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Getting too old for this: Population ageing and its economic consequences in Finland

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ABSTRACT

Population ageing creates economic burden through shrinking labour forces and rising age-related expenditures, but existing literature provides only limited causal evidence on the magnitude of effects. This limits policymakers' ability to prepare for demographic transitions. This paper studies Finland's uniquely rapid demographic transition, where the old-age dependency ratio nearly doubled during 2010–2019, to identify causal effects of accelerated ageing. The paper uses the Synthetic Control Method and instrumental variable analysis to study the economic consequences of rapid ageing. Accelerated ageing operates through two channels: the contraction of the labour force reduces productive capacity while fiscal pressures increase due to pension and healthcare spending. Results show Finland's rapid ageing reduced GDP per capita and productivity substantially over the decade, while general government debt increased significantly. These findings quantify the considerable costs of delayed demographic adaptation, demonstrating that the speed of ageing fundamentally determines economic outcomes and public finances in ageing societies worldwide.

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 the global population peaked in the 1960s at approximately 2% per year. Since then, 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 have significantly increased life expectancy (Roffia et al., 2023).

Currently, Finland stands out among advanced countries with one of the highest age 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 the 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. Between 2010 and 2019, the total number of people in Finland aged 65 or over increased by 292,000, which was a substantial demographic shift in a short period in a nation with a population of roughly 5.5 million.

Given its quite unique demographic trajectory, Finland provides a compelling case study for examining the economic effects of ageing. Although the window for pre-emptive action has closed for Finland, it serves as a cautionary tale for policymakers about

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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 econometric technique of the Synthetic Control Method (SCM) to analyse the macroeconomic and fiscal effects experienced in Finland. It 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 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*, it is possible that the SCM also captures other factors beyond the effects of ageing. We, therefore, also estimate the effects using the IV method and obtain similar, slightly smaller elasticities for demographic changes. *Third*, we contribute to the 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. *Fourth*, 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 a part of the gap.

Section 2 examines the case of Finland and its relevance in comparison to other advanced economies. Section 3 reviews the existing literature on the economic effects of population ageing. Section 4 outlines the theoretical framework, while Section 5 details the methodology of the SCM, data sources, and sample as well as presents the main empirical findings. Section 6 explores an alternative approach using instrumental variable methodology and a different dataset. Finally, Section 7 concludes the paper and offers some policy advice.

2. The unique case of Finland and cross-country comparisons

Finland presents a unique case for examining the macroeconomic consequences of rapid population ageing. While ageing is a widespread trend across advanced economies, Finland stands out due to the exceptional speed, scale, and demographic context of its transition. As displayed in Fig. 1, the country's old-age dependency ratio (OADR) rose rapidly between 2010 and 2019, at a speed roughly twice the increase observed across the EU and Organisation for Economic Co-operation and Development (OECD) on average during the same period. This shift occurred in a small, open economy marked by persistently low fertility since the early 1990s, rising life expectancy, and limited structural reforms to slow down the transition. Moreover, unlike many other advanced economies, Finland has experienced relatively low levels of immigration, limiting the inflow of younger working-age segments of population that might have softened the economic and fiscal impacts. These traits make Finland a clean empirical case: unlike larger or better-buffered economies, its ageing-related effects are more transparent and measurable. As such, Finland serves as an upper-bound scenario of what can occur when population ageing proceeds rapidly and policy adaptation lags behind.

As seen in Fig. 2, several other countries have undergone (or are currently undergoing) similar demographic transitions, although with different institutional and policy contexts. Japan, for instance, represents a longstanding case of continuous population ageing, marked by a high old-age dependency ratio, decades of sluggish economic growth, and rising public debt. In response, Japan has invested in automation and implemented labour market reforms. However, these measures have only partially mitigated the macroeconomic stagnation.[1] Italy has also experienced persistently low fertility and slow economic growth, but with fewer structural reforms and more limited fiscal space. In contrast, Germany has aged more gradually and responded more proactively, notably through comprehensive labour market reforms and increased immigration, particularly during the 2015 refugee inflow. These responses have helped stabilise employment and contain the fiscal pressures associated with ageing.

South Korea presents another compelling case, as it is currently experiencing population ageing at an even faster speed than Finland, although the OADR is still at a lower level. Unlike Finland, South Korea has adopted a more proactive approach, combining pension reforms, productivity-enhancing policies, and selective immigration, even though immigration levels remain modest compared to many other countries. As Aksoy et al. (2019) demonstrate, countries undergoing sharp demographic transitions often face slower economic growth, reduced investment, and declining labour supply. The scale and persistence of these effects vary significantly depending on policy responses and institutional capacity. South Korea's experience shows that rapid ageing can yield different economic outcomes when accompanied by timely and targeted policy adaptation.

Other OECD countries, such as Australia, Canada, Switzerland have, at least so far, largely avoided the severe economic impacts of population ageing. These countries benefit from sustained net immigration and relatively higher fertility rates, which have helped maintain the size of their working-age populations. In addition, flexible labour markets and active ageing policies have further mitigated potential declines in labour force participation.

Similar demographic resilience can be observed in other Nordic countries. Sweden, in particular, stands out for combining a comprehensive welfare model with relatively high immigration rates, especially during the 2010s. This has helped counterbalance its

[1] See Jones and Seitani (2019) on labour market reforms and Schneider and Le (2018) on automation in Japan.

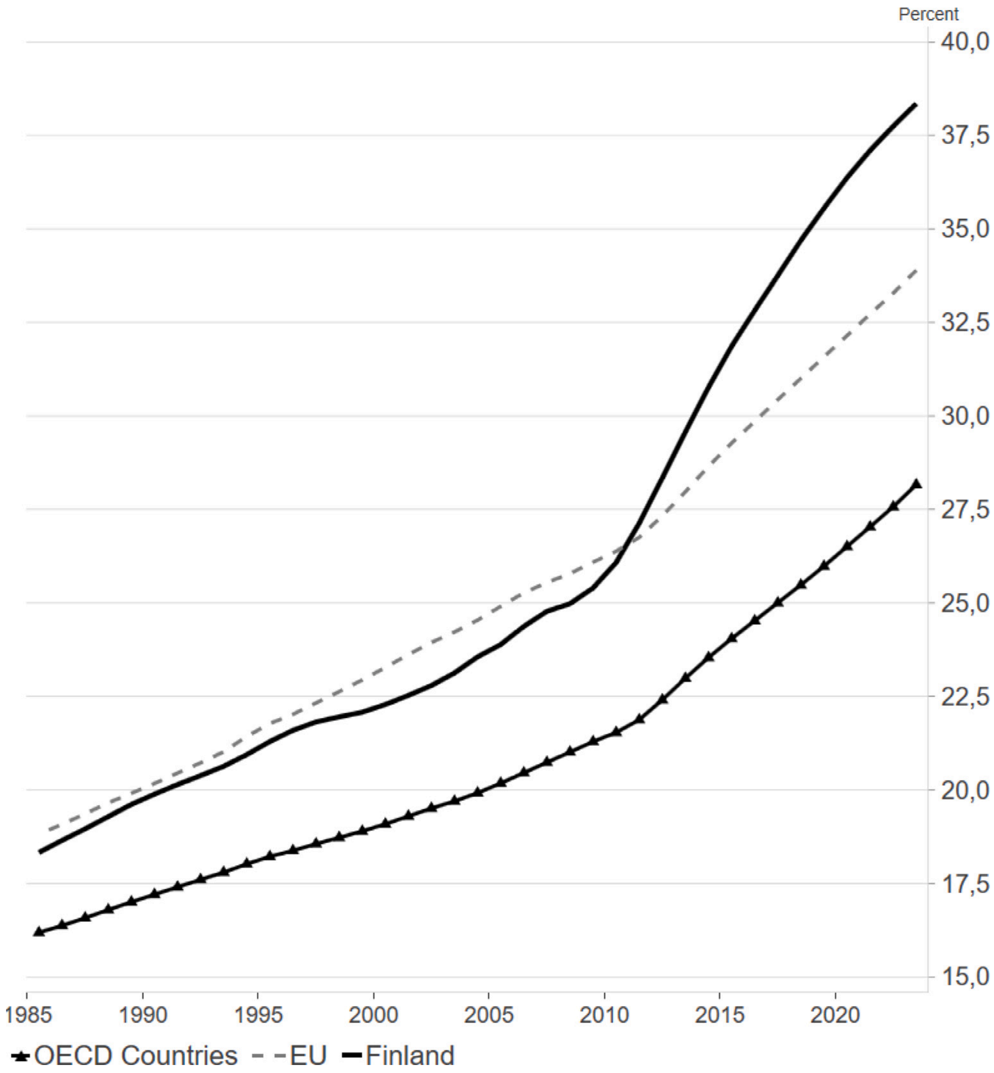


Fig. 1. Old-age dependency ratio in Finland, EU and OECD. Defined as the population aged 65+ divided by the working-age population (15–64 years), expressed as a percentage.
Source: World Bank.

ageing trend. Moreover, Sweden has actively promoted labour market participation among both older adults and women, reinforcing its demographic resilience. Denmark, Iceland and Norway share institutional characteristics with Finland but have experienced less acute ageing due to more balanced demographic inflows and slower transitions. While all Nordic countries are undergoing demographic ageing, the pace has been slower and the transition more gradual than in Finland, partly due to proactive institutional and demographic policy choices.

Several advanced economies are currently in a demographic "grace period", but are expected to face more pronounced ageing-related challenges in the near future. For example, the United States remains relatively young demographically due to its institutional history of immigration and higher fertility rates. Nevertheless, its old-age dependency ratio is steadily increasing. Importantly, Maestas et al. (2023) demonstrate that even in a dynamic and flexible economy like the U.S., ageing slows the growth of GDP per capita and productivity at the state level. This suggests that the core mechanisms observed in Finland are already unfolding in other countries as well. In Southern Europe, countries such as Portugal and Spain are on demographic paths that resemble Finland's, albeit with some delay. Without substantial anticipatory policy action, these countries may face similarly severe economic implications.

Finally, while institutionally different, China presents a particularly notable case due to its growing influence in the global economy. After decades of benefiting from demographic momentum driven by a growing working-age population, China is now undergoing a sharp demographic inversion. This shift is the result of long-term effects from the one-child policy, persistently low fertility rates, and rising life expectancy. Although China's economic structure differs significantly from that of Finland or other OECD

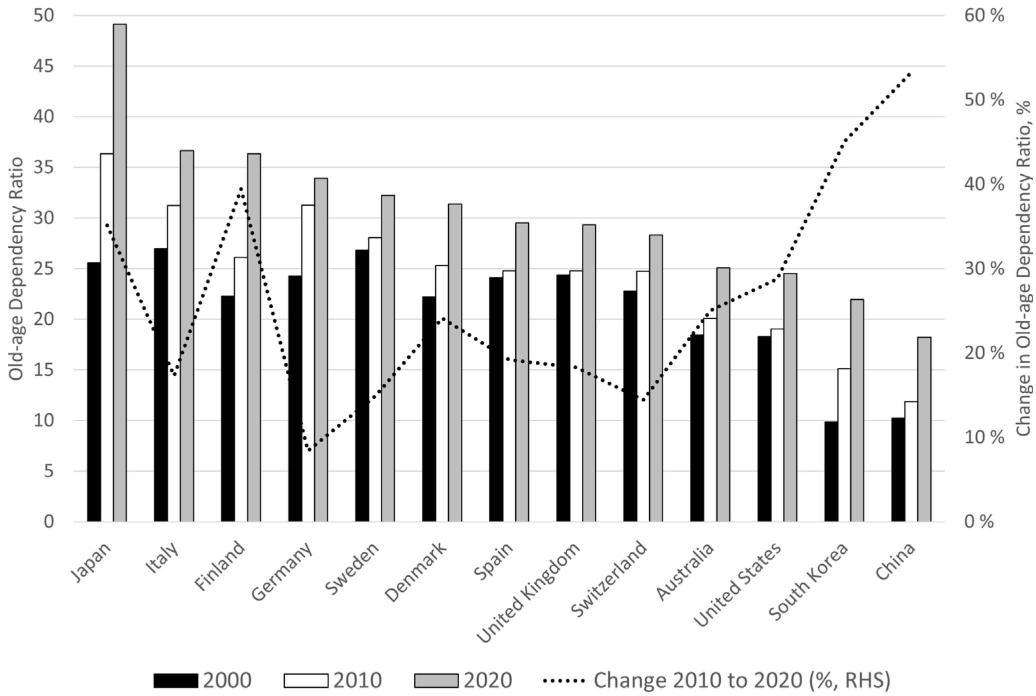


Fig. 2. Old-age dependency ratio in various countries in 2000, 2010 and 2020 and relative change in old-age dependency ratio between 2010 and 2020.
Source: World Bank.

countries, the fundamental mechanisms of population ageing are beginning to emerge. However, the country's distinct institutional context introduces additional complexities that may either magnify the challenges of ageing or alter the way these challenges develop. As such, China offers a critical example of a non-OECD country where the speed and potential economic consequences of demographic ageing may be even more substantial, particularly if structural reforms in areas such as pensions, healthcare, and rural–urban integration fail to progress simultaneously with demographic change.

These comparisons demonstrate both the generalisability and distinctiveness of the Finnish case. Core economic mechanisms, such as reduced labour supply, slowing productivity, and rising fiscal pressure, are already observable across many advanced economies (Aksoy et al., 2019; Maestas et al., 2023). As Cravino et al. (2022) show, ageing systematically shifts activity towards low-productivity, non-tradable sectors like healthcare and personal services. This structural transformation, driven by the consumption needs of ageing populations, partly explains Finland's productivity decline and is likely to affect other countries with similar demographic profiles.

However, Finland provides an unusually clear and early example of these dynamics, with minimal confounding factors such as large-scale immigration or overlapping reforms. This strengthens its role as a valuable empirical case for estimating the economic impact of ageing.

Moreover, Finland's scope for automation-led productivity gains is limited by the expansion of ageing-related public sector employment, especially in healthcare and social work sectors, which benefit less from potential automation. This sectoral shift supports the broader mechanism identified by Göbel and Zwick (2012), whereby ageing depresses aggregate productivity through industrial composition, not just individual labour supply effects.

Finland, thus, serves as both a cautionary tale as well as a forward-looking benchmark. It illustrates the consequences of rapid ageing with delayed policy response and offers insights into what other countries may face if similar demographic and structural trends remain unaddressed. Though Finland's demographic specifics may not be fully replicable, its economic outcomes and the urgency they signal are highly relevant for advanced economies preparing for their own ageing transitions.

3. Previous literature

The economic implications of population ageing have been a subject of active research since the early 1990s, as declining fertility rates and their long-term consequences became increasingly evident.[2] Numerous empirical studies have studied the potential causal

[2] For a comprehensive recent review of the literature, see, for example, Vlandas et al. (2021) or Bodnár and Nerlich (2022) for a euro area (EA) perspective.

links between population ageing and economic outcomes. A seminal contribution by Feyrer (2007) laid the empirical groundwork for this field.

