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JEL Codes: E52; E58

Inflation Targeting Mattered: a multivariate synthetic control approach [*]

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Abstract

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1. Introduction

The 1990s witnessed a revolution in the conduct of monetary policy worldwide. Several central banks stopped pursuing intermediate targets, such as monetary aggregates or exchange rates, and started to target inflation explicitly. Since New Zealand first adopted the inflation targeting (IT) regime in 1990, it quickly spread, although without evidence of its better economic performance among developed economies (see Ball and Sheridan 2005, Walsh 2009, and Ball 2010).

The adoption of IT may either: (i) make monetary policy more efficient, reducing its costs in terms of output forgone to control inflation; or (ii) merely imply a change in the preferences of the central bank, which then gives more weight to inflation control (see Stiglitz 2008 and Brito and Bystedt 2010). Since it is not trivial to build a multivariate counterfactual, – that is, a nontreated synthetic country that jointly matches the inflation and output growth of the IT country – it is difficult to determine which of those two unfolded.

Does IT effectively lower the output costs of inflation control? We examine this question through the Multivariate Synthetic Control Method using Time-Series (MSCMT) by Klößner and Pfeifer (2018), which matches the IT country to a synthetic counterfactual country with similar joint dynamics of inflation and output growth before IT adoption. From this bivariate perspective, we use comparative case studies to evaluate the effects of IT on the macroeconomic performance of pioneering IT countries (hereafter, ITers): New Zealand, Canada, the United Kingdom, Sweden, and Australia. On considering almost 25 years of IT experience that encompasses different economic events, we add to previous evidence and address concerns like Stiglitz's (2008) on the ability of IT to recover from macroeconomic shocks.

Ball and Sheridan (2005), Batini and Laxton (2006), Gonçalves and Salles (2008), and Ball (2010) employed a difference-in-differences (DID) strategy and found controversial results about the effects of IT on macroeconomic performance. However, the adoption of IT can be endogenous since countries may be more likely to adopt it when experiencing severe economic problems or due to the failure of other strategies for conducting monetary policy. Lin and Ye (2007) attempted to handle this self-selection bias of IT adoption through propensity score matching (PSM). However, the PSM matches observable predictors' means before the intervention and does not easily control for the dynamics of these observables or control for time-varying unobserved confounders.

The MSCMT is a generalization of the univariate synthetic control method (SCM) by Abadie and Gardeazabal (2003) and Abadie et al. (2010), which addresses difficulties faced by these standard econometric methods. Like the SCM, the MSCMT allows to control for time-varying unobserved confounders and the evolution of economic predictors to construct the counterfactual. In addition, the MSCMT provides a single counterfactual unit for multiple outcome variables, enabling the joint assessment of the multiple effects of a policy. [1]

From a methodological standpoint, our paper extends Lee (2011), who estimates the treatment effect of IT on emerging economies inflations using the univariate SCM. Because his counterfactual unit aims only at the inflation of the ITer before adoption, he does not necessarily match the ITer simultaneous output growth, abstracting the inflation-output trade-off. In other words, Lee (2011) does estimate the treatment effect of IT on

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[1] There are other methods to find artificial counterfactuals for multiple outcomes, like Carvalho et al. (2018). However, only the MSCMT imposes that those multiple outcomes must come from a single entity to the best of our knowledge.

inflation, yet the efficiency evaluation of the IT policy must also account for the resulting output growth. In contrast to Lee's (2011) SCM counterfactual, our MSCMT counterfactual unit simultaneously matches the inflation and output growth of the ITer before adoption, accounting for the inflation-output interdependencies to provide a multicriteria evaluation.

Our results indicate that IT had positive effects on most pioneering ITers relative to their synthetic counterfactuals. Sweden had lower inflation and enhanced output growth. The United Kingdom showed a similar pattern until 2007. Canada lowered inflation without significant output cost at adoption. New Zealand enjoyed significant disinflation despite transitory negative effects on output at adoption and grew more in the medium term. And Australia grew more with slightly higher inflation. Additionally, although heavily hit by the financial crisis, the United Kingdom and Sweden presented better economic performance during the Great Recession than their synthetics, suggesting an IT advantage against deflation spirals. All these results are robust to relevant variations in the pool of control countries, pre-treatment period, data frequency and IT adoption dates.

We also compute the average effects of treatment on treated (ATT). The average effects of IT on inflation and output growth are estimated jointly from the inflation and output growth differences between ITers and their synthetics, in a multivariate extension of the difference-in-difference method.

IT had a significant average effect in lowering inflation and enhancing growth over time. In the early years of adoption, IT lowered inflation without reducing output growth. From IT adoption until 1999, the ITers had average consumer price inflation *1.34* percentage points per year (*p.p.p.y.*) lower and GDP growth *0.60 p.p.p.y.* higher. As the IT experience extended, GDP growth could be higher without accelerating inflation.

From adoption until 2016, the ITers had average GDP growth *1.19 p.p.p.y.* higher and consumer price inflation *0.42 p.p.p.y.* lower.

The rest of the paper is organized as follows. Section 2 presents the MSCMT. Section 3 describes the data. Section 4 analyzes the results. Section 5 concludes.

2. Synthetic Control Methodology

We use the Multivariate Synthetic Control Method using Time Series (MSCMT) to identify the effects of IT. In this section, we recap the univariate synthetic control method (SCM) developed in Abadie and Gardeazabal (2003), Abadie et al. (2010), and Abadie et al. (2015) and compare it to the MSCMT extension by Klößner and Pfeifer (2018).[2]

The SCM was conceived for policy intervention evaluation on an outcome variable of the treated unit, providing a synthetic comparison unit given by the weighted combination of untreated control units that best resembles the outcome variable of the treated unit before the intervention (i.e., respecting the conditional independence assumption, CIA). The SCM extends the traditional linear panel data framework, allowing to control for time-varying unobserved confounders. Within this framework, the measured effect of a policy is the difference in the evolution of the outcome variables for the treated and its synthetic counterfactual after the intervention.

Let $Y_{j,t}$ denote the observed outcome variable for unit $j = 1, \ldots, J, (J+1)$ in period t, $Y_{j,t}^{N}$ is the potential outcome that would be observed in the absence of the

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[2] Klößner and Pfeifer (2018) and Becker and Klößner (2017) use the MSCMT to analyze the impact of European car scrappage programs on sales of new vehicles and CO2 emissions and the economic costs of organized crime in southern Italy, respectively.

intervention, $Y_{j,t}^I$ is the potential outcome that would be observed due to the intervention in periods $t > T_0$, and $D_{j,t}$ is a binary variable that assumes the value of 1 if the unit j is treated in $t > T_0$. Then, the potential outcomes model can be written as:[3]

$$Y_{j,t} = Y_{j,t}^N(1 - D_{j,t}) + Y_{j,t}^I D_{j,t} = Y_{j,t}^N + D_{j,t}(Y_{j,t}^I - Y_{j,t}^N)\,. \tag{1}$$

Note that when assuming the intervention only affected unit $j = 1$ and had no effect on the outcome before $T_0 + 1$, the effect of the policy on the treated unit could be computed as $Y_{1,t}^I - Y_{1,t}^N$ when $t > T_0$. However, $Y_{1,t}^N$ is not observable and the SCM aims to come up with the synthetic control $\hat{Y}_{1,t}^N$, which is the counterfactual value that would be observed if there had been no treatment.

The SCM optimizes control weight vector $W = (\varpi_2, \dots, \varpi_{J+1})'$ for the J control units, with $\varpi_j \geq 0$ and $\sum_{j=2}^{J+1} \varpi_j = 1$, to replicate the pretreatment observations of the treated unit $j = 1$, $\hat{Y}_{1,t}^N = \sum_{j=2}^{J+1} \hat{\varpi}_j \, Y_{j,t}$. In other words, the potential outcome variable of the treated unit in the absence of treatment is approximated by the weighted combination of nontreated units' outcomes, and the point estimate of the intervention effect is given by:

$$\hat{\alpha}_{1,t} = Y_{1,t} - \hat{Y}_{1,t}^N = Y_{1t} - \sum_{j=2}^{J+1} \hat{\varpi}_j \, Y_{j,t}, \text{ for } t > T_0\,. \tag{2}$$

The vector of control unit weights W is obtained through a nested optimization problem consisting of inner and outer optimizations. Given $Y_{j,t}$ is predicted by the

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[3] We are assuming that intervention takes place in period $T_0 + 1$.

$(K \times 1)$ vector $X_j = \left(X_{1,j}, \dots, X_{k,j}\right)'$ in period $t \leq T_0$ and the $(K \times K)$ diagonal matrix of predictor weights V, the inner optimization finds $W^*(V)$ such that difference in the predictor values of the treated unit X_1 and the W combination of the respective $(K \times J)$ control units' matrix $X_0 = \left(X_2, X_3, \dots, X_{J+1}\right)$ is as small as possible:

$$\min_{\substack{W \geq 0 \\ 1'W=1}} (X_1 - X_0 W)' V (X_1 - X_0 W) = \min_{\substack{W \geq 0 \\ 1'W=1}} \sum_{k=1}^{K} v_k \left(X_{k,1} - \sum_{j=2}^{J+1} X_{k,j} \varpi_j \right)^2 . \quad (3)$$

On the other hand, the outer optimization uses the previous result $W^*(V)$ to find V^* such that the difference between the time-series of the outcome variable for the treated unit over the pre-intervention $Y_1 = \left(Y_{1,1}, \dots, Y_{1,T_0}\right)'$ and the W combination of the respective $(T_0 \times J)$ control units' matrix of outcome variables $Y_0 = \left(Y_2, Y_3, \dots, Y_{J+1}\right)$ is minimal:

$$\min_{\substack{V \geq 0 \\ 1'V=1}} \left(Y_1 - Y_0 W^*(V)\right)' \left(Y_1 - Y_0 W^*(V)\right) = \min_{\substack{V \geq 0 \\ 1'V=1}} \sum_{m=1}^{T_0} \left(Y_{1,m} - \sum_{j=2}^{J+1} Y_{j,m} \varpi_j^*(V) \right)^2 . \quad (4)$$

By iteratively solving this nested optimization problem, both W^* (the optimal vector of weights for the control units) and V^* (the optimal matrix of weights for the predictor variables) are obtained.

The MSCMT by Klößner and Pfeifer (2018) generalizes the SCM in two different aspects. First, the MSCMT models multiple outcome variables simultaneously (i.e., $Y_{l,j,t}$ as opposed to only one variable $Y_{j,t}$), similar to Robbins et al. (2017). Second, it uses the time-series information of the predictor variables to construct the counterfactual (i.e., $X_{k,j,t}$ as opposed to $X_{k,j}$), like Gobillon and Magnac (2016) and Xu (2017).

Simultaneously modeling multiple outcome variables is relevant in our context to deal with the inexorable short-run inflation-output trade-off in the conduct of monetary policy (see Christiano et al., 1996 and Mankiw, 2001). In the panel of 18 industrial economies of the present study, the lagged GDP growth is important to explain inflation even after controlling for lagged inflation, time and country fixed effects.

The use of predictor variables time series allows us to match pretreatment similarities in their dynamics. For example, Lin and Ye (2007) use propensity score matching (PSM) to examine the effects of IT on industrial economies. However, because PSM is a cross-sectional technique that matches predictor means before the intervention, it does not capture trends and changes in trends.

Like in the SCM, the nested optimization problem provides both W^* and V^* in the MSCMT. The generalized inner optimization is represented as:

$$\min_{\substack{W\geq 0\\ 1'W=1}} \sum_{k=1}^{K} v_k \sum_{n=1}^{N_k^{pre}} \left(X_{k,1,n} - \sum_{j=2}^{J+1} X_{k,j,n}\, \varpi_j \right)^2 , \tag{5}$$

where $X_{k,j,n}$ is the value of the economic predictor $k = 1, \dots, K$ over the pretreatment period $n = 1, \dots, N_k^{pre}$ for unit j and v_k is the weight of k .

Analogously, the outer optimization uses $W^*(V)$ to obtain V^* by minimizing the following criterion:

$$\min_{\substack{V\geq 0\\ 1'V=1}} \sum_{l=1}^{2}\sum_{m=1}^{T_0}\left(Y_{l,1,m} - \sum_{j=2}^{J+1} Y_{l,j,m}\varpi_j^*(V)\right)^2 , \tag{6}$$

where $Y_{l,j,m}$ are the observed outcome variables $l = 1, 2$ (that is, in the case of two variables of interest) over the pretreatment period $m = 1, \ldots, T_0$ for unit j.[4]

Klößner and Pfeifer (2018) state the necessary conditions and prove the MSCMT estimator is unbiased. Assuming $Z_{j,t} = (Y_{j,t}', X_{j,t}')'$ follow an $AR(p)$ structure with possibly time-varying coefficients but without time-varying unobserved confounders, the vector of effect estimators $\hat{Y}_{1,t} = \sum_{j=2}^{J+1} Y_{j,t}\varpi_j^*$ is unbiased for all $t \geq T_0 + 1$ if $W^* = (\varpi_2^*, \ldots, \varpi_{J+1}^*)'$ satisfy $Z_{1,t} = \sum_{j=2}^{J+1} Z_{j,t}\varpi_j^*$ for $t = T_0 - (p-1), \ldots, T_0$. For $Z_{j,t}$ containing time-varying unobserved confounders, the vector of effect estimators $\hat{Y}_{1,t}$ is asymptotically unbiased under some technical assumptions,[5] i.e., the bias is close to zero if the number of preintervention observations is large relative to the scale of the transitory shocks.[6]

We choose X_j to be the entire pre-treatment path of the outcome variables Y_j. That is, we assume that lagged inflation and lagged output growth explain current inflation or output growth. The consequence of this choice is that the predictors' weight matrix V will give equal importance to inflation and output growth (i.e., $V^* = (0.5, 0.5)$), and the synthetic control unit (i.e., W^*) will be determined by solely minimizing the

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[4] See Becker and Klößner (2018) for a more general presentation of the MSCMT with different weights for the outcome variables and time-series observations. They also demonstrate how Equations (5) and (6) can be written in vector notation like Equations (3) and (4) after defining vectors $\tilde{Y}_j$ and $\tilde{X}_j$ that respectively stack different l outcome variables $Y_{l,j}$ and k time-series predictor observations $X_{k,j}$.

[5] See Abadie el al. (2010) for such conditions.

[6] We note that with l outcome variables, the number of preintervention observations is $l \times T_0$.

outer objective function, as demonstrated in Kaul et al. (2021).[7] This is actually in line with the monetary economics tradition to keep the inflation-output trade-off analysis circumscribed to these very same variables, like in the Phillips curve or the misperceptions model of Lucas (1972). Additionally, the assignment of equal weights to inflation and output carries the objective of a central bank equally concerned with both inflation and output growth.[8]

The synthetic methods provide point estimates of the program's impact $\hat{\alpha}_{l,t} = \left(Y_{l,1,t}^{I} - \hat{Y}_{l,1,t}^{N}\right)$ for $t > T_0$ but do not offer confidence intervals to infer its significance. To address this issue, Abadie et al. (2010) propose an inference procedure, the placebo effect test, which is analogous to the permutation test and is useful in cases where the number of units in the control group is small.[9] As they explain, this alternative model of inference is based on the premise that our confidence that a particular treated-synthetic difference estimate reflects the impact of the intervention under study would be severely undermined if we obtained estimated effects of similar or even greater magnitudes in cases where the intervention did not take place (i.e., placebo effects).

