Introduction to Python for Economists

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1 Introduction

The recent decision by France to construct new nuclear reactors[1], as well as the citizen-led initiative and petition advocating for the inclusion of nuclear energy in Italy's energy mix[2], demonstrate a renewed interest in nuclear energy in recent years. This resurgence is likely influenced by the energy crises that affected many European countries in 2022 and continue to disrupt energy markets. Furthermore, the increasingly evident consequences of climate change may have prompted a reconsideration of nuclear energy as a critical component of strategies to reduce greenhouse gas emissions.
Despite these developments, nuclear energy remains controversial in many countries. For instance, Germany mandated the decommissioning of its last three operational nuclear plants in 2023[3]. Similarly, in the United States, the share of nuclear energy in electricity production is projected to decline from 19% to 17% by 2040 due to the lack of new nuclear facility projects[4]. In contrast, China is making substantial investments in nuclear energy.[5].
It is well-established that nuclear energy production is associated with low greenhouse gas emissions and that technological advancements have achieved high safety standards. Additionally, the inclusion of nuclear energy in a country's energy mix is known to lower electricity prices in energy markets. Beyond these benefits, nuclear facilities have benefits to the local communities in which are located, including providing reliable employment, increasing local tax revenues, and decreasing consumer vulnerability to electricity price volatility. Moreover, nuclear power plants may also have other positive socio-economic effects on their surrounding communities [2]. This is due to the significant capital investments and employment opportunities generated by nuclear projects.
The objective of this paper is to assess whether nuclear facilities contribute positively to the economic development of their neighboring regions, in particular to the local Gross Domestic Product (GDP).
The economic effects of nuclear plants on local communities have already been the subject of academic inquiry. For example, Yamamoto and Greco (2022) [3] examine the socio-economic impacts of nuclear power plant shutdowns on host communities in the United States using a "quasi-experimental" approach. Similarly, Kim and Yoo (2021) [1]analyze the economic effects of nuclear power and renewable energy in South Korea through an "input-output" analysis.
Our research will be limited to European Union (EU) countries, as there is relatively little research activity focused on this region. This limited attention may be attributed to the lack of popularity of nuclear energy within this part of the world, which has led to minimal investment, particularly throughout the 21st century.

[1] https://www.nytimes.com/2022/02/10/world/europe/france-macron-nuclear-power.html
[2] https://www.cleanenergywire.org/factsheets/qa-italy-considers-controversial-return-nuclear-power
[3] https://edition.cnn.com/2023/04/15/europe/germany-nuclear-phase-out-climate-intl/index.html
[4] https://www.eia.gov/todayinenergy/detail.php?id=61106
[5] https://www-pub.iaea.org/MTCD/Publications/PDF/cnpp2022/countryprofiles/China/China.htm

2 Methods and Data

2.1 Data

Our analysis utilized three primary datasets:

1. **NUTS3 Regions Shapefile**: This dataset, provided by Eurostat, was essential for mapping the regions of Europe, including detailed maps of France and the Czech Republic.

2. **Nuclear lants Data**:This dataset includes the geographical coordinates of all nuclear facilities, their operational status (e.g., under construction), and the dates they became operational. It was made available by Cristinel Stoica, a Romanian researcher, who published this data on GitHub.[6].

3. **GDP Values by NUTS3 Regions**: This dataset, also supplied by Eurostat, provides GDP values at the NUTS3 regional level.

In addition to these datasets, we also obtained population and employment data from Eurostat. Due to the limited availability of data prior to 2001 and for the most recent two years, our analysis focuses on the period from 2001 to 2022. Furthermore, despite efforts to extend and enhance the analysis, no additional relevant data could be identified, and as a result, we relied exclusively on the previously enumerated datasets.

2.2 Methods

The analysis commenced with standard data cleaning procedures.

We subsequently filtered the nuclear plants dataset and the NUTS3 Regions shapefile to include only European Union (EU) countries.

As the GDP, population, and employment data provided by Eurostat were already pre-filtered for EU countries, no additional filtering was required for these datasets.

