A dynamic structural analysis of health and retirement

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Introduction and summary

1. Relevance of the research theme

In the later decades many European countries including Norway have been experiencing a considerable increase in life expectancy accompanied with a tendency for earlier withdrawal from the labour force. In addition to these long term effects, the cohorts of baby boomers are approaching the retirement age. In these circumstances, the financial stability of the social security systems based on the defined benefit principle and where pensions are financed through the social tax on the earnings of the current employees (PAYGO or PAY-AS-YOU-GO), is exposed to a considerable and growing financial threat. Recent forecasts suggest that in the absence of major change in the National Insurance System in Norway (NIS) the expenditure on old age pension will increase from 6 to about 15 percent of mainland Norwegian GDP before year 2050 (Summary of Report to Storting Nr. 12, 2005) with the consequent increase of the tax burden.

To counteract these effects and to increase the stability of the social security systems, the governments are forced to undertake certain policy reforms which are many times of a rather large scale (Lindbeck and Persson, 2003). In Norway, the work on the pension reform has started in 2001 when the Pension Commission was appointed to evaluate the prospects of the NIS. The commission reported in (Nou 2004:1, 2004) that the system is in fact incapable to cope with the growing threats and suggested some policy measures. The retirement age in Norway is already relatively high, but the existence of other exit routes significantly lowers the labour force supply among the older workers. The generous access to the disability pension makes it a second major type of retirement, which accounts for about 30% of the active labour force before the earliest old age retirement is feasible (Røed and Haugen, 2003)[a]. In addition, the introduction of the Norwegian early retirement program (AFP) in 1989 has also contributed to the reduction of the labour force participation because the system provides strong economic incentives to stop working when the AFP retirement option is available (Bratberg, Holmas et al., 2004).

[a] The importance of health conditions for the time of retirement is also shown in other countries Bound and Waidmann (1992).

Hence, in order to induce higher labour force participation the policy measures have to be designed as to affect a whole complicated family of institutional restrictions and economic incentives that influence the retirement decisions made by the individuals. Typically, such policies have never been in affect before, which makes it hard to assess their behavioural consequences. Therefore structural modelling as opposed to the reduced form approaches becomes an ultimate tool for the job of predicting and comparing the implications and the outcomes of the social security reforms.

An additional argument in favour of the topic of the dissertation is the increasing scientific output in this area which can be seen in the literature.

2. The objectives of the research

The main objective of the dissertation is establishing a structural dynamic model of the retirement behaviour which would be on one hand complicated enough to incorporate heterogeneity among the decision makers with respect to their health, labour market position, income levels and some personal and family characteristics, and to carefully replicate the existing Norwegian institutional settings influencing the retirement process. On the other hand the model would still have to be computationally tractable. Application of the developed model to the real life policy design through simulations of the consequences of potential policy changes is another objective of this dissertation.

All three papers included into the dissertation contribute to these objectives. The first paper constructs the dynamic structural model of health and retirement which meets the specified criteria, develops an estimation strategy and proceed with the estimation. In addition, the applied question of potential substitution of the early retirees into the disability system is investigated. The second paper is devoted to measuring the goodness of fit in the class of structural dynamic models similar to the one established in the first paper, in particular with the help of exogenous policy change. The paper gives a foundation for the use of the model in the real life applications. Finally, the third paper applies the developed model for the forecasting of the behavioural and economic implications of the pension reform which is currently under discussion and development in Norway.

3. Literature review of the field

The existing literature on retirement behaviour and policy analysis is generally in consensus about the important role of health in the retirement process. Many of the retirement studies

which have established a strong influence of the economic incentives to the retirement decision neglect the health effects, although do acknowledge the need to take them into account (Gordon and Blinder, 1980; Blau, 1994; Hernæs, Sollie et al., 2000; Borsch-Supan and Schmidt, 2000; Hernæs and Strom, 2000; Powers, Neumark et al., 2001; Krueger, Meyer et al., 2002; Chan, Stevens et al., 2003; Conti, Berndt et al., 2006). (Bloom, Canning et al., 2004) shows in a theoretical model how dropping out of labour market may be induced by worsening health. (Bound, 1998) takes this approach to the data and finds empirical evidence of health effects which are especially strong when measured on the relative rather than absolute scale. (Bound, Schoenbaum et al., 1995, 1996) show that controlling for health in a static model accounts for most of the racial gap in the labour force attachment and disability status of older American men and women in the 1990s. (Disney, Emmerson et al., 2006) use British household panel survey (1991-1998) to find that both current and lagged health shocks are positively correlated with a decision to drop out of labour force. (Au, Crossley et al., 2005) also find evidence of the influence of health on the retirement behaviour when they use Canadian data. After (Henretta, 1983; Hurd, 1989; Bourguignon and Chiappori, 1992a; Bourguignon and Chiappori, 1992b; Blau, 1997) showed the influence of a spouse to the individual retirement decision and the household approach was widely taken into the retirement research[b], (Coile, 2004) examines the "added worker effect" which suggests an increase of labour force participation of an individual after a negative health shock to the spouse. (Olson, 1998) studies American households and shows that wives without spousal health benefits are more likely to work full-time than those who are covered by the spousal health insurance. Health insurance is also shown by (Rogowski and Karoly, 2000) to be important for the retirement decisions, in particular, access to post-retirement health insurance has a large effect on retirement[c].

