-20.00%	20.00%
	Central public administrations (including of the state)	-3.00%	5.00%
	Local government	-3.00%	5.00%
	Social Security funds	-3.00%	5.00%
	Variations in public expenses allocated to public employment and collateral: subcontractors, etc.	-20.00%	20.00%
	Recovery rate shortfall in tax evasion	5.00%	15.00%
	Recovery rate shortfall social fraud	5.00%	15.00%
	Corruption: recovery rate	0.00%	5.00%
	Rate Purchases (<0) / Sales (> 0) public Assets, Companies, Funds	-30.00%	20.00%
	Rate Purchases (<0) / Sales (> 0) public Gold, Vehicles, etc.	-30.00%	20.00%
	Rate Expenses (<0) / Income (> 0) Rental property compared to the previous year	-30.00%	20.00%

8. Evaluation Function (Objective Function) of Scenarios and Programs. Scenario and Program Objectives

The scoring of each scenarioand program is done using an evaluation function which is a weighted sum of criteria. This function is based on four categories of criteria: number of unemployed, macroeconomic data, environmental macroeconomic data, and financial data.The weights of these criteria are defined according to the objectives in the contexts in which thescenarios and programs are evaluated. The scenarios and programs for France for 2022–2026 are studied with the following five objectives: reducing unemployment, improving the economy, improving environmental economic data, improving finances, and improving a mix of theprevious four objectives equally weighted.This last objective “improving a mix of the four objectives” is defined in Table 12.An unlimited number of objectives can be defined.

Table 12. Objectivesof study and evaluation of non-optimized macroeconomic and environmental scenarios and programs, and of optimization and evaluation of optimized macroeconomic and environmental scenarios and programs.

Evaluation function (objective function) of scenarios and programs Variables and weights of the evaluation function	Weight of unsigned criteria ↓
Var. nb. jobseekers available and actively seeking work from 2021 to 2026	25.01%
Macroeconomics	
Var. inflation from 2021 to 2026	2.27%
Var. growth rate change (of GDP) from 2021 to 2026	6.82%
Var. household purchasing power from 2021 to 2026	6.82%
Competitiveness variation from 2021 to 2026	9.09%
Environmental macroeconomic data	
Var. green growth rate (included in growth rate) from 2021 to 2026	12.50%
Var. environmental protection decided by economists, environmental experts, and politicians + resulting from growth from 2021 to 2026	12.50%
Finance	
Var. public expenditure / GDP from 2021 to 2026	1.54%
Variation public deficit from 2021 to 2026	3.08%
Var. public deficit / public GDP from 2021 to 2026	6.17%
Variation in Public debt in Bn of € from 2021 to 2026	6.17%
Var. public debt / public GDP from 2021 to 2026	2.47%
Var. max increase in deficit / revenue year preceding the period from 2021 to 2026	3.08%
Var. max increase in deficit / deficit year preceding the period from 2021 to 2026	2.47%
Evaluation function (objective function) of scenarios and programs	100.00%
Scores: higher the score is, better the program is Best: Max; Worse: Min; Scale of: 0.00 à 10.00	

9. Statistical Historical Data. Calculated Historical Data

We built up an historical database of macroeconomicand environmental data for France for 2011-2021. Creating of this database was difficult because some data is different according to the sources.

Rationale for historical macroeconomic data not being a longer time series

Economic forecasting studies are often made using long previous years’ time series data. We have (only) considered historical data from the period 2011-2021 for three reasons.

1) We assume that the values of the parameters of the rules will be valid for the studies and the optimizations of the scenarios and programs for a future study period (for example 2022-2026).

2) The data the studies of the scenarios and programs carried out interactively with users and of their optimizations for a year N are only calculated from the data for the year N-1.Consequently, the data for the first year of a period studied (for example 2022), are calculated from the historical data of the previous year (for example 2021). Data from historical years prior to year N-1 are only used to optimize the parameters of the rules.

3) If we had considered historical data prior to the period 2011-2021, we would have taken into account atypical years during the subprime crisis from 2007 to 2009.To take into account atypical years, economists use “dummy variables”, see Suits[19].

