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Getting too old for this: Economic effects of ageing population in Finland

Aboa Centre for Economics

Discussion paper No. 168

Turku

November 2024

The Aboa Centre for Economics is a joint initiative of the economics departments of the University of Turku and Åbo Akademi University.

ISSN 1796-3133

Printed in Uniprint
Turku
November 2024

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ABSTRACT

This paper investigates the impact of population ageing on the economic and fiscal performance of Finland, a small open economy, which has undergone a rapid and significant demographic shift since 2010. By employing the Synthetic Control Method (SCM) to create a counterfactual scenario without ageing while also controlling for a major part of structural changes in the industrial and business environments, we find that in 2019, Finland's real GDP per capita would have been 15.9% to 27.5% higher, productivity 8.4% to 13.9% higher, and general government debt 26.0 to 28.4 percentage points lower. Our findings are further validated by an instrumental variable approach, which supports the SCM results.

JEL Classification: E6, E61, E62, E65, J1

Keywords: Macroeconomic Policy, Macroeconomic Aspects of Public Finance, Fiscal Policy, Studies of Particular Policy Episodes, Demographic Economics

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Acknowledgements

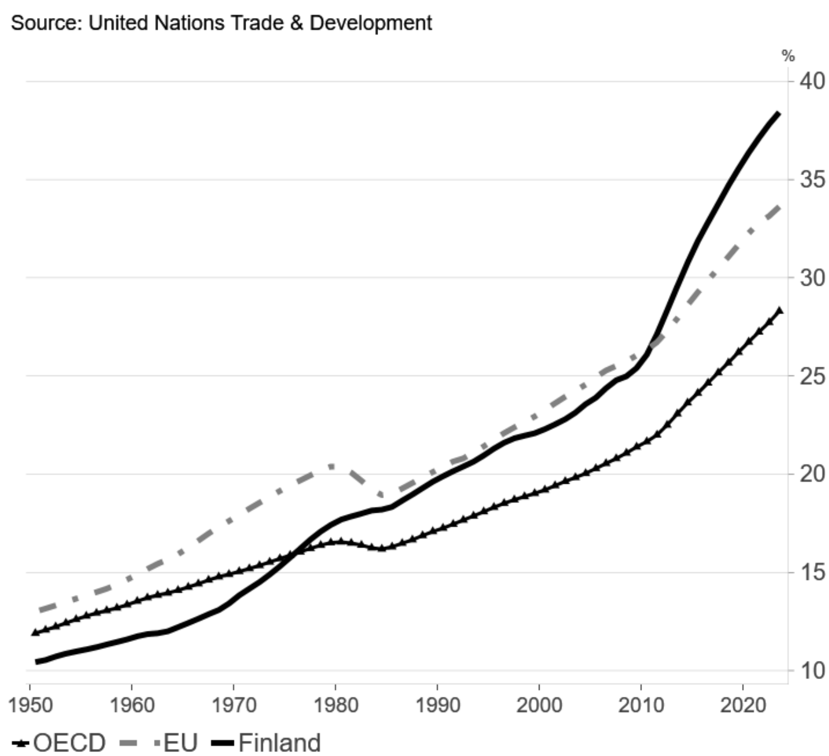
The views expressed in this paper are those of the authors. The authors would like to thank Elias Einiö, Daniela Filip, Janne Huovari and the participants of The Labour Institute for Economic Research LABORE and Pellervo economic research PTT research seminars.

1 Introduction

Demographic challenges related to an ageing population are prevalent in most advanced countries, particularly within the European Union (EU). The origins of this trend can be found in the post-World War II era, when the growth of global population peaked in the 1960s at approximately 2% per year. Since the 1960s, total fertility rates have declined, with the number of children per family halving between 1960 and 2020 in high-income countries. This trend is even more pronounced in Europe, where fertility rates have been around 1.5 since the 1990s. In addition, advancements in health and technology significantly increased life expectancy (Roffia et al. (2023)).

Finland stands out among advanced countries with one of the highest dependency ratios, alongside Japan, Portugal, and Italy. However, the other countries generally have higher shares of young people relative to the working-age population or have experienced a gradual and slow increase in age dependency ratios whereas Finland has seen a rapid rise in the ratio of elderly to the working-age population over the last decade. This ratio increased from 22% in 2000 to 26% in 2010, and further accelerated to 38% in 2023.

Figure 1: Old-age Dependency Ratio in Finland, EU and OECD.



Given its unique demographic trajectory, Finland provides a compelling case study for examining the economic effects of ageing. Although the window for preemptive action has closed for Finland, it serves as a cautionary tale for policymakers about the risks of delaying action on ageing-related issues. Many advanced countries will soon face similar challenges in varying degrees, making it crucial to understand the economic impacts of ageing. This understanding can motivate policymakers to address these issues early, as ageing populations can impose significant strains on economic outcomes and public finances.

The approach of this study is to use the novel econometric technique of the Synthetic Control Method (SCM) to analyse the macroeconomic and fiscal effects experienced in Finland. The study also provides a theoretical foundation for the analysis using an augmented Diamond-Samuelson Overlapping Generations (OLG) framework. Additionally, the results are validated through an analysis based on the Instrumental Variable (IV) method.

This paper contributes to the literature in several ways. *First*, the SCM has not been widely used to analyse the economic effects of ageing. We argue that this method is particularly informative in extreme cases where the ageing process is rapid and occurs over a short period while also providing information on the scale of real economy effects. The analysis covers the effects on economic growth, productivity, and government debt, showing significant impacts that are not dependent on individual aspects of the comparison sample. *Second*, we contribute to the ongoing discussion on the subject. For instance, Eggertsson et al. (2019) argue that the negative effects of ageing are related to the zero lower bound in interest rates. In the theoretical section of the paper, we demonstrate that the assumption of a constant interest rate (small open economy assumption) is sufficient to show that population ageing has negative effects on GDP per capita and productivity. *Third*, there is surprisingly little counterfactual evidence on the macroeconomic effects of ageing in small open economies. Given the importance and urgency of this issue as well as potential implications for larger countries, more empirical evidence is needed, and this paper aims to fill that gap.

The remainder of the paper is organised as follows: Section 2 reviews the previous literature on the subject. Section 3 describes the theoretical framework and Section 4 outlines the primary methodology, data sources, and sample. The empirical results are presented and discussed in Section 5 whereas Section 6 provides robustness checks for the results using an alternative empirical approach. Section 7 concludes the paper.

2 Previous Literature

The economic effects of an ageing population have been actively studied since the early 1990s, as declining fertility rates and their long-term implications became more apparent[1]. Several empirical studies have aimed to establish a causal relationship between population ageing and economic outcomes. A seminal paper by Feyrer (2007) laid the groundwork for this field.

[1] For a comprehensive recent review of previous literature, see for example Vlandas et al. (2021).

Following Feyrer's methodological work, Maestas et al. (2023) examined the effect of ageing on GDP and its components in the US. Using state-level variation in population ageing and instrumental variable (IV) methodology, they concluded that a 10% increase in the population share of individuals aged 60 and older decreases GDP per capita by 5.5%. One-third of this reduction is due to slower employment growth, and two-thirds is due to slower labour productivity growth.

Aiyar et al. (2016) studied the impact of workforce ageing on euro area productivity, finding that projected workforce ageing will slow annual Total Factor Productivity (TFP) growth by 0.2 percentage points on average over the next two decades. This corresponds to a semi-elasticity of -0.75, meaning a 1 percentage point increase in the 55-64 age cohort is associated with a 0.75 percentage point reduction in TFP growth. Similarly, Calvo-Sotomayor et al. (2019) found that a 1% increase in the size of the old-age workforce (workers aged 55-64) is associated with a productivity decline of 0.1 to 0.5%.

A common feature among the studies by Feyrer (2007), Aiyar et al. (2016), and Calvo-Sotomayor et al. (2019) is the use of lagged population development as an instrument for current population development, which is arguably exogenous to current or future economic outcomes. Maestas et al. (2023) used projected population development as an instrument, a method closely related to our robustness analysis. The key idea is that if the population share of older workers is predetermined, it is exogenous to economic outcomes, allowing for causal interpretation. We follow this approach in Section 6 to test the robustness of our results obtained using the SCM.

Aksoy et al. (2019) construct a panel VAR model for OECD countries using data from 1970 to 2014. They find that population ageing and low fertility impacts economic growth, investment, savings, hours worked per capita, real interest rates and inflation, and the impact is, according to the authors, large. Aksoy et al. (2019) project that due to ageing population, annual growth rate will decrease by 0.64 % between 2015 and 2025. These results imply that the elasticity of old-age dependency ratio with respect to GDP per capita growth is 0.45, which is in line with our findings.

The relationship between ageing and productivity is multifaceted, with recent studies providing more nuanced insights. Ozimek et al. (2018) confirmed the negative association between ageing and productivity at the state-industry level, showing that having older coworkers reduces individual wages and productivity. This effect is implicitly considered in the aforementioned empirical studies, but the Ozimek et al. (2018) paper provides new evidence on the transmission mechanisms, one of which could be the unwillingness to adopt new technologies.

Conversely, some research suggests a positive impact of ageing on productivity through increased automation. Acemoglu and Restrepo (2017) argued that ageing leads to greater use of automation technologies, which can improve productivity. While they do not provide specific elasticities or impact figures, they highlight the potential significance of this mechanism.

Eggertsson et al. (2019) showed a positive correlation between population ageing and output per capita growth, which breaks down in a zero-lower-bound regime or "secular stagnation regime", where interest rates are constrained, resulting in welfare losses. In the context of Eggertsson et al. (2019), this paper is relevant for two reasons. First, we confirm the direction of the post-financial crisis correlation; second, in Section 3, we formalise an overlapping generations model, showing that the positive correlation between ageing and growth breaks down in a small open economy with endogenous labour supply and distortive taxation.

3 Theoretical Considerations

Our theoretical thinking and testable hypothesis can be illustrated using a Diamond-Samuelson Overlapping Generations Model (OLG). A sufficient formulation of the model for our purposes augments the textbook model with a public economy with distorting taxation with an assumption of a small open economy (SOE).

