Essays on Macroeconomic Implications of Demographic Change

Sveinsson, Thorsteinn S.

COPENHAGEN BUSINESS SCHOOL
SOLBJERG PLADS 3
DK-2000 FREDERIKSBERG
DANMARK

WWW.CBS.DK

ISSN 0906-6934

Print ISBN: 978-87-93956-37-7
Online ISBN: 978-87-93956-38-4

ESSAYS ON MACROECONOMIC IMPLICATIONS OF DEMOGRAPHIC CHANGE

PhD Series 13.2020

Thorsteinn Sigurdur Svensson

ESSAYS ON MACROECONOMIC IMPLICATIONS OF DEMOGRAPHIC CHANGE

CBS PhD School

PhD Series 13.2020

CBS COPENHAGEN BUSINESS SCHOOL
HANDELSHØJSKOLEN

Essays on Macroeconomic Implications of Demographic Change

Thorsteinn Sigurdur Sveinsson

Supervisor: Svend E. Hougaard Jensen

PhD School in Economics and Management
Copenhagen Business School

Thorsteinn Sigurdur Sveinsson
Essays on Macroeconomic Implications of
Demographic Change

1st edition 2020
PhD Series 13.2020

ISSN 0906-6934

Print ISBN: 978-87-93956-37-7
Online ISBN: 978-87-93956-38-4

The CBS PhD School is an active and international research environment at Copenhagen Business School for PhD students working on theoretical and empirical research projects, including interdisciplinary ones, related to economics and the organisation and management of private businesses, as well as public and voluntary institutions, at business, industry and country level.

Foreword

This dissertation is the result of my PhD studies at the Department of Economics at Copenhagen Business School (CBS) as a member of the Pension Research Centre (PeRCent). I had the privilege of completing my PhD studies as an employee of the Central Bank of Iceland while having the liberty to travel to Copenhagen multiple times a year. I express my gratitude to the Central Bank of Iceland for facilitating my PhD studies and providing an excellent research atmosphere. I'm also grateful for the support of PeRCent during my studies. There are many individuals that I would like to mention, but I will start with the four that made the biggest impact on my PhD studies, Svend, Gylfi, Filipe and Andy, all of which are co-authors of chapters of this dissertation.

Svend E. Hougaard Jensen and I first met roughly six years ago when I approached him as a potential supervisor for my MSc thesis. Svend has enforced my interest in macroeconomics, cultivated my academic development and motivated me to pursue a PhD. I sometimes get the impression that Svend has transferred the effort he once put towards coaching tennis towards coaching me as an economist.

Gylfi Zoega has proved to be an excellent PhD supervisor. Our biweekly meetings on Fridays at 5 pm (at which time I sometimes felt more like meeting over a pint of beer) were both academically and personally rewarding as Gylfi's supervision style is to pepper serious academic topics with life lessons and creative perspectives.

Filipe "Chipi" António Eslau Bonito Vieira, not only has a long name, but also has a long personal history as my friend and fellow MSc and PhD student. Filipe and I have a symbiotic relationship, we provide each other with thought provoking economic discussions, collaborate on research and when in Denmark I usually sleep on his sofa. On my many visits to Copenhagen we would usually start the day off by relaxing with

a cup of coffee watching a quiz show on TV with Filipe's wife, Amalie, imagining what the personal lives of the contestants are like. This has been an anchor to normality in the stormy seas of PhD studies.

Andrew Hughes-Hallett collaborated with Svend, Filipe and me on a few projects throughout my studies. Andy taught me unforgettable lessons about the realities of academia and life in general. His cheerful attitude and excellent economic guidance certainly put a positive spin on my PhD experience.

I would like to extend my gratitude to colleagues at the Central Bank of Iceland. In general, the entire staff of the Economics and Monetary Policy Department have been a source of support. I would especially like to thank Þórarinn G. Pétursson for his interest in my PhD studies. Ásgeir Daníelsson, Elís Pétursson, Lúðvík Elíasson, Ólafur Ö. Klemensson, Pálmar Þorsteinsson and Önundur P. Ragnarsson have all proved to be great conversation partners about the research topics of my dissertation. My close colleagues at the Forecasting and Research Division, Lilja S. Kro, Magnús F. Guðmundsson and Svava J. Haraldsdóttir, deserve my appreciation for their flexibility and understanding throughout the duration of my studies. I would also like to give credit to Guðjón Emilsson, Gunnar Gunnarsson, Páll Þ. Björnsson, Sigurður H. Pálmason and Telma Ýr Unnsteinsdóttir. They encouraged me during the low points and celebrated with me during the high points of my studies. Without exception I've been received positively by the staff of the Central Bank, for that I am truly grateful. I'm thankful for the advice Marías H. Gestsson, at the University of Iceland, provided me. I would also like to thank Sveriges Riksbank and the supporting colleagues I got to know there during my PhD internship in the autumn of 2019.

Finally, my family and friends have been a source of support and inspiration. My wife Steinunn has always supported me in my studies, her unwavering belief in me has spillover effects, boosting my own confidence. My parents, Sveinn and Anna Þóra have always provided me with the advice and motivation to reach my fullest potential. Their individual styles of guidance differ but their advice is perfectly complementary (much like pop-corn and cola). My siblings, Inga and Þorri, have inspired me to never be overcome by adversity. I have also been blessed with a supportive family-in-law, who have taken a keen interest in my studies. I want to conclude by mentioning my Icelandic and international friends, Amalie, Ana, Andrea, Birta, Davide, Erlend, Francesco, Gunnar, Ingvar, Ísak, Jón Erlingur, Kiddi, Magnús, Priscilla, Ragnar, Róbert, Svavar, Viktor, Weronika and Þorsteinn Gunnar. Having the chance to goof around in good company is the perfect antidote to PhD stress.

Þorsteinn Sigurður Sveinsson

Abstract

Demographic change is becoming increasingly important to the economic wellbeing of industrialized countries. These changes bring with them a set of implications, among which are the sustainability of public finance, pension- and social security systems. These implication cause a response, the span of which can range from pension reforms and fiscal policy to the individual's life cycle plan. Understanding the economic implication of these demographic changes is instrumental to a sound resolution of the issues they spark. This dissertation is composed of four independent chapters, all of which are concerned with the economic implications of demographic change.

Chapter one, *"Sustainable fiscal strategies under changing demographics"*, develops an overlapping generations model to evaluate, first, the steady state growth maximizing level of public debt around which an economy needs to stabilize; second, how the optimal level of public debt varies as a function of key population parameters; third, how fiscal rules designed to stabilize the economy around that debt level need to vary with the population parameters; and, fourth, how well the model performs as a reasonable and plausible representation of the advanced economies that face fiscal strain and deteriorating demographics. The main conclusion is: despite diminished fiscal space and flexibility due to deteriorating population parameters, a relatively benign steady state is feasible and available under mild fiscal restraints. The bigger problem will be how to get there without financial or fiscal breakdowns along the way. We offer some political economy perspectives on how best to manage that risk.

Chapter two, *"Reform and Backlash to Reform: Longevity Adjustment of the Retirement Age"*, uses an overlapping generations model, *ad modum* Blanchard-Yaari, to analyse the effects of retirement reform on labour supply, and found there is not a one-to-one relationship between an increase in the statutory retirement age and the

corresponding increase in aggregate labour supply: Rather, a backlash effect is observed, where a reform aimed at broadening the labour supply on the extensive margin, has the unintended effect of decreasing labour supply on the intensive margin. Following a calibration exercise to analyse the robustness of these backlash effects on different pension scheme designs, we found that, under a defined-benefit scheme, the effects on the intensive margin of labour supply are drastically increased, compared to the defined-contribution scheme and the fully-funded scheme.

Chapter three, *"Longevity, Pension Reform and Intra-Generational Equity"*, finds that segments of society who have shorter life expectancy can expect a lower income from their pensions and lifetime utility due to the longevity of other groups participating in the same pension scheme. Linking the pension age to average life expectancy magnifies the negative effect on the lifetime utility of those who suffer low longevity. Furthermore, when the income of those with greater longevity increases, those with shorter life expectancy become even worse off. Conversely, when the income of those with shorter life expectancy increases, they end up paying more into the pension scheme, which benefits those who live longer. The relative sizes of the low and high longevity groups in the population determine the magnitude of these effects. We calibrate the model based on data on differences in life expectancy of different socio-economic groups and find that low-income workers suffer from a 10-13 percent drop in pension benefits from being forced to pay into the same scheme as high-income workers.

Chapter four, *"Healthy aging, saving and retirement"*, argues that healthy aging is an essential factor in individuals' retirement behaviour and should therefore be considered in the design of retirement reforms. A model is constructed where agents make consumption, saving, and retirement decisions based on their expectations of future health and their uncertainty about their time of death. Changes in health shift the agent’s utility curve and increase the disutility of work, providing a connection between healthy aging and the agent’s life-cycle decisions. The author finds, among other things, that healthy aging is associated with later retirement and that as the risk of adverse health shocks increases, the agent saves less. Life-cycle health developments are found to explain to an extent the hump-shape of the individual’s consumption plan. These effects are established with various formulations of health functions and simulated with data on life-cycle health and longevity to obtain estimates of the impact of healthy aging on retirement decisions.

Resumé (Abstract in Danish)

Demografiske ændringer får større og større indflydelse på økonomi og velfærd i de industrialiserede lande. Ændringerne har en række konsekvenser, bl.a. for holdbarheden af de offentlige finanser, pensionssystemerne og velfærdsstaten mere generelt. Disse konsekvenser afføder en række tiltag, som kan variere fra pensionsreformer og overordnede økonomiske indgreb til ændringer i den enkeltes langsigtede planlægning. En bedre forståelse af de økonomiske konsekvenser af de demografiske ændringer kan medvirke til mere robuste løsninger på de udfordringer, de skaber. Denne afhandling består af fire uafhængige kapitler, der alle beskæftiger sig med økonomiske konsekvenser af demografiske ændringer.

Kapitel et, *"Sustainable fiscal strategies under changing demographics,"* ("*Bæredygtige finanspolitiske strategier under ændret demografi*") præsenterer en overlappende generationsmodel til evaluering af 1) Det maksimale niveau af langsigtsvækstraten for den offentlige gæld, omkring hvilken en økonomi bør stabilisere sig; 2) Hvordan det optimale niveau af offentlig gæld varierer som en funktion af væsentlige befolkningsparametre; 3) Hvordan økonomiske indgreb, som har til formål at stabilisere økonomien omkring dette gældsniveau, er nødt til at variere i forhold til befolkningsparametrene; og 4) Hvor godt modellen fungerer som en plausibel repræsentation af de avancerede økonomier, der går en fremtid i møde med svækket demografi og pres på de offentlige finanser. Hovedkonklusionen er, at selv med et svækket økonomisk råderum som følge af ændrede befolkningsparametre er en relativt gunstig langsigtsligevægt stadig mulig at opnå gennem relativt beskedne økonomiske indgreb. Sværere vil det være at nå dertil uden finansielle eller fiskale sammenbrud undervejs. I kapitlet fremlægges nogle politisk-økonomiske perspektiver på, hvordan man kan håndtere denne risiko bedst muligt.

Kapitel to, "*Reform and Backlash to Reform: Longevity Adjustment of the Retirement Age,*" ("*Reform og modreaktion mod reform: levetidsindeksering af tilbagetrækningsalderen*") anvender en model med overlappende generationer *ad modum* Blanchard-Yaari til at analysere effekterne af en tilbagetrækningsreform på arbejdsudbuddet. Resultaterne viser, at der ikke er et ét-til-ét forhold mellem en forhøjelse af den lovbestemte tilbagetrækningsalder og tilsvarende forøgelse af arbejdsudbuddet. Tværtimod demonstreres en modsatrettet effekt, hvor en reform, der har til hensigt at øge arbejdsudbuddet på den ekstensive margin, vil have den ikke-intenderede effekt, at den mindsker arbejdsudbuddet på den intensive margin. Der gennemføres en kalibreringsøvelse for at analysere betydningen af disse modsatrettede effekter på forskellige pensionsmodeller. Her ses det, at effekterne øges kraftigt på den intensive margin for arbejdsudbuddet ved en ydelsesbaseret ordning sammenlignet med en bidragsbaseret ordning og en opsparingsbaseret ordning.

Kapitel tre, *"Longevity, Pension Reform and Intra-Generational Equity," (Levetid, pensionsreform og intra-generationel fairness,")* viser, at grupper i samfundet, der har kortere forventet levetid, også kan forvente en lavere indkomst fra deres pensionsopsparinger og livstidsnytte pga. levetiden hos de andre grupper, som deltager i den samme pensionsordning. At knytte reguleringen af pensionsalderen til den gennemsnitlige levetid forstørrer den negative indvirkning på livstidsnytten for dem, der ikke lever så længe. Desuden vil dem med kortere forventet levetid stå i en endnu dårligere situation, når indkomsten hos dem med længere levetid går op. Omvendt, når indkomsten hos dem med kortere forventet levetid går op, ender de med at betale mere ind på en pensionsordning, der kommer dem, der lever længere, til gode. Størrelsesforholdene mellem grupperne med høj og lav levetid afgør størrelsen af disse konsekvenser. Med en kalibrering ud fra data om forskellene i forventet levetid i forskellige socioøkonomiske grupper vises, at lavindkomstgrupperne oplever et fald i pensionsudbetaling på 10–13 procent ved at være tvunget til at betale til de samme ordninger som højindkomstgrupperne.

Kapitel fire, *"Healthy aging, saving and retirement,"("Sund aldring, opsparing og pension")* argumenterer for, at såkaldt "sund aldring" er en afgørende faktor for den enkeltes pensionsadfærd, og som derfor bør tages højde for i udformningen af pensionsreformer. I kapitlet opstilles en model, hvor forbrug, opsparing og pension er udgangspunkt for agenters forventninger til fremtidigt helbred og usikkerhed omkring tidspunktet for deres død. Ændringer i helbred ændrer agentens nyttekurve og hæver ikke-nytten ved arbejde, og angiver således en forbindelse mellem livscyklus-beslutninger hos agenterne og sund aldring. Resultaterne viser bl.a., at sund aldring hænger sammen med senere tilbagetrækning, og at agenten mindsker sin opsparing i takt med, at risikoen for negativt helbredschok stiger. Udviklingen i livscyklus-helbred forklarer til en vis grad den pukkelformede kurve for den enkeltes forbrugsplan. Disse virkninger er opstillet gennem formulering af sundhedsfunktioner og er simuleret med data om livscyklus-helbred og levetid for at opnå skøn over indvirkningen af sund aldring på beslutninger om tilbagetrækning.

Contents

Foreword i

Abstract v

Resumé (Abstract in Danish) ix

Introduction 3

1 Sustainable fiscal strategies under changing demographics 11

2 Reform and Backlash to Reform: Longevity Adjustment of the Retirement Age 61

3 Longevity, Pension Reform and Intra-Generational Equity 109

4 Healthy aging, saving and retirement 149

Satire demonstrates the public's interest in the issue of sustainable pensions.
Cartoon from Icelandic newspaper, January 30th 2019

Yellow box: Three suggestions for achieving a sustainable pension system,
1. Increase contributions | 2. Increase the pension age | 3. Shorter life expectancy

Source: Halldór Baldursson, visir.is

Introduction

National economies are affected by many variables: While government policy, international trade and even the weather are among the causes of economic conditions in the relatively short-run, and technological progress is a key determinant of long-run economic growth, other factors such as demographics have gained attention as drivers of economic outcomes.

Demographic changes are a prominent feature of the economic landscape of industrialized countries. Longevity increases coupled with lower fertility rates have sparked a serious debate on the sustainability of public finance, pension and social security systems. This debate is not confined to a small group of specialists, but rather is open to a broad range of discussants, from academics, to policymakers and the general public. Even though these issues are driven by a simple cause, their resolution can prove to be precarious.

Many advanced economies rely on a pension scheme where the benefits to the retired population are financed by contributions of the current working population. Reform of these pension schemes can principally take three forms: Firstly, an increase in the pension contributions, which redistributes incomes from the working population to the retired; secondly, a decrease in the pension benefits, which has the opposite effect, i.e., distributing income from the retired population to the working population; thirdly, an increase in the official retirement age, which strikes at the issue by both broadening the labour force and reducing the retired population. These three avenues of pension reforms will all result in some degree of redistribution of inter-generational welfare.

Due to these redistribution effects, pension reforms can prove to be a heated issue. Recently, this has become evident across Europe. In 2018, the Russian government was forced to reconsider a proposed gradual retirement age rise for women following public outcry (BBC, 2018). In France, strikes starting in December 2019 were also sparked by pension reforms. These reforms have been criticized for being too opaque, as the exact amount of eventual pension benefits are not explicitly stated, but workers earn points which will be transformed to pension benefits at a later date. Furthermore, the opponents state that the reforms will force people to choose, either to work longer or face reduced pension benefits. Yet the official retirement age in France is still one of the lowest in the OECD (BBC, 2019).

In light of the potential of pension reforms to spark turmoil, one popular way of ensuring long-run pension sustainability is to link the official pension age to the average life expectancy of the population (Jensen et al., 2019). In fact, Denmark has implemented a pension rule, which keeps the average length of retirement fixed; effectively tying the official pension age to average longevity on a one-to-one basis (Andersen, 2015). Similar plans are prevalent across Europe: Last year the pension scheme of the Netherlands was reformed so that a year's increase in life expectancy would be followed by an 8-month rise in the pension age, reverting from the one-to-one rule applied in Denmark. Sweden has established a recommended retirement age, which serves as a benchmark for the calculation of pension benefits and will be linked to longevity (OECD, 2019).

While longevity indexation of the pension age is a concise way to reduce the pressure on public finances, these indexation schemes are based on a stylized version of the world; notably the assumption of a homogeneous population. Members of the top income quartile in the US can expect to live about a decade longer than those in the bottom quartile (Chetty et al., 2016). The same pattern, can also be observed in Denmark, as the gap in life expectancy at age 30 for men with primary or lower secondary education and tertiary education stood at 6.4 years in 2011, and has increased since 1987 (Brønnum-Hansen & Baadsgaard, 2012). Moreover, this heterogeneity in longevity is not explained by extreme poverty, but rather longevity is a gradient across the socio-economic scale (Waldron, 2007). A similar gradient can also be observed when it comes to healthy aging (Eurostat, 2019).

The heterogeneity of the population raises concerns about the distributional consequences of pension systems applying a one-size-fits-all design. Changes in the pension age based on increases in average life expectancy and healthy aging might therefore affect socio-economic groups differently. For instance, increases in the pension age that are driven to a large extent by higher longevity of white-collar workers, could cause the lifetime welfare of the blue-collar workers to decrease. Understandably, blue-collar workers could, following a long and physically demanding working life, prefer to retire at an earlier age than white-collar workers, who perhaps spend a substantial time on education and are subject to less physically strenuous work. Therefore, due to these intra-generational transfers, the broad political support of longevity indexation of pension ages might gradually drop in Nordic welfare states.

The official pension age does not, in most cases, force people into retirement: Any increases in the official pension age may affect the financial incentives to retire at a specific age, and could potentially affect individuals of different socio-economic status differently. However, the timing of retirement cannot solely be explained as a financial decision (Cribb et al., 2016). In fact, the official pension age has been found to serve as a reference point or a signal of the appropriate time to retire (Lumsdaine et al., 1996, Manoli & Weber, 2016). This illustrates the complexity of potential outcomes of reforms triggered by demographic change.

The issues discussed above are addressed in this dissertation, which is composed of four independent, yet interconnected, chapters. Each chapter applies an overlapping generations model, to theoretically analyse economic implications of demographic change.

The first chapter analyses how demographics can affect the optimality of public capital. The analysis is motivated by fiscal rules aimed at mitigating the deficit bias associated with fiscal policy. Instead of formulating generic fiscal rules, the analysis features a government which seeks to maximize economic growth subject to the golden rule of public capital (Hughes Hallett & Jensen, 2012). This allows for conditioning the government's optimal strategy on demographic parameters and age-related government spending (Bokan et al., 2016). The chapter then explores the effects of demographics on key economic variables, including economic growth, public debt and taxation. Finally, the severity of projected demographic change on the capacity of fiscal policy in a typical OECD economy is assessed.

The second chapter examines one of the three avenues of addressing the effects of adverse demographics on pension schemes; namely, raising the retirement age (Börsch-Supan & Ludwig, 2013). The life-cycle consumption, saving and leisure plan of individuals is analysed subject to retirement age raises. The chapter analytically establishes the existence of a "backlash" effect: When the retirement age is raised, individuals work for more years, but this might lead to the unintended effect of individuals choosing to work less each year. This implies that retirement age rises will cause a less than one-to-one increase in the labour force. The size of this "backlash" effect is examined in the context of the pension scheme design, namely whether the pension scheme is fully funded or features either defined contributions or defined benefits.

The third chapter addresses the fact that longevity is unequally shared between socio-economic groups and illustrates equalitarian effects of a uniform statutory pension age. Various implications of such one-size-fits-all pension designs are proved theoretically. These include redistribution of welfare from those that suffer low longevity to those who enjoy higher longevity. These intra-generational effects are magnified when accounting for the income distribution of society. When those that live long become richer, the pension scheme harms the low longevity group even more. This is supplemented by policy advice and a calibration to match empirical demographic structures and longevity improvements.

The fourth chapter focuses on healthy aging. The chapter is motivated by providing guidance to policymakers designing retirement reforms. To this extent, the analysis investigates the effects of the individual's expectations of future health on his life-cycle plan. Other recent articles have analysed the effects of health on retirement (French, 2005) and the welfare implications of retirement reforms (Laun et al., 2019). This chapter goes one step further, providing a connection between expected wellbeing after retirement and the time chosen to retire. In other words, it shows that not only does the length of retirement matter, but also the quality of life during retirement.

When viewed as a whole, the dissertation demonstrates the intricacies of the economic implications of demographic change. The first chapter shows how demographic change affects the optimal level of public capital. This is supplemented by three chapters that address distinct aspects of retirement reforms: The unintended effects of retirement age hikes; the intra-generational considerations and the significance of healthy aging for retirement and savings.

Each chapter provides a distinct contribution to the literature. The first chapter shows that when following the golden rule of public finance, the demographic changes projected this century tend to have a benign effect on the optimal level of public debt. However, the effects on other economic variables, such as taxation, are much more pronounced. The second chapter analytically establishes the existence of the backlash effect and the capacity of pension scheme design to affect its magnitude. The third chapter clarifies how pension reforms will cause intra-generational transfers. Finally, the fourth chapter establishes a link between the quality of life after retirement and the time chosen to retire.

References

Andersen, T. (2015). Robustness of the Danish pension system. *CESifo DICE Report 2/205*, 25-30.

Auerbach, A. J., Charles, K. K., Coile, C., Gale, W., Goldman, D., Lee, R., . . . Wong, R. (2017). How the growing grap in life expectancy may affect retirement benefits and reforms. *Working Paper 23329, National Bureau of Economic Research*.

BBC. (2018, August 29). *Russia's Putin softens pension reforms after outcry*. Retrieved January 14, 2020, from BBC NEWS: www.bbc.com/news/world-europe-45342721

BBC. (2019, December 5). *Macron pension reform: Why are French workers on strike?* Retrieved January 14, 2020, from BBC NEWS: https://www.bbc.com/news/world-europe-50670613

Bokan, N., Hughes Hallett, A., & Jensen, S. (2016). Growth-maximizing debt under changing demographics. *Macroeconomic Dynamics 20*, 1640-1651.

Brønnum-Hansen, H., & Baadsgaard, M. (2012). Widening social inequality in life expectancy in Denmark. A register-based study on social composition and mortality trends for the Danish population. *BMC Public Health*.

Börsch-Supan, A., & Ludwig, A. (2013). Modeling the Effects of Structural Reforms and Reform Backlashes: The Cases of Pension and Labour Market Reforms. *Economic Modelling*, vol. 35 pp.999-1007.

Chetty, R., Stepner, M., Abraham, S., Lin, S., Scuderi, B., Turner, N., . . . Cutler, D. (2016). The association between income and life expectancy in the United States. *Journal of American Medical Association*, 1750-1766.

Cribb, J., Emmerson, C., & Tetlow, G. (2016). Signals Matter? Large Retirement Responses to Limited Financial Incentives. *Labour Economics*, vol. 42, 203-212.

Eurostat. (2019, December 17). *Self-perceived health by sex, age and income quintile*. Retrieved January 2020, 14, from Eurostat: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=hlth_silc_10&lang=en

French, E. (2005). The Effects of Health, Wealth, and Wages on Labour Supply and Retirement Behaviour. *Review of Economic Studies*, 395-427.

Hughes Hallett, A., & Jensen, S. (2012). Fiscal Governance in the Eurozone: Institutions vs. Rules. *Journal of European Public Policy 19*, 646-664.

Jensen, S., Lassia, J., Määttänen, N., Valkonen, T., & Westerhout, E. (2019). Top 3: Pension systems in Denmark, Finland, and the Netherlands. *ETLA Working Paper #66*.

Laun, T., Markussen, S., Vigtel, T. C., & Wallenius, J. (2019). Health, longevity and retirement reform. *Journal of Economic Dynamics & Control*, 123-157.

Lumsdaine, R., Stock, J., & Wise, D. (1996). Why are Retirement Rates so high at Age 65? In D. A. Wise, *Advances in Economics of Aging* (pp. 61-82). NBER.

Manoli, D., & Weber, A. (2016). The Effects of the Early Retirement Age on Retirement Decisions. *NBER Working Paper No. 22561*.

OECD. (2019). *Pensions at a Glance 2019: OECD and G20 Indicators.* Paris: OECD Publishing.

Waldron, H. (2007). Trends in mortality differentials and life expectancy for male social security-covered workers, by average relative earnings. *ORES Working Paper Series*.

Chapter 1

Sustainable fiscal strategies under changing demographics

This chapter has been published in the *European Journal of Political Economy*

https://doi.org/10.1016/j.ejpoleco.2018.07.003

Sustainable fiscal strategies under changing demographics*

By

Andrew Hughes Hallett
School of Public Policy, George Mason University,
3351 N. Fairfax Drive, Arlington, VA 22201, USA
ahughesh@gmu.edu

Svend E. Hougaard Jensen
Department of Economics, Copenhagen Business School
Porcelaenshaven 16A, 2000 Frederiksberg C, Denmark
shj.eco@cbs.dk

Thorsteinn Sigurdur Sveinsson
Economics and Monetary Policy, Central Bank of Iceland
Kalkofnsvegur 1, 150 Reykjavik, Iceland
tss@cb.is

and

Filipe Bonito Vieira
Department of Economics, Copenhagen Business School
Porcelaenshaven 16A, 2000 Frederiksberg C, Denmark
fv.eco@cbs.dk

Abstract: This paper develops an overlapping generations model to evaluate, first, the steady state growth maximizing level of public debt around which an economy needs to stabilise; second, how the optimal level of public debt varies as a function of key population parameters; third, how fiscal rules designed to stabilise the economy around that debt level need to vary with the population parameters; and, fourth, how well the model performs as a reasonable and plausible representation of the advanced economies that face fiscal strain and deteriorating demographics. The main conclusion is: despite diminished fiscal space and flexibility due to deteriorating population parameters, a relatively benign steady state is feasible and available under mild fiscal restraints. The bigger problem will be how to get there without financial or fiscal breakdowns along the way. We offer some political economy perspectives on how best to manage that risk.

Keywords: Fiscal rules, Public debt, Economic growth, Demographic changes
JEL codes: E62, H63, J11

---

* An earlier version of this paper was presented at the conference on "Fiscal Frameworks in Europe: Background and Perspectives", Copenhagen, June 1–2, 2017. We gratefully acknowledge comments from the conference participants and referees. Remaining errors and shortcomings remain the responsibility of the authors.

1. Introduction

General fiscal rules are legislative agreements intended to mitigate the deficit bias usually associated with fiscal policy and typically due to myopia by governments. Recent empirical research suggests that national fiscal rules are helpful in achieving greater budgetary discipline (Debrun et al., 2008; Nerlich and Reuter, 2013; Foremny, 2014). The question of which specific rule is most effective in promoting fiscal discipline has recently attracted a lot of attention. For example, Bergman et al. (2016) find that a combination of an expenditure rule and a balanced budget rule, or a combination of an expenditure rule, a balanced budget rule and debt rules, give significant positive effects on the primary balance for virtually all levels of government efficiency.[1] However that does not guarantee acceptable economic outcomes.

In this paper, we take a different route. Rather than formulating generic rules designed to reduce the deficit bias, we set up specific rules aimed at maximising economic growth.[2] This enables us to condition those rules on population parameters and age-related spending, and to show the impact of population change on fiscal balances and debt. We ask: first, whether, to what extent and when do changing demographics affect the net fiscal position; second, whether it is acceptable to allow larger debt burdens, or whether tax and spending austerity are always necessary when demographic change leads to pressure on public finances.

Then, rather than evaluating alternative forms of fiscal rule, we restrict attention to a rule for public debt. This is in line with previous work where we have argued that debt targets are superior to deficit targets for theoretical and practical reasons (Hughes

---

[1] For a fuller discussion of what makes a fiscal rule successful, see Eyraud et al. (2018) of the IMF fiscal rules project.

[2] Existing models in the fiscal literature that aim to determine optimal levels of debt include Aschauer (2000), Aiyagari and McGrattan (1998) and Checherita et al. (2014).

Hallett and Jensen, 2012).[3] But choosing a debt target is not a trivial task. A key issue is how to account for (the discounted value of) future spending liabilities. If the implicit liabilities created by ageing populations are ignored, the debt criterion will ignore the future revenues required to avoid default despite the obvious need to cover the benefits promised to existing and future beneficiaries.

This is the case for extending debt targeting rules to account for predictable demographic changes. Put differently, forward looking fiscal rules are needed to allow for future liabilities created by adverse demographics. The implication is that governments facing demographic change, or the need for higher social spending, will have to adjust (most likely restrict) their fiscal plans to accommodate those changes. Hence our key contribution is to make debt control forward looking by designing a rule where fiscal policy reacts, not only to changes in existing levels of debt, but also to anticipated changes in future liabilities.

This study provides a comparative static analysis of the problem. Within that framework, the paper makes three new contributions.[4] First, we offer a formal evaluation of the optimal debt level around which the economy needs to stabilise.[5]

---

[3] If debt targeting is preferred, the question is: what debt or debt-to-GDP ratio should be targeted (Auerbach, 2009)? Deriving optimal levels of public debt may involve several complicated trade-offs. For example, how should inter-generational equity be balanced against economic performance and long term fiscal sustainability?

[4] In a follow up paper, Hughes Hallett et al. (2017) focus on the dynamics of how different economies might reach the new steady state. In this paper, by contrast, we focus on establishing (from a political economy perspective) that a feasible steady state does indeed exist before going on to analyse how to reach it. It makes little sense to study the transition before we can show that an acceptable/sustainable steady state exists.

[5] The optimal debt level depends on the marginal productivity of public capital, defined as public spending on investment projects which are (a) productive, (b) have an identifiable rate of return and (c) have a longer horizon than consumption expenditures. Conceptually, this is clear-cut. But in practice there are often problems in separating public investment from public consumption in the data (Checherita et al., 2014).

Second, we study how the optimal debt level varies with the key population parameters. Third, we show how fiscal rules designed to stabilise the economy around that debt level need to react to population age, life expectancy, the birth rate and rising welfare expenditures.[6]

While general fiscal rules primarily address the deficit bias, this paper also looks at specific rules to deal with ageing and lack of growth in the work force. Such policies imply three roles for public policy: i) to improve the incentives to raise children, to maintain the number of taxpayers and a capacity to sustain a certain level of public debt; ii) to improve the volume and effectiveness of public capital in order to boost productivity and growth; and iii) to smooth the distributional consequences of demographic change and offset negative effects on growth. In this paper, we focus on all three roles because they explain *how* we can reach a benign steady state and good fiscal outcomes despite adverse demographics: an explanation that has been missing in the literature so far, but is perhaps the main contribution of the paper.

How and whether the government should incentivize child-rearing is a controversial issue. Since the children of today are the workers of tomorrow, we consider how demographics and sustainable government finances are related. We do that by allowing social spending aimed at alleviating the private cost of child-rearing. We include fiscal balances because a growing population has a feedback that can help maintain a certain level of public spending and debt. Specifically, we model government spending related to child-rearing; and then analyse how those expenditures influence the economy.

---

[6] Previous work has tended to focus on impact of worsening demographics on the financial markets; Auerbach and Herrmann (2002) for example devote 7 out of 8 chapters to that theme, and only one to fiscal issues. On the other hand, Bohn (2002) stresses the importance of managing debt for a successful resolution of the impact of ageing.

We consider public and private capital to be labour productivity-enhancing factors in production. Public capital can be interpreted as education, R&D and the social infrastructure that underpins human capital formation *and* leads to a more skilled and productive workforce. Private capital, however, provides the incentives for innovation and competition. The ratio of public to private capital is therefore a key factor for economic prosperity. The government seeks to improve the volume and effectiveness of public infrastructure, helping to raise productivity and the economy's rate of growth. Having a government with this mandate enables this study to present an optimal (public) debt policy which allows for demographic factors.

The roadmap of the paper is as follows. In Section 2 we set out our analytical framework: an OLG model extended to allow for public debt. Section 3 derives the optimal debt-to-GDP ratio; section 4 outlines policies to manage demographic change and introduces the political economy forces that underlie the main issue: intergenerational equity and transfers. Sections 5 and 6 provide a simulation treatment of the effects of population change on optimal debt. Section 7 then illustrates the political economy trade-offs that underlie policy problems of this type. Section 8 provides our principle conclusions and an agenda for future research.

2. The model

We use a model with overlapping generations, changing demographics, welfare spending, and productive public and private capital accumulation (Yakita, 2008; Bokan et al., 2016). The economy contains homogenous individuals and firms operating in competitive markets. Individuals have two periods in their lives, first as a worker and then as a retiree. To introduce population ageing and entitlement spending, people face a risk of dying in the transition from worker to retirement, so that not every worker will live a full two-period life. However, in each period, working people form the young cohort and make decisions about consumption, savings and child rearing. Surviving retirees then form the old cohort. Public investment decisions are made by a government that issues debt and levies taxes in order to fulfil its objectives.

2.1. Firms

The economy is composed of a large number of identical firms which produce a homogenous product by utilizing the services of private capital and labour. The production technology for each firm j is characterized by constant returns to scale between the private capital and productivity-adjusted labour inputs that each firm employs:

$$Y_{j,t} = AK_{j,t}^{\alpha}\left(h_t L_{j,t}\right)^{1-\alpha} \; ; 0 < \alpha < 1 \tag{1}$$

where $Y_{j,t}$, $K_{j,t}$ and $L_{j,t}$ denote, respectively, the output level, the private capital stock, and labour input in firm j for period t. Total factor productivity (TFP) is captured by a standard scale factor, A (which may be time dependent), and labour augmenting productivity (not firm specific) described by h_t, where α is the output elasticity with respect to private capital.

Given the assumption of perfectly competitive markets for production goods and inputs, the equilibrium rental rate of capital, r_t, and wage rate, w_t, can be found in the usual way as the solutions to the firm's profit maximization problem:

$$r_t = A\alpha\left(\frac{K_{j,t}}{L_{j,t}}\right)^{\alpha-1}(h_t)^{1-\alpha} \tag{2}$$

$$w_t = A(1-\alpha)\left(\frac{K_{j,t}}{L_{j,t}}\right)^{\alpha}(h_t)^{1-\alpha} \tag{3}$$

The labour augmenting productivity, h_t, is determined by both the aggregate public and private capital stocks. From a macroeconomic perspective, it is important to recognize the productivity effects stemming from government productive inputs that combine with the productivity effects of private capital.[7] We do not model these productivity effects as public goods; instead we treat them as rival goods that are universally available to workers.[8] This implies that it is the per capita values of productive activities and private capital that matter, not their absolute level. So, the productivity adjustment process h_t is defined as[9]:

$$h_t = \frac{K_t^{\beta} G_t^{1-\beta}}{L_t}; \ 0 < \beta < 1 \tag{4}$$

where G_t is the public capital stock and β is the productivity elasticity of private capital (i.e. private capital's share of any income gains from increased productivity).

Equations (2) and (3) reflect a perfectly competitive environment where the marginal product of an input equals its price. Notice that, since h_t reflects a macro-level measurement, the actions of an individual or firm cannot influence h_t. So, at equilibrium, the competitive pricing of inputs does not take into account marginal changes to h_t: h_t is taken as given by firms and individuals. The aggregate private capital stock and the aggregate labour input are, respectively, defined as $K_t = \sum_j K_{j,t}$ and $L_t = \sum_j L_{j,t}$. Moreover, given the symmetry of firms, the equilibrium pricing expressions (2) and (3) imply that all firms share the same optimal solution, such that the ratio of input choices of each firm is the same in equilibrium: $K_{j,t}/L_{j,t} = K_t/L_t$. This allows us to rewrite expression (1) in terms of aggregate output at time t:

$$Y_t = AK_t^{\alpha}(h_t L_t)^{1-\alpha} = AK_t^{\alpha+\beta(1-\alpha)} G_t^{(1-\beta)(1-\alpha)} = AK_t^{\omega} G_t^{1-\omega} \tag{5}$$

[7] We consider aggregate private capital to be as in Arrow's (1962) Learning by Doing model. For a literature review on the importance of both private and public investment in the economic growth process, see Makuyana and Odhiambo (2016).
[8] We take the view of Barro (1990) that actual nonrival government activities are relatively few, so we do not consider them.
[9] See Kalaitzidakis and Kalyvitis (2004).

where $Y_t = \sum_j Y_{j,t}$ and $\omega \equiv \alpha + \beta(1-\alpha)$. Note that Equation (5) does not include the aggregate labour input. This is a simple consequence of our definition of the (endogenous) labour productivity input, h_t.

The firm specific optimality conditions can now be rewritten in aggregate terms as:

$$r_t = A\alpha\left(\frac{K_t}{G_t}\right)^{\omega-1} \tag{6}$$

$$w_t = A(1-\alpha)\left(\frac{K_t}{G_t}\right)^{\omega}\left(\frac{G_t}{L_t}\right) \tag{7}$$

Finally, for the purpose of simplification only, this model assumes that neither private nor public capital depreciates over time. We define the ratio of public-to-private capital, G_t/K_t, as X_t.

2.2. Households

The economy is populated by homogeneous individuals. The lives of individuals are divided into working and retirement periods. The working period is of fixed length. Individuals in the working period form the young cohort; those in retirement the old cohort. At the end of the working period, a fraction of the young agents die while the rest move into retirement. The probability of dying by the end of the working period is given by the hazard rate λ; the same for all agents. The probability of being alive at the start of the retirement period is $1-\lambda$. As there is no third period, the size of the retired cohort is $(1-\lambda)$ times the size of the working cohort in the previous period. With N_t being the population of working-age people, the total population of the economy at t is equal to $N_t + (1-\lambda)N_{t-1}$.

Young individuals work, consume, save and raise children. The retirees do not have children but they consume based on the return on savings from the previous period. The representative individual's decisions in both periods are based on the maximization of life-time utility which is given by the following function in period t:

$$\ln c_t + (1-\lambda)\rho \ln d_{t+1} + \varepsilon \ln n_t \tag{8}$$

where c_t (d_{t+1}) is consumption in the working (retirement) period, n_t is the number of children the individual has, ε is the priority/weight of having children in a person's life-time utility, and ρ denotes the usual time discount factor, being a value between 0 and 1.

The time endowment for a young individual is normalized to 1. The model does not include leisure explicitly, but rather includes the child rearing time during which the young individual receives no wages.[10] Labour income is then allocated between current consumption, savings and tax payments. However, the individual receives a subsidy for child rearing which is also subject to taxation. This subsidy, denoted by ρ_w; is a fixed ratio of the wage rate, w_t. The tax rate is the same for wages and the child-rearing subsidy.[11] The budget constraint of the representative young agent at time t therefore reads as:

$$(1-\theta)[w_t(1-zn_t) + \rho_w w_t z n_t] = c_t + s_t \tag{9}$$

where z > 0 is the rearing time per child, and θ_t denotes the flat tax rate. Savings are given by s_t and are exclusively invested in purchasing annuity assets. We assume that

[10] Hence the desire to have children crowds out the time spent working. A more general approach might allow extra saving, to leave bequests or invest in education. But to do that, workers have to have the children and pay carers to rear the children while agents are working extra hours to make the extra savings. The result is little or no ***net*** effect on incomes, savings or the fiscal position. So we treat these cases in a simpler way in Section 3 below.

[11] We can think of the child-rearing subsidy as a cost that is covered by the government. As such, the subsidy accounts for the amount of income that would be spent by the individual on child-rearing. Hence the subsidy is a labour income augmenting subsidy. Because that is income that could end up not being spent on child-rearing (hiring a nanny for example), this subsidy is taxed at the same rate as labour income. This interpretation forces us to see the subsidy as something that diminishes out-of-pocket costs of child-rearing.

not all of each individual's time endowment can go towards child rearing: $(1 - zn_t) > 0$.[12]

As in Blanchard (1985), we assume the existence of an actuarially fair insurance company operating in a perfectly competitive market for insurance. This insurance company collects savings from agents and invests them in private capital and/or government bonds. We assume that government bond purchases can crowd out private capital. The insurance company pays a return on savings to the agents that survive into retirement. The retirees therefore receive a rate of return of $\frac{r_{t+1}}{(1-\lambda)}$on their savings. The returns (not the principal) on savings are taxed at a rate equal to that on labour income. The second period budget constraint therefore reads as:

$$\frac{1 + (1 - \theta_{t+1})r_{t+1}}{(1 - \lambda)} s_t = d_{t+1} \tag{10}$$

The maximization problem of young individuals consists of choosing the optimal amount of savings and number of children to maximize life-time utility subject to the budget constraints for the working and retirement periods. The amount of savings directly influences the amount consumed in both periods. Meanwhile labour income not saved in the working period goes to current consumption, c_t; while that saved goes towards consumption in retirement, d_{t+1}. The overall maximization problem now is:

[12] $(1 - zn_t) > 0$ is guaranteed if the interval between the lower bound on ε in (15), and the upper bound on ε when $(1 - zn_t) = 0$, is nonempty. That interval is always nonempty if $z < 1$, a restriction that has to hold since not all agents can spend all of their allotted life time rearing children and still survive. The parameter restrictions in this model therefore guarantee $(1 - zn_t) > 0$.

$$\max_{c_t, d_{t+1}, n_t} \ln c_t + (1-\lambda)\rho \ln d_{t+1} + \varepsilon \ln n_t$$

$$s.t. (i)\ c_t + s_t = (1-\theta_t)[w_t(1-zn_t) + \rho_w w_t z n_t]$$

$$(ii)\ d_{t+1} = \frac{1+(1-\theta_{t+1})r_{t+1}}{(1-\lambda)} s_t$$

By rearranging the first order conditions for this maximization, the following relationships are obtained:

$$\frac{d_{t+1}}{c_t} = \rho[1 + (1-\theta_{t+1})r_{t+1}] \tag{11}$$

$$\frac{n_t}{c_t} = \frac{\varepsilon}{(1-\theta_t)(1-\rho_w)w_t z} \tag{12}$$

From these two conditions we find optimal solutions for savings s_t, and number of children per individual, n_t:

$$s_t = \frac{(1-\lambda)\rho}{1+(1-\lambda)\rho+\varepsilon}(1-\theta_t)w_t \tag{13}$$

$$n_t = \frac{\varepsilon}{z(1-\rho_w)[1+(1-\lambda)\rho+\varepsilon]} \equiv n > 0 \tag{14}$$

Two insights follow. First, we see the fraction in equation (13) is solely composed of demographic related factors, meaning that savings are a fixed share of after-tax income *only* if population parameters do not change. Second, the same is true for the fraction in equation (14), except that it includes ρ_w which is set by the government. Moreover, n is increasing in ρ_w. This should not be a surprise since increasing ρ_w lowers the financial burden of raising children, which gives individuals an incentive to have more children. The economy will then continue to survive so long as $n_t \geq 1$, which holds true as long as:

$$\varepsilon \geq \frac{z(1-\rho_w)[1+(1-\lambda)\rho]}{1-z(1-\rho_w)} \tag{15}$$

In this analysis we focus on the case of non shrinking populations ($n \geq 1$). If $n < 1$, the economy would disappear asymptotically. For the sustainability of the steady state, we need to assume that the inequality in (15) holds. In practice, to ensure such a steady state exists, we do not restrict n to be greater than the replacement rate of the population, but instead impose a restraint on the preferences of agents for children such that it does. The reality is that, with immigration, population growth is positive (if small in some places) almost everywhere – as data from the *World Development Indicators* show. Revealed preference therefore justifies (15) as the appropriate restriction. Population growth may also be improved by changes in mortality (λ) as well as by fertility decisions (n, ε).

2.3. Government

The government collects taxes from the wage income of the working population, from the child-rearing subsidy, and from the returns on savings of the retired population. The tax rate is denoted by θ_t and is fixed regardless of income type. The government also issues public debt, b_t, and invests the proceeds in public capital, G_t. In addition, the government pays the child-rearing subsidy as specified above. The government budget constraint is therefore:

$$b_{t+1} = (1 + r_t)b_t + (G_{t+1} - G_t) + \rho_w w_t z n_t N_t \\ -\theta_t(w_t L_t + \rho_w w_t z n_t N_t + r_t s_{t-1} N_{t-1)} \tag{16}$$

We assume debt interest payments and public consumption are financed by taxes on wages, subsidies and returns on savings. That leads to the period-by-period budget constraint:

$$r_t b_t + \rho_w w_t z n_t N_t = \theta_t(w_t L_t + \rho_w w_t z n_t N_t + r_t s_{t-1} N_{t-1}) \tag{17}$$

Public debt is then issued as needed to finance public capital formation, that is:

$$b_t = G_t \tag{18}$$

The model is thus stated in terms of the "golden rule" for public finance: the government only borrows to invest, not to finance its consumption or transfer payments.[13] The question is then, what is the optimal level of public debt and how is it determined?

3. The optimal level of public debt

3.1. Growth maximising public debt

The representative insurance company, and hence the young generation, can invest in both private and public capital. Equilibrium in capital markets requires that

$$s_t N_t = K_{t+1} + G_{t+1} \quad (19)$$

We can use conditions (17), (18) and (19), and combine them with capital rents and wages, (6) and (7), and with the fact that $L_t = (1 - zn)N_t$ (labour supply equals the time endowment less child rearing time), to derive an expression for the income tax rate, θ_t ; needed to satisfy current public spending:

$$\theta_t = 1 - \frac{1}{\alpha X + \rho_w (1-\alpha) zn/(1-zn) + 1} \quad (20)$$

Using the equilibrium condition for capital markets (19), and the solution for s_t in (13), we obtain:

$$\frac{(1-\lambda)\rho}{1 + (1-\lambda)\rho + \varepsilon}(1 - \theta_t) w_t N_t = K_{t+1} + G_{t+1} \quad (21)$$

This equation determines the dynamic relationship between wages, working population, and public and private capital. We define balanced growth to be a situation in which public and private capital grow at a constant rate. Specifically, let the aggregate steady state growth rate γ^A be defined as:

---

[13] The rationale for this golden rule is given in Blanchard and Givazzi (2002) and Fatas et al. (2003). It is, or has been, practiced in Germany, the UK and several other advanced economies.

$$\frac{G_{t+1}}{G_t} = \frac{K_{t+1}}{K_t} = \frac{Y_{t+1}}{Y_t} = \gamma n \equiv \gamma^A \tag{22}$$

where n is the constant growth rate of the population and γ is the aggregate growth rate per capita. This now implies that the public-to-private capital ratio is constant in steady state. It also implies that the tax rate, θ_t, and the interest rate, r_t, are constant in steady state.

