

# Systematic Review of the Application of Synthetic Control Method in the Field of Health Policy Evaluation

Pengjie Cui, Mengjiao He and Yun Lu\*

School of Pharmaceutical Business, China Pharmaceutical University, Nanjing 211198, China

## Abstract

**Objective:** To review the application of synthetic control method in the field of health policy evaluation, and provide reference for its application in China. **Methods:** Search in PubMed, Web of Science database, etc., systematically collect literatures on synthetic control method for evaluating health policy, extract information, and conduct qualitative analysis on basic characteristics and development steps. **Results:** 14 documents were included in the study, and the publication time was from 2005 to 2020. The application of synthetic control method is still in the stage of exploration and development. There are differences among the studies, but the selection of dimensions and development steps are of great reference significance. **Conclusion:** The characteristics of synthetic control method are suitable for the environment of health policy in China, and it is worth popularizing to use it in the evaluation of health policy in China.

## Keywords

**Synthetic Control Method; Health Policy; Systematic Review.**

## 1. Introduction

Randomized controlled trials are considered the gold standard of current research methods, and the test results have high reliability. However, when evaluating policy effects, randomized controlled trials face cost and ethical challenges. Researching policy impacts usually requires long-term intervention, and the time and capital costs are high. For example, researching the impact of tobacco control policies, forcing control group's populations to smoke is unethical. For policies that cannot be evaluated by randomized controlled trials, methods based on observational data can be used for evaluation. Common methods include Differences-in-Differences, propensity score matching method, Regression Discontinuity method, and synthetic control method. Differences-in-Differences method, Propensity score matching method, Regression Discontinuity method are widely used in the field of policy evaluation. Although the application of these methods has been widely used, they all have limitations that cannot be ignored.

The Differences-in-Differences method is limited by parallel assumptions and cannot control the confounding factors that change over time. The propensity score matching method requires a large number of cross-sectional data sets to correctly match the units. The Regression Discontinuity method is only suitable for processing data with breakpoints, and often faces multiple interruptions. The synthetic control method is not restricted by parallel assumptions, has no confounding factors that change over time, and has lower requirements for data volume. Especially for the study of evaluating a single intervention object, it has a unique application value. This article will summarize the application of synthetic control method in the field of health policy evaluation through the method of systematic review, This article will summarize the application of synthetic control method in the field of health policy evaluation through the method of systematic review.

Sort out the index selection and implementation steps of the synthetic control method, and provide references for the application of the synthetic control method in the field of health policy evaluation in China. The relevant characteristics of each method are shown in Table 1.

**Table 1.** Summary of characteristics of policy evaluation methods based on observational data

Method	Main points	Main hypothesis	Advantage	Limitations
DID	Compare the results of the intervention group and the control group before and after the intervention, and then estimate the policy effect	Parallel trend assumption; linear form condition; policy does not have an interactive effect on the control group	The model is simple	Parallel trend assumption; unable to control confounding factors that change over time
PSM	Match each unit in the intervention group with untreated units with similar characteristics in the control group	Conditional independence hypothesis; joint support hypothesis	Reduce selection errors	No unobserved confounding factors are allowed; a large data set is required to match the units correctly
RD	The outcome variable is not continuous near the critical value, and the policy effect is estimated by comparing the observations on both sides of the threshold	The result variable at the breakpoint is not continuous, and the covariate is continuous	High internal effectiveness	Only the causality at the breakpoint can be inferred, and the external effectiveness is low; multiple interruptions
SCM	Assign different weights to multiple subjects who have not implemented the intervention, and construct a control group with similar characteristics to the intervention group	There is only one intervention object in a period of time	Allows for unobserved confounding factors that change over time; does not rely on the parallel trends assumption	Requires a long-trem data

## 2. Application of Synthetic Control Method in the Field of Health Policy Evaluation

### 2.1. Search Strategy

Systematically search PubMed platform, Ovid database, Web of Science database, CNKI, Wanfang data knowledge platform, collecting the literature on the application of synthetic control method in the field of health policy. The English search terms are: synthetic control method, synthetic control, SCM, health, medical, medicine, policy, policies. The Chinese search terms are synthetic control method, synthetic control, health, medical, insurance, and policy. Taking the PubMed platform as an example, the search strategy of PubMed is shown in Table 2.