Consider the Diamond-Samuelson model, where consumers face a following optimization problem:

$$\max U(c_t^1, h_t, c_t^2) \tag{1}$$

$$\text{s.t.}$$

$$c_t^1 + s_t = (1-\tau_t) w_t \epsilon h_t, \tag{2}$$

$$c_{t+1}^2 = b_{t+1} + (1 + r_{t+1}) s_t, \tag{3}$$

where c denotes consumption, s saving, w wage rate, h labour supply, r (real) interest rate, b public transfers to the retired, τ tax rate and ϵ is a productivity index. Superscript denotes the cohort: 1 denotes active population and 2 passive population (the old). Assuming the following lifetime utility function $U(.) = \ln c_t^1 - \gamma \frac{h_t^{1+\phi}}{1+\phi} + \beta \ln c_{t+1}^2$, we obtain the following Euler equations:

$$c_{t+1}^2 = \beta(1 + r_{t+1}) c_t^1, \tag{4}$$

$$\frac{(1-\tau_t) w_t}{c_t^1} = \gamma h^{\phi}, \tag{5}$$

where equation (4) determines the time path of consumption and (5) equates the marginal disutility of labour supply to the marginal utility of consumption.

Let N_t^1 denote the number of active population and assume no between-period mortality: $N_t^1 = N_{t+1}^2$. The growth rate of active population is given by n so that $N_t^1 = (1+n) N_{t-1}^1$, thus, the old-age dependency ratio is given by $DR = 1/(1+n)$.

Furthermore, assume a productive sector, where output is produced using capital and labour as inputs a la Cobb-Douglas: $y_t = (k_t)^\alpha(\epsilon h_t)^{1-\alpha}$ and factor prices are determined by the marginal productivity of those inputs: $w_t = (1-\alpha)\left(\frac{k_t}{h_t}\right)^\alpha$ and $r_t = \alpha\left(\frac{k_t}{h_t}\right)^{\alpha-1} - \delta$. The labour income tax rate adjusts in order to achieve a balanced budget at all times, while subsidies to the elderly ($b_t = rr\ w_t h_t$) is given exogenously, rr being the replacement rate. The public sector budget constraint reads $(1+n)\tau_t = rr$. Assume at first, that ϵ=1.

We assume a small open economy, thus, equalizing the local and global interest rates, which is given exogenously. The evolution of capital can thus be denoted:

$$k_{t+1} + a_{t+1} = \frac{s_t}{1+n}, \tag{6}$$

where a_t denotes net foreign assets, which are negative if capital is borrowed from abroad and positive if capital is flowing into the country.

Proposition 1 *In long-run steady state equilibrium, an increase in the old-age dependency ratio leads to lower GDP per employee.*

Proof 1 *In the SOE environment, interest rate is given exogenously leading to constant* $\frac{k}{h}$ *ratio and, thus, constant gross wage rate. From the Cobb-Douglas production function we can see that* $y_t = \left(\frac{k_t}{h_t}\right)^\alpha h_t$ *so that the evolution of labour supply fully determines the evolution of output per employee. Substituting the individual inter-temporal budget constraint and inter-temporal Euler equation into labour supply equation* (5)*, we get the following expression for steady state labour supply:*

$$h = \left(B\frac{(1-\tau)}{(1-\tau+\frac{rr}{1+r})}\right)^{1/(1+\phi)}, \tag{7}$$

where $B = \frac{1+\beta}{\gamma}$*. Taking* $\frac{\partial h}{\partial n}$ *and after a little bit of algebra, it can be shown that* $\frac{\partial h}{\partial n} > 0$ *as long as* $\frac{rr}{1+r} > 0$*, which is trivially true as long as* $rr > 0$*. This implies that the old-age dependency ratio (DR) and output per employee (y) have a negative association.* □

Proposition 2 *Effect of ageing on productivity* ($\frac{y_t}{h_t}$) *is negative, when* $\epsilon = f(DR)$ *and* $\frac{\partial \epsilon}{\partial n} > 0$*.*

Proof 2 *Divide* y_t *by* h_t *to get* $\frac{y_t}{h_t} = \left(\frac{k_t}{h_t}\right)\epsilon^{1-\alpha}$*. Remember that* $\frac{k_t}{h_t}$ *is constant due to SOE assumption, thus,* $\frac{\partial y_t/h_t}{\partial n} > 0$*, because by assumption* $\frac{\partial \epsilon}{\partial n} > 0$*. Therefore, population aging decreases* $\frac{y_t}{h_t}$*.* □

Intuition to Proposition 1 runs through the distorting nature of taxation. As the economy ages, taxes must adjust in order to finance the increased public expenditure, which has negative effect on labor supply, which is the main working channel in SOE.

The Proposition 2 is almost true by assumption, but the aim of the proposition is to bring forth the mechanism that the effects of ageing population work through the labour productivity channel. The possible explanations for this mechanisms could be, for example, 1) the association between ageing and risk-taking behavior (Dohmen et al. (2011) and Dohmen et al. (2017)), 2) the association between ageing workforce and productivity (Aiyar et al. (2016), Ozimek et al. (2018) and Calvo-Sotomayor et al. (2019)) and 3) increase in the activity of service sector, especially publicly provided services, which decreases average productivity of the economy (Daniele et al. (2019) and Cravino et al. (2022)).

Our model departs from the one used in Eggertsson et al. (2019) in some respects. First, we allow for distortive taxation as, arguably, a considerable share of costs of ageing come from the government's need to increase distortive taxes in order to finance public pay-as-you-go type of public transfers. Second, in the model, we have an exogenous parameter for labour productivity, because it is an important part of the story as underlined previously. Third, the assumption of SOE alters the evolution of capital, which is crucially driving the results in the Eggertsson et al. (2019) model.

The model outlined in this section is sufficient to address the mechanics studied in this paper. It is not complex and lacks many important elements and could be expanded to include other aspects. However, the model contains the central ideas of this paper and provides a venue for discussing the mechanisms that are at work with respect to the association of population ageing and economic outcomes.

4 Methodology and Data

Synthetic Control Method

The SCM, originally presented in Abadie and Gardeazabal (2003) and later developed further in Abadie et al. (2010) and Abadie et al. (2015), is a case study analysis approach designed to separate actual effects of different reforms or structural changes (or their absence) from other developments by simulating a counterfactual based on a comparison group. The theoretical framework of the SCM is shortly summarised in Appendix A

We investigate the impact of ageing on three key economic indicators: GDP per capita, labour productivity, and government debt. The SCM allows us to construct a synthetic control group that closely mirrors the characteristics of the treated country, Finland, thereby enabling a more accurate estimation of the causal effect of ageing.

Our analysis focuses on Finland, with comparative data drawn from other Euro area (EA) countries, EU countries, Organisation for Economic Co-operation and Development (OECD) countries as well as a group of countries outside these two where sufficient data is broadly available. Therefore, the total comparison group consists of 54 other countries and they provide a comparative baseline against which the effects of ageing in Finland are measured. Arguably, especially the EU and OECD countries are in many dimensions good comparisons to Finland in terms of economic development level and institutional features.

The SCM estimates the effect of ageing on our dependent variables by comparing the actual values for Finland with those of a synthetic Finland, constructed from a weighted combination of control countries that did not experience the same quick trend of ageing. This approach allows us to isolate the effect of ageing from other confounding factors.

The SCM has, to the best of the authors' knowledge, not been previously used to study the economic effects of ageing. On the other hand, a growing amount of literature has applied the SCM to study different economic questions and some recent studies are relevant for the questions of this paper, at least when it comes to the variables of interest.

Using the SCM, evolution of real GDP is studied, for example, in Campos et al. (2019), who study the effects of EU membership on economic growth, Cieślik and Turgut (2021), who study the growth effects of the EU's eastern enlargement, Lehtimäki and Sondermann (2022), who study the growth effects of the European single market, and lastly in Muchová and Šuláková (2022), who study the effects of EMU membership for Baltic countries.

When it comes to productivity, there are only a few studies, where the SCM is used as the primary method of analysis. The most notable ones are Farid et al. (2020), who conclude a 2.24 % decrease in labour productivity from the Brexit vote and Zhuang et al. (2023), who find a productivity-enhancing effect from EMU membership through business cycle synchronization and similar labour markets.

There are also some studies done on government debt levels with especially Koehler and König (2015), who study the total effects of the Stability and Growth Pact (SGP), Strong (2023), who studies the effect of fiscal rules in the West African CFA zone and Kraemer and Lehtimäki (2024), who study the effects of EU membership and country-level effects of the SGP.

Data

The data used in the study is compiled from the databases of international organisations and the Penn World Table. All data transformations, sources and descriptive statistics are listed in Appendix B.

In our model, we include a wide range of economic and demographic variables based on previous literature to ensure the robustness of our findings. These control variables include real GDP per capita, government debt, the age dependency ratio, government expenditure, inflation, trade openness, interest rate, population size, a dummy variable for banking crises, the share of gross capital formation, and the share of household consumption in GDP, the share of information and communications technology (ICT) exports and an indicator for economic complexity.

Each of these control variables play a crucial role in our analysis. For instance, trade openness controls for the degree of integration with the global economy, the banking crisis dummy controls for financial stability, while the ICT exports and economic complexity indicator control for the structural changes in the overall business and industry environment, which took place in Finland during the studied sample. Finally, the shares of gross capital formation and household consumption control for the structure of the economy.

By including these controls in our model, we ensure that our estimates of the effect of ageing on GDP per capita, labour productivity, and government debt are not confounded by these other factors. This comprehensive approach strengthens the validity of our findings and contributes to the robustness of the model. While the ageing of population is generally a continuous process and its dynamics are affected by many factors, Finland offers a case study which is quite unique as the historical developments have resulted in a very rapid increase of the old-age dependency ratio.

5 Main Results: Synthetic Control Method

Our main focus is on the macroeconomic effects of ageing on real GDP per capita, productivity (real GDP per worker) and general government debt. Appendix C lists all common diagnostics used in SCM studies with the donor country weights for all comparison country groups in Table A.2 and variable weights in Table A.3. The donor country weights and their robustness is also discussed after the main results of the study. When assessing the fit of the model for different comparison groups, the common practice of studying the pre-treatment and post-treatment Root Mean Square Prediction Errors (RMSPE) as well as their ratios is used.

Table 1 and Figure 2 provide the main results in terms of real GDP per capita using the different comparison groups. The results imply that, depending on the synthetic comparison group, Finland's real GDP per capita is between 15.9% (all EU and OECD countries) and 27.5% (EA countries) lower in 2019 than it would have been if population aged according to the control group. In terms of the highest RMSPE-ratio, the best fit is found for the comparison sample of other EU countries and the difference to actual for this group is 17.6% in 2019.

Figure 2: Actual and synthetic cohort log real GDP per capita before and after treatment.

