'The Japan DataScientist Society'

(Technical Research and Development Paper)

"Proposals to use ESG Investments to Climate Change Measures and the Japanese Economy in 2050: Bayesian Machine Learning and Dynamic Stochastic Applied General Equilibrium Models"

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Abstract

The purpose of this paper is to propose the use of ESG (Environmental, Social, and Corporate Governance) Investment as solutions to Climate Change Measures and Japan's Economic 2050 Issues based on the theoretical design and implementation of a Bayesian Machine Learning and Dynamic Stochastic Applied General Equilibrium Models.

The objective is to propose the use of ESG (Environmental, Social, and, Corporate Governance) investment as means to solve the problems.

From the point of view of Environmental, Economic, and Social Influences, as well as the contribution of non- financial information, this paper these collected raw data form a probability vector as Panel Data.

The dynamic direct correlation coefficients from the panel VAPCR-SPDE (Vector Auto Principal Component Regressive - Stochastic Partial Differential Equation) Models judged to be appropriate, and specific values derived by taking partial derivatives in the regression equation and adopting Bayesian estimation, in which time series values continuously substituted and analyzed using representative values.

Although the number of samples was small, the reproducibility of these concrete values demonstrated by XGBoost.

Based on the results of the above analysis, we proposed that ESG Investment used as a solution to Climate Change and the Japanese economy's 2050 Issues, especially for renewable energy, which is in dire need of financial resources but for which demand expected to grow:
Promote measures to spread renewable energy;
Development and introduction of CCS (Carbon dioxide Capture and Storage) thermal technology;
Import and industrial use of shale resources;
Promotion of international consensus building on Climate Change Measures.

Keywords:
- Econometric Time Series Analysis;
- Republican tests, Unit root tests;
- Partial Granger Causality tests;
- Non-orthogonalized impulse response function;
- Panel VAPCR-SPDE Models;
- XGBoost

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1. Problem setting

The purpose of this chapter is to present the whole picture by organizing the issues in the research structure.

1.1. Research Objectives / Significance

Based on the above, climate change and Japanese economics2050We have developed a Bainzian machine learning / dynamic stochastic applied general equilibrium model for the year problem.

With reproducibility in view of the evaluation function of the regression tree based on its statistically optimized causal inferenceProbabilistically elucidate the transition to 2050That is the purpose of this paper.

As a result, it will be necessary in the future to deal with the location of the problem.ESGLet's contribute to the consideration of investment proposals.

However, as a result of a literature survey, some government statistics, etc. dealing with this theme became limited raw data.

Therefore, we replaced it by systematizing various statistical significance tests, metric time series analysis, stochastic partial differential equations, and machine learning.

1.2. Background and whereabouts of problems

on the other hand,2050 issue raisedThe background of this is that after the Cold War, global environmental problems were tackled internationally.

Ministry of Economy, Trade and Industry(2016: 1-2)[2]According to the report, in view of the seriousness of climate change, the international community has taken the opportunity of the "International Climate Change Framework Convention" (adopted in 1992 and entered into force in 1994) to deal with climate change, and the "Kyoto Protocol" (adopted in 1997). The Kyoto Mechanism (ie, Joint Implementation, Emissions Trading, Clean Development Mechanism) was mentioned as the result of the first international framework (effective in 2005).

However, the "Kyoto Protocol" is a "Climate Change Framework Convention".As a result of sticking to the "common but different responsibilities" raised by (1992)As a result of obliging virtually only developed countries to reduce greenhouse gas emissions, the United States has withdrawn.

Also, greenhouse gas inventoryAccording to (2017), the average emissions from 1990 to 2015 account for Japan's greenhouse gas emissions.The percentage of energy origin is92.7% or more, accounting for the majority[3]..

According to the Ministry of the Environment of Japan, the international community has a new legal framework.COP (Conference of Parties) 21 Paris Agreement 2015Adopted in[4].. Ministry of Economy, Trade and Industry of JapanAccording to (2016: 5), this COP21Japan's international commitment under the Paris Agreement is to reduce greenhouse gas emissionsBy 2030, it will be reduced by 26.0% compared to 2013.[5].. Since the adoption and entry into force of the "Kyoto Protocol," Japan has already taken steps to reduce greenhouse gas emissions, including the Kyoto mechanism. In addition, considering the shutdowns and restrictions of nuclear power plants throughout Japan due to the Fukushima Daiichi Nuclear Power Station accident, it can be said that it is difficult to achieve with conventional efforts.