**Table 2.** Search Strategy of PubMed

Order	Search terms	Search results
1	Search: ((synthetic control method[Title/Abstract]) OR (synthetic control[Title/Abstract])) OR (SCM[Title/Abstract]) Sort by: Best Match	4,252
2	Search: ((health[Title/Abstract]) OR (medical[Title/Abstract])) OR (medicine[Title/Abstract]) Sort by: Best Match	3,412,272
3	Search: (policy[Title/Abstract]) OR (policies[Title/Abstract]) Sort by: Best Match	281,531
4	#1 AND #2 AND #3	50

## 2.2. Inclusion and Exclusion Criteria

The inclusion of relevant literature that assesses the impact of health policies does not depend on effect indicators. For example, the effect of increasing medical insurance rates on savings is included, and the effect of increasing taxes on medical insurance participation rates is excluded. Include literature using synthetic control methods. Exclude literature materials such as reviews, meeting minutes, theoretical research, etc.; exclude literature that has been republished.

## 2.3. Literature Screening and Data Extraction

Using Endnote X9 software for literatures management, the two researchers independently screened the literatures according to the inclusion and exclusion criteria, and cross-checked them. If there is a disagreement, they will discuss and resolve with a third person until reach an agreement. The main information extracted includes intervention policies, effect indicators, research objects of the intervention group and synthetic control group and implementation steps. Secondary information includes the name of the first author, the year of publication, the location of the study, etc.

## 3. Results

### 3.1. Literature Search Results

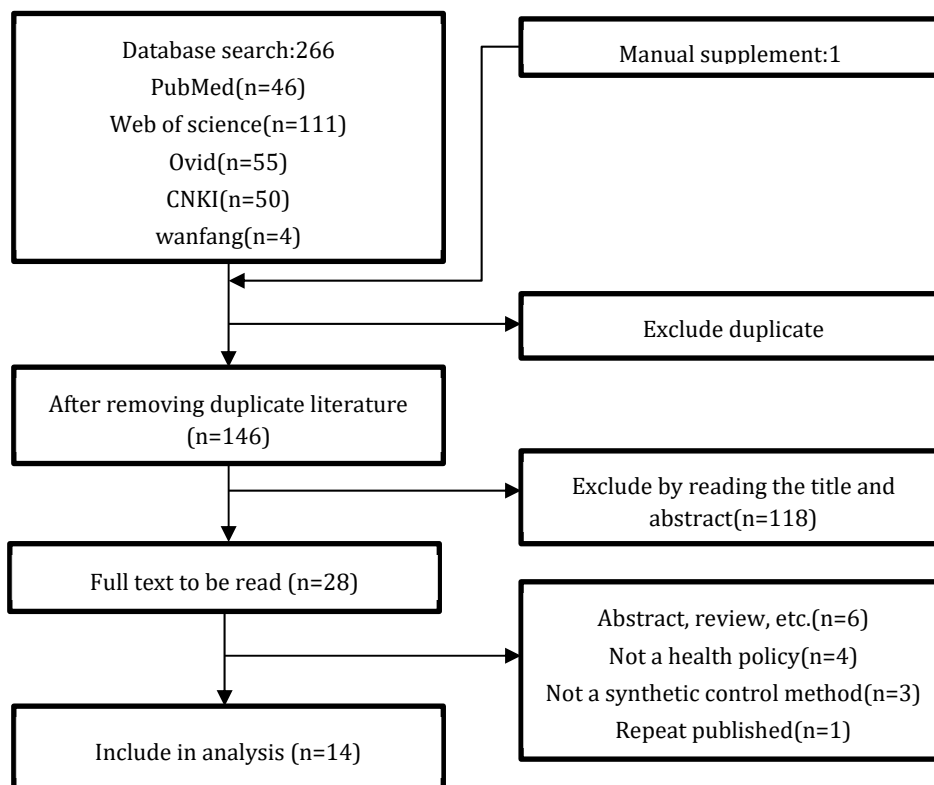
The database was initially searched to obtain 266 literatures, 1 was manually supplemented, 121 duplicate literatures were excluded, 118 literatures were excluded from reading titles and abstracts, 13 literatures were excluded after reading the full text, and 14 literatures were finally included in the analysis. The literatures screening flowchart is shown in Figure 1.