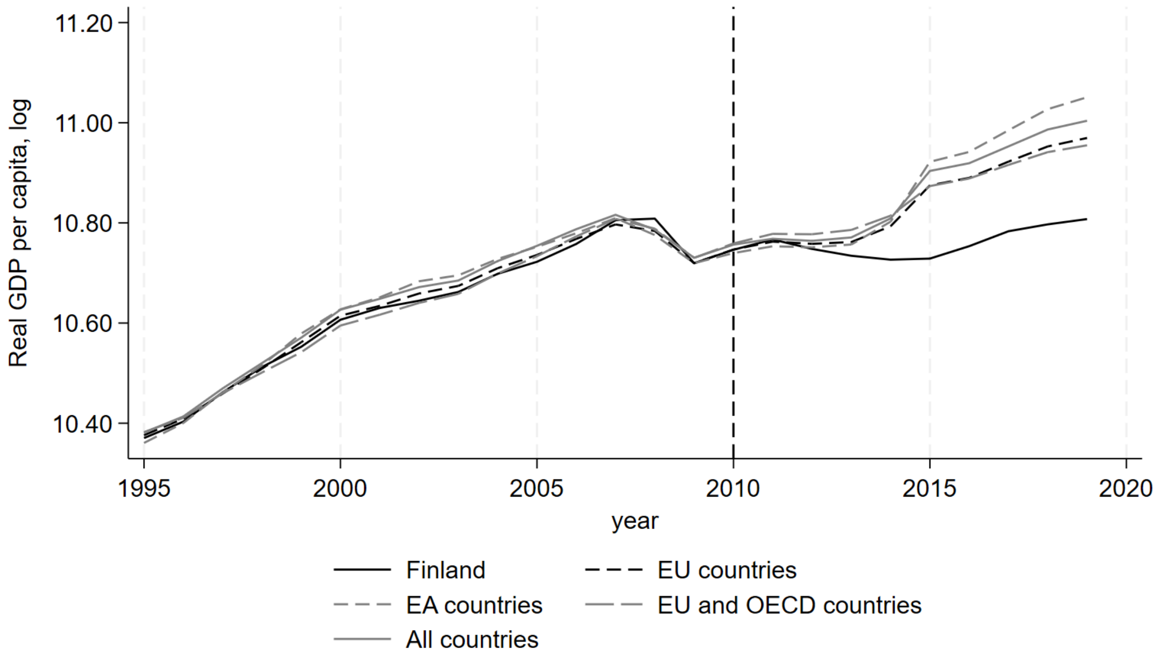


Table 1: Actual and Synthetic log Real GDP per capita, differences in 2019 and descriptive statistics for all comparison groups

		Comparison Group, 2019			
	Actual	EU	EA	EU and OECD	Full
Finland	10.81	10.97	11.05	10.95	11.00
Difference to actual		0.16	0.24	0.15	0.20
Difference in pct		17.6%	27.5%	15.9%	21.7%
RMSPE					
Pre-treatment		0.001	0.002	0.001	0.001
Post-treatment		0.011	0.015	0.010	0.011
Ratio		9.16	6.56	7.01	8.58

Figure 3 presents the observed evolution of productivity and the synthetic control groups and Table 2 reports the relevant statistics. The results imply a difference of 8.4% to 13.9% of lower productivity in real GDP per worker. The RMSPE ratio for the comparison sample of EA country group is the highest.

Figure 3: Actual and synthetic cohort labour productivity before and after treatment.

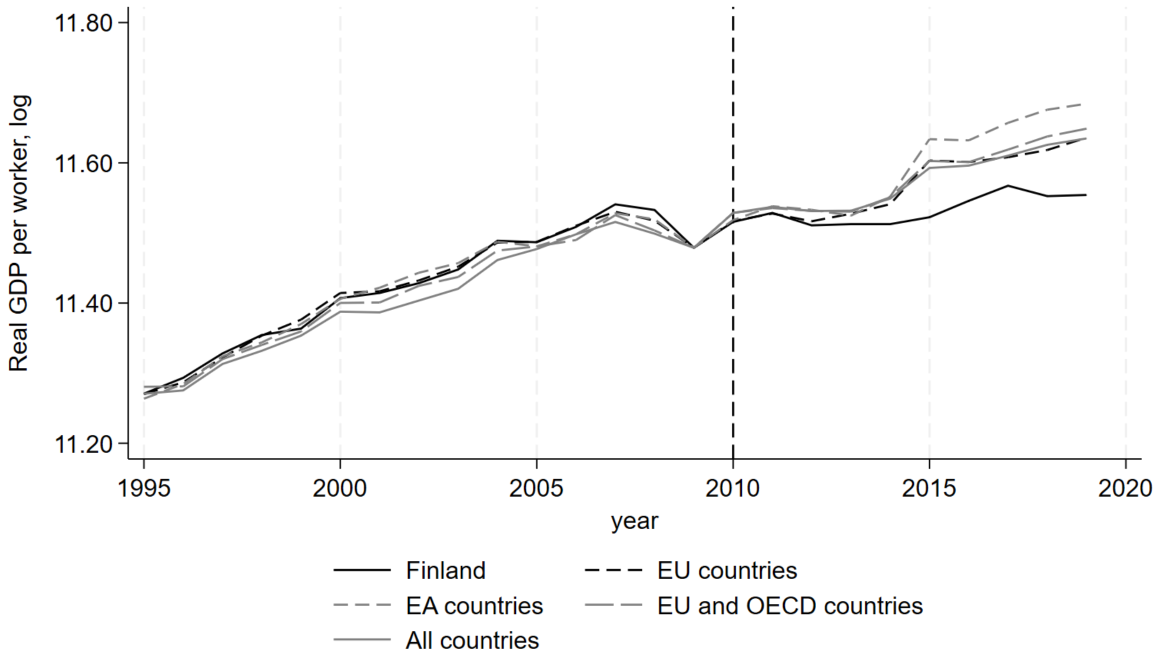


Table 2: Actual and synthetic productivity, differences and descriptive statistics for all comparison groups

	Actual	Comparison Group, 2019			
		EU	EA	EU and OECD	Full
Finland	11.55	11.64	11.68	11.65	11.64
Difference to actual		0.08	0.13	0.09	0.08
Difference in pct		8.5%	13.9%	9.9%	8.4%
RMSPE					
Pre-treatment		0.001	0.001	0.002	0.002
Post-treatment		0.003	0.007	0.005	0.005
Ratio		5.50	6.53	2.46	2.61

The results in Figure 4 and Table 3 imply a difference of 26.0 pp. to 28.4 pp. higher level of government debt to GDP for observed Finland at the end of the sample. The RMSPE ratio for the comparison sample with all EU countries is the highest and it implies a difference of 26.9 pp. lower government debt to GDP compared to observed data.

Figure 4: Government debt

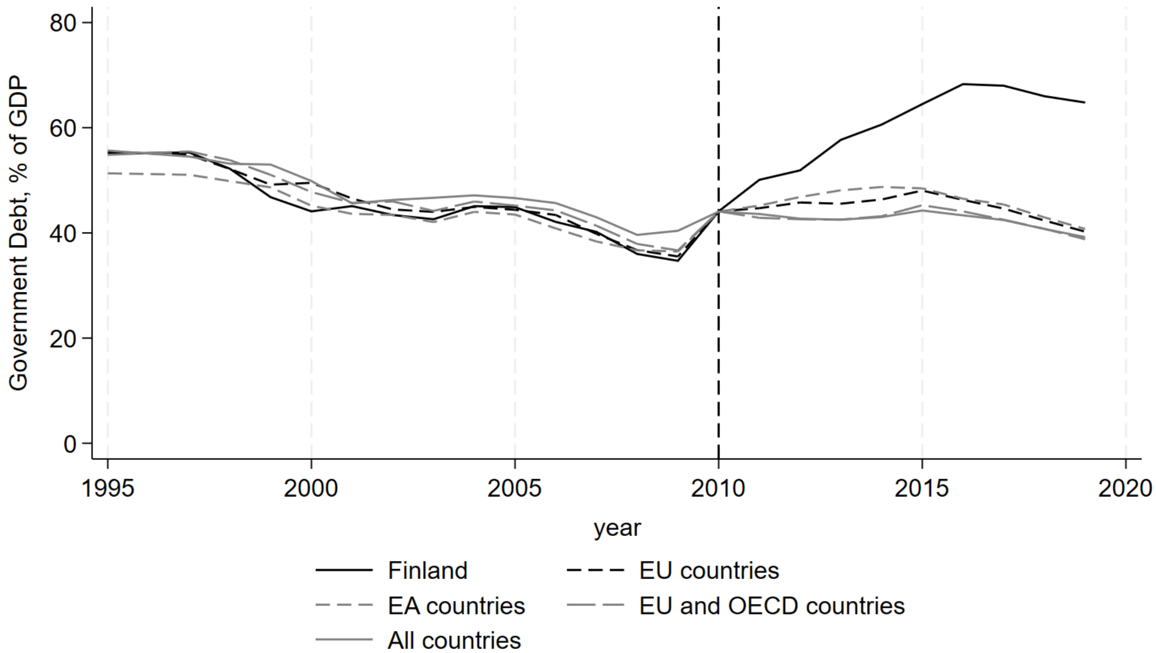


Table 3: Actual and Synthetic Government debt to GDP, differences and descriptive statistics for all comparison groups

	Actual	Comparison Group, 2019 EU	EA	EU and OECD	Full
Finland	64.9	38.0	38.9	36.5	37.5
Difference to actual, pp		-26.9	-26.0	-28.4	-27.4
RMSPE					
Pre-treatment		0.062	0.066	0.010	0.078
Post-treatment		0.454	0.435	0.051	0.501
Ratio		7.33	6.60	5.10	6.45

The country weights for all cases are presented in Appendix C. Sweden receives the largest donor country weight in the EU sample, from 0.323 when the outcome variable is productivity to 0.556 when outcome is government debt. Ireland, Germany, Estonia and Luxembourg also often receive weights but the level depends on the specification. The fact that Sweden received a heavy weight adds credibility to the analysis, as the model is able to identify a country, which is arguably the closest comparison to Finland in terms of economic institutions. On the other hand, the results remain very similar when the comparison sample of other EA countries is used, which does not include Sweden. This observation supports the robustness of the model. For economic growth and government debt, a total of 13 different countries receive at least some weight in one of the four cases. For productivity the total is slightly higher at 16 countries. 22 different countries from the comparison sample (total of 54 countries) receive some weight in at least one of the studied cases.