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[2] Ministry of Economy, Trade and Industry(2016) "Results of COP21 and future issues"

[3] Greenhouse gas inventory(2017) "AnnexGreenhouse gas emission data by gas sector in Country I ”

[4] Ministry of the EnvironmentHP "United Nations Framework Convention on Climate Change No.21st Conference of the Parties (COP21) andKyoto Protocol No.Results of the 11th Conference of the Parties (COP / MOP11)Be

[5] Ministry of Economy, Trade and Industry(2016) "Results of COP21 and future issues"

In fact, Japan has increased the operation of thermal power generation as an alternative to nuclear power generation.

On the other hand AI-RPAIn view of concerns about employment due to further research and development and the crisis of social security financial resources due to the declining birthrate and aging population, even in the Japanese economy2050 problemIs being raised.

From the above, in addition to energy / climate change and nuclear risk, the causal relationship between electricity demand, nuclear industry, natural disaster risk, geopolitical risk, etc.2050It is possible to point out the necessity of forecasting the future up to the year, and the empirical elucidation is the problem.

1.3. Empirical analysis / prediction

As a method, the panelVAR-SPDEModel andXGBoostTheoretical design and implementation of regression prediction.

The output of the summary statistics and the drawing of the graph shall be performed in a timely manner.

In addition, in the capitalist economy, since everything is established by the supply and demand equilibrium, it is not necessary to formulate the supply and demand equilibrium equation, and the following identity is a constraint.

$$\partial \forall D(\forall S) = \partial \forall S(\forall D),$$

D:: Demand function,
S:: Supply function

1.3.1. RImplementation procedure by

1. Preprocessing
    1. Preprocess raw data.
    2. Error term adjustment is applied to each probability vector.
    3. Empirical analysis and prediction are performed on the geometric probability vector.
1. Statistical significance test
    1. Multicollinearity by uncorrelated test
    2. Steady state by unit root test
    3. Spurious regression by cointegration test
    4. Biased Granger causality test
    5. Non-orthogonalized impulse response function
1. Statistical optimization causal inference model
    1. panelVAPCR-SPDEmodel
    2. Total derivative of principal component regression equation
    3. Derivation of the dynamic direct correlation coefficient.
    4. Extract the standard error of the model.
    5. Derivation of the standard partial regression coefficient.
    6. XGBoost Demonstration of reproducibility by regression tree prediction

1.4. Selection of random variables and individual effects

On the other hand, random variables / individual effects are described later in energy / climate change and the Japanese economy, and in energy / climate change and the Japanese economy.Judged as a characteristic indicator of the 2050 problemStatistical values were selected.

$y_{it,1}$(Final energy consumption)

Random variables are primarily final energy consumption[6].. It was judged that the final energy consumption has a causal relationship with changes in Japanese economic activities, nuclear power administration and greenhouse gas emissions, as well as the existence of an international agreement on climate change.

Increases and decreases in final energy consumption will even affect climate change through Japan Energy Mix.

[6] Agency for Natural Resources and Energy "" Heisei2015 Annual Report on Energy "(EnergyWhite paper2016) HTML version "

$y_{it,2}$(Greenhouse gas emissions)

Second, greenhouse gas emissions[7].. Greenhouse gas emissions will increase or decrease as fossil fuels other than uranium are converted and used as secondary energy.

"Basic Act on Energy Policy"(Article 3) states that it is compatible with the environment.It has been legalized, and it is speculated that changes in greenhouse gas emissions will also affect the formulation and revision of the "Basic Act on Energy Policy" by increasing or decreasing the climate change load through energy sources.

$y_{it,3}$(Nuclear power plant accident / abnormal event)

Third, the presence and degree of accidents and abnormal events at nuclear power plants in Japan.[8].. Nuclear power generation has a historical history of using at least greenhouse gases as its main power source before the accident at the Fukushima Daiichi Nuclear Power Station, without emitting greenhouse gases during power generation.

However, once an accident or anomalous event occurs and the risk of radioactive contamination becomes known, the operation of a nuclear power plant will tend to be politically difficult.

In fact, Chubu Electric PowerAccording to (2015), Prime Minister Suga at that time was Hamaoka.Extrajudicial measures taken to shut down nuclear power plants[9]..

The panel described laterVPCRIn the model parameters, it was set as a premise of the impact on the environment, economy, and employment.