To provide an initial overview of the data, we generated a series of maps for visualization purposes. These included maps of the EU countries as a whole, as well as separate maps for France and the Czech Republic. These two countries were selected for further investigation because they were the only EU nations with new reactors constructed during the years for which data were available.

Then, we aim to provide both a graphical visualization and a fixed-effects regression analysis to explore the relationship between GDP and the presence of nuclear plants.

Unlike much of the prior literature, which predominantly relies on "quasi-experimental" approaches or "input-output" analysis, we have opted for a different methodological path. Specifically, our analysis focuses on eliminating the heterogeneity associated with individual countries or provinces by leveraging fixed-effects models. By doing so, we effectively isolate and highlight the specific impact of the presence of a nuclear plant on GDP.

This approach allows us to present a clearer and more understanding of the relationship, ensuring that the results are not confounded by unobserved regional characteristics or systemic differences across locations.

3 Results

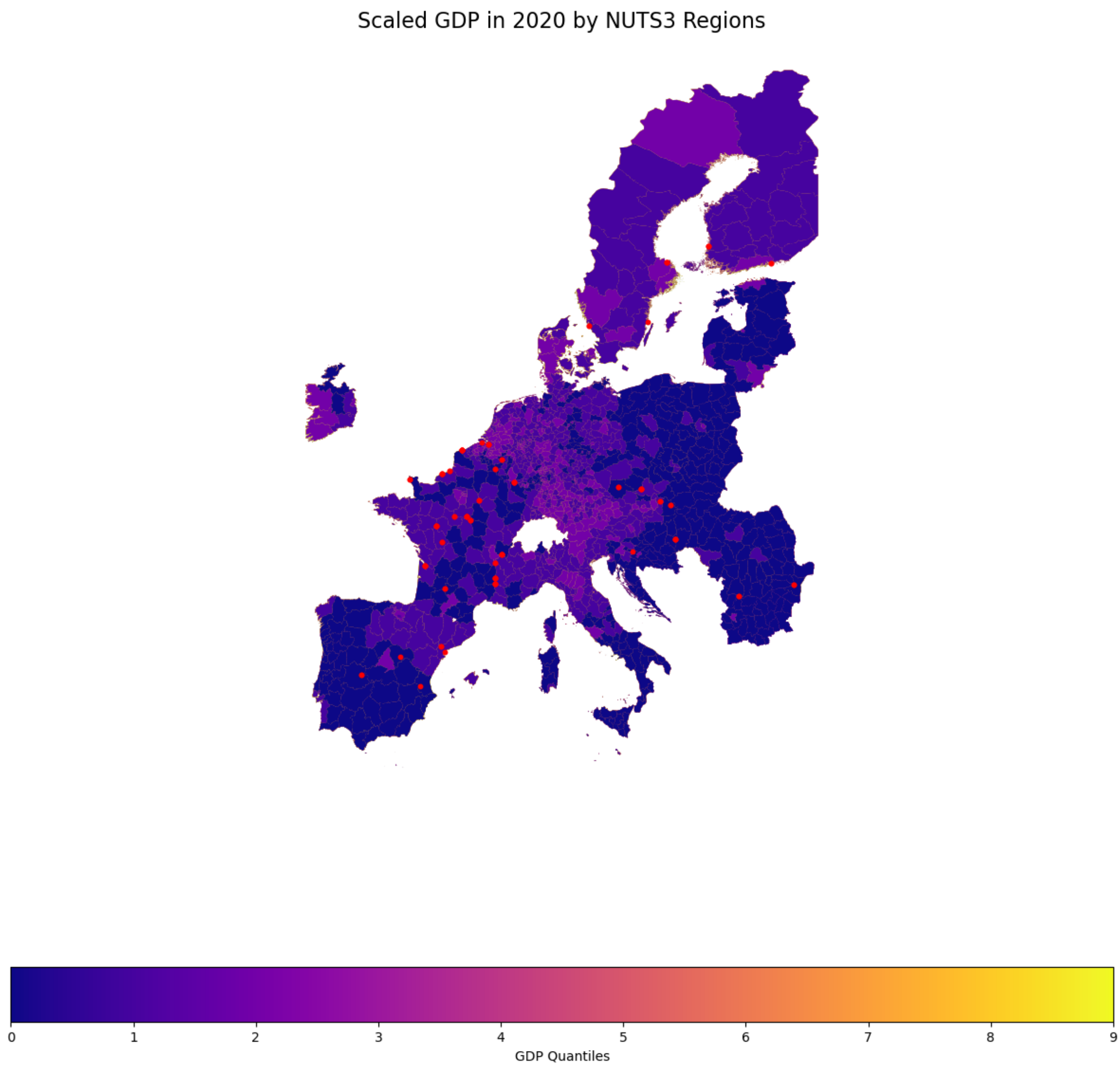
3.1 Graphical Data Visualization

It is anticipated that nuclear facilities exert a positive social and economic impact on individuals residing in proximity to the nuclear plant.

To begin with the Graphic Visualization, in 2024, 39 operation nuclear plants were present in the European Union. The first graph**??** shows 39 operational nuclear plants in EU countries by NUTS3 Regions. As depicted in the map, the majority of nuclear plants are concentrated in France, with a smaller number located in the Iberian Peninsula, Eastern Europe, and Scandinavia.

