

**Matěj Opatrný, Václav Brož, Tomáš Havránek**

**Anglický název projektu: Application of Synthetic Control Method to Various Economic Policy Interventions**

**Český název projektu: Aplikace syntetické kontrolní metody na intervence k hospodářským politikám**

**Délka řešení projektu:**

3 roky

**Řešitelský kolektiv + charakteristika řešitelského kolektivu:**

Matěj Opatrný is the bachelor of Institute of Economic Studies (IES), Faculty of Social Sciences, Charles University in Prague and the master of Erasmus University in Rotterdam, Erasmus School of Economics in Economics and Business. Currently, he is a third-year doctoral student at the Department of Macroeconomics and Econometrics. He works as economist at the Asset management in Expobank, a.s. Matej was awarded in the competition of Young Economist 2016 (Honourable recognition for outstanding working paper) and in the competition of Czech Econometric Society 2018 (Honourable recognition for promising paper). He has already published one article *Quantifying the Effects of the CNB's Exchange Rate Commitment: A Synthetic Control Method Approach* in impacted journal and he has three IES working papers *The Impact of Agricultural Subsidies on Farm Production: A Synthetic Control Method Approach*, *The Impact of the Brexit Vote on UK Financial Markets: A Synthetic Control Method Approach* and *Extent of Irrationality of the Consumer: Combining the Critical Cost Efficiency and Houtman Maks Indices* (awarded by Czech Econometric Society - mentioned above).

Václav Brož is a graduate of Institute of Economic Studies (IES), Faculty of Social Sciences, Charles University in Prague with a major in Economic Theories and Modeling. Currently, he is a third-year doctoral student at the Department of Finance and Capital Markets and Economic Analyst at the Macroprudential Division of the Financial Stability Department of the Czech National Bank. In his research, he focuses on topics in central banking, with an emphasis on financial stability. He has already published three papers *Dynamics and factors of inflation convergence in the European Union*, *What drives the distributional dynamics of client interest rates on consumer loans in the Czech Republic?*, and *Does monetary policy influence banks' risk weights under the internal ratings-based approach?* in impacted journals and has three IES working papers *Dynamics and factors of inflation convergence in the European Union*, *Does monetary policy influence banks' perception of risks?*, and *Mortgage-related bank penalties and systemic risk among U.S. banks*. Václav is a successful applicant as a principal investigator for GA UK from last year (No. 1250218: Pokuty americkým bankám a systémové riziko: přístup na základě asymetrických přelivů volatility).

Tomáš Havránek is an Associate Professor at IES at the Department of Macroeconomics and Econometrics and he was Advisor to the Board at Czech National Bank. According to RePEc he is currently the most cited Czech economist. He also ranks globally among the 10 most influential young economists and top economists in his cohort. He received the following awards: Excellent Reviewer Award (2017, 2016) in Economics by Publons (the service collecting data on peer review), Best PhD thesis award (2014) by the UniCredit & Universities Foundation (best PhD thesis in economics and finance in the 17 countries where UniCredit operates), Young Economist Award (2012) by the Czech Economic Society, Medal for Research on Development (2010) by the Global Development Network, World Bank, Olga Radzyner Award (2009) by the Austrian National Bank (best

research work on European integration), Karel Englis Prize (2009) by Charles University (best alumnus in social sciences), Best Publication Award (2016, 2015, 2014, 2013, 2012) by the Czech National Bank.

Responsibilities of team members:

Principal investigator (Matěj Opatrný)

- Data collection and summary of the literature
- Conducting empirical analysis
- Preparing a paper with results of the research
- Submission of the paper to a relevant journal as suggested by the supervisor
- Presentation of results of the research at conferences

Participant (Václav Brož)

- Data collection and summary of the literature
- Preparing a paper with results of the research

Supervisor (Tomáš Havránek)

- Advisory and consulting role over the entire project (hypotheses, methodology, description of results of the research, the final form of the publication)
- Suggesting an appropriate journal for submission of the paper