Next we use equation (21), together with (7) and (20), to obtain a relationship from which we can derive a closed form expression for the economy's growth rate (see Appendix A for the full solution and definition of $\tilde{C}$):

$$\gamma^A = \frac{A\tilde{C}[(1-\alpha)/(1-zn)]}{X^{\omega-1}(X+1)(\alpha X + C + 1)} \tag{23}$$

In order to derive the public-to-private capital ratio which maximizes the aggregate growth rate along the balanced growth path, we take the first derivative of equation (23) with respect to the public-to-private capital ratio, X; set it equal to zero, and solve for X. The result is a general solution of the form (Appendix A):

$$X_{1,2} = \frac{-\omega\left(\rho_W \frac{(1-\alpha)zn}{1-zn} + 1 + \alpha\right) \pm \sqrt{\omega^2\left(\rho_W \frac{(1-\alpha)zn}{1-zn} + 1 + \alpha\right)^2 - 4\alpha(1-\omega)(\omega-1)\left(\rho_W \frac{(1-\alpha)zn}{1-zn} + 1\right)}}{2\alpha(1+\omega)} \tag{24}$$

With our parameter restrictions, it is easy to show that the positive solution to this equation is also positive (see Appendix B)[14]:

$$X^* = \frac{-\omega\left(\rho_W \frac{(1-\alpha)zn}{1-zn} + 1 + \alpha\right) + \sqrt{\omega^2\left(\rho_W \frac{(1-\alpha)zn}{1-zn} + 1 + \alpha\right)^2 - 4\alpha(1-\omega)(\omega-1)\left(\rho_W \frac{(1-\alpha)zn}{1-zn} + 1\right)}}{2\alpha(1+\omega)} \tag{25}$$

Given equation (5), the optimal debt to GDP ratio in this model is therefore:

$$d^* = \frac{1}{A} X^{*\omega} \tag{26}$$

[14] We are only interested in a positive solution since capital stock ratios must be nonnegative.

3.2. Optimal debt policy and demographic factors

It is now apparent that the optimal debt policy depends on the child-rearing subsidy rate. This subsidy rate is also an important component in the balanced-budget tax rate. As a result, the subsidy plays a central role in the savings-investment balance. It also affects fertility choices and hence population growth. The subsidy rate is thus inescapably part of the optimal debt policy. Furthermore, by maximizing aggregate growth per capita, $\gamma = \frac{\gamma^A}{n}$, we can reach the same results as for maximal aggregate growth, γ^A: equations (24)–(26). This is expected since the optimal level of government debt does not affect childbearing decisions of agents. But the optimal debt level is influenced by childbearing through the subsidy ρ_w. Hence demographics affect the optimal debt ratio; but the debt ratio does not affect population growth.

As we might expect, in the special case without subsides ($\rho_w \to 0$) the optimal debt ratio becomes independent of the population parameters; it becomes solely dependent on the elasticities of private capital to public capital (ω) and labour (α). It is important to note that the choice of ρ_w is not treated as a policy tool in this analysis, in the sense that we do not attempt to derive an optimal subsidy policy. An optimal subsidy rate would depend on efficiency and welfare concerns in relation to endogenous population growth, which would turn this analysis into a normative one with respect to fertility choices. Instead, the choice of ρ_w is a parameter used to explore different calibrations, to show the economic effects of manipulating the child-rearing subsidy. The ultimate focus is on providing the growth maximizing optimal debt-to-GDP ratio with balanced budgets for any *given* child-rearing subsidy.

Moreover, the structure of the labour productivity-enhancing factors in production is key to the optimality of debt policy. Notice that if public capital becomes irrelevant relative to private capital in the productivity process h_t in equation (4), we will have (other things equal) $\beta \rightarrow 1$ and consequently $(1-\omega) \rightarrow 0$. In this case, both the optimal public-private capital ratio, X^* in equation (25), and the optimal level of debt, d^* in equation (26), tend to zero. This is in line with Greiner (2010) and Checherita et al. (2014).

Finally, the subsidies described above may be interpreted in different ways to cover the different types of age-related spending or social support available. The subsidies may be designed to support raising children. For example, the UK provides child benefit payments which were taxed at standard rates until the 1980s and again from 2012. In fact, *any* grant which is either taxed or means tested can be written as equation (9) under uniform grant or means test rates. Most tax codes, including those in the US, offer a tax free element per child equivalent to the net income supplement of $\rho_w(1-\theta_t)wzn$, which is then taxed at the standard rate (where ρ_w is set to make this expression equal to the tax saving).

But the subsidies could also be in the form of support to higher education. The US, for example, taxes certain training grants and fee waivers. Subsidised loans or means tested tax reductions on fees operate like child benefits, except that z now refers to time spent in education (child rearing by society, rather than by parents). Subsidies could also support education in general, where state spending per pupil is related to the average wage and taxes (levied at standard rates on steady state earnings) that fund that spending. In this case, z is the proportion of the young population in state funded schools.

In addition, subsidies could be directed at health care costs, where caregivers are paid via a state subsidy; or where those costs contain hidden subsidies. Another possibility is sick pay. For example, most EU countries pay a fraction of the wage for time off sick, but then tax it as income. Similarly, caregivers may be paid with a state subsidy, but taxed at standard rates.

4. Policies to manage demographic change

This section examines how two major demographic trends, reduced mortality and reduced fertility, affect fiscal policy and optimal levels of public debt. These two trends lead to ageing populations. In addition, we study the effects on optimal debt of an increase in preferences for current consumption over future consumption, as has been observed for the baby-boomer generation throughout the OECD area. Finally, we also study optimal debt responses to changes in public child-rearing support.

4.1. Increased longevity

Within the framework developed above, we can evaluate how increased longevity impacts the debt-to-GDP ratio. Increased longevity is simulated by lowering the probability of death in transition between periods, λ. By differentiating the optimal debt-to-GDP ratio in equation (26) with respect to λ, we get:

$$d_{\lambda}^{*} = \underbrace{\frac{1}{A}\omega X^{*\omega-1}}_{>0}\ \underbrace{X_{n}^{*}}_{>0}\underbrace{n_{\lambda}}_{>0} \geq 0 \qquad (27)$$

where X_n^* denotes the first derivative of X^* with respect to n; and n_λ is the first derivative of n with respect to λ. Note that equation (14) implies $n_\lambda > 0$. The sign of the partial derivative X_n^* is determined in Appendix C.

Expression (27) implies that rising life expectancy, in the form of a lower probability of death in the transition between periods, leads to a fall in the optimal debt ratio for the whole economy.[15] As the hazard rate decreases, consumption during retirement becomes a more pressing source of utility. Since consumption is financed by labour activities, people need to spend more time at work. As a result they have fewer children.

[15] A variation on this result is that a rise in the retirement age would be reflected, all else equal, in a rise in λ since fewer agents would survive into the retirement period. This is the opposite to the previous example: higher debt is now required to finance the extra output agents would need to produce during their working lives.

Individuals thus shift from utility derived from having children, to utility derived from consumption.

With lower population growth and higher longevity (lower λ), it is no longer optimal for the government to sustain the same public debt level as it did before. The fact that agents choose to have fewer children has a direct impact on the government's budget constraint through the child-rearing subsidy. Since the government spends less on the subsidy, the tax rate needed to balance the current account budget becomes lower, as shown in equation (20). The servicing costs of public debt will also be less since the optimal debt level falls. This further lowers debt servicing cost through a drop in the interest rate payable, this can be seen by equation (6). In short, a fall in λ leads to a rise in savings by the working population ($\partial s_t/\partial\lambda < 0$) that now realizes it needs to save more for retirement than before, at the cost of fewer children.

4.2. A fall in the preference for children

We next consider the case of a fall in the preference towards children, defined as a drop in ε which leads to a fall in the birth rate. In this case we can write, upon differentiating the optimal debt-to-GDP ratio (26) with respect to ε,

$$d_\varepsilon^* = \frac{1}{A}\omega X^{*\omega-1}X_n^* n_\varepsilon \tag{28}$$

where d_ε^* denotes the derivative of d with respect to ε; and where

$$n_\varepsilon = \frac{1+(1-\lambda)\rho}{z(1-\rho_w)[1+(1-\lambda)\rho+\varepsilon]^2} > 0 \tag{29}$$

which confirms that a fall in the preference for children leads to a fall in the birth rate. We may therefore work with change in either ε or n. It follows that

$$d_\varepsilon^* = \underbrace{\frac{1}{A}\omega X^{*\omega-1}}_{>0}\ \underbrace{X_n^*}_{>0}\underbrace{n_\varepsilon}_{>0} \geq 0 \tag{30}$$

So, for positive subsidies, a fall in the birth rate would lead to lower optimal debt levels. Since the sign of n_ε is the same as n_λ, the story here is similar to the one of greater longevity. The explanation: a lower preference for children increases labour force participation in period t, due to less time spent rearing children. That leads to increased rates of consumption, now and in the future. Additionally, the drop in fertility eases the tax burden of the child-rearing subsidy, leading to lower tax rates and greater savings and consumption, yielding an optimal fiscal policy with lower public debt.

4.3. Higher discount factors

The third example is the effect of an increase in the discount factor, taking the form of a fall in ρ. This is often referred to as the baby boomer problem. It is exactly what happened with the baby-boomer generation in Europe, albeit less dramatically than in the US or UK, where the preference for current consumption over future consumption increased and savings rates fell.[16] Those are exactly the changes implied by (8), which then implies, *ceteris paribus*, $\partial s_t/\partial\rho > 0$ by (13).

To examine the debt consequences of this, we need to determine the sign of

$$d_\rho^* = \frac{1}{A}\omega X^{*\omega-1}X_n^* n_\rho \tag{31}$$

where, by eqn. (14),

$$n_\rho = \frac{-\varepsilon(1-\lambda)}{z(1-\rho_w)[1+(1-\lambda)\rho+\varepsilon]^2} > 0 \tag{32}$$

Hence we have:

$$d_\rho^* = \underbrace{\frac{1}{A}\omega X^{*\omega-1}}_{>0}\ \underbrace{X_n^*}_{>0}\ \underbrace{n_\rho}_{>0} \geq 0 \tag{33}$$

---

[16] This example assumes social support, ρ_w, is unchanged. If not, savings may increase – as in Japan or China.

In words, a lower concern for the future (the revealed preference of the baby boomers) leads to higher levels of public debt. This matches exactly what has happened in nearly all European and OECD countries over the past two decades, although baby-boomers may not have been the only cause. However, higher future discounting is not the only effect in play. Mortality trends and fertility choices coexist in the observed data associated with the baby boomer generation. The end result depends on the *net* combined effects of a drop in ρ, λ and ε. The model would then match observed data; lower savings combined with fewer children.

The intuition is that baby boomers have lower preferences for saving and higher preferences for immediate gratification which, in this model, is present consumption and child rearing at the cost of future consumption. Consequently the birth rate increases, but so does the child-rearing subsidy bill. Thus, even though individuals save less now, implying lower economic growth, the optimal level of debt rises (a higher public-to-private capital ratio, X) for the same reason as in the hazard rate and preference for children examples.

This poses a policy challenge: not only do current levels of debt need to be reduced to normal levels, but they need to fall further than that as the baby boomers retire. This might be taken as a justification for imposing a "granny tax" on retirees in cases where social support and excess debt are allowed to continue unchecked. However, a proper analysis of that case would need a model with separate tax rates for young and old, since those rates may affect working and saving behaviour.

4.4. An increase in support for child-rearing

Finally, we consider the effects of ρ_w on growth-maximizing debt. This highlights how different government policies related to fertility can impact optimal fiscal policy. The subsidy rate reduces the cost of raising children, so higher subsidies naturally lead to higher fertility n by equation (14). This would be useful if fertility falls below the replacement rate.

Using the previous framework, we now need to determine the sign of $d^*_{\rho_w}$. The relevant derivative of d^* with respect to ρ_w can be written as:

$$d^*_{\rho_w} = \underbrace{\frac{1}{A}\omega X^{*\omega-1}}_{>0}\left(\underbrace{X^*_{\rho_w}}_{>0} + \underbrace{X^*_n n_{\rho_w}}_{>0}\right) \tag{34}$$

where $X^*_{\rho_w}$ and n_{ρ_w} denote first derivatives with respect to ρ_w. The signs of n_{ρ_w} and $X^*_{\rho_w}$ are determined in Appendix C.

It follows from equation (34) that the optimal debt burden in equation (26), d^*; will increase with subsidies ρ_w. The reason: the subsidy reduces the private cost of raising children, so higher subsidies lead to higher fertility n: (14). It also increases the tax rate θ_t and time spent on child rearing (zn). Anything not related to public debt maintenance (rb_t) that increases the tax rate and budget cover, increases the optimal level of public debt and public-private capital ratio, directly and indirectly, as can be seen from (34) where subsidy rates and the fertility rate are increased at the same time.

5. Calibration

To test the performance of our model as a reasonable and plausible representation of the type of advanced economy that we might be interested in, we calibrate it to match the typical OECD economy for the period 1969–2013.[17] We then alter the underlying demographic structure to match the following 45 year periods. This allows us to assess fiscal sustainability under social or demographic changes of different sorts; how that compares to the long-run fiscal position and growth rates observed in the OECD

[17] Given the time period at hand and the focus group (the OECD countries), some of the data required for the calibration exercise is missing. We use mean imputation to fill those gaps.

economies in the past; and whether these economies would find it easy or feasible to transition to the corresponding steady state.[18]

To gain some insight into the potential problems of OECD economies facing demographic change, we first perform a baseline calibration of those economies using the model in section 2. The calibration is based on a period of 45 years in length. This assumes that agents in the model start working at age 20, work for 45 years and retire at age 65. We choose the remaining parameters to produce a realistic demographic and production structure for the average OECD economy. Table 1 sets out the parameter values; the motivation for each value follows below.

5.1. Production parameters

We focus first on production. The value of the output elasticity of private capital, α, is 0.37. Given the production function is CobbDouglas, this value then matches the average private wage income share of GDP in the OECD from 1969 to 2013, as measured by the AMECO database: "Adjusted wage share, total economy, as percentage of GDP at current factor cost".

Parameter β captures the private sector share in labour productivity gains: that is, the share of income gains that come from productivity increases due to private as opposed to public capital. This is not a figure that is reported in national accounts. But Checherita et al. (2014) estimate ω to be equal to 0.716.[19] Having α equal to 0.37, the

---

[18] In future work, we could go on to look at the steady states implied in particular economies, including: (1) the "Anglo-Saxon economies" (US, Canada, UK); (2) countries where the process of population ageing is particularly strong (Japan, Italy, Germany); (3) the Nordic welfare states with flexible markets and strong social provision (Denmark, Sweden); (4) economies with slow population growth and limited social support (Russia, China); or (5) those with young and fast growing populations (India, Mexico, the Philippines).

[19] This paper uses a slightly more general production function than we do, the difference being that Checherita et al. do not include per-employee productivity gains to labour inputs to production. We have the following production function $Y_t = AK_t^{\omega} G_t^{1-\omega}$ whereas they have $Y_t =$

definition of ω implies that β equals 0.55. In section 7 we analyse the sensitivity of our results to this assumption.

The TFP scale effect A is subject to interpretation. In this model, productivity contributes to growth in two ways: one endogenous, the other exogenous. Labour-augmenting productivity h_t represents the endogenous component, and the TFP parameter A is the exogenous component (Fehr et al., 2013; Hviding and Merette, 1998). We use the expression for production in equation (5) to calibrate A. This expression links GDP, the private capital stock and public capital stock, all available figures. We obtain these figures from IMF's Investment and Capital Stock Dataset and MEI database (2017). We then use the value for ω specified above. Solving equation (5) with these values then yields $A = 34$.

5.2. Preference and demographic parameters

Parameter ρ is designed to capture the value an agent puts on future consumption relative to present consumption; that is, the discount to be applied at the start of the working period to decisions made for retirement 45 years later. Given the long time period relating the preference for consumption in the present vs. that in the future, we apply an annual discount rate of 1% hyperbolically. For a period of 45 years, this yields ρ equal to 0.69.

Parameter z captures time taken off work due to child-rearing activities. We use data from the US Census Bureau's "Annual Social and Economic Supplement to the Current Population Survey" for "Persons who did not work or look for work by age, gender, and reason for not working in 2014". The proportion of working-age people not

---

$A(K/L)_t^{\varphi} K_t^{\omega} L_t^{1-\omega}$ (in our notation, where φ is the output elasticity of the labour-capital ratio to GDP). For our specification to match theirs, φ must be zero. In fact, their estimate of the OECD average for φ is very close to zero at 0.037 (Table 2, Model 2, Checherita et al., 2014).

working in order to undertake home responsibilities is 28.1%. Interpreting "home responsibilities" as a measure of people not working for child-rearing reasons, z simply becomes 0.281.

Table 1
Parameter values of the baseline simulation, OECD area.

α	Private capital's share in national income	0.37
β	Private capital elasticity in productivity gains	0.55
γ	Private capital elasticity in production	0.716
A	TFP scale factor	34
ρ	Discounting	0.69
z	Rearing time per child	0.281
ρ_w	Child rearing subsidy rate	0.193
λ	Hazard rate	0.7
ε	Importance of children in utility	0.539

Table 2
OECD population growth, old-age dependency ratios and life expectancy (45 year averages).

	1970–2015	2015–2060	2060–2100
45-year population growth rate	36.1%	6.3%	−5.2%
Old-age dependency ratio	21.9%	44.0%	60.1%
Life expectancy at birth	75.2	83.9	89.2

Source: United Nations

Next we calibrate the child-rearing subsidy rate. We use the OECD's Family Database, and the "Total public social expenditure on families as a percentage of GDP" data in particular. Social spending by families in the OECD from 2001 to 2013 averaged 2.36% of GDP. This number does not include primary to tertiary schooling. For this, we use the OECD "Education at a glance" reports. The OECD average public expenditure on primary to tertiary education, for 2001–2013, is 5.15% of GDP. Total public expenditures on children measured as a percent-age of GDP then becomes 7.51%. In order to match those expenditures as a proportion of GDP with the model's expenditures measured as a proportion of wages, we match total expenditures in the real world to total public expenditures in the model with children, $Nwzn\rho_w$ (where Nw

is total spending in the economy). Knowing that the population growth factor in the OECD for 1970–2015 is $n = 1.361$ (see Table 2), $\alpha = 0.37$ and $z = 0.281$, we get $\rho = 0.193$.

Next, λ and ε are the key demographic parameters. Both influence the age structure and the growth of the population. Starting with λ, the hazard rate, it needs to be set so that the model's old-age dependency ratio matches the observed data. The model's old-age dependency ratio is equal to $(1 - \lambda)/n$. And for the old-age dependency ratio in the data, as seen in Table 2, is 21.9% for the period 1970–2015. Table 2 also reveals that $n = 1.361$ for the same period. Solving for lambda, we obtain $\lambda = 0.7$.

Finally, the children preference parameter, ε, needs to be set so that the model's fertility rate per individual in the model matches OECD data. In the model, the 45-year population growth rate is simply equal to the fertility rate per individual, n. Again, Table 2 indicates that the 45-year population growth rate for the period 1970–2015 is 36.1% or 0.69% annually. Solving (14), the expression that defines fertility choices, for ε yields $\varepsilon = 0.539$.

Notice that $\varepsilon = 0.539$ ensures that a non-trivial steady state will exist; the lowest permissible value, by (15), being $\varepsilon \approx 0.35$. We make an important distinction between reality and the model here. The model does not recognise that not every woman is able or willing to have children. The rule of thumb is that 10% of adults do not have children which means that, to maintain a constant population, each woman needs to have 2.2 children. These figures therefore ensure we have a non-trivial steady state, but also a realistic population growth in steady state.

6. Steady state characterisation

6.1. A first look at the results

Table 3 summarizes the output of the baseline simulation. We see that the demographic parameters, the number of children per agent and the age dependency ratio, are in line with what was experienced in a typical OECD economy as represented in Table 2 for the period 1970–2015. Life expectancy at birth, as calculated by $20 + 45 + 45(1 - \lambda)$, stands at 78.5 years, which is not far from the value observed in the data for the OECD (75.3 years, source: United Nations Population Division).

The optimal debt to GDP ratio, d^*, is then 49.67% which indicates a value that is somewhat lower than the historical value for most OECD economies. This does not come as a surprise, given the fact that most countries are far from respecting the golden rule of public finance. The optimal ratio of public-to-private capital is roughly 25.5%, while the optimized growth rate of output is 90% over the 45year period. This *per period* growth implies *annual* average growth rates of 1.44% in steady state (0.75% per capita). These values are a bit lower than the OECD economies actually experienced in the 1969–2013 period (an average of 2.8%, or 1.91% per capita[20]). The reason for this is that we only include endogenous growth components, and not exogenous growth effects (a growing TFP parameter A).[21]

Table 3
Results of steady state baseline simulation.

$d*$	Optimal debt to GDP ratio in steady state (no TFP)	49.67%
X	Public private capital ratio	0.2546
γ^A	Annual economic growth rate	1.44%
γ	Annual economic growth rate per capita	0.75%
θ	Tax rate	14.50%
$\tilde{C}$	Saving rate (of disposable income)	11.86%
r	Annualized interest rate	5.14%
n	Number of children per person	1.36
	Old-age dependency ratio	22%
	Life expectancy at birth	78.5

[20] The OECD Economic Outlook dataset for growth rates; World Bank WDI report for per capita growth rates.
[21] The model is not well equipped to have a growing TFP parameter A, since doing so may imply ever growing steady state interest rates (see equation (6)).

The resulting tax rate is 14.5%, which is a reasonable rate for taxes that finance (service) only public debt and child-related spending. Furthermore, the savings rate from disposable income is 11.86%, in line with OECD data in the AMECO database (11.3%). Also, the *annualized* steady-state interest rate sits at 5.14%, somewhat higher than the observed average OECD rate interest rate of 4.37% in the period 1969–2013.

What are the lessons from these simulation results? First: that a steady state solution and a sensible and sustainable set of fiscal policies is both feasible and available. Second: based on reasonable parameter values for the average OECD economy, the steady state solution demonstrates realistic properties in view of the OECD experience in 1969–2013.

They also suggest that public debt at just below 50% of GDP is a reasonable target level to aim at. This accords well with the Maastricht Treaty/Fiscal Compact upper limit of 60% to create a debt target with a 10% safe zone to accommodate shocks. Moreover, it accords well with the pre-crisis experience of non-Eurozone economies (the US or UK) where debt was held in the 35%–45% range. It also suggests a mixed economy with a public sector share of around 25.5%: that is lower than in Scandinavia or the Eurozone (Sweden, Denmark, France, Italy, Germany, the Netherlands), but similar to that in the US, Canada, Australia or the UK in the pre-crisis era. Finally, it suggests population growth very close to that projected for the OECD (Table 2).[22]

A first impression of these results is that the demographic situation is perhaps not as bad as many commentators fear. But it will not be easy for most OECD countries to get themselves down to this optimal steady state level of debt (that is to remove an

[22] Our calibration also yields an old-age dependency ratio of 22%, see Table 2. This is rather low and suggests a new a risk: if migrants arrive but then adopt the mores of the domestic population, as assumed by our model, then age-dependency ratios will rise without a corresponding increase in long term population growth rates.

average of 65% points from current debt ratios for those OECD economies with excessive debt-GDP ratios in 2013[23]), and to maintain the steady state rate of growth in productivity at the same time, currently a problem of major concern to OECD policymakers.

Our results are also consistent with standard growth theory models that show GDP growth ultimately comes from either growth in productivity or growth in the workforce. Since we have little of the latter (the annual population growth rate of 0.69%, is only a little above the constant population replacement rate), GDP growth has to come from productivity growth. Demographics do not affect that: the population growth is simply too slow to make up the difference. However, the transition to steady state growth could become more difficult for economies that currently find themselves a long way from that steady state.

6.2. Changes in the population parameters

To provide insight into the effect of demographic change on the steady state, we evaluate the partial derivatives in Section 4 around the baseline in Table 3. The results are in Table 4.

A general finding is that the changes in outcomes are all rather small with respect to both X^* and d^*. Table 5 goes further; it reports the effects on X^* and d^* when we calibrate the model to match variations in the demographics that might be expected in the future (Table 2). We see that the effect in 2015–2060 is a decrease of 0.3 percentage points in both X^* and d^*. That is extremely small. For 2060–2100, the decrease is even smaller: 0.1 percentage points. These negligible impacts illustrate the economy's *structural* robustness to age-related transfers. But ε and λ influence optimal debt

[23] These countries are all OECD economies, except Chile, Estonia, Luxembourg, Norway, and Turkey.

through n and the child-rearing subsidy. So other performance indicators may be more sensitive to variations in age-related government spending.[24]

Thus, we conclude that not only is the optimal steady state under the new demographics relatively benign, but likely future demographic and social *changes* will make little difference to that steady state once the economy gets there. In short, there is not much long-term sensitivity to demographic or economic shocks. Instead, for most OECD economies, the difficulty will be how best to manage the transition from where they are now to their steady state.

Table 4
Sensitivities to demographic parameters, OECD economies.

X_n^*	$\partial X^*/\partial n$	0.0067
n_λ	$\partial n/\partial \lambda$	0.538
n_ε	$\partial n/\partial \varepsilon$	1.746
n_ρ	$\partial n/\partial \rho$	−0.234
d_λ^*	$\partial d^*/\partial \lambda$	0.005
d_ε^*	$\partial d^*/\partial \varepsilon$	0.016
d_ρ^*	$\partial d^*/\partial \rho$	−0.002

Table 5
Optimal public debt/investment policies with balanced budgets.

	1970–2015	2015–2060	2060–2100
λ	0.7	0.532	0.43
ε	0.539	0.42	0.382
Life expectancy at birth	78.5	86.1	90.65
X^*	25.5%	25.3%	25.2%
d^*	49.7%	49.4%	49.3%

6.3. Changes in the child-rearing subsidy

We now analyse how changes to the child-rearing subsidy rate ρ_w impact the steady state and fiscal policy. As an example, we consider a case where the government uses

[24] Some generalisations of the model might be useful here: removing the assumption of no capital depreciation, or equal taxes on wages and subsidies, or subsidies as a fixed ratio to wages.

the child-rearing subsidy to reverse adverse demographic shocks. Specifically, suppose a preference shift takes place such that agents have a lower propensity to raise children, directing their income towards more consumption instead. This could be problematic for society if fertility rates drop below the replacement rate (as is expected to happen sometime in the period 2060–2100, see Table 2). Faced with this problem, the government might wish to raise the child-rearing subsidy. From Section 4, we know that (a) a drop in the preference for children leads to a lower optimal debt-GDP ratio; and (b) a higher subsidy rate leads to increases in the optimal debt-GDP ratio. These two effects conflict, so the end result on the debt ratio is ambiguous. It all depends on which effect on d^* is larger.

To answer that question, we introduce a calibration exercise where we look at the steady state effects of a composite shock where there is first a drop in the preference for children, sufficient to bring the fertility rate to the population replacement rate (1.1 per person), and then a rise in the child-rearing subsidy to bring the fertility rate back to its baseline value (1.36 per person).

The results are reported in Table 6. All parameters are as in the baseline calibration (Table 1) except for the explicit changes made to ε and ρ_w. For clarity, the tax rate has been decomposed into the taxes necessary to service public debt and taxes needed to cover the subsidies. From this calibration, we see that, ceteris paribus, a drop in the preference for children decreases the total tax rate since, with fewer children, there is less strain on the government's budget. There is also some extra saving as agents divert their time allocation away from child-rearing to employment. Taxes to cover debt service therefore increase when the preference for children goes down because more public investment will be needed to generate the extra output and jobs. There are two opposing forces here. On one hand, optimal public debt decreases, equation (30), as do interest rates (though by a negligible amount, as Table 6 reveals). On the other, tax revenues decrease because subsidy payments (a *partial* income replacement) are subject to tax, so fewer children enter the work force. This may create fiscal pressures in order to service public debt. Ultimately, if the tax revenue effect dominates the public debt effect, a higher tax rate will be necessary for debt servicing. However, growth per capita may increase even if aggregate economic output falls because fewer children are available for work in the future.

When we allow increasing subsidies to recover the baseline fertility rate, a different picture emerges. The additional subsidy spending is covered by taxation, increasing the total tax rate to well above baseline. This is due to the higher subsidy rate; the tax rate associated with debt servicing actually decreases as a result of the extra tax revenues stemming from the increased subsidy rates. The saving rate from post-tax income remains the same. The public-private capital ratio and optimal public debt are now both above baseline.

Table 6
Subsidies used as a policy tool.

	Baseline	Decreased preference for children	Increased subsidy
Preference for children (ε)	0.539	0.401	0.401
Child-rearing subsidy (ρ_w)	0.193	0.193	0.348
Fertility rate	1.36	1.10	1.36
Total tax rate …	14.5%	12.9%	18.8%
…of which debt servicing	8.1%	8.2%	7.8%
…of which subsidy coverage	6.4%	4.7%	11.0%
Saving rate	11.86%	12.87%	12.87%
Interest rate (per year in steady state)	5.14%	5.14%	5.15%
Public-private capital ratio	25.5%	25.3%	25.9%
Government debt-GDP ratio	49.7%	49.5%	50.3%
GDP growth (per year in steady state)	1.44%	1.41%	1.51%
GDP growth per capita (per year)	0.75%	1.2%	0.82%

Interestingly, per capita GDP growth and GDP growth are also both above baseline, revealing that, in the face of a decreasing preference for children, an economy can still benefit from increased public support for child-rearing at the aggregate level. When the increase to the child-rearing subsidy is considered in isolation to the drop in the preference towards children, we see that aggregate economic growth is increased, whereas its per capita measure decreases. This reveals a trade-off in fertility-boosting policies: changes in the subsidies may have opposing effects on economic growth and growth per capita.

In sum, when a government attempts to preserve the fertility rate at current levels by increased public support for child-rearing, the optimal level of public debt increases along with higher tax rates and lower economic growth per capita. These results illustrate the trade-off between population growth and economic growth when policies are used to influence population size. Our analysis does not address the issue of an optimal child subsidy of course; it merely reveals alternative steady state outcomes.

7. Sensitivity analysis and political economy trade-offs

7.1. Sensitivity analysis

The optimal debt level depends, to a large extent, on the composition of labour productivity, in which β plays a key role. Fig. 1 therefore demonstrates the sensitivity of our results to different choices for β.

As β increases, we expect to see private capital become increasingly important to output and labour productivity (h_t in equation (4)), while public capital becomes less important (decreasing returns to scale). The public-private capital ratio should therefore decrease, along with the optimal level of debt (26). That much we see, with rising growth rates, in Fig. 1. Conversely, X^* and d^* *rise* with falling β; but growth rates fall (if decreasingly so).

In other words, the economy becomes increasingly dependent on public capital and lower growth when the private sector's income share from productivity gains falls. This is hardly a surprise. The question is, why would that income share fall; and why are the impacts on X^*, d^* so large? It is worth stressing though that the impacts on growth are relatively small if we restrict ourselves to *plausible* changes in β, say $0.4 \leq \beta \leq 0.7$. The share of private capital income in GDP is not likely to change beyond those bounds – in which case annual growth rates would vary between roughly 1.25% and 1.75%, a fairly narrow range. However, X^* and d^* then vary from 18% to 35%, and 30%–70% respectively, a larger range but still consistent with a feasible and sustainable steady state solution (and less debt than many currently have).

To some extent, the sensitivity of economic growth to changes in β is due to the impact of taxation. Fig. 1 depicts a negative relationship between economic growth and taxation.

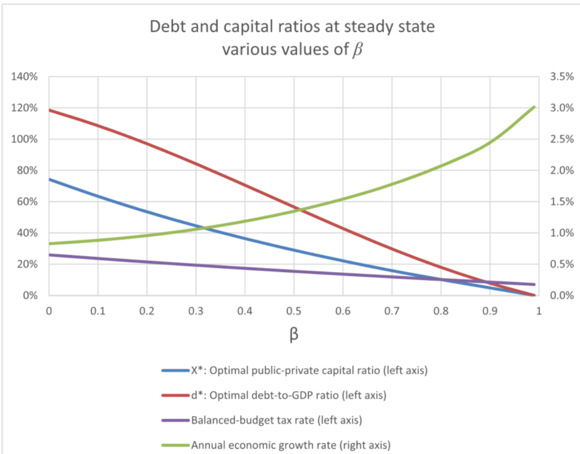


Fig. 1. Debt and capital ratios in steady state, various beta values.

A lower value of β implies an economy where public capital plays a larger role in determining labour productivity. However taxes have to rise to cover the cost of servicing the debt used to create that public capital. The negative effects of taxation manifests itself directly through a reduction in savings at any given generation; this partly explains why the economic growth curve is upward sloping.

Having to issue more government bonds crowds out the quantity of private capital that can be generated from a finite amount of aggregate savings; this further increases the sensitivity of X^* with respect to the issuing of public capital. Coupling this crowding-out with the fact that ω falls when β falls, equation (26) reveals why the debt-GDP ratio is the more sensitive variable. This suggests that fiscal discipline (rules) should focus on the debt burden, rather than on the deficit. At the same time, real wages are likely to fall, and returns to investment rise, if private capital's income share were to fall (see (6) and (7)) when taxes and interest rates are low (as they are now). This gives further insight into current concern for inequality.

7.2. Sensitivity to different subsidy and hazard rates

Next we explore sensitivities due to different child-rearing subsidy rates ρ_w and hazard rates λ. Fig. 2 depicts the change in the optimal debt-to-GDP ratio, d^*, and optimal public-private capital ratio X^* as a result of doubling the child-rearing subsidy rate; Fig. 3 depicts the effects of increased longevity (lower λ values) on the same variables. The main observation is that the impacts on X^* and d^* are rather small for plausible values of β, say $0.4 \leq \beta \leq 0.7$. So the effects on growth rates will be considerably smaller.

Since β is a key determinant of the positive effects public capital on growth, the d^* and X^* curves are downward sloping in Fig. 2. Thus, a government that attempts to incentivize higher fertility choices in an economy that is heavily dependent on public capital will tend to have higher optimal debt-GDP ratios (increases of more than 2 percentage points for $\beta < 0.5$). In the opposite case, an economy where labour productivity is little dependent on public capital, doubling of the subsidy rate produces low to negligible effects on both d^* and X^*. Similar effects can be seen from increased longevity, in Fig. 3: the effect on both d^* and $X^*$is now negative and negligible across the board when the hazard rate is halved. In sum, economies that depend on public capital to boost productivity (and thus, wage rates) are more sensitive to demographic and public finance shocks; though these shocks never translate into meaningful changes to optimal public debt schedule for the whole range of β values.

In general, the value of 0.55 for β in the baseline calibration seems to be a good middle ground for plausible β values: $0.4 \leq \beta \leq 0.7$. Extremes on both sides are eliminated as we neither observe, or are likely to observe, the extremes associated with low β values relative to the small variations associated with high β values. A key take away is that the value of β does not change the sign of the impacts of demographic change, but only their size.

7.3. Political economy considerations

Fig. 4 provides isoquant lines for different values of growth and debt. The isoquants are determined by considering different mixes of α and β values. In this sense, who benefits from productivity gains can be discussed in the wider context of economic performance and debt sustainability.

The political economy implications here depend on specific interpretations of α and β. As the value of β increases, private capital's share of the income generated by labour augmenting productivity gains rises. By contrast, a fall in β implies greater importance for public capital. At the same time, a rise in α increases the share of private capital relative to the share of labour income in national income.

Fig. 4 can be interpreted as follows: If we go northeast in the diagram, private capital becomes the main driving force of economic growth, both by having a major influence on labour productivity and by being the chief input in the production function. This area represents economies marked by higher private capital income shares (relative to both public capital and labour). Here we get lower debt, but little (if any) additional growth, and none at all if the movement is mostly east. Conversely, movement to the south-west would result in an economy largely dependent on public capital, resulting in higher debt levels (and higher growth if the movement is sufficiently to the west).

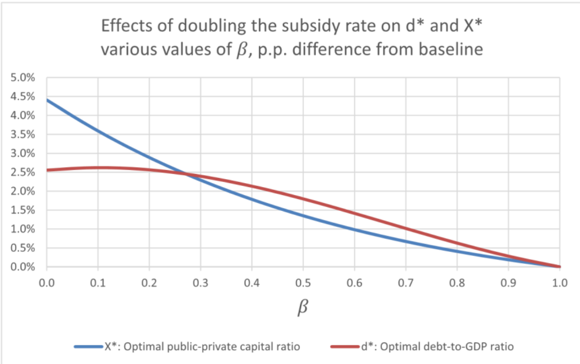


Fig. 2. Changing the subsidy rate, impacts on d^* and X^*.

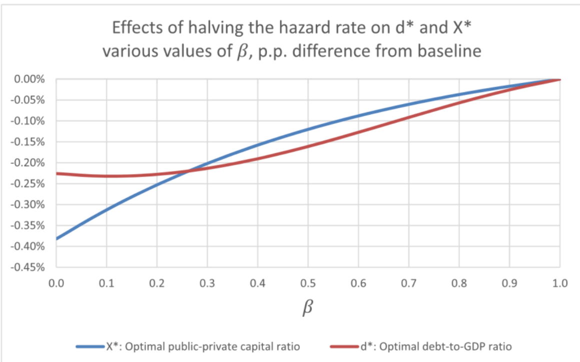


Fig. 3. Changes in life expectancy, the effects on d^* and X^*.

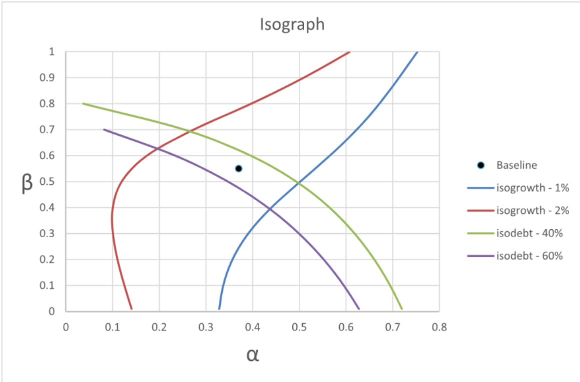


Fig. 4. Steady state growth-public debt possibility frontiers under different income shares for private and public capital.

By contrast, moving northwest up the diagram, an area where there is a larger share of labour income at the same time that private capital is still highly relevant for the productivity of labour, brings higher growth more rapidly. Debt reductions will become increasingly elusive (and may not materialize at all if there is too much movement west). The income gains from higher productivity will increasingly accrue to workers. Conversely, movement to the south-east could lead to low shares of income going to workers while there might be little change in the debt level. This is because, as α decreases, the marginal productivity of labour decreases.

The implication of these results is that, in steady state, public sector productivity is crucial to economic performance. The political economy trade-offs, in terms of performance and fiscal imbalances, are laid out in uncompromising reality once we account for changing demographics and how the gains from productivity are distributed. It would appear that productivity plays a key role, perhaps even more than we thought before.

Furthermore, even if demographic change has small impacts on d^* and X^*, it is important to highlight that changes to tax rates due to demographic change may not be trivial. As Fig. 5 shows, the child-rearing subsidy is heavily correlated with the tax rate, so that, for countries with stronger subsidies, a balanced budget rule obviously requires stronger shifts in the tax rate to balance the fiscal current account. Thus, if there is any impact of demographic change on optimal fiscal policy, it won't be on public debt, but on tax rates and fiscal policy.

The process of demographic change has economic growth effects that are quite small, but may cumulate into something larger over time. We also saw that economic growth depends on population growth as well as productivity growth. This just confirms the standard models of growth theory. However, once fertility choices are endogenised, the problem of maximizing economic growth is not the same as maximising growth per capita.

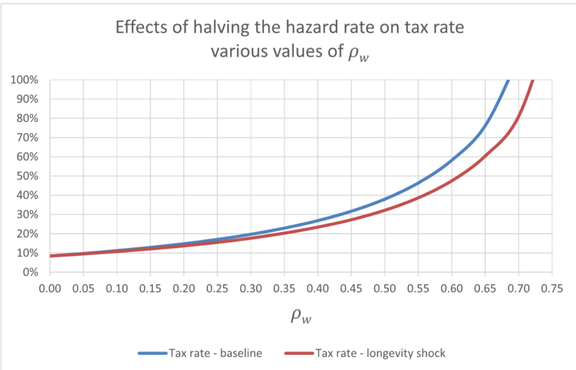


Fig. 5. The effect of changes in the subsidy rate on the general tax rate.

In fact, if the government turns fertility into a policy objective by introducing child-rearing subsidies (and nearly all advanced economies do), the maximization of economic growth may imply reductions in growth per capita. The reasoning is as follows: an increase in the subsidy rate at time t has three effects. One, it stimulates a higher *incoming* rate of workers (higherN_{t+1}, N_{t+2}, etc.), since more children are born at t. Two, labour supply permanently decreases [lower $(1-zn)$] because more time has to be spent on child rearing. The effect of increased subsidies on labour supply is therefore ambiguous. Three, tax rates increase as a consequence of a higher subsidy (and the rise in zn). But the increase in the number of future workers does not automatically lead to higher savings in the future since the extra workers face a decrease in disposable wages. In addition, any increases in labour supply will lead to a permanent decrease in real wages, as seen in equation (7). Those effects, if they prevail over increased post-tax earnings and employment, will decrease the flow of funds available for investment. That is not guaranteed however. The overall effect of increased subsidies on aggregate savings is therefore also ambiguous.

Be that as it may, even if higher subsidies lead to stronger wealth accumulation and stronger growth, the impact on growth per capita γ^A/n, via the increase to the denominator of this expression, may outweigh the positive effects of any decrease in labour supply $1/(1-zn)$. Thus, increasing the subsidy rate may lead to reduced economic growth per capita.

8. Concluding remarks

1) Our model and simulations show that steady state outcomes for an advanced economy facing today's demographic and social trends are always feasible and available. They are relatively benign and resemble those of the OECD economies a few decades back.
2) Plausible changes to population parameters and social conditions in the future make rather little difference to the steady state outcomes for the optimal public-private capital ratio and public debt once we get there.

3) Instead the steady state is driven by economic fundamentals: productivity, the production structure, and income generation. The real problem is therefore to get to the chosen steady state without being derailed by undue strains or fiscal collapse along the way. That is the next step in our research (Hughes Hallett et al., 2017).
4) Fiscal sustainability is a matter of changes in tax or spending in transition, not so much long term debt.
5) Sensitivity tests show we can get a variety of outcomes for the public ownership mix and debt level in the economy, but without much change in the performance levels. In that sense our results are robust to parameter or assumption variations.

Hence demographic change is not necessarily a problem, if properly handled, compared to the fiscal laxity seen over the past 20–30 years. This is contrary to a conventional reading of the IMF's earlier advice. But it is consistent with the IMF view if we reinterpret that to mean "ageing and social change are not a problem, in steady state, so long as reliable fiscal rules or credible fiscal restraints are set up in advance to manage fiscal policy and the transition". We have shown that the golden rule of public finance (the least intrusive form of fiscal restraint) is sufficient to do the job.

But to imply that ageing and changing demographics are not a problem in steady state does *not* say that all OECD economies will find it easy to get used to living in an era of slower growth and lower debt than they enjoyed for three or four decades past. In fact, the real problem is likely to be how to create and then safeguard the transition to that steady state. In short, the challenge is to find and maintain durable dynamic adjustment paths.

References

Aiyagari, S. Rao, McGrattan, Ellen R., 1998. The optimum quantity of debt. J. Monetary Econ. 42, 447–469.

Arrow, Kenneth, 1962. The economic implications of learning by doing. Rev. Econ. Stud. 29, 155–173.

Aschauer, David A., 2000. Do states optimise? Public capital and economic growth. Ann. Reg. Sci. 34, 343–363.

Auerbach, Alan, 2009. Long-term objectives for government debt. Finanzarchiv 65, 472–501.

Auerbach, Alan, Herrmann, Heinz, 2002. Ageing, Financial Markets and Monetary Policy. Springer Verlag, Berlin.

Barro, Robert, 1990. Government spending in a simple model of endogenous growth. J. Polit. Econ. 98 (5), 103–125.

Bergman, U. Michael, Hutchison, Michael M., Jensen, Svend E. Hougaard, 2016. Promoting sustainable public finances in the European Union: the role of fiscal rules and government efficiency. Eur. J. Polit. Econ. https://doi.org/10.1016/j.ejpoleco.2016.04.005.

Blanchard, Olivier, 1985. Debt, deficits, and finite horizons. J. Polit. Econ. 93, 223–247.

Blanchard, O., Giavazzi, F., 2002. Reforms that Can Be Done: Improving the SGP through a Better Accounting of Public Investment. Dept. of Economics, MIT, Cambridge, MA (November).

Bohn, H., 2002. “Retirement Savings in an Ageing Economy: a Case for Innovative Government Debt Management” in Auerbach and Herrmann (2002) op. cit.

Bokan, Nikola, Hughes Hallett, Andrew, Svend, E., Jensen, Hougaard, 2016. Growth-maximizing debt under changing demographics. Macroecon. Dyn. 20, 1640–1651. Checherita, Westphal Cristina, Hughes Hallett, Andrew, Rother, Philipp, 2014. Fiscal sustainability using growth-maximizing debt targets. Appl. Econ. 46 (6), 638–647.

Debrun, X., Moulin, L., Turrini, A., Ayuso-i-Casals, J., Kumar, M.S., 2008. Tied to the mast? National fiscal rules in the European Union. Econ. Pol. 23, 297–362.

Eyraud, L., Duarte Lledo, V., Dudine, P., Peralta, A., 2018. Fiscal Policy: How to Select Fiscal Rules. Fiscal Affairs Department (Occasional Note 9, March). IMF, Washington, DC.

Fatas, A., von Hagen, J., Hughes Hallett, A., Strauch, R., Siebert, A., 2003. "Stability and Growth in Europe: towards a Better Pact" Monitoring European Integration 13. Centre for Economic Policy, London.

Fehr, H., Jokisch, S., Kallweit, M., Kindermann, F., Kotlikoff, L., 2013. Generational policy and aging in closed and open dynamic equilibrium models. In: Handbook of Computable General Equilibrium Models, vol. 1. Elsevier, Amsterdam (chapter 27).

Foremny, D., 2014. Subnational deficits in european countries: the impact of fiscal rules and tax autonomy. Eur. J. Polit. Econ. 34, 86–110.

Greiner, A., 2010. Economic growth, public debt and welfare: comparing three budgetary rules. Ger. Econ. Rev. 12, 205–222.

Hughes Hallett, A., Jensen, Svend E. Hougaard, 2012. Fiscal governance in the Eurozone: institutions vs. Rules. J. Eur. Publ. Pol. 19, 646–664.

Hughes Hallett, A., Jensen, Hougaard, Svend E., Sveinsson, T.S., Vieira, F., 2017. From Here to There: Transition Paths from High Debt to Sustainable Fiscal

Strategies under Adverse Demographics. Economics Department, Copenhagen Business School (mimeo).

Hviding, K., Merette, M., 1998. "Macroeconomic Effects of Pension Reforms in the Context of Aging Populations: OLG Model Simulations for 7 OECD Countries", Economics Working Paper 201. Economics Department, OECD, Paris.

Kalaitzidakis, Pantelis, Kalyvitis, Sarantis, 2004. On the macroeconomic implications of maintenance in public capital. J. Publ. Econ. 88, 695–712.

Makuyana, Garikai, Odhiambo, N., 2016. Public and private investment and economic growth: a review. J. Account. Manag. 6 (No.02), 25–42.

Nerlich, C., Reuter, W.H., 2013. The Design of National Fiscal Frameworks and Their Budgetary Impact. ECB Working Paper Series No. 1588.

Yakita, Akira, 2008. Ageing and public capital accumulation. Int. Tax Publ. Finance 15, 582.

Appendix A. The solution to the optimal level of debt problem

We start from (21), with (20) and (7), to obtain an expression from which we can derive a closed form expression for the economy's growth rate γ^A:

$$\tilde{C}\left(\frac{1}{\alpha X+\rho_w(1-\alpha)\frac{zn}{1-zn}+1}\right)A(1-\alpha)\left(\frac{K_t}{G_t}\right)^{\omega}\frac{G_t}{L_t}N_t = K_{t+1}+G_{t+1} \tag{A1}$$

where $\tilde{C}=\frac{(1-\lambda)\rho}{1+(1-\lambda)\rho+\varepsilon}$. Next we set $C=\rho_w(1-\alpha)\frac{zn}{1-zn}$ so that (A1) becomes

$$A\tilde{C}\left(\frac{1}{\alpha X+C+1}\right)\frac{1-\alpha}{1-zn}\frac{1}{X^{\omega}}=\frac{K_{t+1}}{G_{t+1}}\frac{G_{t+1}}{G_t}+\frac{G_{t+1}}{G_t} \tag{A2}$$

Using (22) we can rewrite (A2) as

$$A\tilde{C}\left(\frac{1}{\alpha X+C+1}\right)\frac{1-\alpha}{1-zn}\frac{1}{X^{\omega}}=\gamma^{A}\left(1+\frac{1}{X}\right)$$

This allows us to solve for the economy's aggregate growth rate, γ^A, to get

$$\gamma^{A}=\frac{A\tilde{C}\frac{1-\alpha}{1-zn}}{X^{\omega-1}(X+1)(\alpha X+C+1)} \tag{A3}$$

which is the growth rate we need to optimize with respect to the public-private capital ratio.