Upon zooming in on the map to focus on France and the Czech Republic during the years 2001 to 2004, it becomes evident that provinces surrounding nuclear plants often exhibit higher GDP levels compared to other regions12.

[6] `https://github.com/cristianst85/GeoNuclearData/tree/master`


Scaled GDP in 2020 by NUTS3 Regions
0
1
2
3
4
5
6
7
8
9
GDP Quantiles

3.2 Fixed Effects Regression Analysis

In this section, a Fixed Effects Regression Analysis is conducted for the period 2001–2004, focusing on the countries of France and the Czech Republic. The analysis will be performed using two distinct models:

1. First Model:

$$GDP_{i,t} = \alpha + \beta_1 Plant\_Operational_{i,t} + \beta_2 Employment\_Rate_{i,t} + a_i + \varepsilon \quad (1)$$

2. Second Model:

$$GDP_{i,t} = \alpha + \beta_1 Plant\_Operational_{i,t} + \beta_2 Employment\_Rate_{i,t} + \beta_3 Population\_Growth_{i,t} + a_i + \varepsilon \quad (2)$$

The output from the first FE regression is:

Dep. Variable:	GDP	**R-squared:**	3.611e-06
Estimator:	PanelOLS	**R-squared (Between):**	-0.0013
No. Observations:	1158703	**R-squared (Within):**	3.611e-06
Date:	Mon, Jan 20 2025	**R-squared (Overall):**	0.0013
Time:	11:20:27	**Log-likelihood**	-1.252e+07
Cov. Estimator:	Robust		
		F-statistic:	2.0920
Entities:	96	**P-value**	0.1234
Avg Obs:	1.207e+04	**Distribution:**	F(2,1158605)
Min Obs:	7238.0		
Max Obs:	5.12e+04	**F-statistic (robust):**	5.3099
		P-value	0.0049
Time periods:	3	**Distribution:**	F(2,1158605)
Avg Obs:	3.862e+05		
Min Obs:	3.862e+05		
Max Obs:	3.863e+05		

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
const	1.317e+04	51.428	256.02	0.0000	1.307e+04	1.327e+04
plant_operational	393.28	120.68	3.2588	0.0011	156.74	629.82
employment_rate	-0.0064	0.4917	-0.0130	0.9897	-0.9701	0.9573

F-test for Poolability: 7375.1
P-value: 0.0000
Distribution: F(95,1158605)

Included effects: Entity
The output from the second FE regression is:

