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The relationship between nuclear energy consumption and economic growth: evidence from Switzerland

Cosimo Magazzino¹ , Marco Mele², Nicolas Schneider³ and Guillaume Vallet⁴

¹ Roma Tre University, Rome, Italy

² University of Teramo, Teramo, Italy

³ Paris-1 Pantheon Sorbonne University, Paris, France

⁴ Grenoble-Alpes University, Grenoble, France

E-mail: cosimo.magazzino@uniroma3.it, mmele@unite.it, Nicolas.Schneider@etu.univ-paris1.fr and guillaume.vallet@univ-grenoble-alpes.fr

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Supplementary material for this article is available [online](#)

Abstract

This study aims to investigate the relationship between nuclear energy consumption and economic growth in Switzerland over the period 1970–2018. We use data on capital, labour, and exports within a multivariate framework. Starting from the consideration that Switzerland has decided to phase out nuclear energy by 2034, we examine the effect of this structural economic-energy change in the country. To do so, two distinct estimation tools are performed. The first model, using a time-series approach, analyze the relationship between bivariate and multivariate causality. The second, using a Machine Learning methodology, test the results of the econometric modelling through an Artificial Neural Networks process. This last empirical procedure represents our original contribution with respect to the previous energy-GDP papers. The results, in the logarithmic propagation of neural networks, suggest a careful analysis of the process that will lead to the abandonment of nuclear energy in Switzerland to avoid adverse effects on economic growth.

1. Introduction

The environmental challenge facing Switzerland as well as other advanced economies is how to answer the growing sectoral energy demands in more secure and less costly energy procurement, and, at the same time, how to reduce greenhouse gas emissions associated with the economic activity (Menyah and Wolde-Rufael 2010, Intergovernmental Panel on Climate Change (IPCC) 2014, Li and Jiang 2019). While renewable energy is considered to be the unavoidable solution to reduce carbon dioxide (CO₂) emissions, nuclear power is claimed as a means of providing a low-carbon alternative to electricity generation based-fossil fuels and reinforcing energy security (Elliot 2007, Ferguson 2007, International Energy Agency (IEA) 2008, Adamantiades and Kessides 2009, Menyah and Wolde-Rufael 2010, Jacobson 2020, Yu *et al* 2020). Tightly linked to this view, the Nuclear Energy Agency (NEA) (2002) highlighted that 10% of total CO₂ emissions from energy use are saved annually through nuclear power in OECD countries.

Therefore, both emerging and advanced economies have shown or are showing a keen interest for this singular energy source (Kakodkar 2004, Xu 2008, Dos Santos *et al* 2013, Luqman *et al* 2019). In contrast, Switzerland decided very recently to phase-out from nuclear power.

When we look at the characteristics of this economy, on the issue of industry competitiveness in advanced sectors, the case of Switzerland is highly relevant⁵ (Baranzini *et al* 2013, Ponsot and Vallet 2013). But this country also displays prominent energy management strategies. In fact, Switzerland was identified as one of the most energy-efficient (and least energy intensive) countries in the OECD for the year 2011 and is currently designated as the country with the lowest carbon intensity of all 30 International Energy Agency (IEA) member states (Filippini and Hunt

⁵ The World Economic Forum (World Economic Forum (WEF) 2019) ranked Switzerland as the 5th most competitive economy in 2019 (over 144 countries) according to the Global Competitiveness Index (GCI).

2011, International Energy Agency (IEA) 2019a). Furthermore, the World Energy Council (WEC) (2011) ranked Switzerland as the best country performer (with Sweden) regarding the energy sustainability index, which is in line with its recent recognition as the best 'energy mix country' among 120 others by the World Economic Forum (WEF) (2017).

Despite such promising characteristics, this country is undergoing profound mutations regarding its electricity supply. Dealing with the numerous controversies associated with nuclear power, the 2017 national referendum definitively endorsed the nuclear energy phase-out. As well-known critics against nuclear energy, the operational waste safety and the radioactive waste disposal have come to the fore (Toth and Rogner 2006). Also, this diffidence has been reinforced by the recent 2011 Fukushima nuclear accident which facilitated the emergence of protest movements against nuclear in Europe.⁶ As in Germany and Belgium, the Swiss federal authorities established a national strategy (i.e. *Energy Strategy 2050*) aiming to close the five nuclear power plants (currently in operation) by 2034 (Swiss Federal Office of Energy (SFOE) 2018). Since power-based nuclear still represented 32% of the Swiss electricity generation in 2017, this economy will undoubtedly face crucial energy, economic and environmental challenges in the future (Pattupara and Kannan 2016). Hence, there is a point in asking if the coming nuclear energy conservation policy would jeopardize the Swiss economic growth. Considering the new scenario after the national vote of May 2017, the purpose of this study is to understand the nature of the nuclear energy-GDP relationship in this country. If economic growth leads to the consumption of nuclear energy sources in the country itself, then phasing-out from nuclear power may not significantly affect growth. Inversely, if a unidirectional causal link is running from nuclear energy consumption and aggregate income, then the economy is said to be a nuclear-dependent one and any conservation policy may adversely impact its growth. This latter hypothesis is congruent with the theory that nuclear energy may have become an important input in the production process and thus, should be included alongside other standard factors of production (Alam 2006). Like aggregate energy, nuclear may also enhance the productivity of other factors of production, making it essential for the economic development (Cheng and Lai 1997, Toman and Jemelkova 2003).