Economists set values for dummy variables for atypical years.If we had proceeded in this way for the atypical years the parameters of the rules might not have been better and would depend on the values of the dummy variables.Admittedly, we have taken into account the historical data for 2020 and 2021, which are atypical years due to the COVID pandemic.

The unemployment figures published byInsee (“InstitutNational de la Statistique et des Études Économiques”) and “PôleEmploi” (national job center) are not the same. We used the figures from the national job center because this organization manages the unemployed. Most of the other statistics we used were published by Insee.

10. STUDY OF MACROECONOMIC AND ENVIRONMENTAL PROGRAMS OF FRANCE FOR 2022-2026

10.1. Scenarios and Programs Studied

Four non-optimized scenarios of the PR3 program have been analyzed and optimized with two objectives and with or without a change in France's situation in relation to the European Union, and the Euro Area. These four scenarios and seven programs were defined starting from the sameneutral parameters - initialized to zero - but with different modalities for the period 2022-2026.
These four scenarios and seven programs were studied and optimized in line with the five objectives presented in Section8. Some of these scenarios and programs were studied and optimized without investigating a changein the country’s membership of country unions. Others have been with these investigations.

The four non-optimized scenarios and the seven non-optimized programs have been optimized. Thebest non-optimized scenario was compared to the seven non-optimized programs. The best optimized scenario was compared to the seven optimized programs.The four non-optimized scenarios of the PR3 program and theirfour optimized scenarios are in Table 13. The sevennon-optimized and the best non-optimized scenario, and the seven optimized programs and the best optimized scenario are in Table 14.

10.2.Neutral Initial Parameters from which the Scenarios and the Programs were Optimized

The scenarios and programs were studied and optimized starting from the same neutral parameters (initialized to zero) for the period 2022–2026 (Table 15).

Table 13. The 4 non-optimized scenarios studied of the program PR3 and the 4 optimized scenarios studied of the program PR3.

The 4 non-optimized macroeconomic and environmental scenarios studied of the program PR3. The best non-optimized scenario of the PR3 program should be selected in order to be compared to the other programs.				The 4 optimized macroeconomic and environmental scenarios studied of the program PR3. The best optimized scenario of the PR3 program should be selected in order to be compared to the other programs.				
								Computation times
PR3SceA1	Economy	Scenario non-optimized without changing to the country's membership of country unions	Objective 2: Improving economy	PR3SceA1Opti	Economy	Scenario optimized (with 200 iterations) without investigation into changing of situation => No change to the country's membership of country unions	Objective 2: Improving economy	00:27:03
PR3SceB1	Economy	Scenario non-optimized with changing to the country's membership of country unions	Objective 2: Improving economy	PR3SceB1Opti	Economy	Scenario optimized (with 200 iterations) with investigations into changing in situations => Change to the country's membership of country unions	Objective 2: Improving economy	00:30:50
PR3SceC1	Finance	Scenario non-optimized without changing to the country's membership of country unions	Objective 4: Improving finances	PR3SceC1Opti	Finance	Scenario optimized (with 200 iterations) without investigation into changing of situation => No change to the country's membership of country unions	Objective 4: Improving finances	00:31:52
PR3SceD1	Finance	Scenario non-optimized with changing to the country's membership of country unions	Objective 4: Improving finances	PR3SceD1Opti	Finance	Scenario optimized (with 200 iterations) with investigations into changing in situations => Change to the country's membership of country unions	Objective 4: Improving finances	00:41:18
							Total	2:11:03

10.3. Ranking of the Seven Non-Optimized Programs, the Best Non-Optimized Scenario, the Seven Optimized Programs, and the Best Optimized Scenario

The ranking depicted in Table 16 was obtained by evaluating all scenarios and programs from the same neutral initial parameters, with different modalities, but in line with the common objective: "improving a mix of the four objectives" defined in Section 8 in Table 12. In this ranking there are no scenarios or programs aimed at improving the economybecause the four scenarios with this objectivewere not selected after being compared with the other scenarios.PR3SceC1 and PR3SceC1Opti were selected.