In our notation terms, suppose there are $(J + 1)$ countries, of whom 1 will be randomly selected to receive treatment. Let Y_1^I be the observation of the treated country and $Y_2^N, \dots, Y_{j+1}^N$ be the observations of countries that did not receive treatment. The impact of the treatment in outcome variable l at time t is the difference $\hat{\alpha}_{l,1,t} =$

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[7] As explained in Kaul et al. (2021), such a choice is problematic if other ignored covariates are relevant to predict post-treatment values of the outcome variable.

[8] Yet another reason for $V^* = (0.5{,}0.5)$, Kuosmanen et al. (2021) demonstrate that the joint optimization of donor weights and predictor weights might result in numerical instability and a tendency towards corner solutions. Therefore, the choice of equal weights to standardized predictors (as we do for inflation and GDP growth) is a grounded alternative.

[9] See Ernst (2004) for permutation methods, tests, and exact inference.

$\left(Y_{l,1,t}^{I}-\hat{Y}_{l,1,t}^{N}\right)$, with $\hat{Y}_{l,1,t}^{N}=J^{-1}\sum_{j=2}^{J+1}\varpi_{j}Y_{l,j,t}^{N}$, for given weights $(\varpi_{2},\dots,\varpi_{J+1})$. Under the null hypothesis that the treatment does not affect the patient, the value of $\hat{\alpha}_{l,j,t}$ should be the same regardless of the individual selected for treatment, and there are $(J+1)$ different possibilities of selection (i.e., H_0: $\hat{\alpha}_{l,j,t}=0\ \forall j=1,\dots,(J+1)$), each with probability $(J+1)^{-1}$ of being observed. In the inference procedure suggested by Abadie et al. (2010), we obtain the distribution of those $(J+1)$ differences $\hat{\alpha}_{l,j,t}=\left(Y_{l,j,t}^{I}-\hat{Y}_{l,j,t}^{N}\right)$ computed for every control unit $j=2,\dots,(J+1)$, swapping the treated country with control country j. The intervention is considered to have significant effects – that is, H_0 is rejected – if the estimated difference for the country effectively treated is extreme in relation to such distribution.

Recalling that $\hat{Y}_{l,j,t}^{N}$ is unbiased if its $\left(Y_{l,j,t}^{I}-\hat{Y}_{l,j,t}^{N}\right)$ pretreatment root mean square errors (RMSE) is small, in such distributions, we do not include placebo-synthetics differences with RMSE larger than three times the RMSE of the ITer-synthetic difference. This is because if a synthetic failed to fit its "treated" country's price and output indices before treatment, much of the "post-treatment" differences likely result from its poor fit rather than the effects of "treatment". Therefore, it does not provide a valid reference to judge the post-treatment gaps of the treated country.

Additionally, given that we have more than one treated country, we compute the average effect of IT on ITers, which we implement through the seemingly unrelated regressions (SUR) of inflation and output growth differences on the IT dummy variable:

$$\hat{\alpha}_{l,k,t}=\alpha_{l}+\beta_{l}D_{k,t}+\upsilon_{l,k,t}\ ,\ \text{for } l=\{1,2\},\ k=\{1,2,3,4,5\} \text{ and } t=1,\dots T \quad (7)$$

where $l=\{1,2\}=\{inflation, output\ growth\}$; α_{l} are the intercepts and β_{l} are the average effects of IT on the ITer inflation and output growth, which multiply the IT dummy $D_{k,t}$ that equals to *1* if ITer k has adopted IT in period t or *0* if it has not; $k = \{1,2,3,4,5\} = \{UK, Canada, Australia, Sweden, New\ Zealand\}$; and $\upsilon_{l,k,t}$ are the errors. Because correlation of the errors $\upsilon_{1,k,t}$ and $\upsilon_{2,k,t}$ renders the equation-by-equation ordinary least squares (OLS) estimator inconsistent, we estimate Equations (7) for maximum likelihood. We cluster the standard errors by ITer for accurate inference purposes.

Our measurement of the average effect of treatment on treated (ATT) in Equations (7) resembles Bertrand et al.'s (2004, p. 267) prescription when the treatment is staggered over time. In a panel context, these authors suggest that one should first regress $Y_{l,j,t}$ for all j's on fixed effects, period dummies, and any relevant covariates to compute the panel residuals. Then, one should separate and analyze the residuals of the treated units only. The estimate of the ATT and its standard error can be obtained through an OLS regression of the panel of treated units residuals on $D_{k,t}$. Our $\hat{\alpha}_{j,k,t}$ is analogous to Bertrand et al.'s (2004) panel of treated residuals, but obtained through the MSCMT estimation, which is additionally robust to time-varying unobserved confounders.

3. Data

The sample includes eighteen developed countries from the first quarter of 1985 to the fourth quarter of 2016. The choice of countries follows Ball and Sheridan (2005) on the effects of IT on advanced economies, excluding Finland and Spain, which discontinued their short IT experience to adopt the Euro and the ECB monetary policy.

Table 1 lists the IT countries with their quarters of IT policy adoption and the nontreated countries. Based on Roger (2009), Ball (2010), and Hammond (2012), our IT adoption dates reflect the time countries adopted IT *de jure*. The first country to adopt IT was New Zealand in 1990q1. Then, Canada adopted in 1991q1, followed by the United Kingdom in 1992q4, Sweden in 1995q1, and Australia in 1996q3.[10]

< Insert **Table 1** around here >

The nontreated countries are Austria, Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Portugal, Switzerland, and the United States, which never formally adopted IT. Additionally, although Switzerland, Norway, and Japan adopted IT in 2000q1, 2001q1, and 2013q1, respectively, they also serve as control units since our focus is on pioneering IT countries.[11] Among the non-IT countries, Switzerland, the United States, and those from the Euro area do not describe their monetary policy as IT, but they seem to have been incorporating its key features. That is, there is an increasing convergence of monetary practices over time. Nevertheless, our goal is to analyze whether IT adoption enhanced macro performances over the following years of its introduction.

The quarterly data of the consumer price index (CPI) and real gross domestic product index (GDPI) for the eighteen countries are from the OECD. Figures A.1 and A.2 in Appendix A illustrate each country's annual rates of inflation and output growth. Table 2 shows 5-year annualized inflation and output growth rates (i.e., the growth rates of CPI and GDPI) across ITers and non-IT countries before and after IT adoption. For comparison purposes, we use the average date of IT adoption (1993q2) to compute the averages for the non-ITers.

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[10] The Riksbank of Sweden announced IT intentions in 1993q1 but formally implemented it only in 1995q1 (see Berg and Grottheim, 1997). The RBA of Australia started using the concept of IT in 1993q2, but officially adopted it only in 1996q3 (see Edey, 2006). We have considered these anticipations of the IT effects, which can be provided upon request.

[11] We conduct robustness checks without including them among the potential control units in Appendix C.

The comparisons of the Pre-IT averages in Table 2 indicate that, as groups, the ITers' was not similar to the non-ITers' before IT adoption. Moreover, there was heterogeneity within the ITers, which suggests particular control groups for each ITer. In general, ITers reduced inflation and enhanced output growth. In contrast, the non-ITers show less evident improvements in these indicators, departing from relatively better performances pre-IT.

< Insert **Table 2** around here >

To document that our vintage of data is not much different from Ball and Sheridan (2005), columns (1) and (2) of Table 3 present least square dummy variable (LSDV) estimates of the IT effects in AR(1) equations for inflation and GDP growth from 1985 to 1999. We note that the *-0.64* and *0.84* effects of IT on inflation and growth are similar to Ball and Sheridan's (2005) estimates of -0.55 and 0.81 in "*Equation 2, columns (3)-(2)*" of their Tables 6.3 and 6.6.[12]

To demonstrate the pertinency of bivariate models of inflation and output growth, columns (3) and (4) of Table 3 show LSDV equation-by-equation estimates of univariate AR(1) models, columns (5) and (6) show LSDV equation-by-equation estimates of bivariate AR(1) models, and columns (7) and (8) show the panel vector autoregression estimates. Aside from the biases in dynamic models with fixed effects beyond the scope of this paper, [13] we note the significant effect of lagged growth on inflation in column (5). Thus, there is an important positive inflation-output trade-off, so that to compute the net effect of the IT policy on inflation, it is necessary to consider the variation in inflation due to recent variation in growth. Additionally, we note the difference in estimates from

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[12] With the caveat that Ball and Sheridan (2005) input 20 countries and data summarized into pre- and post-IT averages.

[13] See Nickell (1981) and Holtz-Eakin, Newey, and Rosen (1988).

columns (5)-(6) to (7)-(8), where the inflation and growth equations have been jointly estimated. Thus, a simultaneous approach of inflation and growth is justified to account for the effects of IT.

< Insert **Table 3** around here >

4. Main MSCMT Results

In this section, we present our main MSCMT estimates. The pretreatment period is from 1985 to the adoption of IT, while the posttreatment period comprises the quarters after policy adoption. The outcome and predictor variables are the log-transformed CPI and real GDPI, both scaled to zero at the quarter of IT adoption so that the trends of these variables represent cumulated inflation and GDP growth since IT adoption. All five ITers have the 13 non-IT countries from Table 1 as available donors.

The MSCMT optimally chooses the weights of donor countries. Table 4 reports each ITer synthetic's weights resulting from the MSCMT. For example, it builds the synthetic of the United Kingdom with 88.2% of Italy and 11.8% of Switzerland.

< Insert **Table 4** around here >

In Table 5, columns (1) and (2) compare the pretreatment averages of CP and GDP growth rates of each ITer to its respective synthetic values. Recalling that our outcome variables are the CP and GDP indices, and the MSCMT matches the trends of these indices (i.e., it matches these indices' growth rates), such comparisons of pretreatment average growth rates verify the synthetic good fit.[14] In general, the differences between pre-IT averages of the ITer and its synthetic are smaller than those between the ITer and

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[14] We warn that the MSCMT fitted the period from 1985q1 to IT adoption, while Table 5 shows just the five years before adoption.

the simple mean of all donor countries' pre-IT averages, indicating the synthetics' superior track of ITers dynamics before IT adoption.

< Insert **Table 5** around here >

In Figures X below, for $X = \{1, 2, 3, 4, 5\}$, we illustrate the dynamics for the five ITers. In every case, there are four graphs with the shaded area representing the pre-IT period. The top graphs depict the CPI (left) and GDPI (right) of the ITer (in solid black) and its synthetic version (in dashed red). Note that the CPI and GDPI behaviors of all ITers are very similar to their respective synthetics during the pre-IT period. Buttressed on these pre-IT similarities, we can attribute ITer-synthetic differences in the post-IT period to the effect of IT, especially in the years closer to adoption.

The bottom graphs of Figure X illustrate the differences of the CPI (left) and GDPI (right) between an ITer and its synthetic (in solid black) or between a non-ITer and its synthetic (in light gray). These gray lines are placebo effect tests used to infer the significance of the results for the ITers relative to pseudo-treated ones. In these placebo studies, we assume the IT adoption date of the analyzed ITer for non-ITers and compute the differences in performances of non-ITers relative to their synthetics. To assert the effects of IT on an ITer, the ITer-synthetic absolute differences should be clearly greater than the non-ITer-synthetic absolute differences.

In Table 5, columns (3)-(6) show average annual inflation and output growth rates for each ITer, its synthetic and the ITer-synthetic differences over 5 and 10 years after the IT adoption. As explained in Section 2, we recur to the permutation method to infer the statistical significance of an ITer-synthetic difference. Specifically, we rank the ITer-synthetic difference among the placebo effects with pretreatment RMSEs smaller than 3 times the ITer-synthetic difference's RMSE. The ranks improve with lower CPI difference and higher GDPI difference, reflecting the goals of lower inflation and higher output growth (i.e., rank #1 is attributed to the most negative inflation difference or the most positive output growth difference). We report the ITer-synthetic difference rank followed by its *p*-value, computed out of the total number of ranked placebo effects. For example, the Australian 5-year post-IT inflation difference is ranked 5 in column (3), and the Australian 5-year post-IT GDP growth difference is ranked 3 in column (4), out of 12 ranked placebos. Under the null hypothesis of nil treatment effect, the probability of ranking equal to or better than 5 is *0.42* for inflation (i.e., 0.42=5/12), and the probability of ranking equal to or better than 3 is *0.25* for the GDP growth (i.e., 0.25=3/12).

Additionally, we compute the joint probability of the pair of ranks under the null hypothesis of nil treatment effects and assuming independence between inflation and growth – thus providing a conservative inference given the established positive relationship between growth and inflation. For example, looking at the Australian post-IT 5-year performance, the joint probability of simultaneously ranking 5 or better on inflation and 3 or better on growth is *0.105* (i.e., 0.105=0.42x0.25).

Like Table 5, Table 6 presents average annual inflation and output growth rates for each ITer and its synthetic from the IT adoption up to 1999, 2007, or 2016. Furthermore, we also evaluate the recoveries of ITers after the Great Recession through 2008-2009 and 2008-2011.

<Insert **Table 6** around here>

Overall, our baseline results indicate that pioneering IT countries had positive results from adopting this policy. The United Kingdom and Sweden seem to have benefited by enjoying lower inflation and higher output growth compared to a hypothetical situation without IT. Canada enjoyed lower inflation without giving up output growth. New Zealand had good results in lower inflation but paid an initial output cost to build credibility, which seems to have returned in higher medium-term growth.

Finally, IT did not affect Australia's inflation, but its output growth was significantly higher than its synthetic's.

Next, we discuss each ITer case in more detail.