To perform this optimisation, define $C_3=A\tilde{C}\,\frac{1-\alpha}{1-zn}$. Take the first order derivative of γ^A (denoted by $\hat{\gamma}$) with respect to X:

$$\hat{\gamma}(x)=-C_3\,\frac{(\omega-1)X^{\omega-2}[\alpha X^2+(\alpha+C+1)X+C+1]+X^{\omega-1}(2\alpha X+\alpha+C+1)}{[X^{\omega-1}(X+1)(\alpha X+C+1)]^2}$$

Setting this expression equal to zero, we can write

$$\alpha(\omega-1)X^{\omega}+(\omega-1)(\alpha+C+1)X^{\omega-1}+(\omega-1)(C+1)X^{\omega-2}+2\alpha X^{\omega}+(\alpha+C+1)X^{\omega-1}=0$$

which results in a quadratic equation in the optimal public-private capital ratio X:

$$\alpha(\omega+1)X^2+\omega(\alpha+C+1)X+(\omega-1)(C+1)=0$$

The optimal solution for X is therefore:

$$X_{1,2}=\frac{-\omega\left(\rho_w\frac{(1-\alpha)zn}{1-zn}+1+\alpha\right)\pm\sqrt{\omega^2\left(\rho_w\frac{(1-\alpha)zn}{1-zn}+1+\alpha\right)^2-4\alpha(1+\omega)(\omega-1)\left(\rho_w\frac{(1-\alpha)zn}{1-zn}+1\right)}}{2\alpha(1+\omega)}$$

which is (24) in the main text.

Appendix B. The positive root

We now demonstrate that our solution for X^* is postive. We start from (25) in the text. Since $\omega>0$, $0<z<1$, $n\geq 1$, and $0<\alpha<1$, it follows that $\omega\left(\rho_w\frac{(1-\alpha)zn}{1-zn}+1+\alpha\right)>0$ and $2\alpha(1-\omega)>0$. Therefore to get a positive solution, $X^*>0$, we need the numerator of (25) to be positive. It will be positive if and only if

$$-\omega\left(\rho_w\frac{(1-\alpha)zn}{1-zn}+1+\alpha\right)+\sqrt{\omega^2\left(\rho_w\frac{(1-\alpha)zn}{1-zn}+1+\alpha\right)^2-4\alpha(1+\omega)(\omega-1)\left(\rho_w\frac{(1-\alpha)zn}{1-zn}+1\right)}$$

is positive. We therefore need to check if this condition is in fact satisfied for the parameter constraints that we have imposed. We require

$$\sqrt{\omega^2\left(\rho_w\frac{(1-\alpha)zn}{1-zn}+1+\alpha\right)^2-4\alpha(1+\omega)(\omega-1)\left(\rho_w\frac{(1-\alpha)zn}{1-zn}+1\right)}>\omega\left(\rho_w\frac{(1-\alpha)zn}{1-zn}+1+\alpha\right),$$

or

$$\omega^2\left(\rho_w\frac{(1-\alpha)zn}{1-zn}+1+\alpha\right)^2-4\alpha(1+\omega)(\omega-1)\left(\rho_w\frac{(1-\alpha)zn}{1-zn}+1\right)>\omega^2\left(\rho_w\frac{(1-\alpha)zn}{1-zn}+1+\alpha\right)^2;$$

that is, $-4\alpha(1+\omega)(\omega-1)\left(\rho_w\frac{(1-\alpha)zn}{1-zn}+1\right)>0$

which is true since $-4\alpha(1+\omega)(\omega-1)=-4\alpha(\omega^2-1)>0$ and $\rho_w\frac{(1-\alpha)zn}{1-zn}+1>0$ both necessarily hold. Hence X^* in (25) is positive.

Appendix C. Signs of partial derivatives of X^* and d^*

In order to determine the sign of the partial derivative X_n^*, we introduce a shorthand notation to write the solution for X^*. Let $f(n)=\rho_w\frac{(1-\alpha)zn}{1-zn}+1+\alpha$, so $f(n)-\alpha=\rho_w\frac{(1-\alpha)zn}{1-zn}+1$. We define $c=-\frac{\omega}{2\alpha(1+\omega)}$. We now rewrite X^* in equation (25) as

$$X^*=cf(n)-\frac{c}{\omega}\sqrt{\omega^2f^2(n)-4\alpha(\omega^2-1)[f(n)-\alpha]}$$

Now let $\alpha F(n)=f(n)$, so that

$$X^*=c\alpha F(n)-\frac{c}{\omega}2\alpha\omega\sqrt{\frac{1}{4}F^2(n)-[F(n)-1]+\frac{1}{\omega^2}[F(n)-1]}$$

After taking the first order derivative with respect to n, we get:

$$X^*=c\alpha F(n)-\alpha c\frac{1}{\sqrt{\frac{1}{4}F^2(n)-[F(n)-1]+\frac{1}{\omega^2}[F(n)-1]}}\left[\frac{1}{2}F(n)F_n(n)+\left(\frac{1}{\omega^2}-1\right)F_n(n)\right]$$

Now let $G(n)=\frac{1}{2}F(n)+\left(\frac{1}{\omega^2}-1\right)$. Rewrite the denominator above as,

$$\sqrt{\frac{1}{4}F^2(n)-[F(n)-1]\left(\frac{1}{\omega^2}-1\right)}=\sqrt{\left[\frac{1}{2}F(n)+\left(\frac{1}{\omega^2}-1\right)\right]^2-\left(\frac{1}{\omega^2}-1\right)^2-\left(\frac{1}{\omega^2}-1\right)}$$

so that

$$X_n^* = c\alpha F_n(n)\left[1 - \frac{G(n)}{\sqrt{G^2(n) - \left(\frac{1}{\omega^2} - 1\right)^2 - \left(\frac{1}{\omega^2} - 1\right)}}\right]$$

To see the sign of X_n^*, we need to determine the signs of c, F_n and the expression in brackets. Since $c = -\frac{\omega}{2\alpha(1-\omega)} < 0$, and $F_n(n) = \rho_w \frac{(1-\alpha)z}{\alpha(1-zn)^2} > 0$, the expression in square brackets is negative because the numerator is larger than denominator.

We now determine the sign of $d_{\rho_w}^*$. Note that, through the chain rule, the differentiation of d^* with respect to ρ_w can be written as:

$$d_{\rho_w}^* = \frac{1}{A}\omega X^{*\omega-1}\left(X_{\rho_w}^* + X_n^* n_{\rho_w}\right)$$

where $X_{\rho_w}^*$ and n_{ρ_w} denote first derivatives with respect to ρ_w. We already know the sign of X_n^*. We are left to determine the sign of n_{ρ_w} and $X_{\rho_w}^*$. For the first of the two, we have that:

$$n_{\rho_w} = \frac{\varepsilon}{z(1+(1-\lambda)\rho+\varepsilon)(1-\rho_w)^2} > 0$$

For the second, in order to determine the sign of $X_{\rho_w}^*$ we can perform an identical analysis to that done for X_n^* in sub-section 4.1, except that now we define instead $f(\rho_w) = \rho_w \frac{(1-\alpha)zn}{1-zn} + 1 + \alpha$, $\alpha F(\rho_w) = f(\rho_w)$, and $G(\rho_w) = \frac{1}{2}F(\rho_w) + \left(\frac{1}{\omega^2} - 1\right)$. With these definitions, we write:

$$X_{\rho_w}^* = c\alpha F_{\rho_w}(\rho_w)\left[1 - \frac{G(\rho_w)}{\sqrt{G^2(\rho_w) - \left(\frac{1}{\omega^2} - 1\right)^2 - \left(\frac{1}{\omega^2} - 1\right)}}\right]$$

As before, to see the sign of $X_{\rho_w}^*$ we need to determine the signs of c, F_{ρ_w} and the expression in brackets. We still have that $c = -\frac{\omega}{2\alpha(1-\omega)} < 0$ and that the expression in square brackets is negative because the numerator is larger than denominator. But now we have a different expression to evaluate: $F_{\rho_w}(\rho_w) = \frac{(1-\alpha)zn}{\alpha(1-zn)}$. The numerator of this expression is always positive. As for the denominator, since we have assumed that not all of the individual's time endowment goes towards child rearing, i.e. $(1 - zn_t) > 0$, we have that$F_{\rho_w}(\rho_w) > 0$.

Thus $X^*_{\rho_w}$ is positive, and $d^*_{\rho_w}$ is positive.

Chapter 2

Reform and Backlash to Reform: Longevity Adjustment of the Retirement Age

Reform and Backlash to Reform: Longevity Adjustment of the Retirement Age*

By

Svend E. Hougaard Jensen
Department of Economics, Copenhagen Business School
Porcelaenshaven 16A, 2000 Frederiksberg C, Denmark
shj.eco@cbs.dk

Thorsteinn Sigurdur Sveinsson
Economics and Monetary Policy, Central Bank of Iceland
Kalkofnsvegur 1, 150 Reykjavik, Iceland
tss@cb.is

and

Filipe Bonito Vieira
Department of Economics, Copenhagen Business School
Porcelaenshaven 16A, 2000 Frederiksberg C, Denmark
fv.eco@cbs.dk

January 2020

Abstract: Using an overlapping generations model, *ad modum* Blanchard-Yaari, we analysed the effects of retirement reform on labour supply, and found there is not a one-to-one relationship between an increase in the statutory retirement age and the corresponding increase in aggregate labour supply: Rather, we observed a backlash effect, where a reform aimed at broadening the labour supply on the extensive margin, has the unintended effect of decreasing labour supply on the intensive margin. Following a calibration exercise to analyse the robustness of these backlash effects on different pension scheme designs, we found that, under a defined-benefit scheme, the effects on the intensive margin of labour supply are drastically increased, compared to the defined-contribution scheme and the fully-funded scheme.

Keywords: Demographic change, pension reform, retirement.
JEL codes: E71, J26, H55

∗ We are grateful for comments on a previous version of this paper made by participants at the conference, "*Macroeconomic Effects of Changing Demographics*", held at the Central Bank of Iceland on November 16, 2018. In particular, we are grateful to Torben M. Andersen, our discussant, for his thoughtful comments. This research was supported by PeRCent, which receives base funding from the Danish pension funds and Copenhagen Business School.

1. Introduction

The phenomenon of demographic ageing driven by increased longevity and lower fertility has led to a serious policy and academic debate about the sustainability of pension systems. Many industrialized countries rely on pay-as-you-go (PAYG) pension schemes, where payments to retirees are covered by current contributions by the working population. The demographic structure is a key determinant of the sustainability of such schemes and how generous they can be. In general, there are three ways of adjusting PAYG schemes faced by ageing populations: The contribution rate can be increased; the benefit rate can be decreased; or the retirement age can be increased.

Preserving the living standards of both the retired and the working-age population in an era of demographic ageing presents a very complex challenge. For example, while lower pension benefits would improve the sustainability of the PAYG pension system, they would also redistribute income from retirees to workers. The opposite distributional effect holds for an increase in contributions to the pension system. The point is that any distinct shift in either the benefit or the contribution rate will necessarily imply some degree of redistribution of intergenerational welfare.[25]

An alternative solution to keeping the pension system on a sustainable path in an era of ageing populations is to raise the retirement age. This would broaden the labour supply by having individuals work for a longer period in their lives (the extensive margin), while simultaneously decreasing the number of retirees by the same amount. Such a policy would counter the adverse effects of population ageing on PAYG

[25] The issue of intergenerational equity/fairness is indeed complicated and contentious, depending, among other things, on dynamic efficiency concerns and the definition of fairness. See, for example, Howse (2007) for a discussion.

pension systems, by exogenously decreasing the old-age dependency ratio and thus increasing the number of contributors relative to beneficiaries.[26]

Retirement decisions of individuals are complex, and affected by financial and social factors. While financial incentives undoubtedly matter, the empirical evidence on retirement behaviour shows a large spike in actual retirement at the statutory (or official) retirement age. Furthermore, there is evidence that indicates large and sharp hikes in the actual retirement age in response to changes in the statutory retirement age.

The statutory retirement age can serve as a reference point to which agents anchor their retirement plans. For example, Lumsdaine et al. (1996) finds that 48% of men working at age 64 retire at age 65 in Fortune 500 companies. Rather than being explained by financial or demographic factors, the study suggests that the spike is simply caused by an “age-65, rule of thumb” based on customs or accepted practice. This observation is consistent with the findings by Cribb et al. (2016) who find that changes in actual retirement age, when early retirement provisions are changed, are not driven by financial incentives but rather a signal about the appropriate time to retire.

A number of studies related to retirement reform further demonstrate the role of the statutory retirement age as a reference point. Based on Austrian data on reforms of the public pension system between 2000 and 2004, Staubli and Zweimuller (2013) analyse the effects of an increase in official early retirement age on labour market participation. They find that an increase in the early retirement age has significant effects on delaying pension claims. The labour market effects of the Austrian reforms are also evaluated by Manoli and Weber (2016). They find that the reforms both increased pension-claiming ages and job market exits. They further state that the official early retirement

[26] For a deeper discussion see for example, Queisser and Whitehouse (2006) who elaborate on pension design in the context of actuarial fairness and neutrality. We do not pursue this discussion in this paper.

age is potentially an important reference point for retirement decisions[27]. These results hold even when accounting for the financial incentives agents are subject to when leaving the labour market. This is investigated by Manoli and Weber (2014), who find that financial incentives alone cannot explain retirement decisions; implying that non-financial factors also play an instrumental role in retirement planning.

Brown and Laschever (2012) observe a peer effect on retirement timing, implying that individuals tend to retire at the same time as their peers. The peer effect on retirement decisions is also identified by Chalmers et al. (2008) who found that individuals are more likely to retire when one or more of their co-workers retire: This further highlights that retirement decisions are not solely driven by financial incentives. These anchoring effects, coupled with specific schemes to incentivize older workers to retire, tie the official retirement age tightly to the actual retirement age.

The focus of this paper is on how such exogenous changes in the statutory retirement age interact with the endogenous labour supply decisions of households. Changes in the intensive margin of labour supply have already attracted some attention, with a focus on the tax-like disincentives of pension contributions; see, for example, Fisher and Keuschnigg (2007) and Keuschnigg and Fisher (2011). Weil (2006) has also argued that the distortionary effect of PAYG systems is the most important channel through which ageing will affect output.

Backlash effects, where labour supply decreases on the intensive margin as a response to increases on the extensive margin, have been found in previous theoretical studies: Jensen and Jorgensen (2010) find the numerical existence of these backlash effects under a public DB scheme when the retirement age increases in response to

[27] Similar effects of reforms on actual retirement ages are found by Lalive and Staubli (2015) and Mastrobouni (2009).

decreased fertility rates. They find that a more-than-proportional increase to the retirement age is necessary when fertility rates decrease. Börsch-Supan and Ludwig (2010, 2013) numerically find similar backlash effects for public DB and private FF schemes. In line with our results, they also find that backlash effects are stronger in DB schemes as opposed to only private savings. We add to this line of research by, first, showing the analytical existence of these backlash effects regardless of calibration, and second, numerically show the size of these backlash effects under three different pension schemes.

To our best knowledge, the empirical literature on backlash effect is very scarce. This could be (partly) due to the rigidity of the labour market on the intensive margin. Typically, workers face a choice between working full time or not at all. There is, however, significant literature on the effects of taxation on the labour supply, which relates indirectly to the themes addressed in this paper. For example, Meghir and Phillips (2008), review the empirical literature and perform their own empirical analysis to demonstrate the effects of taxation on labour supply on the intensive and extensive margin. Their main conclusion is that incentives matter and that different groups in society react to taxation differently. Women, and especially women with young children, respond substantially to tax and benefits incentives on the intensive margin. However, hours worked for males (intensive margin) is irresponsive to incentives, while participation (extensive margin) is highly responsive.

When designing retirement reforms, our basic insight is that a higher statutory retirement age can discourage workers from working, leading to a drop in hours worked as an endogenous mechanism. Thus, retirement reform, implemented through increases in labour supply on the extensive margin, might come hand-in-hand with a backlash effect on the intensive margin. Identifying the existence of these backlash effects, and their potential magnitude, is the key objective of this paper.

Our analytical framework for demonstrating these effects is a simple lifecycle model over consumption-leisure choices at the steady state level.[28] In addition, we check to what extent the sensitivity of these backlash effects depends on the design of the pension system. Specifically, we distinguish three alternative schemes: a public PAYG scheme, either of the defined-benefit (DB) or the defined-contributions (DC) version, and a private, fully funded (FF) scheme. It turns out that the backlash effect critically depends on the pension system in operation. The intended positive effect on the labour supply is most successfully obtained with a public DC scheme in place, followed by a private FF scheme, whereas the public DB scheme displays the strongest backlash effects.

The roadmap of the paper is as follows: In section 2 we explain the basic assumptions and build the model; Section 3 elaborates on the implications of demographic change and shows the existence of the backlash effects following pension reform; Section 4 features a calibration exercise to quantify the implications of longevity shocks and retirement reform under different pension regimes; Section 5 provides an additional robustness analysis, providing further perspective on the numerical results for different calibrations; Section 6 concludes.

2. The model

2.1. Basic assumptions

In order to analyse the effects of an increase in the retirement age on individual labour supply, we base the analysis on the overlapping generations model in line with Yaari (1965) and Blanchard (1985). We consider a small open economy and incorporate endogenous labour supply decisions. Since the analysis is performed only

[28] Our focus on steady state impacts should be regarded as a starting point. In later work we plan to include transitional dynamics which, admittedly, may be even more important.

at steady state, the small open economy is assumed to start at some point in the past to the point where it is at steady state at time $t = 0$. Hence, the analysis is carried out via the age of a generation which enters the labour market at $t = 0$.

The economy is populated by agents who face a stochastic risk of death. This *hazard rate*, or the instantaneous probability of death, is age-independent. We assume a fixed population size, resulting in the number of agents "born" into the labour market being equal to how many die at each moment in time. The hazard rate can be manipulated to simulate longevity, since a lower hazard rate implies that agents live longer.[29] Agents save through actuarial notes, which include a component of life insurance that pays a constant amount until the agent's death, thus mitigating the loss of utility sustained from the uncertainty of death.

Working agents can choose to spend a fraction of their time endowment working, earning a wage at rate w. An individuals' productivity is uniform and the wage is therefore assumed to be constant both between individuals and throughout the lifecycle[30]. However, the labour supply decision of working agents varies with age. A mandatory retirement age is also implemented, labelled g, where agents are forced to leave the labour market.

We abstract from welfare impacts that this mandatory retirement age may have, since our analysis is not dependent on social welfare considerations. We simply focus on the labour supply effects of shifting that retirement age under different pension

---

[29] Having a fixed population size is compatible with our research objective, since what matters is that we simulate a worker/retiree composition shift. A change in the hazard rate with fixed population size provides us exactly that, a decrease in fertility and an equal decrease in mortality. We acknowledge that it would be interesting to see individual results for both reductions in fertility and mortality, but we leave that choice for future work and use the simpler setting here.

[30] See discussion in section 5.7 about age dependent wage profiles and 5.10 about decreasing returns to labour

regimes. The aim of the analysis is to shed light on the labour market response on the intensive margin from changes on the extensive margin. The analysis therefore considers policy reform in a narrower perspective, evaluating the actual performance of the reform in question versus its original intent, a key consideration. Introduction of a welfare analysis of different pension schemes and their effect on the intensive (and extensive) margin labour supply is interesting, but in order to demonstrate clearly the labour supply effects of changes to the statutory retirement age, these considerations are left to future work.

2.2. Pension system

The introduction of a pension system in the style of Nielsen (1994) allows us to extend the analysis to include judgements about the extent to which different types of pension systems mitigate or amplify the adverse effects on individual labour supply caused by pension reforms.

Since the mortality rate, β, is age-independent, the fraction of the population that is retired can be expressed as:

$$\int_g^\infty \beta e^{-\beta\tau} d\tau = e^{-\beta g} \tag{1}$$

Hence, the fraction of working agents is $(1 - e^{-\beta g})$. The pension system introduced consists of contributions denoted by k and paid by workers. The collected contributions are transferred as pension benefits, denoted by b, to the retired population. These contributions act as lump-sum “taxes” on those who have not reached the retirement age. The pension system is a balanced budget period-by-period, meaning that it must always hold that:

$$\left(1 - e^{-\beta g}\right)k = e^{-\beta g} b \tag{2}$$

This allows us to analyse three different pension schemes: First, a DC scheme where b is a function of k. Second, a DB scheme, where k is a function of b. Third, an FF scheme, where $b = k = 0$. Most pension schemes are either DC or FF, here we also analyse DB. In this setting (DB and DC) the agents are forced to contribute the same amount to the pension scheme regardless of how much they work.

For an agent born into the labour market at t=0 with age a, the discounted stream of future transfers from the pension system is denoted by $p(a)$ and for a working agent is defined as:

$$p(a) = \int_a^g -ke^{(r+\beta)(a-\tau)}d\tau + \int_g^\infty be^{(r+\beta)(a-\tau)}d\tau$$
$$= \begin{cases} \dfrac{(-1 + e^{\beta g+(r+\beta)(a-g)})}{r+\beta} k \; for \; DC \\ \dfrac{(-1 + e^{\beta g+(r+\beta)(a-g)})}{(-1 + e^{\beta g})(r+\beta)} b \; for \; DB \\ 0 \; for \; FF \end{cases} \tag{3}$$

The first integral represents the pension system transfer for working agents until retirement. The latter integral represents pension benefits that agents receive after retirement. In the case of a retired agent, the first integral equals zero and the pension system transfers are found using only the second integral.

For both the DC and DB cases, note that the value of the pension system at labour market entry (age 0 in the model) is always negative. This is due to the static productivity and population size, which makes the implicit return on unfunded pension systems zero. Combined with positive returns on investment for the private savings market, the pension contributions are worth less than an equal amount of savings.[31]

[31] Our results are thus within the context of a dynamically efficient economy, where long-run growth, as dictated by population growth, is smaller than the interest rate. Abel et al. (1989) and, more recently, Luo et al. (2018) find dynamic efficiency to be the case for the US and most other developed nations.

We aggregate values for pension transfers at steady state, denoted by P. That is, the present value of all future pension transfers of all agents currently alive in the economy, note that this is a steady state analysis and therefore the individual valuations of the pension system, $p(a)$, remains stable over time. This yields:

$$P = \beta \int_0^\infty e^{-\beta a} p(a) da = \begin{cases} \dfrac{\beta(1 - e^{-rg})}{r(r + \beta)} k \; for \; DC \\ \dfrac{\beta(e^{-rg} - 1)}{r(1 - e^{\beta g})(r + \beta)} b \; for \; DB \end{cases} \quad (4)$$

We see that the present value of the aggregated stream of future pension transfers of those agents currently alive is dependent on the pension system type, the size of the contributions (benefits) for a DC (DB) scheme, the demographic structure (through the hazard rate, β) and the interest rate, r. Note that this function is not negative, even though the pension stream for agents at labour-market entry is negative. This is a result of the fact that the present value of pension transfers is never negative during retirement, meaning that $P > 0$ when $\beta > 0$ and $P = 0$ when $\beta \to 0$.

2.3. Production and wages

The aggregate production function is given by $Y = \omega L$ where ω is exogenous and potentially time varying and represents the economy's technological level. L represents aggregate labour supply. Perfect markets are assumed, which implies that wages are also exogenous and given by $w = \omega$. This is due to the marginal productivity of labour being equal to the producer's cost of employing labour. The labour supply and technology level determine the economy's output.

With wages set exogenously, we can determine the potential income over the life cycle of the agent. The present value of *earnings potential*, or the potential future wages of an individual aged a working in all his/her available time, where the time allowance is normalized to one, is defined as:

$$h(a) = \int_a^g we^{(r+\beta)(a-\tau)} d\tau = \frac{(1 - e^{(r+\beta)(a-g)})}{(r+\beta)} w \tag{5}$$

If the agent has already retired, the earnings potential is equal to zero. The actual income of the agent is dependent on the labour-leisure choice of the agent, while the potential income is not. Therefore, the potential earnings separate the exogenous part of the agent's income from the endogenous part. Aggregate earnings potential at steady state is then:

$$H = \beta \int_0^g e^{-\beta a} h(a) da = w \frac{\beta}{r+\beta} \left(\frac{1 - e^{-\beta g}}{\beta} - \frac{e^{-\beta g}(1 - e^{-rg})}{r} \right) \tag{6}$$

Aggregate earning potential depends positively on the retirement age. In terms of longevity, its effect on aggregate earnings potential is ambiguous. There are two forces in effect: on one hand, higher longevity increases the chances that workers live for longer, thus increasing total labour supply; on the other hand, higher longevity decreases the proportion of workers in the population due to the fixed population size, which has a negative effect on total labour supply. There is no closed-form solution to the total effect, and the result is reverted to the numerical exercise section.

2.4. Consumption and labour choices

The agent derives utility from instantaneous consumption, denoted by c, and instantaneous leisure, denoted by $1 - l$. The instantaneous utility function and discounted stream of lifetime utility at age a are respectively denoted as:

$$u = \ln(c^{\varepsilon}[1 - l]^{1-\varepsilon}) \tag{7}$$

$$u(a) = \int_a^{\infty} \varepsilon \ln c(\tau)\, e^{(\rho+\beta)(a-\tau)} + (1 - \varepsilon) \ln\big(1 - l(\tau)\big)\, e^{(\rho+\beta)(a-\tau)} d\tau \tag{8}$$

Here, $\rho > 0$ is the discount rate and $0 \leq \varepsilon \leq 1$ dictates the relative weight the agent puts on consumption and leisure respectively. Agents can work until they reach the age

g, after which they are forced to retire. Note that as the agent reaches retirement age, $l(\tau)$ is set to zero and the second term reduces to zero.

When faced with a positive risk of death, an agent would be less inclined to save for the future. We thus introduce actuarial notes issued at a *fair rate* (Yaari, 1965) that include a component of life insurance. The purchaser of an actuarial note gets a constant stream of payments until his/her death, and the assets of those who die are redistributed to those currently living. These assets therefore act as savings for individuals with an extra component of life insurance to the purchaser, indicated by $i(a)$. The rate of return on the actuarial note is then $r^A = r + \beta$. We have adopted the small open economy case, so the rate r is exogenous and equals the world interest rate.

Agents in the economy can freely lend and borrow at the international interest rate. Parameter values distinguish whether a nation is a debtor nation, with relatively impatient inhabitants, a creditor nation, with relatively patient inhabitants, or the razor edge case of a perfectly balanced economy. In our setting, there is no intrinsic characteristic that distinguishes foreign and domestic assets, so that, in the context of a small open economy, it can be assumed that all an agent's wealth is held in an unspecified mix of national and foreign assets. Note that the only traded assets for saving purposes are the actuarial notes described above.

The working agent is faced with the budget constraint:

$$\int_a^{\infty} c(\tau) e^{(r+\beta)(a-\tau)}\, d\tau = i(a) + \int_a^{g} wl(\tau) e^{(r+\beta)(a-\tau)} d\tau + p(a) \qquad (9)$$

$i(a)$ denotes total assets, or stock of actuarial notes, the agent holds at age a. For a retired agent, the integral on the right-hand side reduces to zero. Solving the utility maximization yields a relationship between labour supply and consumption for a working agent:

$$wl(a) = w - \frac{1-\varepsilon}{\varepsilon} c(a) \tag{10}$$

Differentiating the first-order conditions, and acknowledging that an agent is forced to retire at age g, yields the Euler equations:

$$\frac{\dot{c}(a)}{c(a)} = r - \rho \tag{11}$$

$$\begin{cases} \dfrac{-\dot{l}(a)}{[1-l(a)]} = r - \rho \; for \; a < g \\ 0 \; for \; a \geq g \end{cases} \tag{12}$$

This implies that consumption throughout the lifecycle follows the path $c(a+\tau) = c(a)e^{(r-\rho)\tau}$. A similar relationship can be found for the time path of leisure (valid only for when the agent is a worker).

Applying the first-order condition for consumption with the consumption/labour supply relationship, equation (10), and the Euler equation, equation (11), on the budget constraint and integrating, we arrive at a relation for the consumption at each age for the agent:

$$c(a) = \mu[i(a) + p(a) + h(a)] \tag{13}$$

Here, we define $\mu \equiv (\rho + \beta)\left\{\frac{\varepsilon}{1-(1-\varepsilon)e^{(\rho+\beta)(a-g)}}\right\}$ for the working agent, which is a corrective term for consumption and leisure choices that account for the forced retirement age. For a retired agent, the term reduces to $\mu \equiv (\rho + \beta)\left\{\frac{\varepsilon}{1+\varepsilon}\right\}$. For the working agent, between the ages $0 < a < g$, we arrive at the following relation for leisure:

$$1 - l(a) = \frac{(1-\varepsilon)}{\varepsilon w} \mu[i(a) + p(a) + h(a)] \tag{14}$$

Consumption is thus directly related to the time until retirement (also captured in μ), the risk of death and the discount rate. For a working agent, the μ expression always starts at a value lower than 1. Up towards retirement, this expression converges to $(\rho+\beta)$ and stays there throughout retirement, leading to the standard Blanchard-Yaari style relation for consumption.

We can aggregate consumption over all households by applying the consumption path based on the Euler equation. At steady state, aggregate consumption, C, and aggregate labour supply, L, become:

$$C=\beta\int_0^\infty c(a)e^{-\beta a}da=\beta c(0)\int_0^\infty e^{(r-\rho-\beta)a}da=\frac{\beta c(0)}{\rho+\beta-r} \tag{15}$$

$$L=\beta\int_0^g l(a)e^{-\beta a}da$$

$$=\frac{\beta(1-l(0))\left(1-e^{(r-\beta-\rho)g}\right)}{r-\beta-\rho}+(1-e^{-\beta g}) \tag{16}$$

2.5. Assets

From the budget constraint and realization about the aggregate pension transfers and earning potential we establish the steady state aggregate stock of actuarial notes, I:

$$I=\beta\int_0^\infty e^{-\beta a}\int_a^\infty c(\tau)e^{(r+\beta)(a-\tau)}d\tau\,da-\beta\int_0^\infty e^{-\beta a}p(a)da$$
$$-\beta\int_0^g e^{-\beta a}\int_a^g wl(\tau)e^{(r+\beta)(a-\tau)}d\tau\,da$$

By applying the relationship between labour supply and consumption and by plugging in aggregate earnings potential and aggregate future stream of pension income we arrive at:

$$I=\beta\int_0^\infty e^{-\beta a}\frac{c(a)}{\rho+\beta}da-P-H+\frac{1-\varepsilon}{\varepsilon}\beta\int_0^g e^{-\beta a}\frac{c(a)}{\rho+\beta}\left(e^{(r+\beta)(a-g)}-1\right)da$$
$$\Leftrightarrow I=\frac{C}{\rho+\beta}-P-H+\frac{1-\varepsilon}{\varepsilon}\beta\int_0^g e^{-\beta a}\frac{c(a)}{\rho+\beta}\left(e^{(r+\beta)(a-g)}-1\right)da$$

Solving the integral, the steady state aggregate stock of assets can be expressed as:

$$I = \frac{\gamma}{\rho + \beta} C - P - H \tag{17}$$

Here, for convenience, we define:

$$\gamma = 1 + \frac{1-\varepsilon}{\varepsilon}\left(1 - \frac{\rho+\beta}{r} e^{-g(\rho+\beta-r)} + \frac{\rho+\beta-r}{r} e^{-g(\rho+\beta)}\right) > 1$$

Note, that when we abolish the retirement age by making g approach infinity, the γ expression reduces to $1/\varepsilon$. Adding to this, by abolishing the pension scheme, we arrive at the same expression as in the standard Blanchard-Yaari model, i.e., $C = \varepsilon(\rho + \beta)(I + H)$.

3. Impact of population ageing and pension reform

3.1. Effects of demographic ageing

The effects of ageing in the form of a decrease in mortality and fertility rates are now analysed for an agent just entering the labour market at the beginning of their economic life ($a = 0$)[32]. This analysis is performed in a steady state perspective only and for the razor-edge case, when $r = \rho$, though this assumption is relaxed in the numerical analysis (below). Under this assumption, agents have perfectly flat consumption (and labour supply) smoothing over their life cycle. If we relax this assumption and allow $r > \rho$, agents plan their life cycle consumption and labour supply paths with constant exponential growth when they enter the labour market; The existence of backlash effects is not dependent on this assumption.

An agent entering the labour market chooses his consumption and leisure according to:

$$c(0) = \mu[p(0) + h(0)] \tag{18}$$

[32] Given homogenous agents and zero population growth, the case in point in this section can be generalized to any other generation or point in time (if at steady state).

$$1 - l(0) = \frac{(1-\varepsilon)}{\varepsilon w}\mu[p(0) + h(0)] \qquad (19)$$

We see that any effects on the mandatory retirement age adjustment factor, μ, the pension value, $p(0)$, and earnings potential, $h(0)$, stemming from longevity shifts in β will yield a level impact to consumption and leisure choices. Hence, these types of shocks work only through income channels, and not through substitution channels between consumption and leisure (see Euler equations 11 and 12 and the absence of longevity factors there).

Starting with the longevity shock related to labour supply on the intensive margin for new incoming generations with higher longevity. A decreased hazard rate makes it more likely that an individual survives into a (now longer) retirement period. With longer life expectancy and a fixed official retirement age, an agent now works for a smaller portion of their lifetime. We therefore observe a downwards adjustment to consumption-leisure during the working period, compared to a generation of individuals with lower longevity.

Turning to the second effect of the longevity shock, in terms of labour supply effects on the intensive margin, the effect of a change in the hazard rate on the present value of earnings potential, $h(a)$, is independent of the pension system type, and it reacts positively to decreases to the hazard rate, β. This makes intuitive sense, since a lower β implies that an agent is more likely to survive throughout their working life. This makes the agent feel wealthier, resulting in a desire for higher consumption and leisure.

The third component of the longevity shock is related to labour supply intensity and the existence of unfunded pension schemes: The individual values of these pension schemes are described by $p(a)$, and they react negatively to a decreasing β for both DC and DB pension systems. This is easily seen by noting that the value of an unfunded pension system always starts negatively for an agent just entering the labour market, turning positive when the agent reaches the age $a = rg/(\beta + r)$. When longevity increases, the hazard rate, β, decreases. That implies that the age at which the value of the unfunded pension scheme turns positive for the agent is now higher, which makes the value of the pension system even more negative at labour market entry. This has a negative impact on consumption and leisure choices.

Given the different directions of the effect on μ, h and p from a decrease in β, the effect of a mortality/fertility reduction on leisure choices (or conversely, labour supply choices) can only be asserted with a numerical exercise for all pension types (performed below).

3.2. Increase in the retirement age

Since a decrease in the hazard rate exerts negative pressure on the pension system, a natural pension reform would be to simply increase the retirement age so that the portion of working life gets rebalanced. Such a retirement reform is now analysed in a steady state context.

Increasing the official retirement age is analogous to increasing labour supply at the extensive margin. This effectively increases the present value of potential future earnings, as that will increase the amount of time an agent can work. On the intensive margin, however it can have the effect of individuals choosing to alter their work intensity. Where unfunded pension systems are concerned, the impact of retirement age increase now depends on the type of unfunded pension system in place.

Basically, when the pension system is of the DC type, an exogenous increase to the retirement age will decrease the present value at birth of the pension system, $p(0)$, since the contributions to the pension system are fixed. Additionally, a longer working life implies a longer schedule of contributions relative to the expected benefits upon retirement. In the DB case, an increase in g has a positive effect on $p(0)$, since the amount of contributions necessary to finance the pension system is now lower.

The overall effect on the intensity of labour supply is determined by the joint effects on both $h(a)$ and $p(a)$. In the DC case, the overall effect is ambiguous since the effect on the value of the pension system is opposite to the effect on earnings potential. In the DB case, the increased value of the pension system, when the retirement age is increased, goes in tandem with the effects on earnings potential, and always dominates the negative extensive margin effects. In the FF scheme, we have $p(0) = 0$ and the sole effect of the retirement reform is captured by $h(0)$ and μ.

The conclusion is that, in the DB and the FF case, consumption and leisure (labour supply) choices will increase (reduce) when the retirement age is raised for new incoming generations. Therefore, in economies operating under DB and FF pension systems, we get:

$$\frac{\partial c(a)}{\partial g} > 0 \tag{20}$$

$$\frac{\partial l(a)}{\partial g} < 0 \tag{21}$$

A retirement reform aimed at increasing the labour supply on the extensive margin will have the unintended effect of lowering the labour supply on the intensive margin at steady state. Thus, with DB and FF pension systems, there will always be backlash effect to reform, where retirement age increases need to be more-than-proportional relative to increases in longevity, in order for intensive margin labour supply to return to its previous level. In these cases, agents who are faced with working for more years, choose to work less each year. In the DC case, the effect is ambiguous, and the result is reverted to the numerical exercise.

Finally, note that the retirement age does not enter the aggregation of consumption at steady state, c, in any other way than through $c(0)$. We can therefore conclude, that under a DB or an FF pension system, aggregate consumption will necessarily increase as the retirement age increases. But the retirement age makes an extra appearance on aggregate labour supply outside of $l(0)$, as seen in the two exponentials in the equation (16). These extra factors react positively to retirement age increases and ensure that aggregate labour supply will always increase with the raising of the retirement age, the backlash effect does therefore not dominate on the aggregate level. The effects of ageing, or a pension reform of increasing the retirement age under DC has ambiguous effects on both aggregate consumption and leisure. Again, we come back to this in the numerical exercise.

4. Calibration

4.1. Baseline

So far, we have laid out the theoretical building blocks of our model. We now turn to a numerical exercise that will allow us to explore the differences and dimensions of ageing and reform of the pension system at steady state in the form of a retirement age increase. The razor-edge assumption of $r = \rho$ will now be relaxed. This numerical exercise will be performed for different pension schemes, whether it is FF, unfunded with DC or unfunded with DB plans. This analysis quantifies the backlash effects of increasing the extensive margin of labour supply. It will also tell us, first, the direction of impact from a change in the instantaneous death probability, or hazard rate, on leisure choices for all pension types, and second, the direction of the impact on leisure of changing the retirement age in the DC case.

We begin by establishing a baseline calibration: Since 47% of 15-24 year-olds participated in the labour market in 2015 (OECD, 2019), we assume agents will enter the labour market at the age of 20. The average effective retirement age in the OECD was 64 years in 2015 (OECD, 2017), making $g = 64 - 20 = 44$. In terms of the hazard rate, β, we calibrate it to obtain a realistic old-age dependency ratio. The observed dependency ratios in OECD countries in 2015 is 29% (United Nations, 2017), which implies $\beta = 0.034$.[33]

The interest rate, r, is assumed to be 1.8%. This is in line with recent calibration of the Blanchard-Yaari model in Benhabib, Bisin and Zhu (2014). The subjective discount rate, ρ, is set at 1.5% which implies that the condition, $r > \rho$ holds. It is thus a case where the inhabitants of the economy are relatively patient compared to the outside world, implying growing consumption and leisure choices over time. Following Heijdra (2003), the relative weight of consumption in leisure is set to $\varepsilon = 0.25$. Furthermore, we normalize the wage rate to one. The average net replacement rate of unfunded PAYG pension schemes in the OECD in 2013[34] was 53.3% of life-time labour income (DICE Database, 2015). This results in the steady state lump-sum benefit rate of 0.15 and a lump-sum contribution rate of 0.044.

The baseline calibration is summarized in the table below:

β	hazard rate	0.034
ρ	discount rate	0.015
r	interest rate	0.018
g	retirement age	44
w	wage rate	1
b	pension benefit rate	0.15
k	pension contribution rate	0.044
ε	weight of consumption in utility	0.25

[33] Since life expectancy is at every time $1/\beta$ for all members of society (aged 20+), an alternative approach would be to calibrate β to match average years left of life of all currently living. This turns out to be roughly 33 years for the European members of the OECD in 2015 (Eurostat, 2018a, 2018b). The baseline calibration is based on a realistic dependency ratio, and it implies an average life expectancy of 29.5 years, which resonates with the observed data.

34 We use year 2013 here since data for year 2015 is missing.

Given these parameter values we can calculate the relevant aggregate values for the baseline case. We can compare the two cases: with a mandatory PAYG pension scheme, and without a mandatory PAYG pension scheme. At this stage we do not make a distinction between the DB and DC case as the results are identical. These results are summarized in the table below for each pension system:

		FF pension scheme	**PAYG pension scheme**
C	Aggregate consumption	0.254	0.247
L	Aggregate labour supply	0.208	0.223
P	Aggregate pension transfers	0	0.869
H	Aggregate earnings potential	10.47	10.47
I	Aggregate assets	2.564	1.347

The introduction of the pension system implies that aggregate consumption and the aggregate stock of actuarial notes, or assets, drop significantly. This is due to the foregone interest income the agents would have earned if their pension transfers were invested instead. Consumption in the FF case is also higher, since the existence of the unfunded pension system makes agents poorer. The same reasoning justifies a higher labour supply in the DB and DC cases.

4.2. Fully-funded (FF) pension scheme

We now look at the effect of increased longevity on the lifecycle path of leisure. We simulate the demographic shock by decreasing the value of β to 0.025, which represents an increase in the average lifespan of 10 years.[35] The effects of the longevity shock over the lifecycle of an agent is shown in Figure 1 below.

[35] The implicit assumption here is that the economy will have converged to the new steady state after longevity shock and reform in one lifetime.

The baseline labour supply is the dashed blue line and the path of labour supply after the shock is the yellow line. Agents who are faced with higher longevity substitute current consumption and leisure for future consumption. This is a combined result of a higher chance of surviving and an expectation of being able to work for longer because they're more likely to survive until retirement, and individuals discounting the future less heavily because they are more likely to be alive to enjoy their savings.

From Figure 1 we can see that the effect of increased longevity on leisure. Leisure is subject to a negative shock from increased longevity, such that the negative effects in the retirement age adjustment, factor μ outweigh the increased expectation of earnings potential $h(0)$. But as the expected agent lifespan has increased dramatically for *all age groups*, aggregate consumption has risen (see table below). We see an increase in aggregate consumption of 1.3%. In this case, there is a hike in the labour supply each time of around 4.7% while the agent is working and aggregate labour supply drops by 9.3%. This drop is caused by the higher proportion of individuals in retirement, where labour supply is 0.

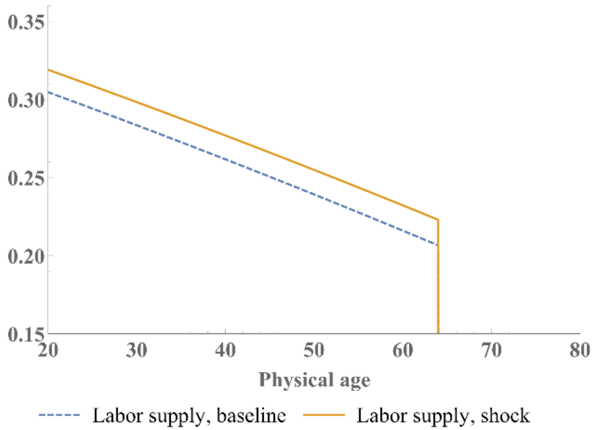
We now analyse the effects of countering the life expectancy increase with an increase in the retirement age.[36] We assume that the government attempts to preserve the initial demographic structure as it was before the longevity shock took place, in that the old-age dependency ratio goes back to its original value. In this case, we choose a retirement age increase of 15 years, making g equal to 59. The implication with this experiment is that, because the new retirement age makes the new old-age dependency ratio equal to the original one before the longevity increase, the proportion of life spent

[36] Again, the results displayed here are for when the retirement age increase has fully matured, meaning that the economy is at steady state under the new longevity level and under the new retirement age, where everybody in the economy is also under the new retirement age for the entirety of their lives.

as part of the labour force relative to time spent in retirement remains the same. In this case, changes in aggregates stem solely from individual consumption and labour supply choices, and not aggregate demographic composition effects.

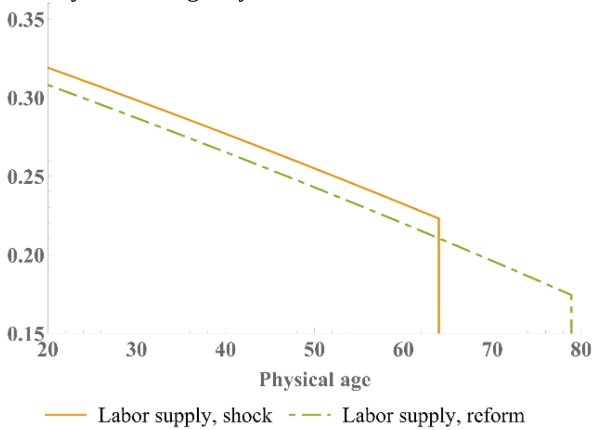
When faced with a increase in the retirement age, the new higher longevity agents anticipate being able to work longer during their lives, making them less likely to survive into retirement compared to the case where the retirement age was unchanged. This has the effect of lowering labour supply on the intensive margin and increasing consumption at each time, as there is less of a need to save for retirement. The effects are summarized in figure 2.

Figure 1. Life Cycle Path of Labour Supply in a Fully-Funded System: Baseline and Longevity Shock



Even though aggregate labour supply increases by 6.5%, it does not return to the original value before the longevity shock. This is a result of decreased labour supply at the intensive margin due to the existence of the backlash effect, which is reflected in a reduction on individual labour supply at each point in time of around 3.4%, a result seen in Figure 2 where the yellow line shifts to the dashed green line when the reform is implemented. The following table summarizes the aggregates.

Figure 2. Life Cycle Path of Labour Supply in a Fully-Funded system: Longevity Shock and Retirement Reform



Again, we see that the effect of a 15-year increase in the retirement age on aggregate labour supply has a smaller effect than the longevity shock. Showing this result on a smaller scale, in order to arrive at the same labour supply level on the intensive margin, an increase in longevity of 1 year should be followed by an approximately 1.6-year increase in the retirement age, under the FF pension regime.

Variable	**Initial scenario**	**Longevity shock**	**Retirement age increase**
C	0.254	0.257	0.2262
L	0.208	0.189	0.201
P	0	0	0
H	10.47	9.678	13.12
I	2.564	3.822	3.376
Backlash	-	$\mathbf{4.7\%}$	$\mathbf{-3.4\%}$

4.3. Defined-benefits (DB) pension scheme

We now perform the same experiments for an economy with a DB pension scheme: This case has an important consideration: When the size of the retired population changes relative to the working population, the lump-sum contributions of the currently working automatically change. An agent just entering the labour market will certainly experience this change in contributions, but will not necessarily experience the pension benefits, since they are not guaranteed to survive until retirement.

As before, we start by looking at the case of a longevity increase of 10 years. This has the effect of increasing the survival probability of all agents. Those entering the labour market are now more likely to reach retirement, and those retired are more likely to survive longer after retirement. These two factors weigh in the same direction causing the lump-sum pension contributions to increase.

As seen in the FF case, agents are expecting to enjoy a longer retirement, incentivising them to increase their labour supply and decrease their current consumption in order to finance consumption during retirement. The existence of the DB pension scheme introduces a new channel of effects, where the increase in the mandatory lump-sum pension contribution due to demographic ageing has the effect of making the agents poorer, which further drives them to decrease consumption and leisure.

We see that the negative pension effect dominates the positive earnings potential effect when the hazard rate goes down. Hence, if a longevity shock is allowed to fully mature in the economy, the intensive margin of labour supply would see an increase of 8.7% with consumption dropping by 4.1% at each point in time. Aggregate consumption would drop by 0.9%, which is a change in the opposite direction relative to the effects seen with the FF pension scheme. This is due to the reduced present value of the unfunded public pension system at birth, which is not present in the FF case. The lifecycle paths of consumption and leisure for the baseline case and after the longevity shock are displayed in Figure 3.

We now perform the same pension reform of increasing the retirement age by 15 years, such that the old-age dependency ratio remains the same as before the longevity shock took place. The effects of an increase in labour supply on the extensive margin has the effect of increasing the relative size of the working population and decreasing the retired population by the same amount. In addition to the effects associated with a shorter retirement, as traced above in the context of Figure 2, the retirement reform has the effect of decreasing pension contributions, since the number of retirees receiving pension benefits has shrunk and the number of workers has increased. These two effects work in the same direction of lowering lump-sum contributions.

As a result, the working agents have more disposable income, leading to an increase in both consumption and leisure. The backlash effect here, measured again as a lowering in labour supply at each point in time, is 6.2%. These effects can be seen in Figure 4, below. This effect works in the same direction as the effect of a longer working life, but as seen when comparing Figures 2 and 4, the observed backlash effects under an unfunded pension scheme are much more pronounced compared to the case without them.