Our results enable us to perform broad calculations regarding future projections. Using the results from the comparison group, where the RMSPE-ratio is generally the highest (the other EU countries), we observe changes in GDP per capita, productivity, and the debt-to-GDP ratio of -17.6%, -8.5%, and 26.9 percentage points, respectively, between 2010 and 2019. During this period, the old-age dependency ratio increased by 36%, which is 21 percentage points more than in the synthetic Finland. This translates to elasticities (or semi-elasticity in terms of the debt-to-GDP ratio) of -0.84, -0.50, and 1.26, respectively. The World Bank projects that the old-age dependency ratio in Finland will increase by 15.2% between 2020 and 2029 and by 4.5% between 2030 and 2039.

Table 4: Calculations for the future effect of ageing on the Finnish economy

	Change in OADR	GDP per capita	Productivity	Debt to GDP
Elasticity		*-0.84*	*-0.50*	*1.26*
2010-2019	36.0 %	-17.6 %	-8.5 %	26.9 pp
2020-2029	15.2 %	-12.8 %	-7.6 %	7.6 pp
2030-2039	4.5 %	-3.8 %	-2.3 %	5.7 pp

The aggregate effect on GDP per capita between 2010 and 2019 was -17.6% whereas it can be projected to be -12.8% between 2020 and 2029 and -3.8% between 2030 and 2039 based on the observed elasticities and old-age dependency ratio projections. The effects in terms of productivity and debt-to-GDP ratio are reported in Table 4. It is worth noting that the projected aggregate effect declines considerably due to the slowing pace of population ageing in Finland. The modest silver lining for the Finnish economy is that the projected 3.8% drop in GDP per capita between 2030 and 2039, while not negligible, is relatively minor compared to the declines observed from 2010 to 2019. It should be noted that the effects would be slightly different with different comparison groups and the estimated developments are conducted with the assumption of ceteris paribus, i.e. not taking into account all potential aspects such as substantial technological leaps or fundamental structural reforms, which could offset the economic effects of ageing in the future.

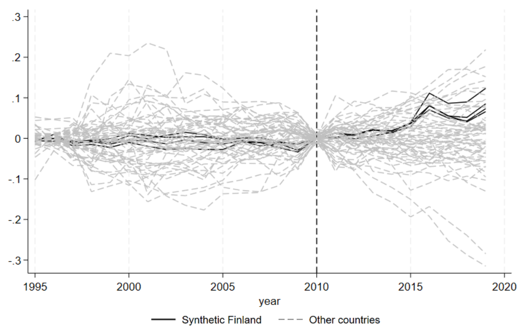
Placebo experiments

One of the primary methods for studying the robustness of SCM results is through placebo experiments. This section applies the most common ones to the case of Finland. The graphs presented here are also included in larger scale in Appendix D and Appendix E.

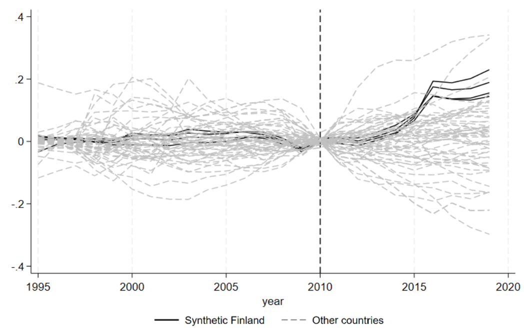
In these experiments, the treated unit is replaced by each individual unit in the control group to observe whether a similar effect occurs. In our case this is relatively straightforward to do with the full sample. The results are displayed in Figure 5a for economic growth, Figure 5b for productivity and Figure 5c for government debt. In all three cases the Finnish case with different comparison groups (black solid lines) appear amongst the highest. While there are some cases where there are higher effects for individual countries, they are associated with very poor pre-treatment fits, which also implies an absence of a structural change the SCM could capture.

Figure 5: In-space placebo experiments

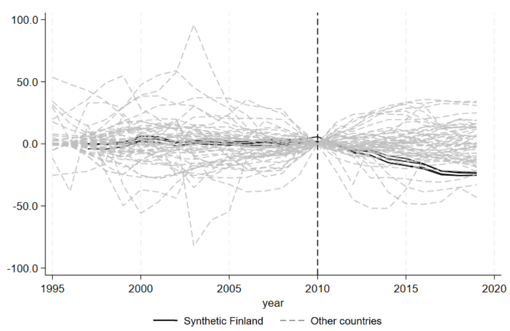
(a) In-space placebos, Real GDP per capita



(b) In-space placebos, Productivity

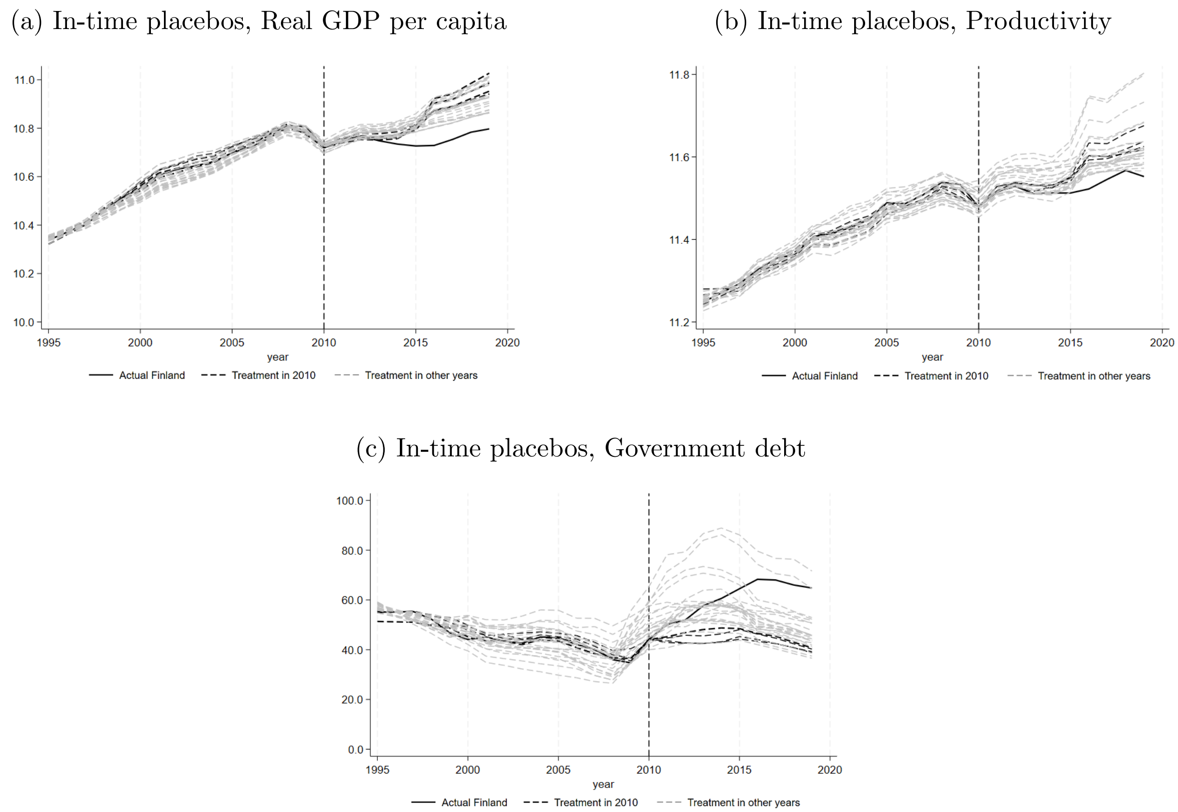


(c) In-space placebos, Government debt



In terms of *economic growth* there are four cases where the economic growth effect is higher than for Finland. They are Argentina, Croatia, Greece and Nigeria. The pre-treatment fits of these cases are poor and none of them receive any weight in any of the studied cases. For *productivity* the countries are the same apart from Croatia, which is replaced by Hungary and United States. The pre-treatment fit is, again, poor for these cases and they are countries, which do not get positive weights in the main analysis. With respect to *government debt*, the set of countries with higher effects with the same sign consists of Argentina, Australia, Costa Rica, Nigeria and Portugal. Simultaneously some countries get a high effect of an opposite sign, namely Canada, Hungary, Poland, Sri Lanka and Turkey. Pre-treatment fits are still generally poor for these countries and they receive no weight in any of the studied cases. The different and more varied set of countries for government debt does potentially imply that the nature of fiscal dynamics differs from the dynamics of economic growth and productivity.

Figure 6: In-time placebo experiments

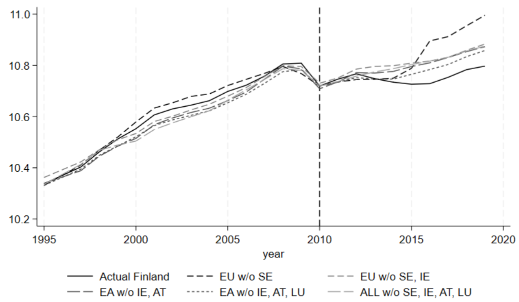


Next, Figure 6 illustrates the in-time placebos, where the treatment is hypothetically applied in different years. For this study, the treatment years are set from 2007 to 2009 and 2011 to 2013 across all four comparison samples, resulting in 24 placebo cases for each variable of interest. The results for 2010 generally fall in the middle range of potential outcomes. Notably, the pre-treatment fits are quite poor when the treatment is set before 2010. Although the fit improves slightly in 2011 compared to 2009, it begins to deteriorate in the subsequent years.

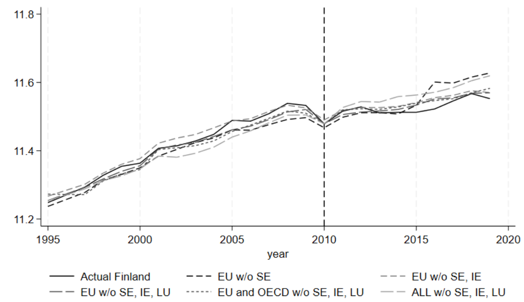
Finally, Klößner et al. (2018) argue that the results of many studies done with the SCM might be driven by an individual unit in the comparison sample. Their concern mainly relates to the United States, which gets no weight in the case of Finland and, therefore, is not a notable issue. However, in this study Sweden does receive a relatively high weight in many cases, followed by Ireland, Luxembourg and some other individual countries depending on the

Figure 7: Removing high-weight countries from comparison sample

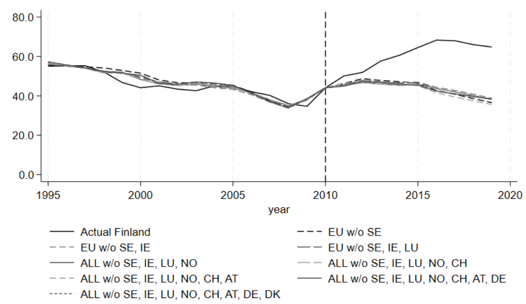
(a) Real GDP per capita



(b) Productivity



(c) Government debt



case. While these countries resemble Finland in many ways, there are also notable differences in their economic structures. Therefore, it is prudent to study whether the results are strongly driven by these individual countries. Figure 7 presents the SCM results when these countries are iteratively removed from the comparison sample.