$y_{it,4}$(OPEC crude oil average price)

Fourth,OPEC crude oil average price[10].. In light of the two oil crisesOPEC Crude Oil Average Price Increases and Decreases Fossil Fuel DependenceLet's influence Japan Energy Mix and climate change countermeasures.

As fossil fuels soar, renewable energy becomes relatively cheap, and so does the back. The relative price of fossil fuels and renewable energy may be affected by the formulation and revision of the "Basic Act on Energy Policy."

$y_{it,5}$(Real GDP)

Fifth, the substanceGDP[11].. At least before the energy reform measures after the Fukushima Daiichi nuclear power plant accident, economic growth and environmental protection will be in a trade-off relationship.

However, "Basic Act on Energy Policy"(Article 4) is the marketThe conjugation of the principle is statutory, and it is practical.Logical consistency with GDPGender can also be considered to have been influenced by the formulation and revision of Japan Energy Mix and the "Basic Act on Energy Policy."

$y_{it,6}$(Balance of government bonds relative to GDP)

Sixth,GDP-to-government bond balance[12].. If at least tax revenue and budget dependence on government bonds are equal, the balance of government bonds will accumulate in proportion to

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[7] Greenhouse gas emissions were sampled based on both of the following documents.
(1) THE WORLD BANK
"CO2 emissions (metric tons per capita) Japan"
(2) Greenhouse gas inventory office
"Japan's greenhouse gas emission data (1990-2015 preliminary reportvalue)"

[8] Ministry of the Environment
"INES (International Atomic Energy Agency / Radiation Event Evaluation Scale) ”

[9] Chubu Electric Power(2015)
"Responding to the request to shut down the Hamaoka Nuclear Power Station"

[10] THE WORLD BANK

[11] Calculated by the author of this paper based on both of the following documents.
(1) THE WORLD BANK "GDP (current US $) Japan"
(2) Statistics Bureau, Ministry of Internal Affairs and Communications"2015 CPI ”

[12] Statistics Bureau, Ministry of Internal Affairs and Communications

GDP. Therefore, in order to substantiate the accumulation of government bond balances, it is set as the ratio to GDP.

thisAccumulation of GDP-to-government bond balance leads to an increase in public investmentLet's get and increase the final energy consumption. It is estimated that the increase or decrease in final energy consumption is proportional to the increase or decrease in the demand for each primary energy source.

$y_{it,7}$(Annual average consumer price index)

Seventh, the annual average consumer price index[13].. Deterioration of price levels can reflect the recession of the real economy in particular.

At that time, the government could increase greenhouse gas emissions as well as final energy consumption, giving priority to fiscal stimulus over environmental friendliness, as in the second Abe Cabinet's new economic policy.

If greenhouse gas emissions increase, the demand for renewable energy will increase and nuclear power generation will be allowed to operate.

$y_{it,8}$(Annual average unemployment rate)

Eighth, the average annual unemployment rate[14].. The unemployment rate is a characteristic economic indicator. The deterioration can reflect the recession of the real economy in particular.

At that time, the government could increase greenhouse gas emissions as well as final energy consumption, giving priority to fiscal stimulus over environmental friendliness, as in the second Abe Cabinet's new economic policy.

$y_{it,9}$(Nikkei Stock Average)

Ninth, the Nikkei Stock Average[15].. Stock prices represent the state of the Japanese economy through financial markets, and Japan Energy Mix can be formed in view of the economic situation.

In fact, "Basic Act on Energy Policy"(Article 4) is the activity of market principlesThe statutory law is used, and it can be seen that it is logically consistent with the Japanese economy.

$y_{it,10}$(LDP seat acquisition rate in the House of Representatives)

Tenth, the rate of winning seats in the House of Representatives of the Liberal Democratic Party[16].. From the perspective of historically emphasizing fiscal mobilization, the Liberal Democratic Party speculated that changes in the rate of seat acquisition in the House of Representatives could lead to an increase in final energy consumption due to an increase in environmental load and economic activity through public works projects.

In addition, it is possible that changes in political parties will affect Japan's energy mix and greenhouse gas emissions.

The panel described laterVPCRIn the model parameters, it was set as the extrinsic effect on the environment, economy, and employment.