The implication is that the setup of the DB pension system affects the size of the backlash effect. When the retirement age is increased, it rebalances the pension scheme such that its value for individuals is improved. This in turn further stimulates the backlash effect, reducing labour supply on the intensive margin. The following table summarizes the aggregates.

Figure 3. Life Cycle Path of Labour Supply in a Defined-Benefits Scheme: Baseline and Longevity Shock

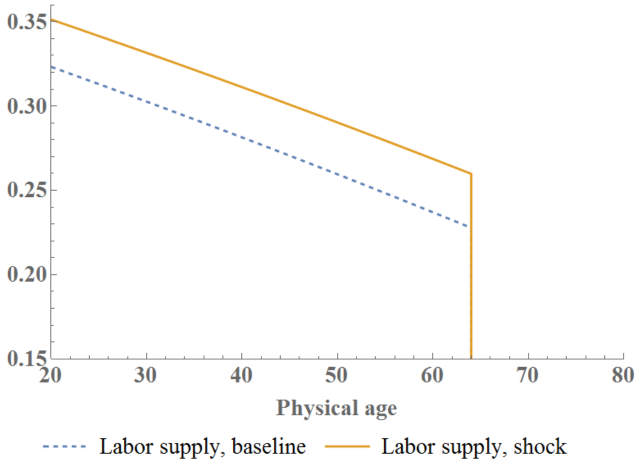
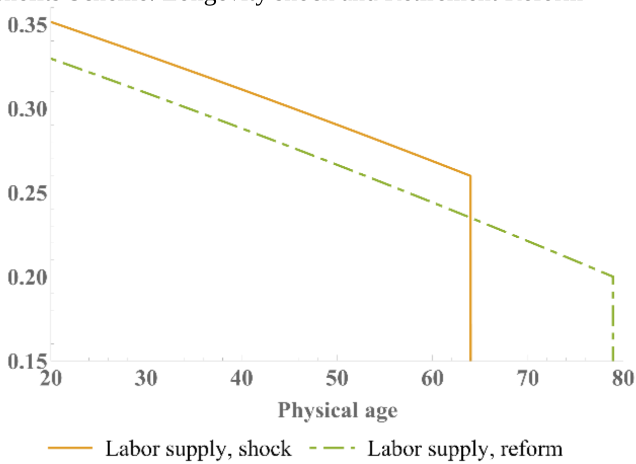


Figure 4. Life Cycle Path of Labour Supply in a Defined-Benefits Scheme: Longevity shock and Retirement Reform



Variable	Initial scenario	Longevity shock	Retirement age increase
C	0.247	0.245	0.254
L	0.223	0.212	0.219
P	0.869	1.310	0.930
H	10.47	9.678	13.12
I	1.347	1.873	1.935
Backlash	$-$	$\mathbf{8.7}\%$	$\mathbf{-6.2}\%$

4.4. Defined-contributions (DC) pension scheme

Finally, we perform our experiment in the setting of a DC pension scheme. The effects on the labour supply and consumption decisions of agents when faced with demographic ageing or pension reform have a different scale than in the DB scheme. As longevity increases the proportional size of the retired population increases, pension benefits drop as a result. This has the impact of decreasing the present value of future pension transfers at labour market entry. The agent is more likely to reach retirement, but when they do, pension benefits are drastically reduced. This causes agents to increase their labour supply by approximately the same amount as in the FF case, as well as saving more through private saving schemes. This results in the ability to have a higher lifetime consumption. This is demonstrated in the table and Figure 5 below.

When faced with an increase in the retirement age of 15 years, we see a backlash effect of reduced labour supply at each point in time of 2.6%. This effect is far smaller than in the DB case, and even smaller than in the FF case. The reason is that the increase to the retirement age now reduces the value of the pension system to the individual, which softens the backlash effect.[37]

[37] This effect is dependent on the size of the contributions, but here we begin with the same baseline for the DC as in the DB case.

Figure 5. Life Cycle Path of Labour Supply in a Defined-Contributions Scheme: Baseline and Longevity Shock

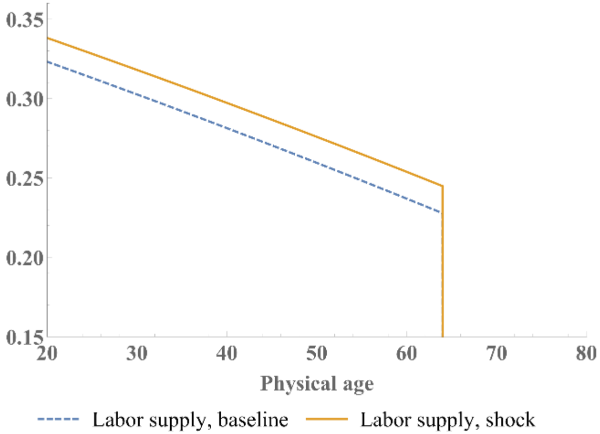
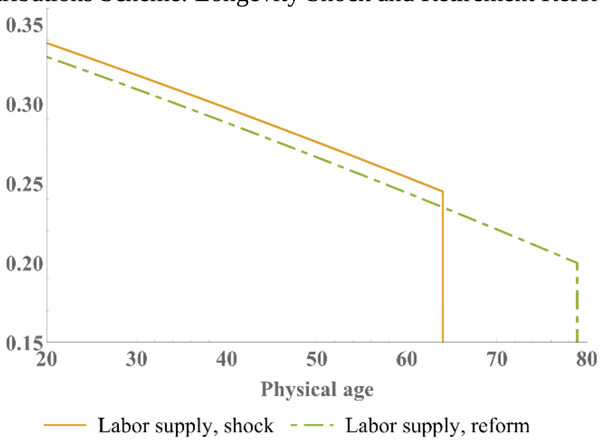


Figure 6. Life Cycle Path of Labour Supply in a Defined-Contributions Scheme: Longevity Shock and Retirement Reform



Once again, this demonstrates how important the existence and type of unfunded pension schemes are for the behaviour of the intensive margin of labour supply. Whether retirement age increases have negative or positive effects on the value of the pension system to an individual just entering the labour market matters in explaining the sizes of backlash effects. This explains why the aggregates of longevity shock and retirement age reform are the same in the DB and DC cases, but the observed backlash effects are nonetheless different. The following table summarizes the aggregates for the DC case:

Variable	**Initial scenario**	**Longevity shock**	**Retirement age increase**
C	0.247	0.250	0.254
L	0.223	0.202	0.219
P	0.869	0.778	0.930
H	10.47	9.678	13.12
I	1.347	2.665	1.935
Backlash	$-$	$\mathbf{4.6}\%$	$\mathbf{-2.6}\%$

5. Robustness analysis and further discussion

We now perform a robustness check on the sensitivity of the observed baseline backlash effects to certain key parameters. We continue with a discussion on how the lack of certain modelling devices can influence our results. These modelling devices are endogenous retirement decisions, realistic mortality and productivity profiles, and generalising the CRRA utility function to assume an intertemporal elasticity of substitution different than 1. The numerical experiments we perform in the following robustness analysis, and the associated parameter changes, are summarized in the following table:

Experiment		Old parameter(s)	New parameter(s)
Increased importance of consumption in utility		$\varepsilon = 0.25$	$\varepsilon = 0.5$
Debtor nation scenario	Stronger discounting	$\rho = 0.015$	$\rho = 0.02$
	Lower interest rates	$r = 0.018$	$r = 0.012$
Higher interest rate		$r = 0.018$	$r = 0.024$
Higher pension replacement ratio		53.3%	100%

5.1. Decreased importance of leisure in utility

We simulate an economy with a much lower preference towards leisure as opposed to consumption. This makes individuals less sensitive to leisure choices, serving as a check into how important this sensitivity is to the size of the baseline backlash results. We do so by doubling the baseline consumption preference parameter ε to 0.5. The backlash effects, measured by the decrease in labour supply at the intensive margin as a response to an increased retirement age, are now summarized for each pension system type and put in context of the baseline results:

Backlash effect:
Baseline and lower preference for leisure

Pension system	Baseline case	Robustness case
FF	−3.4%	−3.0%
DB	−6.2%	−4.8%
DC	−2.6%	−2.4%

The robustness checks confirm that the baseline results are not heavily dependent on the consumption preference parameter ε for any of the pension types, especially considering the extreme experiment performed here of doubling the parameter. When the preference towards consumption is increased, the backlash effects are diminished, since the individual now values consumption more compared to the baseline case, making the individual want to work relatively more when the retirement age is increased to finance a higher desire for consumption. The differences between pension systems are still preserved as in the baseline case for the same reasons. The case with the strongest reduction is still the DB case, where the backlash weakened by 1.4 pp. Both the FF and DC pension types saw decreases of less than half a percentage point, with the DC system seeing the smallest backlash effect of them all.

5.2. Debtor nation scenario

We now consider a debtor nation scenario under two different experiments. For the first debtor nation scenario, we perform an increase to the subjective discount rate of one third, making $\rho = 0.02$. This makes the discount rate relatively bigger than the interest rate, making individuals choose decreasing paths for consumption and leisure (see equations 11 and 12). The economy, in turn, becomes one composed of impatient individuals, making it a debtor nation. The results are now summarized:

Backlash effect:
Baseline and higher time preference

Pension system	Baseline case	Robustness case
FF	-3.4%	-7.5%
DB	-6.2%	-10.6%
DC	-2.6%	-5.9%

The backlash effects increase dramatically the rise in ρ, making the backlash effects higher in the order of 3-4 pp. By increasing how much individuals discount the future, consumption-leisure choices become stronger during the working period since μ increases with ρ. Note that the present value of earnings potential and pensions are unaffected by changes in ρ. The result is an increase in the sensitivity of labour-leisure choices to changes in the retirement age.

The second debtor nation scenario is performed by reducing the interest rate, r by one third, making it equal to 0.012. Again, the nation becomes an external debtor, with relatively fewer patient individuals. The backlash results are summarized in the following table:

Backlash effect:
Baseline and lower interest rate

Pension system	**Baseline case**	**Robustness case**
FF	-3.4%	-10.2%
DB	-6.2%	-12.4%
DC	-2.6%	-8.5%

We see that backlash effects are more sensitive to interest rate decreases than to increased subjective discount rates. Decreasing the interest rate by one third, doubles or even triples the observed backlash effects. The mechanism of action is different compared to changes to the subjective discount rate. In this case, when the interest rate is reduced, the value of μ remains the same, but the present value of earnings potential and pensions increase. Now, when the retirement age is raised, it produces stronger value changes for earnings potential and pension wealth compared to when the interest rate was higher. Individuals feel even more wealthy when the retirement age is increased, exacerbating the backlash effect when compared to the baseline case.

5.3. Higher interest rate

We next simulate an economy that has an interest rate one third higher than in the baseline case, making the economy a stronger creditor nation, with individuals saving more aggressively in the beginning of their lives, choosing steeper consumption-leisure paths when compared to the baseline case. The backlash results are:

Backlash effect:
Baseline and higher interest rate

Pension system	Baseline case	Robustness case
FF	−3.4%	−0.2%
DB	−6.2%	−2.8%
DC	−2.6%	0.2%

Overall, the more relatively patient individuals are, the weaker backlash effects become. The reason is opposite to the case studied just above, where the value of future earnings and pension wealth drops with a higher interest rate, which attenuate the backlash effects associated with a higher retirement age.

Interestingly, the backlash effect vanishes in the DC case, where the retirement age increase raises individual labour supply on the intensive margin by 0.2%. Backlash effects are nonetheless still present in the FF and DB cases. The takeaway is that, if the difference between interest rates and subjective discount rates are large enough, backlash effects tend to be mitigated or disappear altogether. Though it is important to underline that large positive gap between interest rates and subjective discount rates are unlikely to be observed in reality, so that our results remain robust for the average OECD economy.

5.4. Stronger unfunded pensions

We also consider a case where the economy has a 100% unfunded pension replacement ratio, as opposed to the baseline scenario of 53.3%. Since the FF situation represents the case of 0% replacement rate, it is interesting to reveal the backlash effects in the opposite situation as well:

Backlash effect:
Baseline and stronger unfunded pensions

Pension system	Baseline case	Robustness case
DB	-6.2%	-8.5%
DC	-2.6%	-1.8%

Here, the increased volume of inter-generational transfers introduces stronger impacts of the individual value of unfunded pensions $p(a)$ in how wealthy an individual feels. As asserted in section 2, when a DB system is in place, a later retirement age increases the value of the pension system to the individual. When the replacement ratio is 100%, this effect is amplified, so the backlash effects are now stronger compared to the baseline case.

If a DC pension system is in place, a later retirement age reduces the value the pension transfers at birth to the agent. That means that, with a higher pension replacement ratio, the agent feels even poorer when compared to the baseline scenario when the retirement age is increased. This results in diminished backlash effects, as seen in the table above. Note that changes to the pension replacement ratio result in opposite impacts to the backlash effects. Countries with full public pension replacement of the DB type are more vulnerable to backlash effects than countries with DC systems.

5.5. Generalized CRRA utility function

When considering changing the intertemporal elasticity of substitution from 1 (the log case) to a more inelastic setting, it is important to consider that the model as it is, has no substitution effect where longevity and the retirement age are concerned, meaning that the relative "price" of consumption and leisure remains static when an individual now lives for longer or has a longer period to work in. As such, changing the intertemporal elasticity should have no relevant impact on the income effects we measure.

We take the position that the lack of substitution effects, with respect to longevity and the retirement age is not a completely unrealistic setting. After all, when thinking about one's lifetime, longevity and retirement issues are more closely related to financially planning a longer retirement than to one's wish to enjoy more or less leisure due to a different length of lifecycle. The implication then, is that it is on the *level* of consumption-leisure that the main focus should be placed - and not its intertemporal allocation rate - when considering shifts in longevity and retirement age.

5.6. Realistic mortality profile

The mortality profile featured in the model is a classic Blanchard-Yaari style perpetual youth model where agents face the same mortality risk at all ages. We apply a mandatory retirement age, making agents' proximity to retirement age an important aspect when making consumption-savings decisions. In order to portray a fair picture of the size of the backlash effect, we calibrated the baseline to fit a dependency ratio that is close to those observed in reality, see more details in section 4.

This does however imply that the age structure of society, both before and after the retirement age is not realistic. Agents face a higher probability of dying before retirement, and once retired they live longer than observed. The existence of actuarial notes mitigates the mortality risk for savings, but pension transfers are not subject to any such mitigation. These factors affect the absolute size of the backlash effect, but should not change our main results: Namely, the existence of the backlash effect and the fact that the set-up of the pension scheme matters.

5.7. Age-dependent wage profiles

The model features a flat wage-profile, implying that agents' productivity is constant over their life cycle. The fact is that young and old workers are not perfect substitutes in reality. Younger workers might adapt better to new production technologies while older workers have more experience. By applying age dependent wages, the labour supply over the lifecycle would feature a hump shape where agents work more during the ages where they are relatively more productive, see equation (10). This in turn would have an interesting impact on the backlash effect. As labour supply is increased on the extensive margin, those extra years available to the agent are now less productive compared to the case with constant wages.

This implies two things; first, that the size of the backlash effect would be smaller, since their lifetime earnings potential is increased to a lesser extent; Second, the backlash effect would, in absolute terms, be more pronounced at specific ages due to the hump shape of the labour supply. This extension would then invite analysis on how different age groups respond to retirement reform.

5.8. Endogenous retirement decisions

Agents in this model are forced out of the labour force at a specific age, at which they might want to work for more years. As noted in the introduction, the connection between the official and actual retirement age is complex and explained by both social and financial factors. An interesting extension to this model would be to allow for endogenous retirement. Analysing both the intensive and extensive margin of retirement decisions requires a utility function featuring a distinctive mechanism for intensive and extensive labour supply decisions. This could, for example, be done by applying disutility of work similar to the one currently featured in the model, coupled with extra utility from being retired (see for example: Kalemli-Ozcan and Weil (2010)). The lifetime utility function could be re-written as:

$$u(a) = \int_0^{\infty} \varepsilon \ln\big(c(a)\big)\, e^{-a(\rho+\beta)} da + \int_0^{g} \Big(\ln\big(1 - l(a)\big)\,(1-\varepsilon) - \gamma\Big)\, e^{-a(\rho+\beta)} da$$

where γ is disutility from being a part of the labour force. The agent would then maximize his lifetime utility based on his consumption profile $c(a)$, intensive labour supply $l(a)$ and time of retirement g. This would surely allow for endogenous retirement on both intensive and extensive margins, but also invite a host of questions about the set-up of the pension scheme - and how the pension age would be tied to the retirement age. In order to provide a realistic response to the actual retirement age when the official retirement age increases, as traced in the introduction, some explicit link between the two has to be established. We leave this to future work.

5.9. Proportional pension contributions

Applying pension contributions proportional to the labour income of the agents is another interesting extension. This would establish a link between intensive margin labour supply decisions of the agents and the pension scheme. These effects would fundamentally change the dynamics of the model: First, equation (10) would change to include proportional contributions which would act like taxation; Second, the pension system balance would include aggregate labour supply in addition to the demographic parameters.

The representative agent would therefore make labour supply decisions, which would in turn affect the balance of the pension scheme, implying either a change in the contribution or benefits rates, which would then impact the agent's labour supply choice. This dynamic would lead to changes in the Euler equation of labour supply, affecting the shape of the intensive margin of labour supply.

Having an impact on the intensive margin of labour supply, proportional pension contributions would deepen the sophistication of the analysis of the backlash effect. The ability to separate the backlash effect into income and substitution effects is one possible avenue this extension could provide the analysis with. We leave this to future work.

5.10. Decreasing returns to labour

In the analysis, constant returns to scale of labour supply was assumed. Production, Y, is assumed to be a function of labour supply, L, and the economy's technology level,

ω, which was assumed to be exogenous and potentially time varying. Perfect markets imply that wages are set equal to the technology level, $w = \omega$. This set-up of the labour market implies that wages do not impact an agent's decisions on labour market participation.

By introducing decreasing (or increasing) returns to scale, the agent's wages would react to changes in the aggregate labour supply, both on the intensive and extensive margins. This implies that in a DRS setting, the backlash effect would become greater, since as labour supply drops on the intensive margin, the wages per hour worked would increase, causing agents less financial loss from reducing their working hours. The opposite would hold true in the increasing returns to scale case.

6. Concluding remarks

We specify a model of leisure-consumption choices that confirms our insights about retirement reform. A reform that aims at increasing the labour supply on the extensive margin, will have the unintended effect of decreasing labour supply on the intensive margin. This was done in a steady state setting of dynamic efficiency with an unfunded pension system, where backlash effects were shown to exist in an analytical setting for DB and FF pension schemes.

We have shown that the type of mandatory pension scheme matters a great deal in the context of either increased longevity or an increase in the retirement age. The calibration exercises demonstrated how important the design of the pension system is when implementing retirement age increases. A feature as simple as DC and DB can make a difference to the decision-making process of agents when choosing the intensity of labour supply throughout their lives. Basically, whoever pays the "longevity bill" matters for how agents react to retirement age increases. In this case, the existence and type of pension scheme can either reduce or increase the unintended effects of increased extensive margin labour supply on intensive magin labour supply - or as we call it, the backlash effect.

Through our calibration exercise, we found that the effects under a FF pension regime were in line with our insights about labour intensity. In the FF case, changes in labour intensity were driven by anticipated length of the working life and retirement. By adding a pension system, where pension benefits were contemporaneously covered by contributions by the working population, another layer of complexity arose. The effects of retirement reform on labour supply increased substantially in the DB case compared to the FF case, leading to a relatively large drop in labour supply on the intensive margin as a result of an increase on the extensive margin. But in the case of DC, the opposite situation occurred, where the *backlash* effects of pension reform were smaller than in the FF case. These differences indeed stem from the existence of an unfunded pension scheme, its value to individuals, and how that value changes when the retirement age is raised.

We confirmed the existence of backlash effects under different calibration exercises. Our results are generally robust to changes in leisure preferences. In terms of the interplay between interest rates and subjective discount rates, a key relationship for our results, we conclude that debtor nations, where individuals have stronger subjective discount rates compared to the world interest rate, have more pronounced backlash effects. A one third increase (decrease) to the subjective discount rate (interest rate) yields two to three times stronger backlash effects. In the case of an even more relative patient economy, making it more of a creditor nation compared to the baseline, the backlash effects tend to be mitigated.

The lesson to take from this study is that pension rebalancing reforms aimed at either indexing retirement age increases in a one-to-one manner with respect to increases in life expectancy or increasing the retirement age to preserve the same old-age dependency ratio, may fall short from accomplishing their goals at steady state. Increases to the retirement age must be more-than-proportional with respect to increases in longevity and need to account for the type of pension system in place.

For countries running DB unfunded schemes, increases to the retirement age should most likely be much stronger relative to expected longevity increases, when compared to other pension system types. Complimentary pension reforms should therefore be explored. The situation looks much more benign for DC pension systems, where retirement age increases seem to create relatively weak backlash effects. This pension system type is much more robust to retirement age increases where intensive margin labour supply responses are concerned.

Given the results presented here, a further look into these backlash results is warranted, where other features should be considered. Future work should consider features such as endogenous retirement decisions, realistic mortality, wage profiles and proportional taxation. We acknowledge that the addition of these features would provide a more accurate measurement of the backlash effects. The question of economic transition to the new steady state is also a relevant one, which this paper does not answer.

References

Abel, A. B., G. Mankiw, L. H. Summers and R. J. Zeckhauser (1989), "Assessing Dynamic Efficiency: Theory and Evidence", *Review of Economic Studies*, Oxford University Press, vol. 56(1), pp. 1-19.

Benhabib, J., A. Bisin, and S. Zhu (2014), "The Distribution of Wealth in the Blanchard-Yaari Model", *Macroeconomic Dynamics*, vol. 20(2), pp. 466-481.

Blanchard, O. (1985), "Debt, Deficits, and Finite Horizons", *Journal of Political Economy*, vol. 93(2), pp. 223-247.

Brown, Kristine M., Laschever, Ron A., 2012. When they're sixty-four: Peer effects and the timing of retirement. American Economic Journal: Applied Economics 4 (3), 90–115.

Börsch-Supan, A. and A. Ludwig (2010), "Old Europe Ages: Reforms and Reform Backlashes", NBER Working Papers 15744, *National Bureau of Economic Research*, Inc.

Börsch-Supan, A. and A. Ludwig (2013), "Modeling the Effects of Structural Reforms and Reform Backlashes: The Cases of Pension and Labour Market Reforms", *Economic Modelling*, vol. 35, pp. 999-1007.

Chalmers, J. M., W. T. Johnson and J. Reuter (2008), 'Who Determines When You Retire? Peer Effects and Retirement'. NBER Retirement Research Center Paper No. NB 13-08.

Cribb, J., C. Emmerson and G. Tetlow (2016), 'Signals Matter? Large Retirement Responses to Limited Financial Incentives', *Labour Economics*, vol. 42, 203–212.

DICE Database (2015), "Gross / Net Pensions Replacement Rates from Public, Mandatory Private and Voluntary Private Pension Schemes, 2005 - 2012", Ifo Institute, Munich, online available at http://www.cesifo-group.de/DICE/fb/3W8xJEqkP.

Eurostat (2018a), "Life Expectancy by Age and Sex", retrieved 11/7/2018 from Eurostat.eu: https://ec.europa.eu/eurostat/data/database.

Eurostat. (2018b), "Population on 1 January by Sex and by Age Group", retrieved 11/7/2018 from Eurostat.eu: https://ec.europa.eu/eurostat/web/products-datasets/-/med_ps112.

Fisher, Walter H. and Keuschnigg, Christian, "Pension Reform and Labor Market Incentives" (July 2007). CESifo Working Paper No. 2057; University of St. Gallen Economics Discussion Paper No. 2007-13. Available at SSRN: https://ssrn.com/abstract=984168

Heijdra, B. J. (2003), "Foundations of Modern Macroeconomics", 2nd ed. Oxford, New York, United States: Oxford University Press.

Howse, K. (2007), "Updating the Debate on Intergenerational Fairness in Pension Reform", *Social Policy & Administration*, vol. 41(1), pp. 50-64.

Jensen, S. E. and O. H. Jorgensen (2010), "Reform and Backlash to Reform: Economic Effects of Ageing and Retirement Policy", Policy Research Working Paper, no. WPS 5470. Retrieved from https://openknowledge.worldbank.org/handle/10986/3952.

Kalemli-Ozcan, S. and D. N. Weil (2010), "Mortality Change, the Uncertainty Effect, and Retirement." *Journal of Economic Growth*, vol. 15(1), pp. 65-91.

Keuschnigg, C. and W. Fisher (2011), "Life Cycle Unemployment, Retirement and Parametric Pension Reform", Economics Working Paper Series 1119, University of St. Gallen, School of Economics and Political Science.

Lalive, R. and S. Staubli (2015), "How Does Raising Women's Full Retirement Age Affect Labor Supply, Income, and Mortality?", NBER Retirement Research Center Paper No. NB 14-09.

Lumsdaine, R. L., J. H. Stock and D. A. Wise (1996), "Why are Retirement Rates so high at Age 65?", in D. A. Wise, ed., 'Advances in the Economics of Aging', NBER, pp. 61–82.

Luo, K., T. Kinugasa and K. Kajitani (2018), "Dynamic Efficiency in World Economy", Discussion Papers 1801, Graduate School of Economics, Kobe University.

Manoli, D. and A. Weber (2014), "Nonparametric Evidence on the Effects of Financial Incentives on Retirement Decisions", CESifo Working Paper no. 4619.

Manoli, D. and A. Weber (2016), "The Effects of the Early Retirement Age on Retirement Decisions", Working paper.

Mastrobuoni, G. (2009), "Labor Supply Effects of the Recent Social Security Benefit Cuts: Empirical Estimates using Cohort Discontinuities", *Journal of Public Economics*, vol. 93(11–12), pp. 1224–1233.

Meghir, C. and D. Phillips (2008), "Labour Supply and Taxes", IZA Discussion Papers, Institute of Labor Economics (IZA), No 3405.

Nielsen, S. B. (1994), "Social Security and Foreign Indebtedness in a Small Open Economy", *Open Economies Review*, vol. 5(1), pp. 47-63.

OECD (2017), "Pensions at a Glance 2017: OECD and G20 Indicators", OECD Publishing, Paris, https://doi.org/10.1787/pension_glance-2017-en.

OECD (2018), "Net Pension Replacement Rates" (indicator), retrieved 05/11/2018, doi: 10.1787/4b03f028-en.

OECD (2019), "Employment Dataset – Labour Force Participation Rate" (indicator), retrieved 25/04/2019 from: stats.oecd.org.

Queisser, M. and E. Whitehouse (2006), "Neutral or Fair? Actuarial Concepts and Pension-System Design", OECD Social, Employment and Migration Working Papers, 40, doi: https://doi.org/10.1787/351382456457.

United Nations (2017), "World Population Prospects Database", Department of Economic and Social Affairs, Population Division.

Weil, D. N. (2006), "Population Aging", NBER Working Papers 12147, National Bureau of Economic Research, Inc.

Yaari, M. E. (1965), "Uncertain Lifetime, Life Insurance, and the Theory of the Consumer", *Review of Economic Studies,* vol. 32(2), pp. 137-150.

Staubli, S. and J. Zweimüller (2013), "Does Raising the Early Retirement Age Increase Employment of Older Workers?", *Journal of Public Economics,* vol. 108, pp. 17–32.

Chapter 3

Longevity, Pension Reform and Intra-Generational Equity

Longevity, Pension Reform and Intra-Generational Equity*

By

Svend E. Hougaard Jensen
Department of Economics, Copenhagen Business School
Porcelaenshaven 16A, 2000 Frederiksberg C, Denmark
shj.eco@cbs.dk

Thorsteinn Sigurdur Sveinsson
Economics and Monetary Policy, Central Bank of Iceland
Kalkofnsvegur 1, 150 Reykjavik, Iceland
tss@cb.is

and

Gylfi Zoega
Department of Economics, University of Iceland, and Department of Economics, Mathematics and Statistics, Birkbeck College, University of London
Sæmundargata 2, 101 Reykjavik, Iceland
gz@hi.is

January 2020

Abstract: We find that segments of society who have shorter life expectancy can expect a lower income from their pensions and lifetime utility due to the longevity of other groups participating in the same pension scheme. Linking the pension age to average life expectancy magnifies the negative effect on the lifetime utility of those who suffer low longevity. Furthermore, when the income of those with greater longevity increases, those with shorter life expectancy become even worse off. Conversely, when the income of those with shorter life expectancy increases, they end up paying more into the pension scheme, which benefits those who live longer. The relative sizes of the low and high longevity groups in the population determine the magnitude of these effects. We calibrate the model based on data on differences in life expectancy of different socio-economic groups and find that low-income workers suffer from a 10-13 percent drop in pension benefits from being forced to pay into the same scheme as high-income workers.

Keywords: Longevity, pension age, retirement, inequality.
JEL Classification: E21, E24

* We are grateful for comments made by participants at the conference "*Macroeconomic Effects of Changing Demographics*", held at the Central Bank of Iceland on November 16, 2018. In particular, we are grateful to Arna Olafsson, our discussant, for her thoughtful comments. We also gratefully acknowledge comments from participants of the conference "*Icelandic Economists Abroad",* held at the University of Iceland on May 27, 2019. We thank Sarah K. Andersen for research assistance. This research was supported by PeRCent, which receives base funding from the Danish pension funds and Copenhagen Business School.

1. Introduction

Everything points towards an increase in life expectancy for the elderly, i.e., individuals aged 65 and above. A typical estimate today is that the remaining life expectancy for a 65-year old will increase by a year every ten years (OECD, 2017). This raises a number of economic issues: One concerns public finances, which will come under pressure as pension and elderly care expenses increase. Therefore, the practice of linking pension age to life expectancy has become quite common (Jensen et al., 2019).

While simple and logical, such longevity indexation rules pose a number of challenges. One of them, and the theme addressed in this paper, is that they are designed in terms of average measures. In Denmark, for example, the official pension age increases in line with changes in average longevity (Andersen, 2015). However, differences in life expectancy between high- and low-education workers, or high-income and low-income workers, as well as between men and women, are well known. Therefore, changes in the pension age based on an increase in average life expectancy may affect different socioeconomic groups differently. Such intra-generational differences may have important implications for lifetime utility for different groups in society.

Therefore, if average figures are calculated over a highly heterogeneous population, longevity indexation may widen inequality among the elderly. Such unintended effects may seriously jeopardize the egalitarian objectives pursued by, say, Nordic welfare states. For example, if longevity indexation would reduce lifetime utility of blue-collar workers with health issues, due to wearing-out following a long working-life with physically demanding routine work, unlike that of white-collar workers with a long education and a shorter working-life, the broad political support behind longevity adjustment might well gradually disappear.

In this paper, we study these issues in further detail. Our key theme is the implications of a longevity-indexed pension age in an economy where some segments of the population live longer than others, in order to explore whether a longevity-indexed pension age implicitly leads to intra-generational disparities. We believe this fills an important gap in the academic literature. While a few papers have addressed aspects related to intergenerational redistribution following the introduction of longevity adjustment (see, e.g., Andersen, 2010; Jensen and Jørgensen, 2008), the intra-generational dimension has, to our best knowledge, not been studied as extensively so far.

In a recent paper, Laun et al. (2019) study possible retirement reforms in Norway intended to achieve solvency of social security in the face of population ageing taking into account both efficiency and equity across education groups. They find that proportionally lowering old-age retirement benefits as well as disability benefits maximizes average welfare of all education groups although it generates inequality in that recipients of disability benefits are more adversely affected. Auerbach et al. (2017) study the effects of Social Security and Medicare on intra-generational equity in the U.S. They compare changes in average lifetime benefits received by men in the highest and lowest income quintiles between the 1930 and the 1960 birth cohorts and find that the difference widens considerably over this period.[38] In an earlier paper, Fuster et al. (2003) used an overlapping-generations model to study the heterogeneity in the value households assign to the insurance role of unfunded social security due to differences in mortality risk.[39]

---

[38] The present value of lifetime benefits at age 50 is equal for those in the highest and lowest quintile of lifetime income for the 1930 cohort while for the 1960 there is a $130,000 gap in benefits.

[39] Households where the children pay high taxes and the father has the shortest lifetime tend to dislike social security. They like it most when the father is transferring income to his children and facing borrowing constraints.

We contribute to this literature by deriving a continuous-time model to show the intra-generational effects of an unfunded pension scheme; how linking the pension age to average life expectancy magnifies these intra-generational effects by increasing the negative effect on the lifetime utility of those who have short life expectancy; and to show the effect of changes in the income distribution between those with long and short life expectancy on the intra-generational effect of such unfunded pension schemes.

From here, the paper proceeds as follows: We start by providing some additional evidence of differences in life expectancy in Denmark of observably different groups of individuals. We then derive an overlapping-generations model for groups that differ in life expectancy but face a common pension age. Next, we use the model to explore the externalities between the groups associated with their differing life expectancies and provide policy recommendations. Thereafter, we calibrate our model based on the different life expectancy of, respectively, blue-collar and white-collar workers in order to get an estimate of the effect of the common pension age on the utility of different socio-economic groups. Finally, we summarize our findings, point out some implications for social and pension policy, and make suggestions for future research.

2. Heterogeneous life expectancy

In order to set the scene for this paper, we provide some additional evidence of differences in life expectancy of observably different groups of individuals who share the same system of a (flow) state pension or belong to the same pension fund. The example that may first come to mind is that of men and women. Differences in the life expectancy of men and women are well known and widely documented. The United Nations published data on developed and developing countries in 2015 where significant differences can be seen, with women having longer life expectancy than men. Thus, the life expectancy for men is 80.9 in Japan, 79.4 in Spain, 81.9 in Sweden and 80.0 in Denmark while the corresponding numbers for women are 86.6 in Japan, 85.1 in Spain, 83.7 in Sweden and 81.9 in Denmark (United Nations, 2015). But these numbers also reflect infant mortality, which is not a part of the issues addressed in this paper. According to the OECD, the life expectancy at age 65 for men in these countries is 19.6 in Japan, 19.4 in Spain, 19.1 in Sweden and 18.2 in Denmark while the corresponding numbers for women are 24.4 in Japan, 23.6 in Spain, 21.5 in Sweden and 20.8 in Denmark (OECD, 2019). Thus, a woman at age 65 can expect to live 4.8 more years than a man in Japan, 4.2 in Spain, 2.4 in Sweden and 2.6 in Denmark.

There are also differences in life expectancy across income groups. Table 1 shows life expectancy in Denmark at age 60 by income quantiles. The difference between the life expectancy of men in the top and bottom income group at age 60 was 5.9 years in 1996 and grew to 6.0 years in 2016. Similar numbers for women are 5.2 years in 1996 and 3.8 years in 2016. Thus, the gap between low-income and high-income women was becoming smaller while the gap for men increased slightly.

Table 1. Life expectancy at 60 by income quantiles, Denmark

	Q1	**Q2**	**Q3**	**Q4**
	Men			
1996	14.9	17.6	18.9	20.8
2016	18.9	21.3	23.1	24.9
	Women			
1996	18.8	21.7	22.4	24.0
2016	23.5	23.9	24.9	27.3

Source: Danish Ministry of Finance.

In addition, there are differences between skill groups. Table 2 illustrates life expectancy at 60 by skill groups in Denmark.

Table 2. Life expectancy at 60 by education, Denmark

	Unskilled	Skilled	Shorter higher education	Longer higher education
		Men		
2002	18.5	19.1	20.5	21.4
2016	20.6	22.0	23.3	24.0
		Women		
2002	21.8	22.8	23.6	23.8
2016	23.8	25.2	26.0	26.3

Source: Danish Ministry of Finance.

Comparing with income groups, the differences are smaller. For men, the difference in life expectancy between those having longer higher education and those who are unskilled was 3.4 years in 2016 and 2.9 years in 2002. For women, the difference was 2.5 years in 2016 and 2.0 years in 2002. In this case, the gap between the two groups – those unskilled and those with long higher education – is becoming larger. This trend is not necessarily a recent trend, based on Danish registry data Brønnum-Hansen and Baadsgaard (2012) find that the social life expectancy gap in Denmark has widened since 1987.

Not surprisingly, the differences between the life expectancy of high-income and low-income workers are larger in the US. In an early study, Kitagawa and Hauser (1973) found significant difference in 1969 mortality by education. Waldron (2007) found differences in life expectancy of the rich and the poor in the US and that this is a gradient across the socioeconomic scale. More recently, Chetty et al. (2016) showed that the life expectancy of the richest 1 percent in the U.S. is 14 years longer than that of the poorest 1 percent and the top income quartile can expect to live about a decade longer than the bottom quartile. These are much bigger differences than those found for Denmark (see Table 1).

Furthermore, both studies have found that the spread in life expectancy between income groups is increasing. Case and Deaton (2017) find an increase in mortality and morbidity among white non-Hispanic Americans in midlife (35-59) since the beginning of this century, continuing until at least 2015 due to increases in drug overdoses, suicides and alcohol-related liver mortality. Case and Deaton attribute this development to progressively worsening labour market opportunities of whites with low levels of education at the time of entry into the labour market, which is magnified by the over prescription of opioids and other drugs. Educational differences in mortality among whites are increasing to such an extent that mortality has risen for those without a college degree while decreasing for those with a college degree.

The gap between income groups is evidently not as wide in Europe. The OECD (2017) reported that the average gap in life expectancy in Europe between those with tertiary education and those below upper secondary education is 2.7 years. For example, the gap is only 1.5 years for Denmark. Moreover, Case and Deaton show how mortality rates have continued to drop in Europe, especially for those with lower levels of education. Thus, European countries had an average rate of decline of age-adjusted mortality of 2.0 percent per year between 1990 and 2015, while non-Hispanic whites without a college degree in the US saw that same decline only until the late 1990s, when mortality started to increase for those without a college degree.

Differences in longevity also exist between a wide array of other social groups, such as those defined on the basis of race, country of origin in the case of immigrants, professions, and so forth. However, in this paper we will calibrate our model for socio-economic groups since they are an obvious example of groups that pay the same amount into pension schemes but have different life expectancies.

3. A model with overlapping generations and a heterogeneous population

In this section, we explore the implications of differences in longevity across groups and lifetime utility when there is a common pension age for the whole population. We set up an overlapping generations (OLG), stated in continuous time, and with a heterogeneous population based on Andersen and Gestsson (2016) and Gestsson and Zoega (2018). We, as well as these two papers, depart from Blanchard (1985) by assuming that the probability of dying increases with age. Thus, the old differ from the young in facing a higher probability of death and there is a maximum possible age for every cohort.

We depart from the basic model in Andersen and Gestsson (2016) by introducing a more realistic mortality profile and splitting the population into two heterogeneous groups. In that paper, no one dies before reaching pension age and thereafter, the size of a cohort gradually reduces until no one is left. In contrast, we start with data on actual mortality profiles and calibrate our theoretical model to fit this profile. In addition, and this is the key contribution of our paper, one half of the population, denoted by H, enjoys high life expectancy, while the other half, denoted by L, suffers low life expectancy. Agents can choose when to retire, making consumption and saving decisions while paying into a pay-as-you-go (PAYG) pension scheme. When they reach the pension age, they becomes eligible for pension benefits. After retirement, they consume based on their savings and pension transfers. Agents can die at any time, but their instantaneous death probability, or hazard rate, is dependent on their age and societal group. The maximum age possible is A. We can then use the model to explore the effect of increased longevity of one group on the lifetime utility of the other, the effect of changes in the pension age on the utility of both groups, and, finally, the effect of changes in the income of both groups on their lifetime utility.

3.1. Age-dependent death probability

The cumulative distribution function (CDF) captures the chance of being dead at age a, where $i \in \{H, L\}$. The superscript denotes which group each agent belongs to. We adopt the realistic mortality structure introduced by Boucekkine et al (2002). The CDF of time of death (D) takes the following form:

$$\Phi^i(a) = \Pr(D \leq a) = \int_D^a \varphi^i(D)dD = \frac{e^{\mu_1^i a} - 1}{\mu_0^i - 1}, i = H, L \qquad (1)$$

The parameters $\mu_0^i > 1$ and $\mu_1^i > 0$ determine the shape of the CDF. An increase in μ_0^i makes the denominator of the CDF greater, proportionally increasing the probability of being dead at each age. Importantly, any change in μ_1^i has an age-dependent positive effect on the numerator. Therefore, a manipulation of both parameters allows us to change the slope and reach of the CDF, effectively creating a mortality profile that closely resembles reality, see Figure 1. Equation (1) can be used to approximate the empirical survival curves shown in Figure 3. In general, we have to assume that the group that suffers from a shorter expected lifespan has either a lower value of μ_0^i or a higher value of μ_1^i (or both) than the high longevity group.

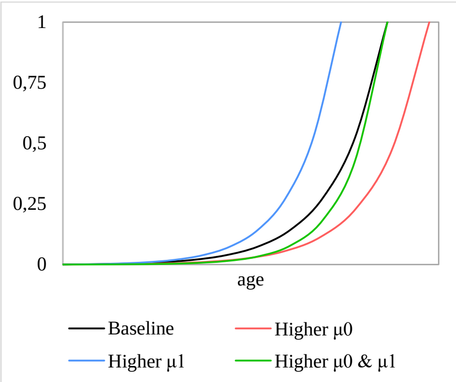
From the CDF we can find that the chance of being alive at a given age, a, denoted by $m^i(a)$, is:

$$m^i(a) = 1 - \Phi^i(a) = \frac{\mu_0^i - e^{\mu_1^i a}}{\mu_0^i - 1} \qquad (2)$$

The maximum age for each group, $A^i = \ln(\mu_0^i) / \mu_1^i$, can be found through the CDF. We see that the chance of being alive is strictly decreasing and strictly concave at an increased age.

$$\frac{\partial m^i(a)}{\partial a} < 0 \quad and \quad \frac{\partial^2 m^i(a)}{\partial a^2} < 0$$

Figure 1. Cumulative distribution function of time of death

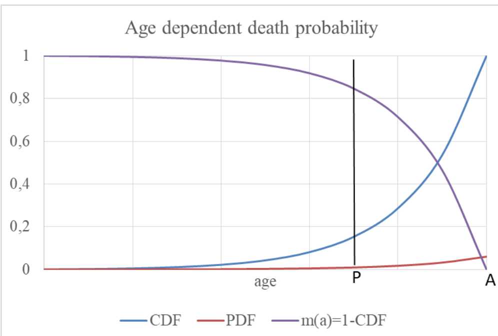


The probability density function (PDF) of death, is found by differentiation:

$$\varphi^i(a) = \frac{\mu_1^i e^{\mu_1^i a}}{\mu_0^i - 1} \tag{3}$$

These functions are depicted in Figure 2 along with a hypothetical pension age, P, and the maximum possible age A.

Figure 2. Mortality over the lifespan



3.2. Private insurance/pension system

In line with (Yaari, 1965), we introduce an actuarially fair insurance company that provides agents with actuarial notes. The purchaser of an actuarial note gets a constant stream of payment until his death. The notes are in a sense an annuity, which, at the time of the purchaser's death, leave the insurance company free of any obligations. This mitigates the loss of utility caused by the uncertainty of death, as all of the agent's private assets are held in these notes. These notes pay the rate $r^i(a) = \int_0^a r + \beta^i(z)dz$, where $\beta^i(z)$ is the instantaneous death probability of agent aged a:

$$\beta^i(a) = \frac{\varphi^i(a)}{1 - \Phi^i(a)} = \frac{\mu_1^i e^{\mu_1^i a}}{\mu_0^i - e^{\mu_1^i a}} \tag{4}$$

Here, the small open economy setting, where r is exogenous, has been adopted. Equation (4) implies the insurance company can observe which group each agent belongs to, paying group L a higher rate of return, because their instantaneous death probability is higher than those of group H. Therefore, assets held in these notes can be interpreted as a private pension fund or a life insurance policy. From this we get the rate of return:

$$r^i(a) = \int_0^a r + \beta^i(z)dz = ar - \ln\left(\mu_0^i - e^{\mu_1^i a}\right) + \ln\left(\mu_0^i - 1\right) \tag{5}$$

which implies: $e^{-r^i(a)} = e^{-ar}\frac{\mu_0^i - e^{\mu_1^i a}}{\mu_0^i - 1} = e^{-ar} m^i(a)$.

It can directly be observed that the mortality profile influences the rate of return and therefore plays a key role in the consumption-saving decisions of agents.

3.3. Beveridgean-type public PAYG pension system

Agents are forced to pay into a government-run PAYG pension scheme. Contrary to the private insurance company, the government, and therefore this pension scheme, cannot "see" which group each agent belongs to. So, all agents pay the same amount into the PAYG system while contributing and receive identical pension benefits after reaching the pension age, providing that the agent is alive. This system represents the social security system of the economy.

The pension system is run on a balanced budget basis:

$$\Pi = \frac{\mathrm{T}N_c}{N_b} \tag{6}$$

Here we operate in the defined contributions (DC) case, where we treat pension benefits, Π, as endogenous, implying a defined contribution scheme, and the pension contributions, T, as exogenous. Conversely, in the defined benefits (DB) case, we treat pension contributions as endogenous and the benefits as exogenous. Here both groups pay the same amount into the pension scheme. In section 5 we will wage-index the pension transfers and allow for an asymmetric income distribution. For simplicity, we start with a uniform income across the groups causing any wage-indexation to yield identical results as in the case where the groups pay the same dollar-amount.

The subscript denotes which group an agent belongs to; N_b and N_c represent the number of pension benefits recipients and contributors, respectively. P represents the pension age. We can find the number of contributing agents and agents receiving benefits from the pension scheme:

$$\begin{aligned} N_c = N_c^L + N_c^H &= \sigma \int_0^P m^L(a)da + (1-\sigma) \int_0^P m^H(a)da \\ &= \sigma \frac{e^{\mu_1^L P} - P\mu_1^L\mu_0^L - 1}{\mu_1^L - \mu_1^L\mu_0^L} + (1-\sigma) \frac{e^{\mu_1^H P} - P\mu_1^H\mu_0^H - 1}{\mu_1^H - \mu_1^H\mu_0^H} \end{aligned} \tag{7}$$

$$\begin{aligned} N_b = N_b^L + N_b^H &= \sigma \int_P^{A^L} m^L(a)da + (1-\sigma) \int_P^{A^H} m^H(a)da \\ &= \sigma \frac{\mu_0^L - \ln(\mu_0^L)\mu_0^L - e^{\mu_1^L P} + P\mu_1^L\mu_0^L}{\mu_1^L - \mu_1^L\mu_0^L} + (1-\sigma) \frac{\mu_0^H - \ln(\mu_0^H)\mu_0^H - e^{\mu_1^H P} + P\mu_1^H\mu_0^H}{\mu_1^H - \mu_1^H\mu_0^H} \end{aligned} \tag{8}$$

We impose $0 < \sigma < 1$, where σ and $1 - \sigma$ are the proportional size of the new-born cohorts of group L and H, respectively. Agents in this economy are continuously dying and new agents are continuously being born. The whole population is of size:

$$N = N^L + N^H$$
$$= \sigma \frac{\mu_0^L - \ln(\mu_0^L)\,\mu_0^L - 1}{\mu_1^L - \mu_1^L \mu_0^L} + (1-\sigma)\frac{\mu_0^H - \ln(\mu_0^H)\,\mu_0^H - 1}{\mu_1^H - \mu_1^H \mu_0^H} \quad (9)$$

Population size is therefore dependent on the life expectancy of each group. Naturally, the population size is not a function of the pension age and is not affected by the pension system. However, the structure of the pension scheme depends on the demographic structure.

3.4. Utility maximization

Agents maximize expected lifetime utility:

$$E(U) = \int_0^{A^i} e^{-\delta a} m^i(a) u\big(c(a)\big)\, da + \int_{R^i}^{A^i} \omega e^{-\delta a} m^i(a) da \quad (10)$$

Where $u(c(a))$ is utility derived from consumption at age a, utility derived from leisure during retirement is denoted by ω and δ is the discount rate. We assume that the agent can choose between two alternatives, either he works full time or is retired and doesn't work at all. The agent decides when to retire from the labour force but once retired, the agent cannot transition back into the workforce. This setup of utility during retirement is in the style of Kalemli-Ozcan and Weil (2010).