For economic growth the results remain qualitatively similar without these three countries as well as without Austria, which gets a high weight in the EA country group. When these countries are removed, the weight of Denmark increases and Czech Republic as well as Japan for the full sample get some weight as additional countries compared to the baseline cases.

The effects for productivity for the EU comparison are somewhat driven by Sweden but the matching of the pre-treatment also becomes worse. The results still remain unchanged for larger samples with Denmark gaining additional weight and Iceland, Spain as well as Switzerland getting a small weight as new countries compared to the baseline case.

Finally, for government debt the results remain unchanged, although for some cases the pre-treatment fit worsens. As Norway, Switzerland, Austria, Germany and Denmark in turn receive a very high weight after the removal of Sweden, Ireland and Luxembourg, the results are also presented after the iterative removal of these five countries. In these cases the weight of France is increased and Japan, Netherlands, Slovenia as well as the United Kingdom are new countries with very small weights.

It should be noted that especially the removal of Sweden generally weakens the pre-treatment fit, even if the results remain qualitatively unchanged and in some cases the effects are even more substantial. This is not a huge surprise as the country is, in many ways, the closest matching comparison country to Finland. It is notable that, especially important for the questions of this study, Sweden is far less affected by an ageing population than Finland due to very different historical population dynamics.

6 Robustness of the Results: An IV Approach

As an additional analysis, we also estimate the effect of ageing on GDP per capita and productivity applying the approach employed by Maestas et al. (2023). In our context, we utilise the variation in demographic trends between geographical areas in Finland. To estimate the causal effect, we apply instrumental variable approach (IV). Our instrument, following previous research, is the predicted value of the dependency ratio, which allows us to control for differences caused by varying migration and mortality rates across geographic areas.

All the data for this analysis was compiled from the public databases of Statistics Finland. Regional population figures were obtained from the Population Structure database (Table 11re). The GDP growth series was compiled from the Regional Accounts (Table 12bd) and the Historical Archive (Table 903). Employment figures were retrieved from the Employment Database (Table 115w). Our dataset spans from 1997 to 2021, covering 19 regions, resulting in total of 475 observations. A structural break in the regional GDP data occurred in 2000. Consequently, we also estimated the model using data starting from 2001 to avoid the potential problems emerging from the structural break in the data. In this case, the elasticities are larger, but the results remain statistically highly accurate.

Our model relates the old-age dependency ratio to the variables of interest. We use 10-year growth rates to avoid the business cycle variation and focus on the structural issue at hand:

$$\ln\left(Y_{s,t+10}\right) - \ln\left(Y_{s,t}\right) = \beta\left[\ln\left(\frac{A^{65}_{s,t+10}}{N^{25}_{s,t+10}}\right) - \ln\left(\frac{A^{65}_{s,t}}{N^{25}_{s,t}}\right)\right] + \delta_t + \epsilon_t, \quad (8)$$

where Y denotes GDP per capita or productivity (GDP per employee), A^{65} the number of individuals aged 65 and older, N^{25} the total population older than 25 years, δ is time fixed effects and ϵ is the error term. The subscript s refers to area and t to time. The parameter β measures the effect of change in old-age dependency ratio on change in our outcome variable. As we estimate the model in differences, we implicitly account for the fixed differences across areas.

While Equation (8) is straightforward to estimate, it is possible that changes in demographic structure may have an effect on economic outcomes. A challenging economic environment might induce people to move from one area to another, leading to a correlation between the dependency ratio and economic growth that might not be causal.

Our solution, following Maestas et al. (2023), is to use the IV approach by exploiting the variation in the predetermined component of population ageing while filtering out the subsequent state-specific variation. We calculate the change in *nation-wide* old-age dependency ratio and use this measure to calculate the projected area-specific change in old-age dependency ratio. Specifically, we use $\ln\left(\frac{\widehat{A^{65}_{s,t+10}}}{N^{25}_{s,t+10}}\right) - \ln\left(\frac{A^{65}_{s,t}}{N^{25}_{s,t}}\right)$ as an instrument for $\ln\left(\frac{A^{65}_{s,t+10}}{N^{25}_{s,t+10}}\right) - \ln\left(\frac{A^{65}_{s,t}}{N^{25}_{s,t}}\right)$ from Equation (8), where:

$$\frac{\widehat{A^{65}_{s,t+10}}}{N^{25}_{s,t+10}} = \frac{s^{55}_{t+10} A^{55}_{s,t}}{s^{15}_{t+10} N^{15}_{s,t}}, \tag{9}$$

where $A^{5}5$ is the total population aged 55 and older, N^{15} is the total population older than 15 years and $s^{55}_{t} = \frac{A^{65}_{t}}{A^{55}_{t-10}}$ and $s^{15}_{t} = \frac{A^{25}_{t}}{A^{15}_{t-10}}$ are aggregate survival rates. Simplifying the equation (9), we can rewrite the instrument as follows:

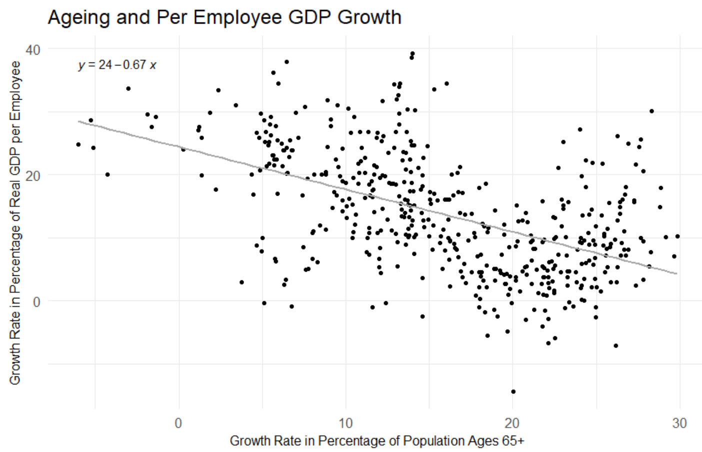
$$\ln\left(\frac{\widehat{A^{65}_{s,t+10}}}{N^{25}_{s,t+10}}\right) - \ln\left(\frac{A^{65}_{s,t}}{N^{25}_{s,t}}\right) = \ln\left(\frac{s^{55}_{t+10}}{s^{15}_{t+10}} \frac{A^{55}_{s,t}}{N^{15}_{s,t}} \frac{N^{25}_{s,t}}{A^{65}_{s,t}}\right) \tag{10}$$

From equation (10) we can see that the area-specific variation comes from differences in population shares in the initial period (t), which is arguably exogeneous to economic outcomes in the end period ($t + 10$). Note also, that we only use 10-year steps due to data limitations whereas Maestas et al. (2023) use up to 30-year time steps.

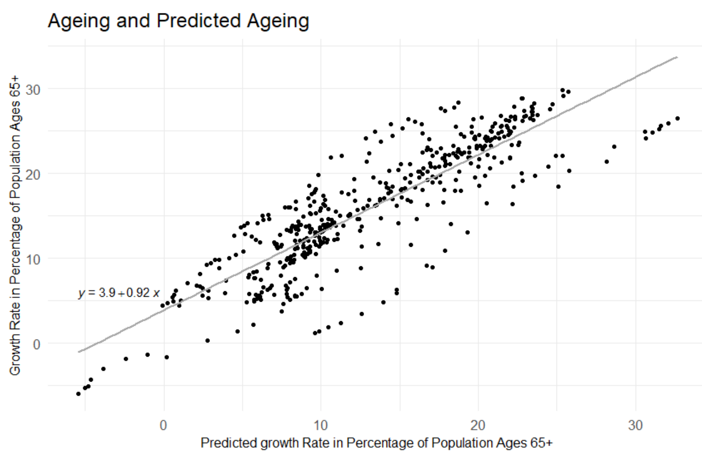
Our research design is illustrated in Figure 8. The top figure shows the negative association between the 10-year growth rate of productivity (GDP per employee) and population ageing. The middle figure depicts the first stage relationship between observed and predicted ageing. The bottom panel depicts the relationship between productivity and our instrument.

Figure 8: Relationships between ageing, predicted ageing, and productivity growth

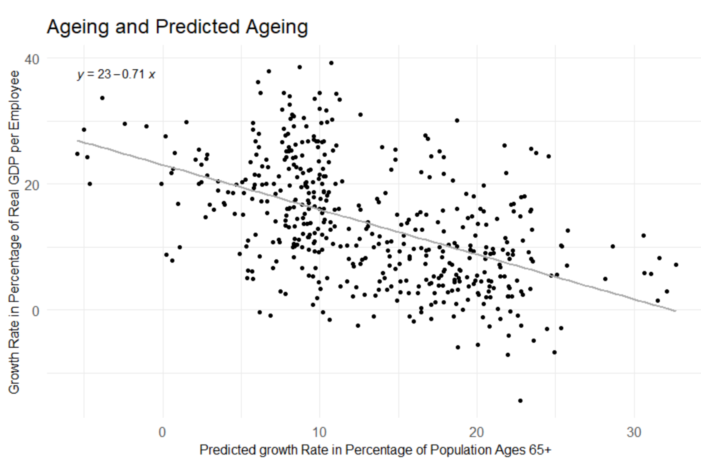
(a) Ageing and productivity



(b) Predicted ageing and observed ageing



(c) Combined effects on productivity



The results from the IV approach are presented in Table 5. The IV estimates are -0.286 and -0.734 for productivity and GDP per capita, respectively, with both parameters estimated accurately at below the 5 % significance level. *First*, the result for productivity is roughly in line with Maestas et al. (2023) who obtain an estimate of approximately -0.5 using US state-level variation. It should be noted that the comparison between the results is not exact as the dependent variable in that study is GDP per population over 20 years old, which is neither an exact measure for productivity nor GDP per capita. Nevertheless, the result is qualitatively similar. *Second*, we obtain a larger (in absolute value) parameter estimate for GDP per capita compared to productivity. This finding aligns with earlier literature and is consistent with the results obtained using the SCM in Section 5.