### **Finanční požadavky:**

#### **Struktura finančních požadavků – rok 2020:**

I plan to conduct a research trip to New Zealand to The University of Auckland in 2020 using the GEMCLIME programme for 4 months. During the research trip I plan to visit the Summer School in Energy Economics held at the University of Auckland Business School. The flight tickets cost 27 000 Kč, I expect the accommodation about 1 000 Kč/ per night, which is 120 000 Kč. Insurance will cost about 5 760 Kč and visa about 750 Kč. Food expense by law is 55 USD/day, which is 151 800 Kč. Therefore, this is in total 305 063 Kč. I would receive funding from GEMCLIME programme, which is 213 504 Kč and IES support which is 20 000 Kč. Moreover, during autumn in the year 2020 I plan the research trip to the University of Berkeley in the U.S. for 3 months again via using GEMCLIME programme. The flight tickets cost 20 000 Kč. I expect accommodation 1 200 Kč/night, which is 108 000 Kč. Insurance costs 4320 Kč and visa about 3520 Kč. There is the university fee of 500 USD per month, in total 33 000 Kč. Food expense by law is 55 USD/day, in total 113 850 Kč. In this case I would receive 153 600 Kč from GEMCLIME and 15 000 Kč from IES support. I expect the allowance for both trip in total 22 384 Kč. To sum up, for both trip the expenses are 610 137 Kč and funding from GEMCLIME and IES is 402 104 Kč. Therefore, I am asking for 208 033 Kč for travel purposes, 80 000 Kč as stipend for me and 12 000 Kč for submission fee and proofreadings.

### **Anotace:**

Recently, the comparative case studies have started to be conducted by the synthetic control method (SCM).<sup>1</sup> This method was introduced by Abadie & Gardeazabal (2003), Abadie, Diamond, & Hainmueller (2010), and Abadie, Diamond, & Hainmueller (2015) to find a counterfactual development of a treated unit. In general, the SCM assigns weights to control units so that these units best fit the pre-treatment characteristics of the treated unit.

The focus of this project is twofold. First, we aim to apply the SCM on various economic policy interventions. Specifically, we will analyse 1) the impact of agricultural subsidies on the farm production in the Czech Republic after the accession of the European Union (EU) in 2004, 2) the Impact of the Brexit Vote on UK Financial Markets: A Synthetic Control Method Approach, and 3) the impact of two hikes by the European Central Bank (ECB) in 2011 on macroeconomic indicators of selected eurozone countries. Second, this project aims to deliver methodological improvements to the SCM, such as the implementation of confidence intervals as one of the robustness checks of the SCM. Therefore, the added value of the project will be the proper analysis of the aforementioned policy interventions using SCM and improve the SCM by using confidence intervals as one of the robustness check. Furthermore, we will compare Difference in Difference method (DiD) and SCM in the study of the impact of agricultural subsidies on the farm production in the Czech Republic after the accession of the European Union (EU) in 2004. We plan to finish first two articles in the year 2019/2020 and 2020/21 and the last one in the year 2020/2021 and 2021/2022.

#### **Současný stav poznání:**

Economists and social scientists are often interested in the impact of events or interventions at an aggregate level on entities such as countries, regions or firms. One approach that they can use is based on comparative studies. However, they usually suffer from ambiguously chosen comparison units as researchers often base their decision about control units on subjective affinity between the treatment and the control unit. Furthermore, the most commonly used Difference in Difference method (DiD) does not have to provide the best results for evaluating such interventions as it assumes that the magnitude of the effect of the intervention does not change after its implementation. Put differently, the major assumption of the DiD is that the observed and unobserved characteristics of the treatment and the control unit remain constant over time. This assumption, however, is unlikely to hold in most cases.

To overcome these shortcomings, Abadie & Gardeazabal (2003) introduced the synthetic control method (SCM), which allows for

- variation of characteristics of the treatment and control unit,
- effective evaluation of the intervention in the absence of the event by systematically choosing the control group. In other words, SCM allows for quantitative inference without precluding the application of qualitative approaches,
- and quantitative inference which is in contrast with what comparative case studies offer.