The lifetime budget constraint becomes:

$$\int_0^{R^i} y^i\, e^{-r^i(a)} da + \int_P^{A^i} \Pi e^{-r^i(a)} da = \int_0^{A^i} c(a)\, e^{-r^i(a)} da + \int_0^P \mathrm{T}\, e^{-r^i(a)} da \quad (11)$$

Notice that while the retirement age, R^i, is endogenous the pension age, P, is exogenous. The agent cannot decide the rules of the pension scheme, but he can decide when to retire. Here y^i is the income of agents. The first order condition of the utility maximization problem w.r.t. $c(a)$ yields:

$$e^{-\delta a} m^i(a)\, u'\big(c(a)\big) = \gamma e^{-ar} m^i(a) \tag{12}$$

where γ is the Lagrange multiplier. By assuming the real interest rate, r, equals the subjective rate of time preference, δ, we get:[40]

$$u'\big(c(a)\big) = \gamma \quad \forall a \in [0, A^i] \tag{13}$$

which implies: $c(a) = c^i \quad \forall a \in [0, A^i]$.

Finally, from this realization, the budget constraint, and applying the identity of the PAYG-pension system ($\Pi = \frac{\mathrm{T}N_w}{N_o}$), we get that each agent consumes according to:

$$\begin{aligned} c^i \int_0^{A^i} e^{-ar}\, m^i(a)da \\ = y^i \int_0^{R^i} e^{-ar} m^i(a)da - \mathrm{T}\int_0^{P} e^{-ar}\, m^i(a)da \\ + \frac{\mathrm{T}N_w}{N_o}\int_P^{A^i} e^{-ar} m^i(a)da \end{aligned} \tag{14}$$

By rearranging we arrive at:

$$\begin{aligned} c^i = \mathrm{y^i}\, \frac{\int_0^{R^i} e^{-ar} m^i(a)da}{\int_0^{A^i} e^{-ar}\, m^i(a)da} - \mathrm{T}\, \frac{\int_0^{P} e^{-ar}\, m^i(a)da}{\int_0^{A^i} e^{-ar}\, m^i(a)da} \\ + \frac{\mathrm{T}N_w}{N_o} \frac{\int_P^{A^i} e^{-ar}\, m^i(a)da}{\int_0^{A^i} e^{-ar}\, m^i(a)da} \end{aligned} \tag{15}$$

[40] We can do this, as we are not interested in the lifetime consumption *path* of each group, but rather the *total* lifetime consumption of each group.

The consumption of the agent is dependent on the relative portions of his expected lifetime spent working, captured by the first fraction in equation (15), time spent contributing to the pension scheme, captured by the second fraction, and time spent receiving pension benefits, captured by the last fraction. When planning his consumption, the agent accounts for his contributions to the pension scheme and expected pension benefits later in life, both of which are influenced by the demographic structure of society. Therefore, the agent has to account for his own life expectancy and the life expectancy of the whole population when making consumption decisions.

The old-age dependency ratio dictates the contributions/benefits structure of the pension scheme. This is an obvious way in which the demographic structure of society influences the consumption plan of the agent. These effects are analyzed in sections 4.1 and 4.2. More subtly, as the pension age is uniform across the population, any changes in the life expectancy of one group will raise the average life expectancy of the whole population, which might lead to a rise in the pension age. In sections 4.3 and 4.4 we elaborate further on the implications of pension age increases.

4. Experiments

Having presented our analytical framework, we next study some of the results that can be derived from it. We concentrate on longevity shocks and changes in the pension age.

4.1. Asymmetric longevity shock

We now turn our attention towards the implications of increased longevity by deriving the effect of a widening of the gap between the life expectancies of the two groups. The widening of the gap between the life expectancies of the two groups can either manifest itself in a lowering of μ_1^H or increases in μ_0^H causing the high longevity group (H) to live even longer.

We begin by lowering μ_1^H and keep μ_0^H, μ_1^L, μ_0^L and P constant. This rise will therefore not affect the mortality profile of the L group but will change the consumption pattern of the L group through the pension system.

$$\frac{\partial N_c}{\partial \mu_1^H} = (1-\sigma)\frac{e^{\mu_1^H P}(1-P\mu_1^H)-1}{(\mu_1^H)^2(\mu_0^H-1)} < 0 \tag{16}$$

$$\frac{\partial N_b}{\partial \mu_1^H} = (1-\sigma)\frac{\mu_0^H - \ln(\mu_0^H)\,\mu_0^H - e^{\mu_1^H P}(1-P\mu_1^H)}{(\mu_1^H)^2(\mu_0^H-1)} < 0 \tag{17}$$

We are not only interested in the effect on each population, but also the effect on the ratio of pensioner to contributors. We find that the contributing population grows more than the pensioner population when we raise longevity via μ_1^H. This implies that pension benefits will decrease for both groups. Therefore, group L will receive a lower return for their contributions, because the drop in pension benefits is not caused by an increase in their own lifespan. The expected lifetime consumption of members of the H group will rise, since their expected pension benefits will increase because of their increased life expectancy. Therefore, a positive longevity shock on one group has a negative financial effect on the other.

We can also simulate the asymmetric shock by increasing μ_0^H while keeping all other parameters in the mortality profile, μ_1^H, μ_0^L and μ_1^L, and the pension age, P, constant.

$$\frac{\partial N_c}{\partial \mu_0^H} = (1-\sigma)\frac{e^{\mu_1^H P} - P\mu_1^H - 1}{\mu_1^H(\mu_0^H-1)^2} > 0 \tag{18}$$

$$\frac{\partial N_b}{\partial \mu_0^H} = (1-\sigma)\frac{\mu_0^H + P\mu_1^H - \ln(\mu_0^H) - e^{\mu_1^H P}}{\mu_1^H(\mu_0^H-1)^2} > 0 \tag{19}$$

We observe the same effects in this case; the expected lifetime consumption of the H group increases at the cost of the L group.

4.2. Population shock

We have seen that the longevity of one group has an effect on the welfare of the other through the PAYG scheme. This welfare effect depends on the relative sizes of the H and L groups. Let's define the PAYG equality, from equation (6), as [41]

$$\Pi = \mathrm{T}\frac{N_c}{N_b} = \mathrm{T}\frac{\sigma\widetilde{N}_c^L + (1-\sigma)\widetilde{N}_c^H}{\sigma\widetilde{N}_b^L + (1-\sigma)\widetilde{N}_b^H} \qquad (20)$$

where: $\widetilde{N}_c^L \equiv \int_0^P m^L(a)da$, $\widetilde{N}_b^L \equiv \int_P^{A^L} m^L(a)da$, $\widetilde{N}_c^H \equiv \int_0^P m^H(a)da$ and $\widetilde{N}_b^H \equiv \int_P^{A^H} m^H(a)da$.

Now we can see what happens to the PAYG benefits (or contributions in the DB case) when the relative sizes of the group changes:

$$\frac{\partial\Pi}{\partial\sigma} = \mathrm{T}\frac{(\widetilde{N}_c^L-\widetilde{N}_c^H)\left(\sigma\widetilde{N}_b^L+(1-\sigma)\widetilde{N}_b^H\right)-(\widetilde{N}_b^L-\widetilde{N}_b^H)(\sigma\widetilde{N}_c^L+(1-\sigma)\widetilde{N}_c^H)}{\left(\sigma\widetilde{N}_b^L+(1-\sigma)\widetilde{N}_b^H\right)^2} > 0 \qquad (21)$$

The sign of equation (21) can be determined by solving the numerator:

$$(1-\sigma)\widetilde{N}_c^L\widetilde{N}_b^H + \sigma\widetilde{N}_c^L\widetilde{N}_b^H - (1-\sigma)\widetilde{N}_c^H\widetilde{N}_b^L - \sigma\widetilde{N}_c^H\widetilde{N}_b^L = \frac{\widetilde{N}_b^H}{\widetilde{N}_c^H} - \frac{\widetilde{N}_b^L}{\widetilde{N}_c^L} > 0 \qquad (22)$$

This implies that when the size of the L group increases, the pension benefits for both groups increase. This is due to the fact that the L group pays proportionally more into the PAYG scheme than it receives as benefits. So, as the number of L agents increases, there are proportionally fewer long-lived agents who collect benefits in old age. Because the PAYG scheme is balanced at each time, this translates into either a drop in the contributions, T, in the DB case or a rise in the benefits, Π, in the DC case as described in equation (21).

[41] To analyze the effect on the size of one group on the pension transfers we have separated σ from the definition of the relative size of each population group, see equations (7) and (8).

This implies that when the H group gets smaller the remaining members get even richer through the PAYG scheme. Conversely, as the L group gets smaller its members are even worse off.

4.3. Rise in the pension age

Having derived the effects of a longevity shock we now turn to changes in the pension age. At first glance, we see that the probability of surviving until the pension age is always lower for members of the L group than the H group. Furthermore, by differentiation of the survival chance, we get:

$$\frac{\partial m^i(P)}{\partial P} = -\frac{\mu_1^i e^{\mu_1^i P}}{\mu_0^i - 1} < 0 \tag{23}$$

From this expression, we see that any change in the pension age will have a greater impact on the probability of reaching the pension age on members of the L group. The L group already suffers from a lower chance of survival to the pension age, but any raising of the pension age will widen this gap in survival probabilities.

The effects of the pension system are not only captured in the probability of reaching the pension age, but also with the relative population size of pensioners. The rise in the pension age entails:

$$\frac{\partial N_c}{\partial P} = \sigma \frac{e^{\mu_1^L P} - \mu_0^L}{1 - \mu_0^L} + (1 - \sigma)\frac{e^{\mu_1^H P} - \mu_0^H}{1 - \mu_0^H} > 0 \tag{24}$$

$$\frac{\partial N_b}{\partial P} = -\frac{\partial N_c}{\partial P} = \sigma \frac{\mu_0^L - e^{\mu_1^L P}}{1 - \mu_0^L} + (1 - \sigma)\frac{\mu_0^H - e^{\mu_1^H P}}{1 - \mu_0^H} < 0 \tag{25}$$

Since we treat the pension contributions, T, as exogenous in the DC case, the pension benefits increase with the pension age. Regardless of whether the difference in longevity is caused by $\mu_1^L > \mu_1^H$ or $\mu_0^L < \mu_0^H$ we can see that the following holds (assuming that $\sigma = 0.5$):

$$\frac{\partial N_c^L}{\partial P} = \sigma \frac{e^{\mu_1^L P} - \mu_0^L}{1 - \mu_0^L} < (1 - \sigma) \frac{e^{\mu_1^H P} - \mu_0^H}{1 - \mu_0^H} = \frac{\partial N_c^H}{\partial P} \tag{26}$$

$$\frac{\partial N_b^L}{\partial P} = \sigma \frac{\mu_0^L - e^{\mu_1^L P}}{1 - \mu_0^L} > (1 - \sigma) \frac{\mu_0^H - e^{\mu_1^H P}}{1 - \mu_0^H} = \frac{\partial N_c^H}{\partial P} \tag{27}$$

This implies that the change in the size of the contributing (or pensioner) population, when the pension age increases, is greater for the H group. But this is solely due to the fact that the population of the H group is higher when reaching the pension age, because members of the L group are more likely to die before then.

The ratio between population contributing to the pension scheme and population receiving benefits for each group will shed further light on this. Let's define the dependency ratio, Γ^i for $i \in \{H, L\}$ as:

$$\begin{aligned} \Gamma^i \equiv \frac{N_b^i}{N_c^i} &= \frac{\mu_0^i - \ln(\mu_0^i)\,\mu_0^i - e^{\mu_1^i P} + P\mu_1^i\mu_0^i}{e^{\mu_1^i R} - P\mu_1^i\mu_0^i - 1} \\ &= \frac{\mu_0^i - \ln(\mu_0^i)\,\mu_0^i - 1}{e^{\mu_1^i P} - P\mu_1^i\mu_0^i - 1} - 1 \end{aligned} \tag{28}$$

We see from the denominator of the fraction on the right-hand side that the size of the impact of a pension age hike is greater when μ_1 is bigger. This implies that the impact on the dependency ratio of the population of the L group is higher than the H group. Next, we find the effect of an increase in the pension age:

$$\frac{\partial \Gamma^i}{\partial P} = \frac{\mu_1^i(1 + \ln(\mu_0^i)\,\mu_0^i - \mu_0^i)(e^{\mu_1^i P} - \mu_0^i)}{\left(P\mu_1^i\mu_0^i - e^{\mu_1^i P} + 1\right)^2} < 0 \tag{29}$$

We conclude that when the pension age, P, increases, the dependency ratio decreases. From the expression above we also see that this impact is greater for the L group, which suffers from high values of μ_1. An increase in the pension age will therefore affect the dependency ratio of both groups, but it will affect the L group disproportionately. Agents in the L group will be forced to contribute longer, and the gap between the H and L group in the probability of reaching the pension age will widen. This leads to the negative financial effect associated with the longevity shock becoming even greater. A rise in the pension age will exacerbate the negative financial effect caused by the disparities in longevity between the groups. The L group will end up contributing more than before to the PAYG scheme while getting lower benefits, since they are less likely to reach the pension age.[42] We arrive at the same results when simulating the asymmetric longevity through μ_0.[43]

4.4. Longevity indexed pension age

In the previous section, we explored an exogenous rise in the pension age increase. Now we treat the pension age as endogenous by linking it to the average life expectancy of the whole population. The life expectancy of each agent when entering the labour market, Λ, is:

$$\Lambda^{\mathrm{i}} = \frac{\ln\left(\mu_0^i\right)\mu_0^i + 1 - \mu_0^i}{\mu_1^i(\mu_0^i - 1)} \tag{30}$$

The pension age follows;

$$P(\Lambda) = \lambda\left(\sigma\frac{\ln(\mu_0^L)\,\mu_0^L + 1 - \mu_0^L}{\mu_1^L(\mu_0^L - 1)} + (1-\sigma)\frac{\ln(\mu_0^H)\,\mu_0^H + 1 - \mu_0^H}{\mu_1^H(\mu_0^H - 1)}\right) \tag{31}$$

where the average life expectancy of the whole population when entering the labour-market is $\Lambda = \sigma\Lambda^{\mathrm{L}} + (1-\sigma)\Lambda^H$ and λ is the proportional indexation parameter. We generally expect λ to be greater than zero and less than one. For example, a population that has the life expectancy of 80 years, that enters the labour market at age 21 and

---

[42] The members of the L group that reach the pension age also have shorter life expectancies when they reach the pension age.

[43] A numerical exercise was used to explore the effects when the asymmetric longevity structure is driven by μ_0.

reaches the pension age at 65 would have an indexation parameter of: $\lambda = \frac{65-21}{80-21} = 0.75$. As we treat λ as exogenous, any rise in life expectancy would affect the pension age through equation (31).

Whether longevity increases of the H group are driven by decreases in μ_1^i or increase in μ_0^i they will lead to higher life expectancy. This will in turn affect the pension age:

$$\frac{\partial \mathrm{P}}{\partial \mu_1^H} = \lambda(1-\sigma)\frac{\partial \Lambda^{\mathrm{H}}}{\partial \mu_1^H} < 0 \quad \text{and} \quad \frac{\partial \mathrm{P}}{\partial \mu_0^H} = \lambda(1-\sigma)\frac{\partial \Lambda^{\mathrm{H}}}{\partial \mu_0^H} > 0$$

In the case of a longevity-indexed pension age we therefore observe that as the H group enjoys greater longevity, they will both affect the L group through the pension scheme, as seen in section 4.1, and through a rise in the pension age, as seen in section 4.3. This is further explored in section 7.2.

We can summarize the findings so far as follows: A positive longevity shock to one group has a negative financial effect on the other. Moreover, any longevity adjustment of the pension age based on the average life expectancy of the whole population will exacerbate the effect on the group that didn't enjoy the increased longevity. Both of these effects are then magnified by the relative sizes of the H and L groups. As the L group gets smaller, the members are even worse off. Conversely, as the H group gets smaller, its remaining members benefit.

5. Income inequality and pension transfers

So far, the re-distributional effects of pension schemes that operate based on average life expectancy and old-age dependency ratios of a heterogeneous population have been analyzed. For simplicity, we assumed that all agents, regardless of longevity, paid the same contributions and received the same benefits from the pension scheme, provided they were alive. By introducing contribution and benefits proportional to wages, we can further deepen the analysis of intra-generational transfers due to pension systems. This allows us to demonstrate intra-generational transfers imposed by the pension system that are driven by, and exacerbate, income inequality, hence adding to the results of section 4.

5.1. Wage indexed pension contributions

We replace the contribution in the Beveridge case with proportional taxation as introduced by Bismarck in late 19th century Germany. Each agent pays into the PAYG scheme while young, according to τy^i and receives πy^i after reaching the pension age. Here $0 < \pi < 1$ is the replacement rate of the pension benefits and $0 < \tau < 1$ is the proportional wage tax used to finance the benefits to the pensioners. We assume that the L group has the same wage replacement rate as the H group (π and τ are uniform between groups). However, we allow for distinct income levels across groups. The PAYG scheme is balanced each time (aggregate inflows equal aggregate outflows).

$$\pi(y^H N_b^H + y^L N_b^L) = \tau(y^H N_c^H + y^L N_c^L) \quad (32)$$

On the left hand, we have the outflows from the PAYG scheme. This is composed of members the H group, N_b^H, receiving the pension of πy^H and members of the L group, N_b^L, receiving the pension of πy^L. On the right-hand side, we have flows into the PAYG scheme; both groups pay the same proportion of their wages to the scheme. Total inflows from the H and L groups are $\tau y^H N_c^H$ and $\tau y^L N_c^L$, respectively.

We arrive at a new equation for the relationship between pension benefits and pension contributions:

$$\pi = \tau \frac{y^H N_c^H + y^L N_c^L}{y^H N_b^H + y^L N_b^L} \quad (33)$$

In the case of perfect income equality, $y^H = y^L$, equation (30) reduces to the same PAYG equality as in equation (6). In the case of income inequality, $y^H \neq y^L$, the utility maximization follows near-identical steps as in section 3.4, yielding:

$$c^i = y^i \left(\frac{\int_0^{R^i} e^{-ar}\, m^i(a)da}{\int_0^{A^i} e^{-ar}\, m^i(a)da} - \tau \frac{\int_0^{P} e^{-ar}\, m^i(a)da}{\int_0^{A^i} e^{-ar}\, m^i(a)da} + \tau \frac{y^H N_c^H + y^L N_c^L}{y^H N_b^H + y^L N_b^L} \frac{\int_P^{A^i} e^{-ar}\, m^i(a)da}{\int_0^{A^i} e^{-ar}\, m^i(a)da} \right) \tag{34}$$

In addition to the effects observed in sections 4.1-4.4, we now see from equation (33) and (34) that the income of one group has an effect on the pension contributions paid out to the other, which ultimately affects consumption.

5.2. Wealth shock to high longevity group

To study this in further detail, let us look first at the PAYG scheme under defined contributions (DC). In this case τ is exogenous and π endogenous. The effect of changes in the demographic or income distribution on the PAYG scheme is therefore captured through changes in π. When the income of the group that enjoys greater longevity increases, we see that:

$$\frac{\partial \pi}{\partial y^H} = \tau \frac{y^L (N_c^H N_b^L - N_c^L N_b^H)}{(y^H N_b^H + y^L N_b^L)^2} < 0 \tag{35}$$

Notice that if there was no difference in the mortality profiles of the two groups $(N_c^H N_b^L - N_c^L N_b^H = 0)$ an increase in the income of one group would not affect the pension benefits/contributions of the other. However, since we impose different mortality profiles, any change in the income of one group imposes externalities on the other through the PAYG scheme.

The old age dependency ratio is higher for the H group because they enjoy higher longevity, implying that the sign of equation (35) is negative. We see that when the income of the H group increases, the pension replacement rate π decreases, causing the pension benefits paid to the L group to decrease – even though they did not enjoy a rise in their income. The H group pays more into the PAYG scheme while young but also receives more benefits during the pension period. This would not have any effect on the replacement rate if the dependency ratio was identical for both groups – the increased benefits would be exactly financed by the increase in contributions. But because the H group enjoys higher longevity than the L group, they collect benefits disproportional to their contributions. When their income goes up they are entitled to more benefits, πy^H, during the pension period than can be financed by their current levels of the contributions, τy^H. In order for the PAYG scheme to remain balanced, the income replacement rate, π, drops for both the H and L group, thereby causing members of the L group to get lower pension benefits than before the H group's income rose. This effect adds to the effect tied to the demographic structure as described in section 4.

5.3. Wealth shock to low longevity group

Now let's look at the effects of an increase in the income of the L group. The derivative is similar to the one we saw above:

$$\frac{\partial \pi}{\partial y^L} = \tau \frac{y^H (N_c^L N_b^H - N_c^H N_b^L)}{(y^H N_b^H + y^L N_b^L)^2} > 0 \quad (36)$$

Just as above, we see that the sign of the derivative is driven by the relative sizes of the pensioned and contributing cohorts of each group. However, in this case we see that an increase in the wages of the L group actually increases π.

When the L group's income rises, they pay more into the PAYG scheme, just as in the case where the H group's income rose. But the L group pays proportionally more than they receive out of the PAYG scheme. These new funds entering the PAYG scheme allow for an increase in the benefits paid out to the pensioners, causing π to increase. Therefore, the H group pays the same into the PAYG scheme, but receives more as a result of an increase in the income of the L group. The H group is better off when the L group's income rises.

In the defined benefits (DB) case the replacement rate, π, is treated as exogenous and τ as endogenous and is defined as:

$$\tau = \pi \frac{y^H N_b^H + y^L N_b^L}{y^H N_c^H + y^L N_c^L} \tag{37}$$

And the derivatives become:

$$\frac{\partial \tau}{\partial y^H} = \pi \frac{y^L (N_b^H N_c^L - N_b^L N_c^H)}{(y^H N_c^H + y^L N_c^L)^2} > 0 \tag{38}$$

$$\frac{\partial \tau}{\partial y^L} = \pi \frac{y^H (N_b^L N_c^H - N_b^H N_c^L)}{(y^H N_c^H + y^L N_c^L)^2} < 0 \tag{39}$$

We see similar effects here as in the DC case, as the income of the H group (L group) goes up, the L group (H group) is worse off (better off) through negative (positive) externalities of the PAYG system.

To summarize, both in the DC or the DB case, when the income of those that have greater longevity goes up, those that have shorter life expectancy are made even worse off. Conversely, when the income of those who have shorter life expectancy goes up they end up paying more into the PAYG scheme, which benefits those that live longer.

6. Public-private pension partnership

We have found that pooling together groups that differ in life expectancy causes a public pension system to redistribute income from the short lived to the long lived. In some cases, such a system is inevitable as policymakers do not have perfect information about the life expectancy of various socio-economic groups. In this section, we propose a policy that would go far in mitigating the distributional effects associated with the PAYG scheme presented in previous sections.

Now let the government collect pension contributions from the working-age population as before but instead of financing the pension benefits with current contributions, the government pays a lump sum to the cohort that reaches retirement at each time while not paying anything to those already retired. This new system is balanced at each time, implying

$$\pi^R\left(y^H m^H(P) + y^L m^L(P)\right) = \tau(y^H N_c^H + y^L N_c^L) \tag{40}$$

where each lump sum recipient receives $y^i \pi^R$ at retirement. As before τ is exogenous and in this case, π^R , which maps the wage into a lump sum, is endogenous in the equation. This sum is transferred to a private pension scheme where the average longevity of members is known.[44] The private pension scheme is balanced at each time, covering benefits by lump-sum transfers of agents of the same type:

$$\pi_{PPP}^i y^i N_b^i = \pi^R y^i m^i(P), \quad i = H, L \tag{41}$$

When maximizing his utility the agent therefore faces the pension rule implied by equations (40) and (41):

$$\pi_{PPP}^i = \tau \frac{y^H N_c^H + y^L N_c^L}{y^H m^H(P) + y^L m^L(P)} \frac{m^i(P)}{N_b^i} \tag{42}$$

Just as before, the agent maximizes his utility taking into account his mortality and the mortality of the other agents paying into the pension scheme.

This public-private partnership eliminates all the intra-generational transfers caused by the different life expectancies after retirement. However, as the members of the L group are also less likely to reach retirement, the policy would not eliminate intra-generational transfers associated with members of the L dying before reaching retirement. The ability of public-private partnership in mitigating the effects of intra-generational transfers is analyzed further in the following section.

---

[44] The scheme is not affected by the so-called „annuitization puzzle“ that makes people prefer a cash treatment to an annuity because no cash transfers to individuals are involved. Instead, the system involves pension funds paying out benefits instead of the government, only difference being that the former can better assess life expectancy. See Benartzi et al. (2011) and Robinson and Comerford (2019), amongst others, on the annuitization puzzle.

7. Calibration of the mortality profile

We now turn to comparing the level of pension benefits between two groups that differ in terms of life expectancy and wages and then calculate the effect of increased longevity on their benefits. As demonstrated above, individuals of higher socio-economic statues live on average longer than those of lower and we exploit this difference to estimate the effects of these different groups paying into the same pension scheme.

7.1. Comparing pension benefits of socio-economic groups

The chief parameters are essentially two, μ_0^i and μ_1^i, which determine the probability of death at each time. We apply parameter values to μ_0^i and μ_1^i, which can be done by matching empirical survival functions. Two calibrations of the mortality profile are needed when comparing the effects on each group since they differ in the value of μ_1^i and μ_0^i. The calibration minimizes the error in total survival probability for all ages across the population while still maintaining each group's observed life expectancy.

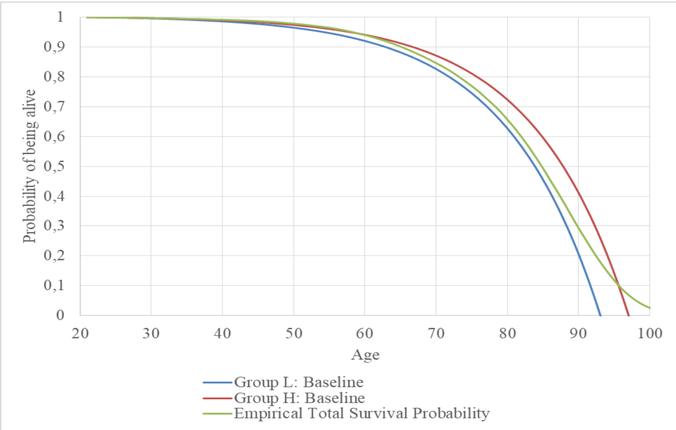
We assume agents of both groups enter the labour market at the age of 20 years. The baseline calibration is based on the life expectancy in Denmark by income in 2016 as presented in Table 1 in the introduction. There is approximately a 3.9 year gap in life expectancy between those two groups. The H and L groups are calibrated to match the top and bottom half of the income distribution for men. We refer to them as *white-collar* and *blue-collar* groups, respectively.

Table 3. Calibrated parameters

	White-collar (H)	Blue-collar (L)
μ_1	0.075	0.075
μ_0	299	222
Simulated life expectancy (years)	83.0	79.1
Observed life expectancy (years)	83.0	79.1

Figure 3 depicts the calibrated survival functions of each class and the empirical total survival function.

Figure 3. Survival functions



Note: Estimated White/Blue collar Survival Probability.

Source: Human Mortality Database, 2018

Now we can calculate to which extent paying into a joint pension scheme will have a negative (positive) effect on the blue-collars (white-collars) compared to the case where they each pay into their own pension scheme. We assume that the pension age is 66.5 years and both classes earn the same level of wages. Now we can determine the pension benefits received by each group when paying into the different pension schemes, captured in equations (6), (33) and (42). We compare this to the benefits received if the agent paid into a pension scheme where all the agents are of the same type $\left(\pi_{type}^{i} \equiv \tau N_c^i \backslash N_b^i\right)$. This difference in benefits received when retired is captured by:

PAYG government scheme: $$\frac{\pi^i}{\pi^i_{type}} = \frac{y^H N_c^H + y^L N_c^L}{y^H N_b^H + y^L N_b^L} \Big/ \frac{N_c^i}{N_b^i} \tag{43}$$

Public-private partnership: $$\frac{\pi^i_{PPP}}{\pi^i_{type}} = \frac{y^H N_c^H + y^L N_c^L}{y^H m^H(P) + y^L m^L(P)} \frac{m^i(P)}{N_b^i} \Big/ \frac{N_c^i}{N_b^i} \tag{44}$$

We find that blue-collar workers suffer from a 10.4% drop in pension benefits from paying into the same scheme as white-collar workers, while white-collar workers enjoy an increase in the pension benefits by approximately the same amount (equation 43). In line with our model findings, these effects are increasing in the pension age. In the public-private pension scheme, described in section 6, this difference in pension benefits received by the blue-collars (equation 44) would drop to 1.6%, implying that even without perfect information governments can substantially mitigate the intra-generational disparities by giving the money to pension funds that have more information on life expectancy and where within-group differences are smaller.

According to Statistics Denmark's Income Statistics, the top half of the Danish population receives 69.3% of equalized disposable income in 2016 while the bottom part received 30.7%. By allowing for effects of income, as traced in section 5, the effects of being forced to pay into the same pension become asymmetric. In this case, the blue-collar group suffers a 13.8% drop in their pension benefits while the white-collar group's benefits rise by 6.1% per month. This is in line with the findings of section 5. When those that live longer become better off those that suffer low longevity are made even worse off. Conversely, when those that suffer low longevity become poorer those who enjoy high life expectancy do not gain as much from contributing to the same PAYG scheme. In contrast, in the public-private pension scheme described in section 6, the intra-generational effects diminish substantially. The blue-collar group would now only suffer a 2.2% drop in pension benefits while the white-collar group's benefits would rise by 1.0%. We therefore find that the public-private scheme eliminates around 80-90% of the intra-generational transfers associated with the communal pension scheme. The remaining intra-generational transfers are caused by the fact that members of the L group are more likely to die before reaching retirement.

7.2. Longevity increase with pension age indexed to longevity

Now we increase the longevity of both classes proportionally. This allows us to determine the effects of increased longevity on the benefits received by both classes when the pension age is indexed to longevity. The life expectancy of white- and blue-collar workers from equation (30) can be rewritten as:

$$\Lambda^{\mathrm{i}} = \frac{1}{\mu_1^i}\left(\frac{\ln\left(\mu_0^i\right)\mu_0^i + 1 - \mu_0^i}{(\mu_0^i - 1)}\right) \tag{45}$$

In the baseline above, we assigned identical μ_1 values for both groups, making the fraction $1/\mu_1^i$ in equation (45) identical for the groups. Any difference in the lifespan of the groups is then captured by differences in μ_0. We can then simulate a proportional increase in life expectancy through a decrease in μ_1.

We consider two cases. In the first case, the pension age is increased so that individuals spend the same proportion of their lifetime as before, on average, contributing to the pension system. In the second case, which is what is practiced in Denmark, the system is designed to keep the years spent as a pension recipient constant and the pension age therefore increases on a one-to-one basis with life expectancy.

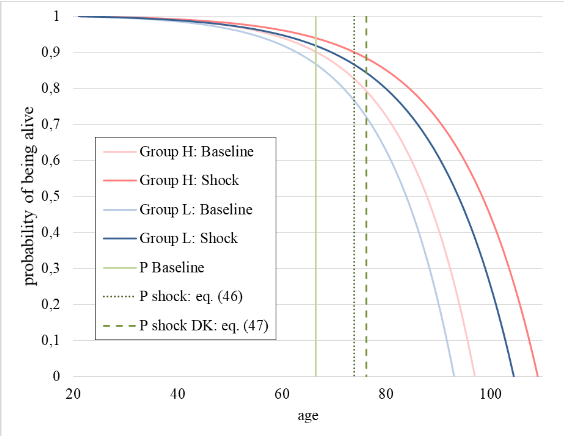
In the proportional indexation setting we arrive at this formula for the pension age:

$$P(\Lambda) = \frac{\lambda}{\mu_1}\left(\sigma\frac{\ln(\mu_0^L)\,\mu_0^L + 1 - \mu_0^L}{(\mu_0^L - 1)} + (1-\sigma)\frac{\ln(\mu_0^H)\,\mu_0^H + 1 - \mu_0^H}{(\mu_0^H - 1)}\right) \tag{46}$$

while in the Danish system we find:

$$P^{DK}(\Lambda) = \frac{1}{\mu_1}\left(\sigma\frac{\ln(\mu_0^L)\mu_0^L + 1 - \mu_0^L}{(\mu_0^L - 1)} + (1-\sigma)\frac{\ln(\mu_0^H)\mu_0^H + 1 - \mu_0^H}{(\mu_0^H - 1)}\right) - 14.5 \tag{47}$$

Figure 4. Symmetric increases in life expectancy



Now we can impose a symmetric longevity shock by increasing the life expectancy of both groups and the pension age simultaneously. The baseline is the case presented in Table 3 and Figure 3. Assume an increase in life expectancy of ten years for white-collar and an increase in the life expectancy of the blue-collar group of 9.4 years.[45] The shift of the mortality curves and the pension age are presented in Figure 4 where the dotted green vertical line corresponds to equation (46) and the dashed green one to the Danish system in equation (47). The results of the calibration exercise are presented in Table 4.

In the case where the retirement age increases proportionally to life expectancy (equation (46)) we see that the loss experienced by blue-collar workers from paying into the same pension fund as white-collar workers has not changed at all. This holds true both if we allow for income disparities between the groups and when we do not.

[45] Notice that even though the longevity increase for the white-collar groups is greater in years compared to the blue-collar group, their life expectancy rose by the same percentage.

Table 4. Symmetric longevity increase

	White-collar (H) (baseline)	Blue-collar (L) (baseline)	White-collar (H) (shock)	Blue-collar (L) (shock)
μ_1	0.075	0.075	0.065	0.065
μ_0	299	222	299	222
Life expectancy (years)	83.0	79.1	93.0	88.4
Pension age ($\lambda = 0{,}76$) (years)	66.5	66.5	73.9	73.9
Pension age (DK style) (years)	66.5	66.5	76.2	76.2

The Danish pension age indexation rule does however affect the intra-generational transfers. In the case where both groups pay the same dollar-amount into the pension scheme the loss from paying into the same fund as white-collars increases by an additional 1.0%, from 10.4% to 11.4%, compared to paying into their own pension fund. By allowing for income disparities between the groups, the blue-collar's loss from the join pension scheme becomes 15.1% (compared to 13.8% in the baseline) and the gain of the white-collar class becomes 6.6% (6.1% before). The Danish style indexation rule therefore exasperates the intra-generational consequences of the pension scheme.

To demonstrate the sensitivity of a longevity-indexed rule based on life expectancy to the shape of the mortality function we perform the same experiment, but with a new baseline in terms of μ_0 and μ_1, for white-collar workers. Now both classes share identical μ_0 values and any differences between the classes are captured by μ_1. We can then simulate longevity increases for both classes by changing the value of μ_0. The results are presented in Table 5.

Table 5. Asymmetric longevity increase

	White-collar (H) (baseline)	Blue-collar (L) (baseline)	White-collar (H) (shock)	Blue-collar (L) (shock)
μ_1	0.075	0.080	0.075	0.080
μ_0	299	299	640	640
Life expectancy (years)	83.0	79.1	93.0	88.4
Pension age ($\lambda = 0{,}76$) (years)	66.5	66.5	73.9	73.9
Pension age (DK style) (years)	66.5	66.5	76.2	76.2

In this new baseline, we have the same life expectancies and pension ages as in the previous baseline. As before, the longevity increases are ten years for white-collar workers and 9.4 years for blue-collar workers. The pension age responses to the longevity increase are identical to the experiment presented in Table 4. These two experiments therefore appear identical, but the subtle difference in how the mortality curve shifted have implications for the intra-generational transfers.

Now we see that in the case where the pension age increases proportionally to life expectancy the loss experienced by blue-collar workers from paying the identical dollar-amount into the same pension fund as white-collar workers has increased by an additional 0.4% (compared to no change in the symmetric longevity shock). This demonstrates that the shape of the mortality curve over the lifecycle matters, not just life expectancy. When the pension age follows the Danish rule the loss from paying into the same fund as white-collar workers increases by 2.4% instead of 1% before.

We conclude that even though the life expectancy increases are enjoyed across society, the longevity indexation of the pension age will increase the intra-generational disparities. Furthermore, the type of longevity indexation of the pension age has a substantial effect on the magnitude of the intra-generational transfers due to longevity developments. The Danish system of maintaining a constant length of time receiving benefits penalizes the short-lived group more.

8. Concluding remarks

We have found that groups who have lower life expectancy suffer a drop in lifetime income when forced to share a pension scheme with others who have longer life expectancies. In effect, the lower life-expectancy group pays as much into the PAYG scheme, provided they reach the pension age, but receives less during the pension period due to lower life expectancy.

When the pension age is increased to reflect the increased longevity of the higher life-expectancy group the lower life-expectancy group suffers because even fewer of them will reach the pension age. Also, when contributions are made proportional to wage income, as is typically the case for PAYG schemes, it follows that an increase in the income of the group that enjoys greater longevity will reduce the pension benefits and lifetime utility of the group with less longevity.

These findings may have important implications for pension policy in economies where PAYG is the dominant scheme. Indeed, the spread between life expectancies between, say, academics and blue-collar workers could reach such high levels that it would hardly be controversial to allow for differentiated pension ages. In practice, schemes designed to link the pension age to changes in longevity and which operate on average figures should be extended to allow for variability in physical and mental disabilities across different groups in society.

Our proposed solution to the problem of intra-generational inequities is to give each retiree a lump sum at a certain age that may coincide with formal retirement from the labour force, which the worker gives to her occupational pension fund. The pension fund then decides on the monthly benefits for its members depending on their average life expectancy. Alternatively, if there is too much heterogeneity in life expectancy within the pension fund or occupation, the retiree could go to an annuity company that would assess his expected longevity.

In effect, the government is giving the money used to fund retirement to an entity that has more information about life expectancy and discontinuing the pooling of a heterogeneous group of workers. In practice, the government would issue a bond and give it to a pension fund, amount depending on the number of members reaching a certain age, providing the pension fund with a fixed income that it can then use to finance the retirement benefit of members.

There is also the possibility that the disutility of work may differ between groups, so that the group with lower life expectancy also has a greater disutility of work, and that this disutility may increase with age.[46] The shorter life expectancy and the rising disutility of work may both stem from the depreciation in health and human capital that workers experience due to more difficult tasks and working conditions. In this case, the short-lived group is adversely affected by a common pension age, due both to the redistribution of pension income shown in this paper to those who, on average, live longer and because their lifetime utility is adversely affected by raising the pension age due to the higher disutility of work. This latter effect remains a topic of future research.

To sum up, introducing a longevity-indexed pension age is critical for keeping fiscal policy on a sustainable track in economies that are subject to population ageing. That is why it is important to maintain a broad support of such schemes, both in the population and across a broad political majority. If the legitimacy and credibility of introducing such key welfare reforms critically depends on easier access to earlier pension age for citizens with lower life expectancy and diminished (physical and

[46] See Böckerman, Petri and Pekka Ilmakunnas (2019).

mental) ability to work, then such adjustments to the reforms might well be worth advocating.

References

Andersen, T. M. and M. H. Gestsson (2016), “Longevity, growth and intergeneration equity – The deterministic case,” Macroeconomic Dynamics, 20 (4), 985-1021.

Andersen, T. M. (2015), “Robustness of the Danish pension system”, CESifo DICE Report 2/2015, pp. 25-30

Auerbach, Alan J., Kerwin K. Charles, Courtney C. Coile, William Gale, Dana Goldman, Ronald Lee, Charles M. Lucas, Peter R. Orszag, Louise M. Sheiner, Bryan Tysinger, David N. Weil, Justin Wolfers and Rebeca Wong (2017), How the growing gap in life expectancy may affect retirement benefits and reforms,” The Geneva Papers on Risk and Insurance – Issues and Practice, 42 (3), 475-499.

Bemartzo. S., Previtero, A. and R.H. Thaler (2011), “Annuitization puzzles,” Journal of Economic Perspectives, 25 (4), 143-164.

Blanchard, O. (1985), “Debt, deficits and finite horizons,” Journal of Political Economy, 93 (2), 223-247.

Boucekkine, R., D. de la Croix and O. Licandro (2002), “Vintage human capital, demographic trends, and endogenous growth,” Journal of Economic Theory, 104, 340-375.

Böckerman, P. and P. Ilmakunnas (2019), “Do good working conditions make you work longer? Analyzing retirement decision using linked survey and register data,” The Journal of the Economics of Ageing, online 10 February 2019.

Brønnum-Hansen H, Baadsgaard M. (2012) “Widening social inequality in life expectancy in Denmark. A register-based study on social composition and mortality trends for the Danish population.” BMC Public Health 12;994

Case, A. and A. Deaton (2017), “Mortality and morbidity in the 21st century,” Brookings Papers on Economic Activity, 397-476.

Chetty, R., M. Stepner, S. Abraham, S. Lin, B. Scuderi, N. Turner, A. Bergeron and D. Cutler, (2016), “The association between income and life expectancy in the United States, JAMA, 2001-2014,” 315(16), 1750–66.

Fuster, Luisa, Ayse Imrohoroglu and Selahattin Imrohoroglu (2003), “A welfare analysis of social security in a dynastic framework,” International Economic Review, 44 (4), 1247-1274.

Gestsson, M. and G. Zoega (2018), “The golden rule of longevity,” Macroeconomic Dynamics, 23 (1), 384-419.

Human Mortality Database, University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany), Available at www.mortality.org or www.humanmortality.de

Jensen, S.H. and O.H. Jørgensen (2008), “Uncertain Demographics, Longevity Adjustment of the Retirement Age, and Intergenerational Risk-Sharing”, in J. Alho, S.H. Jensen and J. Lassila (eds.) Uncertain Demographics and Fiscal Sustainability, Cambridge University Press

Jensen, S.H., J. Lassila, N. Määttänen, T. Valkonen and E. Westerhout (2019), “Top 3: Pension systems in Denmark, Finland, and the Netherlands”, ETLA Working Paper # 66.

Kalemli-Ozcan, S. and Weil, D. N. (2010), “Mortality change, the uncertainty effect, and retirement,” Journal of Economic Growh, 15:61-91

Kitagawa, Evelyn M. and Philip M. Hauser (1973), Differential Mortality in the United States: A Study in Socioeconomic Epidemiology, Cambridge, MA: Harvard University Press.

Laun, Tobias, Simen Markussen, Trond Christian Vigtel and Johanna Wallenius (2019), "Health, longevity and retirement reform" Journal of Economic Dynamics & Control, 103, 123-157.

OECD (2017), "Understanding the Socio-Economic Divide in Europe". (https://www.oecd.org/els/soc/cope-divide-europe-2017-background-report.pdf).

OECD (2019), Life expectancy at 65 (indicator). doi: 10.1787/0e9a3f00-en (Accessed on 16 May 2019)

Robinson, Jenny and David A. Comerford (2019), "The effect on annuities preference of prompts to consider life expectancy: Evidence from a UK quota sample," Economica, forthcoming.

Yaari, M. (1965), "Uncertain lifetime, life insurance, and the theory of the consumer," The Review of Economic Studies, 32 (2), 137-150.

Waldron, H. (2007), "Trends in Mortality Differentials and Life Expectancy for Male Social Security-Covered Workers, by Socioeconomic Status" (https://www.ssa.gov/policy/docs/ssb/v67n3/v67n3p1.html).

United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP.241.

Chapter 4

Healthy aging, saving and retirement

Healthy aging, saving, and retirement*

By

Thorsteinn Sigurdur Sveinsson
Economics and Monetary Policy, Central Bank of Iceland
Kalkofnsvegur 1, 150 Reykjavik, Iceland
tss@cb.is

January 2020

Abstract: Demographic change in the form of increased longevity has prompted policy debate centring on pension system reform. Here it is argued that healthy aging is an essential factor in individuals' retirement behaviour and should therefore be considered in the design of retirement reforms. A model is constructed where agents make consumption, saving, and retirement decisions based on their expectations of future health and their uncertainty about their time of death. Changes in health shift the agent's utility curve and increase the disutility of work, providing a connection between healthy aging and the agent's life-cycle decisions. The author finds, among other things, that healthy aging is associated with later retirement and that as the risk of adverse health shocks increases, the agent saves less. Life-cycle health developments are found to explain to an extent the hump-shape of the individual's consumption plan. These effects are established with various formulations of health functions and simulated with data on life-cycle health and longevity to obtain estimates of the impact of healthy aging on retirement decisions.

Keywords: Longevity, retirement, health
JEL Classification: E21, I14, J11, J26

---

* I am grateful for comments and lively discussion at two research seminars during my PhD internship at Sveriges Riksbank in autumn 2019. I am also grateful for helpful comments from Filipe Vieira, Gylfi Zoega, and Svend E. Hougaard Jensen. This research has been supported by PeRCent, which receives base funding from the Danish pension funds and Copenhagen Business School.

1. Introduction

National economies are affected by many variables, one of which – demographics – is garnering increasing attention. Increased longevity is a well-established trend in advanced economies, and when coupled with an observed decrease in fertility, it significantly increases the old-age-dependency ratio, with serious implications for the sustainability of fiscal policy, pension schemes, healthcare, labour supply and intergenerational transfers. These demographic changes have triggered responses, one of which is to increase the pension age.

In Denmark, for example, the pension age has been linked explicitly to life expectancy. In short, the Danish system aims to keep the retirement period at a fixed average duration of 14.5 years (OECD 2019). This implies that longevity increases will be followed on a one-to-one basis by increases in the pension age. People can therefore expect all future increases in life expectancy to be spent in the labour market. A similar system has emerged in Sweden and Finland, where the aim is to keep the ratio of working life to retired life constant. In essence, 2/3 of a person's adult life should be spent working and 1/3 in retirement. Pension reforms such as these focus on length of retirement and are based on a one-size-fits-all solution. Furthermore, they assume that healthy aging is experienced equally by all. The fact is, however, that across society, some groups do not enjoy the longevity and healthy aging that others do.

The gap in life expectancy among socioeconomic groups has been widely documented. In fact, Chetty *et al.* (2016) found that the life expectancy gap between the lowest and highest income quartiles in the United State stood around 6 years in 2014. Furthermore, they found that this gap is widening, as the life expectancy of the top 5% of the income distribution rose by 2.6 years between 2001 and 2014 while the life expectancy of the bottom 5% rose by only 0.2 years in the same period. Similarly, Waldon (2007) finds that mortality is a gradient across the socioeconomic scale rather than low longevity only being associated with extreme poverty. The intragenerational effects of retirement reform in populations with a non-uniform longevity structure are analysed in recent papers such as Auerbach *et al.* (2017).

As is the case with longevity, healthy aging is not shared uniformly across the population. The heterogeneous nature of healthy aging is analysed by van Ooijen and Knoef (2015), who find a strong socioeconomic factor and conclude that low-income individuals tend to have poorer health. Moreover, these authors find that males begin suffering from declining health at an earlier age than females do, and that people with less education begin suffering from poorer health earlier than their more educated counterparts. The link between socioeconomic status and healthy aging is also addressed by Case and Deaton (2005), who conclude that the link is not eliminated by controlling for occupation. This implies that the strenuousness of some traditionally low-wage occupations does not fully explain differences in healthy aging.[47]

There is a substantial literature on the connection between health and retirement. In a meta-analysis, Currie and Madrian (1999) find that poor health reduces work capacity and affects wages, labour force participation, and job choice. Recently, Laun *et al.* (2019) developed a model matching health and mortality risk to Norwegian data to analyse the effects of different social security reforms, taking into account differences in health and longevity and illustrating the connection between old-age retirement and claims for disability benefits. French (2005) finds a link between health and hours worked near retirement but also states that the most striking deterioration in health

[47] The socioeconomic gradient of health and longevity is also captured in Pijoan-Mas and Ríos-Rull (2014) and in Braveman *et al.* (2010)

takes place after retirement, implying that health at retirement alone cannot fully explain retirement decisions.[48]

A novel perspective on how health interacts with life-cycle choices is provided by Finkelstein *et al.* (2013), who estimate the extent to which the marginal utility of consumption is affected by health. Using data on health, income, and utility proxies across a range of specifications, they find that the marginal utility of consumption drops as health deteriorates. They find that the magnitude of the health effect on the marginal utility of consumption lies within the bound of a 10-25% drop for each standard deviation increase in the number of diseases from which the individual suffers. This implies that the marginal utility of consumption is one of the channels through which health affects individuals' consumption-saving decisions. By extension, expectations of future health could affect the timing of individuals' retirement.

There is a growing literature that links utility derived from consumption to health. Scholz and Seshadri (2013) find that health and consumption are complements. This link is further strengthened by the application of a survey-based method by Brown, Goda, and McGarry (2016), who find that individuals in poor health value consumption less than those in good health do. Hammitt, Haninger, and Treich (2009) apply health-dependent utility to analyse the interaction between health and longevity, on the one hand, and financial risk tolerance, on the other, and find that healthy agents are more risk-tolerant. Kools and Knoef (2017) build on the Finkelstein *et al.* (2013) approach to establish a positive health state dependence of utility from consumption.