Table 5: Results from instrumental variables regression

	Reduced Form Estimates	
Dependent Variable:	$\Delta\ln(GDP/E)$	$\Delta\ln(GDP/N)$
$\Delta ln(\hat{A}/\hat{N})$	-0.257*	-0.660***
	(0.0821)	(< 0.0001)
	First Stage Estimates	
Dependent Variable:	$\Delta\ln(A/N)$	
$\Delta ln(\hat{A}/\hat{N})$	0.900***	
	(< 0.0001)	
F-statistic	337***	
	Instrumental Variable Estimates	
Dependent Variable:	$\Delta\ln(GDP/E)$	$\Delta\ln(GDP/N)$
$\Delta ln(A/N)$	-0.286**	-0.734***
	(0.0295)	(< 0.0001)
Wu-Hausman test	5.104*	
	(0.0244)	

Number of observations=475. GDP/E denotes productivity and GDP/N is GDP per capita. Area level clustered standard errors are in parentheses: *** $p < 0.01$, ** $p < 0.05$, *$p < 0.1$. Other variables include decade dummies. Δ refers to 10-year difference.

7 Conclusions

Many advanced countries are facing challenges related to an ageing population due to increases in life expectancy and declining total fertility rates. Consequently, more macroeconomic research is needed. This study aims to fill this gap.

This paper examines the issue in the pronounced case of Finland, employing various approaches to provide a comprehensive picture of the economic effects of an ageing population. Finland's case is quite unique due to historical trends in population dynamics, but similar demographic developments are either already occurring or will soon be taking place in many advanced countries. The results of this paper suggest that the economic and fiscal effects of ageing are considerable. Therefore, it is essential for policymakers to adjust institutional frameworks and structures to prepare their economies for this development, ensuring economic resilience and the sustainability of public finances.

Using the Synthetic Control Method, we find that the rapid ageing of Finland's population over the past decade has had significant economic effects. Real GDP per capita is 15.9 % to 27.5 % lower, productivity is 8.4 % to 13.9 % lower, and government debt is 26.0 to 28.4 percentage points higher, depending on the comparison sample. While it is prudent to interpret the level of these results with some caution due to the continuous nature of ageing and other economic dynamics, such as the heterogeneous effects of the financial crisis and industry-level structural changes in Finland, they still indicate very substantial and wide-ranging effects from an ageing population. The results are robust, remaining qualitatively similar across different comparison groups and after common robustness checks.

Membership in the Economic and Monetary Union, the adoption of the common currency, and the lack of independent monetary policy have previously been suggested as potential explanations for lagging productivity growth in Finland. However, our results indicate that this is not the primary cause, as the effects for the euro area comparison group are generally even higher (lower in the case of government debt) than for the comparison groups consisting of EU and OECD countries. It is worth noting that this should not be interpreted as a conclusive result about the role of EMU membership, as the results could also be attributed to differing country weightings in comparison groups.

There are several avenues for future research. Broader analysis should be conducted on how country-specific aspects influence the effects of ageing and how different policy choices can mitigate or alter these dynamics. Finland is an extreme example of a small open economy where demographic changes have occurred rapidly. However, a majority of advanced countries of all sizes will face similar levels of economic and fiscal stress from an ageing population, but the process may be more gradual, making corrective policy action easier to implement, especially if undertaken early. Further research should also explore the drivers of slowing economic growth and potential methods for enhancing productivity or developing new technologies to counteract the increasing ratio of elderly individuals to the labour force.

Acknowledgements

The authors would like to thank Daniela Filip, Janne Huovari and the participants of The Labour Institute for Economic Research LABORE and Pellervo economic research PTT research seminars.

Declarations

The authors did not receive any specific funding for this research and declare no conflicts of interest. There has been no use of artificial intelligence in any part of this study. The views expressed in this study are those of the authors.

Data Availability

The data is compiled from the public databases of national and international organisations. The data used in the study is available upon reasonable request.

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Appendix

A SCM technical formulation

Abadie and Gardeazabal (2003) and Abadie et al. (2010) define a studied group $J+1$. The group includes an individual observation of interest $j=1$ where a treatment takes place in period T_i. The remaining set of observations in the group $j=2,...,J+1$ are not affected by the treatment and, therefore, form the control group. The control group is used to simulate a counterfactual. Abadie et al. (2010) express $j=1$, the individual country, area, etc., as the "treated unit" while the non-treated units form the "donor pool".

The sample $t=1,...,T$ used in this study consists of data from 1995 to 2019. The pre-treatment T_0 consists of the 15 years up to 2010 and post-treatment years T_1 (with $T_0+T_1=T$) consists of the years up to the end of the sample.

The SCM algorithm calculates the counterfactual non-treatment development by using the donor pool. Abadie et al. (2015) define it as a weighted average of observations in the donor pool, consisting of a $J \times 1$ vector of weights $W=(w_2,...,w_{J+1})'$ with $0 \leq w_j \leq 1$ of $j=2,...,J+1$ and $w_2,...,w_{J+1}=1$. It then chooses the value of W to match the characteristics of the treated unit with the synthetic control.

X_1 is a $(k \times 1)$ vector consisting of all the pre-treatment control variables of the treated unit which should match the ones of the comparison group, formed by X_0 which is the $k \times J$ matrix, as closely as possible. The selected synthetic control, W^*, should minimise the difference between the treated unit and the synthetic control (this implies the minimum of vector $X_1 - X_0W$).

By combining these elements, the formal approach can be defined. $m=1,...,k$, X_{1m} is the value of the m-th variable for the treated country, Finland, and X_{0m} is a $1 \times J$ vector of the values of the m-th variable for countries in the donor pool. Following Abadie and Gardeazabal (2003), W^* is chosen as the value of W that minimises:

$$W^* = \sum_{m=1}^{k} v_m (X_{1m} - X_{0m}W)^2, \tag{11}$$

where v_m is the weight reflecting the importance the model assigns to m-th variable when defining the difference between X_1 and X_0W. These weights are used for the synthetic control estimator for the effect of the treatment, which is the difference of post-treatment outcomes in the treated unit and the effects observed in the donor pool:

$$Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt}, \tag{12}$$

where Y_{jt} is the observed effect in country j at time t and Y_1 a $(T_1 \times 1)$ vector of the post-treatment values of the treated country. Y_0 is therefore a $(T_1 \times J)$ matrix, with j being the post-treatment values of the effect for country $j+1$.

Combining equations (11) and (12), it is possible to see that the matching variables in X_0 and X_1 serve as predictors of the post-treatment outcome.

B Data description, descriptive statistics and sources

Table A.1: Variables

variable	**unit/transformation**	**mean**	**min**	**max**	**std.dev.**	**source**
Real GDP per capita	log	9.74	6.51	11.63	1.09	World Bank
Productivity	real GDP per worker, log	10.98	8.79	12.53	0.67	World Bank
Government debt	% of GDP	56.46	3.77	235.45	35.22	IMF
Age dependency ratio	% of working age population	51.90	26.99	96.75	9.45	World Bank
Government expenditure	log	24.41	21.07	28.55	1.67	World Bank
Inflation	% change of GDP deflator	5.28	-9.48	1040.18	36.01	World Bank
Trade openness	% of GDP	93.73	16.68	437.33	66.42	World Bank
Real interest rate	%	4.60	-69.13	183.20	9.83	ECB, IMF
Banking crises	[0, 1]	0.11	0.00	1.00	0.31	Laeven and Valencia (2020)
Population	log	16.45	12.50	21.04	1.66	World Bank
Share of gross capital formation	share of total	0.25	0.00	0.65	0.06	Penn World Table
Share of household consumption	share of total	0.58	0.21	0.86	0.10	Penn World Table
Unemployment	%	7.82	0.25	33.29	4.81	World Bank
Share of ICT exports	% of total goods exports	9.92	0.00	327.98	17.54	World Bank
Economic Complexity	index	0.82	-2.34	2.86	0.84	Atlas of Economic Complexity

C SCM weights

Table A.2: Donor country weights

	Economic Growth				Productivity				Government Debt			
	EU	EA	OECD+EU	All	EU	EA	OECD+EU	All	EU	EA	OECD+EU	All
EU countries												
Austria	0.064	0.328										
Belgium	0.033				0.078							
Cyprus						0.104						
Denmark			0.177	0.029	0.115		0.109					
Estonia	0.098	0.004	0.103		0.017	0.032				0.081	0.137	0.085
France						0.191				0.054		
Germany	0.012	0.067			0.039				0.026	0.215		0.044
Ireland	0.159	0.600	0.026	0.270	0.353	0.673	0.381	0.058	0.163	0.513		
Luxembourg	0.069		0.033	0.010			0.012	0.120	0.129	0.136	0.008	
Malta	0.009				0.076		0.071					0.021
Slovak Republic								0.090	0.125		0.007	
Slovenia				0.092								
Spain			0.027									
Sweden	0.554		0.541	0.531	0.323		0.277	0.325	0.556		0.508	0.286
Non-EU OECD												
Canada							0.099	0.030				
Iceland			0.063	0.047							0.015	
Israel							0.052				0.076	0.075
Norway								0.184			0.090	0.165
Republic of Korea			0.030	0.022								
Switzerland											0.159	0.202
Other countries												
Singapore								0.094				
South Africa								0.099				0.124

Notes: Donor country weights for different studied variables and country samples. All countries with no weight omitted from table.