Building on Feyrer's methodological approach, Maestas et al. (2023) examined the impact of ageing on GDP and its components in the United States. Exploiting state-level variation in population ageing and employing an instrumental variable (IV) strategy, they found that a 10% increase in the population share of individuals aged 60 and older reduces GDP per capita by 5.5%. Approximately one-third of this decline is attributable to slower employment growth, while the remaining two-thirds stem from reduced labour productivity growth.

Aiyar et al. (2016) investigated the effects of workforce ageing on productivity in the EA, projecting that ageing will reduce 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, indicating that a 1 percentage point increase in the 55–64 age cohort is associated with a 0.75 percentage point decline in TFP growth. Similarly, Calvo-Sotomayor et al. (2019) found that a 1% increase in the size of the older workforce (aged 55–64) is associated with a 0.1 to 0.5% decline in productivity. Chen et al. (2025) also report a significant decline in patent applications per capita attributable to population ageing, driven by rising labour costs and increased demand for less-innovative goods and services.

A common methodological feature in the studies by Feyrer (2007), Aiyar et al. (2016), and Calvo-Sotomayor et al. (2019) is the use of lagged demographic trends as instruments for current population structure, which are arguably exogenous to contemporaneous economic outcomes. Maestas et al. (2023) instead used projected demographic changes as instruments, a strategy closely aligned with our IV approach. The underlying assumption is that projected demographic changes, based on fertility and mortality trends established before the economic outcomes, are exogenous to contemporaneous economic shocks, enabling causal inference. We adopt this approach in Section 6.

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 negatively affect economic growth, investment, savings, hours worked per capita, real interest rates, and inflation. According to the authors, these effects are substantial. They project that, due to population ageing, the annual growth rate will decline by 0.64% between 2015 and 2025. These results imply an elasticity of GDP per capita growth with respect to the old-age dependency ratio of 0.45. A similar approach is taken by Emerson et al. (2024), who estimate a panel of OECD countries from 1975 to 2014 and confirm the negative association between the old-age dependency ratio and economic growth. Uddin et al. (2016) examine the Australian economy and reach a similar qualitative conclusion using a variety of econometric methods.

Compared to economic growth, the relationship between ageing and productivity seems to be more complex with recent studies offering varied conclusions. Ozimek et al. (2018) confirm 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 captured in the studies on economic growth, but the approach provides new evidence on the transmission mechanisms. One such mechanism may be the reluctance of older workers to adopt new technologies, potentially diminishing firm-level productivity gains. This technological conservatism, particularly in ICT-intensive sectors, may help explain the observed productivity stagnation in Finland, a country significantly affected by the decline of its information and communications technology (ICT) sector. As the average age of Finnish workers has steadily increased, technology diffusion[3] may have slowed precisely when investment in new technologies was most needed.

Conversely, some research suggests that ageing may positively affect productivity through increased automation. Acemoglu and Restrepo (2017, 2022) argue that ageing induces greater adoption of automation technologies, which can enhance productivity. Although they do not provide specific elasticities or quantitative estimates, they highlight the potential importance of this mechanism. In principle, this "automation response" could offset labour force decline by boosting productivity per worker. However, Finland's adoption of automation has been uneven across sectors (Kuosmanen et al., 2024). While some manufacturing industries have experienced moderate increases in automation, service sectors, particularly health, education, and social services, remain labour-intensive and have benefited less. Therefore, although the theoretical potential for productivity-enhancing automation exists, Finland's sectoral structure may have limited its effectiveness.

Furthermore, Göbel and Zwick (2012) examine sector-specific ageing effects and find that the productivity impact of older workers varies significantly across industries. Applied to the Finnish context, the findings in Section 5 align with a compositional explanation: as the population aged, employment shifted from higher-productivity manufacturing sectors towards lower-productivity service sectors, particularly public services such as elderly care and healthcare. This structural transformation may reduce aggregate productivity even if within-sector productivity remains constant. These results are consistent with the findings of Cravino et al. (2022) and, to some extent, with those of Tamai and Wang (2025).

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, we formalise an overlapping generations model in Section 4, showing that the positive correlation between ageing and growth breaks down in a small open economy with endogenous labour supply and distortive taxation.

[3] For example Pulkki-Brännström and Stoneman (2013), Stokey (2021) and Labhard et al. (2025).

4. Theoretical considerations

Our theoretical framework and testable hypothesis are illustrated using a Diamond–Samuelson OLG model.[4] For our purposes, we augment the standard textbook formulation by incorporating a public sector with distortionary taxation and assuming a small open economy (SOE) setting. In a later extension, we introduce simple mechanisms that link ageing and productivity.

The model by Eggertsson et al. (2019) has received considerable attention in previous literature and serves as a valuable benchmark, but our results diverge due to key differences in assumptions. First, we incorporate distortionary taxation, reflecting the fiscal reality that a significant portion of the costs associated with population ageing arises from the need to finance public pay-as-you-go transfers through taxes that distort economic behaviour. Second, we treat labour productivity as an exogenous parameter, consistent with its central role in shaping long-run macroeconomic outcomes. Third, we adopt a SOE framework, which alters the dynamics of capital accumulation, which is a mechanism that is central to the results in Eggertsson et al. (2019).

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 framework for exploring the mechanisms of the relationships between population ageing and economic outcomes.

Consider the Diamond–Samuelson model, where consumers face a following optimisation problem:

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

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. The superscripts denote the population cohort: 1 denotes active population and 2 passive population (the old). Assuming the following lifetime utility function $U(.) = \ln c_t^1 - \gamma \frac{h_t^{1+\phi}}{1+\phi} + \beta \ln c_{t+1}^2$, where β is the discount factor and ϕ the parameter that governs the curvature of the disutility of labour, we obtain the following Euler equations:

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

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

where Eq. (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 $OADR = \frac{1}{(1+n)}$.

Furthermore, assume a sector, where output (y_t) is produced using capital (k_t) 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: $\frac{w_t}{\epsilon_t} = (1-\alpha)\left(\frac{k_t}{\epsilon h_t}\right)^{\alpha}$ and $r_t = \alpha \left(\frac{k_t}{\epsilon h_t}\right)^{\alpha-1} - \delta$. The labour income tax rate adjusts in order to achieve a balanced budget at all times, while subsidies to the elderly are $b_t = rr\, w_t \epsilon h_t$, where rr denotes the replacement rate. The public sector budget constraint is $N_t^1 \tau_t w_t \epsilon h_t = N_t^2 rr w_t \epsilon h_t$, which reduces to $(1+n)\tau_t = rr$. Initially $\epsilon_t = 1$.

If we assume a SOE, the local and global interest rates are equal and 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 the long-run steady state equilibrium, an increase in the old-age dependency ratio leads to lower GDP per employee.*

Proof. In the SOE environment, interest rate is given exogenously leading to constant $\frac{k}{\epsilon h}$ ratio and, thus, constant gross wage rate. From the Cobb–Douglas production function we can see that $y_t = \left(\frac{k_t}{\epsilon h_t}\right)^{\alpha} \epsilon h_t$ 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 Eq. (5), we get the following expression for steady state labour supply:

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

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 ($OADR$) and output per employee (y) have a negative association. □

[4] See Weil (2008) for a review of overlapping generations models.

The intuition behind Proposition 1 stems from the distortionary effects of taxation. As the population ages, the government must adjust tax rates upward to finance rising public expenditures, particularly those related to age-dependent transfers. These higher taxes reduce labour supply incentives, which constitutes the primary transmission channel in our SOE framework. This mechanism can also be interpreted through Ricardian equivalence: increases in public spending necessitate future tax hikes to maintain intertemporal fiscal balance.

The impact is even more pronounced when considering GDP per capita. This can be illustrated by expressing output per capita as

$$\frac{Y_t}{N_t} = y_t \cdot \frac{N_t^1}{N_t} = y_t \left(1 - \frac{1}{2+n}\right),$$

where $N_t = N_t^1 + N_t^2$ and n denotes the population growth rate. Differentiating with respect to n, we obtain

$$\frac{\partial\left(\frac{Y_t}{N_t}\right)}{\partial n} = \frac{\partial y_t}{\partial n} - \frac{\partial\left(\frac{y_t}{2+n}\right)}{\partial n} > \frac{y_t}{n} > 0,$$

indicating that a decline in the share of the working-age population reduces GDP per capita. This result combines two effects: the direct negative impact of distortionary taxation on labour productivity, and the demographic effect which leads to a decline in the ratio of active workers to total population.

In subsequent sections, we empirically investigate the relationship between population ageing and GDP per capita, aiming to quantify the magnitude of these theoretical effects.

While the model offers valuable insights into the interplay between ageing, taxation, and labour supply, it abstracts from endogenous policy responses. This limitation is particularly notable in the Finnish context, where public expenditures have risen substantially over the past decade, but tax rates have remained relatively stable. Consequently, the general government debt-to-GDP ratio has increased substantially. One notable policy intervention has been the gradual elevation of the statutory retirement age. However, this reform was implemented very late to effectively counteract the demographic pressures of the 2010s. Simultaneously, persistently low productivity growth has contributed to subdued aggregate output, suggesting that the relationships between ageing, taxation, and labour supply may also be affected by more complex human capital dynamics than the model presented in this Section captures.

A natural extension of the model would be to incorporate endogenous human capital investment. This could be achieved by augmenting the utility function to include time allocated to education or skill accumulation, e_t, such that:

$$U = \ln c_t^1 - \gamma \frac{h_t^{1+\phi}}{1+\phi} - A\frac{e_t^B}{B} + \beta \ln c_{t+1}^2,$$

where individual productivity is a function of human capital investment, $\epsilon = \epsilon(e_t)$. This formulation would allow the model to capture an endogenous productivity response to ageing analogous to the labour supply channel, as the incentive to invest in human capital diminishes under tightening fiscal conditions due to higher distortionary taxation.

Nevertheless, the effects of ageing on productivity may extend beyond the incentive effects of taxation. General equilibrium models often incorporate age-dependent productivity profiles, typically inferred from observed wage patterns, to account for these complexities without explicitly modelling all underlying mechanisms.[5] We adopt a similar approach in Proposition 2, while discussing the underlying mechanisms in more detail in the subsequent analysis.

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

Proof. Divide y_t by h_t to get $\frac{y_t}{h_t} = \left(\frac{k_t}{\epsilon h_t}\right)^{\alpha} \epsilon$. Remember that $\frac{k_t}{\epsilon h_t}$ 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 ageing decreases $\frac{y_t}{h_t}$. □

Possible explanations for the negative association between ageing and labour productivity (beyond the distortionary effects of taxation) may include: (1) the relationship between ageing and risk-taking behaviour; (2) the impact of an ageing workforce on productivity; and (3) the expansion of the service sector, particularly publicly provided services, which tends to lower the average productivity of the economy. In the following, these three channels will be discussed in greater detail.

Risk-taking behaviour

Entrepreneurial activity and innovation are frequently linked to risk-taking behaviour. Theoretical frameworks emphasise the importance of individual risk tolerance in occupational choice, suggesting that more risk-averse individuals are inclined towards wage employment, whereas those with greater risk tolerance are more likely to engage in self-employment (Kan and Tsai, 2006).

Empirical evidence indicates that risk aversion tends to increase with age, which may have implications for a range of economic behaviours, including investment decisions, career trajectories, and innovative output (Holt and Laury, 2002). These shifts in risk preferences over the life cycle can influence financial and occupational choices as well as broader life decisions such as family

[5] See Auerbach and Kotlikoff (1987) for a seminal contribution to applied macroeconomic modelling of ageing.

formation and political engagement. For example Breza and Kaur (2025) find large effects from improved labour market matching, which relies on the propensity for agents to switch jobs, which, in turn, relies on risk-taking preferences.

Immigration has been identified as a potential counterbalance to the economic effects of demographic ageing. Immigrants tend to be younger than the native population and may exhibit higher risk tolerance, which could contribute to entrepreneurial activity and innovation. For example, according to Koski (2024) individuals with immigrant backgrounds are disproportionately represented among patent holders and other innovators in several countries, including Finland. However, the scale of immigration in Finland has been relatively modest in recent decades, potentially limiting its macroeconomic impact compared to countries with higher immigration rates.

Recent research has attempted to quantify the relationship between ageing and risk preferences. Dohmen et al. (2017) use panel data from Germany and the Netherlands to estimate age-related changes in risk tolerance, controlling for cohort and period effects. Their findings suggest that average risk tolerance declines until approximately age 65, after which it stabilises. They estimate that each additional year of age reduces risk tolerance by approximately 0.023 standard deviations, implying that a 10-year increase in median age could reduce average risk tolerance by 0.23 standard deviations.

While the estimates in Dohmen et al. (2011, 2017) are subject to methodological limitations and may not provide general implications across different contexts, they provide a framework for considering the economic implications of demographic change. For instance, if similar dynamics apply to Finland, the observed increase in median age between 2000 and 2023 could be associated with modest declines in equity investment and entrepreneurial activity. These effects, though illustrative, point towards the potential for demographic ageing to influence aggregate economic behaviour over time.

The broader implication is that shifts in population age structure may gradually alter the distribution of risk preferences within the economy, with potential consequences for innovation, firm dynamics, and labour market fluidity.

Workforce ageing

Individual labour productivity tends to increase until approximately age 40–50, after which it generally declines, although with considerable heterogeneity across individuals, occupations, and education levels (Skirbekk, 2004). At the population level, this pattern has measurable macroeconomic implications. For instance, Aiyar et al. (2016) estimate that a one percentage point increase in the labour force share of individuals aged 55–64 is associated with a 0.25–0.70 percentage point reduction in annual labour productivity growth. Similarly, Calvo-Sotomayor et al. (2019) report a negative association of 0.1–0.5 percentage points.

The risk of disability also rises significantly with age. In Finland, individuals aged 55–62 face a tenfold higher risk of work disability compared to those aged 25–34. Over the past two decades, Finland has seen a marked increase in the employment of older workers: between 2000 and 2022, employment among those aged 50–59 rose by 43,000, and among those over 60 by more than 183,000. This increase has offset a slight decline in employment among individuals under 50. While this trend reflects successful labour market integration of older cohorts, it may have contributed to slower aggregate productivity growth.

Maestas et al. (2023) provide further evidence using U.S. data, showing that a 10 percentage point increase in the population share aged 60+ reduced per capita GDP by 5.5%, with two-thirds of the decline attributable to slower labour productivity growth.

Some studies suggest that post-retirement employment may be less affected by age-related productivity declines, as it often involves self-selection of healthier and more motivated individuals. However, the broader macroeconomic effects of an ageing workforce remains a concern. The literature generally finds a negative relationship between workforce ageing and productivity at the macro-level, though micro-level findings are more mixed.