10.4.Best Program Found for France for the Period 2022–2026 by Optimizing Programs Defined with Neutral Parameters, but with Different Modalities

The best program found is PR1Opti. It optimizes the PR1 program with 200 iterations, in line with the objective "improving a mix of the four objectives",and without investigating an exit from country unions.It makes sense that this program ranks first because it was optimized in line with this objective, which wasalso used to compare and rank all scenarios and programs.

10.5.Main Results of this Study

The average rating of non-optimized programs, including the best non-optimized scenario, is 7.32. The average rating of optimized programs with 200 iterations, including the best optimized scenario, is 7.66, then an average improvement of 4.54%.This may not seem like much, but for example the average Public debt / GDP ratio of the non-optimized programs in 2026 is 127.88%,

Table 14. The 7 non-optimized programs and the best scenario and the 7 optimized programs and the bestnon-optimized and optimized scenarios.

The non-optimized macroeconomic and environmental 7 programs and the selected scenario					The optimized macroeconomic and environmental 7 programs and the selected scenario					
										Computation times
PR1	Unemp/Eco/Envirt/Finan	Prog. Unemp/Eco/ Envirt/Finan	Program non-optimized without changing to the country's membership of country unions	Objective 5: Improving Unemp / Eco / Envrt / Finan	PR1Opti	Unemp/Eco/Envirt/Finan	Prog. Unemp/Eco/Envirt/Finan optimized	Optimized program (with 200 iterations) without investigation into changing of situation => No change to the country's membership of country unions	Objective 5: Improving Unemp / Eco / Envrt / Finan	00:27:57
PR2	Unemp/Eco/Envirt/Finan	Prog. Unemp/Eco/ Envirt/Finan	Program non-optimized with changing to the country's membership of country unions	Objective 5: Improving Unemp / Eco / Envrt / Finan	PR2Opti	Unemp/Eco/Envirt/Finan	Prog. Unemp/Eco/Envirt/Finan optimized	Optimized program (with 200 iterations) with investigations into changing in situations => Change to the country's membership of country unions	Objective 5: Improving Unemp / Eco / Envrt / Finan	00:31:26
PR3	4 scenarios of the PR3 program are studied and optimized				PR3Opti	4 scenarios of the PR3 program are studied and optimized				
PR4	Unemployment	Prog. Unemployment	Program non-optimized without changing to the country's membership of country unions	Objective 1: Reducing unemployment	PR4Opti	Unemployment	Prog. Unemployment optimized	Optimized program (with 200 iterations) without investigation into changing of situation => No change to the country's membership of country unions	Objective 1: Reducing unemployment	00:32:04
PR5	Unemployment	Prog. Unemployment	Program non-optimized with changing to the country's membership of country unions	Objective 1: Reducing unemployment	PR5Opti	Unemployment	Prog. Unemployment optimized	Optimized program (with 200 iterations) with investigations into changing in situations => Change to the country's membership of country unions	Objective 1: Reducing unemployment	00:40:34
PR6	Environment	Prog. Environment	Program non-optimized without changing to the country's membership of country unions	Objective 3: Improving environmental economic data	PR6Opti	Environment	Prog. Environment optimized	Optimized program (with 200 iterations) without investigation into changing of situation => No change to the country's membership of country unions	Objective 3: Improving environmental economic data	00:38:37
PR7	Environment	Prog. Environment	Program non-optimized with changing to the country's membership of country unions	Objective 3: Improving environmental economic data	PR7Opti	Environment	Prog. Environment optimized	Optimized program (with 200 iterations) with investigations into changing in situations => Change to the country's membership of country unions	Objective 3: Improving environmental economic data	00:31:07
PR8	Finance	Prog. Finance	Program non-optimized without changing to the country's membership of country unions	Objective 4: Improving finances	PR8Opti	Finance	Prog. Finance optimized	Optimized program (with 200 iterations) without investigation into changing of situation => No change to the country's membership of country unions	Objective 4: Improving finances	00:32:06
									Total	3:53:51

while the average Public debt / GDP ratio of the optimized programs in 2026 is 63.69%, then an average improvement of 50.20%.