Once the significance of the health status on the retirement behaviour has been recognized, the issue of establishing a plausible and practical model that is capable of providing reliable simulations of the key policy measures becomes a major concern. (Gruber, 2000) studies the elasticity of labour force participation with respect to disability benefit generosity using a difference-in-difference approach and finds sizable labour supply response to possible

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[b] See, for example, Gustman and Steinmeier (2000), Vermeulen (2002), Coile (2003), Jia (2003), Gustman and Steinmeier (2004), Hernæs, Jia and Strøm (2006).

[c] For the survey of the literature on the effects of health insurance see Gruber and Madrian (2002).

changes in disability benefits. Studies based on the reduced from models, however, can not be applied to simulate the effects of central policy reforms. Therefore structural models have been widely used in the retirement studies within different frameworks: static discrete choice (Dagsvik and Strøm, 1997; Dagsvik, 2002; Bratberg, Holmas et al., 2004; Dagsvik and Strøm, 2006; Dagsvik and Jia, 2006), quasi-dynamic approach (Jia, 2000; Hernæs and Strom, 2001; Iskhakov, 2003), lifecycle approach (French, 1999; Gustman, Steinmeier et al., 2004a, 2004b; Gustman and Steinmeier, 2005) and other (Hurd, 1989; Blau, 1997; Michaud and Vermeulen, 2004).

However, the occurrences of structural modelling of disability are quite rare in the existing literature. This is mainly because of the mentioned difficulty of modelling eligibility for disability pension which could in principle be overcome if reliable and transparent measures of health were available. Unfortunately, absence of essential data makes it impossible to incorporate the process of health screening into the structural model. Moreover, not only health data is hardly reliable and seldom available, but it also bears internal inconsistencies which are given a lot of attention in the literature.

Health can be measured in many different ways. The first and the most straightforward way is to ask respondents health-related questions in a survey and to use the answers for constructing either multidimensional or scalar measures usually on a simple ordinal scale (Bound, Schoenbaum et al., 1996; Dwyer and Mitchell, 1999; Kreider and Riphahn, 2000; McGarry, 2002; Heiss, Hurd et al., 2003). These measures may suffer from multidimensionality and incomparability, scale simplicity (Allison and Foster, 2004) and other problems, but most of all they may suffer from endogeneity concerns described, for example, in (Bound, 1991). Together with other authors they raise the suspicion that answering questions about health status the respondents, especially those unemployed, may be rationalizing their labour market state or work preferences, which leads to overestimation of the influence of health in comparison with economic factors (known as "justification bias"). This suspicion is to some extent neutralized when the survey questions are less direct and address simple activities of daily living (ADL)[d] – health measures based on such questions are considered more "objective" (Heiss, Hurd et al., 2003; Coile, 2004). Another possibility to eliminate the justification bias comes from introducing additional explanatory

[d] "Do you have problems walking up the stairs?" rather then "Is your health limiting your ability to work?"