4.1. The United Kingdom

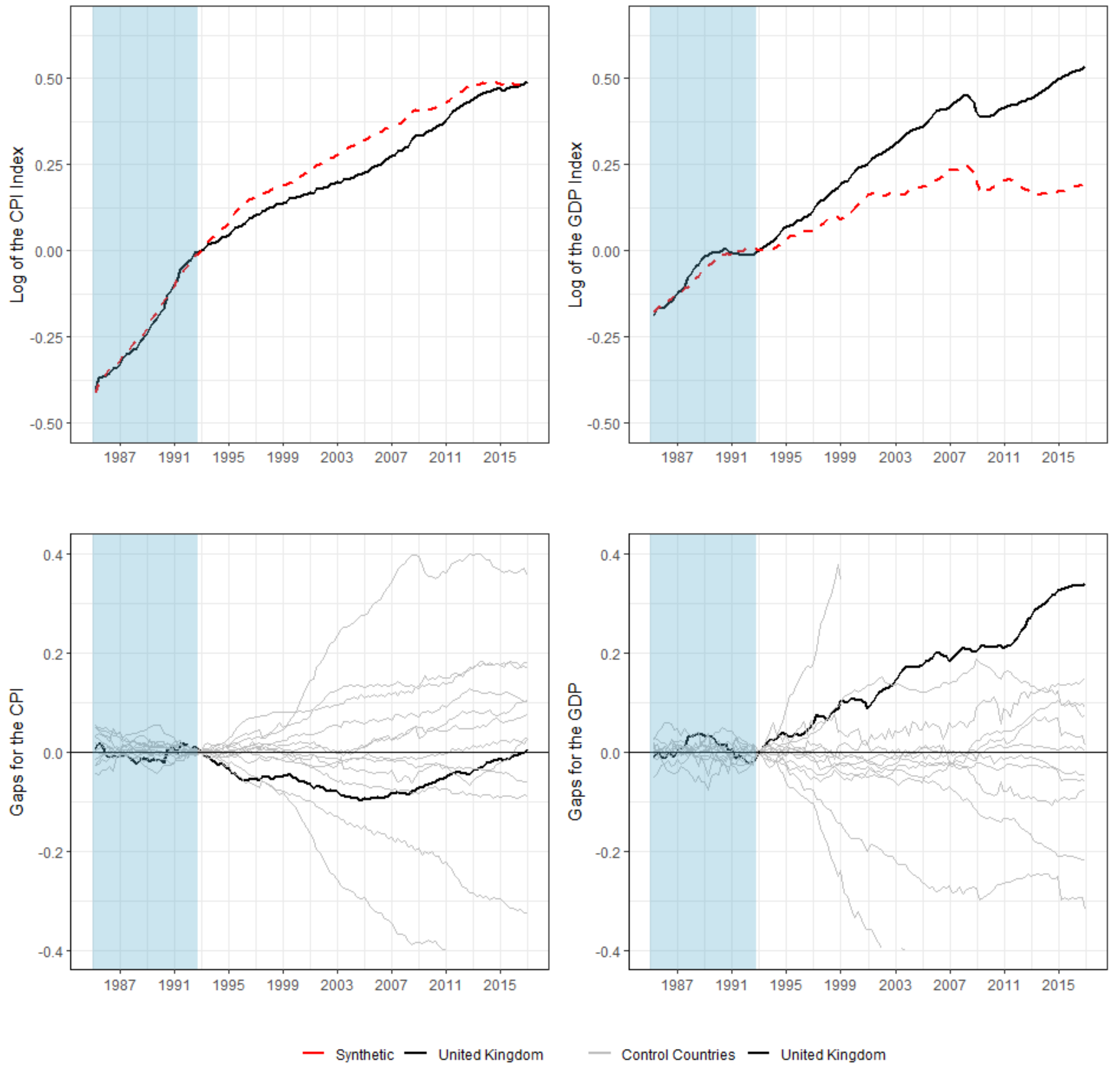
According to Haldane (2000), the UK explicitly adopted targeting inflation in September 1992 amid a sharp currency depreciation that led to the exit of the pound sterling from the European Exchange Rate Mechanism (ERM). At that time, the country raised interest rates but could not prevent the depreciation of the currency, which unfolded in a financial crash known as "Black Wednesday" on September 16th, 1992. Consequently, the IT experience in the United Kingdom began in a context of crisis with rising inflation expectations and a contracting economy.

Figure 1 illustrates the IT effects in the UK. After adopting IT in the last quarter of 1992, inflation reduced relative to its counterfactual, and output growth increased until 1995 (see Figures A.1 and A.2). Since then, the UK's higher growth than its synthetic growth has persisted, opening a wedge between their GDP indices.

From the positive inflation-output trade-off perspective of the Phillips curve, the fact that the UK presents annual output growth rates higher than its synthetic rate, without the side effect of higher inflation, is noted as superior performance.

The significance of these results is supported by the placebo effects test, where the UK-synthetic difference has a very distinct posttreatment trajectory compared to most of the placebo-synthetic differences for the CPI until 1996 and for the GDPI overall (see bottom graphs in Figure 1). According to Table 5, in the first 5 years post-IT, the UK average inflation was *1.0 percent point per year* (*p.p.p.y.*) lower and average output growth *1.29 p.p.p.y.* higher than its synthetic's values, resulting in a joint *p*-value of *0.05* implied by the placebo effects in the same period. According to Vickers (1998), this positive performance was surprising after such a critical exchange rate shock in an economy open to international trade. Over the 10 years post-IT, the UK average inflation was lower in *0.80 p.p.p.y.* and average output growth higher in *1.41 p.p.p.y.* relative to its counterfactual, with a joint *p*-value of *0.04*. The higher average output growth continued to accumulate until 2016, in columns (4) and (6) of Table 6.

Figure 1 - Baseline MSCMT: Inflation Targeting in the United Kingdom



Note: The log-transformed CPI and GDPI are scaled to zero at the quarter of IT adoption. Vertical axes in continuously compounded rates. The top row graphs depict the cumulative inflation and output growth of the United Kingdom (black line) and its synthetic (red dashed line) over time. The bottom row graphs illustrate ITer-synthetic differences in cumulative inflation and output growth (black line) and placebo tests (gray lines), i.e., non-ITer-synthetic differences. We discarded placebos with a pre-IT RMSPE three times higher than the ITer's (in this case, Portugal). The highlighted area represents the pre-IT period of the United Kingdom.

The UK succeeded in sustaining average inflation close to 2% per year through the Great Recession (see Figure A.1), which explains why the gap in UK CPI relative to its synthetic shrank after 2007 (see top-left graph in Figure 1). Moreover, although the UK output was heavily hit by the negative financial shock of 2007-2008 in column (8) of Table 6, its output recovered faster than its synthetic's output in column (10) and sustained its higher growth in column (6).

By looking at the whole experience from the IT adoption up to 2016 in columns (5) and (6) of Table 6, IT enabled the UK to achieve an average output growth of *1.41 p.p.p.y.* higher (i.e., a cumulative *33.9 percentage points* advantage over its synthetic version) without higher inflation, exhibiting a joint *p*-value of *0.06* relative to the placebo effects distribution in the same period. [15], [16]

4.2. Canada

Canada was the second country to adopt formal inflation targets in February 1991 (Bank of Canada, 1991). According to Dodge (2002), in a context of fear that inflation would resurge during the late 1980s, the government and Bank of Canada introduced the IT policy to provide a credible anchor for inflation expectations and gradually reduce inflation.

The results in Figure 2 suggest that Canada was successful in reducing inflation with IT adoption. In parallel, after a brief period of lower growth in the early 1990s, the

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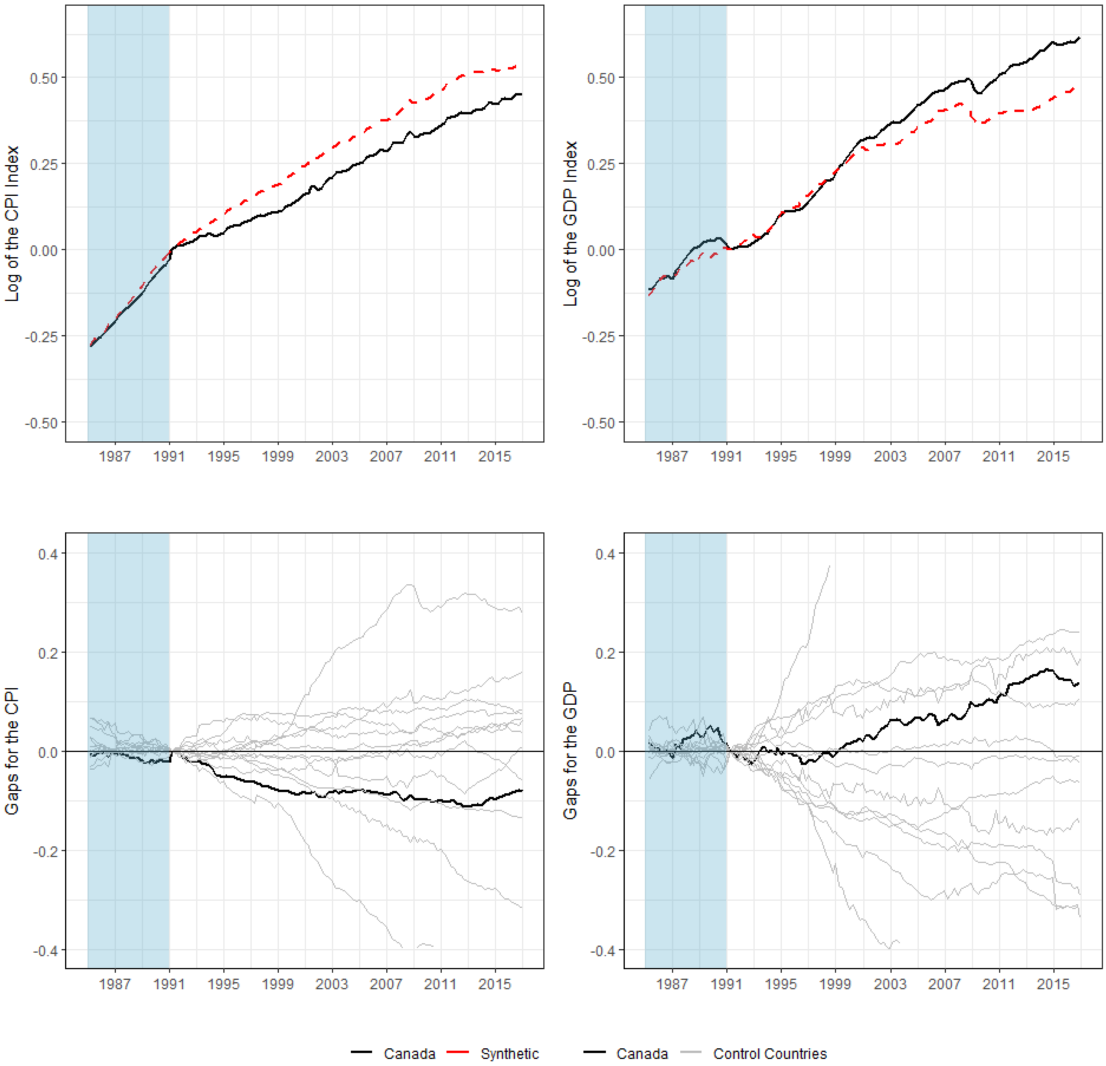
[15] The cumulative growth of 33.9 percentage points results from a higher average growth of 1.414 percentage points per year over 24 years, from 1992q4 until 2016q4.

[16] In Appendix B, for readers' curiosity, we illustrate the differences in results between the MSCMT just presented and the univariate SCM. We show that the synthetic unit that simultaneously matches inflation and GDP growth (from the MSCMT) is quite different from the synthetic unit that only matches inflation (from the univariate SCM).

trend steepened, and Canada's output took off from its synthetic in the 2000s. For instance, after 10 years of IT, the average inflation in Canada was *0.88 p.p.p.y.* lower than its synthetic without giving up growth. While the difference between Canada and its synthetic inflation fades over the years, the higher relative growth continues to accumulate.

Figure 2 - Baseline MSCMT: Inflation Targeting in Canada



Note: The log-transformed CPI and GDPI are scaled to zero at the quarter of IT adoption. Vertical axes in continuously compounded rates. The top row graphs depict the cumulative inflation and output growth of Canada (black line) and its synthetic (red dashed line) over time. The bottom row graphs illustrate ITer-synthetic differences in cumulative inflation and output growth (black line) and placebo tests (gray lines), i.e., non-ITer-synthetic differences. We discarded placebos with a pre-IT RMSPE three times higher than the ITer (in this case, Portugal). The highlighted area represents the pre-IT period of Canada.

The above dynamics are consistent with the successful evolution of Canadian IT. While Beaudry and Ruge-Murcia (2017) document that achieving inflation stability was the main goal motivating the Bank of Canada to adopt inflation targets, they also accept Otto and Voss's (2014) evidence that the Bank of Canada turned to a more flexible inflation-targeting policy over the years.

By looking at the experience from IT adoption to 2016, Canada enjoyed lower average inflation of *0.32 p.p.p.y.* and higher average output growth of *0.52 p.p.p.y.* than its synthetic (i.e., cumulative advantages of *-8.2 p.p.* in inflation and *13.4 p.p.* in output growth during 25.75 years), exhibiting a joint p-value of *0.09* implied by the placebo effects in the same period.[17]

4.3. Australia

Edey (2006) and Cornish (2019) discuss the antecedents of IT in Australia. The adoption of IT was formalized in the 1996 Statement on the Conduct of Monetary Policy.[18] However, as of June 1993, the Reserve Bank had already outlined the goal of holding inflation at approximately 2-3% over the cycle to prevent inflation from rising in the early stages of recovery from recession.[19] Since IT was deprived of some essential elements in

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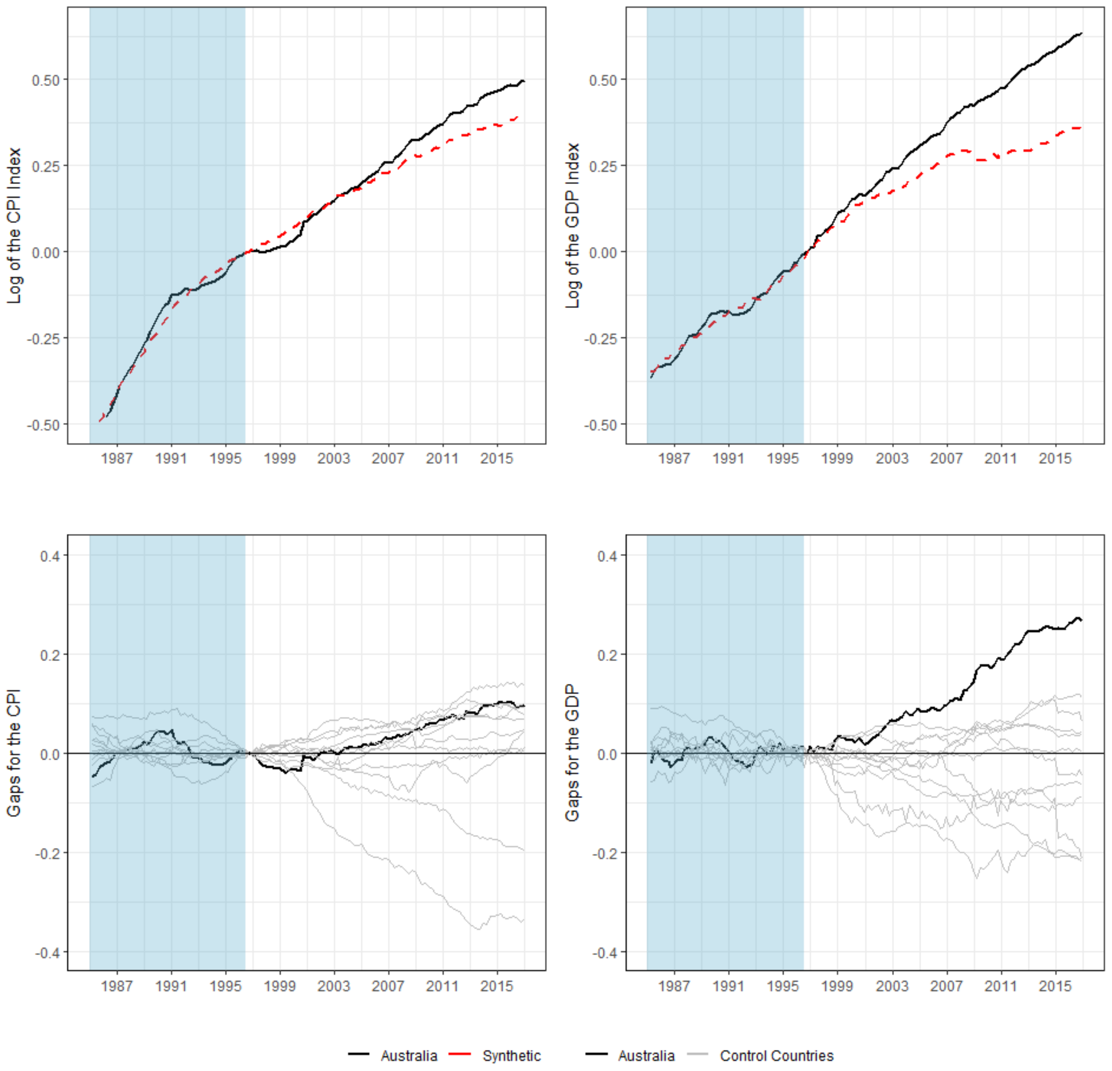
[17] It is interesting to note that although this p-value of Canada is lower than the p-value for the UK, Canada performed better than the UK in absolute terms (Canada had average inflation of 1.75% per year and average GDP growth of 2.39% per year, while the UK had average inflation and 2.04% per year and average GDP growth of 2.23% per year). However, we compare each ITer to its synthetic and not to each other as in Beaudry and Ruge-Murcia (2017). Nevertheless, our results confirm their conclusion that Canada's IT can be viewed as a policy success.