On the other hand it follows from this study that:
- the average of the scores of the non-optimized programs studied without leaving European unions is 7.37, and that of the non-optimized programs studied leaving European unions is 7.25;
- the average of the scores of the optimized programs studied without leaving European unions is 7.70, and that of the optimized programs studied leaving European unions is 7.59;
- the average mandatory levy on products and services that preserve the environment of the non-optimized programs is 0%, and that of the optimized programs is -10.62%;
- the average public expenses of the non-optimized programs is € -259bn, and that of optimized programs is € -521bn; these results show that for France, for 2011–2021, Keynesian theory [8] does not apply while Friedman's does [20].

Table 15. Neutral initial parameters from which scenarios and programs were studied and optimized.

	2022	2023	2024	2025	2026
ECONOMIC UNION(S), MONETARY ZONE(S), COMMERCIAL ZONES(S), and FREE MOVEMENT AREA(S) Devaluations / re-evaluations of € if France :	31	31	31	31	31
3 IS A MEMBER *31 from EU and / or from EEA and / or from Schengen and of € Zo*	-2.91%	-2.47%	-2.47%	-2.47%	-2.47%
Compulsory Levy Rate (CLR) - Variation	0.00%	0.00%	0.00%	0.00%	0.00%
HOUSEHOLDS: Taxes	0.00%	0.00%	0.00%	0.00%	0.00%
HOUSEHOLDS: Levies	0.00%	0.00%	0.00%	0.00%	0.00%
HOUSEHOLDS: Contributions	0.00%	0.00%	0.00%	0.00%	0.00%
COMPANIES: Taxes	0.00%	0.00%	0.00%	0.00%	0.00%
COMPANIES: Levies	0.00%	0.00%	0.00%	0.00%	0.00%
COMPANIES: Contributions	0.00%	0.00%	0.00%	0.00%	0.00%
Variation CLR on products & services that preserve the environment	0.00%	0.00%	0.00%	0.00%	0.00%
Variation in environmental protection decided by economists, environmental experts, and politicians + resulting from growth	0.00%	0.00%	0.00%	0.00%	0.00%
Central public administrations (including of the state)	0.00%	0.00%	0.00%	0.00%	0.00%
Local government	0.00%	0.00%	0.00%	0.00%	0.00%
Social Security funds	0.00%	0.00%	0.00%	0.00%	0.00%
Variations in public expenses allocated to public employment and collateral: subcontractors, etc.	0.00%	0.00%	0.00%	0.00%	0.00%
Recovery rate shortfall in tax evasion	0.00%	0.00%	0.00%	0.00%	0.00%
Recovery rate shortfall social fraud	0.00%	0.00%	0.00%	0.00%	0.00%

Best macroeconomic and environmental programs found for France for the period 2022–2026. *The results found justify that the best programs in line with the objectives:*i.e. reducing unemployment, improving the economy, improving environmental economic data, improvingfinances, and improving a mix of the previous four objectives equally weighted, *would involve moderate anti-austerity and a green program, based on:*

- the economic and financial interests for France of remaining a member of European unions;
- moderate austerity that would improve France's economic and financialsituations;
- a reduction in compulsory levies on products and services that preserve the environment;
- a reduction in public spending.

11. Discussion, Conclusion

11.1. Discussion

Some difficulties encountered. It was very difficult to find statistical historical data, parameters of assumptions, constraints and parameters of unoptimized rules. This is a classic problem when setting an expert system. Fortunately, the optimizer improves the rule parameters.

Observations on the use of Artificial Intelligence. Most of the reasoning we have modeled with an Expert System is based on non-logical data. So we didn't have to use formal logic. To do this, one could have resorted to "Logical Programming" using the Prolog language created by Alain Colmerauer and al. in the early 1970s [21], as used for example in [22].

The rules optimization allows a self-learning of rules parameters because it improves them. It is a kind of machine learning. It is not a deep learning usinga neural network. It is not a reinforcement learning because it doesn't make decisions sequentially to maximize a reward in a particular situation and it does not learn by interacting with its environment.