---

[48] Using Danish data, Datta Gupta and Larsen (2007) show that health shocks dramatically increase the probability of retirement among elderly workers. Gustman and Steinmeier (2018) provide a detailed account of the ways in which different measures of health affect retirement. Kemptner (2019) analyses the impact on saving and early retirement of health-related risks that affect job opportunities and wages.

The observation that healthy aging is not shared uniformly across society, coupled with the effects of health on agents' life-cycle consumption, saving, and retirement decisions, raises questions about the appropriateness of retirement reforms based on the average. This paper contributes to the established literature by providing a link between post-retirement quality of life and the timing of retirement, effectively showing that not only does length of retirement matter, but quality of life during retirement matters as well.

In the model presented below, agents make decisions about consumption, saving, and retirement timing, based on expectations about their future health. Even though the model does not explicitly feature a pension scheme, it provides valuable insight into important factors in the context of pension reform. The paper looks at optimal behaviour of agents in life-cycle planning. For example, how agents' planned retirement age responds to demographic change in the form of longevity and healthy aging. The model shows how health during working life and post-retirement health expectations play distinct roles in the choice to retire. The analysis therefore provides guidance for policymakers considering reforms related to retirement. This paper should be viewed as the first of many about the impact of health on retirement decisions. A logical next step could be to introduce a pension scheme.

The paper is structured as follows. Section 2 briefly outlines stylised facts about healthy aging, retirement, and longevity increases in advanced economies. Section 3 provides a generalised model to demonstrate the basic insights from an analytical standpoint. Section 4 applies realistic mortality and health assumptions to the model. Section 5 analyses the effects of stochastic health shocks on agents' saving behaviour. Section 6 concludes with a summary of the results and a discussion of possible improvements and future research.

2. Stylized facts

In this section, empirical observations about longevity trends, healthy aging, and retirement are briefly outlined and supplemented by theoretical perspectives.

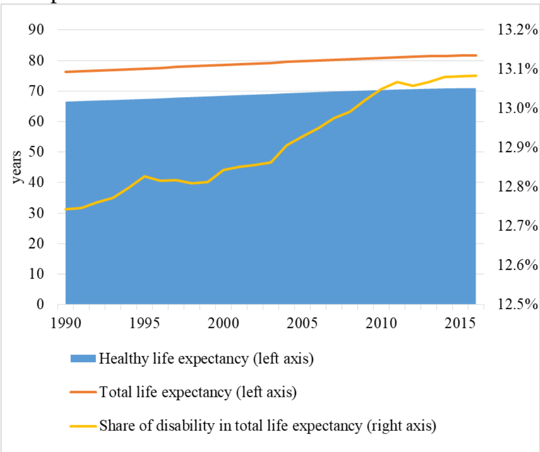
2.1. Longevity

One of the most prominent demographic trends of the past century has been the increase in life expectancy (Wilmoth 2000), which has roughly doubled since the beginning of the 20^{th} century. It is generally assumed that this trend will continue. According to Eurostat data, life expectancy at birth in Europe is assumed to increase by around one year per decade in the 21st century. In the Nordic countries, life expectancy at birth is projected to reach 91 years by 2100, an increase of about 9 years over the 2018 value. Even though longevity projections tend to assume that life expectancy will increase (see, for example, Kontis *et al.*, 2017), a slowdown has been observed. Notably, longevity in the US has declined in recent years (Raleigh 2019). Figure 1 depicts developments in longevity in Western Europe between 1990 and 2015.

2.2. Healthy aging

While life expectancy can be assessed in a purely quantitative manner, the same does not hold true for healthy aging, which is a more subjective concept. A report published by the World Health Organization (2015) analyses the prevalence of healthy aging across countries. One of the findings is that even though longevity increases have been widely documented, the quality of life during those extra years is quite unclear. This is due not to lack of research but to contradictory study findings. Figure 1 depicts the composition of life expectancy: although both total life expectancy and the expected number healthy years (healthy life expectancy) have increased, we see that the share of “disability” years has increased as well.

Figure 1: Composition of life expectancy in Western Europe 1990-2016



Composition of life expectancy in Western Europe. Disability years is the difference between healthy life expectancy and total life expectancy. The share of disability in total life expectancy (right axis) is found by dividing disability years by total life expectancy.

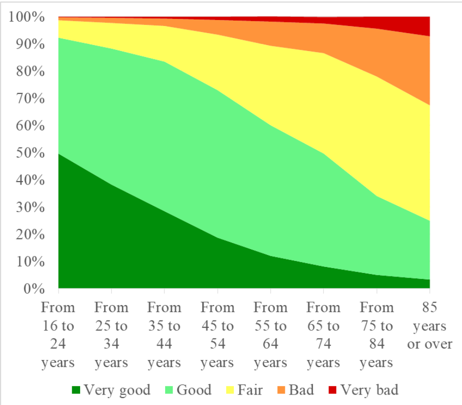
Source: Our World in Data

One of the methods used to assess healthy aging is the Sullivan health expectancy method described in Sullivan (1971) and Imai and Soneji (2007), which estimates the number of disability-free years an individual of a particular age can expect to live. It applies a cross-sectional survey of health indicators on life-table data to provide the health of a population, adjusted for mortality levels. This method is used in the Eurostat "healthy life years" indicator. Eurostat reports that in the European Union, a person's expected healthy life years at birth averaged around 64 years in 2016, while total life expectancy was 81 years.

The OECD publishes health data and indicators, including perceived health status by age and how self-reported health status changes over the life cycle, as is shown in

Figure 2. Figure 3 captures the relationship between income and health status, illustrating the existence of a gradient across the health spectrum where wealthier individuals tend to remain healthier for a longer period of time.

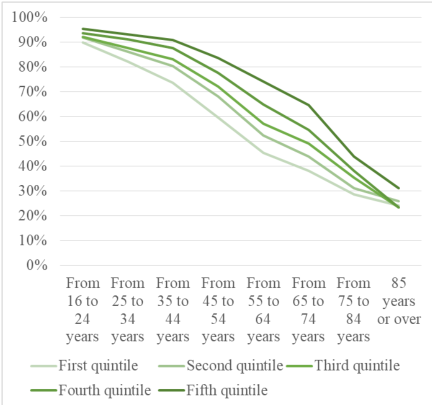
Figure 2: Health by age: Share of total population, European Union, 2017



Self-reported health data on how a person perceives their own general health, using categories: very good / good / fair / bad / very bad.

Source: Eurostat

Figure 3: Share of population in "good" or "very good" health by age and income quintiles: European Union, 2017



Self-reported health data (same as in Figure 2). Income quintile is based on total equivalised disposable income.

Source: Eurostat

Several studies demonstrate the prevalence of healthy aging. Using data on self-reported health, Lowsky *et al.* (2017) analysed the extent to which individuals enjoy healthy aging. They find that 89% of persons aged 51-54 and 56% of those aged 85+ have no health-based limitations on work or household activities. However, they find that the quality of life experienced within each age group differs substantially. Laun *et al.* (2019) use data from the Norwegian labour force survey to map the share in good health by age. For the 51-54 age group, their findings are roughly in line with those of

Lowsky *et al.* (2017); however, for the 85+ age group, the share in good health ranges from 15-40%, depending on the person's educational level.

French (2005), analysing transitions from good health to poor health over the life cycle, observes a concave curve similar to those presented in Figures 2 and 3 above. He finds that the probability of being in good health is approximately 94% at age 30 and then decreases steadily, to 80% at around age 55 and 40% by age 80. While measures of health can vary between studies, we consistently observe this downward, concave trend of roughly the same magnitude. There are several hazards in estimating the connection between self-reported health and retirement choice. One example is that individuals tend to cite their health as a justification for their retirement choice, so that retired agents are more likely to report poor health than those who are still working (see, for example, Disney (2006)).

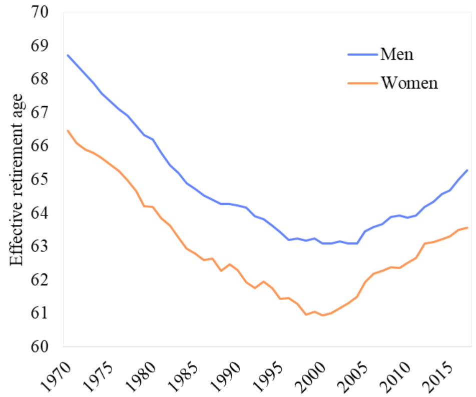
The available data demonstrate the prevalence of healthy aging in advanced economies. In Section 4, these data are used to construct realistic life-cycle profiles of both mortality and health.

2.3. Retirement

Historically, labour force participation among older American men has been steadily dropping since 1880 (Costa 1998). It was not until after the establishment of the Social Security Administration in 1935, however, that the transition to retirement began to grow more prevalent at a specific age. According to Costa the main reasons for the rise in the tendency to retire at a given age are adverse health among the elderly and increased demand for leisure among those who are well off. This perspective harmonises well with the focus of this paper.

Figure 4 depicts developments in the effective retirement age in recent decades: the effective retirement age trended downwards from 1970 until around 2000 and then began to rise again, although it has not yet returned to the levels observed in 1970. This entire period featured steady increases in life expectancy, which caused large increases in the population outside the work force. This period was also characterised by rising incomes, which put downward pressure on retirement age and ultimately overtook the longevity effect (Bloom, Canning and Moore 2014). We therefore see that factors other than physical limitations prompt people to retire.

Figure 4: Effective retirement age, OECD average 1970-2015.



Source: OECD Database on Average Effective Retirement Age

There are several theories about the determinants of retirement timing, apart from the connection between longevity and retirement. First of all, on the production side, older workers could become less productive, which could incentivise them to leave the labour force. Second, with the rise of social security and public pension schemes, workers are more likely to retire at an age associated with eligibility for benefits (Duval 2004). Finally, from a microeconomic perspective treating leisure as a normal good, leisure in the form of retirement increases as wages rise and individuals can finance post-retirement consumption.

Bundell *et al.* (2017) find that health explains between 3% and 15% of the decline in employment near retirement. Similarly, French (2005) estimates that 10% of the drop in labour force participation observed between the ages of 55 and 70 can be explained by health. Riphahn (1999) reports that health shocks reduce the probability of being employed by 6% and triple the probability of dropping out of the labour force completely. Jones *et al.* (2010) estimate the effects of health shocks on the probability of labour market exits and find that, for men, the hazard of becoming non-employed increases by 50-320% following a health shock. For women, the same non-employment hazard is 68-74%.

To summarise, retirement is caused by many different interlinked factors. While the model presented in the next sections does not feature social security, diminishing productivity, or other factors, the importance of such factors is acknowledged. The inclusion of such factors in the model presented below is left to future work.

3. Model overview

In this section, a model is introduced in which agents make retirement decisions subject to a mortality profile and age-dependent health. A general case is first presented to demonstrate key insights of the model without assuming the exact functional form of either the mortality function or the health function.

The model featured here departs from the classic continuous-time OLG model of Blanchard (1985) by allowing for age-dependent probability of death. The model is based roughly on Kalemli-Ozcan and Weil (2010) but departs from their setting by introducing a health function that augments the utility curve and links disutility of work to health. The utility curve is modelled as a special case of Finkelstein *et al.* (2013), who evaluate how the marginal utility of consumption is dependent on agents' health.

3.1. The general case

Consider a model of an agent who receives utility from consumption, $c(a)$, and disutility of work, ω. Furthermore, the agent's labour supply is constrained to be either "working" or "retired" and, once retired, the agent cannot transition back into the workforce. Agents are subject to an instantaneous death probability. The mortality function, $m(a)$, represents the chance of being alive at age a. The maximum age is T, which is determined by the mortality function. The agent maximises his utility subject to the consumption path and the planned retirement age, R.

$$u(c(a)) = \begin{cases} \ln\big(c(a)\big)\, h(a) - \omega g(a) & for\ 0 \leq a \leq R \\ \ln\big(c(a)\big)\, h(a) & for\ R < a \leq T \end{cases} \tag{1}$$

In Finkelstein *et al.* (2013), the utility curve was estimated using CRRA utility, of which the log-utility is a special case. In the setting presented here, the health status of the agent interacts with the utility curve in a manner similar to that described in Finkelstein *et al.* (2013). The health function $0 \leq h(a) \leq 1$ augments the agent's utility from consumption, where higher values of $h(a)$ indicate better health and more utility derived from consumption. Unlike Grossman (1999), the agent cannot change their health level by investment, and health is viewed purely as a fact of life. Typically, the agent's deteriorating health level implies that $h(a)$ shifts the agent's utility curve downwards with age; therefore, the $h(a)$ function is assumed to be downward-sloping. Note that the health level affects the agent's marginal utility of consumption.

$$\frac{\partial u(c(a))}{\partial c(a)} = \frac{h(a)}{c(a)} \tag{2}$$

The modelling of disutility of work is based on a formulation presented in Kalemli-Ozcan and Weil (2010), except that instead of utility from retirement, the focus here is on disutility of work, which is possibly dependent on the age of the agent through the function $g(a)$. In Section 4, the disutility of work is defined more explicitly and is tied directly to the health status of the agent. In order to demonstrate key insights of the model as regards health-dependency of utility from consumption, the disutility of work is kept independent from the agent's health status in this section. An explicit functional form of $h(a)$ is introduced in Sections 4 and 5. The agent's expected lifetime utility is:

$$E(U) = \int_0^T \ln\big(c(a)\big)\, m(a)h(a)e^{-\rho a}da - \int_0^R \omega g(a)m(a)e^{-\rho a}da \qquad (3)$$

where ρ is the subjective rate of time preference. We assume constant wages, w. When faced with the risk of death, the agent is less inclined to save for the future. To account for this, the existence of actuarial notes issued by an insurance company in the style of Yaari (1965) is assumed. The insurance company is assumed to operate in perfect competition, which implies that the notes are issued at a *fair rate*. The agent purchases notes from the insurance company, which invests at the rate of return r. The purchaser of the actuarial note receives a constant stream of payments until death, at which time any outstanding balance on the note is redistributed to the pool of other owners of the same note that are currently living. This setting rules out any accidental bequest. Due to the mortality risk, the notes have a higher rate of return than regular investment does, causing the agent to invest his entire savings in actuarial notes. In effect, the notes include a component of life insurance and perfectly mitigate the effect of uncertainty of death. The notes therefore completely absorb the impact the mortality risk on the agent's consumption path, as can be seen from the Euler equation (Equation 7) below.

The model assumes that both health status and expectation of future health represent private information. The agents know their health prospects, but the insurance company does not. Therefore, the insurance company cannot provide health insurance, which leaves agents completely exposed to the implications of developments in their health. In effect, the risk-absorbing nature of the actuarial notes with respect to mortality risk does not apply to health risk.

The model is based on a small open economy setting where the interest rate r is assumed to be exogenously set equal to the world interest rate. The zero-profit condition from the perfect competition in the annuities market implies that the rate of return on the actuarial note, $\mathrm{r}^A(a)$, is dependent on the mortality function:

$$\mathrm{r}^A(a) = \mathrm{r} - \frac{\frac{\partial m(a)}{\partial a}}{m(a)} \tag{4}$$

Furthermore, we see that the discounting factor can be expressed as:

$$\begin{aligned} e^{-\int_0^a r^A(z)dz} &= e^{-ra+\int_0^a \frac{\frac{\partial m(z)}{\partial z}}{m(z)}dz} = e^{-ra+\int_0^a \frac{d ln(m(a))}{dz}dz} \\ &= e^{-ra+\int_0^a dln(m(a))} = e^{-ra+\ln(m(a))-\ln(m(0))} \\ &= e^{-ra}m(a) \end{aligned} \tag{5}$$

The budget constraint becomes:

$$\int_0^T e^{-ra}m(a)c(a)da = \int_0^R e^{-ra}m(a)wda \tag{6}$$

The utility maximisation's first-order condition (FOC) implies the Euler equation:

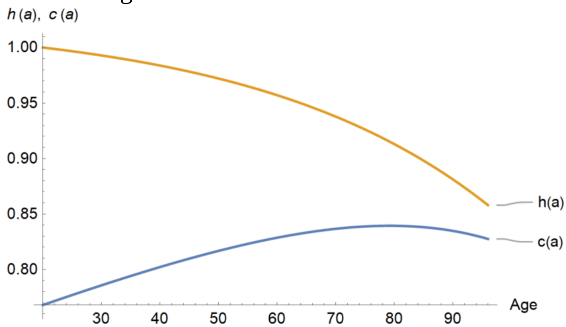
$$\frac{\dot{c}(a)}{c(a)} = r - \rho + \frac{\dot{h}(a)}{h(a)} \tag{7}$$

where $\dot{c}(a) \equiv \frac{\partial}{\partial a}c(a)$ and $\dot{h}(a) \equiv \frac{\partial}{\partial a}h(a)$.

The Euler equation implies that the agent's consumption plan follows developments in his health over the life cycle. The agent's consumption plan allocates consumption more heavily to periods of the agent's life when he expects to enjoy good health. This makes sense from a utility maximisation point of view: the agent's marginal utility is greater when he enjoys good health, so he assigns more consumption to those periods.

As is discussed in Section 2, health usually deteriorates more rapidly in old age (see Figures 2 and 3). Generally, this implies that while the agent is young and enjoys relatively good and stable health, the consumption path grows with age. Due to accumulated savings, the agent becomes wealthier as he ages, and he can therefore afford a higher level of consumption. As the agent grows older, deteriorating health exerts downward pressure on consumption growth. This health effect could in fact dominate and cause consumption to decline in old age, producing a concave consumption path over the life cycle consistent with empirical findings (see, for example, Gourinchas and Parker (2002)). A stylised life-cycle consumption path is depicted in Figure 5.

Figure 5: Consumption path over the life cycle with deteriorating health.



Developments in health, $h(a)$, and their impact on consumption, $c(a)$, over the life cycle. As agents grow older, their health deteriorates, which puts downward pressure on the consumption growth. Perfect health is normalised to 1. Wages are normalised to 1.

In this setting, there is neither insurance nor any risk mitigation linked to the health function; therefore, the agent's consumption path is explicitly linked to health. In the presence of health mitigation analogous to the mortality risk mitigation provided by the actuarial notes, the Euler equation would not be affected by the health of the agent. The agent's optimal consumption path follows:

$$c(a) = e^{(r-\rho)a} c(0) h(a) \quad (8)$$

Here, $c(0)$ represents the agent's consumption when he enters the labour market at age $a = 0$. By applying Equation (8) to the budget constraint, Equation (6), we arrive at the consumption level when the agent enters the labour market:

$$c(0) = \frac{w \int_0^R e^{-ra} m(a) da}{\int_0^T e^{-\rho a} m(a) h(a) da} \tag{9}$$

From Equations (8) and (9), we see that the entire structure of the consumption plan is affected by the way in which the agent's health develops over his expected lifespan. More specifically, consumption at birth, captured by Equation (9), is based on future income, health, and mortality. The numerator captures the present value of future expected labour income. The denominator of Equation (9) captures the length of the agent's expected lifetime, where each future age is weighted by the probability of reaching that age and, due to the importance of health in utility from consumption, the health status if the specific age is indeed reached.

Equations (8) and (9) capture the optimal consumption plan of the agent given a specific retirement age. Now we can determine the optimal retirement age by applying the consumption plan captured in Equations (8) and (9) to the expected lifetime utility function, Equation (3), and maximising with respect to the planned retirement age R. The FOC yields an implicit equation for optimal retirement:

$$\omega g(R) e^{-\rho R} = \frac{e^{-rR} \int_0^T e^{-\rho a} m(a) h(a) da}{\int_0^R e^{-ra} m(a) da} \tag{10}$$

The left-hand side of Equation (10) captures the marginal disutility of work suffered from an increase in the retirement age, while the right-hand side captures the marginal utility of the consumption gained by an increase in the retirement age. The optimal retirement age, R^*, is the age at which Equation (10) holds. To illustrate this, if the agent were to retire earlier than R^*, the left-hand side of Equation (10) would be lower than the right-hand side, implying that the increased utility from the extra consumption gains from working longer would exceed the disutility suffered from working longer. The opposite holds true when R is higher than R^*.

Furthermore, Equation (10) implies that any change in either longevity or health will cause a change in the planned retirement age. Now we can find the effects of health on the optimal planned retirement age. Let us assume that the health function takes the form $h(a) \equiv \eta H(a)$. It would therefore consist of a downward-sloping function that captures life-cycle developments of health, $H(a)$, and a shifting parameter that captures changes the health profile, η. By differentiating on both sides with respect to η, applying the Leibniz rule, and rearranging terms, we arrive at:

$$\frac{\partial R}{\partial \eta} = \frac{\int_0^T e^{-\rho a} m(a) H(a)\, da}{\omega e^{(r-\rho)R} g(R) \left[(r-\rho)\int_0^R e^{-ra} m(a) da + e^{-rR} m(R)\right]} > 0 \qquad (11)$$

We see that $r > \rho$ is a sufficient condition for us to conclude that increased health leads agents to postpone planned retirement. Even under the condition that agents' disutility of work and life expectancy are both health-independent, we find that as agents' anticipated period of good health grows longer, they plan on working longer. This result is driven by the agent's expectation of being able to enjoy consumption at a higher intensity later in life. In turn, this future consumption has to be financed somehow, leading agents to increase saving and postpone planned retirement.

4. Deterministic health profile

In the previous section, we saw that healthy aging leads to later retirement, without explicitly stating the functional form of the mortality and health functions. In this and the following section, we assume an explicit version of both functions. We begin by considering the case where the agent's health deteriorates constantly and predictably. In Section 5 we introduce stochastic health shocks.

4.1. Age-dependent mortality

We start by considering the survival function, which is based on the realistic mortality function introduced by Boucekkine *et al.* (2002). The probability of being alive at age a is given by the mortality function, $m(a)$:

$$m(a) = \frac{\mu_0 - e^{\mu_1 a}}{\mu_0 - 1} \tag{12}$$

Here we have a maximum age, $T = \ln(\mu_0)\,/\mu_1$. The parameters $\mu_0 > 1$ and $\mu_1 > 0$ determine the shape of the mortality function. A decrease (increase) in μ_0 (μ_1) has an age-dependent positive effect on the probability of being alive. By manipulating these parameters, we can change both the slope and the reach of the mortality function, which allows us to choose parameter values that simulate empirical data. The chance of being alive is concave and decreases with age.

$$\frac{\partial m(a)}{\partial a} < 0 \quad \text{and} \quad \frac{\partial^2 \mathrm{m}(a)}{\partial a^2} < 0$$

The mortality function directly feeds into the actuarial notes, as is demonstrated in Equations (4) and (5) above. As the agent ages, his mortality increases, which implies that the return on the actuarial notes also increases.

$$e^{-\int_0^a r^A(z)dz} = e^{-ar} m(a) = e^{-ar}\left(\frac{\mu_0 - e^{\mu_1 a}}{\mu_0 - 1}\right) \tag{13}$$

The return on the actuarial notes therefore depends both on age, a, and on the shape of the mortality function (μ_0 and μ_1). For a calibration of the mortality function, see Figure 8.

4.2. Health profile

In order to keep the effects of health and longevity separate, we assume that the mortality profile is independent of the health profile. This implies that agents of the same age have the same likelihood of dying, regardless of their health status. In reality, agents who have fallen sick are more likely to die; however, we ignored this so as to show analytically the effects of health on agents' retirement decisions. When longevity is endogenously determined by the health function, any increases in healthy aging would translate into a rise in the life expectancy, which affects the retirement age. In this case, it would be hard to determine whether the health increase had any effect on the retirement age except via longevity.

The health function is simulated by applying the Boucekkine *et al.* (2002) function, but with different parameter values. This accords with how health tends to develop over the life cycle, as is described in Section 2.2 above. In general, the health function is concave and decreases with age. The health function is explicitly stated as:

$$h(a) = \frac{\gamma_0 - e^{\gamma_1 a}}{\gamma_0 - 1} \tag{14}$$

In this setting, health deteriorates continuously over the life cycle in a deterministic way. The agent has full knowledge of how his health will develop over his lifetime, provided that he survives, and he can plan accordingly. The health function has properties similar to those of the mortality function in Section 4.1. The parameters $\gamma_0 > 1$ and $\gamma_1 > 0$ determine the shape of the health function. A decrease (increase) in γ_0 (γ_1) has an age-dependent positive effect on health. Through differentiation, we can determine how shifts in the health function affect different age groups:

$$\frac{\partial}{\partial a}\left(\frac{\partial h(a)}{\partial \gamma_0}\right) = \frac{\gamma_1 e^{\gamma_1 a}}{(\gamma_0 - 1)^2} > 0 \tag{15}$$

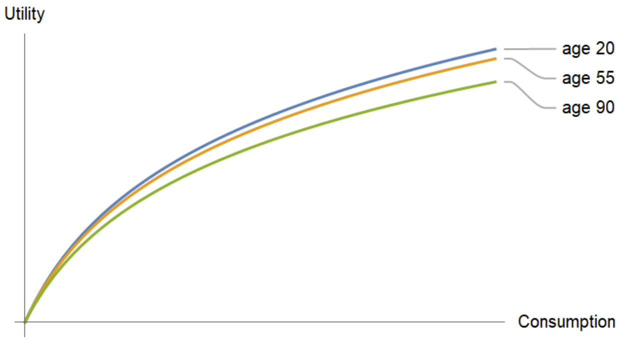
and

$$\frac{\partial}{\partial a}\left(\frac{\partial h(a)}{\partial \gamma_1}\right) = -\frac{(a\gamma_1 + 1)e^{\gamma_1 a}}{(\gamma_0 - 1)^2} < 0 \tag{16}$$

The terms in the large parentheses on the left-hand side of Equations (15) and (16) capture how the health function shifts by changing the parameters, γ_0 and γ_1. Equations

(15) and (16) therefore state that any shifts in the health function have the greatest proportional effect on the elderly.

Figure 6: Health-dependence of utility function, baseline calibration.



As the agent ages, he derives less utility from consumption. In the baseline calibration, we see that the difference between the utility curves of a 20-year-old and a 55-year-old, on the one hand, is less than the difference between the utility curves of a 55-year-old and a 90-year-old, on the other. This implies that that the utility curve shifts downwards more rapidly with age.

The marginal utility of consumption is dependent on the health function.

$$MU_c = \frac{h(a)}{c(a)} \tag{17}$$

As the agent grows older, he loses his health and the marginal utility of consumption decreases. The utility curve shifts constantly with age, as is captured in Figure 6. The age-dependency of the utility curves presented in Figure 6 is found by matching Eurostat data on self-reported health by age (see Section 2.2) to the magnitude of the health shift in the utility curve from Finkelstein *et al.* (2013). Furthermore, by applying $g(R) = 1/h(a)$ to Equation (3), disutility of work becomes indexed to health.

4.3. Demographic change and retirement

Now we can analytically provide a link between demographics and retirement decisions. By plugging the health function into Equation (10), we arrive at the implicit equation for optimal retirement:

$$e^{(r-\rho)R}\int_0^R e^{-ra}m(a)da\,\omega = \left(\frac{\gamma_0 - e^{\gamma_1 R}}{\gamma_0 - 1}\right)\int_0^T e^{-\rho a}m(a)\left(\frac{\gamma_0 - e^{\gamma_1 a}}{\gamma_0 - 1}\right)da \tag{18}$$

Neither the health function nor the mortality function is affected by the retirement age. The effects of agents' enjoyment of better health can be found by a drop in γ_1. A drop in γ_1 shifts the entire health function so that agents at all ages enjoy a higher level of health. By differentiating the implicit equation for optimal retirement with respect to γ_1, we arrive at:

$$\frac{\partial R}{\partial \gamma_1} = -\frac{\int_0^T \frac{ae^{(\gamma_1-\rho)a}}{\gamma_0 - 1}m(a)da + \frac{\omega\varphi R e^{(r+\gamma_1-\rho)R}}{(\gamma_0-1)h(R)^2}\int_0^R e^{-ra}m(a)da}{\omega\left[C_1\int_0^R e^{-ra}m(a)da + e^{-\rho R}m(R)h(R)\right]} < 0 \tag{19}$$

where $C_1 \equiv (r-\rho)e^{(r-\rho)R}h(R)^{-1} + \frac{\varphi\gamma_1 R e^{(r+\gamma_1-\rho)R}}{(\gamma_0-1)h(R)^2}$

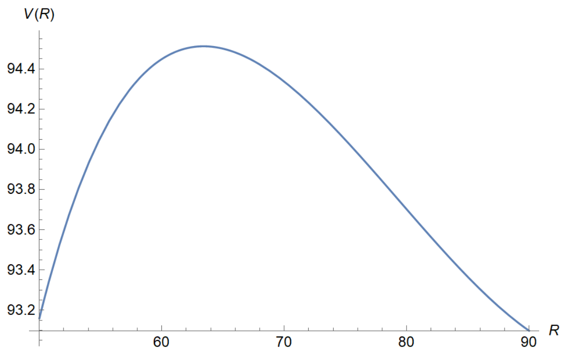
We see that retirement age increases when the agent's health increases. These results hold irrespective of whether or not disutility of work is a function of health. This accords with the results in the general case presented in Section 3. When health increases, the agent derives more utility from consumption throughout his life cycle. The greatest difference in utility from consumption is during retirement years, as is captured by Equations (15), (16), and (17).

The value function for the retirement age can be found by applying the optimal consumption path to the utility maximisation. The function captures the agent's value from retiring at various ages. This implies that the agent chooses to retire when the $V(R)$ function is at its maximum.

$$V(R) = \ln\left(\int_0^R m(a)e^{-ra}da\right)\int_0^T m(a)h(a)e^{-\rho a}da - \int_0^R \frac{\omega m(a)e^{-\rho a}}{h(a)}da \qquad (20)$$

The value function, $V(R)$, captures all terms with which the retirement age interacts in the utility function. On the right-hand side, the first term captures utility from consumption, whereas the last integral captures disutility from work. Figure 7 plots the value function for the retirement age. While the agent is young, the effects of continuing to work on total marginal utility are positive, as is captured by the upward slope of the $V(R)$ function. This implies that given the mortality and health functions, the utility gained by the agent from the consumption he can finance by working longer exceeds the utility he loses by experiencing the disutility of working.

Figure 7: Value function of retirement age, baseline calibration

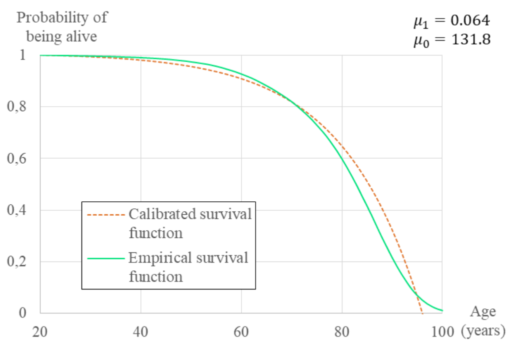


The maximum of the value function determines the agent's retirement age. In the baseline calibration, the agent chooses to retire at age 63.4, which is the effective retirement age in Denmark in 2016.

As the agent ages, he accumulates wealth and his expected remaining lifespan decreases; therefore, the slope of the V(R) function decreases until the function reaches its maximum, at which time the agent retires. Retiring later would cause lower lifetime utility, as is captured by the negative slope in the $V(R)$ function after retirement. The agent therefore retires when his marginal utility of increased consumption (financed by wages earned from working) equals the marginal disutility of work.

The baseline calibration of the health curve is matched to Eurostat data on self-reported health by age (see Figure 2). The health curve is then calibrated so that its value at each age matches the likelihood of being in good health. The magnitude of a health shift (from good to poor health) is associated with a 20% drop in utility from consumption, which is consistent with the findings in Finkelstein *et al.* (2013). The calibration of the health curve therefore takes account of both developments in health over the agent's lifetime and the magnitude of the effect health on utility. The parameters of the health curve for the baseline calibration are $\gamma_0 = 41$ and $\gamma_1 = 0.025$.

Figure 8: Calibration of the mortality function



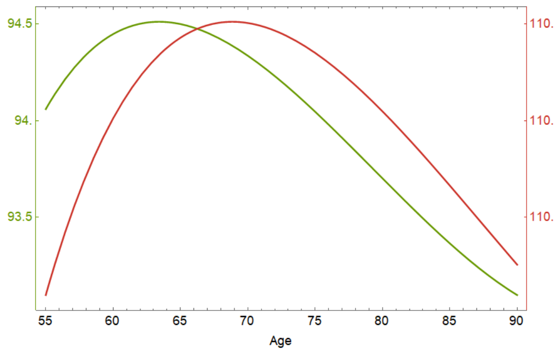
Empirical and calibrated mortality function. The parameter values for the calibrated function are found by minimising the errors between the two curves while keeping implied life expectancy at its empirical value.
Source of empirical survival function: mortality.org

The parameter associated with disutility of work, $\omega = 1.09$, is chosen to match the effective retirement age in Denmark in 2016. The baseline calibration for the survival function depicted in Figure 8 is found by matching life expectancy to total life expectancy at birth in Denmark in 2016 (81 years). The curvature of the survival function is found by minimising the error between the empirical and calibrated survival functions at each age ($\mu_0 = 131$ and $\mu_1 = 0.064$). In a recent calibration of a Blanchard-Yaari style model in Benhabib, Bisin, and Zhu (2014), the time preference, ρ, and the interest rate, r, were set to 1.5% and 1.8%, respectively, the same values are applied here.

Figures 9 and 10 trace the effects of a demographic shift on the optimal retirement age. As is discussed above, the agent chooses to retire at an age corresponding to the maximum of the $V(R)$ function. In both graphs, the green line (left axis) corresponds to the baseline calibration presented in Figure 7, while the red line (right axis) captures how the $V(R)$ curve shifts with demographic change. Figure 9 depicts a case where life expectancy increases by 10 years and the health curve shifts proportionally outwards. This causes the optimal retirement age to shift by 5.4 years, implying a new optimal retirement age of 68.9 years.

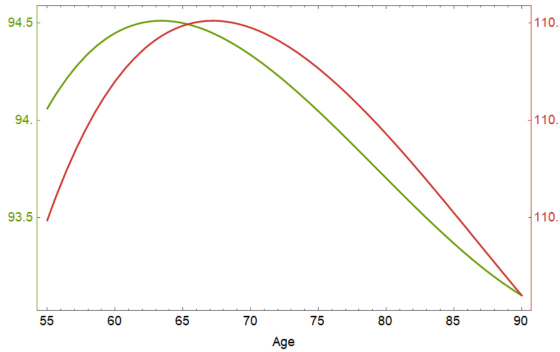
In Figure 10, however, life expectancy increases by the same amount, yet the health profile remains unchanged. This implies that agents expect to live longer, but their health deteriorates at the same pace as in the baseline. In this rather unusual case, the optimal retirement age increases by only 3.8 years, implying a new planned retirement age of 67.2 years. These results suggest that health plays a significant role in explaining how retirement age responds to demographic change. This demonstrates the importance of health in an agent's retirement decisions and the extent to which future longevity increases are associated with healthy aging. A robustness check of these results can be found in Appendix A.

Figure 9: Longevity and health increase



The green curve is the value function of retirement for the baseline scenario (left axis). The red curve is the value function after a longevity and health increase (right axis). The retirement age is determined in each case by the maximum of the value function. The demographic shift implies that following a 10-year increase in life expectancy coupled with an appropriate shift in healthy aging, the agent chooses to retire 5.4 years later.

Figure 10: Longevity increase



The green curve is the value function of retirement for the baseline scenario (left axis). The red curve is the value function after a longevity increase (right axis). The retirement age is determined in each case by the maximum of the value function. If the health curve does not shift, the agent's retirement age increases by only 3.8 years following a 10-year increase in life expectancy.

4.4. Retirement choices of heterogeneous agents

The demographic shift experiment in the previous section can be interpreted in the context of heterogeneous agents. As is discussed in Section 2, neither longevity nor healthy aging is shared uniformly across society. Instead, we observe a gradient across the socioeconomic scale. For example, higher-income individuals have both better health (Figure 3) and greater life expectancy than lower-income individuals do.

In this context, Figure 9 could depict two groups of agents: one group enjoys greater longevity and better health, and the other suffers lesser longevity and poorer health. Evidently, these two groups choose to retire at different times. Furthermore, we see that even in isolation, health plays a crucial role, as can be seen in the vastly different response to the demographic shift in the two cases illustrated in Figures 9 and 10.

When facing a proportional increase in both health and longevity, those on the lower end of the socioeconomic scale would therefore respond by raising their retirement age to a lesser extent than those who enjoy high longevity and better health, effectively widening the gap in the optimal retirement ages of the respective groups.

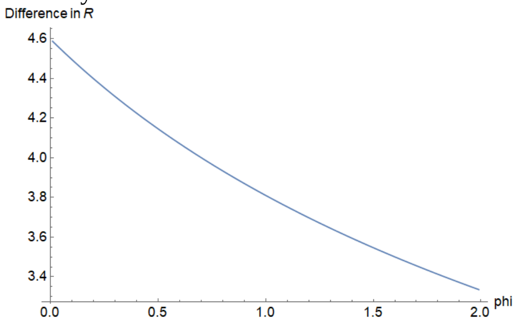
To further demonstrate the difference between socioeconomic groups, let us formulate the disutility of work function as: $g(a) = 1/h(a)^{\phi}$. Here the parameter ϕ captures the relationship between the disutility of work and the agent's health. At $\phi = 0$, the disutility of work is completely independent of health, and as ϕ increases, the disutility of work becomes increasingly sensitive to health. This formulation implies that the agents have identical disutility of work when they enter the labour market in perfect health. As the two groups age, however, agents with higher values of ϕ begin suffering from relatively more disutility of work.

Lower values of ϕ could represent white-collar workers, whose work is largely independent of their physical health. Higher values of ϕ could then represent blue-collar workers, who depend more on their physical health in their labour. We assume here that the agents' health and mortality profiles are identical and that the only difference between the blue- and white-collar groups is the disutility of work function. Any effects of differences in the disutility of work would therefore add to the differences discussed thus far. In this case, the lifetime utility function would become:

$$E(U) = \int_0^T \ln\big(c(a)\big)\, m(a)h(a)e^{-\rho a}da - \int_0^R \omega h(a)^{-\phi} m(a)e^{-\rho a}da \tag{21}$$

Now we are equipped to examine the effect that health-dependency on work has on an agent's retirement decision. Figure 11 depicts the change in the planned retirement age when life expectancy rises by 10 years for different values of ϕ.

Figure 11: Retirement and health-dependency of disutility from work



On the vertical axis, we have the increase in retirement age when the agent enjoys a 10-year increase in life expectancy (the same shift as is captured in Figure 10). On the horizontal axis, we have different sensitivity of the agent's disutility of work to his health status (see Equation (21)). At $\phi = 0$, the agent's disutility of work is health-independent. As the agent's disutility of work becomes more dependent on health, his retirement age responds less to demographic change.

Figure 11 captures the same demographic change as Figure 10 does, but it allows for different sensitivities of disutility of work to health. Note that as the disutility of work becomes more sensitive to the agent's health, the response of the retirement age to the demographic shift grows weaker. This makes intuitive sense: the additional years spent in the labour market provide both agents with equal utility from consumption, but the blue-collar worker experiences greater disutility from work, which causes his optimal retirement age to drop.

To summarise, in the framework presented above, there are three things that can be applied to differentiate agents so as to simulate observed trends across the socioeconomic scale. First, the optimal retirement age is lower for those who suffer from shorter life expectancy. Second, those who enjoy healthy aging to a greater degree are more willing to retire later. Third, varying degrees of linkage between health status and disutility of work could cause blue-collar workers in more physically demanding occupations to retire earlier and respond less to demographic change.

These three examples demonstrate that a pension rule based solely on average life expectancy may disregard conditioning factors that can influence agents' retirement decisions. This does not necessarily suggest, however, that the pension system should be tailored to each group or "class" specifically. Within each class there are individuals who will eventually enjoy varying degrees of healthy aging and longevity. The distribution of demographic factors therefore significantly overlaps between the groups, raising concerns about false classification of individuals into each group. The seriousness of this concern could be investigated further via analysis of the welfare effects of pension schemes based on an average life expectancy benchmark.

4.5. Longevity elasticity of the optimal retirement age

In the previous section, we saw that two groups of agents who enjoy the same life expectancy but different levels of healthy aging have different optimal retirement ages.

Moreover, when we applied realistic mortality and health structures, the optimal retirement age increased less than longevity did. This should not come as a surprise: if we treat consumption and retirement leisure as normal goods, the longer lifespan should naturally lead to an increase in both consumption and leisure during retirement.

We add to this by applying two new formulations of the mortality function to identify the circumstances under which the optimal retirement age rises on a one-to-one basis with life expectancy, which is the pension rule currently applied in Denmark: on the one hand, with the Blanchard (1985) style perpetual youth assumption, and on the other hand, with a deterministic time of death. While these two demographic structures are unrealistic in isolation, they shed light on two cases on either side of the extreme. This, coupled with the realistic mortality profile presented in Section 4.1, creates a cohesive view of how the optimal retirement age responds to longevity increases.

This is analysed by applying new mortality functions to the model in the general case presented in Section 3. For the perpetual youth model, the mortality profile takes the form $m(a) = e^{-\mu a}$, while in the deterministic case there is no risk of death, implying that $m(a) = 1$, until the agent reaches the terminal age and dies. For these experiments, the agent is assumed to be in perfect health for the entirety of his life. In both cases, the response is found to fall short of the one-to-one increase in retirement age and longevity. For the perpetual youth model, the retirement age increases significantly less than life expectancy does. For the deterministic case, the retirement age increases on a one-to-one basis with life expectancy only if the agent works throughout his life; i.e., chooses never to retire. For further detail, see Appendix B.

These results suggest that in general, the optimal retirement age does not follow life expectancy on a one-to-one basis: when life expectancy increases, the agent chooses both to allocate time to leisure during retirement and to consume more throughout his life. Note that if we allow health to deteriorate as is described in Section 4.2, the longevity response of the optimal retirement age is weakened even more. This raises concerns about the appropriateness of the Danish system where the pension age follows life expectancy on a one-to-one basis.

The results imply that in the Danish system, any increases in longevity would inadvertently cause an ever-increasing gap between the optimal retirement age and the pension age presented by the system. This, in turn, raises questions about individuals' response to the pension scheme: because the pension scheme provides an incentive to work longer, agents might choose to work less at any given point in time, effectively increasing the span of their work life while decreasing its intensity. The divergence of the pension age and the optimal retirement age could also complicate pay-as-you-go pension schemes, where the benefits to the retired are financed by the currently working. As the pension age increases, in a system with defined pension benefits, the contributions needed for each member of the work force decrease. This, in turn, could also affect both the extensive and intensive margins of labour supply. Furthermore, basing the pension system on average life expectancy could have the effect of hiding significant variability among agents of different socioeconomic status.

5. Stochastic health shocks

In this section, the assumption that health behaves in a deterministic manner is relaxed. By introducing shocks to the agent's health, we gain valuable insights into the saving behaviour of an agent facing uncertainty about his future health. Now the agent is in full health until he is struck by a stochastic exogenous health shock that shifts his utility curve downwards. The agent does not now know when this shock will strike, but he does know the probability of its striking. The analysis in this section is based on saving behaviour after retirement.

5.1. Recursive utility maximisation

The agent is assumed to be either in good health or in poor health. As before, the utility function is affected by the agent's health status. The health function, $h(a)$, takes the value 1 when the agent is healthy and the value $0 \leq H \leq 1$ when the agent has suffered an adverse health shock. The agent cannot suffer more than one health shock and cannot transfer back into the healthy population once the shock has struck. The utility function therefore has two possible states:

$$u(c) = \begin{cases} \ln(c) & \text{for healthy} \\ \ln(c)\, H & \text{for unhealthy} \end{cases} \tag{22}$$

As is discussed in Section 3, the marginal utility of consumption is lower when the agent has lost his health than it is when he is in full health. Here the classic Blanchard (1985) assumption of age-independent mortality risk is applied, where μ captures the instantaneous probability of death. The health risk is also assumed to be age-independent, with the parameter λ capturing the instantaneous risk of health loss. For a healthy agent, the probability of losing one's health during time interval τ is:

$$\left(1 - e^{-\tau\lambda}\right) \tag{23}$$

where τ is assumed to be a relatively short period. For a healthy agent who has already retired, the maximisation problem can be formalised in a Bellman equation form:

$$V(A) = \tau\, ln(c) + e^{-\tau(\rho+\mu)}\left[e^{-\tau\lambda}V(A') + \left(1 - e^{-\tau\lambda}\right)V_H(A')\right] \tag{24}$$

where $V(A)$ is the agent's value function of having assets A while healthy and $V_H(A)$ is the value function for an unhealthy agent. The first term in Equation (24) reflects the utility derived from consumption during the time interval τ. A' represents assets during the next interval of length τ. As before, ρ is the time preference. In order to solve the maximisation problem, we need first to determine how the agent would react if he were to suffer the health shock at the end of the interval.

The Bellman equation for an unhealthy agent is captured by:

$$V_H(A) = \tau \ln(c)H + e^{-\tau(\rho+\mu)}V_H(A') \quad (25)$$

As before, the existence of actuarial notes issued at a fair rate is assumed, and the small open economy setting is adopted. This implies that the rate of return on savings is $r^A = r + \mu$. The retired agent's budget constraint is therefore:

$$A'e^{-\tau(r+\mu)} = A - c \quad (26)$$

The budget constraint does not depend on the agent's health status, and it applies to both healthy and unhealthy agents. Now the optimal consumption-saving decisions of an agent who suffers from poor health can be determined. By substituting the budget constraint from Equation (26) into the value function in Equation (24), we arrive at:

$$V_H(A) = \tau \ln\left(A - A'e^{-\tau(r+\mu)}\right) H + e^{-\tau(\rho+\mu)}V_H(A') \quad (27)$$

Here the agent chooses how much to consume and how much to save of his accumulated assets, A, at any given time. By using a guess-and-verify process, we conclude that the value function takes the form $V_H(A) = a_H + b_H \ln(A)$. The agent seeks to maximise his lifetime utility by choosing how much of his assets he leaves for future consumption, A'. The Bellman equation can be re-written as:

$$V_H(A) = \tau \ln(A - A'e^{-\tau(r+\mu)})H + e^{-\tau(\rho+\mu)}[a_H + b_H \ln(A')] \quad (28)$$

The first term on the right-hand side captures the utility derived from consumption during the current τ-long interval, while the second term captures the value of future assets. By finding the future asset level that maximises the value function in Equation (28), we can determine the values of a_H and b_H. These values can then be applied to arrive at the following relationship between current and future assets so as to maximise the expected remaining lifetime utility of the agent who has suffered the health shock:

$$\frac{A'}{A} = e^{\tau(r-\rho)} \quad (29)$$

Note that for the agent who has suffered the health shock, the severity of the health shock, *H*, does not affect the growth path of assets. The assumption here is that even though *H* affects the agent's utility, it also affects the future utility of the agent in exactly the same way. Therefore, the utility-maximising growth path of assets is the same, irrespective of the value the health shock takes; however, this does not imply that the value function $V_H(A)$ is independent of the severity of the health shock.

The healthy agent faces a risk of transitioning to the unhealthy state, and he knows which utility-maximising strategy he will adopt if he does so, as is captured by Equations (28) and (29). Applying the procedure used in the case of the agent who has already suffered the health shock, we see that the value function of the healthy agent becomes:

$$\begin{aligned} V(A) = \tau \ln\left(A - A' e^{-\tau(r+\mu)}\right) \\ + e^{-\tau(\rho+\mu)}\left\{e^{-\tau\lambda}[a + b\ln(A')]\right. \\ \left. + \left(1 - e^{-\tau\lambda}\right)[a_H + b_H \ln(A')]\right\} \end{aligned} \tag{30}$$

The future asset level, A', that maximises the agent's utility can now be found. Note that the agent now takes into account both the probability of suffering the health shock and the value function for the case in which the agent has lost his health. By solving we arrive at the following process:

$$\frac{A'}{A} = \left(\frac{e^{-\tau(r-\rho)}}{C_2} + e^{-\tau(r+\mu)}\right)^{-1} \tag{31}$$

where $C_2 \equiv \frac{1+e^{-\tau(r-\rho)}\frac{H\left(1-e^{-\tau\lambda}\right)}{1-e^{-\tau(\rho+\mu)}}}{1-e^{-\tau(\rho+\mu+\lambda)}} + \frac{H\left(1-e^{-\tau\lambda}\right)}{1-e^{-\tau(\rho+\mu)}}$ illustrates where the health-related parameters enter the agent's utility-maximising consumption-saving decision.[49]

[49] If the risk of a health shock is set to zero, Equation (31) reduces to the case where the agent has already suffered the health shock, Equation (29). This implies that when the risk of the health shock

In this case, unlike that of the unhealthy agent in Equation (29), growth in assets depends on both the probability and the severity of the health shock. Let us consider the case where the health shock itself is so severe that the agent derives no utility from consumption if the shock strikes. This actually implies that losing one's health is equivalent to death, in which case H would be set to zero. In this instance, the motion equation for the healthy agent's asset accumulation would become:

$$\frac{A'}{A} = e^{\tau(r-\rho-\lambda)} \tag{32}$$

Equation (32) can be interpreted to represent a world where mortality risk is split into two factors – insurable and uninsurable mortality risk – captured by μ and λ, respectively. Insurable mortality risk is mitigated perfectly by the actuarial notes (see Section 3) and does not affect the utility-maximising path of asset accumulation. Uninsurable mortality risk does affect the agent's consumption-saving decision, however. As uninsurable mortality risk increases, the agent is not compensated for being less likely to enjoy his savings through future consumption. This incentivises the agent to consume more while he is still alive, effectively reducing the speed of asset accumulation, as is captured in Equation (32).