[18] "Statement on the Conduct of Monetary Policy" was released on August 14th 1996 and is available at https://www.rba.gov.au/publications/bulletin/1996/sep/pdf/bu-0996-1.pdf.

[19] "Some Aspects of Monetary Policy", a talk by the Governor, B.W. Fraser, to Australian Business Economists (ABE), Sydney, March 31st 1993, is available at https://www.rba.gov.au/publications/bulletin/1993/apr/pdf/bu-0493-1.pdf.

its early years – for example, without strict fluctuation bands or disciplinary procedures – we focus on the *de jure* IT adoption in the third quarter of 1996.[20]

Figure 3 - Baseline MSCMT: Inflation Targeting in Australia



Note: The log-transformed CPI and GDPI are scaled to zero at the quarter of IT adoption. Vertical axes in continuously compounded rates. The top row graphs depict the cumulative inflation and output growth of Australia (black line) and its synthetic (red dashed line) over time. The bottom row graphs illustrate ITer-synthetic differences in cumulative inflation and output growth (black line) and placebo tests (gray lines), i.e., non-ITer-synthetic differences. We discarded placebos with a pre-IT RMSPE three times higher than that of the ITers (in this case, Ireland and Portugal). The highlighted area represents the pre-IT period of Australia.

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[20] We have analyzed if there were anticipation effects of IT in Australia and Sweden (the other ITer which announced IT intentions years before formal adoption). We did not find evidence of anticipation effects of IT in both cases. Results are available upon request.

In Figure 3, we observe that inflation had been reduced in the early 1990s before IT adoption, and there is no evidence of an impact on inflation in the first 10 years of IT. However, Australia grew more than its synthetic by *0.94 p.p.p.y.* in this period, ranking first among the placebo effects with a p-value of *0.08*.[21]

During the Great Recession, Australia's output growth reduced without major dips, and inflation seemed even less affected. This means that Australia's CPI detachment from its synthetic is not because of undesirable inflation, but due to deflations and output contractions in the countries that compose its synthetic (France, Ireland, Norway, Portugal, and the US).

From IT adoption until 2016, Australia enjoyed higher average inflation of *0.48 p.p.p.y.* and output growth of *1.32 p.p.p.y.* than its synthetic, with respective p-values of *0.83* and *0.08*.[22] This not-lower inflation with higher growth does not seem to be an unexpected consequence, but is caused by the "flexible IT" adopted in Australia with a broader stability objective, according to Edey (2006).

4.4. Sweden

Like the United Kingdom, Sweden was forced to exit the ERM. On November 19th, 1992, the Riksbank had to adopt a floating exchange rate amid the rapid depreciation of the Swedish krona. According to Berg and Grottheim (1997), under this currency crisis, Sweden introduced an inflation target in January 1993 that would formally apply as of 1995 to achieve price stability. Over the period leading up to 1995, monetary policy addressed concerns of an exchange-rate pass-through on inflation, thus preventing

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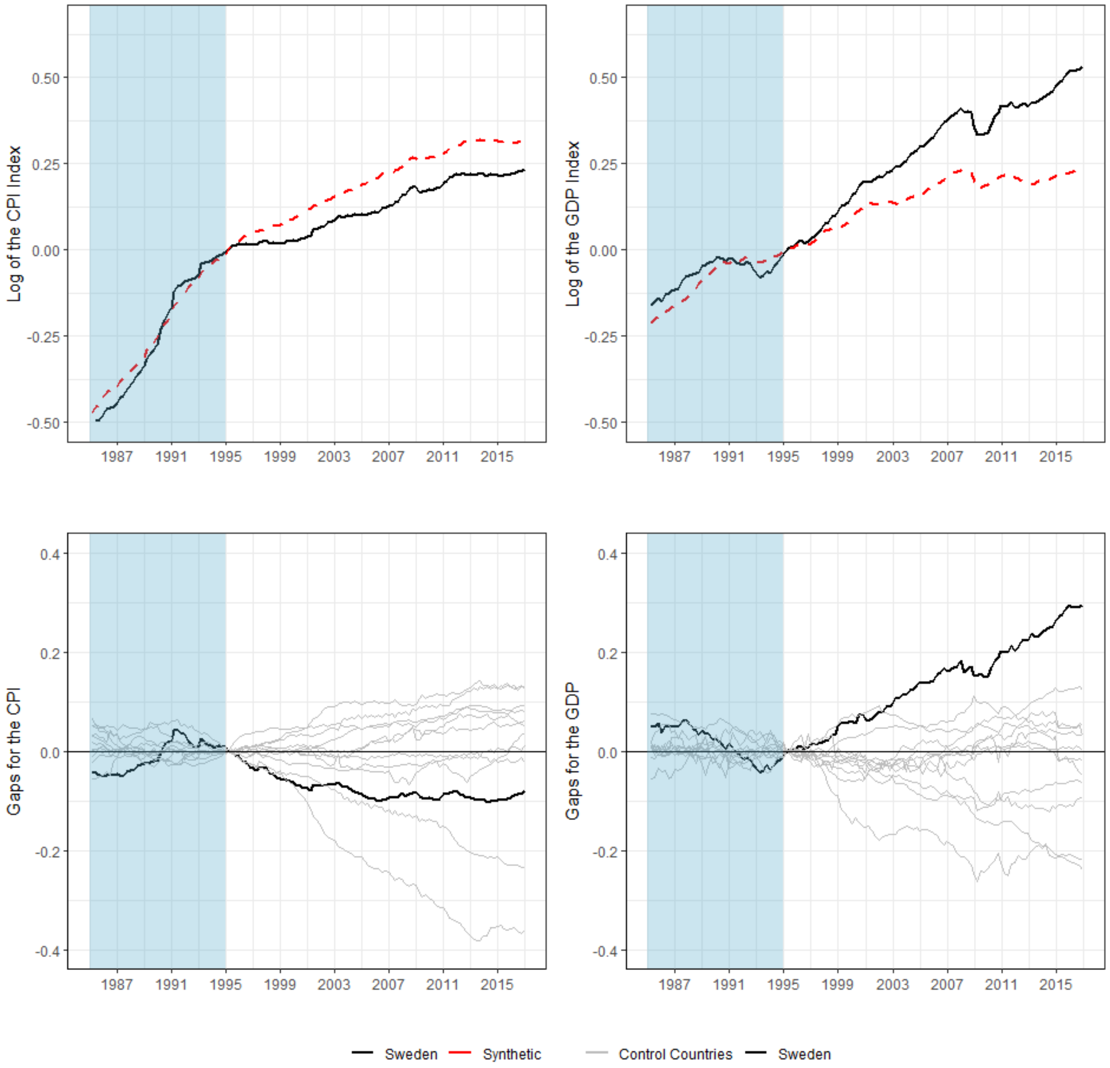
[21] We note that out of 12 cases, the value of *0.08=1/12* is the minimum p-value (or the most significant) an effect can achieve.

[22] Recall that a p-value above *0.50* means above the median. The p-value of *0.83* means that the Australia-synthetic inflation difference ranked the 10th lowest out of 12.

inflation from rising again. Similar to Ball and Sheridan (2005), we consider that Sweden adopted IT *de jure* at the beginning of 1995.

Figure 4 - Baseline MSCMT: Inflation Targeting in Sweden



Note: The log-transformed CPI and GDPI are scaled to zero at the quarter of IT adoption. Vertical axes in continuously compounded rates. The top row graphs depict the cumulative inflation and output growth of Sweden (black line) and its synthetic (red dashed line) over time. The bottom row graphs illustrate ITer-synthetic differences in cumulative inflation and output growth (black line) and placebo tests (gray lines), i.e., non-ITer-synthetic differences. We discarded placebos with a pre-IT RMSPE three times higher than the ITers (in this case, Ireland and Portugal). The highlighted area represents the pre-IT period of Sweden.

As shown in Figure 4, Sweden accomplished not only lower inflation but also higher output growth after adopting IT. In 5 years of IT, Sweden's average inflation was

1.41 p.p.p.y. lower and its output growth was *1.13 p.p.p.y.* higher than its synthetic version, with a joint *p*-value of *0.03* . In 10 years of IT, the average inflation was *0.91 p.p.p.y.* lower and output growth was *1.37 p.p.p.y.* higher, with a joint *p*-value of *0.02* . In addition, these effects continued accumulating. From IT adoption to 2016, Sweden enjoyed an average output growth of *1.42 p.p.p.y.* higher than it would have without IT, with average inflation of *0.38 p.p.p.y.* lower (i.e., a cumulative higher growth of *29.5 p.p.* and lower inflation of *8.0 p.p.)*, with a joint *p*-value of *0.02* .

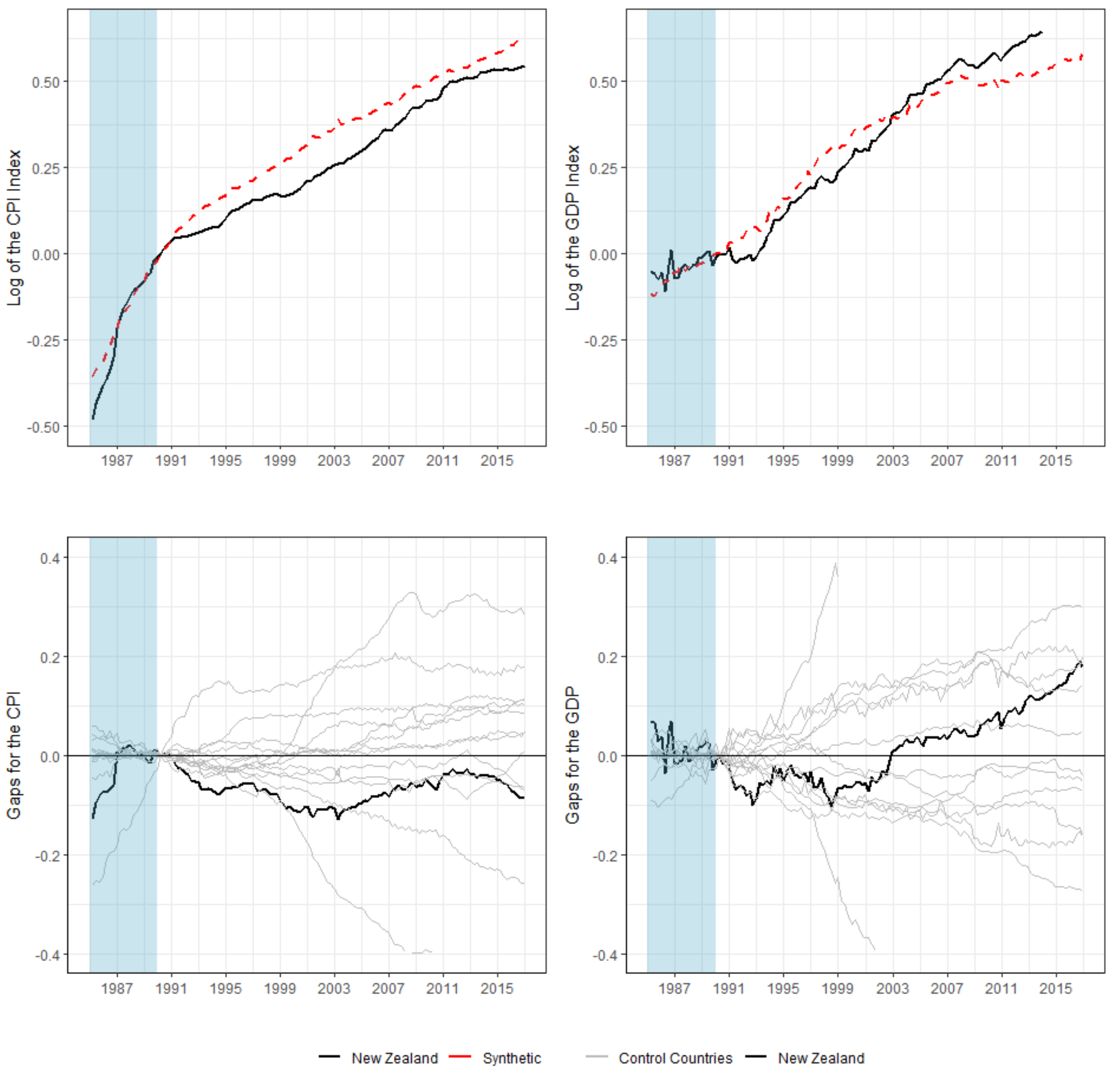
Although the 2007-2008 shocks hit Sweden heavily, with output decreasing more than *7.0 p.p.* in 2008-2009 (in column (8) of Table 6), the country seems to have handled the Great Recession better than its synthetic given a 2.06% per year average inflation and stable output throughout 2008-2011 (in columns (9) and (10) of Table 6).

4.5. New Zealand

McDermott and Williams (2018) review the origins of inflation targeting in New Zealand, the first country to formally adopt IT, in February 1990, when the 1989 Reserve Bank of New Zealand Act came into effect. This institutional change set price stability as the single objective of monetary policy and gave the Reserve Bank of New Zealand (RBNZ) independence.

Figure 5 describes the effects of IT on New Zealand. There were no major differences between New Zealand and its synthetic in terms of inflation and output growth in the pre-IT period. However, after adopting IT, New Zealand reduced the inflation rate at the expense of lower output growth compared to its synthetic. After 5 years of IT, the average inflation and output growth were respectively *1.33 p.p.p.y.* and *0.63 p.p.p.y.* lower in comparison to a situation without IT, with a joint *p*-value of *0.05* . After 10 years of IT, the average inflation and output growth were *1.13 p.p.p.y.* and *0.56 p.p.p.y.*, respectively, lower than the synthetics' ones.