$y_{it,11}$(Agreement on climate change measures (presence or absence))

Eleventh, there is an agreement on climate change countermeasures. Climate changeFirst

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"Transition of postwar government bond management policy"

[13] Statistics Bureau, Ministry of Internal Affairs and Communications "Time series data national (price index by item) annual average (1970Average ~2016 average) ”

[14] Statistics Bureau, Ministry of Internal Affairs and Communications "Unemployment / Unemployment rate [By relationship with the head of household]"

[15] Nikkei 225 profile

[16] Nihon Keizai Shimbun(2015) "Postwar Political History Looking Back at the House of Representatives Election"

scientific question at the Philaha Conference in 1985The subject is raised[17]At the same time, since the Japanese bubble economy started and affected the economic variables described later, 1986 would be the starting year.

On the other hand, the latest data is not in time for the aggregation of government statistics, etc.Since it stayed in 2014, the time axis (t) is from 1986 to 2017.

However, international agreements on climate change were made many times during that time, and model selection was made that it changed greenhouse gas emissions as well as final energy consumption through the Japanese economy.

The panel described laterVPCRIn the model parameters, it was set as the extrinsic effect on the environment, economy, and employment.

it (Formulation / revision (presence / absence) of "Basic Energy Plan")

Individual effect(i)Regarding, formulation and revision of "Energy Basic Plan"(Presence / absence).

We have positioned the formulation and revision of the "Basic Energy Plan" as an indicator of the sustainability of Japan Energy Mix.

Since there was a problem with the sustainability of Japan Energy Mix, the revision was made even though the law was enacted and formulated and only the obligation to reexamine was codified, but there is a problem with sustainability. It can be inferred that the political decision was made.

In addition, the subscript*t*Means that each individual effect has a distribution that follows a stochastic process.

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[17] Agency for Natural Resources and Energy (Energy White Paper2007) HTML version "HeiseiAnnual Report on Energy in FY18 "

2. Empirical analysis / prediction results (summary)

The above random variables and individual effects were arranged in chronological order, and panel data was formed through various preprocessing and error term adjustments.

Based on this panel data, multivariate time series analysis, panelVAPCR-SPDE modelToXGBoostThe accuracy was evaluated using the prediction of the regression tree.

I will outline the summary of the results obtained from each process.

2.1. Pretreatment

In this paper, as preprocessing, summary statistics were obtained for each procedure while organizing raw data, empirical analysis of multicollinearity, and adjusting error terms.

2.1.1. Organizing raw data

Individual effect on each random variable(i) and time axis (t)Subordinate toDefined as a random variable.

After that, in order to treat each time series as the rate of change based on the steady state, it was converted into a logarithmic difference series.

2.1.2. Empirical analysis of multicollinearity

After that, in each probability vector, some combinations of high correlation coefficients were confirmed.

In addition, in the uncorrelated test, we confirmed a combination that rejects the null hypothesis that "there is no correlation".

2.1.3. Error term adjustment

Therefore, in order to overcome the combinations that can point out multicollinearity and to perform regression tree prediction for more accurate statistical inference and accuracy evaluation, error term adjustments were made to each column of the geometric probability vector.

The following geometric probability vectors are probit-mapped. When the logit mapping was tried on the qualitative data, it could not be redefined as a probability vector due to missing values and the like.

- $y_{it,3}$(Nuclear power plant accident / abnormal event)
- $y_{it,11}$(Presence or absence of agreement on climate change measures)

On the other hand, all geometric probability vector sequences were mapped to a logarithmic difference series. It can be treated as a steady state by taking the natural logarithm.

In addition, if the rate of change is sufficiently small, such as by taking the natural logarithm by the first-order Taylor expansion approximation, it is approximated to the time differential coefficient.

After performing the above processing, it was defined as.Y_{it}

2.2. Multivariate time series analysis

On the other hand, in order to prepare for statistical causal estimation and prediction of stochastic process, the properties of each error term adjusted probability vector in the panel data will be elucidated.

This allows the panelDynamic direct correlation derived from VAR modelIt can be probabilistically demonstrated that the coefficient depends on causality without chance.

In addition, the standard of significance level$p$Value = ± 0.050.

2.2.1. ADF test

First, as a unit root testADFI tried the test.

Since it is based on annual data, each lagAs a result of setting to 1All statistical significance was detected.

Therefore, the geometric probability vector can be treated as a steady state.

2.2.2 Cointegration test

Second, we tried the cointegration test.

Since some examples of statistical significance were detected, a dynamic direct correlation coefficient is derived by vector autoregression in order to prevent spurious regression by the least squares method.