To improve the adjustment of the calculated historical macroeconomic and environmental data to the statistical data it is possible:

Table 16. Ranking and key economic data the non-optimized 7 programs and the selected scenario and of the 7 programs and the selected scenario optimized from 2022 to 2026.

France | Optimized rules | The scenarios and programs of THIS RANK are currently being assessed in line with THE COMMON OBJECTIVE below. SORT. (click this button to assess them in line with the SELECTED OBJECTIVES FOR EACH OF THEM) | AISP-V11 07/05/2022

SELECT A COMMON OBJECTIVE below. It will be used to EVALUATE HISTORICAL DATA with OPTIMIZED RULES, SCENARIOS and PROGRAMS in tables and in their rankings (then SORT to display the result) — Objective 5: Improving Unemp / Eco / Envrt / Finan

Ranking and key economic data of the non-optimized 7 programs and the selected scenario, and of the 7 programs and the selected scenario optimized, from 2022 to 2026 (with the Optimized rules)

Sort — the non-optimized 7 programs and the selected scenario, and the optimized 7 programs and the selected scenario

Scenario and program scores are assessed in line with the COMMON OBJECTIVE chosen above (however, the objective below are the SELECTED OBJECTIVES FOR EACH of the scenarios and programs)

Rank	Program	Objective	Selected objective	Economic and financial situation in 2026		Unemployment: Number of jobseekers available and actively seeking work in 2026	Unemployment: Variation from 2022 to 2026	Unemployment: Number of positions officials created (+) or deleted (-)	Macroeconomics: Inflation	Macroeconomics: Average GDP growth rate including green rate from 2022 to 2026	Macroeconomics: Average Annual Purchasing Power	Macroeconomics: Average change in competitiveness from 2022 to 2026	Macroeconomics: Compulsory Levy variation resulting from decisions of economists, environmental experts, and politicians from 2022 to 2026: CL annual var.	Macroeconomics: Compulsory Levy variation resulting from decisions of economists, environmental experts, and politicians from 2022 to 2026	Macroeconomics: HOUSEHOLDS: Var. Compulsory Levies computed prop. CLR var. in Bn of €	Macroeconomics: COMPANIES: Var. Compulsory Levies computed prop. CLR var. in Bn of €	Environmental macroeconomic data: Average GDP growth green rate from 2022 to 2026	Environmental macroeconomic data: Var. environmental protection decided by economists, environmental experts, and politicians + resulting from growth from 2022 to 2026	Environmental macroeconomic data: Variation in Mandatory Levies on products & services that preserve the environment, resulting from decisions of economists, environmental experts, and politicians from 2022 to 2026	Finance: Public expenses variation from 2022 to 2026: "Decided" variation resulting from decisions of economists, environmental experts, and politicians	Finance: Public expenses variation from 2022 to 2026: Total change: "decided" + asset expenditure + expenditure resulting from growth + change in environmental expenditure + change in debt interest	Finance: Public expenses / GDP in 2026	Finance: Deficit / GDP in 2026	Finance: Public debt / GDP in 2026