variables to instrument health. As pointed out by (Bound, 1991) in some circumstances, this gives even worse results, and therefore health indexes incorporating both subjective and objective information (possibly in different proportions) together with some individual characteristics may serve as "best" health measure (Bound, 1998; Dwyer and Mitchell, 1999). (Disney, Emmerson et al., 2006) call a version of such index a "health stock" and use it as one of the explanatory variables in a bigger labour market behaviour model. The most serious drawback of a health index approach is its failure to provide a general theory of index construction – health indexes are task and project specific. Further, (Kreider, 1999) uncovers deeply imbedded inconsistency of health measurement which follows from the fact that health in medical sense is very different from work limitation measures important for labour market studies. The two concepts are very much related but when measurement is not perfect, the implied errors may be large. This is especially vivid when the health indexes are aimed at specific applications. Thus, for example, body mass index (BMI) or health utility index mark 3 (HUI3) used in the labour market analysis in (Rogowski and Karoly, 2000; Au, Crossley et al., 2005) seem mostly medically oriented while (Benitez-Silva, Buchinsky et al., 2004) give an excellent example of constructing a health index that outperforms the procedure used by Social Security Administration in the US for evaluating the disability applications. The last index is based on both the subjective measures (health related questions) and objective measures (ADL questions and individual characteristics) and is optimized for a narrow job. It is possible to come up with yet more "objective" measures for health as, for example, diagnosis (Gjesdal and Bratberg, 2003) or utilization of medical services (Currie, Gruber et al., 1995). While the latter measure is definitely more appropriate for medical rather than labour market study, the former is used in a simplified form when health is measured by different health related events as stroke, cancer diagnosed, etc. (Heiss, Hurd et al., 2003; Coile, 2004). Finally, mortality appears as the most objective but too aggregate measure of health and is therefore not used very often in microeconomic research (McGarry, 2002; Autor and Duggan, 2006). In the same time, self-assessed life expectancy is shown to be well-behaved measure (Hurd and McGarry, 2002) which also can be used in labour economic research (Coile, 2004).

Most of the different approaches for measuring health listed above originate in the corresponding survey questions. When instead it is a register data collected by the authorities which is used for estimation, the choice of health measures is very much reduced. The only

available from the above options are mortality rates, medical services utilization and medical records. When neither of these is suitable or available, sick leave data from the employer registers may be the only option to serve as a health proxy in spite of unclear biases it may have in measuring work limitations (Gjesdal and Bratberg, 2003)[e].

The described controversies about the health measures are only magnified when it comes to modelling health dynamics. Increasing data requirements and multiplied measurement errors limit the available options and force the researches to simplify health related aspects of the models up to their complete elimination as in (Jia, 2005). (Bound, 1998; Au, Crossley et al., 2005; Disney, Emmerson et al., 2006) reflect the dynamic aspects of health by using lagged health measures among the current period explanatory variables. (Gustman, Steinmeier et al., 2002; Heyma, 2004) estimate complicated structural dynamic models but don't include health into the set of stationary variables and use health measures as exogenous. When health is allowed to vary over time, the movements may be very much limited with the restrictions not necessarily implied by the theoretical setup but rather by the tractability considerations (Berkovec and Stern, 1991; Heiss, Hurd et al., 2003). In those rare occasions when health is true endogenous state variable, it is usually measured on a simple dichotomous scale and is assumed to follow a Markovian motion rule (Rust and Phelan, 1997; French, 1999).

4. Theoretical and methodological foundation of the research

The model of the retirement behaviour of the older workers is based on the assumption of rationality within the framework of the random utility. The decision makers are assumed to be maximizing the expectation of the discounted lifetime utility induced by the decision at a particular time period. These assumptions lead to a time consistent behaviour as shown by (Hammond, 1988) and facilitate the use of dynamic programming as the main methodological framework of the research. The model is estimated using the algorithms similar to the nested fixed point algorithm by (Rust, 1994) which follows the tradition of structural stochastic dynamic programming originating in (Rust, 1987) and broadened for labour market analysis in (Rust, 1990; Rust and Phelan, 1997). This framework rests on both the theory of stochastic control (Pontrjagin, 1962) and the econometrics of discrete choice (McFadden, 1974, 1981), especially in part when it coincides with the random utility approach as surveyed in (Dagsvik,

[e] In Gjesdal and Bratberg (2003) the number of days on sick leave is shown to be a significant predictor of the disability condition with the overall pseudo-R^2 in the model at about 30%.

2000). More generally, this work is based on the calculus of variations, mathematical theory of stochastic processes and general theory of probabilities. The estimation of the model is facilitated by the general methods of mathematical statistics, in particular the maximum likelihood method. The general method is somewhat modified for the use with the latent state variables following the incomplete information approach of (Rhenius, 1974) and applies a multi step estimation approach (Rust, 1994; Greene, 2000).