Ozimek et al. (2018) explore potential spillover effects of ageing in the workplace, contrasting two hypotheses: the "albatross" hypothesis, where older workers reduce firm productivity, and the "wise man" hypothesis, where they enhance it through knowledge transfer. Their findings lend more support to the former, suggesting that older workers may resist productivity-enhancing technologies and, therefore, diminish firm-level productivity gains. An alternative perspective is offered by Acemoglu and Restrepo (2017), who hypothesise that ageing-induced labour shortages may incentivise firms to invest in automation, potentially offsetting productivity losses.

In conclusion, while the ageing of the workforce is a well-documented demographic trend, its net effect on productivity seems to be at least somewhat context-dependent. Macro-level studies tend to find negative effects, whereas micro-level analyses reveal more varied outcomes influenced by job characteristics, health, and institutional factors.

Service sector expansion

Demographic ageing is a key driver of structural transformation in advanced economies. As the population ages, demand shifts towards services, particularly health care, long-term care, and leisure-related sectors, resulting in a gradual reallocation of economic activity from manufacturing and industry to services. This process is a consequence of rising incomes and changing demographic profiles.

In Finland, the share of services in total value added has increased from approximately 50% in 1975 to around 70% in recent years. This trend mirrors developments in other high-income countries and is expected to continue as the population ages further. Older individuals not only require more intensive health and social services but also tend to consume more leisure and cultural services, contributing to the expansion of the service economy.

While the shift towards services is a natural feature of economic development, it has important implications for aggregate productivity. Recent research emphasises the complexity of this relationship. Daniele et al. (2019) have shown that productivity growth in services, particularly in publicly provided services, is generally lower than in manufacturing, and argue that the expansion of low-productivity services can lower aggregate productivity, especially when labour reallocation is driven by demographic pressures rather than technological progress. Similarly, Cravino et al. (2022) show that sectoral shifts towards services can increase inequality and reduce aggregate productivity growth, particularly when service sector productivity is stagnant. As the service sector expands, its productivity performance becomes increasingly important for overall economic growth.

These findings emphasise the importance of institutional design and incentive structures in service provision. In particular, the division of labour between public and private providers may influence productivity outcomes. Private firms often operate under stronger incentives to innovate and improve efficiency, suggesting that a greater role for market-based service provisions might solve or mitigate some of the productivity challenges associated with ageing-driven structural change.

To conclude, population ageing contributes to the service-oriented transformation of the economy. While this shift is consistent with broader development trends, it poses challenges for productivity growth that warrant careful policy consideration, particularly in the design of service delivery systems and labour market institutions.

5. Synthetic control method approach

While panel data approaches and their applications summarised in Section 3 provide a basis for considering the effects of ageing, their causal interpretation can be ambiguous. One of our contributions is the application of econometric methods that allow for clearer causal inference.

Methodology

The SCM, originally introduced by Abadie and Gardeazabal (2003) and further developed in Abadie et al. (2010, 2015), is a case study approach designed to isolate the causal effects of structural changes or policy interventions by constructing a counterfactual scenario using a weighted combination of comparison units. A summary of the theoretical framework underpinning SCM is provided in Appendix A.

This study investigates the sharp acceleration in population ageing in Finland, as illustrated in Fig. 1. This demographic shift began around 2010, marked by a rapid increase in Finland's old-age dependency ratio relative to other advanced countries. The structural change examined is not just an increase in the elderly population, but a marked acceleration in the pace of ageing driven by historically low fertility rates and improvements in elderly health and longevity, resulting in a substantial increase in the old-age dependency ratio within a single decade. Unlike many other countries where this ratio has risen gradually, Finland experienced a rapid demographic transition that has placed considerable pressure on labour supply, productivity, and public finances. We study the economic implications of this accelerated ageing process by comparing Finland to a synthetic control group composed of countries with more gradual demographic transitions, treating the rapid change in the speed of ageing as the treatment rather than the level of ageing itself.

The treatment, Finland's accelerated ageing, is exogenous to the economic outcomes being studied. The demographic trends driving population ageing are mostly rooted in historical fertility and mortality patterns, which are largely unaffected by contemporary economic conditions. Consequently, variables such as real GDP per capita, productivity, and the general government debt-to-GDP ratio do not influence the demographic structure, substantially lowering reverse causality concerns and supporting the use of SCM to credibly estimate the causal impact of ageing on economic performance.

The SCM is particularly well-suited for this analysis for several reasons. First, Finland's demographic transition constitutes a discrete and exogenous structural shock, characterised by a sharp increase in the growth path of the old-age dependency ratio, which is unique compared to the smoother ageing trajectories observed in other advanced economies, making Finland an ideal 'treated unit' within the SCM framework. Second, the counterfactual scenario of what would have happened in the absence of rapid ageing is inherently unobservable, and traditional panel regression methods risk conflating the effects of ageing with other confounding factors. The SCM addresses this by constructing a synthetic Finland from a donor pool of countries that did not experience a similar demographic shock, enabling more credible causal inference. Finally, although population ageing is typically a gradual process, the unusually rapid pace of change in Finland during the 2010–2019 period approximates a natural experiment. By treating this acceleration as a structural break, the SCM enables us to isolate its economic effects from those associated with more gradual demographic trends.

The impact of rapid ageing is studied with three key economic indicators: GDP per capita, labour productivity, and government debt. The SCM facilitates the construction of a synthetic control group that closely mirrors Finland's pre-treatment characteristics, allowing for a more accurate estimation of the causal effects of ageing.

Our analysis focuses on Finland, with comparative data drawn from a broad set of countries, including EA members, EU countries, members of the OECD, and a selection of other countries with sufficient data availability. In total, the donor pool comprises 54 countries, providing a robust comparative baseline. Particularly, EU and OECD countries offer relevant benchmarks due to their comparable levels of economic development and institutional structures.

The SCM estimates the impact of ageing by comparing actual economic outcomes in Finland with those of a synthetic Finland, which is constructed as a weighted average of control countries that did not experience a similar demographic shock. This approach allows us to isolate the effects of rapid ageing from other contemporaneous economic developments.

Although SCM has been widely applied to study sudden economic changes and structural reforms, to the best of the authors' knowledge, it has not previously been used to examine the economic consequences of population ageing. Nonetheless, a growing body of literature has employed SCM to investigate related economic questions, particularly those involving the variables of interest in this study.

For instance, the evolution of real GDP has been studied using the SCM in several contexts: in a seminal paper, Abadie et al. (2015) study the impact of Germany's 1990 reunification; Campos et al. (2019) analyse the effects of EU membership on economic growth; Cieślik and Turgut (2021) examine the growth effects of the EU's eastern enlargement; Lehtimäki and Sondermann (2022) assess the impact of the European Single Market; Muchová and Šuláková (2022) explore the effects of Economic and Monetary Union (EMU) membership on the Baltic countries and Gabriel and Pessoa (2024) study how euro adoption has affected the economic growth of EMU member states.

In terms of productivity, the SCM has been used less frequently, but notable examples include Farid et al. (2020), who estimate a 2.24% decline in labour productivity following the Brexit vote, and Zhuang et al. (2023), who find that EMU membership enhanced productivity through business cycle synchronisation and labour market integration.

When it comes to government debt, relevant studies include Koehler and König (2015), who study the overall impact of the Stability and Growth Pact (SGP) on the EA; Strong (2023), who examine the effects of fiscal rules in the West African CFA zone; and Kraemer and Lehtimäki (2024), who investigate the influence of EU membership and the SGP on national debt levels.

Data

The data used in the SCM part of the study is compiled from the databases of international organisations and the Penn World Table (Feenstra et al., 2015) version 10.01. All data transformations, sources and descriptive statistics are listed in Appendix B.

A wide range of economic and demographic variables based on previous literature are included in the model to ensure the robustness of our findings. Along with previous literature, the selection is based on theoretical considerations and the specific institutional context of Finland's economic development during the study period to ensure that the SCM accurately captures Finland's pre-treatment characteristics while accounting for potential confounding factors that could bias the estimated effects of ageing.

The 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 ICT exports and an indicator for economic complexity. These controls aim to isolate the effect of population ageing on GDP per capita, labour productivity, and government debt, minimising potential confounding influences.

Real GDP per capita and government debt serve as baseline indicators of economic performance and fiscal position, while the age dependency ratio is the primary variable of interest. Government expenditure and inflation capture the scale of public sector activity and the macroeconomic policy stance (including monetary conditions), factors essential for matching countries with similar economic environments. Trade openness and interest rates control for external economic conditions, financial market dynamics, and debt servicing costs, which are particularly relevant for Finland as a small, open economy integrated into global markets.

The inclusion of structural and crisis-related variables addresses specific challenges that Finland faced during the post-2008 period, ensuring that the results isolate the effects of ageing rather than other shocks. The banking crisis dummy accounts for financial stability concerns, while the shares of gross capital formation and household consumption control for variations in economic structure across countries. Population size accounts for scale effects, and the economic complexity indicator captures structural changes and shifts in industrial composition. These variables are not only statistical controls but reflect substantive economic channels through which ageing effects could be confounded with other structural changes.

Beyond the effects from an ageing population, there are two primary factors behind Finland's sluggish economic performance following the global financial crisis: the decline of Nokia's mobile phone business and the deterioration of Finnish cost competitiveness.[6] In the model, the share of ICT exports directly controls for the "Nokia-shock", which significantly impacted the country's export structure and innovation capacity, whereas the cost competitiveness is captured by trade openness.

Results from the SCM

The main focus of the study is on the macroeconomic effects of ageing on real GDP per capita, productivity (real GDP per worker) and general government debt. Appendix C provides a full overview of the standard diagnostics used in SCM studies. Donor country weights for all comparison country groups are presented in Table C.1 and variable weights in Table C.2. 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 Fig. 3 present the main results for real GDP per capita across various 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 where the estimated gap is 17.6% in 2019.

[6] See Kajanoja (2019) for discussion about Finnish cost competitiveness and Kaitila et al. (2019) for discussion about the impact of the Nokia shock and cost competitiveness aspects of Finland.

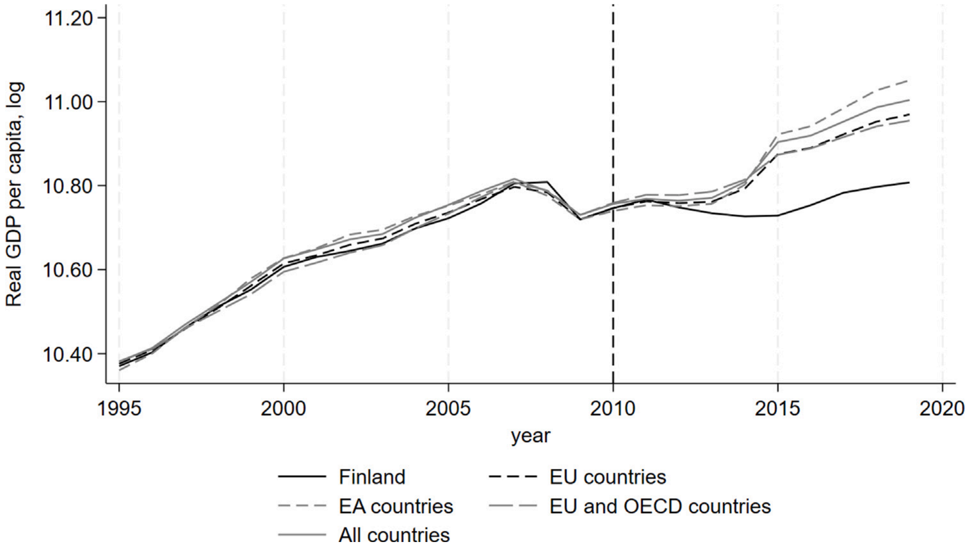


Fig. 3. Comparison of the economic growth of actual Finland (solid black line) with synthetic control groups constructed using different donor pools. Vertical dashed line marks treatment year (2010) when Finland's population ageing accelerated.

Table 1
Actual and synthetic log real GDP per capita, differences in 2019 and descriptive statistics for all comparison groups.

	Actual	Comparison group, 2019			
		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

Notes: Results from SCM comparing Finland with various donor pools, 1995–2019. 'Actual Finland' is the observed real GDP per capita in 2019. 'Difference' is the gap between actual and synthetic Finland. RMSPE = Root Mean Square Prediction Error measuring quality of pre- vs. post-treatment fit. Treatment year: 2010.

The substantially lower GDP per capita observed for Finland in the post-treatment period is not only a statistical association but can be interpreted through several underlying causal mechanisms. First, the rapid increase in the old-age dependency ratio led to less labour force participation. With a lower share of the population actively engaged in the labour market, aggregate output declined, particularly in the absence of compensating productivity gains, which did not materialise during the studied period. Second, the fiscal pressure associated with increased public spending on pensions and healthcare led to increased government expenditure and borrowing as well as expectations of increased taxation at some stage, which in turn can distort labour supply decisions and reduce economic efficiency. This mechanism is also predicted by the OLG model in Section 4.

Fig. 4 displays the observed trajectory of productivity (real GDP per worker) alongside the synthetic control groups, while Table 2 reports the corresponding results and statistics. The results indicate that Finland's productivity was between 8.4% and 13.9% lower in 2019 compared to the synthetic counterfactuals. Among the comparison groups, the EA sample yields the highest RMSPE ratio, suggesting the best model fit for this specification.

The observed lower growth of labour productivity is consistent with several underlying channels. One channel is compositional: an older workforce is, on average, less likely to adopt new technologies and may work fewer hours or experience declines in physical and cognitive efficiency (Aiyar et al., 2016; Ozimek et al., 2018). Another mechanism involves structural change: as the population ages, economic activity shifts towards lower-productivity service sectors, particularly publicly funded care sectors. This sectoral reallocation can lower aggregate productivity by increasing the relative weight of less productive industries in the economy.

The results in Fig. 5 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 development.