Figure 5 - Baseline MSCMT: Inflation Targeting in New Zealand



Note: The log-transformed CPI and GDPI are scaled to zero at the quarter of IT adoption. Vertical axes in continuously compounded rates. The top row graphs depict the cumulative inflation and output growth of New Zealand (black line) and its synthetic (red dashed line) over time. The bottom row graphs illustrate ITer-synthetic differences in cumulative inflation and output growth (black line) and placebo tests (gray lines), i.e., non-ITer-synthetic differences. We discarded placebos with a pre-IT RMSPE three times higher than the ITers (in this case, none). The highlighted area represents the pre-IT period of New Zealand.

In contrast, IT can be credited for both controlled inflation and higher output growth in the medium term. In the 1990-2016 period, New Zealand enjoyed an average output growth of *0.66 p.p.p.y.* higher and inflation of *0.32 p.p.p.y.* lower than its counterfactual (i.e., cumulative output growth *17.7 p.p.* higher and inflation *8.6 p.p.* lower), with a joint *p*-value of *0.08* . During the Great Recession, New Zealand stayed away from the deflation trap and grew more than its synthetic in columns (7) to (10) of Table 6.

Hutchison and Walsh (1998) analyze the output-inflation trade-off in the early years of the New Zealand IT experience and ponder the effects of a lower inflationary environment and greater credibility. With data until 1994q2, they conclude that IT adoption seems to have increased the New Zealand short-run output-inflation trade-off, likely reflecting the dominance of nominal rigidities over credibility. [23] Adding the following 20 years of IT experience, our results suggest that the IT credibility developed to provide a higher output growth with lower inflation than otherwise would be in New Zealand.

4.6. The Average Effect of Inflation Targeting

We note that out of the 10 cases illustrated in the 5- and 10-year post-IT of Table 5 (in columns (3) to (6)), ITers enjoyed lower inflation than their synthetics in 9 situations without simultaneously significantly compromising growth. In the 3 cases where the ITer-synthetic growth difference is negative, the inflation differences are also negative and much more significant. In the 10-year case where the Australia-synthetic inflation difference is positive, the difference in growth is also positive and much more significant.

Out of the 15 cases illustrated from IT adoption up to 1999, 2007, and 2016 in Table 6 (in columns (1)-(6)), ITers enjoyed higher growth than their synthetics in 14 situations without compromising inflation. The one case in which the ITer had lower output growth than its synthetic was New Zealand at IT inception, with a simultaneous negative and more significant difference in inflation. In 12 out of these 15 cases, ITers

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[23] Theoretically, a lower inflationary environment should increase nominal rigidities and the output cost of disinflation. At the same time, greater credibility should decrease the output cost of disinflation by lowering inflation expectations.

enjoyed lower inflation than their synthetics. The other 3 cases with positive ITer-synthetic inflation differences simultaneously presented much more significant positive output growth differences.

Following the Great Recession in columns (7)-(10) of Table 6, when securing the output level was the issue and there was risk of deflation, the ITers' outputs had recovered better than their synthetics by 2011.

Looking at the big picture, what was the average effect of IT on ITers, i.e., the average effect of treatment on treated (ATT)? And how do the results of this study compare with previous analyses such as Ball and Sheridan (2005) and others?

<Insert **Table 7** around here>

To answer these questions, we pool the treated-synthetic pairs and estimate the average effect of IT on inflation and output growth according to the SUR Equations (7). In Table 7, we see that the average IT effect on inflation from IT inception to 1999 was a very significant *1.48 p.p.p.y.* reduction. In the same period, the average effect of IT on output growth, although a positive *0.70 p.p.p.y.* increase, was not significant. The joint estimation of the IT coefficients for inflation and growth provides the *F*-statistic of their joint significance equal to *14.24* with a *p*-value of *0.00* .[24]

In a similar set of countries and period, using standard difference-in-difference controlled for initial outcome value, Ball and Sheridan (2005) estimate insignificant average IT effects on inflation of *-0.55 p.p.p.y.* (*t*-stat.=1.57) and output growth of *0.88 p.p.p.y.* (*t*-stat.=1.09). Our results are thus much stronger for inflation.

As we extend the window until 2007, the average effect of IT on inflation shrinks to *0.89 p.p.p.y.* reduction, which is still significant (*p*-value is lower than *0.04*). Simultaneously, the average effect of IT on growth rises to a very significant *1.08 p.p.p.y.*

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[24] The *F*-statistic is chi-squared distributed with 2 degrees of freedom.

increase, resulting in an F-statistic of joint significance of both IT coefficients equal to *11.27* with a p-value of *0.00* .

In a similar set of countries and period, using standard difference-in-difference controlled for initial outcome value and the Euro adoption, Ball (2010) estimates a significant average IT effects on inflation of *-0.65 p.p.p.y.* (t-stat.=2.60) and an insignificant effect on output growth of *0.14 p.p.p.y.* (t-stat.=0.29). Our results are now much stronger for output growth.

Finally, by looking at the average effect of IT until 2016, IT becomes insignificant on inflation but rises to a very significant *1.29 p.p.p.y.* increase in output growth, which results in an F-statistic of *20.66* with a p-value of *0.00* . That is, over the years of IT experience, the inflation reduction became less important and the output growth enhancement became more important.

It is worth noting that the results presented so far are not incoherent with Brito (2010), who, in a debate with Gonçalves and Carvalho (2009), shows that IT *disinflations* were not less costly in the OECD. They discuss Ball's (1994) *disinflations*, defined as sparse events in which the nine-quarter moving average of inflation went down by more than 2%. In these events, it is better to have a lower output-loss-to-inflation-reduction ratio, called *output sacrifice ratio*. However, a lower *output sacrifice ratio* in Ball's (1994) *disinflations* context is not a necessary or sufficient condition for a policy to be considered more efficient in general, when the whole business cycle must be handled by the monetary policy and not only the sparse disinflations. In other words, the fact that IT did not matter for "big" disinflations does not imply that IT does not matter at all. And, indeed, the 2% cut-off used in these studies is too coarse for the already low OECD inflation levels at the IT inception. Instead, given these industrial economies adopted IT more as a regime to fine-tune the whole business cycle than a transient policy to disinflate, the present study evaluates the average effect of the IT treatment on inflation and output, conditional on their continuing tradeoffs.

Nevertheless, the current paper's findings are qualitatively different from Brito and Bystedt (2010), who conclude that IT rendered no credibility bonus among emerging economies. According to Brito and Bystedt (2010), the emerging ITers' relative inflation reduction was the compensation for their relatively lower output growth. Given the early 1990s' prevalent gap in credibility between industrial countries' monetary authorities and those of emerging economies, the current paper's and Brito and Bystedt's (2010) results together illustrate Ball's (1995) imperfect credibility theory, where inflation control costs less for more credible central banks. They also support Bernanke and Woodford's (2005) and Mishkin's (2000) intuitions that IT would work better in already solid institutional environments.

Because this evidence may be particular to the synthetics chosen, in the following section, we analyze alternative synthetic estimates to ensure the robustness of these conclusions.

4.7. Robustness Checks

To scrutinize the evidence of IT effectiveness, we check whether alternative estimates indicate similar conclusions. In Appendix C, we compute "leave-out" estimates, which drop the control country with the highest weight in each ITer's MSCMT synthetic from Table 4. Additionally, to address concerns that the measured IT effects might be distorted by late IT adopters in the donor group, Japan, Norway, and Switzerland are also dropped.

Table C.1 presents the new synthetic weights. Table C.2 shows the average annual inflation and output growth for each ITer and its MSCMT *leave-out* synthetic over 5 and 10 years after IT adoption, and from IT adoption up to 1999, 2007, and 2016. And Figures

C.1 to C.5 show the ITer-synthetic comparison. The impression of the *leave-out* exercises is that IT experience in the UK is still positive, though weakened relative to the baseline results. The *leave-out* exercises for Canada, Australia, Sweden, and New Zealand confirm that the pioneering ITers benefited from adopting IT, although their *leave-out* synthetics had higher inflation and higher growth than their baseline synthetics. Finally, for New Zealand, the *leave-out* synthetic had higher inflation and lower output growth than its baseline synthetic, thus improving both inflation and output growth differences. Similar to the baseline patterns, the IT effect of lower inflation became less important over the years, while the IT effect of enhanced output growth became more important in Table C.2.

5. Conclusion

We evaluated the effects of adopting the IT policy regime on the macroeconomic performances of pioneering IT countries in a comparative case study using the MSCMT.

We add to the literature on monetary economics by using the multivariate feature of SCM to investigate the effects of a monetary policy regime. This methodology enables the construction of a single counterfactual that simultaneously matches the inflation and output growth of the treated country, thereby effectively accounting for the short-run inflation-output trade-off in the conduct of monetary policy.

We document that IT policies had overall positive effects on these countries. Sweden seems to have benefited the most through lower inflation and enhanced output growth from adoption until 2016. The United Kingdom benefited similarly until 2007. New Zealand and Canada had lower inflation without compromising growth. And Australia enjoyed significant higher growth without significant higher inflation. Our results are robust to various robustness checks, including the placebo test, leave-donor-out estimates, different pretreatment periods and anticipation analysis.

In addition to the countries' case studies, we compute the average treatment effect of IT on the ITers through joint estimation of the IT effects on the ITer-synthetic differences of inflation and output growth. We find significant associations between IT and lower inflation in the early years of IT, and between IT and enhanced output growth in the medium term. These positive results justify central bankers' optimism about the IT system and its widespread adoption then on.

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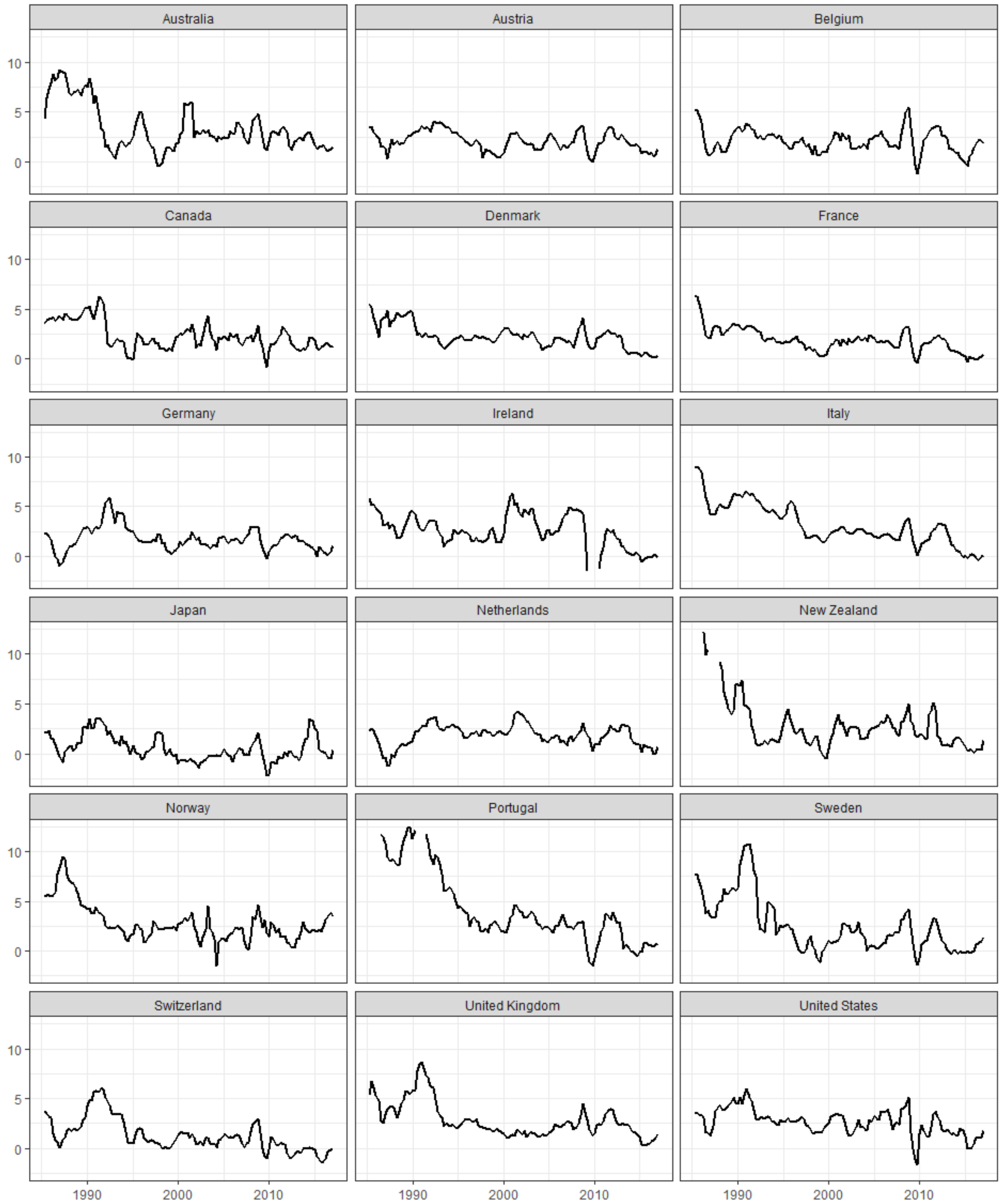
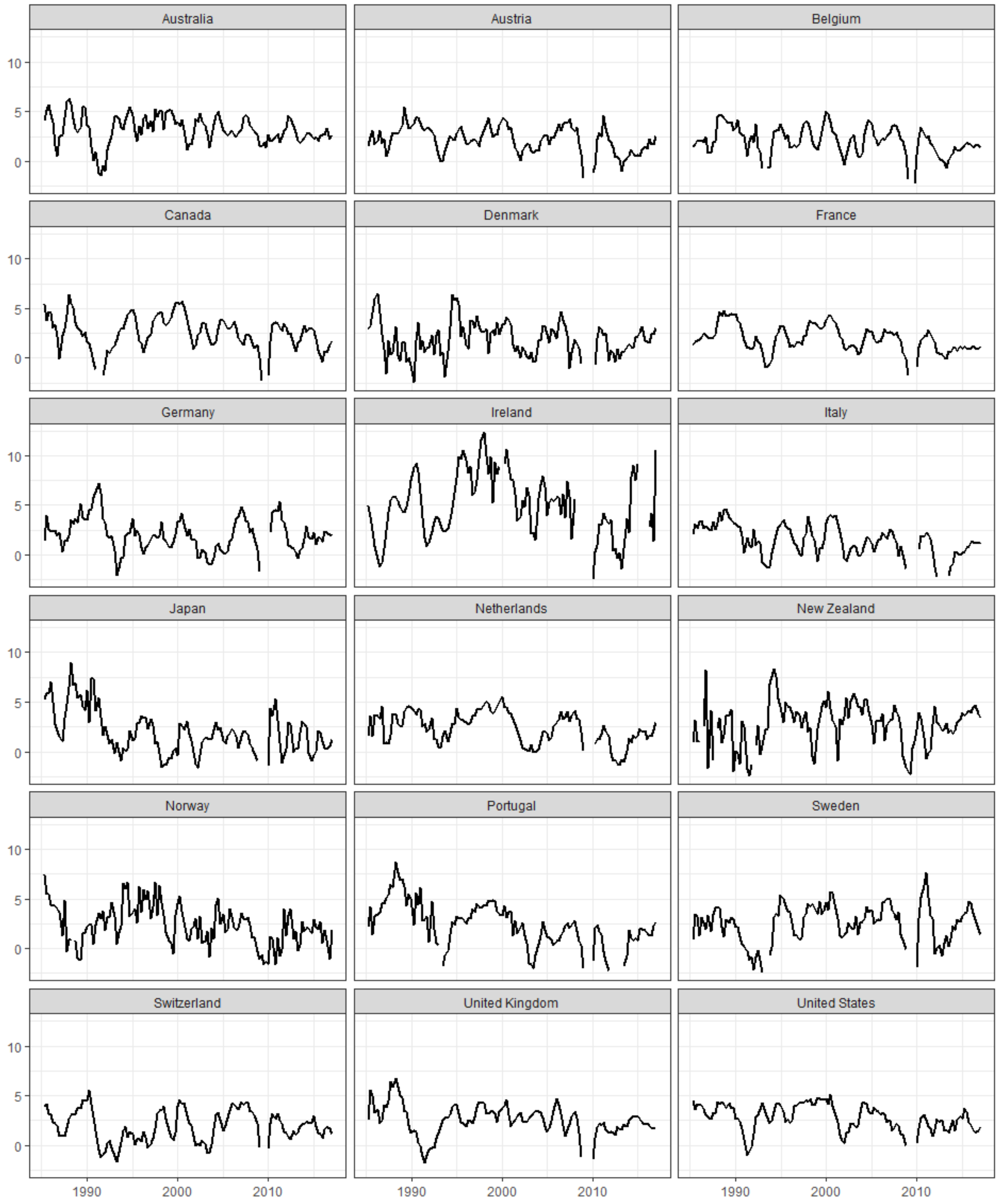
Appendix A – Country's Annual Rate of Inflation and Output Growth

Figure A.1 - Annual Inflation Rates (%)



Note: For illustrational purposes, we restrict the interval of the vertical axis from -2.5% to 12.5%. As a result, the graphs present missing information whenever there are values outside of this range. Annual inflation rate is $\pi_t = 100*[lnP_t - lnP_{t-4}]$.