5. Scientific novelty of the dissertation

Modelling of health process explicitly within the structural dynamic framework is the main scientific novelty of this dissertation. Besides (Rust and Phelan, 1997) the only recent example of endogenous modelling of health dynamics is found in (Bound, Stinebrickner et al., 2007) while the majority of the previous work within this methodology had to either completely drop the health status (Karlstrom, Palme et al., 2004; Jia, 2005) or significantly simplify it's scale and motion (Berkovec and Stern, 1991; Gilleskie, 1998; Gustman, Steinmeier et al., 2002; Burkhauser, Butler et al., 2004; Heyma, 2004; French, 2005). Unlike the previous research which has typically used self reported and indirect measures of disability conditions, I model health as a direct latent indicator of the eligibility to retire through the disability insurance system. There are three values of health status: (α) when health is good (no work limitations) the disability option is infeasible; (β) the bad health adds this option to the choice set, but it may not necessarily be taken, thus enabling the bad health to be concealed; finally, (γ) the very bad (worst) health narrows the choice set to a single option, namely forces an individuals to full time disability. To moderate the discrepancy between the endogenous self reported and more objective health measures, (Bound, 1991; Bound, 1998) suggests modelling health as a latent variable using self reported disability status as an indicator for the latent construct. Unavailability of the reliable instruments for disability conditions in the data forced me to treating the latent health as completely uncontrolled Markovian stochastic process. Although this approach creates an unobservable state variable and results in a significant complication of the estimation procedure, it allows me to accurately model the disability exit in a structural dynamic framework and facilitates the crucial policy simulations.

The developed structural dynamic model carefully replicates the Norwegian institutional settings and takes into account the potential substitution between the different retirement paths induced by the behavioural effects. Using such a model for testing the effects of the

forthcoming pension reform in Norway is a novelty in itself. So far the analysis of the pension reform (Stensnes, Texmon et al., 2007) was performed within the dynamic microeconomic simulation model (Fredriksen, 1995, 1998) which has been developed by Statistics Norway over the decades specifically for calculating long term projections of population, labour force, education and social security spending. The forecasts produced by this model originate in the simulation of a series of social-economic events using certain transition probability distributions. In other words, the behavioural response to the new policies is left out of the simulations. To my knowledge, structural dynamic models of retirement have never been used before for the full scale simulations of the effects of the pension reforms.

6. Practical significance of the research

Structural dynamic model of health and retirement developed in this dissertation has high practical significance. The successful estimation of the model performed in the first paper brings it to the ready state for practical usage which is immediately demonstrated. The conclusions obtained in the first paper, namely, that only about 5-8% of otherwise early retirees would receive disability pension, and that most of these disability pensioners would retain a part time job until the usual retirement age, are very important for the practitioners in the governmental institutions designing a policy change that would induce, for example, later withdrawal from the labour market.

The applied third paper in the dissertation demonstrates the power of the practical use of the dynamic structural modelling for the forecasting of behavioural implications of the new policies and policy changes. The forthcoming in 2010 new pension regulations in Norway which are currently under discussion were imbedded into the model to facilitate the simulations of the behavioural response to the pension reform. Because the model assesses all the important variables determining the economic situation of the individual agent, and therefore these primitives are predicted in the simulations, they are not only capable to reveal the labour market consequences of the reform, but also to forecast the changes in inequality and social welfare. The developed model thus becomes an ultimate tool for the policy design and analysis of the policies never implemented before.

It should be noted that the very latest wage negotiations which took place in March and April 2008 clarified some of the aspects of the pension reform which were undecided when the third

paper was written. Even though by the time of submission of the dissertation some of the assumptions made there appear to be inconsistent, the practical significance of the research remains undisputable.

7. Summary of the papers

The dissertation consists of three individual papers united by the same research theme and modelling approach. The first paper develops the theoretical structure of the dynamic model of health and retirement, designs the estimation strategy, proceeds with the estimation and reports the estimation results. The first paper also studies the substitution effects between early retirement and the disability pension as two main exit routs from the labour market in Norway. The second paper systematizes the measure of quality of the structural dynamic models and suggests the use of the exogenous policy change for the thorough testing of the specification of the models and the structural estimates they produce. The proposed methods are applied for the structural dynamic model developed in the first paper using as a policy change the reduction of the early retirement age in 1998 when a group of agents experienced a sudden change in their choice sets. The third paper is devoted to the ongoing pension reform in Norway and simulates the behavioural response of the older workers retiring under the new pension regulations. Both the labour market consequences as well as welfare and inequality are analysed. Below I present short summaries for all three papers.

Paper 1. Health and retirement in a structural dynamic setting

Abstract: This paper provides an empirical analysis of the substitution between the early retirement and disability as two major exit routes from the labour market in Norway. The analysis is based on a dynamic structural model that addresses the interplay between health, institutional constraints and economic incentives of men and women in the later part of their working lives. Unlike most of the previous work which has typically used self reported and indirect measures of disability conditions, I model health as a direct latent indicator of the eligibility to retire through the disability insurance system. The model is specifically designed to account for the random occurrences of the disability conditions and their possible concealment by the individuals in favour of higher utility and broader choice sets in the future. The model is estimated using Norwegian register data. I investigate the substitution effect between the disability and early retirement exits by simulating a complete elimination

of the latter. My findings suggest only moderate inflow of the otherwise early pensioners into the disability program.