2.2.3. Partial Granger causality test and non-orthogonalized impulse response function

Third, we tried a biased Granger causality test and derived a non-orthogonal impulse response function.
Since the combinations that detect statistical significance are conspicuous and the degree of influence on each other is not low, there is no suitable relationship for the dynamic stochastic applied general equilibrium model.

2.3. Dynamic Stochastic Computable General Equilibrium Models

Based on the above, a dynamic stochastic applied general equilibrium model is formed.

2.3.1. Panel VAPCR Model

First, the panelA VAPCR model was formed. Detect statistical significance and$p$The value was also stable.
In addition, significance was detected by the partial Granger causality test.

Therefore, in the probability vector, the statistical significance of the statistical causality of all combinations was demonstrated.

Given the statistical significance of each row of this geometric probability vector, it is possible to derive a dynamic direct correlation coefficient from this model.

Panel this dynamic direct correlation coefficientVAPCRThe standard deviation of the model was totally differentiated, and the principal component standard partial regression coefficient was derived.

For environmental, economic and social impacts$\boldsymbol{y_{it,3}}$(Nuclear power plant accident / abnormal event)As well as setting on the premise of$y_{it,10}$(Liberal Democratic Party House of Representatives Seat Acquisition Rate)And (agreement on climate change countermeasures (presence or absence)) were extrinsic.$y_{it,11}$

2.3.2. SPDE (Sochastic Partial Dferential Euation)

This Panel VAPCR Model's error terms and constant term were excluded to make the statistical causality more certain, and the panel VAPCR-SPDE model was formed.

Also, convert this model object to a geometric probability vector XGBoost Could be used as a model object for.

2.3.3. XGBoost Regression Trees Prediction

ThisXGBoost made a prediction using regression trees and were able to detect good accuracy in the evaluation function.

Based on the above, this paper is a statistically optimized causal inference models.

3. Proposal for using ESG Investment

Based on the above, in energy / climate change and the Japanese economy ESG on the 2050 issue Propose the use of investment.

3.1. Promotion of renewable energy dissemination measures

Although the final energy consumption is gradually decreasing, it is desirable to use renewable energy as the main energy source in view of the increasing trend of greenhouse gas emissions.

Taking into account the actual and forecast results of nuclear risk, the demand for primary energy is even greater. Nuclear power that continued to depend on less than 30%There will be production demand up to the minute.

Therefore, this industryESGIt can be said that it is an effective destination for investment.

3.2. Development and introduction of CCS thermal power technology

However, after the Fukushima Daiichi Nuclear Power Station, Japan restricted nuclear power generation, but replaced it with thermal power generation.

While implementing FIT (Feed-in Tariff), it relied on thermal power generationThis means that there is a limit to the current production technology for renewable energy.

Therefore, when performing thermal power generation,CCS (Carbon dioxide)
By paralleling Capture and Storage), a greenhouse powered by thermal power generationIt will be possible to partially offset the effect gas emissions.

In view of thisESGPropose industrial use of investment.

3.3. Import and industrial use of shale resources

On the other hand, crude oil is a depleting resource. It was probably the investment in consideration of the risk of depletion that the time derivative of the price began to decrease from a certain point.

However, crude oil is in demand for various uses in addition to its primary energy source.

Therefore, we will import undeveloped shale resources and propose industrial use. Certainly, it is necessary to mine with an environmental impact assessment, but it is desirable to start mining, including legislation, to secure crude oil.

For that, we need financial resources, ESG Propose to cover by investment.

3.4. Promoting the formation of an international consensus on climate change measures financial resources

Moreover, the location of problems in climate change is not in Japan alone, but in the entire international community. There was a lot of discussion after the Cold War, but the US withdrawal from the Paris Agreement supports the simulation results as an example.

On the other hand, the time derivative of the LDP's seat acquisition rate in the House of RepresentativesIt is on a downward trend andConsidering the biased Granger causality with geometric probability vectors, legal policy based on international consensus building is even more desirable.

At that time, the Japanese side needs to negotiate through industry-academia collaboration, and the capitalESGPropose the use of investment.

3.5. Summary

Climate change continues to deteriorate, and the Japanese economy2050In order to reach a further stagnation period due to the annual problem and to achieve economic policy and climate change countermeasures at the same time in view of energy and climate change.ESGThe use of investment has been proposed in this chapter.

1. Promotion of renewable energy dissemination measures
2. Development and introduction of CCS thermal power technology
3. Import and industrial use of shale resources

4. Capital to promote international consensus building on climate change

From the above, climate change and the Japanese economy2050 problemIt is proposed as the third arrow in the new economic policy of the Second Abe Cabinet together with the solution to the problem.