In the case where $H > 0$, improvements in healthy aging can be implied by lowering health risk or decreasing the severity of the health shock. Differentiation of C_2 from Equation (31) with respect to the size of the health shock, H, yields:

$$\frac{\partial C_2}{\partial H} = \frac{1-e^{-\tau\lambda}}{1-e^{-\tau(\mu+\rho)}} + \frac{e^{-\tau(r-\rho)}\left(1-e^{-\tau\lambda}\right)}{\left(1-e^{-\tau(\mu+\rho)}\right)\left(1-e^{-\tau(\lambda+\mu+\rho)}\right)} > 0 \tag{33}$$

is removed, the only remaining uncertainty the agent faces is mortality risk, which is mitigated perfectly by the actuarial notes. In this case, we arrive at the standard Blanchard-Yaari asset accumulation path.

which implies that asset growth, A'/A, increases as the severity of the health shock decreases (H is higher). The underlying assumption is that as the health shock becomes less severe, the agent's prospects of enjoying future consumption increase. This incentivises the agent to save for future consumption. The effects of improvements in healthy aging can also be captured by reducing the probability of the adverse health shock, λ.

$$\frac{\partial}{\partial \lambda}\left(\frac{A'}{A}\right) < 0 \tag{34}$$

Note that the derivative in Equation (31) yields a large expression that is omitted here. The sign of the derivative is analysed in Appendix C. The sign is negative for the entire span of reasonable values for all of the parameters. The reduced probability of the health shock therefore causes stronger asset growth, implying that the agent chooses to consume less and save more. As the probability of the health shock decreases, the agent's prospects of being able to enjoy future consumption improve. This, in turn, incentivises the agent to save more, as he has a greater chance of being able to enjoy his future consumption.

Even though mortality risk is perfectly mitigated by the actuarial notes, it plays an important role in determining the magnitude of the effect of healthy aging on the agent's consumption-saving decision. Differentiation of Equation (33) yields:

$$\frac{\partial}{\partial \mu}\left(\frac{\partial C_2}{\partial H}\right) < 0 \tag{35}$$

The derived expression proves to be large and is omitted above. However, the sign of the expression can be easily seen in Equation (33): when μ increases, the denominators of both fractions increase, causing the entire expression to decrease. This implies that as the agent expects to live longer (μ decreases), the effects of his health expectations on asset accumulation are magnified. This makes intuitive sense: when mortality risk is lower, the agent anticipates living longer, regardless of health status. This, in turn, implies that possible years of poor health weigh more heavily in his expected lifetime utility, magnifying the impact of the health shock on his consumption-saving decision.

To summarise, as the agent's expectations of being able to enjoy future consumption improve, he chooses to decrease current consumption and increase his saving, causing his assets to accumulate at a more rapid pace. A natural extension of the analysis presented in this section would be to analyse how a stochastic health shock affects the agent's retirement plans. Such a study could yield interesting results because of the interaction between retirement age and saving behaviour.

6. Concluding remarks

The model presented here demonstrates that healthy aging plays an important role in agents' life-cycle planning. For most individuals, a significant part of the deterioration in their health takes place after retirement. This paper makes an important connection between post-retirement health and retirement timing, showing that not only does length of retirement matter, but post-retirement quality of life matters as well. Furthermore, the analysis shows that when subject to stochastic health shocks, individuals' propensity to save decreases.

In the model, health has two distinct effects on the agent, through disutility of work and through utility from consumption. Developments in health were modelled in two ways: first, as a constant deterministic process; and second, through stochastic health shocks. Empirically, individuals do not have perfect knowledge of how their health will develop over their life cycle, but actual developments will probably approximate a mixture of the two cases examined here. Lessons from these two perspectives considered together could therefore demonstrate, at least to a degree, how health affects retirement and saving decisions.

The analysis finds consistently that the longer agents expect to remain in good health, the longer they postpone retirement. This holds true irrespective of whether or not health affects disutility of work. It, too, makes intuitive sense: there is less of an incentive to work to acquire savings for a retirement one cannot enjoy. When faced with increases in healthy aging, agents will therefore respond by remaining in the labour market longer, regardless of whether or not these increases are associated with longevity increases.

In the deterministic case, the health function produced a hump-shaped consumption plan over the life cycle. When the agent is younger, his health is relatively stable and his consumption increases due to his accumulation of wealth. As the agent grows older, his health deteriorates at an increased pace, which puts downward pressure on the consumption plan, producing a concave consumption profile. This result is complemented by the stochastic analysis, which found that when agents are less likely to lose their health, or when they expect the health shock to be less severe, their propensity to save increases.

The model was also used to analyse the differences among different socioeconomic groups and how they respond to demographic change. An individual's optimal retirement age is determined to a significant degree by health, longevity, and disutility of work, all of which tend to incentivise typical blue-collar workers to retire earlier than their white-collar counterparts. This does not necessarily imply that a double system should be implemented, however, since empirically there is significant overlap in the distribution of the mortality of the two groups. The longevity elasticity of the retirement age was also analysed, and the findings indicated that in three settings spanning various formulations of the mortality profile, the optimal retirement age will increase on less than a one-to-one basis with longevity increases. These findings indicate that special care should be taken when designing retirement reforms for an inherently heterogeneous population.

Further extensions would add a layer of sophistication to the analysis. Allowing for a planned retirement age in the stochastic setting would provide further insight about optimal life-cycle planning when subject to demographic change. Introducing a pension scheme would facilitate an analysis of the effects of various pension reforms on the planned retirement age, saving behaviour and, ultimately, welfare. This paper should be viewed as the first of many on the effects of healthy aging on retirement and retirement reform. Extensions are left to future work.

References

Auerbach, Alan J., Kerwin K. Charles, Courtney C. Coile, William Gale, Dana Goldman, Roland Lee, Charles M. Lucas, *et al.* 2017. “How the growing gap in life expectancy may affect retirement benefits and reforms.” *Working Paper 23329, National Bureau of Economic Research.*

Benhabib, Jess, Alberto Bisin, and Shenghao Zhu. 2014. “The distribution of wealth in the Blanchard-Yaari model.” *Macroeconomic Dynamics* 466-481.

Blanchard, O.J. 1985. “Debt, Deficits, and Finite Horizons.” *Journal of Political Economy* 223-247.

Bloom, David E., David Canning, and Michael Moore. 2014. “Optimal Retirement with Increasing Longevity.” *Scandinavian Journal of Economics* 838-858.

Blundell, Richard, Jack Britton, Monica Costa Dias, and Eric French. 2017. “The impact of health on labor supply near retirement.” *Institute for Fiscal Studies, WP17/18.*

Boucekkine, Raouf, David de la Croix, and Omar Licandro. 2002. “Vintage human capital, demographic trends, and endogenous growth.” *Journal of Economic Theory* 340-375.

Braveman, Paula A., Catherine Cubbin, Susan Egerter, David R. Williams, and Elsie Pamuk. 2010. “Socioeconomic Disparities in Health in the United States: What the Patterns Tell Us.” *American Journal of Public Health* S186-S196.

Brown, Jefferey R., Gopi Shah Goda, and Kathleen McGarry. 2016. “Heterogeneity in state-dependent utility: Evidence from strategic surveys.” *Economic Inquiry* 847-861.

Case, Anne, and Angus Deaton. 2005. “Broken down by work and sex: How our health declines.” 185-212. University of Chicago Press.

Chetty, Raj, Michael Stepner, Sarah Abraham, Shelby Lin, Benjamin Scuderi, Nicholas Turner, Augustin Bergeron, and David Cutler. 2016. “The association between income and life expectancy in the United States.” *Journal of American Medical Association* 1750-1766.

Costa, Dora L. 1998. *The Evolution of Retirement: An American Economic History, 1880-1990.* Chicago, IL: University of Chicago Press.

Currie, Janet, and Brigitte C. Madrian. 1999. “Health, health insurance and the labor market.” *Handbook of Labor Economics, Volume 3.*

Datta Gupta, Nabanita, and Mona Larsen. 2007. “Health shocks and retirement: the role of welfare state institutions.” *European Journal of Aging* 183-190.

Disney, Richard, Carl Emmerson, and Matthew Wakefield. 2006. “Ill health and retirement in Britain: A panel data-based analysis.” *Journal of Health Economics* 621-649.

Duval, Romain. 2004. “The retirement effects of old-age pension and early retirement schemes in OECD countries.” *Working Paper*, OECD.

Finkelstein, Amy, Erzo F.P. Luttmer, and Matthew J. Notowidigdo. 2013. "What good is wealth without health? The effect of health on the marginal utility of consumption." *Journal of the European Economic Association* 221-258.

French, Eric. 2005. “The Effects of Health, Wealth, and Wages on Labour Supply and Retirement Behaviour.” *Review of Economic Studies* 395-427.

Gourinchas, Pierre-Olivier, and Jonathan A. Parker. 2002. “Consumption over the life cycle.” *Econometrica* (Econometrica) 47-89.

Grossman, Michael. 1999. “The Human Capital Model of the Demand for Health.” *National Bureau of Economic Research Working Papers 7078.*

Gustman, Alan L., and Thomas L. Steinmeier. 2018. “The role of health in retirement.” *Transitions through the Labor Market (Research in Labor Economics, Vol. 46)* 229-297.

Hammitt, James K., Kevin Haninger, and Nicolas Treich. 2009. “Effects of Health and Longevity on Financial Risk Tolerance.” *The Geneva Risk and Insurance Review* 117-139.

Imai, Kosuke, and Samir Soneji. 2007. “On the Estimation of Disability-Free Life Expectancy: Sullivan’s Method and Its Extension.” *Journal of the American Statistical Association* 1199-1211.

Jones, Andrew M., Eugenio Zucchelli, Nigel Rice, and Anthony Harris. 2010. “The Effects of Health Shocks on Labour Market Exits: Evidence from the HILDA Survey.” *Australian Journal of Labour Economics* 191-218.

Kalemli-Ozcan, Sebnem, and David N. Weil. 2010. "Mortality change, the uncertainty effect, and retirement." *Journal of Economic Growth* 65-91.

Kemptner, Daniel. 2019. “Health-related life cycle risks and public insurance.” *DIW Berlin Discussion Paper.*

Kontis, Vasilis, James E. Bennett, Colin D. Mathers, Li Guangquan, Kyle Foreman, and Majid Ezzati. 2017. “Future life expectancy in 35 industrialised countries: projections with a Bayesian model ensemble.” *The Lancet* 1323-1335.

Kools, L. , and M. G. Knoef. 2017. “Health and the Marginal Utility of Consumption; Estimating Health State Dependence using Equivalence Scales.” *Netspar Academic Series (DP 04/2017-008).*

Laun, Tobias, Simen Markussen, Trond Christian Vigtel, and Johanna Wallenius. 2019. “Health, longevity and retirement reform.” *Journal of Economic Dynamics & Control* 123-157.

Lowsky, David J., S. Jay Olshansky, Jay Bhattacharya, and Dana P. Goldman. 2017. “Heterogeneity in Healthy Aging.” *Journal of Gerontology Series A: Biological Sciences and Medical Sciences* 640-649.

OECD. 2019. *Ambitious retirement age indexation ensures sustainable public finances in Denmark.* 15 January. https://oecdecoscope.blog/2019/01/15/ambitious-retirement-age-indexation-ensures-sustainable-public-finances-in-denmark/.

Pijoan-Mas, J., and JV. Ríos-Rull. 2014. “Heterogeneity in expected longevities.” *Demography* 2075-20102.

Raleigh, Veena S. 2019. “Trends in life expectancy in EU and other OECD countries: Why are improvements slowing.” *OECD Health Working Papers No. 108.*

Riphahn, Regina T. 1999. “Income and employment effects of health shocks: A test case for the German welfare state.” *Journal of Population Economics* 363-389.

Scholz, John Karl, and Ananth Seshadri. 2013. “Health insurance and retirement decisions.” *Michigan Retirement Research Center Research Paper No. 2013-292.*

Sullivan, D. 1971. “A Single Index of Mortality and Morbidity.” *HSMHA Health Reports* 347-354.

van Ooijen, Raun, and Marike Knoef. 2015. “Health status over the life cycle.” *The University of York Health, Econometrics and Data Group Working Paper Series.*

Waldron, Hilary. 2007. “Trends in mortality differentials and life expectancy for male social security-covered workers, by average relative earnings.” *ORES Working Paper Series.*

WHO. 2015. *World Report on Ageing and Health.* Luxembourg: World Health Organization.

Wilmoth, J. R. 2000. “Demography of longevity: past, present and future trends.” *Experimental Gerontology* 1111-1129.

Yaari, M. E. 1965. “Uncertain lifetime, life insurance, and the theory.” *Review of Economic Studies 32* 137-150.

Appendix A

Here the robustness of the numerical results of Section 4.3 is checked. The shock presented in Section 4.3 was a demographic shock. Naturally, the demographic parameters drive the shock, but its magnitude could be influenced by other model values. The variables featured in the model that are assumed not to be influenced by demographic factors are the interest rate, r, and the time preference, ρ. To ensure the tractability of the model, a relationship between these two variables has been assumed, $r > \rho$. The baseline values of all parameters are the same as those presented in Section 4.3.

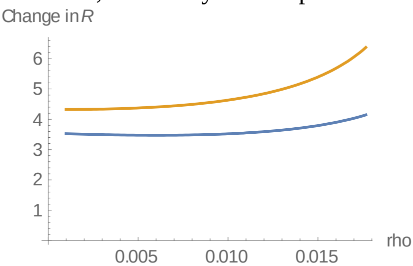
The longevity increase is the same as is presented in Section 4.3. On the one hand, we have an increase in life expectancy of 10 years coupled with an equal increase in the health profile, simulating healthy aging. This is captured by the orange line in Figures A1-A3. On the other hand, we have an increase in life expectancy of 10 years with an unchanged health profile, implying that agents can expect to live longer but will spend those extra years in relatively poor health. This case is depicted by the blue line in Figures A1-A3. On the vertical axis of Figures A1-A3, we have the change in the retirement age when the agent is subject to the two longevity shocks described above. On the horizontal axis, we have different parameter values for the time preference, ρ, and the interest rate, r. This allows us to see how the magnitude of the demographic shift affects the agent's optimal retirement decision.

We can start by examining how the reaction to the longevity shock depends on the time preference. In Figure A1, the value of the time preference, ρ, goes from 0.001 to 0.018, but the interest rate is kept unchanged at 0.018. As the time preference increases and approaches the interest rate, the impact of the demographic change on the optimal retirement age increases. In Figure A2, the interest rate is allowed to change while the time preference is kept constant. A similar pattern emerges. As the interest rate moves closer to the time preference, the impact of the demographic change increases.

From Equations (7) and (8), we know that as ρ and r move closer to the same value, the health profile plays an increasingly significant role in explaining the agent's consumption profile. This difference between ρ and r increases consumption growth over the agent's lifetime, while deteriorating health decreases consumption growth. This explains in part the widening gap between the orange and blue curves in Figures A1 and A2.

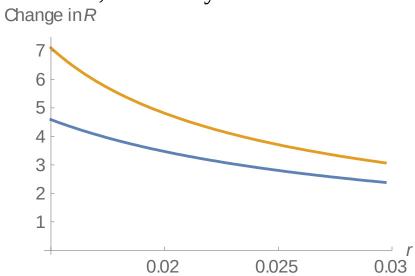
In Figure A3, both ρ and r move together across the horizontal axis, keeping their difference fixed at 0.003. Note that the difference between the two demographic shifts remains approximately proportional. However, the retirement age becomes less sensitive to demographic shifts as the time preference and interest rate increase. This illustrates how the impact of the health profile depends on the time preference and the interest rate. When the difference is smaller, health has a more significant role in shaping the agent's optimal retirement plan.

Figure A1: Change in planned retirement age when life expectancy increases, sensitivity to time preference



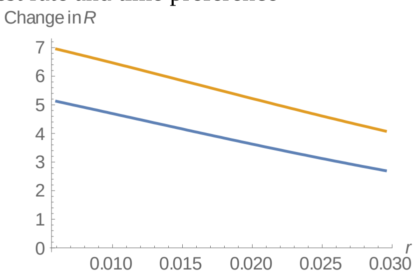
The orange line depicts the change in retirement age when the agent enjoys higher life expectancy and better health. The blue line depicts the change in retirement age when the agent enjoys higher longevity but an unchanged health profile. The parameter value for ρ in the baseline calibration was 0.015.

Figure A2: Change in planned retirement age when life expectancy increases, sensitivity to interest rate



The orange line depicts the change in retirement age when the agent enjoys higher life expectancy and better health. The blue line depicts the change in retirement age when the agent enjoys higher longevity but an unchanged health profile. The parameter value for r in the baseline calibration was 0.018.

Figure A3: Change in planned retirement age when life expectancy increases, sensitivity to interest rate and time preference



The orange line depicts the change in retirement age when the agent enjoys higher life expectancy and better health. The blue line depicts the change in retirement age when the agent enjoys higher longevity but an unchanged health profile. Here the difference between time preference and interest rate is kept constant at: $\rho \equiv r - 0.003$.

Appendix B

Here the responsiveness of the retirement age to increases in longevity is addressed.

As is observed in Equation (11), a deterioration of health puts downward pressure on the optimal retirement age. In this Appendix, we are interested in analysing the conditions necessary for the optimal retirement age to respond to longevity increases on a one-to-one basis. Therefore, we assume that the agent's health is constant and set to 1. In the context of the model presented in Section 3, this implies that the mortality and health profiles take the form of:

$$m(a) = e^{-\mu a} \qquad \text{and} \qquad h(a) = 1 \tag{A1}$$

The agent's life expectancy becomes $\Lambda = 1/\mu$. Furthermore, the knife's edge condition $r = \rho$ is applied, implying perfect consumption smoothing. Finally, the disutility of work, ω, is normalised to 1. By plugging this into the implicit function for the optimal retirement age, Equation (10), and differentiating, we arrive at:

$$-\frac{\partial R}{\partial \mu} = \frac{R}{\mu + r} < \frac{1}{\mu^2} = -\frac{\partial \Lambda}{\partial \mu} \tag{A2}$$

On the left side of the inequality in Expression (A2) is the change in the optimal retirement age when the instantaneous death probability, μ, decreases. On the right hand side, we have the increase in life expectancy following the decrease in μ. Expression (A2) implies that as longevity increases, the response in the optimal retirement age will be less than the increase in life expectancy. The inequality in Expression (A2) holds as long as the agent's optimal planned retirement age is less than $\Lambda(1 + r\Lambda)$, which is substantially greater than the agent's life expectancy.

Let us now turn to the case where mortality is deterministic and the agent knows his exact time of death. This implies that $m(a) = 1$ for all ages until the agent reaches the terminal age, T, at which point $m(T) = 0$. In this case, we relax the knife-edge condition and revert to the $r > \rho$ condition. By plugging this into the model presented in Section 3, we arrive at:

$$\frac{\partial R}{\partial T} = \frac{re^{-\rho(T-R)}}{\rho + (r-\rho)e^{Rr}} < 1 = \frac{\partial}{\partial T}T \tag{A3}$$

The condition in Expression (A3) implies that when the agent's life expectancy increases, his optimal retirement age will increase by less than the increase in life expectancy. The condition that must hold in order for the optimal retirement age to respond on a one-to-one basis to the life expectancy increase is the boundary condition that the agent will never retire, setting $R = T$.

Note that the analysis is based on simplifying assumptions that could influence the results. The agent is forced to work full-time or not at all. The agent's wage profile is also assumed to be constant. The time preference is also assumed to be lower than the interest rate. Finally, the model does not feature a social security scheme that could significantly alter the agent's retirement decision, as is discussed in Section 2.3.

Appendix C

Here the sign of Equation (34), which captures the effects of an increase in the probability of the adverse health shock on the agent's asset accumulation process, is determined numerically. For convenience, Equation (31) is restated here:

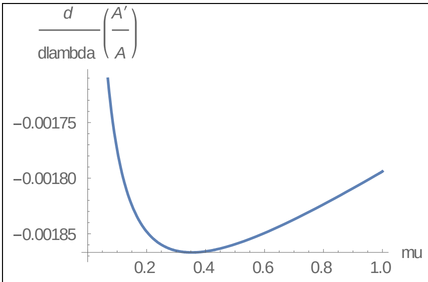
$$\frac{A'}{A} = \left(\frac{e^{-\tau(r-\rho)}}{C_2} + e^{-\tau(r+\mu)}\right)^{-1} \tag{A4}$$

where $C_2 \equiv \frac{1+e^{-\tau(r-\rho)}\frac{H(1-e^{-\tau\lambda})}{1-e^{-\tau(\rho+\mu)}}}{1-e^{-\tau(\rho+\mu+\lambda)}} + \frac{H(1-e^{-\tau\lambda})}{1-e^{-\tau(\rho+\mu)}}$ captures where the health-related parameters enter the agent's utility-maximizing consumption-saving decision. The sign of the derivative of $\frac{A'}{A}$ with respect to h is difficult to prove analytically. A more fruitful way to determine the effect of increased probability of the adverse health shock is to apply parameter values to the derivative and check the sign for all permissible values for all parameters.

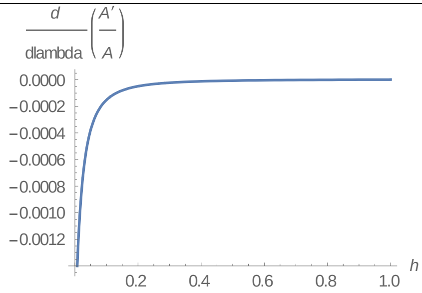
In order to check the sign for the span of each parameter, a baseline calibration is necessary. The baseline calibration's value for the instantaneous death probability is $\mu = 0.016$, which implies a life expectancy of 82.5 years. The probability of the health shock is half the probability of death and is set to $\lambda = 0.008$. The size of the health shock is set to $H = 0.8$, and the interest rate is set to $r = 0.018$. Finally, the time preference is set to $\rho = 0.015$

In Figure A4 below, we see that for the entire span for all the parameters, an increase in the probability of the health shock (higher values of λ) will result in a slower asset growth rate. This implies that the agent saves less and consumes more of his stock of assets when the probability of the health shock increases.

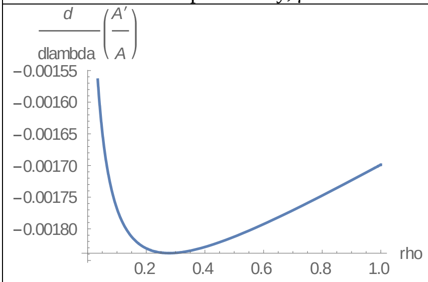
Figure A4: Effect of increased probability of health shock on asset accumulation



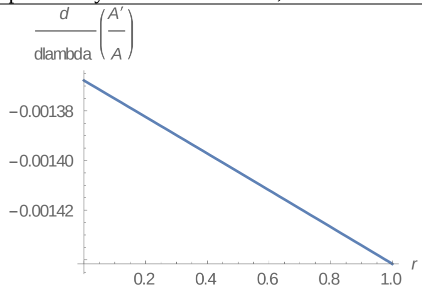
The sign of the derivative in equation (31) is negative for all permissible values of the instantaneous death probability, μ



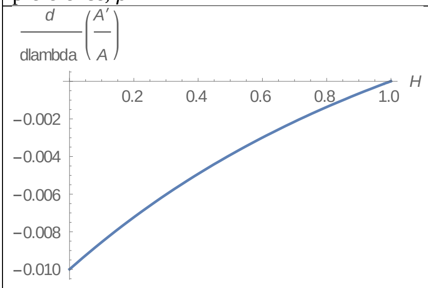
The sign of the derivative in equation (31) is negative for all reasonable values of the probability of the health shock, h



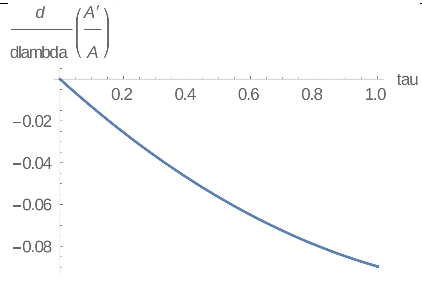
The sign of the derivative in Equation (31) is negative for all permissible values for the time preference, ρ.



The sign of the derivative in Equation (31) is negative for all permissible values of the interest rate, r.



The sign of the derivative in Equation (31) is negative for all permissible values of the size of the health shock, H.



The sign of the derivative in Equation (31) is negative for all reasonable values for current time interval, τ.

TITLER I PH.D.SERIEN:

2004

1. Martin Grieger
   Internet-based Electronic Marketplaces and Supply Chain Management

2. Thomas Basbøll
   LIKENESS
   A Philosophical Investigation

3. Morten Knudsen
   Beslutningens vaklen
   En systemteoretisk analyse of moderniseringen af et amtskommunalt sundhedsvæsen 1980-2000

4. Lars Bo Jeppesen
   Organizing Consumer Innovation
   A product development strategy that is based on online communities and allows some firms to benefit from a distributed process of innovation by consumers

5. Barbara Dragsted
   SEGMENTATION IN TRANSLATION AND TRANSLATION MEMORY SYSTEMS
   An empirical investigation of cognitive segmentation and effects of integrating a TM system into the translation process

6. Jeanet Hardis
   Sociale partnerskaber
   Et socialkonstruktivistisk casestudie af partnerskabsaktørers virkelighedsopfattelse mellem identitet og legitimitet

7. Henriette Hallberg Thygesen
   System Dynamics in Action

8. Carsten Mejer Plath
   Strategisk Økonomistyring

9. Annemette Kjærgaard
   Knowledge Management as Internal Corporate Venturing
   – a Field Study of the Rise and Fall of a Bottom-Up Process

10. Knut Arne Hovdal
    De profesjonelle i endring
    Norsk ph.d., ej til salg gennem Samfundslitteratur

11. Søren Jeppesen
    Environmental Practices and Greening Strategies in Small Manufacturing Enterprises in South Africa
    – A Critical Realist Approach

12. Lars Frode Frederiksen
    Industriel forskningsledelse
    – på sporet af mønstre og samarbejde i danske forskningsintensive virksomheder

13. Martin Jes Iversen
    The Governance of GN Great Nordic
    – in an age of strategic and structural transitions 1939-1988

14. Lars Pynt Andersen
    The Rhetorical Strategies of Danish TV Advertising
    A study of the first fifteen years with special emphasis on genre and irony

15. Jakob Rasmussen
    Business Perspectives on E-learning

16. Sof Thrane
    The Social and Economic Dynamics of Networks
    – a Weberian Analysis of Three Formalised Horizontal Networks

17. Lene Nielsen
    Engaging Personas and Narrative Scenarios – a study on how a user-centered approach influenced the perception of the design process in the e-business group at AstraZeneca

18. S.J Valstad
    Organisationsidentitet
    Norsk ph.d., ej til salg gennem Samfundslitteratur

19. Thomas Lyse Hansen
Six Essays on Pricing and Weather risk in Energy Markets

20. Sabine Madsen
Emerging Methods – An Interpretive Study of ISD Methods in Practice

21. Evis Sinani
The Impact of Foreign Direct Investment on Efficiency, Productivity Growth and Trade: An Empirical Investigation

22. Bent Meier Sørensen
Making Events Work Or, How to Multiply Your Crisis

23. Pernille Schnoor
Brand Ethos
Om troværdige brand- og virksomhedsidentiteter i et retorisk og diskursteoretisk perspektiv

24. Sidsel Fabech
Von welchem Österreich ist hier die Rede?
Diskursive forhandlinger og magtkampe mellem rivaliserende nationale identitetskonstruktioner i østrigske pressediskurser

25. Klavs Odgaard Christensen
Sprogpolitik og identitetsdannelse i flersprogede forbundsstater
Et komparativt studie af Schweiz og Canada

26. Dana B. Minbaeva
Human Resource Practices and Knowledge Transfer in Multinational Corporations

27. Holger Højlund
Markedets politiske fornuft
Et studie af velfærdens organisering i perioden 1990-2003

28. Christine Mølgaard Frandsen
A.s erfaring
Om mellemværendets praktik i en transformation af mennesket og subjektiviteten

29. Sine Nørholm Just
The Constitution of Meaning – A Meaningful Constitution?
Legitimacy, identity, and public opinion in the debate on the future of Europe

2005

1. Claus J. Varnes
Managing product innovation through rules – The role of formal and structured methods in product development

2. Helle Hedegaard Hein
Mellem konflikt og konsensus – Dialogudvikling på hospitalsklinikker

3. Axel Rosenø
Customer Value Driven Product Innovation – A Study of Market Learning in New Product Development

4. Søren Buhl Pedersen
Making space
An outline of place branding

5. Camilla Funck Ellehave
Differences that Matter
An analysis of practices of gender and organizing in contemporary workplaces

6. Rigmor Madeleine Lond
Styring af kommunale forvaltninger

7. Mette Aagaard Andreassen
Supply Chain versus Supply Chain
Benchmarking as a Means to Managing Supply Chains

8. Caroline Aggestam-Pontoppidan
From an idea to a standard
The UN and the global governance of accountants' competence

9. Norsk ph.d.

10. Vivienne Heng Ker-ni
An Experimental Field Study on the

Effectiveness of Grocer Media Advertising
Measuring Ad Recall and Recognition, Purchase Intentions and Short-Term Sales

11. Allan Mortensen
Essays on the Pricing of Corporate Bonds and Credit Derivatives

12. Remo Stefano Chiari
Figure che fanno conoscere
Itinerario sull'idea del valore cognitivo e espressivo della metafora e di altri tropi da Aristotele e da Vico fino al cognitivismo contemporaneo

13. Anders McIlquham-Schmidt
Strategic Planning and Corporate Performance
An integrative research review and a meta-analysis of the strategic planning and corporate performance literature from 1956 to 2003

14. Jens Geersbro
The TDF – PMI Case
Making Sense of the Dynamics of Business Relationships and Networks

15 Mette Andersen
Corporate Social Responsibility in Global Supply Chains
Understanding the uniqueness of firm behaviour

16. Eva Boxenbaum
Institutional Genesis: Micro – Dynamic Foundations of Institutional Change

17. Peter Lund-Thomsen
Capacity Development, Environmental Justice NGOs, and Governance: The Case of South Africa

18. Signe Jarlov
Konstruktioner af offentlig ledelse

19. Lars Stæhr Jensen
Vocabulary Knowledge and Listening Comprehension in English as a Foreign Language
An empirical study employing data elicited from Danish EFL learners

20. Christian Nielsen
Essays on Business Reporting
Production and consumption of strategic information in the market for information

21. Marianne Thejls Fischer
Egos and Ethics of Management Consultants

22. Annie Bekke Kjær
Performance management i Proces-innovation
– belyst i et social-konstruktivistisk perspektiv

23. Suzanne Dee Pedersen
GENTAGELSENS METAMORFOSE
Om organisering af den kreative gøren i den kunstneriske arbejdspraksis

24. Benedikte Dorte Rosenbrink
Revenue Management
Økonomiske, konkurrencemæssige & organisatoriske konsekvenser

25. Thomas Riise Johansen
Written Accounts and Verbal Accounts
The Danish Case of Accounting and Accountability to Employees

26. Ann Fogelgren-Pedersen
The Mobile Internet: Pioneering Users' Adoption Decisions

27. Birgitte Rasmussen
Ledelse i fællesskab – de tillidsvalgtes fornyende rolle

28. Gitte Thit Nielsen
Remerger
– skabende ledelseskræfter i fusion og opkøb

29. Carmine Gioia
A MICROECONOMETRIC ANALYSIS OF MERGERS AND ACQUISITIONS

30. Ole Hinz
Den effektive forandringsleder: pilot, pædagog eller politiker?
Et studie i arbejdslederes meningstilskrivninger i forbindelse med vellykket gennemførelse af ledelsesinitierede forandringsprojekter

31. Kjell-Åge Gotvassli
Et praksisbasert perspektiv på dynamiske
læringsnettverk i toppidretten
Norsk ph.d., ej til salg gennem Samfundslitteratur

32. Henriette Langstrup Nielsen
Linking Healthcare
An inquiry into the changing performances of web-based technology for asthma monitoring

33. Karin Tweddell Levinsen
Virtuel Uddannelsespraksis
Master i IKT og Læring – et casestudie i hvordan proaktiv proceshåndtering kan forbedre praksis i virtuelle læringsmiljøer

34. Anika Liversage
Finding a Path
Labour Market Life Stories of Immigrant Professionals

35. Kasper Elmquist Jørgensen
Studier i samspillet mellem stat og erhvervsliv i Danmark under 1. verdenskrig

36. Finn Janning
A DIFFERENT STORY
Seduction, Conquest and Discovery

37. Patricia Ann Plackett
Strategic Management of the Radical Innovation Process
Leveraging Social Capital for Market Uncertainty Management

2006

1. Christian Vintergaard
Early Phases of Corporate Venturing

2. Niels Rom-Poulsen
Essays in Computational Finance

3. Tina Brandt Husman
Organisational Capabilities, Competitive Advantage & Project-Based Organisations
The Case of Advertising and Creative Good Production

4. Mette Rosenkrands Johansen
Practice at the top
– how top managers mobilise and use non-financial performance measures

5. Eva Parum
Corporate governance som strategisk kommunikations- og ledelsesværktøj

6. Susan Aagaard Petersen
Culture's Influence on Performance Management: The Case of a Danish Company in China

7. Thomas Nicolai Pedersen
The Discursive Constitution of Organizational Governance – Between unity and differentiation
The Case of the governance of environmental risks by World Bank environmental staff

8. Cynthia Selin
Volatile Visions: Transactons in Anticipatory Knowledge

9. Jesper Banghøj
Financial Accounting Information and Compensation in Danish Companies

10. Mikkel Lucas Overby
Strategic Alliances in Emerging High-Tech Markets: What's the Difference and does it Matter?

11. Tine Aage
External Information Acquisition of Industrial Districts and the Impact of Different Knowledge Creation Dimensions

A case study of the Fashion and Design Branch of the Industrial District of Montebelluna, NE Italy

12. Mikkel Flyverbom
Making the Global Information Society Governable
On the Governmentality of Multi-Stakeholder Networks

13. Anette Grønning
Personen bag
Tilstedevær i e-mail som inter-aktionsform mellem kunde og med-arbejder i dansk forsikringskontekst

14. Jørn Helder
One Company – One Language?
The NN-case

15. Lars Bjerregaard Mikkelsen
Differing perceptions of customer value
Development and application of a tool for mapping perceptions of customer value at both ends of customer-supplier dyads in industrial markets

16. Lise Granerud
Exploring Learning
Technological learning within small manufacturers in South Africa

17. Esben Rahbek Pedersen
Between Hopes and Realities: Reflections on the Promises and Practices of Corporate Social Responsibility (CSR)

18. Ramona Samson
The Cultural Integration Model and European Transformation.
The Case of Romania

2007

1. Jakob Vestergaard
Discipline in The Global Economy
Panopticism and the Post-Washington Consensus

2. Heidi Lund Hansen
Spaces for learning and working
A qualitative study of change of work, management, vehicles of power and social practices in open offices

3. Sudhanshu Rai
Exploring the internal dynamics of software development teams during user analysis
A tension enabled Institutionalization Model; "Where process becomes the objective"

4. Norsk ph.d.
Ej til salg gennem Samfundslitteratur

5. Serden Ozcan
EXPLORING HETEROGENEITY IN ORGANIZATIONAL ACTIONS AND OUTCOMES
A Behavioural Perspective

6. Kim Sundtoft Hald
Inter-organizational Performance Measurement and Management in Action
– An Ethnography on the Construction of Management, Identity and Relationships

7. Tobias Lindeberg
Evaluative Technologies
Quality and the Multiplicity of Performance

8. Merete Wedell-Wedellsborg
Den globale soldat
Identitetsdannelse og identitetsledelse i multinationale militære organisationer

9. Lars Frederiksen
Open Innovation Business Models
Innovation in firm-hosted online user communities and inter-firm project ventures in the music industry
– A collection of essays

10. Jonas Gabrielsen
Retorisk toposlære – fra statisk 'sted' til persuasiv aktivitet

11. Christian Moldt-Jørgensen
Fra meningsløs til meningsfuld evaluering.
Anvendelsen af studentertilfredshedsmålinger på de korte og mellemlange videregående uddannelser set fra et psykodynamisk systemperspektiv

12. Ping Gao
Extending the application of actor-network theory
Cases of innovation in the telecommunications industry

13. Peter Mejlby
Frihed og fængsel, en del af den samme drøm?
Et phronetisk baseret casestudie af frigørelsens og kontrollens sameksistens i værdibaseret ledelse!

14. Kristina Birch
Statistical Modelling in Marketing

15. Signe Poulsen
Sense and sensibility:
The language of emotional appeals in insurance marketing

16. Anders Bjerre Trolle
Essays on derivatives pricing and dynamic asset allocation

17. Peter Feldhütter
Empirical Studies of Bond and Credit Markets

18. Jens Henrik Eggert Christensen
Default and Recovery Risk Modeling and Estimation

19. Maria Theresa Larsen
Academic Enterprise: A New Mission for Universities or a Contradiction in Terms?
Four papers on the long-term implications of increasing industry involvement and commercialization in academia

20. Morten Wellendorf
Postimplementering af teknologi i den offentlige forvaltning
Analyser af en organisations kontinuerlige arbejde med informationsteknologi

21. Ekaterina Mhaanna
Concept Relations for Terminological Process Analysis

22. Stefan Ring Thorbjørnsen
Forsvaret i forandring
Et studie i officerers kapabiliteter under påvirkning af omverdenens forandringspres mod øget styring og læring

23. Christa Breum Amhøj
Det selvskabte medlemskab om managementstaten, dens styringsteknologier og indbyggere

24. Karoline Bromose
Between Technological Turbulence and Operational Stability
– An empirical case study of corporate venturing in TDC

25. Susanne Justesen
Navigating the Paradoxes of Diversity in Innovation Practice
– A Longitudinal study of six very different innovation processes – in practice

26. Luise Noring Henler
Conceptualising successful supply chain partnerships
– Viewing supply chain partnerships from an organisational culture perspective

27. Mark Mau
Kampen om telefonen
Det danske telefonvæsen under den tyske besættelse 1940-45

28. Jakob Halskov
The semiautomatic expansion of existing terminological ontologies using knowledge patterns discovered

on the WWW – an implementation and evaluation

29. Gergana Koleva
European Policy Instruments Beyond Networks and Structure: The Innovative Medicines Initiative

30. Christian Geisler Asmussen
Global Strategy and International Diversity: A Double-Edged Sword?

31. Christina Holm-Petersen
Stolthed og fordom
Kultur- og identitetsarbejde ved skabelsen af en ny sengeafdeling gennem fusion

32. Hans Peter Olsen
Hybrid Governance of Standardized States
Causes and Contours of the Global Regulation of Government Auditing

33. Lars Bøge Sørensen
Risk Management in the Supply Chain

34. Peter Aagaard
Det unikkes dynamikker
De institutionelle mulighedsbetingelser bag den individuelle udforskning i professionelt og frivilligt arbejde

35. Yun Mi Antorini
Brand Community Innovation
An Intrinsic Case Study of the Adult Fans of LEGO Community

36. Joachim Lynggaard Boll
Labor Related Corporate Social Performance in Denmark
Organizational and Institutional Perspectives

2008

1. Frederik Christian Vinten
Essays on Private Equity

2. Jesper Clement
Visual Influence of Packaging Design on In-Store Buying Decisions

3. Marius Brostrøm Kousgaard
Tid til kvalitetsmåling?
– Studier af indrulleringsprocesser i forbindelse med introduktionen af kliniske kvalitetsdatabaser i speciallægepraksissektoren

4. Irene Skovgaard Smith
Management Consulting in Action
Value creation and ambiguity in client-consultant relations

5. Anders Rom
Management accounting and integrated information systems
How to exploit the potential for management accounting of information technology

6. Marina Candi
Aesthetic Design as an Element of Service Innovation in New Technology-based Firms

7. Morten Schnack
Teknologi og tværfaglighed
– en analyse af diskussionen omkring indførelse af EPJ på en hospitalsafdeling

8. Helene Balslev Clausen
Juntos pero no revueltos – un estudio sobre emigrantes norteamericanos en un pueblo mexicano

9. Lise Justesen
Kunsten at skrive revisionsrapporter.
En beretning om forvaltningsrevisionens beretninger

10. Michael E. Hansen
The politics of corporate responsibility: CSR and the governance of child labor and core labor rights in the 1990s

11. Anne Roepstorff
Holdning for handling – en etnologisk undersøgelse af Virksomheders Sociale Ansvar/CSR

12. Claus Bajlum
Essays on Credit Risk and Credit Derivatives

13. Anders Bojesen
The Performative Power of Competence – an Inquiry into Subjectivity and Social Technologies at Work

14. Satu Reijonen
Green and Fragile
A Study on Markets and the Natural Environment

15. Ilduara Busta
Corporate Governance in Banking
A European Study

16. Kristian Anders Hvass
A Boolean Analysis Predicting Industry Change: Innovation, Imitation & Business Models
The Winning Hybrid: A case study of isomorphism in the airline industry

17. Trine Paludan
De uvidende og de udviklingsparate
Identitet som mulighed og restriktion blandt fabriksarbejdere på det aftayloriserede fabriksgulv

18. Kristian Jakobsen
Foreign market entry in transition economies: Entry timing and mode choice

19. Jakob Elming
Syntactic reordering in statistical machine translation

20. Lars Brømsøe Termansen
Regional Computable General Equilibrium Models for Denmark
Three papers laying the foundation for regional CGE models with agglomeration characteristics

21. Mia Reinholt
The Motivational Foundations of Knowledge Sharing

22. Frederikke Krogh-Meibom
The Co-Evolution of Institutions and Technology
– A Neo-Institutional Understanding of Change Processes within the Business Press – the Case Study of Financial Times

23. Peter D. Ørberg Jensen
OFFSHORING OF ADVANCED AND HIGH-VALUE TECHNICAL SERVICES: ANTECEDENTS, PROCESS DYNAMICS AND FIRMLEVEL IMPACTS

24. Pham Thi Song Hanh
Functional Upgrading, Relational Capability and Export Performance of Vietnamese Wood Furniture Producers

25. Mads Vangkilde
Why wait?
An Exploration of first-mover advantages among Danish e-grocers through a resource perspective

26. Hubert Buch-Hansen
Rethinking the History of European Level Merger Control
A Critical Political Economy Perspective

2009

1. Vivian Lindhardsen
From Independent Ratings to Communal Ratings: A Study of CWA Raters' Decision-Making Behaviours

2. Guðrið Weihe
Public-Private Partnerships: Meaning and Practice

3. Chris Nøkkentved
Enabling Supply Networks with Collaborative Information Infrastructures
An Empirical Investigation of Business Model Innovation in Supplier Relationship Management

4. Sara Louise Muhr
Wound, Interrupted – On the Vulnerability of Diversity Management

5. Christine Sestoft
Forbrugeradfærd i et Stats- og Livsformsteoretisk perspektiv

6. Michael Pedersen
Tune in, Breakdown, and Reboot: On the production of the stress-fit self-managing employee

7. Salla Lutz
Position and Reposition in Networks – Exemplified by the Transformation of the Danish Pine Furniture Manufacturers

8. Jens Forssbæck
Essays on market discipline in commercial and central banking

9. Tine Murphy
Sense from Silence – A Basis for Organised Action
How do Sensemaking Processes with Minimal Sharing Relate to the Reproduction of Organised Action?

10. Sara Malou Strandvad
Inspirations for a new sociology of art: A sociomaterial study of development processes in the Danish film industry

11. Nicolaas Mouton
On the evolution of social scientific metaphors:
A cognitive-historical enquiry into the divergent trajectories of the idea that collective entities – states and societies, cities and corporations – are biological organisms.