The crucial requirement of the SCM is the selection of suitable control units. On one hand, their combination can provide better results of matching the characteristics of the treated unit than any single control unit alone (Abadie, Diamond, & Hainmueller, 2015). Therefore, control units are systematically chosen in SCM as a weighted average of all relevant units that best fit the characteristics of the treatment unit. Formally, the effect of the intervention with  $t > T_0$ , where  $T_0$  is the intervention period, is represented as follows:

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<sup>1</sup> "From the definitions given in the large body of literature on the subject, a study can be said to be cross-national and comparative if one or more units of two or more societies, cultures or countries are compared in respect of the same concepts and concerning the systematic analysis of phenomena, usually with the intention of explaining them and generalizing from them" (Hantrais & Mangen, 1996:1-2).

$$v_{it} = Y_{it}^I - Y_{it}^N \quad (1)$$

Given that  $Y_{it}^I$  is observed (outcome of the interest of treated country) in equation (1), we must now estimate  $Y_{it}^N$  (outcome of the interest in the absence of the intervention). The key aspect of a synthetic control is that it is defined as a weighted average of the control units with weights  $w = \{w_2, \dots, w_J\}$  with  $0 \leq w_j \leq 1$  for  $j = 2, \dots, J$  and

$$\sum_{j=2}^J w_j = 1$$

Using given weights  $\{w_2, \dots, w_J\}$  the synthetic control estimators of  $Y_{it}^N$  and  $v_{it}$  are:

$$\begin{aligned} \hat{Y}_{it}^N &= w_2 Y_{2t} + \dots + w_J Y_{Jt} \\ \hat{v}_{it} &= Y_{it}^I - \hat{Y}_{it}^N \end{aligned}$$

The next step is to choose weights  $\{w_2, \dots, w_J\}$ . According to Abadie & Gardeazabal (2003) and Abadie et al. (2012), the weights should best reflect the pre-intervention features of the affected unit. Furthermore, Abadie & Gardeazabal (2003) and Abadie et al. (2012) choose  $w^* = \{w_2^*, \dots, w_J^*\}$  which minimizes:

$$v_1(X_{11} - w_2 X_{12} - \dots - w_J X_{1J})^2 + \dots + v_k(X_{k1} - w_2 X_{k2} - \dots - w_J X_{kJ})^2 \quad (2)$$

where  $\{v_1, \dots, v_k\}$  represent the relative importance of the synthetic control assigned to predictors  $\{X_{11}, \dots, X_{k1}\}$ . Therefore, the problem comes down to choosing  $\{v_1, \dots, v_k\}$ . Usually, the weights are chosen so that the synthetic controls minimize the size of the prediction error,  $Y_{it}^I - \hat{Y}_{it}^N$ , in a selected pre-intervention period, this can be done by solving a nested optimization problem with  $v$  selected so that  $w$  minimizes the root mean square predicted error Root Mean Square Predicted Error (RMSPE) during selected periods.<sup>2</sup> Therefore, each choice of  $v$  results in different country weights  $w(v)$ , which then gives a value for the RMSPE. Moreover, using the weighted average approach precludes extrapolation that regression models are usually based on (King & Zeng, 2006). However, if control units are not similar enough to the treatment unit, then any inference about the outcome may merely reflect the real difference in their characteristics.

Also, the SCM suffers from relatively weak robustness checks of its results. In their pioneering work, Abadie & Gardeazabal (2003) introduced two robustness checks. The first one concerns applying the SCM separately to all control units. The other one suggests to run a placebo study in a year when the actual intervention did not occur. The way that the SCM is used in inference procedures originally developed by Abadie, Diamond, & Hainmueller (2010) and Abadie, Diamond, & Hainmueller (2015) is an important research topic. Their inference procedures consist of estimating p-values through permutation tests: using this procedure, they test the null hypothesis of no effect of the intervention. However, Ando & Ando (2015) design two new test statistics that have more power when applied to test the null hypothesis than those introduced by Abadie, Diamond, & Hainmueller (2010) and Abadie, Diamond, & Hainmueller (2015).