Table A.3: Variable weights

	Economic Growth				Productivity				Government Debt			
	EU	EA	EU+OECD	Full	EU	EA	EU+OECD	Full	EU	EA	EU+OECD	Full
Beginning of sample value												
Real GDP per capita (log), 1995	0.444	0.859	0.503	0.864								
Productivity per worker (log), 1995				0.658	0.718	0.746	0.908					
Government debt, 1995									0.065	0.176	0.266	0.508
Control variables												
Real GDP per capita (log)					0.016	0.085	0.011	0.052	0.087	0.008	0.099	0.065
Government debt	0.003	0.000	0.003	0.001	0.000	0.000	0.000	0.000				
Age dependency ratio	0.000	0.000	0.001	0.002	0.001	0.001	0.003	0.008	0.001	0.006	0.002	0.010
Government expenditure (log)	0.306	0.071	0.268	0.062	0.126	0.062	0.103	0.006	0.461	0.361	0.246	0.134
Inflation	0.005	0.001	0.002	0.000	0.014	0.001	0.003	0.000	0.027	0.003	0.048	0.019
Trade openness	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.005	0.013	0.001
Interest rate	0.001	0.000	0.000	0.000	0.009	0.004	0.003	0.003	0.011	0.009	0.029	0.004
Population (log)	0.237	0.034	0.222	0.068	0.166	0.107	0.126	0.016	0.322	0.301	0.253	0.114
Banking crisis	0.001	0.000	0.000	0.000	0.001	0.004	0.001	0.000	0.000	0.006	0.005	0.023
Share of gross capital formation	0.001	0.002	0.001	0.001	0.001	0.005	0.000	0.000	0.003	0.003	0.006	0.047
Share of household consumption	0.000	0.021	0.000	0.001	0.004	0.009	0.003	0.003	0.017	0.092	0.018	0.053
Unemployment	0.001	0.001	0.000	0.000	0.001	0.001	0.000	0.002	0.002	0.007	0.008	0.001
ICT goods	0.000	0.001	0.000	0.000	0.001	0.003	0.000	0.000	0.000	0.004	0.000	0.001
Economic Complexity	0.001	0.005	0.000	0.001	0.001	0.000	0.000	0.000	0.002	0.018	0.008	0.021

Notes: Variable weights for different studied country samples. OECD-EU refers to all Non-EU OECD countries.