12. Lars Andreas Knutsen
Mobile Data Services:
Shaping of user engagements

13. Nikolaos Theodoros Korfiatis
Information Exchange and Behavior
A Multi-method Inquiry on Online Communities

14. Jens Albæk
Forestillinger om kvalitet og tværfaglighed på sygehuse
– skabelse af forestillinger i læge- og plejegrupperne angående relevans af nye idéer om kvalitetsudvikling gennem tolkningsprocesser

15. Maja Lotz
The Business of Co-Creation – and the Co-Creation of Business

16. Gitte P. Jakobsen
Narrative Construction of Leader Identity in a Leader Development Program Context

17. Dorte Hermansen
"Living the brand" som en brandorienteret dialogisk praxis:
Om udvikling af medarbejdernes brandorienterede dømmekraft

18. Aseem Kinra
Supply Chain (logistics) Environmental Complexity

19. Michael Nørager
How to manage SMEs through the transformation from non innovative to innovative?

20. Kristin Wallevik
Corporate Governance in Family Firms
The Norwegian Maritime Sector

21. Bo Hansen Hansen
Beyond the Process
Enriching Software Process Improvement with Knowledge Management

22. Annemette Skot-Hansen
Franske adjektivisk afledte adverbier, der tager præpositionssyntagmer indledt med præpositionen à som argumenter
En valensgrammatisk undersøgelse

23. Line Gry Knudsen
Collaborative R&D Capabilities
In Search of Micro-Foundations

24. Christian Scheuer
Employers meet employees
Essays on sorting and globalization

25. Rasmus Johnsen
The Great Health of Melancholy
A Study of the Pathologies of Performativity

26. Ha Thi Van Pham
Internationalization, Competitiveness Enhancement and Export Performance of Emerging Market Firms:
Evidence from Vietnam

27. Henriette Balieu
Kontrolbegrebets betydning for kausativalternationen i spansk
En kognitiv-typologisk analyse

2010

1. Yen Tran
Organizing Innovationin Turbulent Fashion Market
Four papers on how fashion firms create and appropriate innovation value

2. Anders Raastrup Kristensen
Metaphysical Labour
Flexibility, Performance and Commitment in Work-Life Management

3. Margrét Sigrún Sigurdardottir
Dependently independent
Co-existence of institutional logics in the recorded music industry

4. Ásta Dis Óladóttir
Internationalization from a small domestic base:
An empirical analysis of Economics and Management

5. Christine Secher
E-deltagelse i praksis – politikernes og forvaltningens medkonstruktion og konsekvenserne heraf

6. Marianne Stang Våland
What we talk about when we talk about space:
End User Participation between Processes of Organizational and Architectural Design

7. Rex Degnegaard
Strategic Change Management
Change Management Challenges in the Danish Police Reform

8. Ulrik Schultz Brix
Værdi i rekruttering – den sikre beslutning
En pragmatisk analyse af perception og synliggørelse af værdi i rekrutterings- og udvælgelsesarbejdet

9. Jan Ole Similä
Kontraktsledelse
Relasjonen mellom virksomhetsledelse og kontraktshåndtering, belyst via fire norske virksomheter

10. Susanne Boch Waldorff
Emerging Organizations: In between local translation, institutional logics and discourse

11. Brian Kane
Performance Talk
Next Generation Management of Organizational Performance

12. Lars Ohnemus
Brand Thrust: Strategic Branding and Shareholder Value
An Empirical Reconciliation of two Critical Concepts

13. Jesper Schlamovitz
Håndtering af usikkerhed i film- og byggeprojekter

14. Tommy Moesby-Jensen
Det faktiske livs forbindtlighed
Førsokratisk informeret, ny-aristotelisk ἦθος-tænkning hos Martin Heidegger

15. Christian Fich
Two Nations Divided by Common Values
French National Habitus and the Rejection of American Power

16. Peter Beyer
Processer, sammenhængskraft og fleksibilitet
Et empirisk casestudie af omstillingsforløb i fire virksomheder

17. Adam Buchhorn
Markets of Good Intentions
Constructing and Organizing Biogas Markets Amid Fragility and Controversy

18. Cecilie K. Moesby-Jensen
Social læring og fælles praksis
Et mixed method studie, der belyser læringskonsekvenser af et lederkursus for et praksisfællesskab af offentlige mellemledere

19. Heidi Boye
Fødevarer og sundhed i senmodernismen
– En indsigt i hyggefænomenet og de relaterede fødevarepraksisser

20. Kristine Munkgård Pedersen
Flygtige forbindelser og midlertidige mobiliseringer
Om kulturel produktion på Roskilde Festival

21. Oliver Jacob Weber
Causes of Intercompany Harmony in Business Markets – An Empirical Investigation from a Dyad Perspective

22. Susanne Ekman
Authority and Autonomy
Paradoxes of Modern Knowledge Work

23. Anette Frey Larsen
Kvalitetsledelse på danske hospitaler
– Ledelsernes indflydelse på introduktion og vedligeholdelse af kvalitetsstrategier i det danske sundhedsvæsen

24. Toyoko Sato
Performativity and Discourse: Japanese Advertisements on the Aesthetic Education of Desire

25. Kenneth Brinch Jensen
Identifying the Last Planner System
Lean management in the construction industry

26. Javier Busquets
Orchestrating Network Behavior for Innovation

27. Luke Patey
The Power of Resistance: India's National Oil Company and International Activism in Sudan

28. Mette Vedel
Value Creation in Triadic Business Relationships. Interaction, Interconnection and Position

29. Kristian Tørning
Knowledge Management Systems in Practice – A Work Place Study

30. Qingxin Shi
An Empirical Study of Thinking Aloud Usability Testing from a Cultural Perspective

31. Tanja Juul Christiansen
Corporate blogging: Medarbejderes kommunikative handlekraft

32. Malgorzata Ciesielska
Hybrid Organisations.
A study of the Open Source – business setting

33. Jens Dick-Nielsen
Three Essays on Corporate Bond Market Liquidity

34. Sabrina Speiermann
Modstandens Politik
Kampagnestyring i Velfærdsstaten.
En diskussion af trafikkampagners styringspotentiale

35. Julie Uldam
Fickle Commitment. Fostering political engagement in 'the flighty world of online activism'

36. Annegrete Juul Nielsen
Traveling technologies and transformations in health care

37. Athur Mühlen-Schulte
Organising Development
Power and Organisational Reform in the United Nations Development Programme

38. Louise Rygaard Jonas
Branding på butiksgulvet
Et case-studie af kultur- og identitets-arbejdet i Kvickly

2011

1. Stefan Fraenkel
Key Success Factors for Sales Force Readiness during New Product Launch
A Study of Product Launches in the Swedish Pharmaceutical Industry

2. Christian Plesner Rossing
International Transfer Pricing in Theory and Practice

3. Tobias Dam Hede
Samtalekunst og ledelsesdisciplin
– en analyse af coachingsdiskursens genealogi og governmentality

4. Kim Pettersson
Essays on Audit Quality, Auditor Choice, and Equity Valuation

5. Henrik Merkelsen
The expert-lay controversy in risk research and management. Effects of institutional distances. Studies of risk definitions, perceptions, management and communication

6. Simon S. Torp
Employee Stock Ownership:
Effect on Strategic Management and Performance

7. Mie Harder
Internal Antecedents of Management Innovation

8. Ole Helby Petersen
Public-Private Partnerships: Policy and Regulation – With Comparative and Multi-level Case Studies from Denmark and Ireland

9. Morten Krogh Petersen
'Good' Outcomes. Handling Multiplicity in Government Communication

10. Kristian Tangsgaard Hvelplund
Allocation of cognitive resources in translation - an eye-tracking and key-logging study

11. Moshe Yonatany
The Internationalization Process of Digital Service Providers

12. Anne Vestergaard
Distance and Suffering
Humanitarian Discourse in the age of Mediatization

13. Thorsten Mikkelsen
Personligsheds indflydelse på forretningsrelationer

14. Jane Thostrup Jagd
Hvorfor fortsætter fusionsbølgen udover "the tipping point"?
– en empirisk analyse af information og kognitioner om fusioner

15. Gregory Gimpel
Value-driven Adoption and Consumption of Technology: Understanding Technology Decision Making

16. Thomas Stengade Sønderskov
Den nye mulighed
Social innovation i en forretningsmæssig kontekst

17. Jeppe Christoffersen
Donor supported strategic alliances in developing countries

18. Vibeke Vad Baunsgaard
Dominant Ideological Modes of Rationality: Cross functional

integration in the process of product innovation

19. Throstur Olaf Sigurjonsson
Governance Failure and Icelands's Financial Collapse

20. Allan Sall Tang Andersen
Essays on the modeling of risks in interest-rate and inflation markets

21. Heidi Tscherning
Mobile Devices in Social Contexts

22. Birgitte Gorm Hansen
Adapting in the Knowledge Economy
Lateral Strategies for Scientists and Those Who Study Them

23. Kristina Vaarst Andersen
Optimal Levels of Embeddedness
The Contingent Value of Networked Collaboration

24. Justine Grønbæk Pors
Noisy Management
A History of Danish School Governing from 1970-2010

25. Stefan Linder
Micro-foundations of Strategic Entrepreneurship
Essays on Autonomous Strategic Action

26. Xin Li
Toward an Integrative Framework of National Competitiveness
An application to China

27. Rune Thorbjørn Clausen
Værdifuld arkitektur
Et eksplorativt studie af bygningers rolle i virksomheders værdiskabelse

28. Monica Viken
Markedsundersøkelser som bevis i varemerke- og markedsføringsrett

29. Christian Wymann
Tattooing
The Economic and Artistic Constitution of a Social Phenomenon

30. Sanne Frandsen
Productive Incoherence
A Case Study of Branding and Identity Struggles in a Low-Prestige Organization

31. Mads Stenbo Nielsen
Essays on Correlation Modelling

32. Ivan Häuser
Følelse og sprog
Etablering af en ekspressiv kategori, eksemplificeret på russisk

33. Sebastian Schwenen
Security of Supply in Electricity Markets

2012

1. Peter Holm Andreasen
The Dynamics of Procurement Management
- A Complexity Approach

2. Martin Haulrich
Data-Driven Bitext Dependency Parsing and Alignment

3. Line Kirkegaard
Konsulenten i den anden nat
En undersøgelse af det intense arbejdsliv

4. Tonny Stenheim
Decision usefulness of goodwill under IFRS

5. Morten Lind Larsen
Produktivitet, vækst og velfærd
Industrirådet og efterkrigstidens Danmark 1945 - 1958

6. Petter Berg
Cartel Damages and Cost Asymmetries

7. Lynn Kahle
Experiential Discourse in Marketing
A methodical inquiry into practice and theory

8. Anne Roelsgaard Obling
Management of Emotions in Accelerated Medical Relationships

9. Thomas Frandsen
Managing Modularity of Service Processes Architecture

10. Carina Christine Skovmøller
CSR som noget særligt
Et casestudie om styring og meningsskabelse i relation til CSR ud fra en intern optik

11. Michael Tell
Fradragsbeskæring af selskabers finansieringsudgifter
En skatteretlig analyse af SEL §§ 11, 11B og 11C

12. Morten Holm
Customer Profitability Measurement Models
Their Merits and Sophistication across Contexts

13. Katja Joo Dyppel
Beskatning af derivater
En analyse af dansk skatteret

14. Esben Anton Schultz
Essays in Labor Economics
Evidence from Danish Micro Data

15. Carina Risvig Hansen
"Contracts not covered, or not fully covered, by the Public Sector Directive"

16. Anja Svejgaard Pors
Iværksættelse af kommunikation
- patientfigurer i hospitalets strategiske kommunikation

17. Frans Bévort
Making sense of management with logics
An ethnographic study of accountants who become managers

18. René Kallestrup
The Dynamics of Bank and Sovereign Credit Risk

19. Brett Crawford
Revisiting the Phenomenon of Interests in Organizational Institutionalism
The Case of U.S. Chambers of Commerce

20. Mario Daniele Amore
Essays on Empirical Corporate Finance

21. Arne Stjernholm Madsen
The evolution of innovation strategy
Studied in the context of medical device activities at the pharmaceutical company Novo Nordisk A/S in the period 1980-2008

22. Jacob Holm Hansen
Is Social Integration Necessary for Corporate Branding?
A study of corporate branding strategies at Novo Nordisk

23. Stuart Webber
Corporate Profit Shifting and the Multinational Enterprise

24. Helene Ratner
Promises of Reflexivity
Managing and Researching Inclusive Schools

25. Therese Strand
The Owners and the Power: Insights from Annual General Meetings

26. Robert Gavin Strand
In Praise of Corporate Social Responsibility Bureaucracy

27. Nina Sormunen
Auditor's going-concern reporting
Reporting decision and content of the report

28. John Bang Mathiasen
Learning within a product development working practice:
- an understanding anchored in pragmatism

29. Philip Holst Riis
Understanding Role-Oriented Enterprise Systems: From Vendors to Customers

30. Marie Lisa Dacanay
Social Enterprises and the Poor
Enhancing Social Entrepreneurship and Stakeholder Theory

31. Fumiko Kano Glückstad
Bridging Remote Cultures: Cross-lingual concept mapping based on the information receiver's prior-knowledge

32. Henrik Barslund Fosse
Empirical Essays in International Trade

33. Peter Alexander Albrecht
Foundational hybridity and its reproduction
Security sector reform in Sierra Leone

34. Maja Rosenstock
CSR - hvor svært kan det være?
Kulturanalytisk casestudie om udfordringer og dilemmaer med at forankre Coops CSR-strategi

35. Jeanette Rasmussen
Tweens, medier og forbrug
Et studie af 10-12 årige danske børns brug af internettet, opfattelse og forståelse af markedsføring og forbrug

36. Ib Tunby Gulbrandsen
'This page is not intended for a US Audience'
A five-act spectacle on online communication, collaboration & organization.

37. Kasper Aalling Teilmann
Interactive Approaches to Rural Development

38. Mette Mogensen
The Organization(s) of Well-being and Productivity
(Re)assembling work in the Danish Post

39. Søren Friis Møller
From Disinterestedness to Engagement
Towards Relational Leadership In the Cultural Sector

40. Nico Peter Berhausen
Management Control, Innovation and Strategic Objectives – Interactions and Convergence in Product Development Networks

41. Balder Onarheim
Creativity under Constraints
Creativity as Balancing 'Constrainedness'

42. Haoyong Zhou
Essays on Family Firms

43. Elisabeth Naima Mikkelsen
Making sense of organisational conflict
An empirical study of enacted sense-making in everyday conflict at work

2013

1. Jacob Lyngsie
Entrepreneurship in an Organizational Context

2. Signe Groth-Brodersen
Fra ledelse til selvet
En socialpsykologisk analyse af forholdet imellem selvledelse, ledelse og stress i det moderne arbejdsliv

3. Nis Høyrup Christensen
Shaping Markets: A Neoinstitutional Analysis of the Emerging Organizational Field of Renewable Energy in China

4. Christian Edelvold Berg
As a matter of size
THE IMPORTANCE OF CRITICAL MASS AND THE CONSEQUENCES OF SCARCITY FOR TELEVISION MARKETS

5. Christine D. Isakson
Coworker Influence and Labor Mobility
Essays on Turnover, Entrepreneurship and Location Choice in the Danish Maritime Industry

6. Niels Joseph Jerne Lennon
Accounting Qualities in Practice
Rhizomatic stories of representational faithfulness, decision making and control

7. Shannon O'Donnell
Making Ensemble Possible
How special groups organize for collaborative creativity in conditions of spatial variability and distance

8. Robert W. D. Veitch
Access Decisions in a
Partly-Digital World
Comparing Digital Piracy and Legal Modes for Film and Music

9. Marie Mathiesen
Making Strategy Work
An Organizational Ethnography

10. Arisa Shollo
The role of business intelligence in organizational decision-making

11. Mia Kaspersen
The construction of social and environmental reporting

12. Marcus Møller Larsen
The organizational design of offshoring

13. Mette Ohm Rørdam
EU Law on Food Naming
The prohibition against misleading names in an internal market context

14. Hans Peter Rasmussen
GIV EN GED!
Kan giver-idealtyper forklare støtte til velgørenhed og understøtte relationsopbygning?

15. Ruben Schachtenhaufen
Fonetisk reduktion i dansk

16. Peter Koerver Schmidt
Dansk CFC-beskatning
I et internationalt og komparativt perspektiv

17. Morten Froholdt
Strategi i den offentlige sektor
En kortlægning af styringsmæssig kontekst, strategisk tilgang, samt anvendte redskaber og teknologier for udvalgte danske statslige styrelser

18. Annette Camilla Sjørup
Cognitive effort in metaphor translation
An eye-tracking and key-logging study

19. Tamara Stucchi
The Internationalization of Emerging Market Firms:
A Context-Specific Study

20. Thomas Lopdrup-Hjorth
"Let's Go Outside":
The Value of Co-Creation

21. Ana Alačovska
Genre and Autonomy in Cultural Production
The case of travel guidebook production

22. Marius Gudmand-Høyer
Stemningssindssygdommenes historie i det 19. århundrede
Omtydningen af melankolien og manien som bipolære stemningslidelser i dansk sammenhæng under hensyn til dannelsen af det moderne følelseslivs relative autonomi.
En problematiserings- og erfarings-analytisk undersøgelse

23. Lichen Alex Yu
Fabricating an S&OP Process
Circulating References and Matters of Concern

24. Esben Alfort
The Expression of a Need
Understanding search

25. Trine Pallesen
Assembling Markets for Wind Power
An Inquiry into the Making of Market Devices

26. Anders Koed Madsen
Web-Visions
Repurposing digital traces to organize social attention

27. Lærke Højgaard Christiansen
BREWING ORGANIZATIONAL RESPONSES TO INSTITUTIONAL LOGICS

28. Tommy Kjær Lassen
EGENTLIG SELVLEDELSE
En ledelsesfilosofisk afhandling om selvledelsens paradoksale dynamik og eksistentielle engagement

29. Morten Rossing
Local Adaption and Meaning Creation in Performance Appraisal

30. Søren Obed Madsen
Lederen som oversætter
Et oversættelsesteoretisk perspektiv på strategisk arbejde

31. Thomas Høgenhaven
Open Government Communities
Does Design Affect Participation?

32. Kirstine Zinck Pedersen
Failsafe Organizing?
A Pragmatic Stance on Patient Safety

33. Anne Petersen
Hverdagslogikker i psykiatrisk arbejde
En institutionsetnografisk undersøgelse af hverdagen i psykiatriske organisationer

34. Didde Maria Humle
Fortællinger om arbejde

35. Mark Holst-Mikkelsen
Strategieksekvering i praksis
– barrierer og muligheder!

36. Malek Maalouf
Sustaining lean
Strategies for dealing with organizational paradoxes

37. Nicolaj Tofte Brenneche
Systemic Innovation In The Making
The Social Productivity of Cartographic Crisis and Transitions in the Case of SEEIT

38. Morten Gylling
The Structure of Discourse
A Corpus-Based Cross-Linguistic Study

39. Binzhang YANG
Urban Green Spaces for Quality Life
- Case Study: the landscape architecture for people in Copenhagen

40. Michael Friis Pedersen
Finance and Organization:
The Implications for Whole Farm Risk Management

41. Even Fallan
Issues on supply and demand for environmental accounting information

42. Ather Nawaz
Website user experience
A cross-cultural study of the relation between users´ cognitive style, context of use, and information architecture of local websites

43. Karin Beukel
The Determinants for Creating Valuable Inventions

44. Arjan Markus
External Knowledge Sourcing and Firm Innovation
Essays on the Micro-Foundations of Firms' Search for Innovation

2014

1. Solon Moreira
Four Essays on Technology Licensing and Firm Innovation

2. Karin Strzeletz Ivertsen
Partnership Drift in Innovation Processes
A study of the Think City electric car development

3. Kathrine Hoffmann Pii
Responsibility Flows in Patient-centred Prevention

4. Jane Bjørn Vedel
Managing Strategic Research
An empirical analysis of science-industry collaboration in a pharmaceutical company

5. Martin Gylling
Processuel strategi i organisationer
Monografi om dobbeltheden i tænkning af strategi, dels som vidensfelt i organisationsteori, dels som kunstnerisk tilgang til at skabe i erhvervsmæssig innovation

6. Linne Marie Lauesen
Corporate Social Responsibility in the Water Sector: How Material Practices and their Symbolic and Physical Meanings Form a Colonising Logic

7. Maggie Qiuzhu Mei
LEARNING TO INNOVATE: The role of ambidexterity, standard, and decision process

8. Inger Høedt-Rasmussen
Developing Identity for Lawyers Towards Sustainable Lawyering

9. Sebastian Fux
Essays on Return Predictability and Term Structure Modelling

10. Thorbjørn N. M. Lund-Poulsen
Essays on Value Based Management

11. Oana Brindusa Albu
Transparency in Organizing: A Performative Approach

12. Lena Olaison
Entrepreneurship at the limits

13. Hanne Sørum
DRESSED FOR WEB SUCCESS? An Empirical Study of Website Quality in the Public Sector

14. Lasse Folke Henriksen
Knowing networks How experts shape transnational governance

15. Maria Halbinger
Entrepreneurial Individuals Empirical Investigations into Entrepreneurial Activities of Hackers and Makers

16. Robert Spliid
Kapitalfondenes metoder og kompetencer

17. Christiane Stelling
Public-private partnerships & the need, development and management of trusting A processual and embedded exploration

18. Marta Gasparin
Management of design as a translation process

19. Kåre Moberg
Assessing the Impact of Entrepreneurship Education From ABC to PhD

20. Alexander Cole
Distant neighbors Collective learning beyond the cluster

21. Martin Møller Boje Rasmussen
Is Competitiveness a Question of Being Alike? How the United Kingdom, Germany and Denmark Came to Compete through their Knowledge Regimes from 1993 to 2007

22. Anders Ravn Sørensen
Studies in central bank legitimacy, currency and national identity Four cases from Danish monetary history

23. Nina Bellak
Can Language be Managed in International Business? Insights into Language Choice from a Case Study of Danish and Austrian Multinational Corporations (MNCs)

24. Rikke Kristine Nielsen
Global Mindset as Managerial Meta-competence and Organizational Capability: Boundary-crossing Leadership Cooperation in the MNC The Case of 'Group Mindset' in Solar A/S.

25. Rasmus Koss Hartmann
User Innovation inside government Towards a critically performative foundation for inquiry

26. Kristian Gylling Olesen
Flertydig og emergerende ledelse i folkeskolen
Et aktør-netværksteoretisk ledelses-studie af politiske evalueringsreformers betydning for ledelse i den danske folkeskole

27. Troels Riis Larsen
Kampen om Danmarks omdømme 1945-2010
Omdømmearbejde og omdømmepolitik

28. Klaus Majgaard
Jagten på autenticitet i offentlig styring

29. Ming Hua Li
Institutional Transition and Organizational Diversity: Differentiated internationalization strategies of emerging market state-owned enterprises

30. Sofie Blinkenberg Federspiel
IT, organisation og digitalisering: Institutionelt arbejde i den kommunale digitaliseringsproces

31. Elvi Weinreich
Hvilke offentlige ledere er der brug for når velfærdstænkningen flytter sig – er Diplomuddannelsens lederprofil svaret?

32. Ellen Mølgaard Korsager
Self-conception and image of context in the growth of the firm – A Penrosian History of Fiberline Composites

33. Else Skjold
The Daily Selection

34. Marie Louise Conradsen
The Cancer Centre That Never Was
The Organisation of Danish Cancer Research 1949-1992

35. Virgilio Failla
Three Essays on the Dynamics of Entrepreneurs in the Labor Market

36. Nicky Nedergaard
Brand-Based Innovation
Relational Perspectives on Brand Logics and Design Innovation Strategies and Implementation

37. Mads Gjedsted Nielsen
Essays in Real Estate Finance

38. Kristin Martina Brandl
Process Perspectives on Service Offshoring

39. Mia Rosa Koss Hartmann
In the gray zone
With police in making space for creativity

40. Karen Ingerslev
Healthcare Innovation under The Microscope
Framing Boundaries of Wicked Problems

41. Tim Neerup Themsen
Risk Management in large Danish public capital investment programmes

2015

1. Jakob Ion Wille
Film som design
Design af levende billeder i film og tv-serier

2. Christiane Mossin
Interzones of Law and Metaphysics
Hierarchies, Logics and Foundations of Social Order seen through the Prism of EU Social Rights

3. Thomas Tøth
TRUSTWORTHINESS: ENABLING GLOBAL COLLABORATION
An Ethnographic Study of Trust, Distance, Control, Culture and Boundary Spanning within Offshore Outsourcing of IT Services

4. Steven Højlund
Evaluation Use in Evaluation Systems – The Case of the European Commission

5. Julia Kirch Kirkegaard
AMBIGUOUS WINDS OF CHANGE – OR FIGHTING AGAINST WINDMILLS IN CHINESE WIND POWER
A CONSTRUCTIVIST INQUIRY INTO CHINA'S PRAGMATICS OF GREEN MARKETISATION MAPPING CONTROVERSIES OVER A POTENTIAL TURN TO QUALITY IN CHINESE WIND POWER

6. Michelle Carol Antero
A Multi-case Analysis of the Development of Enterprise Resource Planning Systems (ERP) Business Practices

Morten Friis-Olivarius
The Associative Nature of Creativity

7. Mathew Abraham
New Cooperativism:
A study of emerging producer organisations in India

8. Stine Hedegaard
Sustainability-Focused Identity: Identity work performed to manage, negotiate and resolve barriers and tensions that arise in the process of constructing or ganizational identity in a sustainability context

9. Cecilie Glerup
Organizing Science in Society – the conduct and justification of resposible research

10. Allan Salling Pedersen
Implementering af ITIL® IT-governance - når best practice konflikter med kulturen Løsning af implementerings-problemer gennem anvendelse af kendte CSF i et aktionsforskningsforløb.

11. Nihat Misir
A Real Options Approach to Determining Power Prices

12. Mamdouh Medhat
MEASURING AND PRICING THE RISK OF CORPORATE FAILURES

13. Rina Hansen
Toward a Digital Strategy for Omnichannel Retailing

14. Eva Pallesen
In the rhythm of welfare creation
A relational processual investigation moving beyond the conceptual horizon of welfare management

15. Gouya Harirchi
In Search of Opportunities: Three Essays on Global Linkages for Innovation

16. Lotte Holck
Embedded Diversity: A critical ethnographic study of the structural tensions of organizing diversity

17. Jose Daniel Balarezo
Learning through Scenario Planning

18. Louise Pram Nielsen
Knowledge dissemination based on terminological ontologies. Using eye tracking to further user interface design.

19. Sofie Dam
PUBLIC-PRIVATE PARTNERSHIPS FOR INNOVATION AND SUSTAINABILITY TRANSFORMATION
An embedded, comparative case study of municipal waste management in England and Denmark

20. Ulrik Hartmyer Christiansen
Follwoing the Content of Reported Risk Across the Organization

21. Guro Refsum Sanden
Language strategies in multinational corporations. A cross-sector study of financial service companies and manufacturing companies.

22. Linn Gevoll
Designing performance management for operational level
- A closer look on the role of design choices in framing coordination and motivation

23. Frederik Larsen
Objects and Social Actions
– on Second-hand Valuation Practices

24. Thorhildur Hansdottir Jetzek
The Sustainable Value of Open Government Data
Uncovering the Generative Mechanisms of Open Data through a Mixed Methods Approach

25. Gustav Toppenberg
Innovation-based M&A
– Technological-Integration Challenges – The Case of Digital-Technology Companies

26. Mie Plotnikof
Challenges of Collaborative Governance
An Organizational Discourse Study of Public Managers' Struggles with Collaboration across the Daycare Area

27. Christian Garmann Johnsen
Who Are the Post-Bureaucrats?
A Philosophical Examination of the Creative Manager, the Authentic Leader and the Entrepreneur

28. Jacob Brogaard-Kay
Constituting Performance Management
A field study of a pharmaceutical company

29. Rasmus Ploug Jenle
Engineering Markets for Control: Integrating Wind Power into the Danish Electricity System

30. Morten Lindholst
Complex Business Negotiation: Understanding Preparation and Planning

31. Morten Grynings
TRUST AND TRANSPARENCY FROM AN ALIGNMENT PERSPECTIVE

32. Peter Andreas Norn
Byregimer og styringsevne: Politisk lederskab af store byudviklingsprojekter

33. Milan Miric
Essays on Competition, Innovation and Firm Strategy in Digital Markets

34. Sanne K. Hjordrup
The Value of Talent Management
Rethinking practice, problems and possibilities

35. Johanna Sax
Strategic Risk Management
– Analyzing Antecedents and Contingencies for Value Creation

36. Pernille Rydén
Strategic Cognition of Social Media

37. Mimmi Sjöklint
The Measurable Me
- The Influence of Self-tracking on the User Experience

38. Juan Ignacio Staricco
Towards a Fair Global Economic Regime? A critical assessment of Fair Trade through the examination of the Argentinean wine industry

39. Marie Henriette Madsen
Emerging and temporary connections in Quality work

40. Yangfeng CAO
Toward a Process Framework of Business Model Innovation in the Global Context
Entrepreneurship-Enabled Dynamic Capability of Medium-Sized Multinational Enterprises

41. Carsten Scheibye
Enactment of the Organizational Cost Structure in Value Chain Configuration
A Contribution to Strategic Cost Management

2016

1. Signe Sofie Dyrby
Enterprise Social Media at Work

2. Dorte Boesby Dahl
The making of the public parking attendant
Dirt, aesthetics and inclusion in public service work

3. Verena Girschik
Realizing Corporate Responsibility Positioning and Framing in Nascent Institutional Change

4. Anders Ørding Olsen
IN SEARCH OF SOLUTIONS
Inertia, Knowledge Sources and Diversity in Collaborative Problem-solving

5. Pernille Steen Pedersen
Udkast til et nyt copingbegreb
En kvalifikation af ledelsesmuligheder for at forebygge sygefravær ved psykiske problemer.

6. Kerli Kant Hvass
Weaving a Path from Waste to Value: Exploring fashion industry business models and the circular economy

7. Kasper Lindskow
Exploring Digital News Publishing Business Models – a production network approach

8. Mikkel Mouritz Marfelt
The chameleon workforce: Assembling and negotiating the content of a workforce

9. Marianne Bertelsen
Aesthetic encounters
Rethinking autonomy, space & time in today's world of art

10. Louise Hauberg Wilhelmsen
EU PERSPECTIVES ON INTERNATIONAL COMMERCIAL ARBITRATION

11. Abid Hussain
On the Design, Development and Use of the Social Data Analytics Tool (SODATO): Design Propositions, Patterns, and Principles for Big Social Data Analytics

12. Mark Bruun
Essays on Earnings Predictability

13. Tor Bøe-Lillegraven
BUSINESS PARADOXES, BLACK BOXES, AND BIG DATA: BEYOND ORGANIZATIONAL AMBIDEXTERITY

14. Hadis Khonsary-Atighi
ECONOMIC DETERMINANTS OF DOMESTIC INVESTMENT IN AN OIL-BASED ECONOMY: THE CASE OF IRAN (1965-2010)

15. Maj Lervad Grasten
Rule of Law or Rule by Lawyers?
On the Politics of Translation in Global Governance

16. Lene Granzau Juel-Jacobsen
SUPERMARKEDETS MODUS OPERANDI – en hverdagssociologisk undersøgelse af forholdet mellem rum og handlen og understøtte relationsopbygning?

17. Christine Thalsgård Henriques
In search of entrepreneurial learning – Towards a relational perspective on incubating practices?

18. Patrick Bennett
Essays in Education, Crime, and Job Displacement

19. Søren Korsgaard
Payments and Central Bank Policy

20. Marie Kruse Skibsted
Empirical Essays in Economics of Education and Labor

21. Elizabeth Benedict Christensen
The Constantly Contingent Sense of Belonging of the 1.5 Generation Undocumented Youth
An Everyday Perspective

22. Lasse J. Jessen
Essays on Discounting Behavior and Gambling Behavior

23. Kalle Johannes Rose
Når stifterviljen dør…
Et retsøkonomisk bidrag til 200 års juridisk konflikt om ejendomsretten

24. Andreas Søeborg Kirkedal
Danish Stød and Automatic Speech Recognition

25. Ida Lunde Jørgensen
Institutions and Legitimations in Finance for the Arts

26. Olga Rykov Ibsen
An empirical cross-linguistic study of directives: A semiotic approach to the sentence forms chosen by British, Danish and Russian speakers in native and ELF contexts

27. Desi Volker
Understanding Interest Rate Volatility

28. Angeli Elizabeth Weller
Practice at the Boundaries of Business Ethics & Corporate Social Responsibility

29. Ida Danneskiold-Samsøe
Levende læring i kunstneriske organisationer
En undersøgelse af læringsprocesser mellem projekt og organisation på Aarhus Teater

30. Leif Christensen
Quality of information – The role of internal controls and materiality

31. Olga Zarzecka
Tie Content in Professional Networks

32. Henrik Mahncke
De store gaver
- Filantropiens gensidighedsrelationer i teori og praksis

33. Carsten Lund Pedersen
Using the Collective Wisdom of Frontline Employees in Strategic Issue Management

34. Yun Liu
Essays on Market Design

35. Denitsa Hazarbassanova Blagoeva
The Internationalisation of Service Firms

36. Manya Jaura Lind
Capability development in an off-shoring context: How, why and by whom

37. Luis R. Boscán F.
Essays on the Design of Contracts and Markets for Power System Flexibility

38. Andreas Philipp Distel
Capabilities for Strategic Adaptation: Micro-Foundations, Organizational Conditions, and Performance Implications

39. Lavinia Bleoca
The Usefulness of Innovation and Intellectual Capital in Business Performance: The Financial Effects of Knowledge Management vs. Disclosure

40. Henrik Jensen
Economic Organization and Imperfect Managerial Knowledge: A Study of the Role of Managerial Meta-Knowledge in the Management of Distributed Knowledge

41. Stine Mosekjær
The Understanding of English Emotion Words by Chinese and Japanese Speakers of English as a Lingua Franca An Empirical Study

42. Hallur Tor Sigurdarson
The Ministry of Desire - Anxiety and entrepreneurship in a bureaucracy

43. Kätlin Pulk
Making Time While Being in Time
A study of the temporality of organizational processes

44. Valeria Giacomin
Contextualizing the cluster Palm oil in Southeast Asia in global perspective (1880s–1970s)

45. Jeanette Willert
Managers' use of multiple Management Control Systems: The role and interplay of management control systems and company performance

46. Mads Vestergaard Jensen
Financial Frictions: Implications for Early Option Exercise and Realized Volatility

47. Mikael Reimer Jensen
Interbank Markets and Frictions

48. Benjamin Faigen
Essays on Employee Ownership

49. Adela Michea
Enacting Business Models
An Ethnographic Study of an Emerging Business Model Innovation within the Frame of a Manufacturing Company.

50. Iben Sandal Stjerne
Transcending organization in temporary systems
Aesthetics' organizing work and employment in Creative Industries

51. Simon Krogh
Anticipating Organizational Change

52. Sarah Netter
Exploring the Sharing Economy

53. Lene Tolstrup Christensen
State-owned enterprises as institutional market actors in the marketization of public service provision:
A comparative case study of Danish and Swedish passenger rail 1990–2015

54. Kyoung(Kay) Sun Park
Three Essays on Financial Economics

2017

1. Mari Bjerck
Apparel at work. Work uniforms and women in male-dominated manual occupations.

2. Christoph H. Flöthmann
Who Manages Our Supply Chains? Backgrounds, Competencies and Contributions of Human Resources in Supply Chain Management

3. Aleksandra Anna Rzeźnik
Essays in Empirical Asset Pricing

4. Claes Bäckman
Essays on Housing Markets

5. Kirsti Reitan Andersen
Stabilizing Sustainability
in the Textile and Fashion Industry

6. Kira Hoffmann
Cost Behavior: An Empirical Analysis of Determinants and Consequences of Asymmetries

7. Tobin Hanspal
Essays in Household Finance

8. Nina Lange
Correlation in Energy Markets

9. Anjum Fayyaz
Donor Interventions and SME Networking in Industrial Clusters in Punjab Province, Pakistan

10. Magnus Paulsen Hansen
Trying the unemployed. Justification and critique, emancipation and coercion towards the 'active society'. A study of contemporary reforms in France and Denmark

11. Sameer Azizi
Corporate Social Responsibility in Afghanistan
– a critical case study of the mobile telecommunications industry

12. Malene Myhre
The internationalization of small and medium-sized enterprises: A qualitative study

13. Thomas Presskorn-Thygesen
The Significance of Normativity – Studies in Post-Kantian Philosophy and Social Theory

14. Federico Clementi
Essays on multinational production and international trade

15. Lara Anne Hale
Experimental Standards in Sustainability Transitions: Insights from the Building Sector

16. Richard Pucci
Accounting for Financial Instruments in an Uncertain World
Controversies in IFRS in the Aftermath of the 2008 Financial Crisis

17. Sarah Maria Denta
Kommunale offentlige private partnerskaber
Regulering I skyggen af Farumsagen

18. Christian Östlund
Design for e-training

19. Amalie Martinus Hauge
Organizing Valuations – a pragmatic inquiry

20. Tim Holst Celik
Tension-filled Governance? Exploring the Emergence, Consolidation and Reconfiguration of Legitimatory and Fiscal State-crafting

21. Christian Bason
Leading Public Design: How managers engage with design to transform public governance

22. Davide Tomio
Essays on Arbitrage and Market Liquidity

23. Simone Stæhr
Financial Analysts' Forecasts
Behavioral Aspects and the Impact of Personal Characteristics

24. Mikkel Godt Gregersen
Management Control, Intrinsic Motivation and Creativity
– How Can They Coexist

25. Kristjan Johannes Suse Jespersen
Advancing the Payments for Ecosystem Service Discourse Through Institutional Theory

26. Kristian Bondo Hansen
Crowds and Speculation: A study of crowd phenomena in the U.S. financial markets 1890 to 1940

27. Lars Balslev
Actors and practices – An institutional study on management accounting change in Air Greenland

28. Sven Klingler
Essays on Asset Pricing with Financial Frictions

29. Klement Ahrensbach Rasmussen
Business Model Innovation
The Role of Organizational Design

30. Giulio Zichella
Entrepreneurial Cognition.
Three essays on entrepreneurial behavior and cognition under risk and uncertainty

31. Richard Ledborg Hansen
En forkærlighed til det eksisterende – mellemlederens oplevelse af forandringsmodstand i organisatoriske forandringer

32. Vilhelm Stefan Holsting
Militært chefvirke: Kritik og retfærdiggørelse mellem politik og profession

33. Thomas Jensen
Shipping Information Pipeline: An information infrastructure to improve international containerized shipping

34. Dzmitry Bartalevich
Do economic theories inform policy? Analysis of the influence of the Chicago School on European Union competition policy

35. Kristian Roed Nielsen
Crowdfunding for Sustainability: A study on the potential of reward-based crowdfunding in supporting sustainable entrepreneurship

36. Emil Husted
There is always an alternative: A study of control and commitment in political organization

37. Anders Ludvig Sevelsted
Interpreting Bonds and Boundaries of Obligation. A genealogy of the emergence and development of Protestant voluntary social work in Denmark as shown through the cases of the Copenhagen Home Mission and the Blue Cross (1850 – 1950)

38. Niklas Kohl
Essays on Stock Issuance

39. Maya Christiane Flensborg Jensen
BOUNDARIES OF PROFESSIONALIZATION AT WORK An ethnography-inspired study of care workers' dilemmas at the margin

40. Andreas Kamstrup
Crowdsourcing and the Architectural Competition as Organisational Technologies

41. Louise Lyngfeldt Gorm Hansen
Triggering Earthquakes in Science, Politics and Chinese Hydropower - A Controversy Study

2018

1. Vishv Priya Kohli
Combatting Falsifi cation and Counterfeiting of Medicinal Products in the E uropean Union – A Legal Analysis

2. Helle Haurum
Customer Engagement Behavior in the context of Continuous Service Relationships

3. Nis Grünberg
The Party -state order: Essays on China's political organization and political economic institutions

4. Jesper Christensen
A Behavioral Theory of Human Capital Integration

5. Poula Marie Helth
Learning in practice

6. Rasmus Vendler Toft-Kehler
Entrepreneurship as a career? An investigation of the relationship between entrepreneurial experience and entrepreneurial outcome

7. Szymon Furtak
Sensing the Future: Designing sensor-based predictive information systems for forecasting spare part demand for diesel engines

8. Mette Brehm Johansen
Organizing patient involvement. An ethnographic study

9. Iwona Sulinska
Complexities of Social Capital in Boards of Directors

10. Cecilie Fanøe Petersen
Award of public contracts as a means to conferring State aid: A legal analysis of the interface between public procurement law and State aid law

11. Ahmad Ahmad Barirani
Three Experimental Studies on Entrepreneurship

12. Carsten Allerslev Olsen
Financial Reporting Enforcement: Impact and Consequences

13. Irene Christensen
New product fumbles – Organizing for the Ramp-up process

14. Jacob Taarup-Esbensen
Managing communities – Mining MNEs' community risk management practices

15. Lester Allan Lasrado
Set-Theoretic approach to maturity models

16. Mia B. Münster
Intention vs. Perception of Designed Atmospheres in Fashion Stores

17. Anne Sluhan
Non-Financial Dimensions of Family Firm Ownership: How Socioemotional Wealth and Familiness Influence Internationalization

18. Henrik Yde Andersen
Essays on Debt and Pensions

19. Fabian Heinrich Müller
Valuation Reversed – When Valuators are Valuated. An Analysis of the Perception of and Reaction to Reviewers in Fine-Dining

20. Martin Jarmatz
Organizing for Pricing

21. Niels Joachim Christfort Gormsen
Essays on Empirical Asset Pricing

22. Diego Zunino
Socio-Cognitive Perspectives in Business Venturing

23. Benjamin Asmussen
Networks and Faces between Copenhagen and Canton, 1730-1840

24. Dalia Bagdziunaite
Brains at Brand Touchpoints A Consumer Neuroscience Study of Information Processing of Brand Advertisements and the Store Environment in Compulsive Buying

25. Erol Kazan
Towards a Disruptive Digital Platform Model

26. Andreas Bang Nielsen
Essays on Foreign Exchange and Credit Risk

27. Anne Krebs
Accountable, Operable Knowledge Toward Value Representations of Individual Knowledge in Accounting

28. Matilde Fogh Kirkegaard
A firm- and demand-side perspective on behavioral strategy for value creation: Insights from the hearing aid industry

29. Agnieszka Nowinska
SHIPS AND RELATION-SHIPS Tie formation in the sector of shipping intermediaries in shipping

30. Stine Evald Bentsen
The Comprehension of English Texts by Native Speakers of English and Japanese, Chinese and Russian Speakers of English as a Lingua Franca. An Empirical Study.

31. Stine Louise Daetz
Essays on Financial Frictions in Lending Markets

32. *Christian Skov Jensen*
Essays on Asset Pricing

33. Anders Kryger
Aligning future employee action and corporate strategy in a resource-scarce environment

34. Maitane Elorriaga-Rubio
The behavioral foundations of strategic decision-making: A contextual perspective

35. Roddy Walker
Leadership Development as Organisational Rehabilitation: Shaping Middle-Managers as Double Agents

36. Jinsun Bae
Producing Garments for Global Markets Corporate social responsibility (CSR) in Myanmar's export garment industry 2011–2015

37. Queralt Prat-i-Pubill
Axiological knowledge in a knowledge driven world. Considerations for organizations.

38. Pia Mølgaard
Essays on Corporate Loans and Credit Risk

39. Marzia Aricò
Service Design as a Transformative Force: Introduction and Adoption in an Organizational Context

40. Christian Dyrlund Wåhlin-Jacobsen
Constructing change initiatives in workplace voice activities Studies from a social interaction perspective

41. Peter Kalum Schou
Institutional Logics in Entrepreneurial Ventures: How Competing Logics arise and shape organizational processes and outcomes during scale-up

42. Per Henriksen
Enterprise Risk Management Rationaler og paradokser i en moderne ledelsesteknologi

43. Maximilian Schellmann
The Politics of Organizing Refugee Camps

44. Jacob Halvas Bjerre
Excluding the Jews: The Aryanization of Danish-German Trade and German Anti-Jewish Policy in Denmark 1937-1943

45. Ida Schrøder
Hybridising accounting and caring: A symmetrical study of how costs and needs are connected in Danish child protection work

46. Katrine Kunst
Electronic Word of Behavior: Transforming digital traces of consumer behaviors into communicative content in product design

47. Viktor Avlonitis
Essays on the role of modularity in management: Towards a unified perspective of modular and integral design

48. Anne Sofie Fischer
Negotiating Spaces of Everyday Politics: -An ethnographic study of organizing for social transformation for women in urban poverty, Delhi, India

2019

1. Shihan Du
ESSAYS IN EMPIRICAL STUDIES BASED ON ADMINISTRATIVE LABOUR MARKET DATA

2. Mart Laatsit
Policy learning in innovation policy: A comparative analysis of European Union member states

3. Peter J. Wynne
Proactively Building Capabilities for the Post-Acquisition Integration of Information Systems

4. Kalina S. Staykova
Generative Mechanisms for Digital Platform Ecosystem Evolution

5. Ieva Linkeviciute
Essays on the Demand-Side Management in Electricity Markets

6. Jonatan Echebarria Fernández
Jurisdiction and Arbitration Agreements in Contracts for the Carriage of Goods by Sea – Limitations on Party Autonomy

7. Louise Thorn Bøttkjær
Votes for sale. Essays on clientelism in new democracies.

8. Ditte Vilstrup Holm
The Poetics of Participation: the organizing of participation in contemporary art

9. Philip Rosenbaum
Essays in Labor Markets – Gender, Fertility and Education

10. Mia Olsen
Mobile Betalinger - Succesfaktorer og Adfærdsmæssige Konsekvenser

11. Adrián Luis Mérida Gutiérrez
Entrepreneurial Careers: Determinants, Trajectories, and Outcomes

12. Frederik Regli
Essays on Crude Oil Tanker Markets

13. Cancan Wang
Becoming Adaptive through Social Media: Transforming Governance and Organizational Form in Collaborative E-government

14. Lena Lindbjerg Sperling
Economic and Cultural Development: Empirical Studies of Micro-level Data

15. Xia Zhang
Obligation, face and facework: An empirical study of the communicative act of cancellation of an obligation by Chinese, Danish and British business professionals in both L1 and ELF contexts

16. Stefan Kirkegaard Sløk-Madsen
Entrepreneurial Judgment and Commercialization

17. Erin Leitheiser
The Comparative Dynamics of Private Governance
The case of the Bangladesh Ready-Made Garment Industry

18. Lone Christensen
STRATEGIIMPLEMENTERING: STYRINGSBESTRÆBELSER, IDENTITET OG AFFEKT

19. Thomas Kjær Poulsen
Essays on Asset Pricing with Financial Frictions

20. Maria Lundberg
Trust and self-trust in leadership identity constructions: A qualitative exploration of narrative ecology in the discursive aftermath of heroic discourse

21. Tina Joanes
Sufficiency for sustainability
Determinants and strategies for reducing clothing consumption

22. Benjamin Johannes Flesch
Social Set Visualizer (SoSeVi): Design, Development and Evaluation of a Visual Analytics Tool for Computational Set Analysis of Big Social Data

23. Henriette Sophia Groskopff
Tvede Schleimann
Creating innovation through collaboration – Partnering in the maritime sector

24. Kristian Steensen Nielsen
The Role of Self-Regulation in Environmental Behavior Change

25. Lydia L. Jørgensen
Moving Organizational Atmospheres

26. Theodor Lucian Vladasel
Embracing Heterogeneity: Essays in Entrepreneurship and Human Capital

27. Seidi Suurmets
Contextual Effects in Consumer Research: An Investigation of Consumer Information Processing and Behavior via the Applicati on of Eye-tracking Methodology

28. Marie Sundby Palle Nickelsen
Reformer mellem integritet og innovation: Reform af reformens form i den danske centraladministration fra 1920 til 2019

29. Vibeke Kristine Scheller
The temporal organizing of same-day discharge: A tempography of a Cardiac Day Unit

30. Qian Sun
Adopting Artificial Intelligence in Healthcare in the Digital Age: Perceived Challenges, Frame Incongruence, and Social Power

31. Dorthe Thorning Mejlhede
Artful change agency and organizing for innovation – the case of a Nordic fintech cooperative

32. Benjamin Christoffersen
Corporate Default Models: Empirical Evidence and Methodical Contributions

33. Filipe Antonio Bonito Vieira
Essays on Pensions and Fiscal Sustainability

34. Morten Nicklas Bigler Jensen
Earnings Management in Private Firms: An Empirical Analysis of Determinants and Consequences of Earnings Management in Private Firms

2020

1. Christian Hendriksen
Inside the Blue Box: Explaining industry influence in the International Maritime Organization

2. Vasileios Kosmas
Environmental and social issues in global supply chains:
Emission reduction in the maritime transport industry and maritime search and rescue operational response to migration

3. Thorben Peter Simonsen
The spatial organization of psychiatric practice: A situated inquiry into 'healing architecture'

4. Signe Bruskin
The infinite storm: An ethnographic study of organizational change in a bank

5. Rasmus Corlin Christensen
Politics and Professionals: Transnational Struggles to Change International Taxation

6. Robert Lorenz Törmer
The Architectural Enablement of a Digital Platform Strategy

7. Anna Kirkebæk Johansson Gosovic
Ethics as Practice: An ethnographic study of business ethics in a multi-national biopharmaceutical company

8. Frank Meier
Making up leaders in leadership development

9. Kai Basner
Servitization at work: On proliferation and containment

10. Anestis Keremis
Anti-corruption in action: How is anticorruption practiced in multinational companies?

11. Marie Larsen Ryberg
Governing Interdisciolinarity: Stakes and translations of interdisciplinarity in Danish high school education.

12. Jannick Friis Christensen
Queering organisation(s): Norm-critical orientations to organising and researching diversity

13. Thorsteinn Sigurdur Sveinsson
Essays on Macroeconomic Implications of Demographic Change

TITLER I ATV PH.D.-SERIEN

1992

1. Niels Kornum
Servicesamkørsel – organisation, økonomi og planlægningsmetode

1995

2. Verner Worm
Nordiske virksomheder i Kina
Kulturspecifikke interaktionsrelationer ved nordiske virksomhedsetableringer i Kina

1999

3. Mogens Bjerre
Key Account Management of Complex Strategic Relationships
An Empirical Study of the Fast Moving Consumer Goods Industry

2000

4. Lotte Darsø
Innovation in the Making
Interaction Research with heterogeneous Groups of Knowledge Workers creating new Knowledge and new Leads

2001

5. Peter Hobolt Jensen
Managing Strategic Design Identities
The case of the Lego Developer Network

2002

6. Peter Lohmann
The Deleuzian Other of Organizational Change – Moving Perspectives of the Human

7. Anne Marie Jess Hansen
To lead from a distance: The dynamic interplay between strategy and strategizing – A case study of the strategic management process

2003

8. Lotte Henriksen
Videndeling
– om organisatoriske og ledelsesmæssige udfordringer ved videndeling i praksis

9. Niels Christian Nickelsen
Arrangements of Knowing: Coordinating Procedures Tools and Bodies in Industrial Production – a case study of the collective making of new products

2005

10. Carsten Ørts Hansen
Konstruktion af ledelsesteknologier og effektivitet

TITLER I DBA PH.D.-SERIEN

2007

1. Peter Kastrup-Misir
Endeavoring to Understand Market Orientation – and the concomitant co-mutation of the researched, the re searcher, the research itself and the truth

2009

1. Torkild Leo Thellefsen
Fundamental Signs and Significance effects
A Semeiotic outline of Fundamental Signs, Significance-effects, Knowledge Profiling and their use in Knowledge Organization and Branding

2. Daniel Ronzani
When Bits Learn to Walk Don't Make Them Trip. Technological Innovation and the Role of Regulation by Law in Information Systems Research: the Case of Radio Frequency Identification (RFID)

2010

1. Alexander Carnera
Magten over livet og livet som magt
Studier i den biopolitiske ambivalens