### 3.2. Basic Characteristics of Included Literature

The basic characteristics of the included literature are shown in Table 3. The relevant indicators in the included literature are shown in Table 4. The development steps of the synthetic control method included in the literature are shown in Table 5.

### 3.3. Analysis Result

As a cutting-edge quantitative policy evaluation method, the application of synthetic control method is still in the stage of development in exploration, and no standard operating guidelines have been formed. However, in the process of continuous practice by scholars, the selection of indicators and the development steps are of reference significance.



**Figure 1.** Documents screening process

### 3.3.1. Basic Characteristics

In 2003, Abadie[1] and others first proposed the synthetic control method. In 2005, Michael Schemenaur[2] and others applied the synthetic control method for the first time in the field of health decision-making to evaluate the death of hemodialysis patients hired by a full-time administrative nurse in a New Jersey hemodialysis clinic. Rate and availability of care services. Beginning in 2015, there has been a gradual increase in research on the synthetic control method for evaluating health policies. After determining the evaluation policy and objects, it is necessary to determine alternative controls, mostly multiple objects with similar characteristics to the intervention group, and determine the final composite control group by weighting. Usually not all candidate controls are given weights, therefore, the number of synthetic control group subjects is less than the number of candidate controls. The most commonly used robustness test method is the placebo test, followed by other statistical methods, such as the double difference method. Yu Xinliang[3] also applied methods such as eliminating similar samples and iteratively eliminating weighted cities to test the robustness. The statistical software used for synthetic control method evaluation includes STATA, R Studio and Excel. The "synth" package improves the efficiency of analysis and promotes the application of synthetic control method.