Citation Statistics

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Appendix

A-1. Overview of technical terms

Terminology	Definition
Dynamic Stochastic Computable General Equilibrium Model	A method of describing multiple multivariate time-series events inside and outside the economy with stochastic processes as structural equations and quantitatively analyzing the effects of measures or risks.
Causal inference	To estimate the causal relationship between random variables by performing a significant difference test on the statistical values.
Random variable	A variable determined by the law of probability that describes what kind of value it will be with a certain probability distribution
Probability distribution	A function that gives the probability that a random variable will be a certain value or that it belongs to a certain set
non-linear	Properties that are not described or approximated by a linear expression
Panel data	It is data that combines time series data and cross-section data, and is obtained by observing the same observation unit over multiple periods.
panelVAPCR-SPDE model	When panel data is composed of multiple random variables, an error term is obtained by explaining a certain random variable by the principal component scores of all other random variables, obtaining a dynamic direct correlation coefficient, and fully differentiating the regression equation. And a statistical causal reasoning model that excludes the effects of random variables.
Dynamic direct correlation coefficient	Among random variables, it is a correlation coefficient that one random variable quantifies from another random variable without going through another random variable.
Probability partial differential equation	One or more terms are partial differential equations that are stochastic processes, and the solution itself is a multivariable mathematical model that is also a stochastic process.
Multicollinearity	Multiple linear relationships have been confirmed between the explanatory variables, and the direct correlation coefficient cannot be derived correctly to the objective variable.
Correlation matrix	Method of describing the correlation coefficient by a matrix
Correlation coefficient	It is an index that measures the strength of the linear relationship between two random variables. Value to a real number between −1.0 and 1.0I take the.
Uncorrelated test	Statistical significance test demonstrating the test for uncorrelatedness
Statistical significance test	This is a hypothesis verification method that utilizes the fact that the statistic follows the probability distribution of the object when the null hypothesis is assumed to be correct.
Null hypothesis	It is a hypothesis that is made on the premise of denying a certain hypothesis in order to presume that it is correct.
Biased Granger causality test	The property that one random variable is explained by another and both are changing is called Granger causality, and it is a statistical significance test excluding the influence of other random variables.
Non-orthogonal impulse response function	This is a method for demonstrating how long the effect of fluctuations in one variable on other variables continues, after excluding the effects of correlation between residuals.
Residual error	Statistical inference of error

Logarithmic difference series	In order to use the property of approximating the rate of change when the rate of change is sufficiently small by the first-order Taylor expansion approximation,This is an error term adjustment that takes the natural logarithm of the difference from the time series data that is one time away.
Error term adjustment	Preprocessing for functional mapping of each random variable to minimize the error term in the structural equation
Preprocessing	A series of processes to process the collected data into a form used for statistical causal estimation / prediction
Probit map	Error term adjustment for mapping when qualitative random variables follow a normal distribution for more accurate results
ADF test	Statistical hypothesis test of whether a time series sample has a unit root
Unit root	The nature of stochastic processes that change over time
Sample standard deviation	A numerical value that represents the degree of dispersion in a sample of random variables
Representative value	Statistics that typically represent the characteristics of the sample distribution
Multivariate time series analysis	Methods for forming various statistical significance tests and time series models for multiple random variables
Cointegration test	Statistical significance test for spurious regression in multiple non-stationary time series
Spurious regression	The problem that two statistically independent and unrelated time series variables take estimates of statistically significant coefficients in regression analysis by the least squares method.
XGBoost	It is a machine learning algorithm that optimizes regression / classification problems using decision trees.

A-2. Empirical analysis / prediction method (detailed mathematical explanation)

This article is a panelVAR-SPDE modelWhenXGBoostWe will explain in detail the pretreatment and empirical analysis that are the premise of regression tree prediction together with theoretical design and implementation.

A-2.1. Error term adjustment

In the research and development of this paper, error term adjustment was performed in order to overcome the combination that can point out multicollinearity between each random variable and to perform more accurate statistical causal estimation and prediction of stochastic process.

A-2.1.1. Logarithmic difference series

The logarithmic difference series is before the purpose is to take the difference in each time series data to reduce the calculation cost, reduce the error for the variance non-uniform structure, and take the logarithm to the non-stationary process and treat it as a stationary process. It is a process.