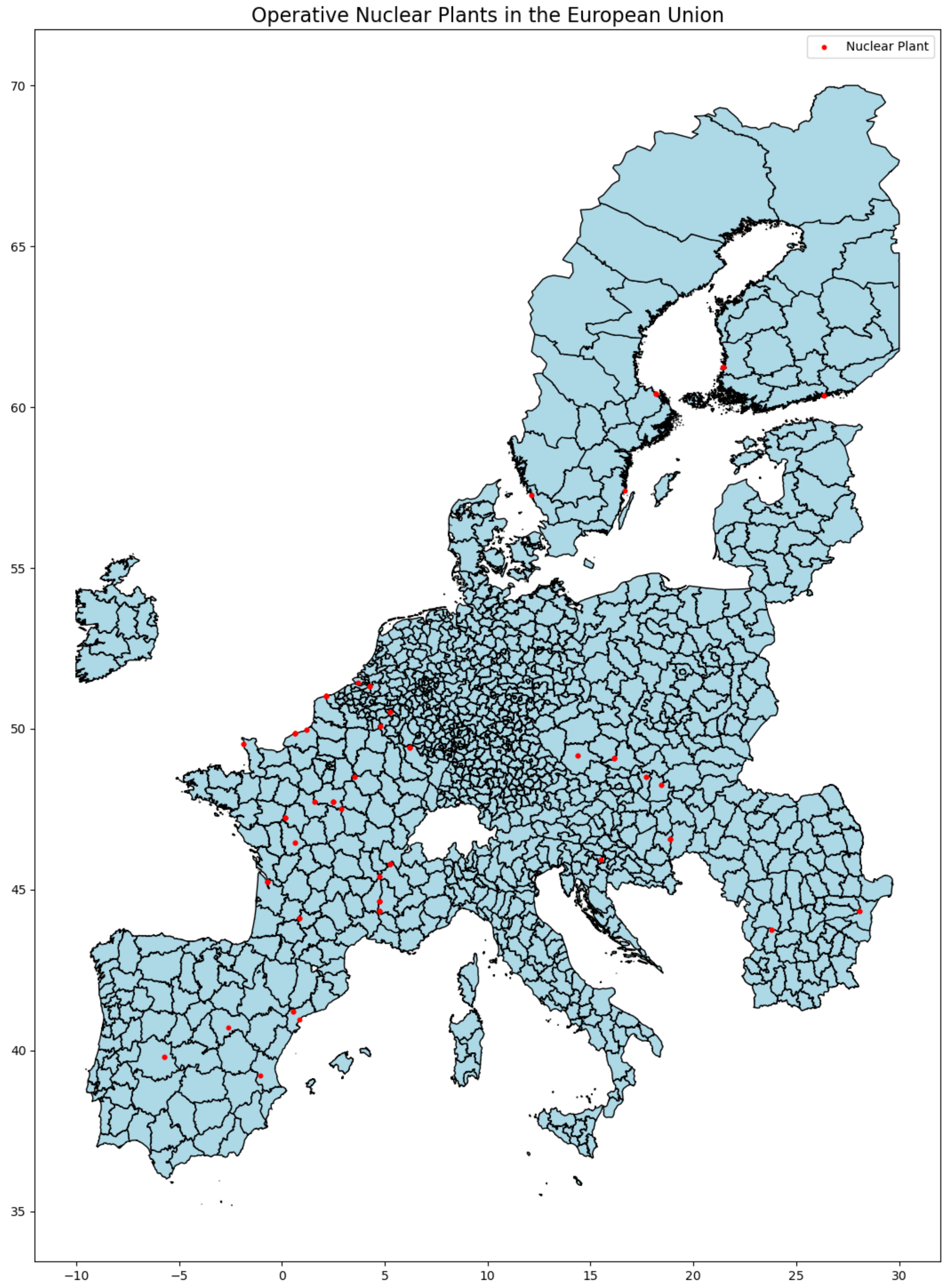
Dep. Variable:	GDP	**R-squared:**	0.0001
Estimator:	PanelOLS	**R-squared (Between):**	-0.0598
No. Observations:	3401965	**R-squared (Within):**	0.0001
Date:	Mon, Jan 20 2025	**R-squared (Overall):**	-0.0068
Time:	11:20:23	**Log-likelihood**	-3.676e+07
Cov. Estimator:	Robust		
		F-statistic:	147.93
Entities:	96	**P-value**	0.0000
Avg Obs:	3.544e+04	**Distribution:**	F(3,3401866)
Min Obs:	2.121e+04		
Max Obs:	1.501e+05	**F-statistic (robust):**	169.64
		P-value	0.0000
Time periods:	3	**Distribution:**	F(3,3401866)
Avg Obs:	1.134e+06		
Min Obs:	1.134e+06		
Max Obs:	1.134e+06		