An in-depth review of the literature highlights two important points based on which novelty aspects can be proposed. First, no single study has assessed the nuclear energy-GDP nexus for the specific case

of Switzerland. Indeed, the energy economics literature has paid little attention to the link between disaggregated energy sources and aggregate income so far (Magazzino 2012). To bridge this gap, Baranzini *et al* (2013) brought the first energy-GDP analysis on the Swiss case. Nonetheless, while the authors used energy data at both aggregate and disaggregate level, they excluded nuclear energy from their empirical exercise. In addition, a range of studies have recently explored the nuclear issue and its link with growth. However, since these papers employed only multi-country approaches (Yoo and Ku 2009, Wolde-Rufael 2010, Apergis and Payne 2010, Apergis *et al* 2010, Saidi and Mbarek 2016), Switzerland has always been included within large and heterogeneous panel members. Far from having results generalizable with consistency to each country, this lack in the literature underlines the necessity to explore the above relationship using a single-country analysis.

A first step was recently reached by Magazzino *et al* (2020)'s contribution which focused on Switzerland and investigated the relationship among municipal waste generation, greenhouse gas emissions, and GDP over the period 1990–2017. Earlier, Jaligot and Chenal (2018) conducted a closed assessment but restricted their regional analysis to the Canton of Vaud.

This is where our paper finds its first contribution. Performing such assessment appears even more crucial since the nuclear phase-out will make the Swiss economy more singular with respect to the other energy patterns in Europe.

A second point is methodological. Previous nuclear energy-GDP studies have displayed conflicting results so far. This is mostly because existing papers differ in terms of empirical strategies, data periods and samples selected (see table 1). Calling for further inquiry within the nuclear energy-GDP nexus, our second contribution stands in our empirical strategy. This paper applies two independent empirical tools: an econometric analysis and a Machine Learning method. To the best of our knowledge, this is the first-time that artificial neural networks (ANNs) experiments are employed to perform such a causal analysis amongst energy and growth variables. Allowing us to validate the times-series results, this practical exercise is believed to bring useful findings for policy purposes.

Therefore, this paper brings two distinct novelty aspects and investigates the causal link between nuclear energy consumption and economic growth in Switzerland. Using the largest available data including the recent historical change in the Swiss nuclear energy policy (1971–2018), this paper applies ANNs experiments (Machine Learning approach) to validate times-series causality tests results (econometric methodology). Data for capital stock, labour, and exports are incorporated as additional production factors to avoid potential omitted variable bias.

⁶ For a complete analysis on the impact of the Fukushima nuclear accident on European energy policy with a special focus on the changes in nuclear energy pattern that occurred thereafter in advanced European economies, see Wittneben (2012).

Table 1. Summary of previous multi-country studies on the nuclear energy-GDP nexus, including Switzerland.

Author(s)	Countries	Data Period	Methodology	Causality for Switzerland
Yoo and Ku (2009)	20 countries	1969–2005	GC	E \leftrightarrow Y
Wolde-Rufael (2010)	9 developed countries	1971–2005	TY	Y \rightarrow E
Apergis and Payne (2010)	16 countries	1980–2008	PPC, GC	E \leftrightarrow Y
Apergis <i>et al</i> (2010)	19 developed and developing countries	1984–2007	ECM, GC	E \leftrightarrow Y
Saidi and Mbarek (2016)	9 developed countries	1990–2013	DPR	E Y

Source: our elaborations. Notes: E and Y represent nuclear energy consumption and economic growth. Y \rightarrow E indicates a unidirectional causality running from economic growth to nuclear energy consumption (the ‘conservation hypothesis’). E \leftrightarrow Y Indicates a bidirectional causality between nuclear energy consumption and economic growth (the ‘feedback hypothesis’); and E Y indicates no causal relationship between nuclear energy consumption and economic growth (the ‘neutral hypothesis’). TY: Toda Yamamoto causality; GC: Granger causality; PPC: Pedroni Panel Cointegration; ECM: Error Correction Model; DPR: Dynamic Panel Regression.

The rest of this paper is organized as follows: section 2 describes the data, the methodologies employed and the empirical results. Section 3 gives concluding remarks and policy recommendations.

2. Data and empirical results

We collected data from the 1970–2018 period, using GDP as a proxy for economic growth. As in Imran *et al* (2012) and many other studies, we use gross fixed capital formation (GFCF) as a proxy for physical capital. GDP (Y) and GFCF (K) are expressed in billions of constant LCU. Labour data (L) refer to occupied active population measured in thousands of workers, while exports of goods and services (EXP) are expressed in millions of constant LCU. Nuclear energy consumption (E) data are expressed in gigawatt hours. GDP, capital and exports data are obtained from the World Development Indicators⁷ (WDI, 2019). Labour data are taken from the Employment Statistics⁸ and published by the Federal Statistical Office (FSO). Nuclear energy consumption data originate from the World Energy Statistics and Balances database⁹ and published by the IEA. All variables are transformed into natural logs. The empirical analysis process followed in this study is illustrated in the appendix through a flow chart (figure A1).

As a preliminary check, in table 2 some descriptive statistics are given.

In figure 1 we show the evolution of the logarithmic transformations for the analyzed series.

In table 5 we report the results of several time series tests on stationarity and unit root in order to determine the order of integration of the variables.

What emerges from table 3 is that our five selected series are trend-stationary at levels. In fact, especially

for K , L and Exp , the null hypothesis (H_0) of non-stationarity is not rejected.