For example, some time series dataYEven when it is unclear whether is a stationary process or with a non-uniform dispersion structure, a linear correlation can be obtained by taking this logarithmic difference. Specifically, thisYIs converted as follows.

$$\ln\left(\frac{Y_t - Y_{t-1}}{Y_{t-1}}\right)$$

It should be noted that this conversion is established by a first-order Taylor expansion approximation. For example, as mentioned aboveYIn the case of, the following relational expression is obtained.

$$\begin{aligned}\ln Y_t - \ln Y_{t-1} &= \ln\left(\frac{Y_t}{Y_{t-1}}\right) \\ &= \ln\left(1 + \frac{Y_t - Y_{t-1}}{Y_{t-1}}\right) \\ &\approx \frac{Y_t - Y_{t-1}}{Y_{t-1}}\end{aligned}$$

A-2.1.2. Probit mapping

On the other hand, for qualitative variables, in view of their summary statistics, we judged that they would follow a normal distribution and performed probit mapping together with the logarithmic difference series.

A probit map is binary data that follows a normal distribution.(For examplex)Is a preprocessing that performs variable transformation with non-linearity in the following relational expression.

$$x \rightarrow \int_{-\infty}^{x'} \frac{1}{\sqrt{2\pi}} exp\left(-\frac{t^2}{2}\right) d_t$$

A-2.2. Econometric Time Series Analysis

Econometric Time Series Analysis is a method of performing empirical analysis by a statistical significance test that verifies the truth of a hypothesis based on time series statistical values.

The purpose of this paper is to clarify the properties of each probability vector whose error term has been adjusted.

A-2.2.1. Uncorrelated test

The uncorrelated test is a statistical significance test of the correlation coefficient, and "the population correlation coefficient is"0" is the null hypothesis.

"The population correlation coefficient is "0" means twoRandom variables are independent and can be determined to be uncorrelated.

resulting in,pIf the value falls below the statistical significance level, the null hypothesis is rejected and it is presumed that it is not uncorrelated.

For example, two random variablesWhen performing an uncorrelated test, the general formula is as follows.

$$t_0 \ ,= \frac{|r|\sqrt{n-2}}{\sqrt{1-r^2}}$$

t_0 ::Test statistic,

r:: Correlation coefficient,

n:: Number of samples ‖

A-2.2.2. ADF test

The unit root test is a statistical hypothesis test that aims to determine whether a time series variable is stationary or not using an autoregressive model, including PanelVAPCR-SPDE Models.

A typical example is ADF (Augmented Dickey–Fuller) which is a test.

ADFThe test is as followsARprocess(p)Perform a statistical significance test on the subject.

$$y_t \ ,= \sum_{k=1}^{p} \varphi y_{t-k} + \varepsilon_t$$

$$\varepsilon_t \ \text{iid}\,(0,) \sim \sigma^2$$

At this time, in the following equation,$|p| < 1 \Rightarrow$ ARprocess(p)Is a steady state.

$$\begin{cases} p \ = \ \sum_{k=1}^{p} \varphi_k \\ \zeta_k \ = \ -\sum_{i=1}^{p} \varphi_i \end{cases}$$

$$\therefore \ y_t = p y_{t-1} + \zeta_1 \Delta y_{t-1} + \ \zeta_2 \Delta y_{t-2} \cdots + \ \zeta_{p-1} \Delta y_{t-p+1} + \varepsilon_t$$

A-2.2.3. Cointegration test

The cointegration test is a statistically significant difference test performed to empirically analyze whether or not there is a cointegration in the target time series data.

Two unit root processesx_t The linear sum β of, follows a stationary process$y_t x_t + \ y_t = z_t$Sometimes, the two have a cointegration relationship.

Also, the linear sum β follows a stationary process.$x_t + y_t = z_t \beta$When there is, the two are said to be in a cointegration relationship.

$$x_t = \omega_{t-1} + \varepsilon_t,$$

$$y_t = -\frac{1}{\beta}\omega_{t-1} + \zeta_t$$

However, according to the unit root process $\omega_t \varepsilon_t \sim$ iid (0,1) And $\zeta_t \sim$ iid (0, 1) Follow.