The significant increase in the debt-to-GDP ratio in Finland likely reflects the interaction between higher age-related expenditures and slower economic growth. As output growth slows down while spending on pensions and healthcare rises, fiscal pressures

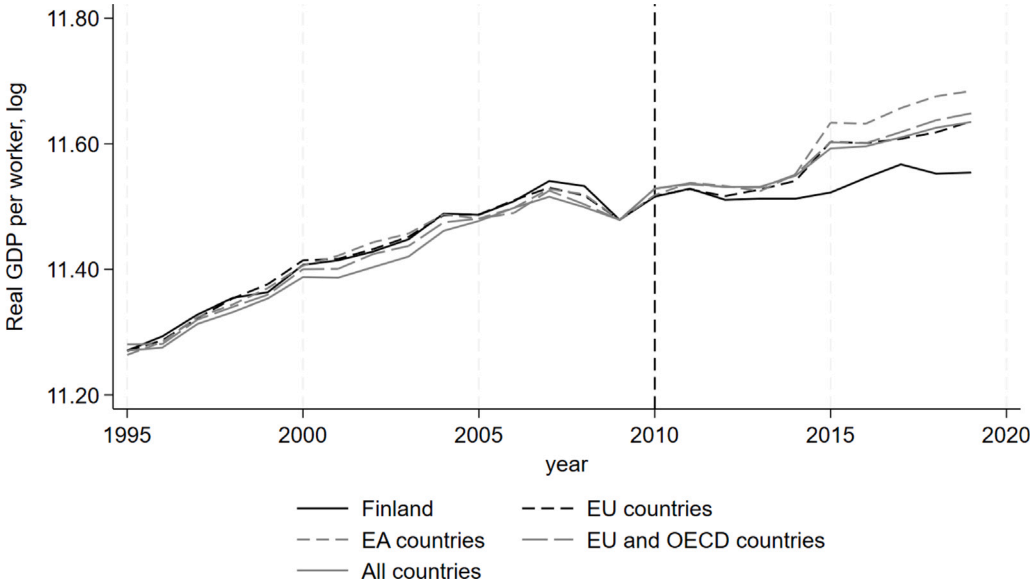


Fig. 4. Comparison of the productivity of actual Finland (solid black line) with synthetic control groups constructed using different donor pools. Vertical dashed line marks treatment year (2010) when Finland's population ageing accelerated.

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

Notes: Results from SCM comparing Finland with various donor pools, 1995–2019. 'Actual Finland' is the observed productivity in 2019. 'Difference' is the gap between actual and synthetic Finland. RMSPE = Root Mean Square Prediction Error measuring quality of pre- vs. post-treatment fit. Treatment year: 2010.

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

Notes: Results from SCM comparing Finland with various donor pools, 1995–2019. 'Actual Finland' is the observed general government debt in 2019. 'Difference' is the gap between actual and synthetic Finland. RMSPE = Root Mean Square Prediction Error measuring quality of pre- vs. post-treatment fit. Treatment year: 2010.

increase, pushing debt levels higher. This dynamic is not just an accounting identity but the result of economic feedback loops: weaker economic growth reduces tax revenues, which in turn accelerates the accumulation of debt if expenditures are not simultaneously adjusted. This is rarely the case in public sector entities, which tend to react with at least some lag. These interactions emphasise the fiscal vulnerability associated with demographic ageing, particularly in the absence of offsetting policy adjustments or productivity gains.

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,

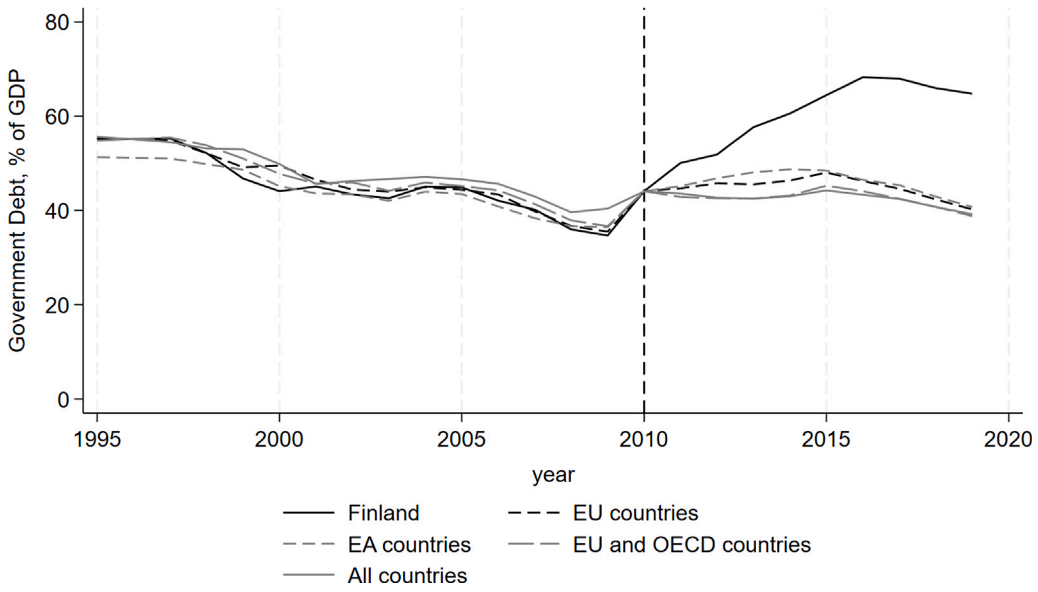


Fig. 5. Comparison of the general government debt of actual Finland (solid black line) with synthetic control groups constructed using different donor pools. Vertical dashed line marks treatment year (2010) when Finland's population ageing accelerated.

Table 4
Calculations for the future effect of ageing on the Finnish economy. Projections based on elasticities estimated from the EU comparison sample and demographic projections from World Bank.

	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

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.

Appendix D presents a wide range of common placebo experiments, which is a standard approach for assessing the robustness of SCM results. These placebo experiments consist of in-space and in-time placebo experiments as well as leaving out high-weight countries from the comparison sample. Finally, the results for all outcome variables are presented with only the age dependency ratio as a control variable. In all cases, the results remain generally unchanged.

The results of the SCM allow for broad projections of future economic outcomes based on observed elasticities. Using the comparison group with the highest RMSPE ratio, other EU countries, we estimate that between 2010 and 2019, Finland experienced declines of 17.6% in GDP per capita and 8.5% in labour productivity, alongside an increase of 26.9 percentage points in the debt-to-GDP ratio. Over the same period, the old-age dependency ratio rose by 36%, which is 21 percentage points higher than in the synthetic control. These changes imply elasticities (or a semi-elasticity in the case of the debt ratio) of −0.84 for GDP per capita, −0.50 for productivity, and 1.26 for the debt-to-GDP ratio.

According to World Bank projections, Finland's old-age dependency ratio is expected to increase by 15.2% between 2020 and 2029, and by 4.5% between 2030 and 2039. Applying the estimated elasticities, we project a decline in (or lower than anticipated) GDP per capita of approximately 12.8% in the 2020s and 3.8% in the 2030s. The corresponding effects on productivity and the debt-to-GDP ratio are reported in Table 4.

It is noteworthy that the projected economic impact diminishes over time, reflecting the slowing pace of population ageing in Finland. While a projected 3.8% decline in GDP per capita during the 2030s is not negligible, it is relatively modest compared to the losses observed in the previous decade. These projections are based on a ceteris paribus assumption, that is, they do not account for potential mitigating factors such as major technological advancements or structural policy reforms, which could offset the economic effects of ageing. Results would also change slightly if a different comparison group was used.

6. Instrumental variable approach

Despite the very robust results of the SCM approach, it is possible that the method does not fully account for the other shocks the Finnish economy experienced between 2010 and 2019. Therefore, we attempt a different approach to study the potential direct link between population ageing and economic outcomes to enhance the credibility of the results. Furthermore, this section provides an independent analysis of the impacts of ageing, as the data and methodology are distinct from Section 5.

Data

The data utilised in the IV approach is compiled from the public databases of Statistics Finland. The Population Structure database (Table 11re) provides detailed regional population figures, with historical demographic variables available beginning from 1751. However, for the purposes of this study, we focus on regional data starting from the 1970s, which aligns with the availability of other economic indicators and can be expected to better capture what the effects of ageing are in a "modern" economy as well as the beginning of the lowering trend of fertility rates. The GDP growth series, compiled from the Regional Accounts (Table 12bd), offers a robust measure of economic performance across different regions, with data available from the year 2000 onwards. Additionally, regional employment figures are retrieved from the Employment database (Table 115w), based on comprehensive registry data from 1987 onwards. This extensive dataset, spanning from 2000 to 2021 and covering 19 regions, provides a total of 418 observations, allowing for a broad analysis of the impact of population ageing on economic outcomes.

Descriptive statistics for central variables are presented in Table 5. The OADR shows significant variability across regions, with a mean of 32.27 and a standard deviation of 7.64. The predicted OADR is based on historical demographic trends and has similar variability. Changes in OADR over a ten-year period highlight the dynamic nature of demographic shifts, with some regions experiencing rapid ageing while others show more gradual changes. The economic variables, such as changes in labour productivity and GDP per capita, also display considerable variation, reflecting the diverse economic conditions across regions. To further illustrate these patterns, Figs. E.1, E.2, E.3, and E.4 in Appendix E provide visual representations of the regional heterogeneity in demographic and economic developments.

Table 5
Summary statistics.
Data source: Statistics Finland.

	Mean	Standard Dev	Min	Max
OADR	32.27	7.64	16.60	58.61
Predicted OADR	31.13	7.14	18.27	54.07
Change in OADR	23.13	10.44	−0.67	44.72
Change in predicted OADR	23.36	10.74	−1.15	48.17
Change in labour productivity	12.07	8.57	−14.41	33.68
Change in GDP per capita	13.90	13.03	−22.29	45.65

Notes: Descriptive statistics for Finnish regional data, 2000–2021. 'Change' refers to 10-year changes.

Methodology

We estimate the effect of ageing on GDP per capita and productivity using the approach of Maestas et al. (2023), who utilise state-level variation in the United States. In our study, the method is applied to the variation between geographic areas in Finland. The setup is, thus, similar even if the scale is different due to the United States being a large closed economy, whereas Finland is a small open economy.

To estimate the causal effect, we apply the IV approach. Our instrument, following previous research literature, is the predicted value of the old-age dependency ratio. The predicted value of the OADR is a valid instrument because it is based on historical demographic trends, which are exogenous to current economic outcomes. This helps in isolating the causal impact of population ageing on economic outcomes by controlling for variations in migration and mortality rates across regions.

Our model relates the OADR to the variables of interest. We use 10-year growth rates to mitigate the influence of short-term business cycle fluctuations and focus on the long-term structural relationships between population ageing and economic outcomes. The model is:

$$\ln\left(Y_{s,t+10}\right) - \ln\left(Y_{s,t}\right) = \beta\left[\ln\left(\frac{N^{65}_{s,t+10}}{N^{15}_{s,t+10}}\right) - \ln\left(\frac{N^{65}_{s,t}}{N^{15}_{s,t}}\right)\right] + \delta_t + \epsilon_t, \tag{8}$$

where Y denotes GDP per capita or productivity (GDP per employee), N^{65} the number of individuals aged 65 and older, N^{15} the total population older than 15 years, δ are time fixed effects and ϵ is the error term. The subscript s refers to area and t to time. The parameter β is an elasticity that measures the effect of the change in old-age dependency ratio on the change in the outcome variable. As we estimate the model in differences, we implicitly account for the fixed differences across areas.

While Eq. (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 lead to people to moving from one area to another, leading to a correlation between the dependency ratio and economic growth that might not be causal.

The solution to this issue, 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 region-specific variation to ensure that the instrument is not correlated with the error term. We calculate the change in the nation-wide old-age dependency ratio and use this measure to calculate the projected area-specific change in the OADR. Specifically, we use $\ln\left(\widehat{\frac{N^{65}_{s,t+10}}{N^{15}_{s,t+10}}}\right) - \ln\left(\frac{N^{65}_{s,t}}{N^{15}_{s,t}}\right) \equiv \Delta \ln \hat{A}$ as an instrument for $\ln\left(\frac{N^{65}_{s,t+10}}{N^{15}_{s,t+10}}\right) - \ln\left(\frac{N^{65}_{s,t}}{N^{15}_{s,t}}\right) \equiv \Delta \ln A$ from Eq. (8), where:

$$\widehat{\frac{N^{65}_{s,t+10}}{N^{15}_{s,t+10}}} = \frac{s^{55}_{t+10} N^{55}_{s,t}}{s^{15}_{t+10} N^{5}_{s,t}}, \tag{9}$$

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

$$\ln\left(\widehat{\frac{N^{65}_{s,t+10}}{N^{15}_{s,t+10}}}\right) - \ln\left(\frac{N^{65}_{s,t}}{N^{15}_{s,t}}\right) = \ln\left(\frac{s^{55}_{t+10}}{s^{5}_{t+10}} \frac{N^{55}_{s,t}}{N^{5}_{s,t}} \frac{N^{15}_{s,t}}{N^{65}_{s,t}}\right) \tag{10}$$

Eq. (10) implies that the area-specific variation comes from differences in population shares in the initial period (t), which is arguably exogenous to economic outcomes in the end period ($t+10$). It is worth noting that this paper focuses on the 10-year changes due to data limitations whereas Maestas et al. (2023) use up to 30-year time windows but obtain similar results across different time specifications.

Results of the IV method

Our research design with respect to productivity is illustrated in Fig. 6. The top figure shows the negative association between the 10-year growth rate of productivity (GDP per employee) and population ageing. The middle figure displays the first stage relationship between observed and predicted ageing. The bottom panel presents the relationship between productivity and our instrument.

The results from the IV approach are presented in Table 6. The second stage IV estimates are −0.478 and −0.716 for productivity and GDP per capita, respectively, with both parameters estimated accurately at below the 1% significance level. The F-statistic is large implying a strong first stage.

First, the result for productivity is roughly in line with Maestas et al. (2023) who obtain an estimate of approximately −0.5 for GDP per capita using U.S. state-level variation. It should be noted that the comparison between the results is not exact as the dependent variable in Maestas et al. (2023) is GDP per population over 20 years old, which is neither an exact measure for productivity nor GDP per capita. Nevertheless, the result is quantitatively 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.