Granger () causality tests following the Toda and Yamamoto (1995) approach require the estimation of an augmented VAR($k + d$) model, where k is the optimal lag length and d is the order of integration of the series. To ensure that the VAR model is well specified and it does not suffer from any non-normality or autocorrelation problems, additional tests are carried out. Though the results are not reported to save space, diagnostic tests suggest the general absence of problems in the estimated VAR models, with regard to normality and autocorrelation in the residuals, stability condition, and lag-exclusion. Moreover, the stability of coefficient estimates is supported, since the plot of cumulative sum fall inside the critical bounds of 5% significance. This indicates that the estimated parameters do not suffer from structural instability.

Table 4 reports the results of causality tests in detail. For the bivariate models (panel on the left), the empirical findings show that a bidirectional causal link between real GDP and nuclear energy consumption emerges. This means that a feedback mechanism exists (‘feedback hypothesis’). In contrast, the multivariate tests indicate the presence of a unidirectional causality flow running from nuclear energy consumption to aggregate income, which is statistically significant at a 1% level. Therefore, the empirical findings based on Toda Yamamoto causality multivariate causality tests are in line with ‘growth hypothesis’.

Now, we test the results of the time-series models using a ML approach with Oryx 2.0.8 software. Although there are numerous ML approaches, we have chosen to use an algorithm capable of generating a dependence on an ANNs.

Table 5 illustrates the use of the variables of our algorithm.

Our calculator has chosen 13 several inputs, compared to a single target. There are no omitted variables. Out of a total of 15 variables, one of them (which does not appear) represents the substrate. Through the pie chart in figure 2, we can observe in detail the use of all instances in the data set. In the reading of our algorithm, the instances represent

⁷ GDP, capital and exports data are available at: <https://databank.worldbank.org/source/world-development-indicators>.

⁸ Labour data are available at: <https://www.bfs.admin.ch/bfs/en/home/statistics/work-income/surveys/es.html>.

⁹ Nuclear energy consumption data are available at: https://www.oecd-ilibrary.org/fr/energy/data/iea-world-energy-statistics-and-balances_enestats-data-en.

Table 2. Exploratory data analysis.

Variable	Mean	Median	Standard Deviation	Skewness	Kurtosis	Range	IQR	10-Trim
Y	6.1213	6.1018	0.2391	0.1515	1.7647	0.7891	0.4427	6.115
E	9.7641	10.0580	0.6920	-2.1220	7.1645	2.9995	0.5279	9.916
K	4.6308	4.6400	0.2882	-0.0698	1.8837	1.0117	0.4977	4.633
L	8.2506	8.2744	0.1555	0.0791	1.8410	0.5154	0.2575	8.246
Exp	12.1125	12.0390	0.5627	-0.0366	1.8586	1.8627	0.9199	12.120

Sources: our calculations on WDI and FSO data.