Figure A.2 - Annual Real Output Growth Rates (%)

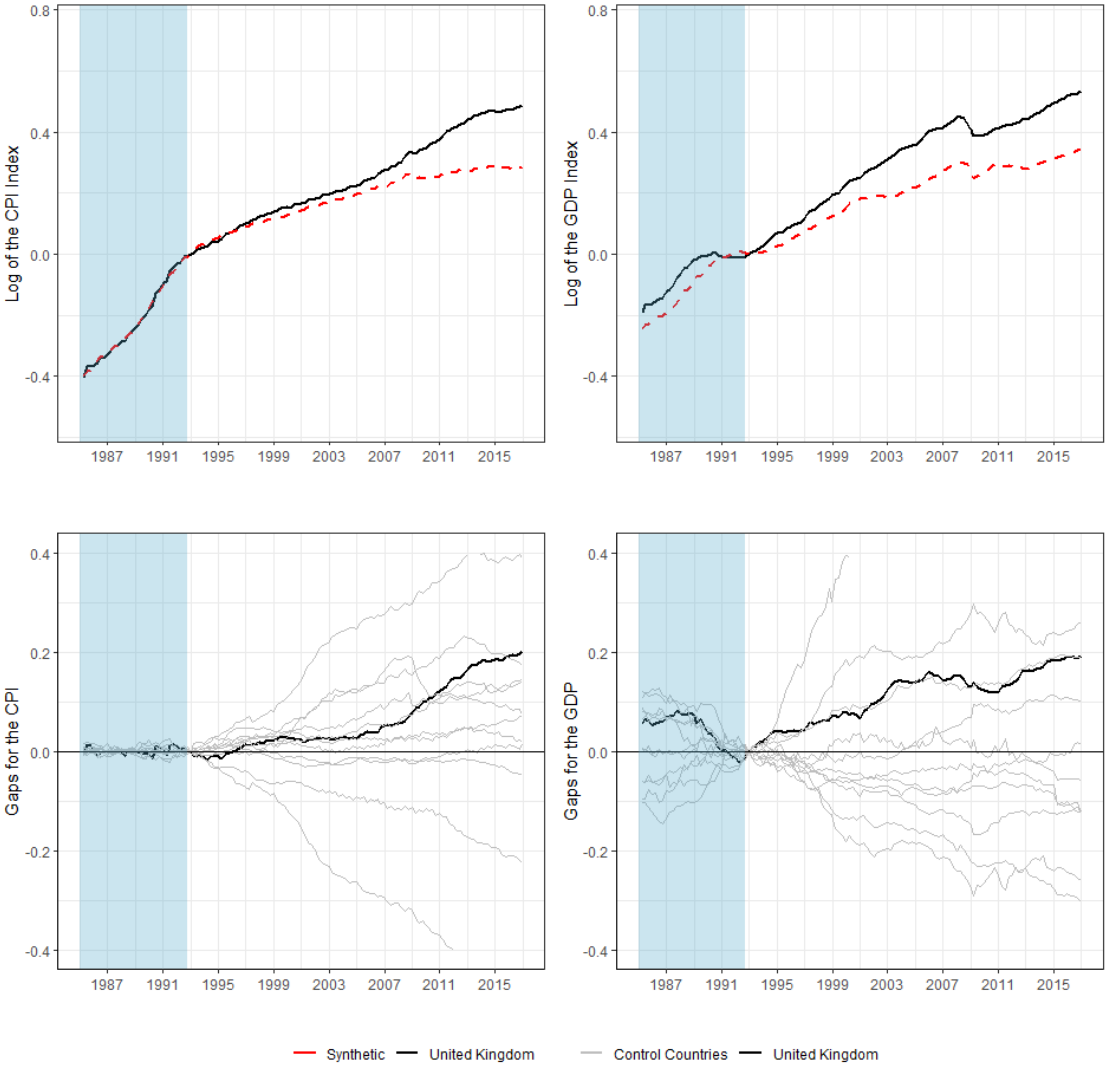


Note: For illustrational purposes, we restrict the interval of the vertical axis from -2.5% to 12.5%. As a result, the graphs present missing information whenever there are values outside of this range. Annual real output growth is $y_t = 100*[lnY_t - lnY_{t-4}]$.

Appendix B – Comparison with the Univariate Synthetic Control Method

We use the MSCMT because it allows us to estimate a counterfactual for the CPI and GDPI jointly, thus considering their simultaneous and interrelated determination.

Figure B.1 - Univariate SCM: Inflation Targeting in the United Kingdom



Note: The univariate SCM estimation uses the log-transformed CPI as the outcome variable and both the CPI and GDPI as predictors. We use these estimated weights to find a counterfactual for the GDPI. The log-transformed indices are scaled to zero at the quarter of IT adoption. Vertical axes in continuously compounded rates. The first row graphs depict the cumulative inflation and output growth of the United Kingdom (black line) and its synthetic (red dashed line) over time. The second row graphs illustrate UK-synthetic differences in cumulative inflation and output growth (black line) and placebo tests (gray lines), i.e., non-ITer-synthetic differences. We discarded placebos with a pre-IT RMSPE three times higher than the ITers (in this case, To assess whether there are major differences between the synthetic from the MSCMT and the univariate SCM alternative, here, similar to Lee (2011), we find the univariate synthetic for the UK CPI while keeping both lagged time series of CPI and GDPI as control variables. The synthetic for the UK CPI draws on Japan, Portugal, Switzerland, and the United States, with weights of 25.8%, 32.2%, 35.8%, and 6.2%, respectively, which are considerably different from the MSCM weights presented in Table 3.[25] Figure B.1, which follows the same structure as the previous figures, presents the CPI and GDPI dynamics from the resulting synthetic.

We note that while ignoring GDP as a simultaneous outcome variable, the inflation of the synthetic UK was not higher than the realized UK inflation in the first decade of IT in Figure B.1, as shown in Figure 1.

However, this is a different answer to a different question. The univariate SCM found weights that better explain the UK pretreatment inflation but do not explain the UK pretreatment output growth, noticeable in the pretreatment gap between UK GDP and the GDP from the synthetic unit which matched inflation only in the top-right graph of Figure B.1. Thus, the synthetic built to match inflation does not match the simultaneous inflation-output dynamics before IT adoption and abstracts the output costs in the conduct of monetary policy in UK, which may bias the net-treatment effect estimates. The efficiency gain of the IT policy on inflation has to discount the variation in inflation that happened because of same sign variation in GDP growth.

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[25] Alternatively, we could have adjusted the GDP index as the univariate outcome for this comparison with the MSCMT bivariate adjustment. We note (for the referee's appraisal) that the UK univariate synthetic for the GDP index combines 72.5% of Italy and 27.5% of Switzerland.

Appendix C – *Leave-out* synthetics

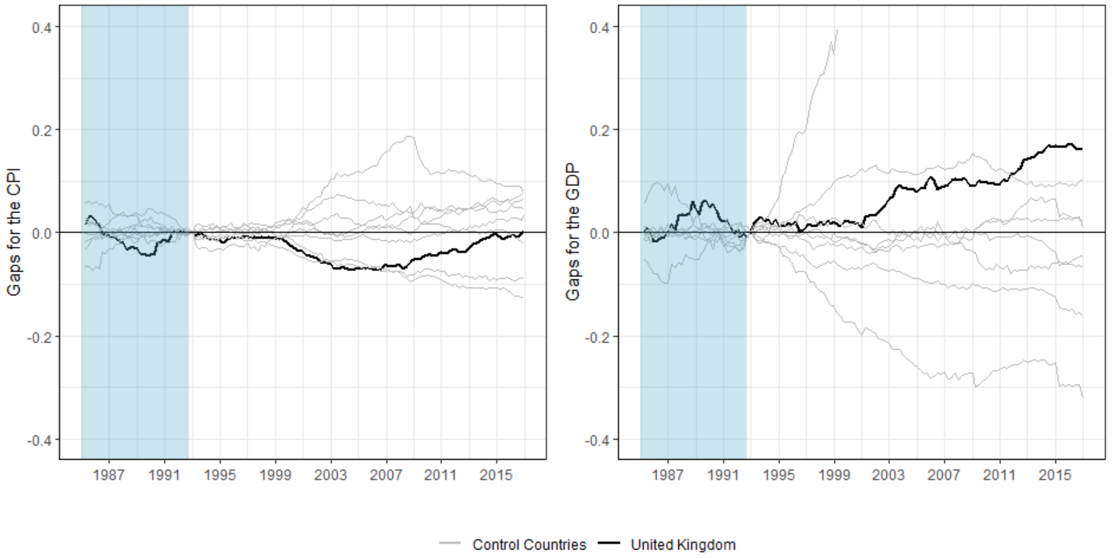
To scrutinize the evidence of IT effectiveness from section 4, we check whether alternative estimates indicate similar conclusions. In section 4, we performed placebo tests. Here, we compute "leave-out" estimates, which drop the country with the highest weight in each ITer's MSCMT synthetic estimate of section 4 from the sample of selectable control units. That is, we drop Italy from the UK's analysis, Denmark from Canada's, Norway from Australia's, Italy from Sweden's, and Norway from New Zealand's (see Table 4). Additionally, to address concerns that the measured IT effects might be distorted by late IT adopters in the control group, then Japan, Norway, and Switzerland are also dropped.

Table C.1 presents the new synthetic weights, and Table C.2 shows the average annual inflation and output growth for each ITer and its MSCMT *leave-out* synthetic over 5 and 10 years after IT adoption, and from IT adoption up to 1999, 2007, and 2016.

<Insert **Table C.1** and **Table C.2** around here>

Figure C.1 shows the UK-synthetic comparison. In this case, the synthetic is composed of Belgium (7.1%), Denmark (62.2%), and Portugal (30.7%). Inflation in the United Kingdom was not much lower than its *leave-out* synthetic in the first 5 years of IT, as was the case in the baseline comparison (bottom graphs in Figure 1). Despite that, in the 10 years of IT, the United Kingdom inflation is convincingly lower than its *leave-out* synthetic. Although the output growth in the UK is higher than its synthetic value, this advantage is smaller than the baseline difference. Overall, the impression of the IT experience in the UK is still positive, though weakened relative to the baseline results of section 4.

Figure C.1 - Simulation MSCMT: Gaps in the United Kingdom and Placebos

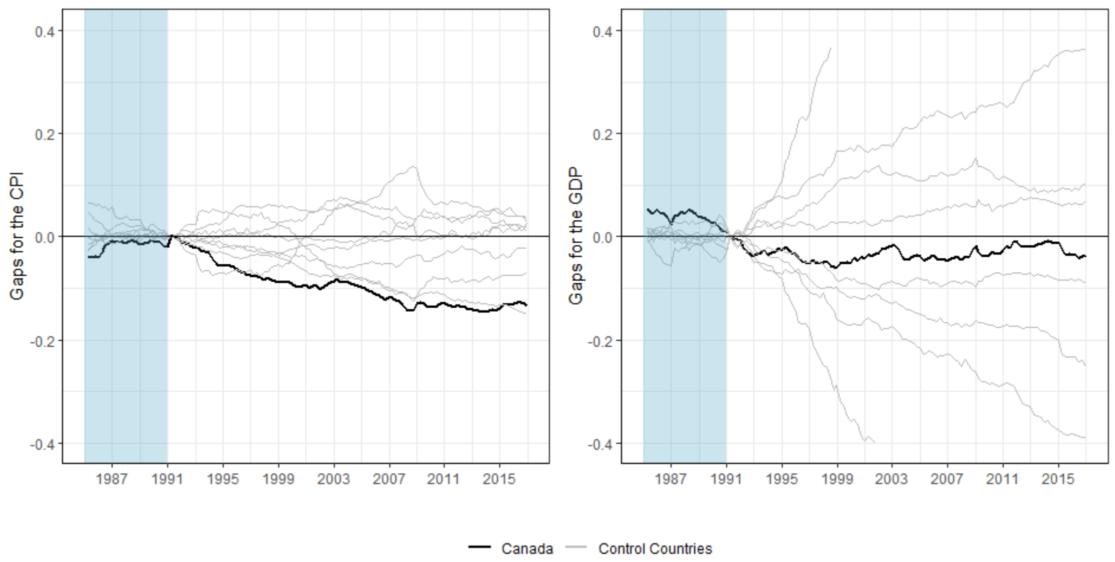


Note: The graphs depict differences in cumulated inflation (left) and output growth (right) between the United Kingdom and its synthetic and placebo tests. Vertical axes in continuously compounded rates. The control sample excludes Italy and later IT adopters. We discarded placebos with a pre-IT RMSPE three times higher than the ITer (in this case, Portugal).

Figures C.2-C.5 reinforce the baseline results for Canada, Australia, Sweden, and New Zealand and show that the pioneering countries benefited from adopting IT.