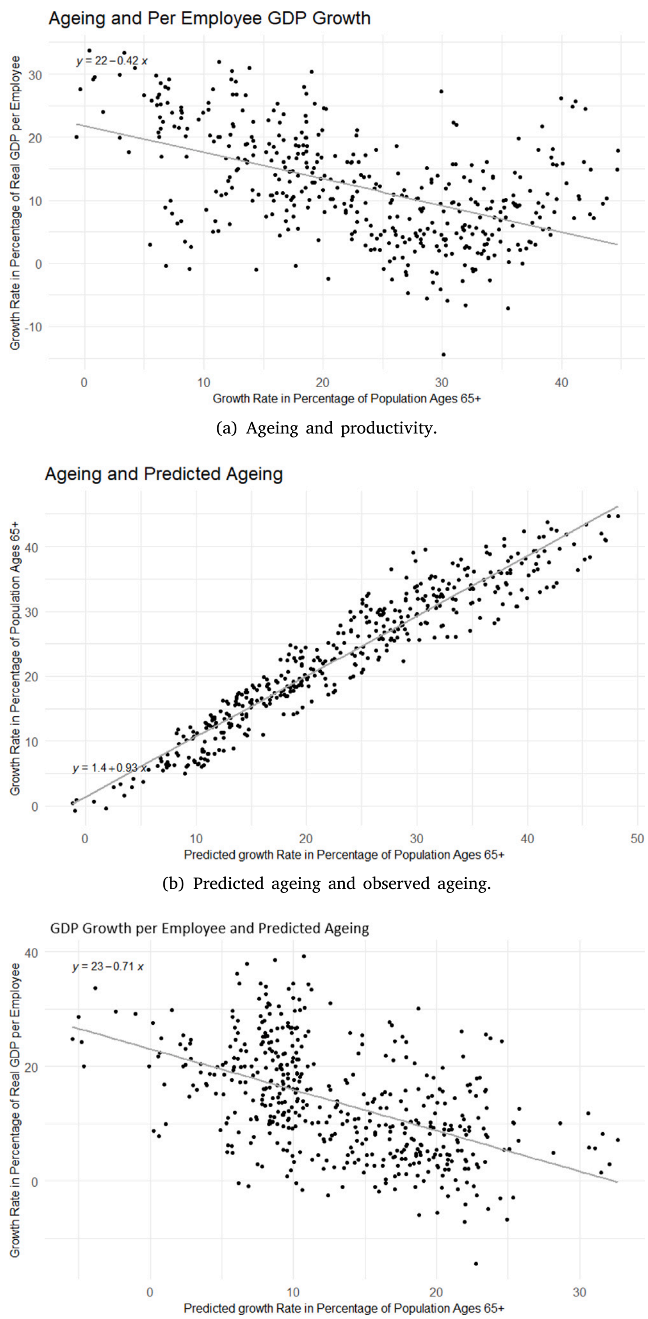
The insignificant value of the Wu–Hausman test suggests that the IV approach did not provide additional insights compared to the ordinary least squares (OLS) estimates. This raises the question of whether endogeneity is a significant concern in our model. Theoretical considerations indicate that the old-age dependency ratio is primarily influenced by long-term demographic trends which are less likely to be correlated with short-term economic fluctuations. The concern of endogeneity might also be smaller in Finland as immigration has been rather low in recent decades. Furthermore, OLS results are consistent with theoretical expectations and previous literature, which supports the validity of the OLS estimates.

The insignificant value of the Wu–Hausman test, while not problematic in itself, raises the question of whether the instrument can account for the possible endogeneity problem apart from migration flows, which calls for comprehensive robustness analysis. This analysis is presented in Appendix F and consists of varying specifications of the model, an analysis where each individual regions are left out of the sample and finally using the active population mortality rate as an instrument. The results remain robust across different approaches with only minor differences compared to the main results from the IV approach.

7. Conclusions

Many advanced economies are facing mounting challenges related to population ageing, driven by rising life expectancy and declining fertility rates. As these demographic shifts intensify, there is a growing need for macroeconomic research to understand their implications for economic performance and public finances, in individual countries as well as in a global context. This study contributes to that effort by examining the quite unique case of Finland.

Using a combination of empirical approaches, this paper provides a comprehensive assessment of the macroeconomic effects of ageing. Finland presents a particularly illustrative case due to its unique demographic trajectory, though similar trends are emerging or expected in many other advanced economies. The findings suggest that the economic and fiscal consequences of ageing are



(a) Ageing and productivity.

(b) Predicted ageing and observed ageing.

(c) Combined effects on productivity.

Fig. 6. Relationships between ageing, predicted ageing, and productivity growth. Each data point represents a region-decade observation. *Data source:* Statistics Finland.

substantial. As such, policymakers must adapt institutional frameworks to enhance economic resilience and ensure the long-term sustainability of public finances.

Applying the Synthetic Control Method, this paper finds 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 these estimates should be interpreted

Table 6
Results from instrumental variables regression.

	Reduced form estimates	
Dependent variable:	$\Delta \ln(GDP/E)$	$\Delta \ln(GDP/N)$
$\Delta \ln(\hat{A})$	−0.478* (<0.01)	−0.716*** (<0.01)
	First stage estimates	
Dependent variable:	$\Delta \ln(A)$	
$\Delta \ln(\hat{A})$	0.990*** (<0.01)	
F-statistic	2820***	
	Instrumental variable estimates	
Dependent variable:	$\Delta \ln(GDP/E)$	$\Delta \ln(GDP/N)$
$\Delta \ln(A)$	−0.483** (<0.01)	−0.724*** (<0.01)
Wu–Hausman test	0.156 (0.693)	0.178 (0.673)

Number of observations: 418. GDP/E denotes productivity and GDP/N is GDP per capita. Area level clustered standard errors are in parentheses. *** = significant at 1% level, ** = significant at 5% level, * = significant at 10% level. Other variables include decade dummies and initial period industry and regional level employment shares interacted with decade dummies. Δ refers to 10-year difference. Regressions are weighted according to regional population shares.

with some caution, given the continuous nature of ageing and concurrent economic developments such as the global financial crisis and structural industry shifts, they nonetheless point to large and wide-ranging effects. The results are robust across different donor pools and standard robustness checks.

The findings suggest that joining the EMU, adopting the euro, and the loss of independent monetary policy are unlikely to be the primary drivers of lagging economic growth and productivity in Finland, as the estimated effects are generally larger for the EA comparison group than for the broader EU and OECD samples. That said, these results should not be interpreted as definitive evidence regarding the role of EMU membership, as differences in country weights across comparison groups may also contribute to the observed patterns.

The study also employs an Instrumental Variable (IV) approach to further examine the causal effects of ageing. The IV results are broadly consistent with both the existing literature, particularly Maestas et al. (2023) as well as the SCM results. The consistency of the results across these two distinct empirical strategies, which rely on different sources of variation and data, reinforces the credibility and robustness of the conclusions.

Beyond quantifying the magnitude of the economic impacts of ageing, the study also enhances the understanding on the underlying mechanisms. Finland's rapid demographic transition has reduced the size of the active labour force, shifted economic activity towards lower-productivity sectors, and increased fiscal pressures, which have contributed to rising public debt. These channels, i.e. labour supply constraints, sectoral reallocation, and fiscal sustainability, are central to understanding how demographic change affects macroeconomic outcomes. They also offer valuable lessons for other advanced economies facing similar demographic challenges.

When it comes to policy advice, the substantial economic effects emphasise the critical importance of pre-emptive and adaptive policy responses to demographic transitions. Finland's experience suggests that the window for corrective action narrows considerably once rapid ageing accelerates and this makes reactive policies not only more costly, but also less effective. Countries currently undergoing gradual demographic changes should consider Finland's trajectory as a cautionary tale that emphasises the value of early intervention over delayed adjustment.

Several policy domains emerge as particularly relevant for mitigating the economic consequences of ageing. First, labour market policies aimed at extending working lives through flexible retirement options, age-inclusive workplace practices, and lifelong learning could help sustain productivity among older workers. Finland might have benefited from earlier implementation of such measures, especially given that productivity losses account for a significant share of the observed decline in GDP per capita. Second, immigration policy could play a more prominent role in addressing demographic imbalances. While politically sensitive, a well-designed, long-term strategy to attract working-age migrants could help stabilise the labour force. Third, fiscal policy must anticipate the rising costs of ageing, particularly in pensions and healthcare. Gradual, forward-looking reforms, rather than abrupt adjustments during periods of fiscal stress, may lead to more sustainable public finances in the long run.

The productivity challenges identified in the analysis point to the critical role of technological innovation and capital deepening in offsetting demographic headwinds. Finland's experience raises the possibility that earlier and more aggressive investment in automation, digitalisation, and productivity-enhancing technologies might have softened the economic impact of ageing. Education and skills policies should also adapt to support longer working careers and facilitate technology adoption across all age groups. Additionally, the significant increases in government debt levels point to the importance of building fiscal space during more favourable demographic periods to provide buffers for subsequent challenges.

For policymakers in countries facing similar demographic trajectories, Finland's experience offers a compelling, if sobering, lesson: the costs of inaction may far exceed the costs of early intervention. The observed declines in GDP per capita and productivity as well as the rise in general government debt represent substantial economic losses, which might have been partially mitigated through more proactive policy design. The broader implication is that demographic transitions demand long-term, strategic planning, ideally designed and implemented well before the most acute phases of ageing are taking place. Once the economic effects are fully realised, they may prove difficult and expensive to reverse.

Looking ahead, there are several promising 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 adjust 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 which makes corrective policy action easier to implement, especially if undertaken early enough. Further research should also explore the drivers of slowing economic growth and potential methods for enhancing productivity or developing new technologies, which could counteract the increasing ratio of elderly individuals to the labour force through efficiency gains.

CRediT authorship contribution statement

Mauri Kotamäki: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Formal analysis. **Jonne Lehtimäki:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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 $j = 2, \dots, J + 1$ 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 $t = 1, \dots, T$ 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 $W = (w_2, \dots, w_{J+1})'$ with $0 \leq w_j \leq 1$ of $j = 2, \dots, J + 1$ and $w_2, \dots, w_{J+1} = 1$. 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 $X_1 - X_0 W$).

By combining these elements, the formal approach can be defined. $m = 1, \dots, k$, X_{1m} is the value of the mth variable for the treated country, Finland, and X_{0m} is a $1 \times J$ vector of the values of the mth 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 mth variable when defining the difference between X_1 and $X_0 W$. 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 Eqs. (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.

Appendix B. Data description, descriptive statistics and sources

See Table B.1.

Table B.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

Appendix C. SCM weights

See Tables C.1 and C.2.

Table C.1
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 C.2
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.

Appendix D. Robustness of SCM results

Placebo experiments are a standard approach for assessing the robustness of synthetic control method (SCM) results. This section applies both in-space and in-time placebo tests to the Finnish case.

In the in-space placebo experiments, the treated unit is sequentially replaced by each country in the donor pool to test whether similar treatment effects emerge elsewhere. This is straightforward to implement using the full sample. The results are shown in Fig. D.1 for real GDP per capita, Fig. D.2 for productivity, and Fig. D.3 for government debt. In all three cases, the Finnish trajectories (black solid lines) rank among the most pronounced effects. Although larger effects arise for a some countries, these are associated with poor pre-treatment fits, indicating that the SCM could not capture a meaningful structural change in those cases.

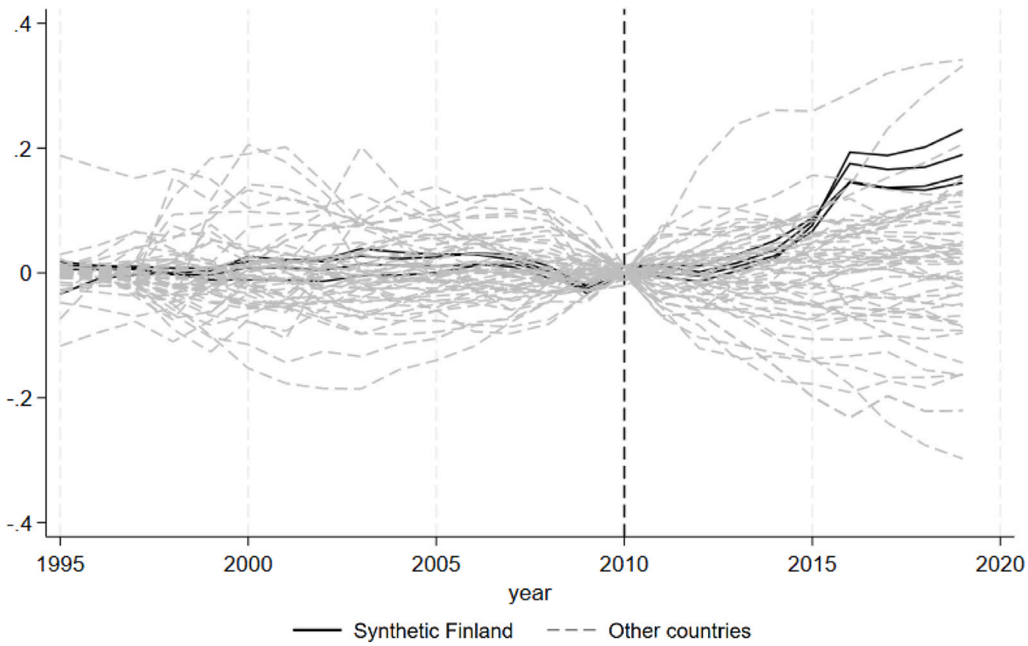


Fig. D.1. In-space placebo test for economic growth where each donor country is sequentially treated as if experiencing Finland's demographic shock in 2010. Finland shown as thick black line. Each grey line represents a placebo treatment for one donor country.

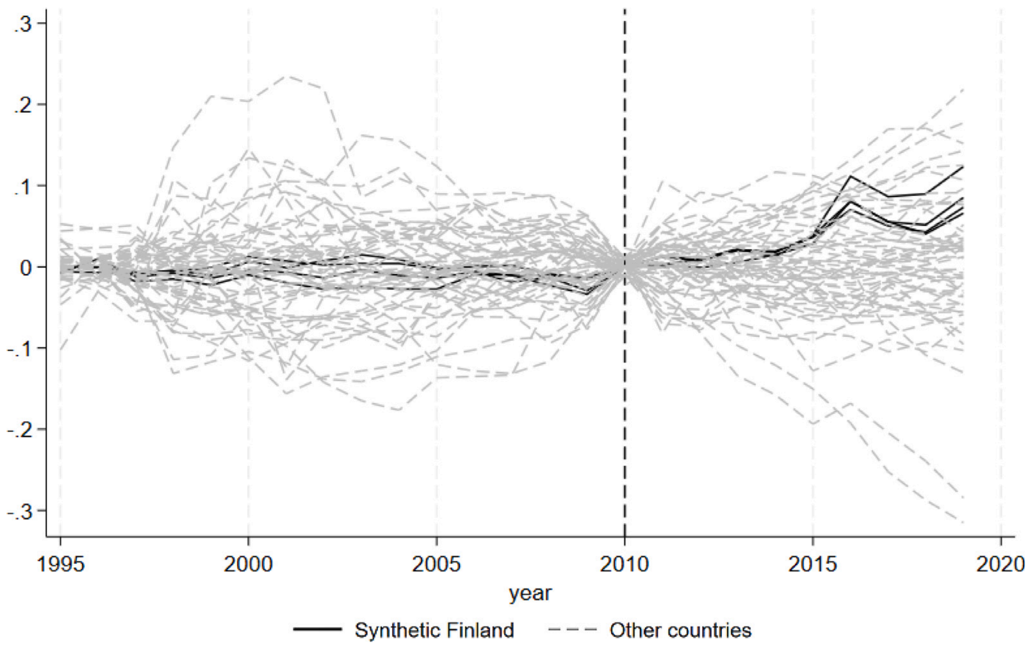


Fig. D.2. In-space placebo test for productivity.