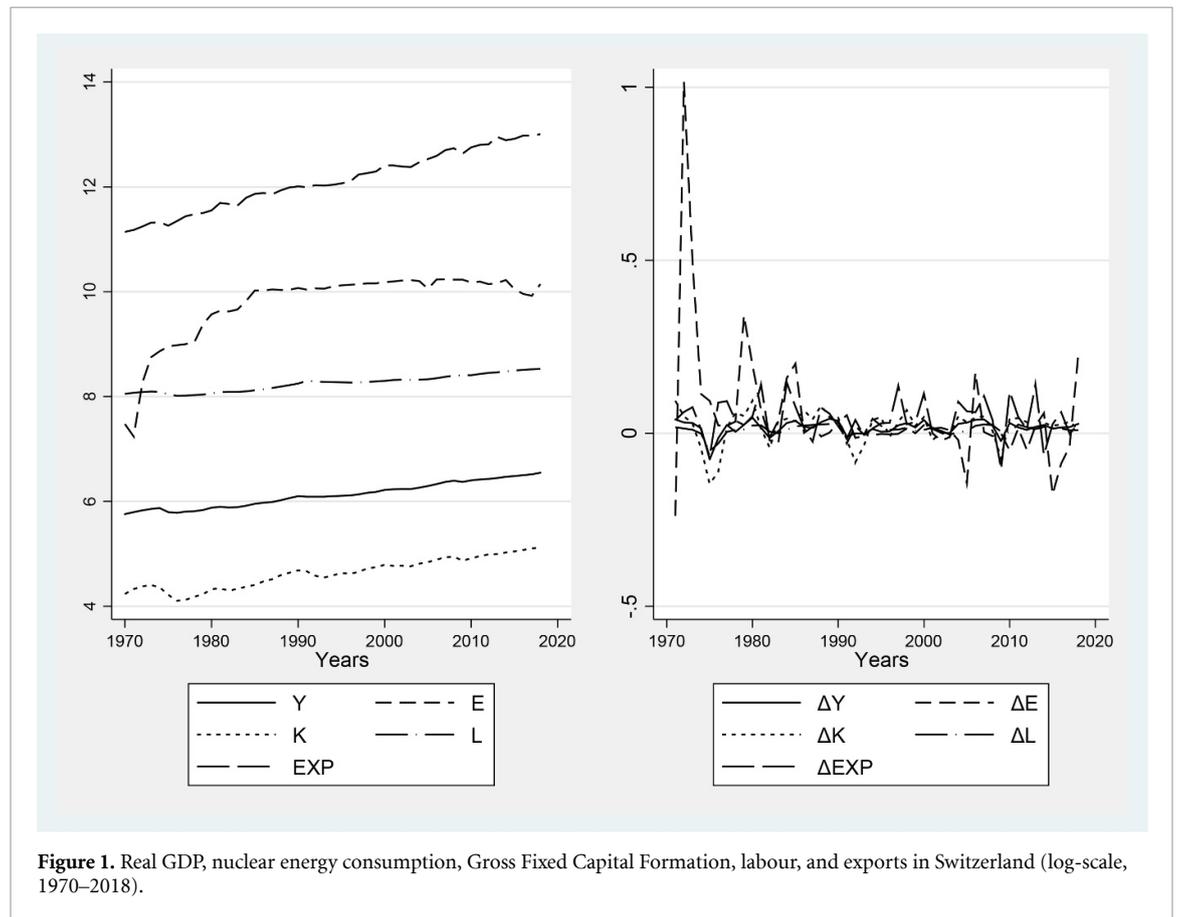


Figure 1. Real GDP, nuclear energy consumption, Gross Fixed Capital Formation, labour, and exports in Switzerland (log-scale, 1970–2018).

Table 3. Results for unit roots and stationarity tests.

Variable	Unit root and stationarity tests				
	ADF	Leybourne	DF-GLS	ERS	PP
Y	-3.612** (-3.512)	-2.652* (-2.888)	-2.265 (-3.247)	-1.697 (-3.320)	-2.529 (-3.508)
E	-4.630*** (-2.947)	1.870 (-2.239)	-0.090 (-2.185)	-0.090 (-2.312)	-7.308*** (-2.936)
K	-4.819*** (-3.512)	-4.399*** (-2.888)	-2.958* (-3.247)	-3.160*** (-2.533)	-2.642 (-3.508)
L	-3.395* (-3.512)	-4.272*** (-2.888)	-2.241 (-3.247)	-2.241 (-3.320)	-2.123 (-3.508)
Exp	-3.944* (-3.512)	-2.399 (-2.888)	-3.283** (-3.247)	-3.593** (-3.320)	-4.176*** (-3.508)

Notes: ADF: Augmented Dickey-Fuller test; DF-GLS: Dickey-Fuller GLS test; ERS: Elliott, Rothenberg, and Stock test; PP: Phillips-Perron test. Deterministic component: constant. When it is required, the lag length is chosen according to the SBIC. 5% Critical Values are given in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

the lines inside the dataset. They, in a ML context, rise to the task of samples or points. In fact, it would be wrong to design an ANN to store a dataset. We want the ANN to behave accurately on new

Table 4. Results of causality tests.

Dep. Var.	Bivariate						Multivariate					
	Dep. Var.	Independent Variables				Exp	Y	Independent Variables				Exp
		Y	E	K	L			E	K	L		
Y	–	18.32*** (0.003)	16.741*** (0.000)	0.87 (0.647)	2.14 (0.544)	Y	–	98.51*** (0.000)	20.89*** (0.000)	4.27 (0.370)	10.14** (0.038)	
E	12.82** (0.025)	–	5.77 (0.123)	7.73 (0.102)	4.857 (0.302)	E	2.16 (0.707)	–	10.03** (0.040)	9.78** (0.044)	6.04 (0.197)	
K	9.01** (0.011)	20.39*** (0.000)	–	3.11* (0.078)	0.29 (0.865)	K	16.76*** (0.002)	19.21*** (0.001)	–	1.59 (0.811)	9.48** (0.050)	
L	14.81*** (0.001)	28.56*** (0.000)	13.54*** (0.000)	–	5.01 (0.171)	L	35.001*** (0.000)	94.59*** (0.000)	3.79 (0.435)	–	7.54 (0.110)	
Exp	7.92** (0.048)	16.33*** (0.003)	3.01 (0.222)	10.53** (0.015)	–	Exp	9.70** (0.046)	16.68*** (0.002)	15.89*** (0.003)	6.22 (0.183)	–	

Notes: Wald tests (*p*-Values in parentheses), ****p* < 0.01, ***p* < 0.05, **p* < 0.10.

Table 5. Variables bars chart.

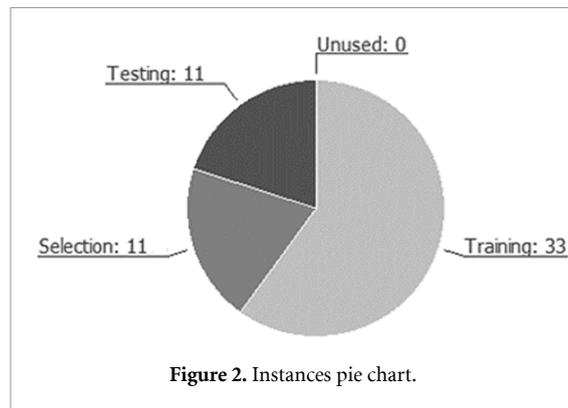
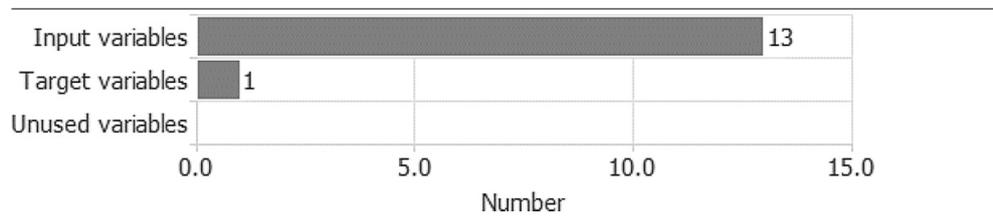


Figure 2. Instances pie chart.

data other than simple ones, that is to be able to generalize.