At this time, the linear sum of the unit root process can be described by the following equation.

$$x_t \quad = \beta y_t = \varepsilon_t + \beta\zeta_t$$

Looking at the above equation transformation, the linear sum of the unit root processes $x_t + \beta y_t$ Can be seen to be represented by the sum of the two disturbing terms on the right-hand side. The sum of the two disturbing terms follows a stationary process.$= z_t$

Therefore, two unit root processes $x_t + \beta y_t$ Can be tested as following a stationary process.$= z_t$

A-2.2.4. Biased Granger causality test

The Granger causality test is a statistically significant difference test for determining whether or not there is Granger causality between two time series when given two time series data.

The Granger causality is not a true causal relationship, but a relationship in which the other data string can be estimated from one data string.

A method that excludes the influence of a third party from this Granger causality test is called a biased Granger causality test. Specifically, 2variable VAR (2) Model OLS Is estimated by, and the residual sum of squares is taken as the sum of squares. SSR_1

$$\begin{aligned} y_{1,t} = c_1 & \\ & + \varphi_{11}^{(1)} y_{1,t-1} \\ & + \varphi_{12}^{(1)} y_{2,t-1} \\ & + \varphi_{11}^{(2)} y_{1,t-2} \\ & + \varphi_{12}^{(2)} y_{2,t-2} \\ & + \varepsilon_{1,t} \end{aligned}$$

Next, Gana $y_{2,t}$ Granger Causality sex Without a time series that can give AR model Is described by the following formula, Is estimated by OLS, and the residual sum of squares is taken as the sum of squares. SSR_0

$$\begin{aligned} y_{1,t} = c_1 & \\ & + \varphi_{11}^{(1)} y_{1,t-1} \\ & + \varphi_{11}^{(2)} y_{1,t-2} \\ & + \varepsilon_{1,t} \end{aligned}$$

This time *F* Statistics are, Defined by the following equation, 2F Is asymptotic X^2 (2) Follow.

2FThe value of$X^2(2)$of95%Compare points2FIf is larger, then to$y_{2,t}y_{1,t}$GrangerThat there is no causality We reject the null hypothesis and conclude that it is useful in predicting the future of.$y_{2,t}y_{1,t}$

$$F = \frac{(SSR_0 - SSR_1)/2}{SSR_1/(T-5)},$$

T: Number of samples

In the development of this paper, in order to exclude the influence of a third party, all combinations of bivariates were extracted and a Granger causality test was performed to obtain a partial Granger causality test.

A-2.3. Dynamic Stochastic Computable General Equilibrium Model

This paper is a panel on the above-mentioned error term-adjusted nonlinear probability vector.VPCAR-SPDEModel andXGBoostWe have developed a method for evaluating accuracy by regression tree prediction.

A-2.3.1. Panel VAR model

This is a method of the following equation that forms a VAR model for panel data and obtains the dynamic direct correlation coefficient and its standard deviation.

$$Y_{it} = \beta'_{it}X_{it} + \varepsilon_{it}\{se(\beta'_{it}), se(Y_{it})\}$$

At this time, the standard deviation of the dynamic direct correlation coefficient is. Therefore, the standard partial regression coefficient can be defined by the following equation.$\beta'_{it}\varepsilon_{it}$

$$\partial Y_{it}^{``} := \frac{\partial\left(\frac{\partial Y_{it}}{\partial X_{it}}\right)}{\partial(\varepsilon_{it})} = \frac{\partial\{\beta_{it}se(Y_{it})\}}{\partial\{\sum_1^{10} se(\beta_{it,k})\}}$$

$$= \frac{\partial\{Y_{it}^{`}\}}{\partial(X_{it}^{`})}$$

$$= \partial\beta_{it}^{`}$$

A-.2.3.2. Bainzian Dynamic Stochastic Computable General Equilibrium Model

$$\therefore \int_{t_1}^{t_n'} \partial\left(dY_{it,t'}''\right)' \left| \text{XGBoost Regression Trees}\{MSE, MAE, RMSE\} \right.$$

$$\boldsymbol{s.t.}$$

$$\boldsymbol{\partial \forall D(\forall S) = \partial \forall S(\forall D)}$$

A-3. Supplementary appendix

1. **XGBoost Regression tree prediction and evaluation function**
   - XGBoostRegression tree is a machine learning algorithm combined with cross-validation method.
   - Specifically, multiple regression analysis was tried for each round to evaluate the model accuracy of this paper.
   - The following isThis materialIt is a quotation of.
2. **Theoretical design of empirical analysis / prediction and implementation by R**
   - The empirical analysis and prediction of this paper were originally theoretically designed and implemented.
   - The language isR 4.1.0Was used.