Another inference procedure that uses confidence intervals was proposed by Gobillon & Magnac (2016). They use a bootstrap technique to compute confidence intervals for the policy effect on more than one treated unit. However, to obtain valid results, a large number of treated and control unit are necessary. The issue regarding the validity of confidence intervals for a small number of control

<sup>2</sup> See Abadie (2011) which describes several methods for choosing the weights  $\{v_1, \dots, v_k\}$

units was finally solved by Firpo & Possebom (2017). They extend the original inference procedures in a way that allows for different treatment assignment probabilities across the units – any unit could have a different probability to face the intervention of interest. Moreover, their modified inference procedure allows for testing any kind of sharp null hypothesis – any other from the null hypothesis of no effect proposed by Abadie, Diamond, & Hainmueller (2010) and Abadie, Diamond, & Hainmueller (2015). Finally, their inference procedure allows for the construction of confidence intervals for the post-intervention outcome as any function of time. Therefore, this project examines construction of confidence intervals of the results as another robustness check connected to the SCM.

Since the introduction of the SCM there have been several articles that extend it. For example, Acemoglu, Johnson, Kermani, Kwak, & Mitton (2016) and Cavallo, Galiani, Noy, & Pantano (2013) modify the SCM in the way that more than one treated unit could be used to assess the intervention effect. Another extension was proposed by Wong (2015), where he applies the SCM to the cross-sectional setting and derives the synthetic control asymptotic distribution when the number of individuals in the sample goes to infinity. Another examination of SCM was done by Kreif, Grieve, Hangartner, Turner, Nikolova, & Sutton (2016), where they put the SCM in contrast with DiD method. They find that in contrast to the DiD method, for the treated condition, the SCM reports not significant result.

Also, the SCM has been recently used for various topic in economics and finance, and social sciences in general. Firpo & Possebom (2017) used the SCM for their study list and this method has been used for many topics, such as politics (Abadie & Gardeazabal, 2003; Bove, Elia, & Smith, 2014; Li, 2012; Montalvo, 2011; Yu & Wang, 2013), natural disasters (Barone & Mocetti, 2014; Cavallo, Galiani, Noy, & Pantano, 2013; Coffman & Noy, 2012; duPont IV & Noy, 2015; Mideksa, 2013; Sills, Herrera, Kirkpatrick, Brandao Jr, Dickson, Hall, Pattanayak, Shoch, Vedoveto, Young, 2015; Smith, 2015), international finance (Jinjarak, Noy, & Zheng, 2013; Sanso-Navarro, 2011), financial policy (Aregger, Leutert, 2017; Bruha & Tonner, 2017; Opatrny, 2017b), education and research policy (Belot, Vandenberghe, 2009; Chan, Frey, Gallus, & Torgler, 2014; Hinrichs, 2012), health policy (Bauhoff, 2014; Kreif, Grieve, Hangartner, Turner, Nikolova, & Sutton, 2016), trade liberalization (Billmeier & Nannicini, 2013; Gathani, Santini, & Stoelinga, 2013; Hosny, 2012), political reforms (Billmeier & Nannicini, 2009; Carrasco, de Mello, & Duarte, 2014; Dhungana, 2011; Ribeiro, Stein, & Kang, 2013), labour (Bohn, Lofstrom, & Raphael, 2014; la Calderón, 2014), taxation (Kleven, Landais, & Saez, 2013), crime (Pinotti, 2012; Saunders, Lundberg, Lundberg, Braga, Braga, Ridgeway, & Miles, 2015), social connections (Acemoglu, Johnson, Kermani, Kwak, & Mitton, 2016), and local development (Ando & Ando, 2015; Gobillon & Magnac, 2016; Kirkpatrick & Benneer, 2014; Liu, 2015; Possebom, 2017; Severnini, 2013).

#### **Přínos projektu k rozvoji fakulty/VŠ:**

Since the SCM is a general method for comparative studies and can be applied for rich variety of events, the further development of this method could be useful for the whole Faculty of Social Sciences or potentially for the whole University.

In a study Opatrny (2017a), we apply the SCM on the Czech National Bank exchange rate commitment which started in 2013. As far as we know, this study was the first application of SCM on Institute of Economic Studies, Faculty of Social Sciences, Charles University. The goal of this study was to quantitatively evaluate the effect of the commitment on key macroeconomic indicators, namely, unemployment rate, inflation rate, and gross domestic product (GDP) per capita. We found that the commitment helped decrease unemployment substantially. The effect on overall output was also strongly positive, almost 2 percentage points for growth in 2015, but only marginally statistically

significant, which might be connected to disturbances created by changes in excise taxes. The effect of the commitment on inflation was positive but not statistically significant at standard levels. This article was awarded by Czech Economic Society as in the competition of Young Economist 2016 – Honourable recognition for outstanding working paper.