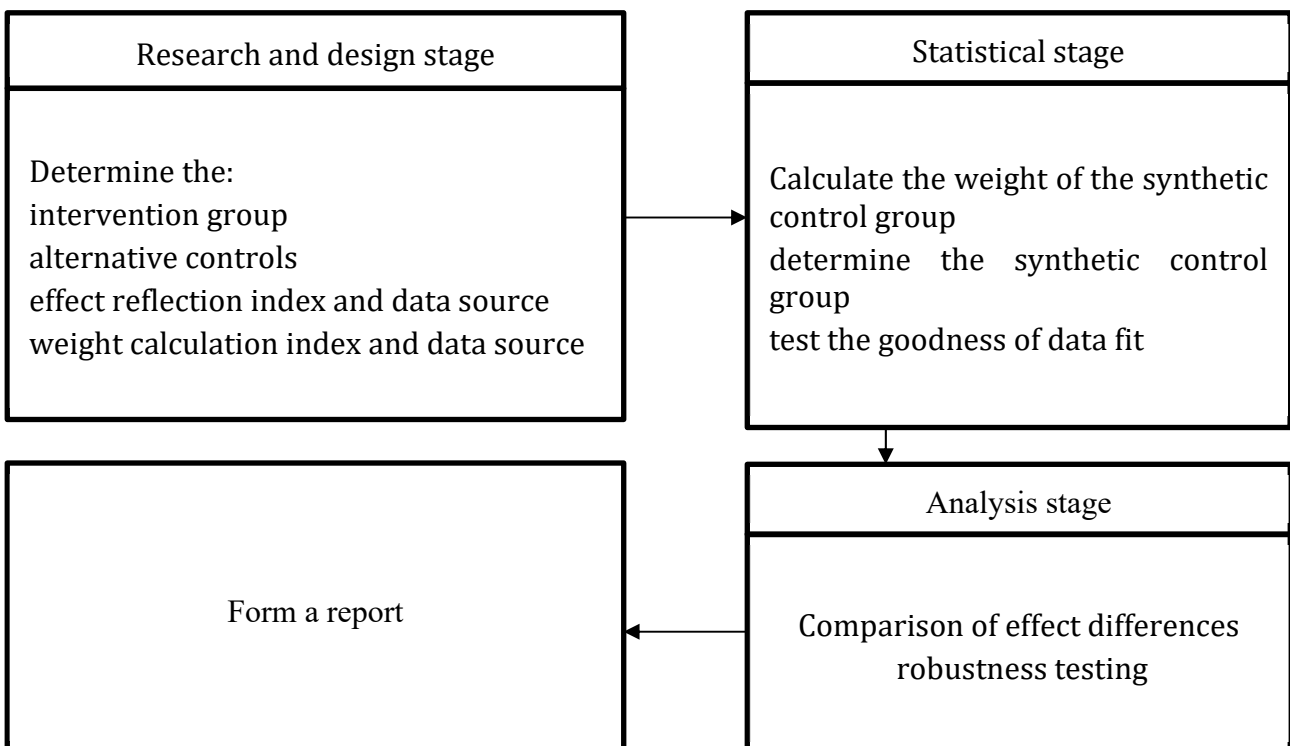
### 3.3.2. Related Indicators

The weight calculation indicators include important variables that may affect the results. The macro-level usually considers factors such as economy, population, and medical care, and the micro-level may consider personal health, insurance participation, education, etc. Single or multiple indicators can be selected when evaluating the effect, Luo Jia Hu[4] quantifies financial status through 8 indicators such as credit score and total debt balance, Restrepo, B. J. [5] only selected one indicator of cardiovascular disease mortality when assessing the control policy of man-made trans fats. The weight calculation index can be the same as the effect index. For example, in the research of Guo Lei[6], and others, the actual rate of basic pension, the actual

rate of basic medical care, and the actual rate of unemployment insurance are both the weight calculation index and the effect index, The weight calculation indicators selected by Xiao Zang [7] and others include population size, urban population proportion, per capita GDP, etc., which are different from the effect indicators.

**3.3.3. Implementation Steps**

The activities carried out by the studies are relatively similar, but the order is quite different. The complete set of activities includes determining the intervention group, determining alternative controls, determining the effect reflection index, determining the data source of the effect reflection index, determining the weight calculation index, determining the data source of the weight calculation index, calculating the weight of the synthetic control group, determining the synthetic control group, and comparing the effect difference , Robustness test, data goodness-of-fit test, and forming a report a total of 12 items. There are no relevant guidelines or regulations on the sequence of activities, and can be roughly divided into four stages. The first is the research design stage, which includes determining the intervention group, determining the alternative controls, determining the effect indicator, determining the data source of the effect indicator, and determining Weight calculation indicators, determine the data source of weight calculation indicators; the second is the statistical phase, including calculating the weight of the synthetic control group, determining the synthetic control group, and testing the goodness of data fit; the third is the analysis phase, including the comparison of effect differences and robustness testing; It is to form a report. The step structure can be shown in Figure 2. It is usually carried out in the order of phases one to four, and there is no specific sequence of activities in the same phase.



**Figure 2.** Step structure diagram of synthetic control method

**4. Discussions**

The synthetic control method does not rely on the "parallel trend hypothesis" and does not require matching at the individual level. The influence of confounders can be explained by the weighted control group. It requires less data volume, and is especially suitable for the

evaluation of studies with only one intervention objective in a time period. This feature is of great significance to the study of the intervention effects of China’s health policies, because China has a vast territory and a large population, and the implementation of new policies usually adopts the “first pilot and then promote” model, which establishes a pre-emptive advantage for the application of synthetic control methods. Intervention targets and alternative controls can be selected according to the scope of different pilot policies, and macro-level statistical data is becoming more and more easily available, for example, the country and some provinces and cities release health statistics yearbooks every year. The use of synthetic control methods in the evaluation of Chinese health policies has huge application potential and is worthy of promotion.

Take the application of synthetic control method to study the hierarchical diagnosis and treatment system as an example. In the research design stage, it is clear that the policy to be evaluated is a hierarchical diagnosis and treatment system, the intervention group is the pilot area (such as Shanghai), and the alternative control is the area with no pilot hierarchical diagnosis and treatment. The effect indicators should reflect the original intention of the policy, such as evaluation The hierarchical diagnosis and treatment system can choose the number of outpatients and emergency departments of tertiary hospitals as the effect indicators, and the weight calculation indicators can choose the number of permanent residents, the number of beds per thousand people and other indicators that may affect the number of outpatients and emergency departments. The relevant data can be made through public or non-public channels. Obtain. The statistical stage can be carried out in statistical software such as Stata or R software. The weight of the synthetic control group is calculated and the synthetic control group is finally determined. If necessary, the goodness of fit of the data can be tested. In the analysis stage, analyze and explain the statistical results, confirm whether the change of the effect index is caused by the evaluation policy, and conduct a robustness test with the help of statistical software. Finally, a report is formed.