	Parameter	**Std. Err.**	**T-stat**	**P-value**	**Lower CI**	**Upper CI**
const	1.647e+04	154.63	106.52	0.0000	1.617e+04	1.677e+04
plant_operational	196.90	71.032	2.7720	0.0056	57.678	336.12
population growth	-490.36	22.425	-21.867	0.0000	-534.31	-446.41
employment_rate	-0.0065	0.6107	-0.0107	0.9915	-1.2035	1.1905

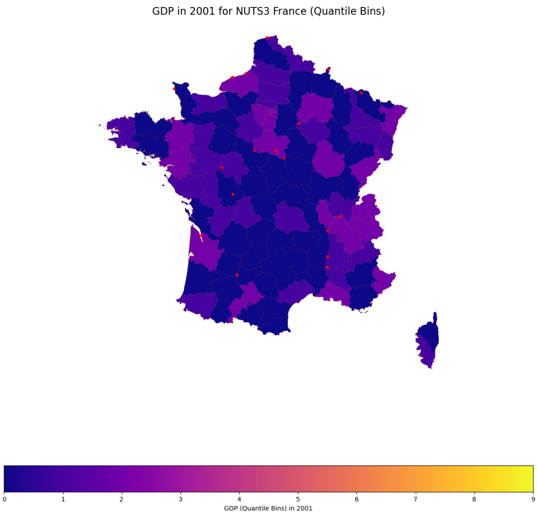
F-test for Poolability: 2.144e+04
P-value: 0.0000
Distribution: F(95,3401866)

Included effects: Entity

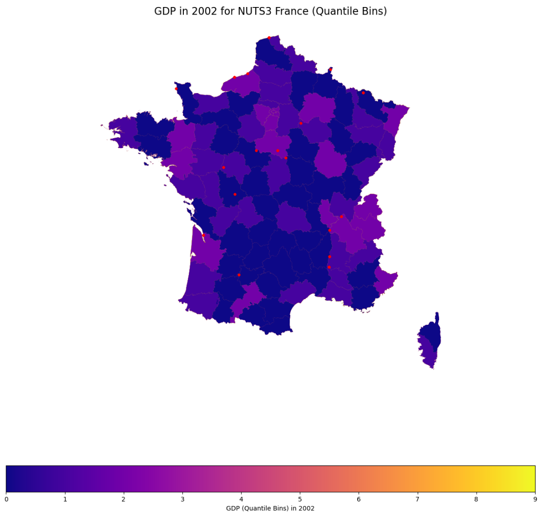
4 Graphs



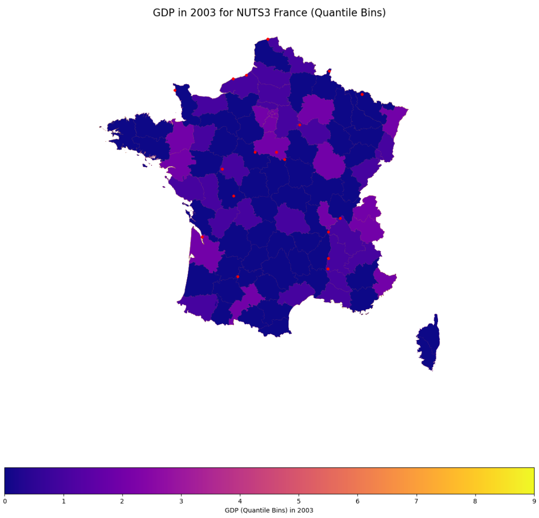
Operative Nuclear Plants in the European Union
Nuclear Plant
70
65
60
55
50
45
40
35
−10
−5
0
5
10
15
20
25
30