1.	PR1Opti	Unemp/Eco/Envirt/Finan	Objective 5: Improving Unemp / Eco / Envrt / Finan	AA-	7.75	0	-3 101 800	9 487	1.20%	4.74%	0.21%	3.790%	-3.45%	-16.21%	-54	-96	0.007%	-62.47%	-9.23%	-278	-606	30.00%	20.55%	-51.94%
2.	PR4Opti	Unemployment	Objective 1: Reducing unemployment	AA-	7.75	0	-3 101 800	-187 199	1.29%	4.85%	0.13%	3.999%	-3.66%	-17.10%	-60	-99	0.016%	-62.47%	-10.82%	-277	-608	29.76%	20.30%	-53.05%
3.	PR6Opti	Environment	Objective 3: Improving environmental economic data	AA-	7.72	565 541	-2 536 259	-15 219	0.80%	3.42%	0.51%	1.482%	-0.66%	-3.53%	-10	-22	0.057%	80.88%	-10.68%	-261	-520	35.27%	21.62%	-55.20%
4.	PR5Opti	Unemployment	Objective 1: Reducing unemployment	AA-	7.64	896 460	-2 205 340	-184 661	1.66%	3.24%	-0.35%	3.729%	-3.56%	-16.68%	-64	-103	0.099%	-63.88%	-11.58%	-273	-533	35.56%	16.38%	-63.50%
5.	PR2Opti	Unemp/Eco/Envirt/Finan	Objective 5: Improving Unemp / Eco / Envrt / Finan	AA-	7.63	1 116 588	-1 985 212	-186 340	1.50%	2.96%	-0.20%	3.364%	-3.16%	-14.96%	-53	-99	0.006%	-63.91%	-10.99%	-270	-524	36.46%	16.74%	-61.54%
6.	PR3SceC1Opti	Finance	Objective 4: Improving finances	AA-	7.63	1 938 791	-1 163 009	61 568	3.79%	1.55%	0.45%	2.195%	0.62%	2.84%	-4	31	0.079%	-64.79%	-12.47%	-115	-492	39.70%	20.67%	-67.15%
7.	PR8Opti	Finance	Objective 4: Improving finances	AA-	7.63	1 938 791	-1 163 009	61 568	0.81%	1.55%	0.45%	0.473%	0.62%	2.84%	-4	31	0.016%	-64.79%	-12.47%	-184	-492	39.70%	20.67%	-67.15%
8.	PR7Opti	Environment	Objective 3: Improving environmental economic data	A+	7.50	2 851 946	-249 854	174 411	3.09%	0.21%	-1.03%	1.202%	-0.64%	-3.35%	-12	-29	0.010%	68.72%	-10.55%	-206	-391	47.45%	13.45%	-89.99%
9.	PR8	Finance	Objective 4: Improving finances	A+	7.37	3 747 721	645 921	0	0.46%	-0.68%	0.41%	0.358%	0.00%	0.00%	0	0	0.000%	0.98%	0.00%	-3	-291	53.11%	5.16%	-121.51%
10.	PR1	Unemp/Eco/Envirt/Finan	Objective 5: Improving Unemp / Eco / Envrt / Finan	A+	7.37	3 747 721	645 921	0	0.46%	-0.68%	0.41%	0.358%	0.00%	0.00%	0	0	0.000%	0.98%	0.00%	-3	-291	53.11%	5.16%	-121.51%
11.	PR3SceC1	Finance	Objective 4: Improving finances	A+	7.37	3 747 721	645 921	0	2.12%	-0.68%	0.41%	1.800%	0.00%	0.00%	0	0	0.000%	0.98%	0.00%	-3	-291	53.11%	5.16%	-121.51%
12.	PR4	Unemployment	Objective 1: Reducing unemployment	A+	7.37	3 747 721	645 921	0	0.46%	-0.68%	0.41%	0.358%	0.00%	0.00%	0	0	0.000%	0.98%	0.00%	-3	-291	53.11%	5.16%	-121.51%
13.	PR6	Environment	Objective 3: Improving environmental economic data	A+	7.37	3 747 721	645 921	0	0.46%	-0.68%	0.41%	0.358%	0.00%	0.00%	0	0	0.000%	0.98%	0.00%	-3	-291	53.11%	5.16%	-121.51%
14.	PR2	Unemp/Eco/Envirt/Finan	Objective 5: Improving Unemp / Eco / Envrt / Finan	A+	7.25	4 866 317	1 764 517	0	0.86%	-2.12%	-0.17%	0.188%	0.00%	0.00%	-5	-10	0.000%	0.15%	0.00%	-5	-204	62.43%	0.12%	-138.50%
15.	PR5	Unemployment	Objective 1: Reducing unemployment	A+	7.25	4 866 317	1 764 517	0	0.86%	-2.12%	-0.17%	0.188%	0.00%	0.00%	-5	-10	0.000%	0.15%	0.00%	-5	-204	62.43%	0.12%	-138.50%
16.	PR7	Environment	Objective 3: Improving environmental economic data	A+	7.25	4 866 317	1 764 517	0	0.86%	-2.12%	-0.17%	0.188%	0.00%	0.00%	-5	-10	0.000%	0.15%	0.00%	-5	-204	62.43%	0.12%	-138.50%