For the first time, this research conducted a systematic search and analysis on the application of the synthetic control method in the field of health policy evaluation, and demonstrated its unique application in the field of health policy evaluation in my country. This study also has certain limitations. Due to the lack of extensively certified quality evaluation tools, the quality of the study was not evaluated, and the interpretation of the results should be more cautious.

**Table 3.** Basic characteristics of included literature

Author	Published year	Country	Health policy	Intervention group	Alternative comparison	Synthetic control group	Robustness test method	Software
Michael Schemenaur [2]	2005	USA	Hemodialysis clinics employ full-time administrative nurses	New Jersey	42 states	8 states	Placebo test	--
Sanjay Basu [8]	2015	USA	Welfare Policy Reform 1996	Single Mother	Married mother, married non-mother, single non-mother	Married mother, married non-mother, single non-mother	Placebo test	STATA
Restrepo, B. J. [5]	2015	Danish	Man-made trans fat control	Denmark	10 OECD countries	5 OECD countries	Placebo test	STATA
Matthias Rieger [9]	2017	Netherlands	National Health Insurance Coverage	Thailand	17 Asia-Pacific countries	Different indicators, 1-4 Asia-Pacific countries	Double differential	--

Gambaryan, M. [10]	2018	Russia	Tobacco Control Policy	Russia	22 countries with tobacco control legislation	Different indicators, 21/13 countries with tobacco control legislation	--	--
Camilla Beck Olsen [11]	2018	Norwegian	Adolescents aged 12-15 years are exempt from the cost of seeing a GP	Young adults aged 12-15 years	Person using GP services	Using GP services Youth aged 0-20 years	Placebo test	--
Xiao Zang [7]	2019	China	Comprehensive reform of pharmaceutical prices in public hospitals	Zhenjiang	12 cities in the same province	4 cities in the same province	Placebo test, double differentiation	--
Nyathi, S. [12]	2019	USA	Cancel Waiver of Non-Medical Vaccines	California	44 US	Different indicators, 3-43 states, mainly 3-5 states, other weights very small	Placebo test	--
Yu Xingliang [3]	2019	China	Long-term care insurance	Qingdao	34 cities	6 cities	Eliminate similar samples, iteratively eliminate weight cities, increase or decrease explanatory variables, placebo test, mean square error ratio test	STATA
LuoJia Hu [4]	2019	USA	Patient Protection and Affordable Care Act	21 US	26 US	Different indicators, US 4-9 states	--	--
Guo Lei [6]	2020	China	Reduce social insurance rates	Shanghai	28 provinces	--	--	--
Ayse Akincigil [13]	2020	USA	Forced Peer Review Program for Antipsychotic Prescriptions	Washington	24 US States	20 US States	Placebo test	STATA
Rado, M. K. [14]	2020	Thailand	Comprehensive smoke-free legislation	Thailand	61 medium countries with no smoke-free legislation	8 medium countries with no smoke-free legislation	Placebo test	--
Nanner, H. [15]	2020	Belgium	Assisted suicide	Belgium	OECD Countries	6 countries	Placebo test	R Studio, Excel

**Table 4.** Relevant indicators in the included literature

Author	Health Policy	Evaluation effect	Effect indicator	Weight calculation index of synthesis control group
Michael Schemenaur [2]	Hemodialysis clinics hire administrative nurses who are not involved in diagnosis, care	Hemodialysis Patient Mortality and Care Service Availability	Mortality, number of haemodialysis facilities	Proportion of dialysis patients in different age groups, proportion of dialysis patients in different population, average income