(a) Map 1 Caption

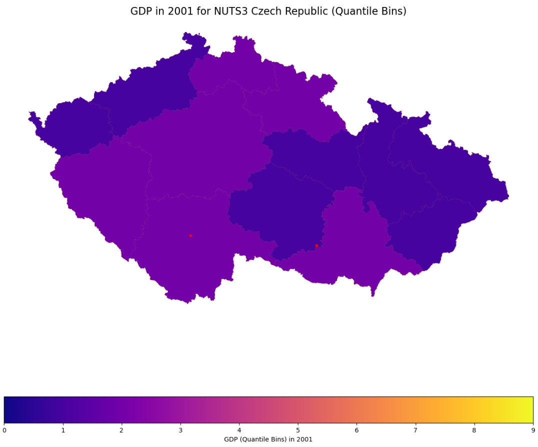


(b) Map 2 Caption

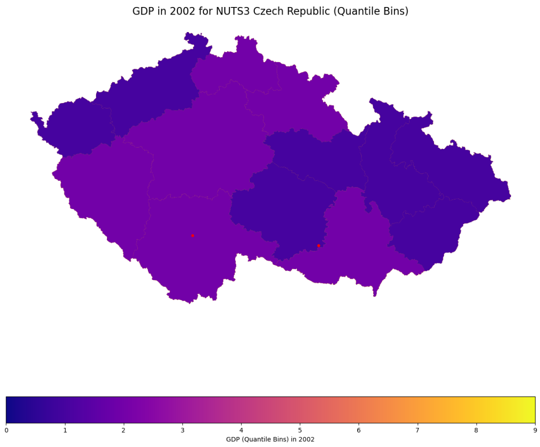


(c) Map 3 Caption

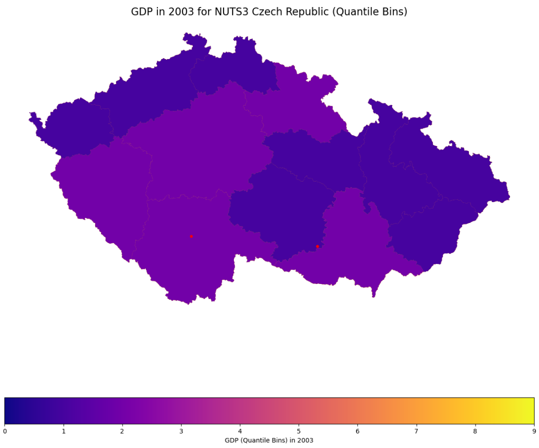
Figure 1: Maps of France (2001-2004).



(a) Map 1 Caption



(b) Map 2 Caption



(c) Map 3 Caption

Figure 2: Maps of Czech Republic (2001-2004).

References

[1] Ju-Hee Kim and Seung-Hoon Yoo. "Comparison of the economic effects of nuclear power and renewable energy deployment in South Korea". In: *Renewable and Sustainable Energy Reviews* 135 (2021), p. 110236. ISSN: 1364-0321. DOI: https://doi.org/10.1016/j.rser.2020.110236. URL: https://www.sciencedirect.com/science/article/pii/S1364032120305256.

[2] NREL. *Nuclear Energy – Providing Power, Building Economies*. American English. Other. 2022.

[3] Daisaku Yamamoto and Angelica Greco. "Cursed forever? Exploring socio-economic effects of nuclear power plant closures across nine communities in the United States". In: *Energy Research Social Science* 92 (2022), p. 102766. ISSN: 2214-6296. DOI: https://doi.org/10.1016/j.erss.2022.102766. URL: https://www.sciencedirect.com/science/article/pii/S2214629622002699.