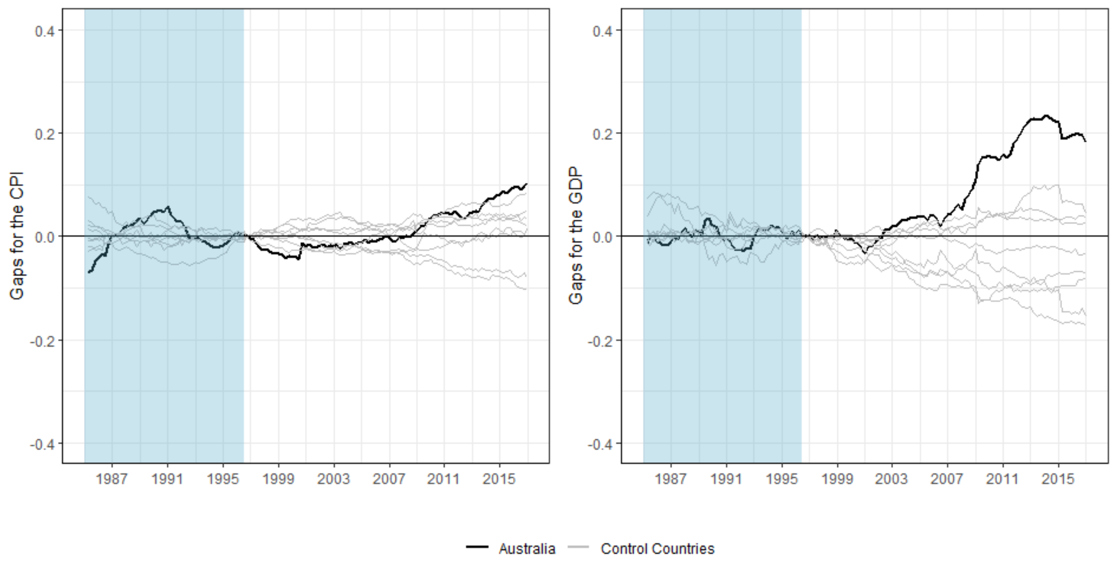
Canada GDP grew on average *0.80 p.p.* per year less than its *leave-out* synthetic in the first five years, and such growth disadvantage remained at an average *0.14 p.p.* per year from adoption to 2016, though output growth differences are never significant (i.e., the univariate *p*-value are close to 0.5). However, simultaneously, Canada had lower inflation than its *leave-out* synthetic, resulting in an annual average difference of *-0.52 p.p.* per year from adoption to 2016. Comparing the Canada-synthetic differences' bivariate *p*-values in Table C.2 with the respective ones in Tables 5 and 6 of section 4, we consider Canada's performance in the *leave-out* exercise as good as that in the baseline exercise.

Figure C.2 - Simulation MSCMT: Gaps in Canada and Placebos



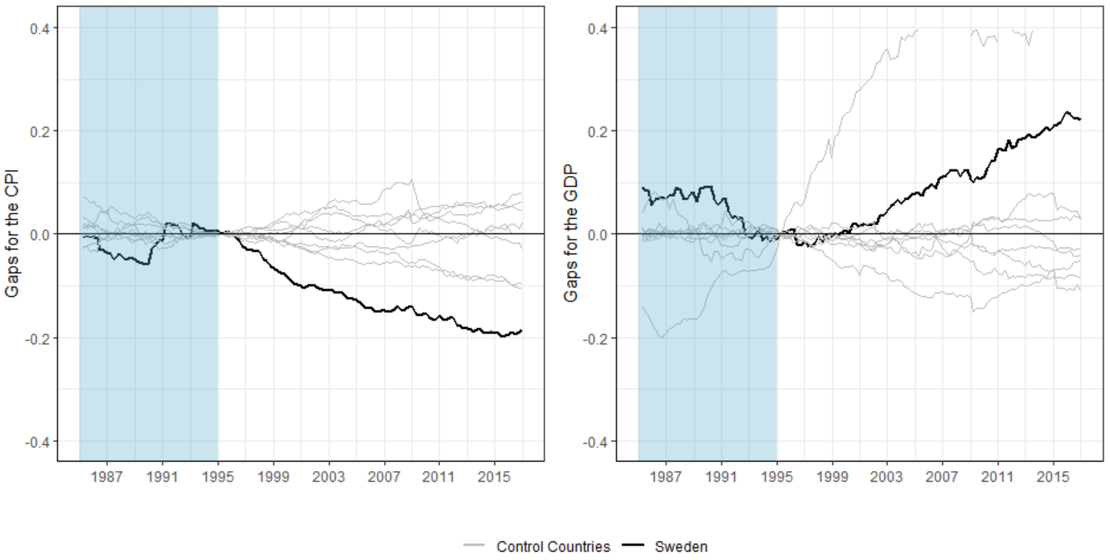
Note: The graphs depict differences in cumulated inflation (left) and output growth (right) between Canada and its synthetic and placebo tests. Vertical axes in continuously compounded rates. The control sample excludes Denmark and later IT adopters. We discarded placebos with a pre-IT RMSPE three times higher than the ITer (in this case, Portugal).

Figure C.3 - Simulation MSCMT: Gaps in Australia and Placebos



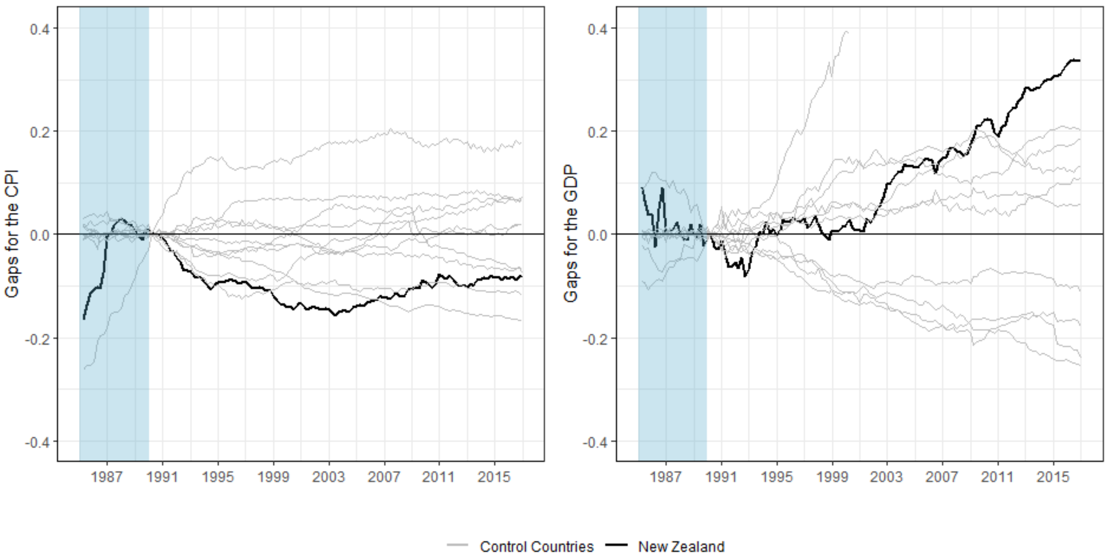
Note: The graphs depict differences in cumulated inflation (left) and output growth (right) between Australia and its synthetic and placebo tests. Vertical axes in continuously compounded rates. The control sample excludes Norway and later IT adopters. We discarded placebos with a pre-IT RMSPE three times higher than the ITers (in this case, Ireland and Portugal).

Figure C.4 - Simulation MSCMT: Gaps in Sweden and Placebos



Note: The graphs depict differences in cumulated inflation (left) and output growth (right) between Sweden and its synthetic and placebo tests. Vertical axes in continuously compounded rates. The control sample excludes Italy and later IT adopters. We discarded placebos with a pre-IT RMSPE three times higher than the ITer (in this case, Portugal).

Figure C.5 - Simulation MSCMT: Gaps in New Zealand and Placebos



Note: The graphs depict differences in cumulated inflation (left) and output growth (right) between New Zealand and its synthetic and placebo tests. Vertical axes in continuously compounded rates. The control sample excludes Norway and later IT adopters. We discarded placebos with a pre-IT RMSPE three times higher than the ITers (in this case, none).

As Canada's *leave-out* synthetic, Australia's and Sweden's *leave-out* synthetics in row "Synthetic" of Table C.2 had higher inflation and higher output growth than their baseline synthetics in row "Synthetic" of Tables 5 and 6, which improve their inflation difference and worsens their output growth difference in row "XX - Synthetic" of Table C.2 relative to Tables 5 and 6, giving the impression of performance as good as that in section 4.

Finally, for New Zealand, the *leave-out* synthetic in row "Synthetic" of Table C.2 has higher inflation and lower output growth than its baseline synthetic in Tables 5 and 6, thus improving both inflation and output growth differences in row "XX - Synthetic" of Table C.2 relative to Tables 5 and 6 and resulting *p*-values in general.

In 9 out of the 10 cases illustrated in the 5- and 10-year post-IT columns (1) to (4) of Table C.2, ITers enjoyed lower inflation than their synthetics without significantly compromising growth. The only situation of ITer-synthetic positive inflation difference cannot claim significance (*p*-value of *0.44*), while the simultaneous output growth difference is positive and more convincing (*p*-value of *0.11*).

Out of the 15 cases illustrated in columns (5)-(10) of Table C.2, ITers enjoyed lower inflation than their synthetics in 13 situations without significantly compromising growth. In the 2 situations of ITer-synthetic positive inflation difference, although significant in the case of Australia until 2016, the simultaneous output growth difference is also positive and as well as significant (i.e., inflation ranks the last and output ranks the first).

In Table C.3, we present estimates of the average IT treatment effect on annual inflation and output from IT adoption up to 1999, 2007, and 2016. Until 1999, there was a very significant *1.60 p.p.* reduction in inflation with an insignificant increase in output growth, which results in an *F*-statistic of joint significance of both IT coefficients with a *p*-value of *0.07* . When we extend the window up to 2007, the average effect of IT on annual inflation is significant at a *1.18 p.p.* reduction, with a simultaneous significant *1.02 p.p.* increase in average annual output growth, which results in an *F*-statistic of joint significance with a *p*-value of *0.05* . Lastly, the average effect of IT until 2016 becomes insignificant on inflation but rises to a very significant *1.22 p.p.* increase in annual output growth, which results in an *F*-statistic of joint significance with a *p*-value of *0.02* .

Therefore, following the pattern described in section 4, the IT effect of lower inflation became less important over the years while the IT effect of enhanced output growth became more important.

Notes to the referees: We have also estimated the baseline MSCMT synthetics with annual data and pre-treatment adjustment period since the 1980s. Although such synthetics look different in terms of donor countries' weights, the conclusions are qualitative similar for the five ITers cases. This exercise is available upon request.

We have also estimated more comprehensive models motivated by the fact that monetary authorities follow not only the level of inflation and output growth but also their volatilities. To that end, we added the average absolute deviation of CPI from its trend and the average absolute deviation of real GDP from potential as outcomes and predictors alongside the CP and real GDP indices used previously. First, the results greatly reinforce the baseline results from section 4. Second, even though the MSCMT can handle multiple variables, the absolute deviations are ungainly to track because the average of the deviations (i.e., the resulting synthetic absolute deviation) is smoother by construction than the individual country's deviation (i.e., the ITer absolute deviation). This exercise is available upon request.

Additionally, we have speculated on the anticipation effects of announcing inflation targeting intentions before formally adopting IT, as was the case of Australia and Sweden. In both cases, we did not find evidence of anticipation effects of IT on the CPI and the GDPI differences in Australia or Sweden, suggesting that the *de jure* dates chosen in our analyses are appropriate. This exercise is available upon request.

TABLES

Table 1 Inflation Targeters and Non-targeters Countries

IT Countries	IT Dates	Non-IT Countries		
New Zealand	1990q1	Austria	Ireland	Portugal
Canada	1991q1	Belgium	Italy	Switzerland*
United Kingdom	1992q4	Denmark	Japan*	United States
Sweden	1995q1	France	Netherlands	
Australia	1996q3	Germany	Norway*	

Note: IT adoption dates are based on Roger (2009), Ball (2010), and Hammond (2012). (*) Switzerland switched to a monetary policy based on inflation targeting in 2000q1, Norway in 2001q1, and Japan in 2013q1, but they are not among the pioneers.

Table 2 5-Year Annual Average Inflation and GDP Growth Rates

Countries	**Pre-IT**		**Post-IT**	
	Inflation	**Growth**	**Inflation**	**Growth**
Australia	2.45	3.57	2.21	3.82
Canada	4.46	1.99	1.43	2.29
New Zealand	9.98	0.83	2.40	2.62
Sweden	5.34	0.23	0.51	3.27
United Kingdom	5.85	1.40	2.44	3.17
ITers Average	**5.62**	**1.60**	**1.80**	**3.04**
Austria	3.27	3.11	1.93	2.72
Belgium	2.96	1.88	1.81	2.54
Denmark	2.76	0.69	2.04	3.24
France	2.96	2.07	1.51	2.30
Germany	3.64	3.34	1.76	1.78
Ireland	3.09	4.45	2.21	8.23
Italy	5.62	1.64	3.47	1.97
Japan	2.28	3.37	0.63	1.23
Netherlands	2.38	2.90	2.23	3.59
Norway	3.51	1.68	1.90	4.84
Portugal	10.58	2.69	3.56	3.55
Switzerland	4.18	1.47	0.78	1.59
United States	4.19	2.43	2.42	3.73
Non-ITers Average	**3.95**	**2.44**	**2.02**	**3.18**

Note: IT adoption dates follow Table 1. For comparison purposes, we use the average IT adoption date of the ITers (1993q2) for the non-IT countries. Continuously compounded rates (i.e., log rates) multiplied by 100. Annual inflation is $\pi_t = 100*[ln(P_t) - ln(P_{t-4})]$ and annual output growth is $y_t = 100*[ln(Y_t) - ln(Y_{t-4})]$. The 5-year annual average for the pre-IT (post-IT) period is the 20-quarters average before (after) IT adoption for the ITers and before (after) 1993q2 for the non-ITers.

Table 3 Panel Estimates of Inflation and GDP Growth from 1985 to 1999

	Equation by equation							
	Univariate AR(1) with the IT dummy		Univariate AR(1)		Bivariate AR(1)		Panel VAR(1)	
Dependent:	**Inflation** (1)	**GDP growth** (2)	**Inflation** (3)	**GDP growth** (4)	**Inflation** (5)	**GDP growth** (6)	**Inflation** (7)	**GDP growth** (8)
L.inflation	0.61*** (10.68)		0.64*** (16.47)		0.67*** (17.82)	-0.18** (-2.27)	0.72*** (25.87)	-0.06 (-0.63)
L.growth		0.25*** (4.27)		0.27*** (4.96)	0.16*** (4.04)	0.23*** (3.90)	0.16*** (4.10)	0.32*** (4.53)
L.IT dummy	-0.67* (-2.02)	0.84* (1.85)						
Intercept	1.10*** (3.47)	3.58*** (6.71)	0.88*** (4.10)	3.76*** (7.57)	0.42 (1.67)	4.05*** (8.20)		
Within-R^2	0.66	0.36	0.66	0.35	0.68	0.38		

Note: Estimated at annual frequency using information from the 4th quarter of the years. Included 18 countries, totaling 252 observations. The inflation and GDP growth are continuously compounded returns multiplied by 100: $\pi_t = 100*[lnP_t - lnP_{t-1}]$ and annual output growth is $y_t = 100*[lnY_t - lnY_{t-1}]$. "*L.X*" is the one year lag of variable X. All regressions include year and country fixed effects. Hetoroskedasticity-robust standard errors clustered by country. *t*-statistics are in parentheses. Within-R^2 is the coefficient of determination after removing country fixed effects.