We obtained the result within three different subsets on the total number of instances equal to 55. The number of training instances is 33 (60%). The number of selection instances is 11 (20%). Instead, these instances choose the ANN with the best generalization properties. The number of testing instances is 11 (20%). These instances validate the operation of our model. Finally, the number of unused instances is 0 (0%). This result is significant for us. It highlights that there are no outliers in the data that can make the ANN malfunction. After observing the behaviour of our datasets concerning the processing in ML of our algorithm, we can analyze the result of the ANNs.

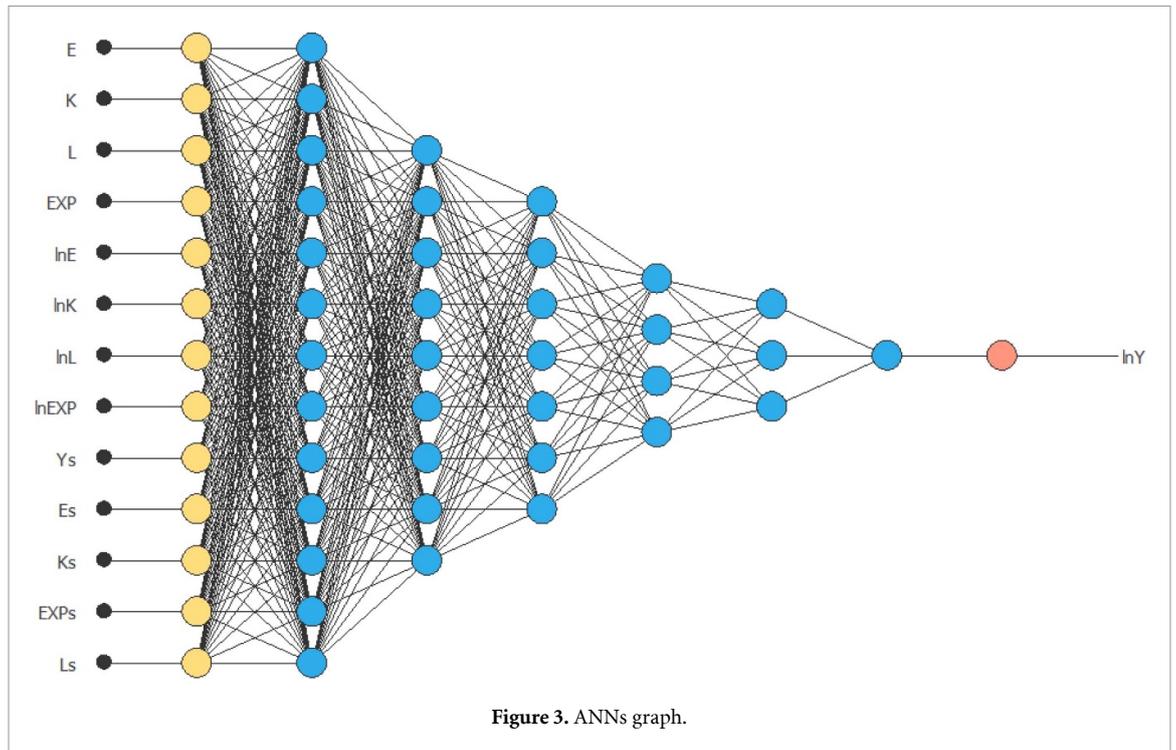
The ANNs graph in figure 3 contains a scaling layer, a NN and an unscaling layer. The yellow circles represent scaling neurons, the blue circles perceptron

Table 6. Confusion Matrix.

	Predicted Positive	Predicted Negative
Actual Positive	10.537	695
Actual Negative	893	10.339

neurons and the red circle unscaling neurons. The number of inputs is 13, and the number of outputs is 1. The complexity, represented by the numbers of hidden neurons, is 13:9:7:4:3. The execution time for each combination of input-target was, on average 28 s, with a peak of 40 s in the possible combinations between logarithmic inputs and targets squared. The distribution of the ANN, as seen from the figure, is a clear and linear process. Each neuron is interconnected with the others and between the perceptrons of the subsequent networks. The absence of anomalous values allowed a pyramid interconnection without the presence of anomalous perceptron networks such that they were more significant than the first ANN. As we can see from the result of the ANN, the pre-set target was lnY . It represents the best choice compared to $DR_{n,k}$ possible combinations of between inputs, to generate a target necessary for the analysis. The Confusion Matrix in table 6 confirms our result obtained through ANNs.

The results of table 6 confirm the goodness of those obtained in figure 5. We can observe that the virtue of the results is very high. The expected values, compared to the actual positive values, cause a change in our target 93.81 times every 100 combinations



between the inputs made. Therefore, compared to the actual positive values, there is only a 6.18% probability of being able to choose a different target than that obtained in the analysis of NNs ($dGDP$).

We obtain the same result by observing, in the confusion matrix, the results between the predicted positive and negative values with the actual negative values. In this case, the probability of obtaining a different target is only 7.95%. Regarding the analysis of the goodness of learning and data generation concerning the target obtained, we performed the Training test (figure 4) and the Predictive Linear Regression test (figure 5).

