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Identifying regime switches using causal recipes☆

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ABSTRACT

This study proposes a new method to identify regime switches in a time series. First, the method uses fuzzy set/qualitative comparative analysis (fsQCA) instead of quantitative methods because studies show that fsQCA outperforms quantitative methods. The new method is unique in that the method examines causes for regime switches instead of outcome as in previous studies. FsQCA explores the relationships between relevant antecedents of energy consumption and gross domestic product as the outcome. Historical events validate the results, which demonstrate that the method successfully identifies regime switches.

1. Introduction

Many economic time series show the behavior of 'regime switches'. Regime switches appear because of large-scale events, such as wars, financial panics, or a significant change in government policies (Brooks, 2002). The behavior of 'regime switches' complicates forecasting. Satchell (2011) considers regime-switching studies as a recurrent research topic, and Huarng (2014) states that the studies of regime switches are important. Hence, this study targets the problem of identification of regime switches.

The conventional studies for regime switches generally use econometric methods (Hamilton, 1989; Hamilton, 1990). Fuentes and Rios (2014) use these regime-switch methods to study the role of the Central Reserve Bank in a dollarized economy. Other studies use different techniques to solve the problem of regime switches. Huarng et al. (2008) apply clustering to analyze structural changes in Taiwan Stock Exchange Capitalization Weighted Stock Index (TAIEX) of 180 data ranging from January 1990 to December 2004. Huarng et al. (2011) also apply clustering to forecast the regime switches in Taiwan tourism demand of 300 data from January 1984 to December 2008. Huarng and Yu (2013) propose a novel model to forecast regime switches in TAIEX. Huarng (2014) proposes new algorithms to keep track of the occurrences of relationships to improve the forecasting results of Huarng and Yu (2013).

This study proposes a method to identify regime switches in time series. The method is different from previous studies in two aspects: First, this study uses a qualitative method, fuzzy set/qualitative comparative analysis (fsQCA), instead of the quantitative methods that most regime-switch studies use. Studies demonstrate the advantages of fsQCA over conventional multiple regression analysis (Huarng, 2015; Huang & Huarng, 2015; Woodside et al., 2013b; Woodside & Zhang, 2013). Hence, the method is very novel. Second, previous studies analyze the regime switches by observing the outcomes. This study analyzes the sufficient conditions to the outcome to identify regime switches. Hence, the analysis results are more insightful for understanding the sufficient conditions that regime switches present.

This study explores the relationships between the relevant antecedents of energy consumption and the outcome gross domestic product (GDP) of each year; Then, the use of causal combinations (or causal recipes) of a time series enables the identification of regime switches in consecutive years. Section 2 reviews the studies of regime switches. Section 3 introduces fsQCA, the variables and data, and the method. Section 4 shows and interprets the empirical results, and provides the discussion. Section 5 concludes this article.

2. Studies of regime switches

Some economic time series seem to go through periods when the behavior of the time series becomes quite different to the previous periods. If the behavior changes once for all, the change is known as

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'structural change'; if the change may return to the original behavior, the change is a 'regime switch' (Brooks, 2002). To reflect the behavior, different models are necessary to describe the time series. For example, suppose the behavior of a time series changes at data *o*. Two models can be

$y_t = \beta_1 + \alpha_1 y_{t-1}$ (for data before *o*),

$y_t = \beta_2 + \alpha_2 y_{t-1}$ (for data after *o*).

Seasonality may exist in problems such as economic (Fiore & Saha, 2015), and climate time series (Ernakovich et al., 2014). A simple regression can model the seasonality problem:

$$y_t = \beta_1 + \gamma_1 S1_t + \gamma_2 S2_t + \gamma_3 S3_t + \gamma_4 S4_t + \ldots$$

For the first season, the intercept is $\beta_1 + \gamma_1 S1_t$ because S1 = 1, S2 = S3 = S4 = 0. For the second season, the intercept is $\beta_1 + \gamma_2 S2_t$ because S2 = 1, S1 = S3 = S4 = 0. The procedure is similar for the other intercepts.

Other models exist to cope with more complex time series of regime switches; namely, the Markov model, the Hamilton model (Hamilton, 1989; Hamilton, 1990), and the threshold autoregressive model (Tong, 1983; Tong, 1990).

However, all these models deal with numerical values, and their target is the outcome. This study proposes a model to handle regime switches through qualitative analysis, such as the causal combinations of the fsQCA instead of outcomes.