Table 4 Baseline MSCMT Control Unit Weights

Control Countries	Control Unit Weights for the Treated:				
	Australia	Canada	New Zealand	Sweden	United Kingdom
Austria	-	-	-	-	-
Belgium	-	-	-	-	-
Denmark	-	62.1%	-	-	-
France	14.6%	-	-	-	-
Germany	-	-	-	-	-
Ireland	1.9%	-	-	-	-
Italy	-	-	-	55.3%	88.2%
Japan	-	-	-	-	-
Netherlands	-	-	-	-	-
Norway	43.6%	-	79.8%	-	-
Portugal	19.2%	11.4%	20.2%	7.9%	-
Switzerland	-	-	-	36.8%	11.8%
United States	20.7%	26.5%	-	-	-

Note: Weights from the solution of Equations (5) and (6) for the ITer in the respective column, including all 13 control countries in the pool of possible donors.

Table 5 Pre- and Post-treatment Inflation and GDP Growth of ITers and Synthetic Controls

Country	**Pre-IT (5 Years)**		**Country**	**Post-IT (5 Years)**		**Post-IT (10 Years)**	
	Inflation	**Growth**		**Inflation**	**Growth**	**Inflation**	**Growth**
	(1)	**(2)**		**(3)**	**(4)**	**(5)**	**(6)**
Australia	2.45	3.57	**Australia**	2.21	3.82	2.59	3.56
Synthetic	2.86	2.97	Synthetic	2.37	3.16	2.28	2.62
Simple mean	2.73	2.23					
			AU - Synthetic	-0.16	0.67	0.32	0.94
			rank	*5*	*3*	*8*	*1*
			univar. p-value	*0.42*	*0.25*	*0.67*	*0.08*
			bivar. p-value	*0.10*		*0.06*	
Canada	4.46	1.99	**Canada**	1.43	2.29	1.64	3.21
Synthetic	4.78	1.81	Synthetic	2.60	2.51	2.52	2.89
Simple mean	3.69	3.24					
			CA - Synthetic	-1.17	-0.23	-0.88	0.32
			rank	*2*	*7*	*2*	*5*
			univar. p-value	*0.15*	*0.54*	*0.15*	*0.38*
			bivar. p-value	*0.08*		*0.06*	
New Zealand	9.98	0.83	**New Zealand**	2.28	2.49	1.80	3.06
Synthetic	7.07	2.44	Synthetic	3.61	3.12	2.93	3.62
Simple mean	3.48	3.30					
			NZ - Synthetic	-1.33	-0.63	-1.13	-0.56
			rank	*1*	*10*	*2*	*9*
			univar. p-value	*0.07*	*0.71*	*0.14*	*0.64*
			bivar. p-value	*0.05*		*0.09*	
Sweden	5.34	0.23	**Sweden**	0.51	3.27	0.99	2.98
Synthetic	4.74	0.92	Synthetic	1.92	2.14	1.90	1.61
Simple mean	3.39	2.21					
			SW - Synthetic	-1.41	1.13	-0.91	1.37
			rank	*2*	*2*	*3*	*1*
			univar. p-value	*0.17*	*0.17*	*0.25*	*0.08*
			bivar. p-value	*0.03*		*0.02*	
United Kingdom	5.85	1.40	**United Kingdom**	2.44	3.17	1.98	3.10
Synthetic	5.49	2.26	Synthetic	3.44	1.88	2.78	1.68
Simple mean	3.95	2.99					
			UK - Synthetic	-1.00	1.29	-0.80	1.41
			rank	*3*	*3*	*3*	*2*
			univar. p-value	*0.23*	*0.23*	*0.23*	*0.15*
			bivar. p-value	*0.05*		*0.04*	

Note: Annual average inflation and GDP growth rates for the ITer, respective synthetic (from Table 4), simple mean of all 13 control countries and ITer-Synthetic difference. Expressed in continuously compounded rates (i.e., log rates) multiplied by 100. Columns (1)-(2) present the 5-year annual averages before the IT adoption of the respective ITer. Columns (3)-(6) present the 5- and 10-year annual averages after IT adoption of the respective ITer. The *rank*s of ITer-synthetic differences are computed among the placebo tests with root mean square errors (RMSE) smaller than three times the RMSE of the ITer-synthetic difference. The ranks improve with more negative inflation difference and with more positive GDP growth difference, reflecting the goals of lower inflation and higher output growth. The *univar. p-value* is computed out of the total number of placebo effects. The *bivar. p-value* is the joint probability of the pair of ranks under the null hypothesis of nil treatment effects, (i.e., their product, assuming independence between inflation and growth).

Table 6 Annual average inflation and GDP growth rates of ITers, baseline synthetics and their differences

IT Countries	**Until 1999**		**Until 2007**		**Until 2016**		**2008-2009**		**2008-2011**	
	Inflation	**Growth**	**Inflation**	**Growth**	**Inflation**	**Growth**	**Inflation**	**Growth**	**Inflation**	**Growth**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
Australia	1.00	4.61	2.55	3.60	2.46	3.14	2.84	2.12	3.78	3.43
Synthetic	2.07	3.72	2.25	2.65	1.98	1.83	1.58	-1.48	2.43	-0.26
AU - Synthetic	-1.08	0.89	0.29	0.95	0.48	1.32	1.26	3.60	1.35	3.69
univar. p-value	*0.17*	*0.25*	*0.67*	*0.08*	*0.83*	*0.08*				
bivar. p-value	*0.04*		*0.06*		*0.07*					
Canada	1.51	3.16	1.85	2.90	1.75	2.39	1.34	-0.86	2.53	1.63
Synthetic	2.47	3.01	2.39	2.52	2.07	1.87	1.73	-2.68	2.84	-0.74
CA - Synthetic	-0.96	0.15	-0.54	0.38	-0.32	0.52	-0.39	1.82	-0.32	2.38
univar. p-value	*0.15*	*0.38*	*0.31*	*0.38*	*0.31*	*0.31*				
bivar. p-value	*0.06*		*0.12*		*0.09*					
New Zealand	1.78	2.88	2.18	3.17	2.04	2.83	2.63	0.08	3.68	1.34
Synthetic	2.92	3.55	2.57	2.92	2.36	2.17	2.04	-1.38	2.60	-0.43
NZ - Synthetic	-1.14	-0.67	-0.38	0.25	-0.32	0.66	0.59	1.46	1.08	1.77
univar. p-value	*0.14*	*0.64*	*0.21*	*0.50*	*0.21*	*0.36*				
bivar. p-value	*0.09*		*0.11*		*0.08*					
Sweden	0.75	4.17	1.33	3.50	1.12	2.55	0.84	-3.52	2.06	0.01
Synthetic	2.41	2.56	2.05	1.95	1.50	1.13	1.23	-1.98	1.89	-0.64
SW - Synthetic	-1.66	1.61	-0.72	1.55	-0.38	1.42	-0.39	-1.54	0.17	0.65
univar. p-value	*0.17*	*0.17*	*0.25*	*0.08*	*0.25*	*0.08*				
bivar. p-value	*0.03*		*0.02*		*0.02*					
United Kingdom	2.20	3.29	1.98	2.98	2.04	2.23	2.61	-2.81	3.96	-0.76
Synthetic	2.95	1.77	2.53	1.57	2.01	0.81	1.59	-2.80	2.53	-1.38
UK - Synthetic	-0.75	1.52	-0.55	1.41	0.02	1.41	1.02	-0.01	1.43	0.62
univar. p-value	*0.23*	*0.23*	*0.23*	*0.15*	*0.38*	*0.15*				
bivar. p-value	*0.05*		*0.04*		*0.06*					

Note: Continuously compounded rates (i.e., log rates) multiplied by 100. For each ITer an its synthetic (from Table 4), the annual averages of inflation and GDP growth are computed from the following quarter of the ITer's IT adoption date until the date indicated in the column. univariate p-values and bivariate p-values follow from the permutation method described in section 2.

Table 7 Average effect of IT on ITers relative to baseline synthetics

	Until 1999		**Until 2007**		**Until 2016**	
Dependent:	**Inflation (1)**	**Growth (2)**	**Inflation (3)**	**Growth (4)**	**Inflation (5)**	**Growth (6)**
Average Effect of IT	-1.48***	0.70	-0.89**	1.08***	-0.62	1.29***
	(-3.05)	(1.52)	(-2.09)	(3.30)	(-1.30)	(4.38)
Intercept	0.49	-0.26	0.49	-0.26	0.49	-0.26
	(1.20)	(-1.00)	(1.20)	(-1.00)	(1.20)	(-1.00)
F-statistic	14.24		11.27		20.66	
p-value	0.00		0.00		0.00	

Note: *Average Effect of IT*s are the IT dummy coefficients simultaneously estimated through the SUR Equations (7) for inflation and GDP growth differences using pooled quarterly ITer-synthetic differences of the 5 ITers from 1985q1 until the 4th quarter of the year indicated in the column. t-statistics are in parentheses. The F-stat. tests if both IT dummies are jointly zero followed by the respective p-value.

Table C.1 "Leave-out" MSCMT Control Unit Weights

Control Countries	Control Unit Weights for the Treated: Australia	Canada	New Zealand	Sweden	United Kingdom
Austria	-	-	-	-	-
Belgium	-	-	-	-	7.1%
Denmark	40.3%	-	64.7%	66.6%	62.2%
France	-	-	-	-	-
Germany	-	-	-	-	-
Ireland	18.2%	-	-	-	-
Italy	-	-	-	-	-
Netherlands	-	-	-	-	-
Portugal	24.4%	-	35.3%	33.4%	30.7%
United States	17.1%	100.0%	-	-	-

Note: Weights from the solution of Equations (5) and (6) for the ITer in the respective column, leaving out from the pool of donors: (i) the highest contributor in the Baseline MSCMT (see Table 4) and (ii) countries that subsequently implemented IT. That means Italy is out of the analysis for the United Kingdom, Denmark for Canada, Norway for Australia, Italy for Sweden, and Norway for New Zealand. Norway, Japan, and Switzerland are also left out from all pools for subsequently implementing IT.

Table C.2 Annual average inflation and GDP growth rates of ITers, "leave-out" synthetics and their differences

IT Countries	**Post-IT (5 Years)**		**Post-IT (10 Years)**		**Until 1999**		**Until 2007**		**Until 2016**	
	Inflation	**Growth**	**Inflation**	**Growth**	**Inflation**	**Growth**	**Inflation**	**Growth**	**Inflation**	**Growth**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
Australia	2.21	3.82	2.59	3.56	1.00	4.61	2.55	3.60	2.46	3.14
Synthetic	2.64	4.03	2.58	3.23	2.20	4.71	2.57	3.14	1.95	2.25
AU - Synthetic	-0.43	-0.21	0.02	0.33	-1.21	-0.10	-0.02	0.46	0.51	0.90
univar. p-value	*0.33*	*0.44*	*0.44*	*0.11*	*0.11*	*0.56*	*0.56*	*0.11*	*1.00*	*0.11*
bivar. p-value	*0.15*		*0.05*		*0.06*		*0.06*		*0.11*	
Canada	1.43	2.29	1.64	3.21	1.51	3.16	1.85	2.90	1.75	2.39
Synthetic	2.79	3.09	2.65	3.55	2.53	3.76	2.64	3.17	2.26	2.53
CA - Synthetic	-1.36	-0.80	-1.01	-0.34	-1.03	-0.60	-0.79	-0.27	-0.52	-0.14
univar. p-value	*0.22*	*0.56*	*0.11*	*0.56*	*0.11*	*0.56*	*0.11*	*0.56*	*0.22*	*0.56*
bivar. p-value	*0.12*		*0.06*		*0.06*		*0.06*		*0.12*	
New Zealand	2.28	2.49	1.80	3.06	1.78	2.88	2.18	3.17	2.04	2.83
Synthetic	4.12	2.31	3.20	2.78	3.23	2.71	2.83	2.26	2.33	1.58
NZ - Synthetic	-1.84	0.18	-1.39	0.28	-1.46	0.17	-0.65	0.91	-0.30	1.25
univar. p-value	*0.18*	*0.55*	*0.09*	*0.64*	*0.09*	*0.64*	*0.18*	*0.27*	*0.27*	*0.18*
bivar. p-value	*0.10*		*0.06*		*0.06*		*0.05*		*0.05*	
Sweden	0.51	3.27	0.99	2.98	0.75	4.17	1.33	3.50	1.12	2.55
Synthetic	2.27	3.23	2.32	2.19	2.91	3.94	2.51	2.43	2.01	1.49
SW - Synthetic	-1.76	0.04	-1.33	0.79	-2.16	0.23	-1.18	1.07	-0.89	1.07
univar. p-value	*0.11*	*0.33*	*0.11*	*0.22*	*0.11*	*0.33*	*0.11*	*0.22*	*0.11*	*0.22*
bivar. p-value	*0.04*		*0.02*		*0.04*		*0.02*		*0.02*	
United Kingdom	2.44	3.17	1.98	3.10	2.20	3.29	1.98	2.98	2.04	2.23
Synthetic	2.59	2.73	2.59	2.44	2.51	2.93	2.40	2.30	2.02	1.55
UK - Synthetic	-0.15	0.44	-0.61	0.66	-0.31	0.35	-0.42	0.68	0.01	0.67
univar. p-value	*0.33*	*0.33*	*0.11*	*0.33*	*0.22*	*0.33*	*0.33*	*0.33*	*0.44*	*0.22*
bivar. p-value	*0.11*		*0.04*		*0.07*		*0.11*		*0.10*	

Notes: Continuously compounded rates (i.e., log rates) multiplied by 100. For each ITer an its synthetic (from Table 8) the annual averages of inflation and GDP growth are computed from the following quarter of the ITer's IT adoption date until the date indicated in the column. univariate p-values and bivariate p-values follow from the permutation method described in section 2.

Table C.3 Average effect of IT on ITers relative to "leave-out" synthetics

	Until 1999		**Until 2007**		**Until 2016**	
Dependent:	**Inflation**	**Growth**	**Inflation**	**Growth**	**Inflation**	**Growth**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Average Effect of IT	-1.60***	0.42	-1.18**	1.02**	-0.81	1.22***
	(-2.32)	(1.08)	(-2.21)	(2.21)	(-1.49)	(2.70)
Intercept	0.56	-(0.48)	0.56	-(0.48)	0.56	-(0.48)
	(1.10)	(-1.52)	(1.10)	(-1.52)	(1.10)	(-1.52)
F-statistic	5.39		6.16		7.50	
p-value	0.07		0.05		0.02	

Notes: *Average Effect of IT*s are the IT dummy coefficients simultaneously estimated through the SUR Equations (7) for inflation and GDP growth differences using pooled quarterly ITer-synthetic differences of the 5 ITers from 1985q1 until the 4th quarter of the year indicated in the column. t-statistics are in parentheses. The F-stat. tests if both IT dummies are jointly zero followed by the respective p-value.