In figure, the 4 training strategy is applied to the ANNs in order to obtain the best possible loss. The type of training is determined by the way in which the adjustment of the parameters in the ANNs takes place. The Quasi-Newton method is used here for training. It is based on Newton's method, but does not require calculation of second derivatives. The blue line represents the training error and the orange line represents the selection error. The initial value of the training error is 1.12195, and the final value after 1 epoch is 0.10466. The initial value of the selection error is 0.88974, and the final value after 1 epoch is 0.00847. Therefore, the training strategy used for our ANNs is adequate.

The best straight line has a smaller distance, on the ordinate axis, from all points of the diagram to the predicted and real values. Therefore, the predicted and real variables of the study (concerning the target) have a linear relationship between them. Thus the points of the scatter plot tend to arrange themselves in a straight line.

The tests that we have carried out on the result of the ANNs passages can be considered as the output of the whole process. Despite this, we wonder which of the outputs generated a more significant variance of the per capita GDP. In this way, we would have useful policy information to advise the use of adequate economic policies to accelerate Switzerland's GDP or not.

The results of the test carried out in figure are very interesting. Our algorithm, which foresees different variations over time (six), has shown that the errors squared by the predictions of the ITE decrease to be minimal to the fourth ITE. This result allows us to analyze the Predicted Correlation Test, since the forecast error would be minimum. Therefore, in table, we show the result of the algorithm on the importance of each input variable in generating the target $\ln Y$. Each positive value will represent the predictive ability, compared to our six ITEs, of causing an acceleration of the target. Negative values, on the other hand, will generate contraction effects of the $\ln Y$.

The results obtained from the Predicted Correlation test in table 7 represent the positive and negative projections about our inputs on the target $\ln Y$. Looking at the table, we can come up with interesting observations. Compared to the total of 13 inputs, all inputs show a positive predictive correlation concerning the target $\ln Y$. However, their strength to vary the output obtained in the ANNs is different for each variable. In particular, we can note that the variables that are not the object of logarithmic transformation, together with those objects of the elevation to the square, cause a positive variation of the target $\ln Y$ lower than the logarithmic ones. The logarithmic



Figure 4. Training test.

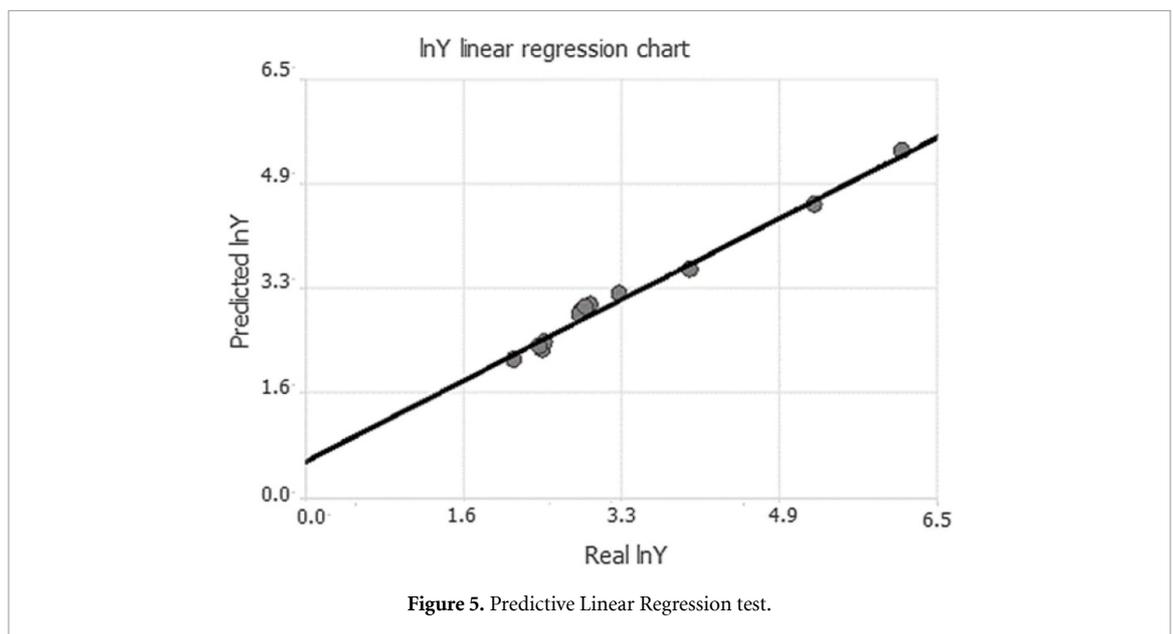


Figure 5. Predictive Linear Regression test.