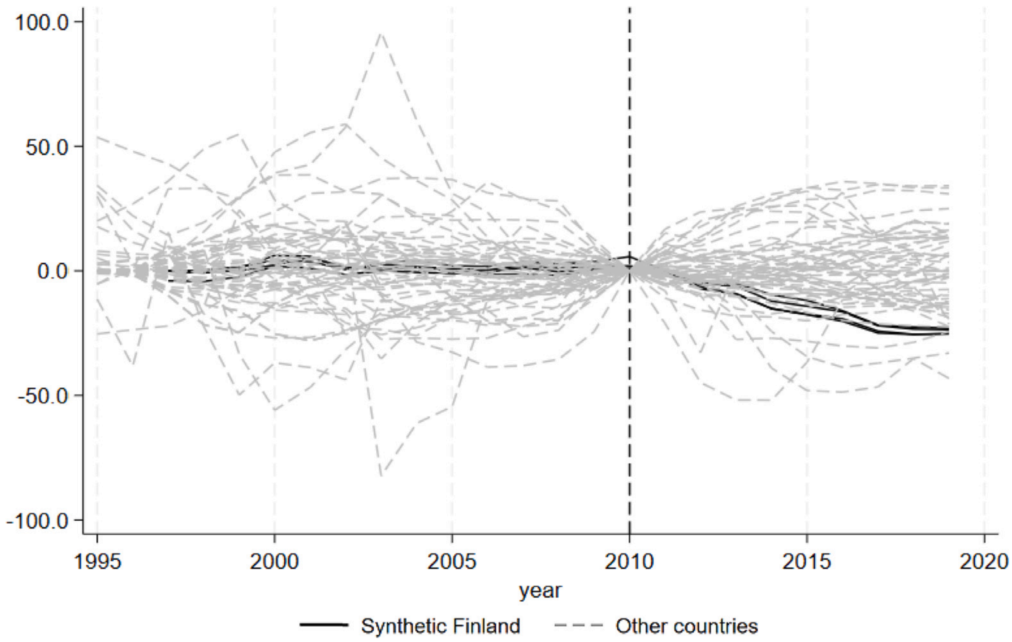


Fig. D.3. In-space placebo test for general government debt.

For *real GDP per capita*, four countries (Argentina, Croatia, Greece, and Nigeria) show larger effects than Finland, but all suffer from poor pre-treatment fits and receive zero weight in the main analysis. For *productivity*, the set is similar, with Croatia replaced by Hungary and the United States. Again, these countries exhibit poor pre-treatment fits and are not included in the weighted donor pool. For *general government debt*, countries with larger effects of the same sign include Argentina, Australia, Costa Rica, Nigeria, and Portugal. Some countries, such as Canada, Hungary, Poland, Sri Lanka, and Turkey, show large effects of the opposite sign. However, these cases also exhibit poor pre-treatment fits and receive no weight in the main SCM estimations. The more varied set of countries in the debt analysis may suggest that fiscal dynamics differ in nature from those of economic growth and productivity.

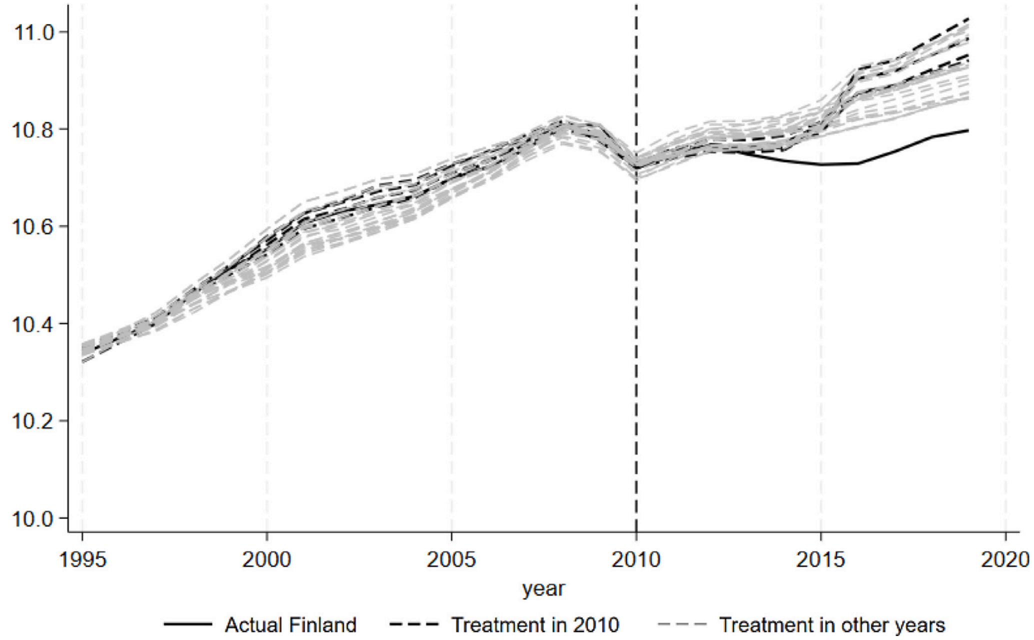


Fig. D.4. In-time placebo test for real GDP per capita with hypothetical treatment years 2007–2009 and 2011–2013 across all four donor pools, yielding a total of 24 placebo cases. Each line represents different comparison group. Actual treatment year (2010) falls within mid-range of placebo outcomes.

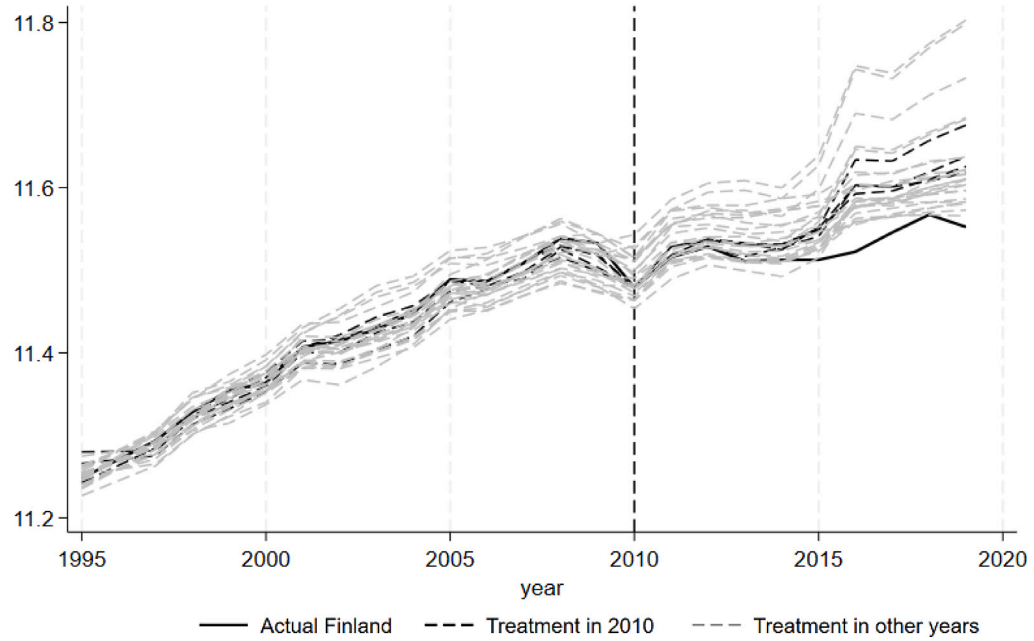


Fig. D.5. In-time placebo test for productivity.

Figs. D.4 to D.6 present the in-time placebo experiments, where the treatment is hypothetically applied in alternative years. For this analysis, treatment years are set from 2007 to 2009 and from 2011 to 2013 across all four comparison groups, yielding 24 placebo cases per outcome variable. The results for the actual treatment year (2010) generally fall within the mid-range of these placebo outcomes. Notably, pre-treatment fits are poor when the treatment is assigned before 2010. Although the fit improves slightly in 2011, it deteriorates again in subsequent years, reinforcing the appropriateness of 2010 as the treatment onset.

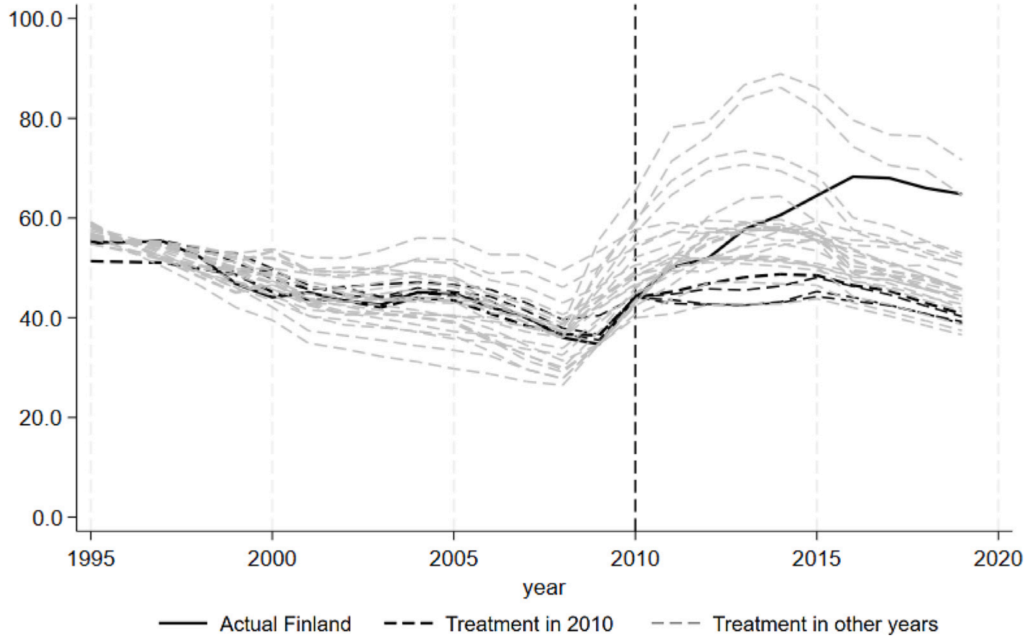


Fig. D.6. In-time placebo test for general government debt.

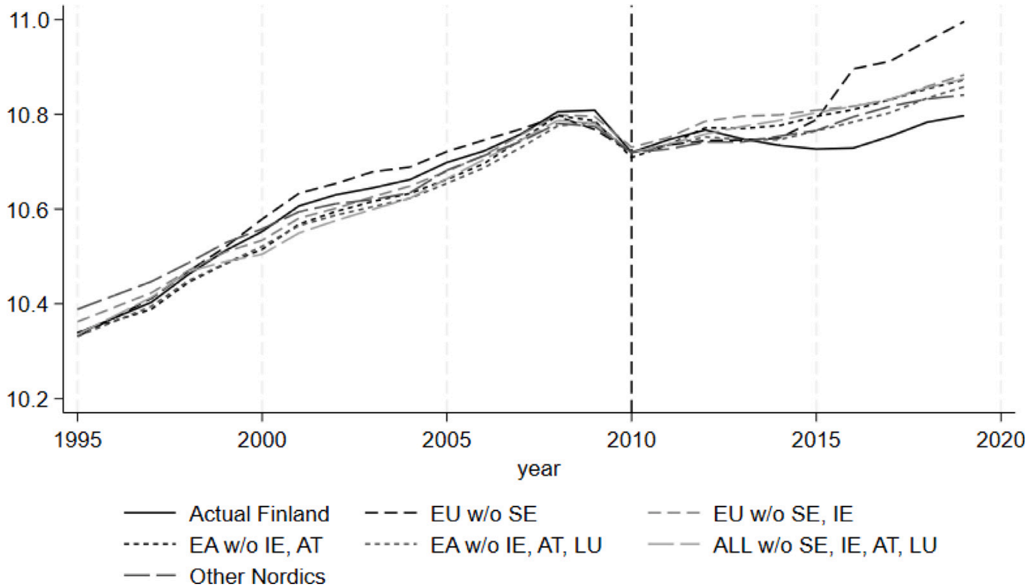


Fig. D.7. Robustness checks for real GDP per capita with high-weight countries iteratively removed.

Next, Klößner et al. (2018) note that SCM results in many studies may be disproportionately influenced by a single unit in the donor pool. Their critique primarily targets the United States, which, in our case, receives zero weight and is therefore not a concern for the Finnish analysis. However, in this study, Sweden consistently receives a relatively high weight across multiple specifications, followed by countries such as Ireland, Luxembourg, and others depending on the outcome variable.

While these countries share several economic similarities with Finland, there are also important structural differences that warrant further scrutiny. To assess whether our results are unduly driven by any single country, we conduct a robustness check by iteratively removing these high-weight countries from the donor pool as well as including only the other Nordic countries (Denmark, Iceland, Norway and Sweden) in the comparison sample. The results of this exercise are presented in Figs. D.7 to D.9.

For economic growth, the results remain qualitatively similar even after excluding Sweden, Ireland, Luxembourg, and Austria, the latter receiving a high weight in the EA comparison group. When these countries are removed, Denmark's weight increases,

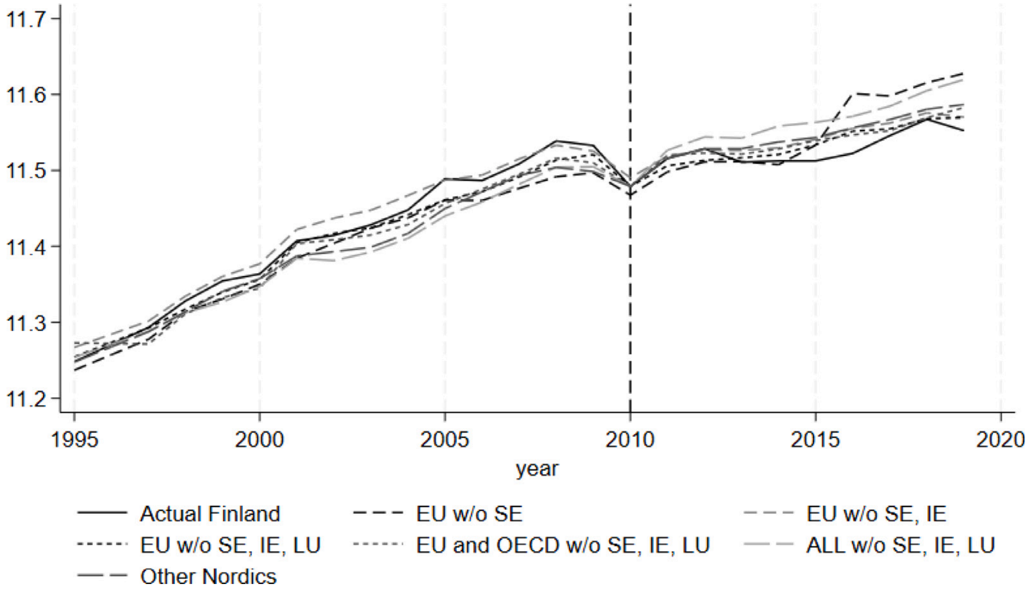


Fig. D.8. Robustness checks for productivity with high-weight countries iteratively removed.