### **Materiální zajištění projektu:**

### **Cíle řešení projektu:**

The goal of this project is to conduct three analyses based on using the SCM. Moreover, we will contribute to the SCM literature by comparing it with DiD method and examining the confidence intervals for the SCM.

### **Způsob řešení:**

Quantitative evaluation of the effects of economic policy changes is of the crucial interest for both policy makers and economists. The aim of this project is to use the SCM as a powerful comparative studies tool to evaluate 1) the effect of the agricultural subsidies on the production of farmers in the Czech Republic after the EU accession in 2004, 2) the impact of the Brexit Vote on UK Financial Markets, and 3) the effect of two ECB hikes in 2011 on macroeconomic indicators of selected eurozone countries. Moreover, this project aims to deliver methodological improvements to the SCM, such as the implementation of confidence intervals as one of its robustness checks.

The first study concerns the evaluation of agricultural subsidies on the production of farmers. Importantly, Common Agricultural Policy (CAP) consumed almost 40% of EU yearly budget in 2015 and is being expected to have the similar share until 2019 (DG Agriculture and Rural Development, 2018).<sup>3</sup> Furthermore, the common agricultural market (CAM) has opened for the Czech Republic since it joined the EU in 2004. Moreover, the Czech agricultural sector had to incorporate the Common Agriculture Policy (CAP) with direct support for farms, known as decoupled subsidies from production (direct payments, agro-environmental measures (AEM), subsidies for less favourable areas (LFA) and rural development programmes (RDP)). These facts motivate us to conduct the analysis of the impact of CAP and CAM on the Czech agricultural sector. We take the joining the EU as an exogenous event in terms of subsidising farmers, this fact allows us to use the SCM. We will evaluate the impact of joining common agricultural market (CAM) and CAP on countries which receive the highest weight from SCM. This allows us to investigate, whether the absolute amount of direct payment per hectare could be one of the triggers of the different reactions to joining the (CAM) and CAP. The analysis will use the food production index as the dependent variable.<sup>4</sup> As a covariates we will use those which reasonably reflect the national agricultural sector as well as the development of the economy such as Cereals' Yield, Final Consumption Expenditures, the Livestock Production Index, the Crop Production Index, Arable Land, Trade Share, Agriculture Forestry and Fishing Added Value, Foreign Direct Investment Net Inflows, Adjusted Net National Income, GDP per capita, Inflation, Unemployment and Rural Population. Given the assumptions of the method, we will use the following control set: Belarus, Bulgaria, Croatia, Georgia, Romania, Turkey and the Ukraine.

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<sup>3</sup> The main goal of the CAP is to establish competitive and sustainable EU agriculture and the subsidies tool plays a key role to achieve this goal. Subsidies are divided into two pillars. First pillar includes direct payments and market-related expenditure to a producer, whereas second pillar includes subsidies for rural development. See [https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance\\_en](https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en) and [https://ec.europa.eu/agriculture/sites/agriculture/files/cap-post-2013/graphs/graph3\\_en.pdf](https://ec.europa.eu/agriculture/sites/agriculture/files/cap-post-2013/graphs/graph3_en.pdf)

<sup>4</sup> The World Bank defines the food production index as follows: 'Food production index covers food crops that are considered edible and that contain nutrients. Coffee and tea are excluded because, although edible, they have no nutritive value.'

Moreover, Bulgaria and Romania joined the CAM and CAP in 2007. Therefore, we will use the time span between 1995 and 2007 as a computation period for building the counterfactual. As a result, this study could contribute to the debate about the policy implication for the criteria on subsidies distribution.