inputs show a causality of variation of the target that is always more significant than 50%. The $\ln E$ variable, in particular, is the one that has a correlation prediction in the test that is superior to all variables. Its value of influencing a change in target $\ln Y$ was higher than 99%. At the level of ML mathematical analysis, these results underline that the variations on the $\ln Y$ target are not linear concerning the six ITEs generated by us. The presence of a substantial variation in the logarithmic inputs highlights how the variables chosen for this study to allow a variation of the GDP. However, it will have a logarithmic trend. In other words, once the sixth ITE threshold has been exceeded, it is necessary to intervene with new inputs or modify existing ones so that the target does not encounter a steady state of growth. In terms of economic comment, this result is very interesting. Over time, the use of nuclear energy in Switzerland has generated a strong link with economic growth. About 40% of the electricity produced in Switzerland

is currently of nuclear origin and comes from the five plants in Beznau I and II, Mühleberg, Gösgen, and Leibstadt. These plants produce 26 billion kilowatt-hours annually. However, because the reactors are ancient, they decrease in generated energy capacity. The lack of investments towards a new generation nuclear system and the decision to abandon nuclear energy by 2034 has produced, in our ANNs, the logarithmic trend from the input $\ln E$ to the target $\ln Y$. We can, therefore, conclude by saying that for Switzerland, the decommissioning of nuclear power plants and the different coverage of energy needs will have a cost in terms of GDP growth. The continuous lower production of nuclear power plants over the years has been recorded in our analysis of ANNs by the logarithmic trend of the generated target. Policymakers, therefore, will have to compensate for nuclear energy lost with that of other renewable energies, which, however, will be an amortized investment cost in the long-run.

Table 7. Predicted Correlation test.

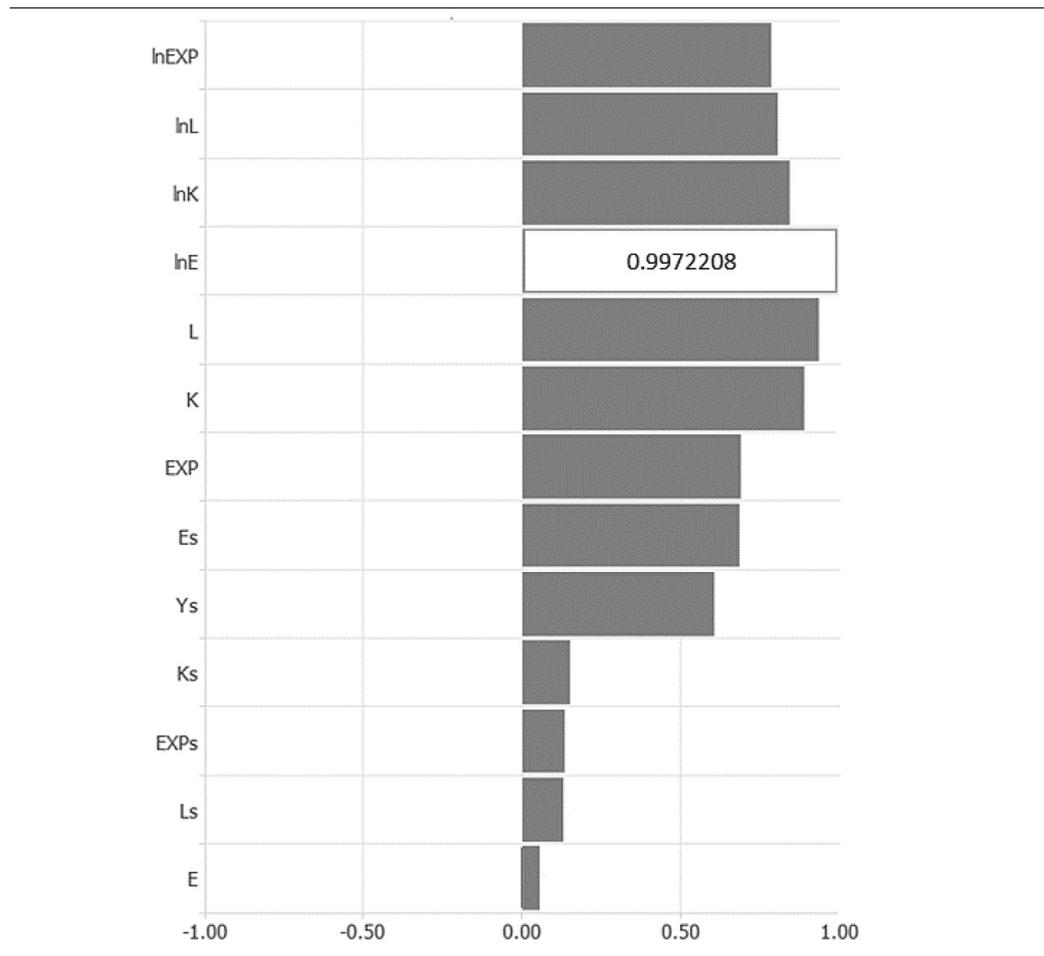


Table 8. Algorithm’s optimization.

Description	Value
Training rate method	Brent Method
Loss tolerance	0.001
Minimum parameters increment norm	1E-09
Minimum loss decrease	1E-12
Loss goal	1E-12
Gradient norm goal	0.001
Maximum selection error increases	100
Maximum epochs number	1000
Maximum time	3600