Sanjay Basu [8]	Welfare Policy Reform 1996	Health status of low-income American women	Safe drinking, no smoking, mental health days, accessibility to medical treatment, affordability to medical treatment, mammography, endometrial pathological screening	Alcohol abuse rate, smoking rate, mental health days, medical accessibility, medical affordability, whether mammography, whether endometrial pathological screening
Restrepo, B. J. [5]	Man-made trans fat control	Cardiovascular mortality	Cardiovascular mortality	Cardiovascular disease mortality, BMI, total cholesterol level, systolic blood pressure, fruit and vegetable consumption, tobacco and alcohol consumption, health care expenditure, GDP per capita, food price inflation and aging rate
Matthias Rieger [9]	National Health Insurance Coverage	Economic and health impacts	The proportion of out-of-pocket expenses to total medical expenses, the proportion of government expenses to total health expenses, GDP per capita (PPP), and under-five mortality	GDP per capita, total population, proportion of population under 14 years old, health expenditure, infant mortality rate
Gambaryan, M. [10]	Tobacco Control Policy	Cardiovascular morbidity and mortality	Discharge rate, mortality	Population weighted average
Camilla Beck Olsen [11]	Adolescents aged 12 – 15 years are exempt from the cost of seeing a GP	Number of GP outpatient visits	Number of GP consultations per capita per year	Number of GP consultations per capita per year
Xiao Zang [7]	Drug prices in public hospitals Comprehensive reform	Outpatient and inpatient drug ratio	Percentage of drugs in sub-average cost of outpatient and inpatient	Population size, proportion of urban population, proportion of population over 60 years old, GDP per capita, life expectancy, health service costs per capita
Nyathi, S. [12]	Cancel Waiver of Non-Medical Vaccines	Vaccine coverage	Primary: the proportion of children enrolled in school receiving two doses of measles, mumps and rubella vaccine Secondary: the proportion of children with medical exemption, non-medical	Vaccine coverage rate, prevalence of exemption, proportion of children without continuous insurance, proportion of children without health prevention service, proportion of children without insurance, proportion of children with private insurance



			exemption	
Yu Xingliang [3]	Long-term care insurance	Medical expenses	Medical cost per capita	GDP per capita, proportion of the second and third industries, failure rate, urbanization rate, number of beds per capita, number of doctors per capita, and number of hospitals per capita
Luojia Hu [4]	Patient Protection and Affordable Care Act	Financial Status	Credit rating, total debt balance, total overdue balance, total credit card balance, credit card balance overdue, total receipt balance, number of receipts, bankruptcy	Medicaid eligibility, unemployment rate, poverty rate, salary, proportion with bachelor's degree or below, proportion without insurance coverage
Guo Lei[6]	Reduce social insurance rates	Payment burden of enterprises	Actual payment rate of basic endowment insurance, actual payment rate of basic medical insurance, actual payment rate of unemployment insurance, and actual payment rate of three items plus	Basic old-age actual rate, basic medical actual rate, unemployment insurance actual rate
Ayse Akincigil [13]	Forced Peer Review Program for Antipsychotic Prescriptions	Reduction of antipsychotic prescription in children	Number of children taking at least one prescribed antipsychotic per 1000 per month	Proportion of children receiving mental health services, proportion of mental health professional shortage, clinically informed prescription feedback system, proportion of population living in urban areas
Rado, M. K. [14]	Comprehensive smoke-free legislation	Neonatal and infant mortality	Neonatal mortality, infant mortality	Infant mortality rate, neonatal mortality rate, GDP (PPP), health expenditure (PPP), proportion of clean diet, number of beds per 1,000, proportion of drinking water population, carbon dioxide, proportion of rural population, completion rate of female primary education, average number of children born, import/export/nominal GDP
Nanner, H. [15]	Assisted suicide	Suicide rate	100,000 suicides	Divorce rate, education level, population density, unemployment rate, alcohol consumption, proportion of medical doctors, total health expenditure, life expectancy

**Table 5.** Steps of implementing the synthetic control method in the included literature

Author	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Step 11
Michael Schemenaur [2]	1	4	6	3	5	2	7	8	9	10	12
Sanjay Basu [8]	1	4	6	3	5	7	8	9	10	12	--
Restrepo, B. J. [5]	1	4	6	3	5	2	7	8	10	10	12
Matthias Rieger [9]	1	2	4	3	7	8	9	10	12	--	--
Gambaryan, M. [10]	1	3	4	5	2	8	9	12	--	--	--
Camilla Beck Olsen [11]	1	3	4	5	6	2	8	9	10	12	--
Xiao Zang [7]	1	2	4	6	3	5	7	8	9	10	12
Nyathi, S. [12]	1	4	3	2	6	7	8	9	10	12	--
Yu Xingliang [3]	1	3	2	5	6	7	8	11	9	10	12
Luojia Hu [4]	4	3	1	2	7	8	9	12	--	--	--
Guo Lei [6]	1	2	5	6	8	3	4	9	12	--	--
Ayse Akincigil [13]	1	2	3	4	5	6	7	8	9	10	12
Rado, M. K. [14]	1	2	3	5	4	6	7	8	9	10	12
Nanner, H. [15]	1	3	4	2	8	9	10	12	--	--	--