D SCM results, in-space and in-time placebos

Figure 9: Real GDP per capita, in-space placebos

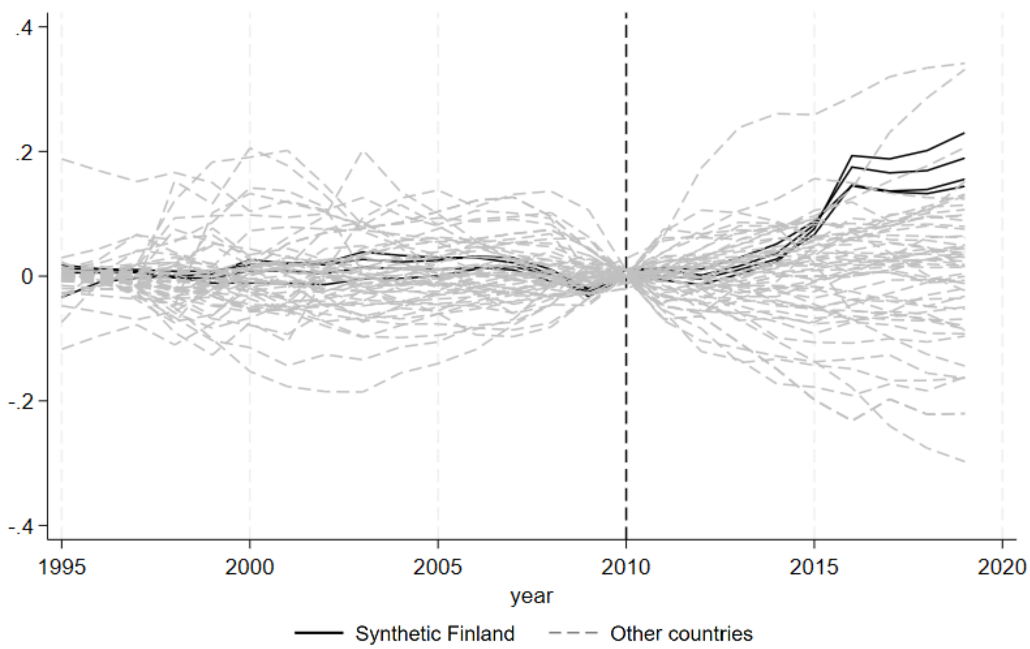


Figure 10: Productivity, in-space placebos

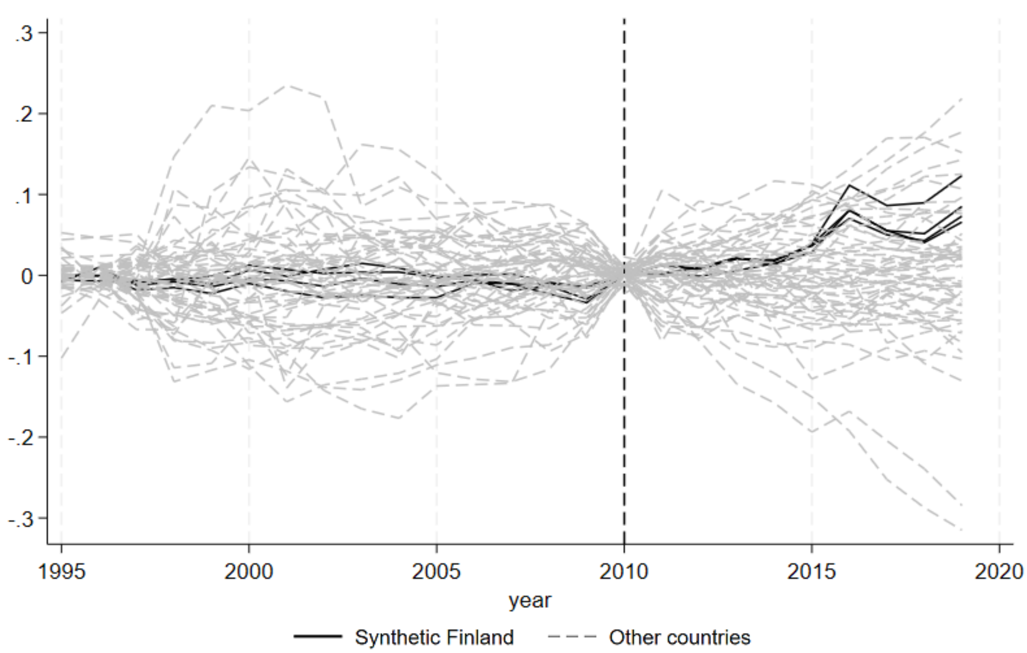


Figure 11: Government debt, in-space placebos

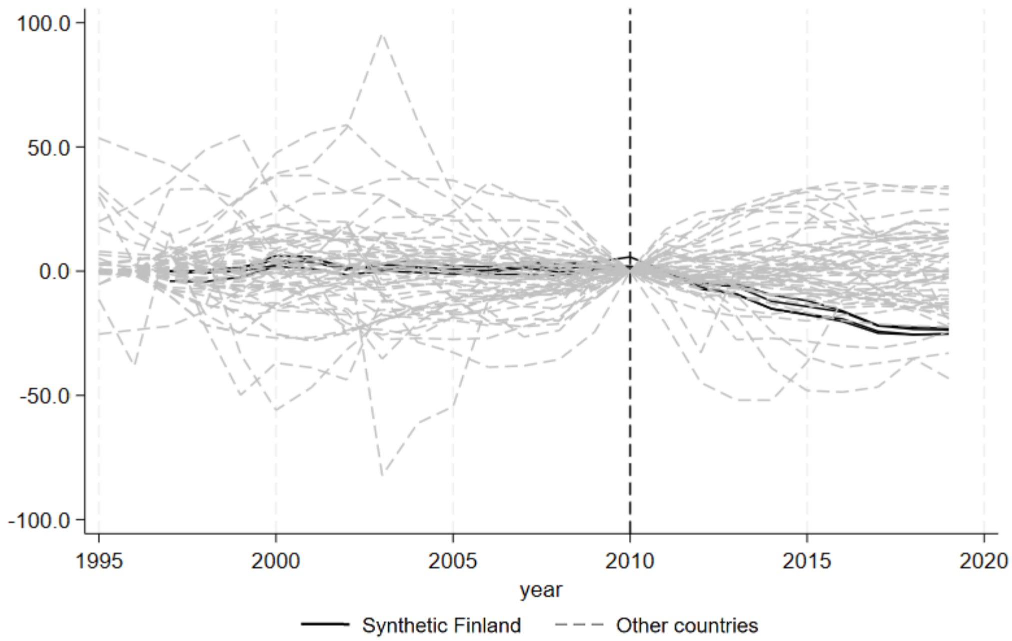


Figure 12: Real GDP per capita, in-time placebos

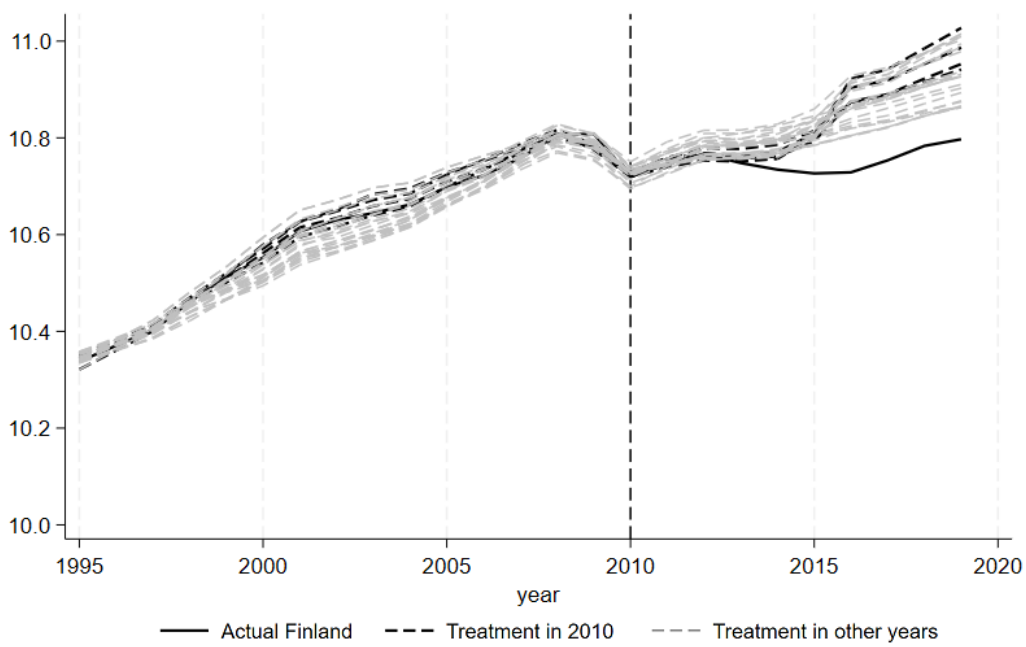


Figure 13: Productivity, in-time placebos

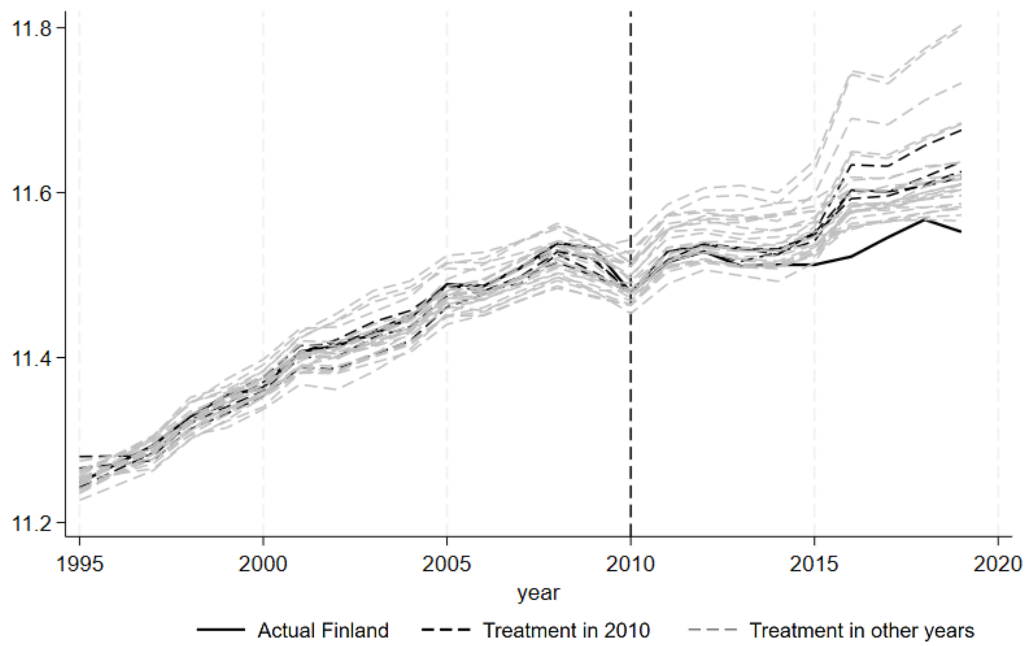
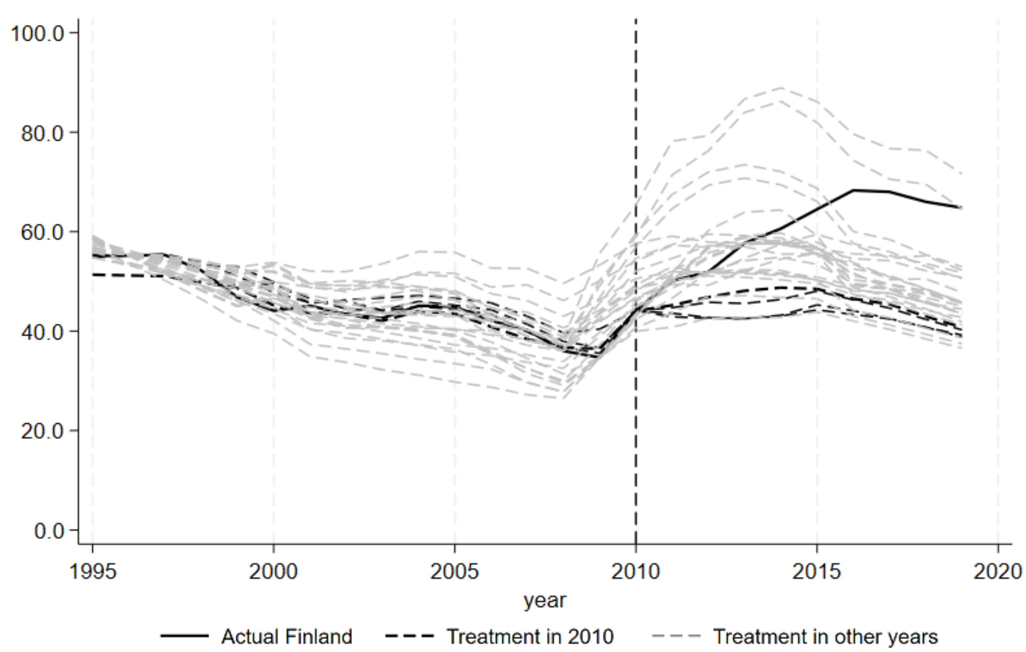


Figure 14: Government debt, in-time placebos



E SCM results without high-weight countries

Figure 15: Real GDP per capita with high-weight countries removed

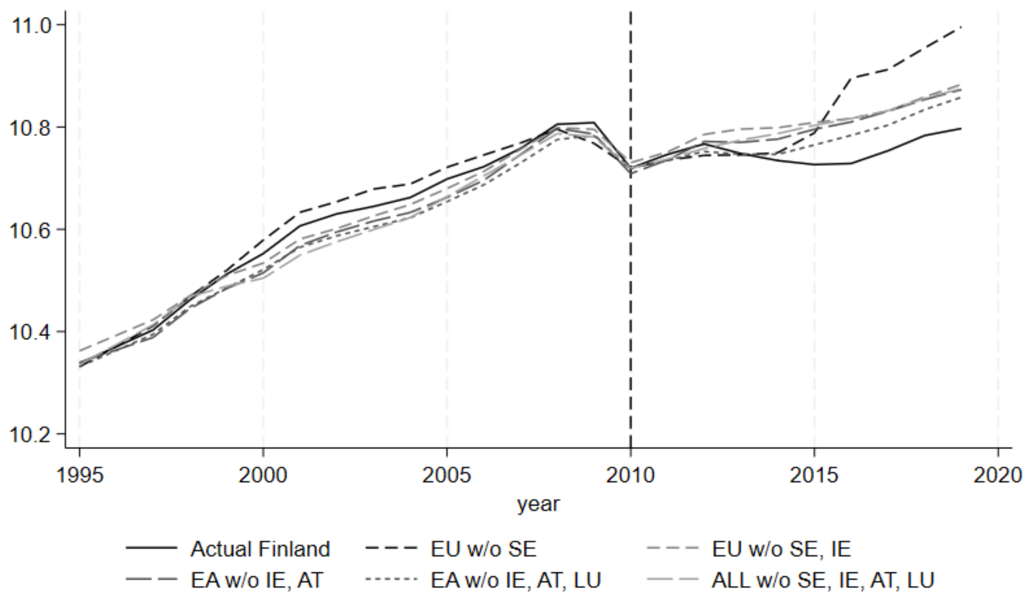


Figure 16: Productivity with high-weight countries removed

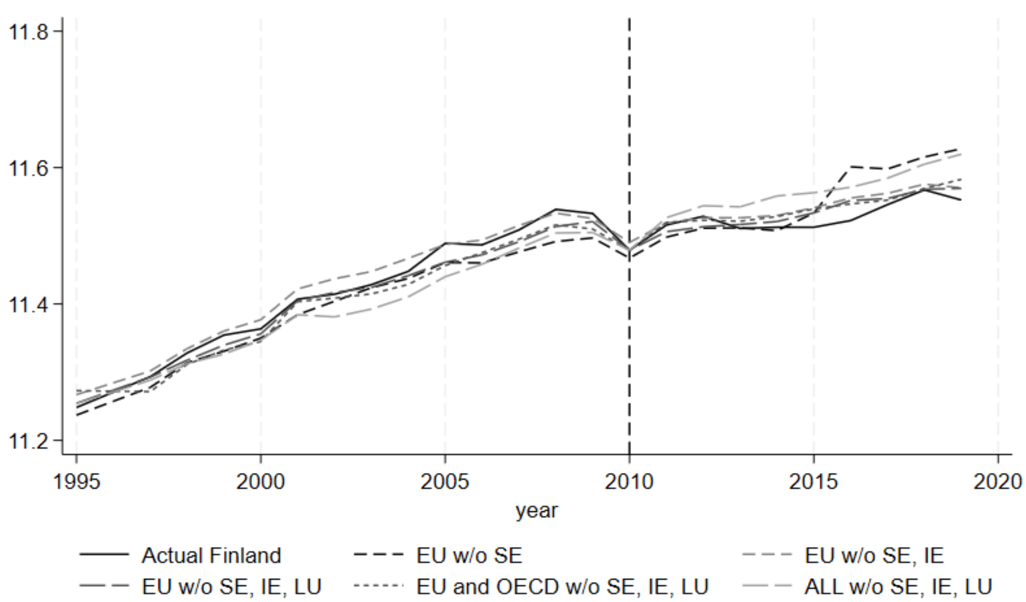
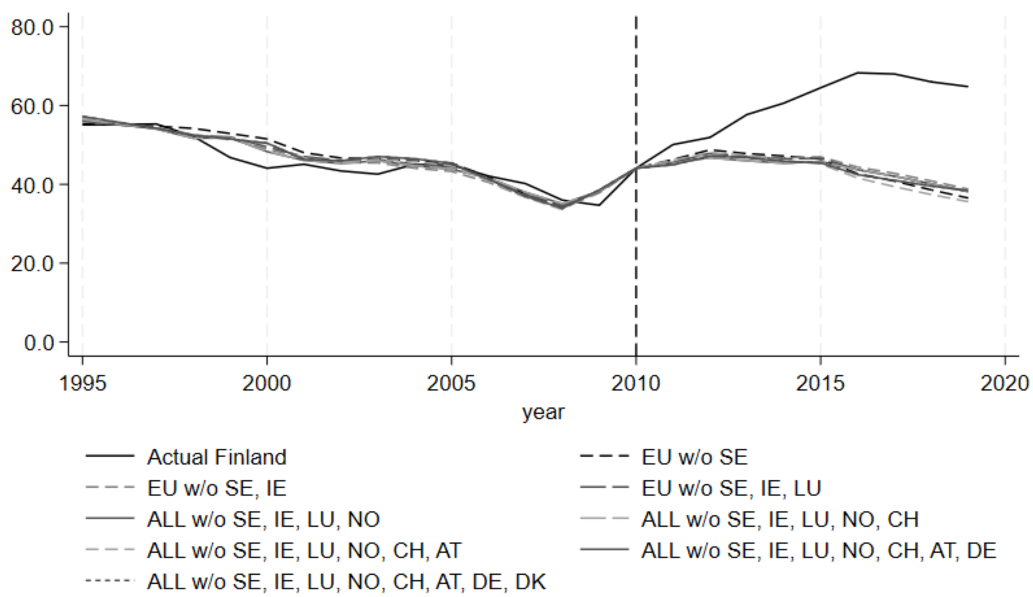


Figure 17: Government debt with high-weight countries removed



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ISSN 1796-3133