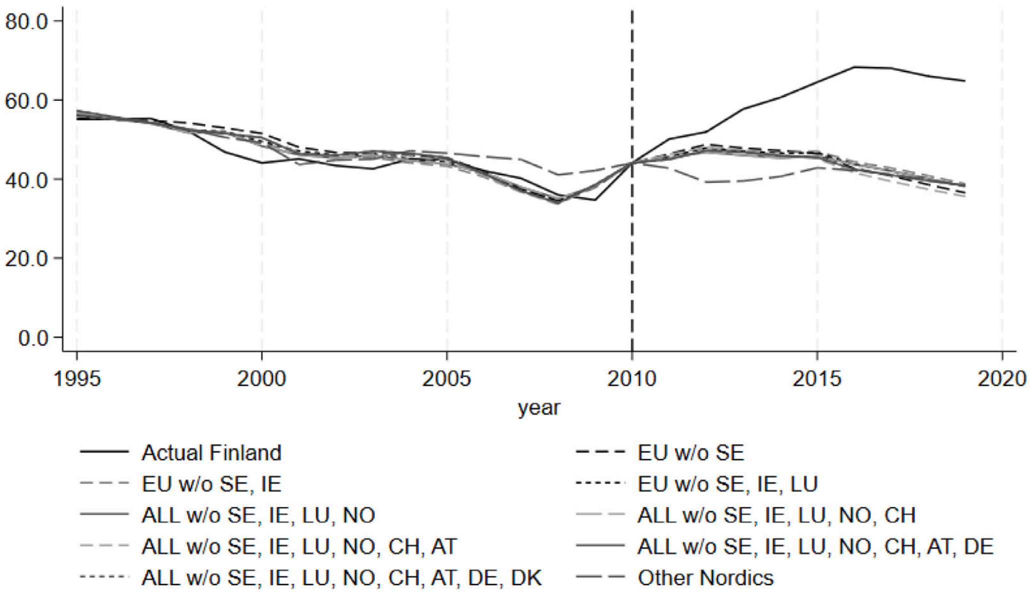


Fig. D.9. Robustness checks for general government debt with high-weight countries iteratively removed.

and additional countries such as the Czech Republic and Japan (in the full sample) receive some weight compared to the baseline specification.

For productivity, the results for the EU comparison group are somewhat influenced by Sweden. However, excluding Sweden also worsens the pre-treatment fit, suggesting a trade-off between robustness and model accuracy. In the larger samples, the results remain stable, with Denmark gaining additional weight and Iceland, Spain, and Switzerland entering the donor pool with small weights.

For government debt, the results remain largely unchanged, although the pre-treatment fit deteriorates slightly in some cases. After removing Sweden, Ireland, and Luxembourg, countries such as Norway, Switzerland, Austria, Germany, and Denmark receive high weights. To further test robustness, we iteratively exclude these five countries as well. In these extended placebo tests, France's weight increases, and new countries such as Japan, the Netherlands, Slovenia, and the United Kingdom enter the donor pool with small weights.

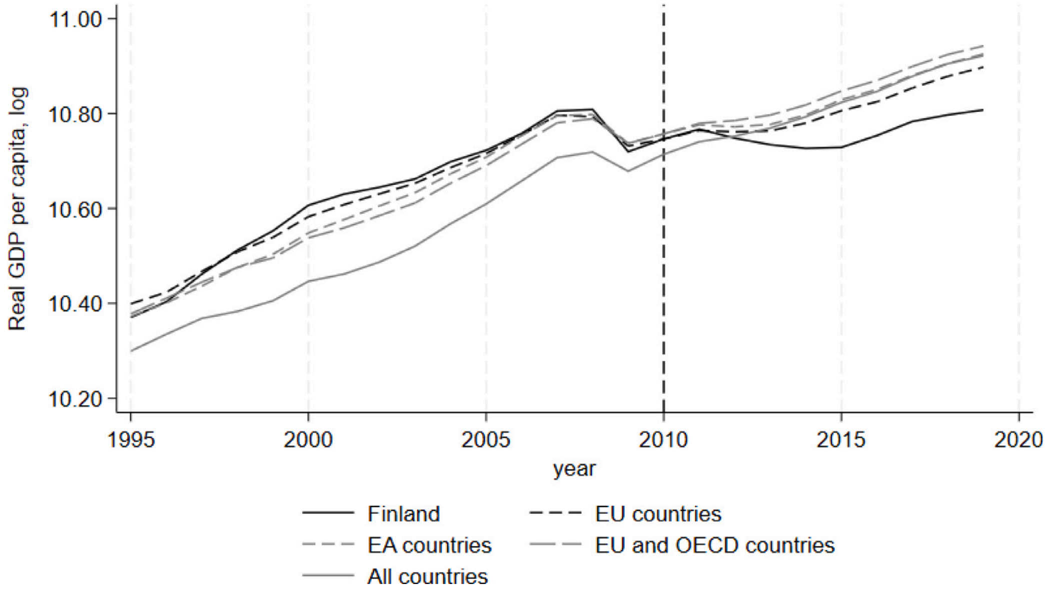


Fig. D.10. Real GDP per capita results with only the age dependency ratio as a control variable.

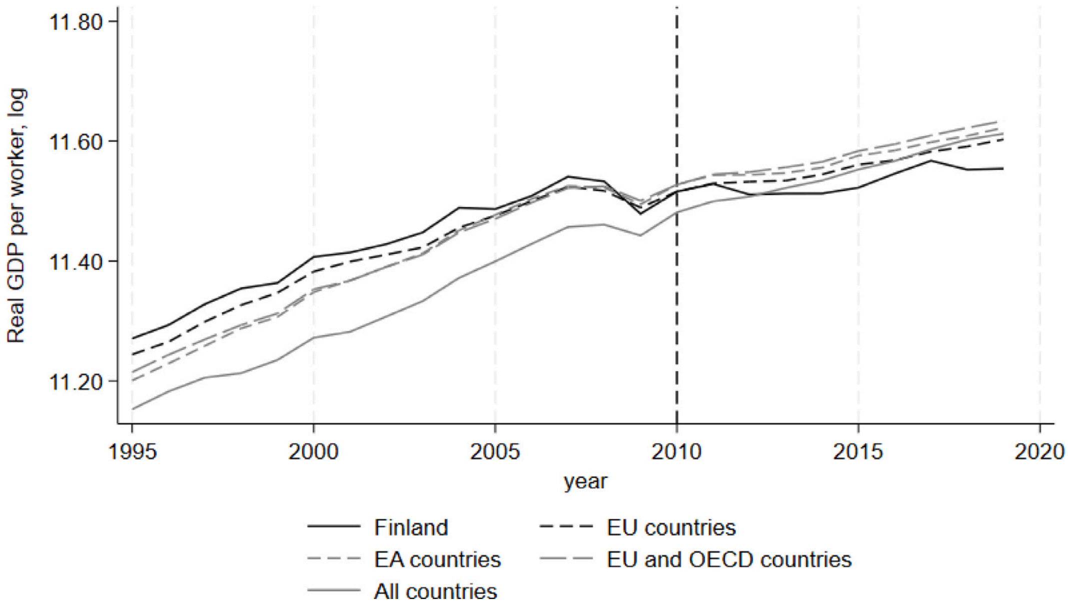


Fig. D.11. Productivity results with only the age dependency ratio as a control variable.

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 surprising as the country is, in many ways, the closest matching comparison country to Finland. Crucially, for the purposes of this study, Sweden has experienced significantly less demographic ageing than Finland, owing to markedly different historical population dynamics. This difference reinforces the validity of using Sweden as a key comparator while also highlighting the unique demographic trajectory that has caused Finland's economic challenges.

Finally, Figs. D.10 to D.12 present the results for all outcome variables across the different country groups, using only the old-age dependency ratio as a control variable. While the quality of pre-treatment matching is generally lower than in the main analysis, the results remain qualitatively similar. This reinforces the central role of demographic ageing in shaping the evolution of GDP per capita, productivity, and government debt.

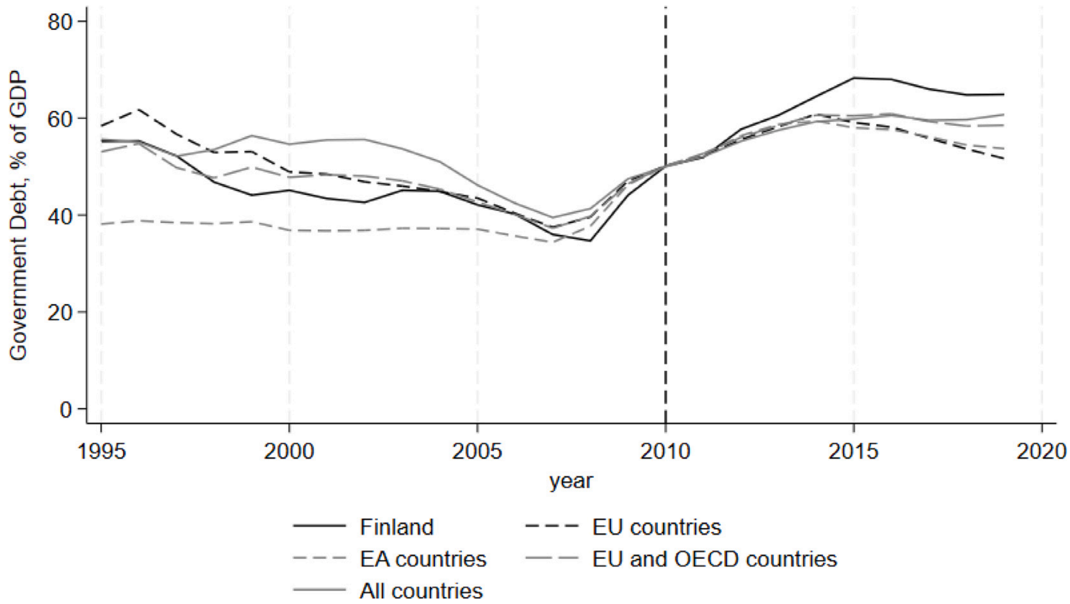


Fig. D.12. General government debt results with only the age dependency ratio as a control variable.

Appendix E. Data used in IV estimation

See Figs. E.1–E.4.

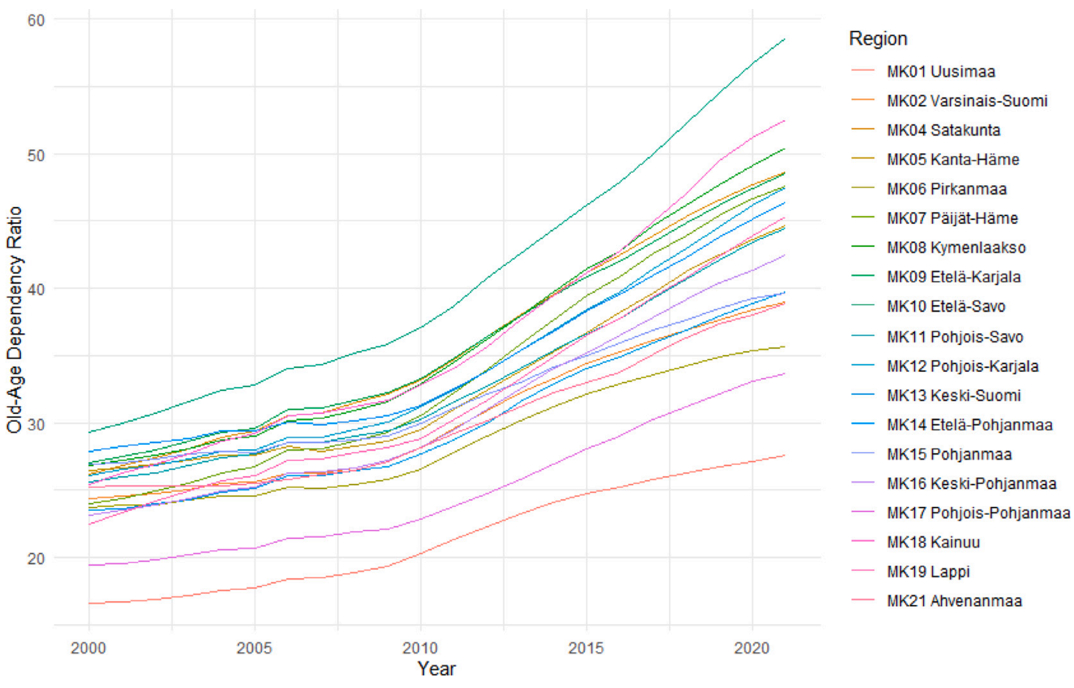


Fig. E.1. Old-age dependency ratio over time by region.

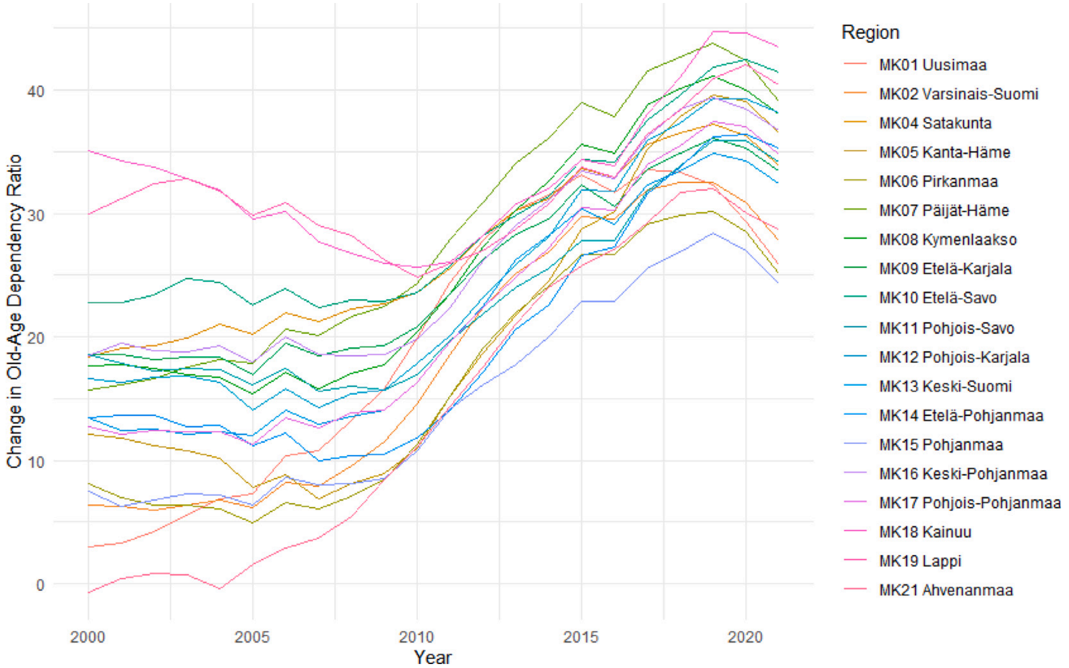


Fig. E.2. 10-year change in old-age dependency ratio over time by region.