1: Determining the intervention group;2: Determining alternative controls;3: Determining the effect reflection index;4: Determining the data source of the effect reflection index;5: Determining the weight calculation index;6: Determining the data source of the weight calculation index;7: Calculating the weight of the synthetic control group;8: Determining the synthetic control group; 9: Comparing the effect difference;10: Robustness test;11: Data goodness-of-fit test;12: Forming a report.

## References

- [1] Abadie A, J. Gardeazabal. The Economic Costs of Conflict: A Case Study of the Basque Country[J]. American Economic Review, 2003: 113-132.
- [2] Schemenaur M, Norris C, Timmons E, et al. Estimating the effect of New Jersey's 2005 administrative nurse mandate on mortality and hospitalizations for medicare hemodialysis patients[J]. Seminars in Dialysis, 2020, 33(5).
- [3] Yu Xinliang, Liu Huimin, Yang Wensheng.The effect of long-term care insurance on medical expenses: A study of synthesis control based on Qingdao model [J].Insurance research, 2019(2): 114-127.
- [4] Luojia H, Robert K, Bhashkar M, et al. The Effect of the Affordable Care Act Medicaid Expansions on Financial Wellbeing[J]. Journal of public economics, 2018, 163.
- [5] Restrepo B J, Rieger M. Denmark's Policy on Artificial Trans Fat and Cardiovascular Disease[J]. American Journal of Preventive Medicine, 2016, 50(1): 69-76.
- [6] Guo Lei, Hu Xiaomeng.Can lowering the social insurance rate reduce the contribution burden of enterprises? Based on the dual test of central mandatory and local initiative [J].Scientific decision making,2020(1): 1-26.
- [7] Xiao Z, Mengran Z, Shihao W, et al. Impact of public hospital pricing reform on medical expenditure structure in Jiangsu, China: a synthetic control analysis[J]. BMC health services research, 2019, 19(1).
- [8] Basu S, Rehkopf D H, Siddiqi A, et al. Health Behaviors, Mental Health, and Health Care Utilization Among Single Mothers After Welfare Reforms in the 1990s. [Article][J]. American Journal of Epidemiology March, 2016, 183(6): 531-538.

- [9] Matthias R, Natascha W, S. B A. Universal health coverage at the macro level: Synthetic control evidence from Thailand[J]. *Social Science & Medicine*, 2016, 172.
- [10] Gambaryan M, Reeves A, Deev A, et al. Effects of tobacco control policy on cardiovascular morbidity and mortality in Russia[J]. *Eur J Public Health*, 2018, 28(suppl\_2): 14-16.
- [11] Camilla Beck Olsen H O M. Did adolescents in Norway respond to the elimination of copayments for general practitioner services?[J]. *Health Economics*, 2018.
- [12] Nyathi S, Karpel H C, Sainani K L, et al. The 2016 California policy to eliminate nonmedical vaccine exemptions and changes in vaccine coverage: An empirical policy analysis[J]. *PLoS Medicine / Public Library of Science*, 2019, 16(12): 12.
- [13] Phd A A, Phd T I M, Mph, et al. Effectiveness of mandatory peer review to reduce antipsychotic prescriptions for Medicaid-insured children[J]. *Health Services Research*, 2020, 55(4).
- [14] Rado M K, Van Lenthe F J, Sheikh A, et al. Investigating the effects of comprehensive smoke-free legislation on neonatal and infant mortality in Thailand using the synthetic control method[J]. *EClinicalMedicine*, 2020, 27(100560).
- [15] Nanner H. The effect of assisted dying on suicidality: a synthetic control analysis of population suicide rates in Belgium[J]. *Journal of Public Health Policy*.