. on one hand to increase the number of historical years studied; we would have had to consider data from atypical years during the subprime crisis from 2007 to 2009; we justified this limit in Section 9;

. on the other hand, to increase the number of optimization iterations: we have optimized the rules with 1,000 iterations (in 12 hours and 47 minutes) to minimize the average gap between historical data (from 2011 to 2021) and calculated historical data; the results obtained with 1,000 iterations are only slightly better than those obtained with 200 iterations.

The optimization of the rules with 1,000 iterations minimized the gap between statistical data for 2011–2021 and calculated historical datawas done in line with the “improving a mix of the fourobjectives”. This gap is 538.93% for the 2011-2021 period (therefore an annual compound gap of 32.44%) with non-optimized rules, and 47.44% (therefore an annual compound gap of 13.44%) with optimized rules, so a reducing of 91.20%.

The scenario and program ranking shows that their optimization leads to significant improvements and greater the number of iterations, the more optimized the programs.As example the optimizations of the PR1 program with different numbers of iterations for the period 2022–2026, without investigations into changing its membership of country unions, in line with the “improving a mix of the four objectives”are depicted by the curve in Figure 6.The score obtained with 400 iterations is only slightly better than that obtained with 200 iterations. This is why we considered that 200 iterations are enough to optimize the programs.The score of the non-optimized PR1 program is 7.3667, and the rating of the optimized PR1Opti program with 200 iterations (in 27 minutes 57 seconds) is 7.5517, an improvement of (only) 5.23%. But the improvements in the other parameters of the program are significant.For example:an average of 3,744,721 job seekers for the non-optimized PR1 programand of0 for optimized PR1Opti program;-121.51% improvement in the public deficit / GDP ratio for the non-optimized PR1programand-51.94% for the optimized PR1Opti program.

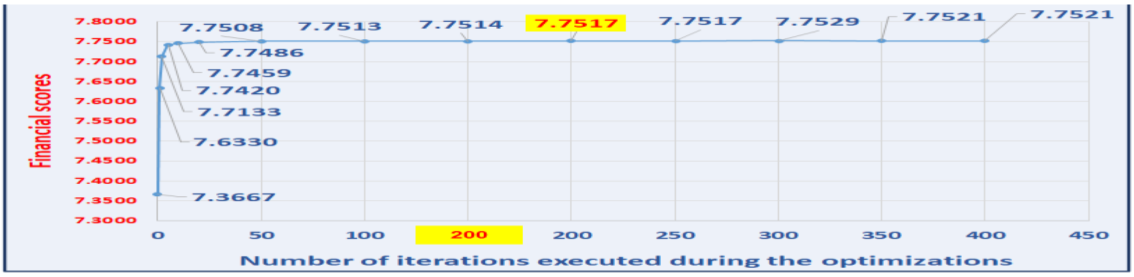


Figure 6. The optimized PR1Opti program financial scores obtained with different numbers of iterations

11.2. Conclusion

We have shown that the optimizations of macroeconomic and environmental programs by using artificial intelligence techniqueslead to significant improvements.These results prove that Artificial Intelligence would greatly optimize the macroeconomic and environmental programs of countries proposed by economists, environmental and political experts.We highlight the effectiveness in optimizing counties' programs the triptych of Artificial Intelligence of collaborative components: Automaton / Expert System / Optimizer. These components are sometimes used together in Artificial Intelligence without highlighting the existence of the triptych.This triptych is a software pattern that can be used to deal with other economic and environmental issues, but also in many other fields.

ACKNOWLEDGEMENTS

I would like to thank Hong Patricia Castellani, PhD in computer science, forher collaboration in the development of the AISP software, and Anne-Marie Harper for her improvement of the English of this article.

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