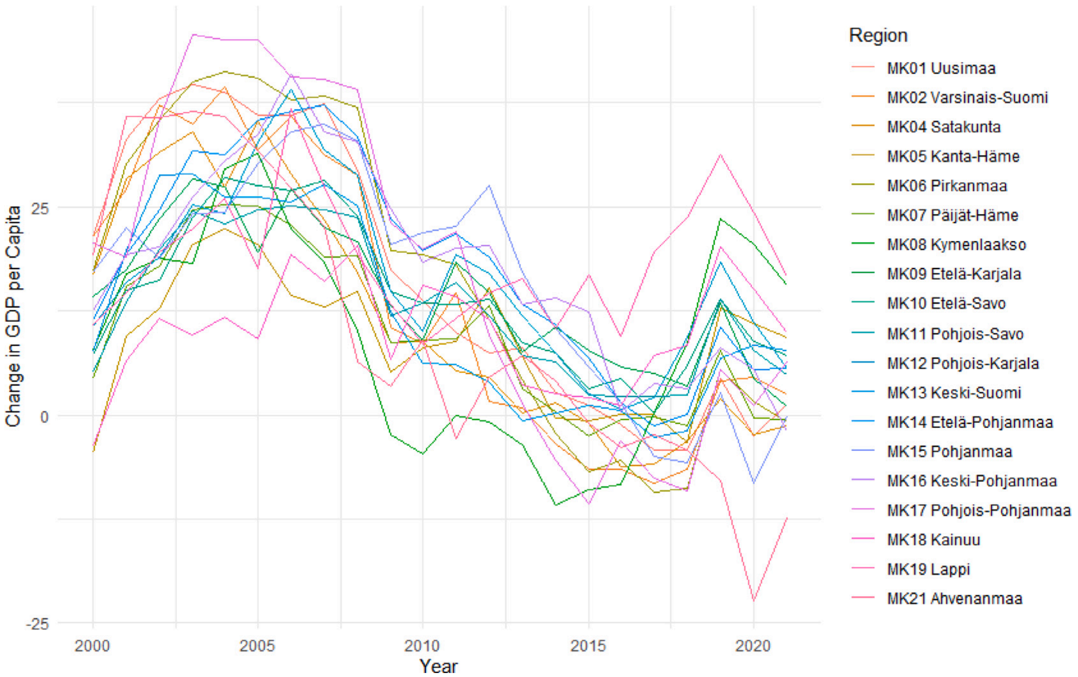


Fig. E.3. 10-year change in GDP per capita.

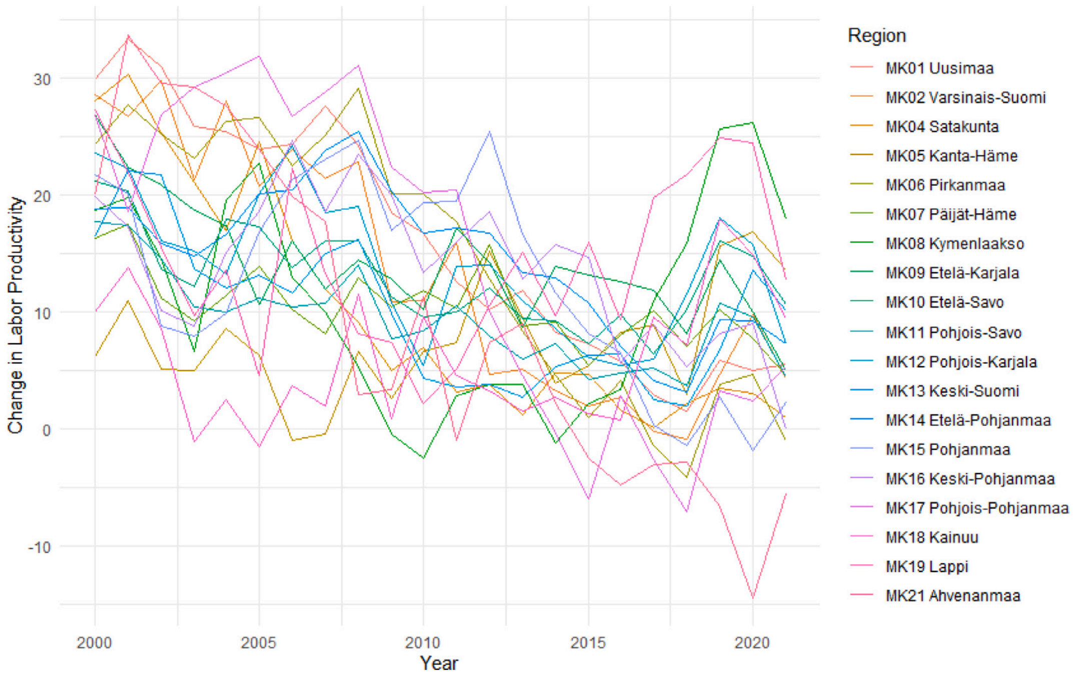


Fig. E.4. 10-year change in productivity.

Appendix F. Robustness of IV approach

This section explores the potential endogeneity issues of the IV approach provides robustness tests for the results in Section 6.

Varying specifications of the model

Table F.1 presents the results of adjusting the model to take into account potential factors through different specifications.

First, a region-decade interaction term is added to the model to show that regional shocks are not driving the results (columns (1) and (4)). This indeed seems to be the case as elasticities retrieved in this specification are very close to those obtained from our baseline model.

Second, the model is adjusted to not take the initial employment shares of industries into account (columns (2) and (5)). The elasticities in this specification are also clearly smaller than in the baseline model, but still sizeable and statistically significant. There is evidence, that the historical industry composition has long-run effects on economic outcomes (Maestas et al., 2013) and not taking this into account makes the elasticities smaller in absolute value terms.

Third, we remove the weighting and consider the results in a case where all regions have equal weight (columns (3) and (6)). The estimated elasticities in this specification are clearly smaller, but still negative and statistically significant. The findings suggest that larger regions have a more significant impact on the overall results.

Table F.1
Results from instrumental variables regression.

Dependent variable:	$\Delta \ln(GDP/E)$			$\Delta \ln(GDP/N)$		
	(1)	(2)	(3)	(4)	(5)	(6)
Second-stage estimate	−0.536*** (<0.01)	−0.383*** (<0.01)	−0.223*** (<0.01)	−0.793*** (<0.01)	−0.449*** (<0.01)	−0.545*** (<0.01)
Uniform weights	No	No	**Yes**	No	No	**Yes**
Initial employment shares	Yes	**No**	Yes	Yes	**No**	Yes
Region-decade interaction term	**Yes**	No	No	**Yes**	No	No

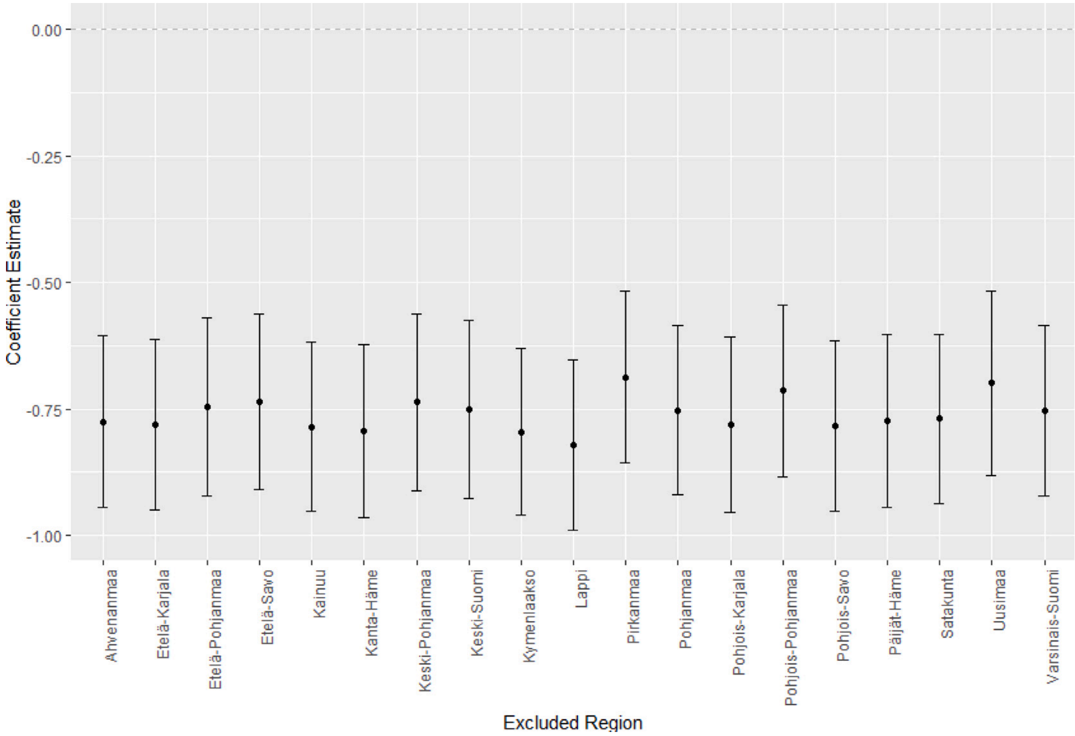


Fig. F.1. IV GDP/capita elasticity estimate: Each region excluded one at a time.

Leave-one-out analysis

To address potential region-level differences, it is worthwhile to study whether any single particular region is driving the results. For example, Uusimaa (wherein the capital Helsinki is located), is by far the largest region in the analysis and could have a substantial effect on the results. We conduct the same IV regression as previously, but each individual region is dropped from the sample in turn. The results are reported in Figs. F.1 and F.2.

In terms of GDP per capita elasticities, the results are almost identical independent of which region is removed from the sample with the largest elasticity, in absolute value, being −0.82 and smallest −0.69. When it comes to labour productivity, the elasticities are also rather uniform, except for when the Uusimaa region is excluded from the sample. In this case the elasticity is smaller in absolute value terms, by approximately −0.35. This suggests that Uusimaa plays an important role in the realisation of the effect.

Active population mortality rate as an instrument

As demonstrated earlier, the IV approach and its results in our main specification does not significantly differ from traditional OLS estimation. This similarity might be attributed to the modest migration flows experienced in Finland during the 2010s. Consequently, migration does not contribute to significant endogeneity issues in Finland, unlike in the case of the United States, which is noted by Maestas et al. (2023).

In this subsection, we construct an additional instrument for population ageing: the lagged regional mortality rate of the working-age population. The intuition behind this approach is that the lagged mortality rate variable, defined as the logarithmic change in the number of deaths per population, influences economic outcomes through demographic development, which is represented by the old-age dependency ratio. A larger change in the mortality rate corresponds to a more significant shift in the active population and, consequently, the labour force.

The number of deaths in population are retrieved from the Statistics Finland database. It should be noted that the mortality rate is defined as the number of deaths of population aged 15–64 divided by the total 15–64 year-old population.

The results are presented in Table F.2. All elasticities are highly statistically significant. According to the F-statistic, the first stage is strong. The Wu–Hausman test is also statistically significant, implying that the IV estimates are statistically different from the OLS estimates.

The estimated coefficients in this specification are considerably larger than what was obtained in the main IV analysis in Section 6 with elasticities of −0.664 and −1.080 for labour productivity and GDP per capita, respectively.

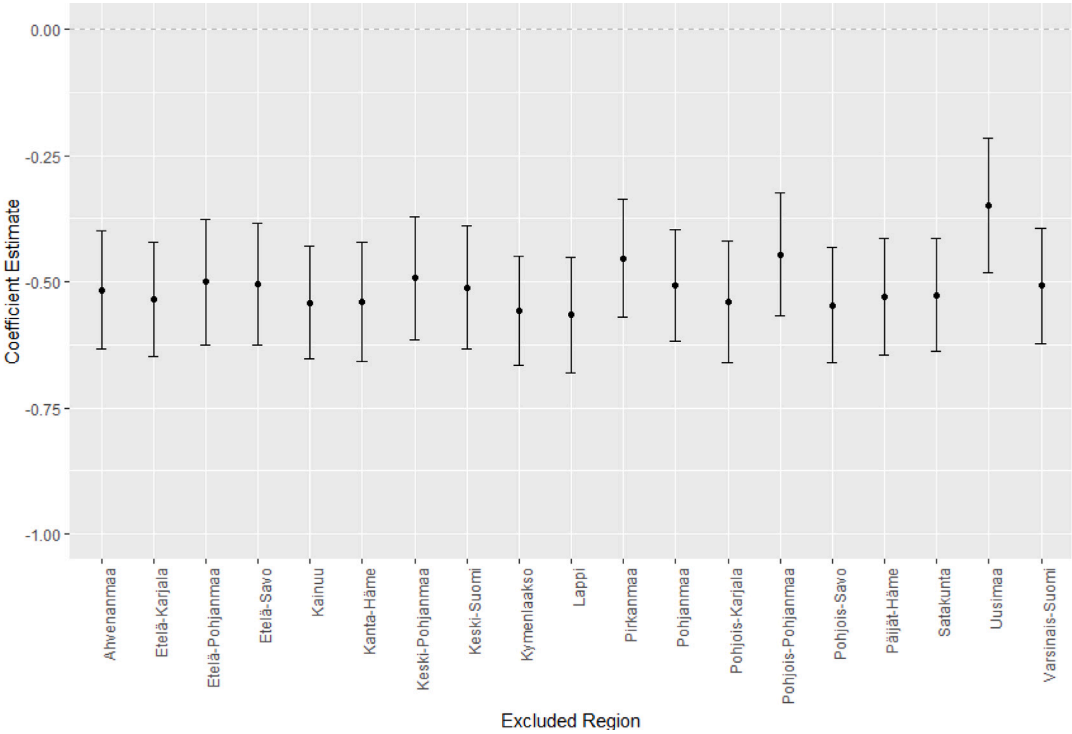


Fig. F.2. IV productivity elasticity estimate: Each region excluded one at a time.

Table F.2
Results from instrumental variables regression.

	Reduced form estimates	
Dependent variable:	$\Delta \ln(GDP/E)$	$\Delta \ln(GDP/N)$
$\Delta \ln(\hat{A})$	−0.269* (<0.01)	−0.438*** (<0.01)
	First stage estimates	
Dependent variable:	$\Delta \ln(A)$	
$\Delta \ln(\hat{A})$	0.405*** (<0.01)	
F-statistic	140***	
	Instrumental variable estimates	
Dependent variable:	$\Delta \ln(GDP/E)$	$\Delta \ln(GDP/N)$
$\Delta \ln(A)$	−0.664** (<0.01)	−1.080*** (<0.01)
Wu–Hausman test	8.513 (<.0.01)	15.34 (<0.01)

Number of observations: 418. GDP/E denotes productivity and GDP/N GDP per capita. Area-level clustered standard errors are in parentheses. *** = significant at 1% level, ** = significant at 5% level, * = significant at 10% level. Other variables include decade dummies and initial period industry and regional level employment shares interacted with decade dummies. Δ refers to a 10-year change. Regressions are weighted according to regional population shares.

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