3. Method

3.1. QCA/fsQCA

Qualitative comparative analysis (QCA) is a technique that uses Boolean algebra to perform comparisons in a qualitative study (Ragin, 1987). By formalizing the logic of qualitative analysis, QCA can bring the logic and empirical intensity of qualitative approaches to studies that comprise more cases. Boolean methods of logical comparison represent each case as a combination of causal conditions and outcome. After comparisons, QCA provides the proper causal conditions as the sufficient conditions for an outcome.

A conventional set is dichotomous: A case is either 'in' (full membership) or 'out' (full non-membership) of a set. A fuzzy set, by contrast, permits membership in the interval between 0 and 1 while retaining the two qualitative states of full membership and full non-membership. FsQCA is an analytical tool that uses fuzzy set theory and Boolean logic (Ragin, 2008). First, fsQCA calibrates the data into 0.0 to 1.0, where 0.0 means full non-membership and 1.0 means full membership. After calibration, fsQCA proceeds to analyze the sufficient conditions for the outcome. As a result, fsQCA provides the causal combinations as the sufficient conditions, such as.

~A * B → C.where ~ represents NOT, A and B are the antecedents, * represents logic AND, and C is the outcome. The equation means that ~A*B (a causal combination) is a sufficient condition for C.

For the outcome C, one or more causal combinations may be sufficient conditions. This study uses the change of causal combinations in consecutive years to identify regime switches.

3.2. Variables and data

This study uses the real GDP (realgdp) as the outcome. The five antecedents are real gross fixed capital formation (realcap), labor force (labor), renewable energy consumption (rec), non-renewable energy consumption (nonrec), and CO_2 emissions (co2).

The data for realgdp, realcap, and labor are from International Monetary Fund, World Economic Outlook Database, 2014. The data source for rec, nonrec, and co2 is the website of US Energy Information Administration (www.eia.gov). The analysis covers the period from 1980 to 2011. The countries under study are OECD countries and Taiwan.

3.3. Method to identify regime switches

First, fsQCA analyses the relationships between the antecedents and the outcome. The results are causal combinations for each year. A rule is to identify if a regime switch exists between any two consecutive time periods.

Matching rule: Suppose *k* causal combinations regarding an outcome for time period *t*. If the results yield less than or equal to *k*/2 causal combinations of *t* as those of *t* + 1, this study considers that a regime switch exists between *t* and *t* + 1.

This study uses matching percentage (mp) to represent the percentage of the *k* causal combinations of *t* appearing in *t* + 1.

4. Analysis and results

4.1. Empirical results

Appendix A lists all the analysis results from 1980 to 2011. Column 1 displays the year. Column 2 lists the causal combinations of each year. Columns 3 and 4 report the corresponding raw coverage and unique coverage for each causal combination and column 5 shows the consistency.

Woodside (2013) stresses the importance of achieving high consistency over the high coverage. Hence, this study considers only those consistencies greater than or equal to 0.8 for identifying regime switches. In total, seven unique causal combinations exist. To facilitate the matching process in the identification of regime switches, Table 1 assigns each unique causal combination a code from 1 to 7.

Table 2 shows the distribution of all the causal combinations of all the year, where "v" marks the code for the causal combination whose consistency is greater than 0.8. This study analyzes Table 2 to identify regime switches. For example, the causal combination of code 1 in 1980 does not appear in 1981. The matching percentage is 0%. Following the matching rule, a regime switch takes place between 1980 and 1981. Similarly, between 1990 and 1991, two of the four causal combinations exist, codes 3 and 4 out of codes 2, 3, 4, and 6 in 1990 appear in 1991. The matching percentage is 50%. Hence, another regime switch occurs. Similarly, regime switches take place between 2001 and 2002, and 2002 and 2003.

For the rest of the years, no regime switches exist. For example, three causal combinations appear in 1981: codes 3, 4, and 5. All of them appear in 1982. Following the matching rule, no regime switch exists between 1981 and 1982.

4.2. Interpretation of causal combinations

This study examines these causal combinations and finds that two basic groups exist: ~co2* ~ nonrec (high carbon countries) and co2*nonrec (low carbon countries).

Table 1
Codes for causal combinations.

Code	Causal combination
1	~co2* ~ nonrec* ~ rec* ~ realcap
2	co2*nonrec*rec*labor
3	~co2* ~ nonrec* ~ labor*realcap
4	~co2* ~ nonrec*rec* ~ labor
5	co2*nonrec*rec*labor*realcap
6	co2*nonrec*labor*realcap
7	co2*nonrec* ~ rec* ~ labor* ~ realcap