The second application of the SCM is the evaluation of the effect of the Brexit referendum on UK financial market. As the exit terms are being negotiated at the moment, the actual voting could be perceived as a start of anticipation effect.<sup>5</sup> Recent estimation done by Born, Muller, Schularick and Sedláček (2018) based on the SCM shows, that due to the Brexit vote there is output loss about 2 % of British GDP.<sup>6</sup> However, as they claim, it is hard to calculate the current cost of Brexit due to no obvious counterfactual. We will contribute to the current literature on the economic impact of the Brexit vote by analysing the development of stock and bond markets and the real effective exchange rate. As far as we know, this paper will be the first to analyse the impact of the Brexit vote on UK financial market using SCM. Our paper relates to the analysis of macroeconomic experiments at the aggregate level Billmeier & Nannicini (2013), Gathani, Santini, & Stoelinga (2013) and Hosny (2012) and the literature on employing the synthetic control method. In this study, we will estimate the impact of Brexit Vote on the UK stock exchange, long-term government bonds and exchange rate. We will approximate the aforementioned variables by long-term treasury yield (10-year gilt yield), Financial Times Stock Exchange 100 Index (FTSE 100 Index) and the real effective exchange rate (REER). We will use monthly data from the OECD database to establish the donor pool of countries that best resembles the economic development of the UK before the vote. In the donor pool we will exclude countries which may be affected by intervention in the 'treated' country, therefore, the donor pool of countries will consist from 9 non- European OECD members -- Australia, Canada, Chile, Israel, Japan, South Korea, Mexico, New Zealand, and the United States. We contribute to the current literature on the economic impact of the Brexit vote by analysing the development of stock and bond markets and the real effective exchange rate. This study will contribute to the public debate about the cost of leaving the EU. Consequently, the result could serve as a background for policy implications.

Third, we will examine the impact of two ECB hikes in 2011 on macroeconomic indicators of selected eurozone countries. Facing accelerating inflation amid the ongoing recovery from the global financial crisis, the ECB decided to hike in April 2011 and July 2011. However, the eurozone fell into a recession after the second hike and the new ECB president Mario Draghi quickly reversed the decision of his predecessor in November and December 2011. While the prompt backtracking points out that the decision to hike might have been premature, it is questionable whether the two hikes (by 50 basis points in total) materially contributed to the sudden negative change in economic conditions. In our approach, we will evaluate the effect of the interest rate increases on macroeconomic indicators (GDP growth, inflation, unemployment) of selected eurozone countries. In particular, we will examine if the impact of the hikes was different in the "North" (e.g. the Netherlands, Germany) and the "South" of the eurozone (e.g. Greece, Italy). This research will have policy implications as it can help to provide a verdict on a situation when a monetary authority decides to increase interest rates in a challenging economic environment and might be relevant the next time when the ECB ponders hiking interest rates.

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<sup>5</sup> As Abadie, Diamond, & Hainmueller (2015) mention, when setting the intervention periods it is necessary to take into account any potential anticipation effect, so that intervention periods can be reset to the period when the first effect of the intervention is assumed to appear.

<sup>6</sup> See <https://voxeu.org/article/300-million-week-output-cost-brexit-vote>

In general, we plan to follow Abadie & Gardeazabal (2003) methodology to employ the SCM. To achieve this approach, we will work with STATA, Matlab or R environment, which allows us to establish empirical estimators of the characteristics of our interest. As for the data, the Eurostat database is likely to be preferred source for macroeconomic indicators of European/EU countries. Moreover, the Czech Statistical Office will serve as a source for data about Czech agricultural industry. However, to establish the control unit, data from other countries (which joined the EU later than the Czech Republic) will be collected from national statistical offices. Finally, to establish a control unit for the Brexit study, data from OECD database or the World Bank will be used.

**Prezentace výsledků:**

The project is a part of the principal investigator's dissertation thesis and the author plans to submit the article to a respected economic journal in a Scopus list. The support from the GA UK project will be acknowledged in all the output materials. The overall research will be compiled in the dissertation thesis. The thesis will include four studies based on published/submitted researches. The first one Quantifying the Effects of the CNB's Exchange Rate Commitment: A Synthetic Control Method Approach, which is already published in Czech Journal of Economics and Finance. The second one with the title The Impact of Agricultural Subsidies on Farm Production: A Synthetic Control Method Approach, and the comparison with DiD method will be presented to show the empirical validation with different method, which besides the main theme, will broaden the confidence interval robustness check approach. The third part has the working title The Impact of the Brexit Vote on UK Financial Markets: A Synthetic Control Method Approach. Finally, the fourth part with the working title What if the ECB did not hike in 2011: a synthetic control method approach will use the methodological improvements from the previous research outputs.