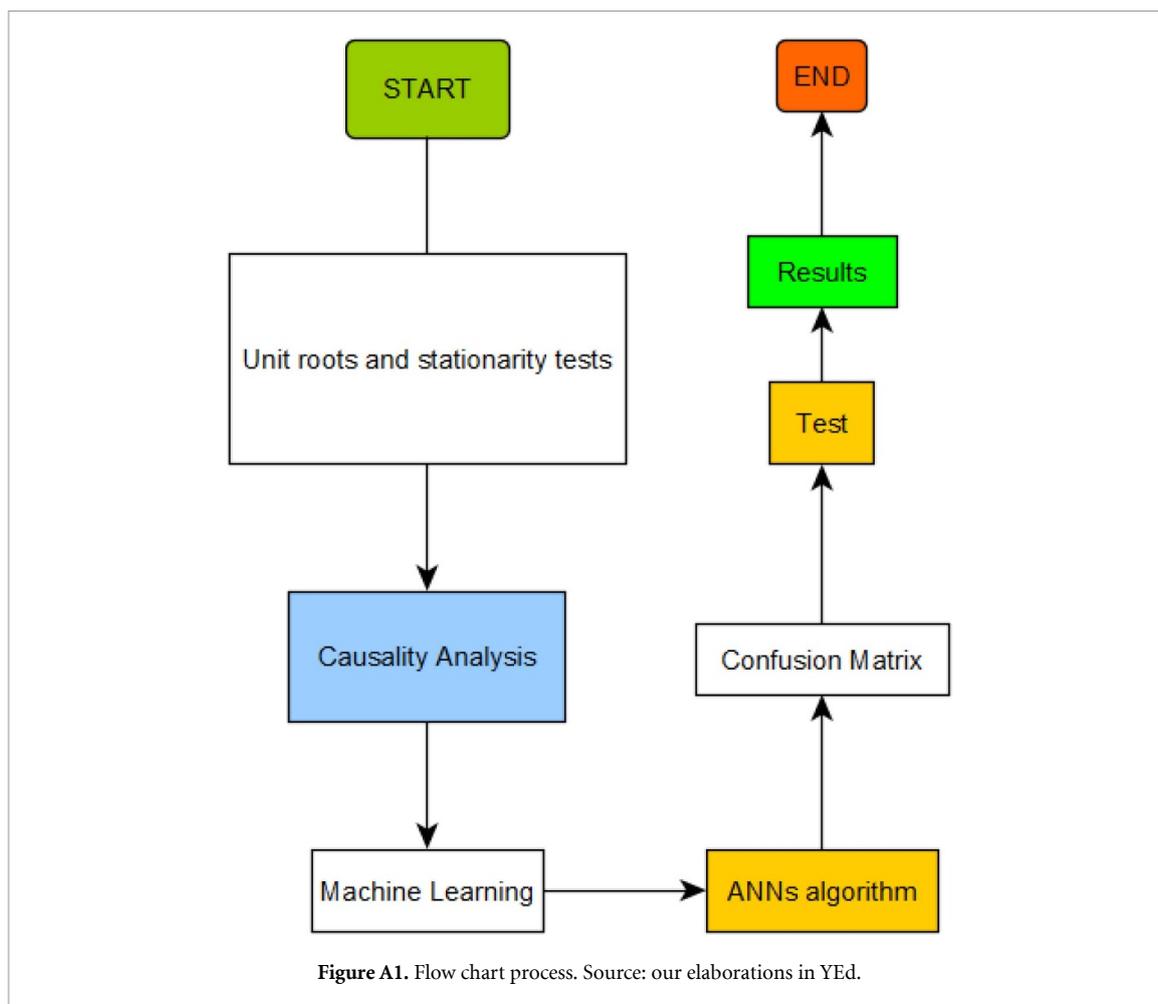
Source: our elaborations.

Finally, the results obtained from the analysis of the predictive correlation are tested with the optimization of the algorithm (table 8). In particular, with this test, we support the hypothesis or not regarding the stability of the ANNs with the growth of the epochs.

Through Brent’s method, we generated 100 epochs in the selection test and 1000 epochs in the Training test. The errors between the training vectors calculated every two successive epochs are almost zero. This result confirms the goodness of our ANNs. In other words, as the epochs grow, the signals of the NN remain constant.

3. Conclusions and policy implications

We analyzed the causal relationship between nuclear energy consumption and economic growth in Switzerland over the period 1970–2018, including also capital, labour, and exports in the model, within a multivariate framework. Our estimation models used two distinct empirical tools: a time-series approach and an ML method. This paper is the first study to apply ANNs to test the correctness of the results elaborated by the time-series causality analysis (Granger and Toda-Yamamoto causality tests) among energy and growth variables. The econometric results



supported the existence of a unidirectional causal link from nuclear energy consumption and economic growth, confirming the ‘growth hypothesis’. It implies that the Swiss economy is a nuclear-dependent one and adverse income effects may occur if no adequate phase-out policies are designed.

Moreover, ANNs experiments results showed that the combination of inputs achieved the presence of a logarithmic target. This effect showed, in the experiment of the neural networks, a growth trend of the GDP—connected to the use of nuclear energy—less than proportional to the time. Then, the six-ITEs predictive approach highlighted how the effects of the abandonment of nuclear energy could generate adverse effects on GDP growth in the coming years. This corroborates our econometric findings arguing that phasing-out from nuclear energy should be carefully implemented by authorities.

Therefore, as policy conclusions, we recommend a temporal balance between the process of shutting down nuclear power plants and enhancing the production of electricity from renewable sources. Although it is ongoing, it will still take a long time to reach the production capacity of nuclear power plants. Hence, the country should import large quantities of energy, especially from neighbouring

countries such as Germany and France. To this observation, we also add that the power lines and other components of the network infrastructure would not be able to sustain a massive increase in imports of electricity today. This situation would, therefore, risk overloading the infrastructure itself. To avoid this, transformers and power lines would need to be upgraded quickly in the coming years. Thus, the initiative to abandon nuclear power plants would endanger the country’s security of energy supply, producing potential adverse effects on the country’s economic growth.

Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

Appendix

ORCID iD

Cosimo Magazzino  <https://orcid.org/0000-0002-3176-9838>

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