The first paper contains six sections including the introduction and the conclusions, which occupy 48 pages and which are followed by two appendices. After the introduction which allocates the paper within the existing literature in the field, Section 2 is devoted to complete description of the model from the initial assumptions through the description of the sample data to the expression for the likelihood function. Structural dynamic model of health and retirement is a finite horizon Markovian discrete stochastic control model in discrete time. Rationally behaving decision makers maximize the expected lifetime discounted utility

$$E\left\{\sum_{t=T_0}^{T}\left(\prod_{\tau=T_0}^{t}\rho_\tau\right)\beta^{t-T_0}U(d_t,s_t)+\Lambda\left(s_T\right)\right\}\underset{\delta\in\mathfrak{F}}{\rightarrow}\max, \tag{1}$$

where the vector $s_t \in S$ taking values from the problem state space S and the scalar $d_t \in D_t(s_t,d_{t-1})$ taking values from the choice sets $D_t(s_t,d_{t-1})$ denote correspondingly state and decision variables, $U(d_t,s_t)$ is instantaneous utility discounted with the discount factor β, and ρ_τ is sample specific exogenous survival probability from period $\tau-1$ to period τ. The time index serves as indicator of age, $T_0-1=50$ and $T=70$, after the age of 70 no transfers occur and no decisions are made. Termination function $\Lambda\left(\tilde{s}_T\right)$ captures the remaining after the age of 70 lifetime utility. Savings are assumed away which eliminates the budget constraint. A solution to the individual sequential decision problem (1) is found among decision rules $\delta=\left(\delta_{T_0},...,\delta_T\right)$ – which define a correspondence between a current state s_t and a chosen control $d_t=\delta_t(s_t)$ – from the class $\mathfrak{F}$ of feasible decision rules. Feasibility conditions are expressed in a family of choice sets $D_t(s_t,d_{t-1})$ that contain the available to the agent options at period *t*. The expectation in (1) is taken with respect to the set of subjective transition probabilities $\left\{p(s_t\mid s_{t-1},d_{t-1})\right\}_{t\in\{T_0,..,T\}}$ that govern stochastic process $\left\{d_t,s_t\right\}_\delta$ induced by the given decision rule $\delta\in\mathfrak{F}$.

The state vector $s_t=(gender,afpage,ps_t,h_t,m_t,e_t,sp_t,nw_t,aw_t)$ is populated with the exogenous gender and the potential early retirement age, previous labour market state ps_t (the model distinguishes between 8 labour market states: out of labour market (OLM), full

time early or regular pension, full time disability, unemployment (including partial unemployment), employment in non-AFP company, partial employment in non-AFP company combined with partial disability, employment in AFP company and partial employment in AFP company combined with partial disability), health status $h_t \in \{0,1,2\}$ of an individual directly defined in the model as eligibility for the disability pension, the job match variable $m_t \in \{0,1,2\}$ which indicates whether no job, AFP or non-AFP job is available for an individual in the given period, the individual AFP eligibility indicator $e_t \in \{0,1\}$ which govern whether an individual AFP conditions are satisfied, spouse existing indicator $sp_t \in \{0,1\}$,and two income indices nw_t and aw_t .

After these state variables determining the choice set $D_t(s_t, d_{t-1})$ are realized in the beginning of each period, the agent makes a decision $d_t \in D_t(s_t, d_{t-1})$ which can be interpreted as a reaction to the evolving environment $\{ps_t, h_t, m_t, e_t\}_{t\in\{T_0,\dots,T\}}$. Decision variable marks different combinations of the answers to the question whether to remain on the labour market and whether to apply for a pension. Taken decision determines the current period labour market state, and the two income related state variables are realized, namely the average wage $aw_t \in \mathbb{R}_+$ which represents individual lifetime trend in the wage earnings, and the number of last consecutive years with wages over the basic pension amount $nw_t \in \{0,1...10\}$ which represents recent dynamics in the wage earnings.

Following (Rust, 1994) the utility function $U(d_t, s_t)$ is assumed to contain an additivity separable random component which elements are distributed independently with the extreme value distribution, so that the choice probabilities take the form

$$P_t(d_t \mid s_t) = \frac{\exp\{v_t(d_t, s_t)\}}{\sum_{d'\in D(s_t, d_{t-1})} \exp\{v_t(d', s_t)\}}, \tag{2}$$

expressed through the value function

$$v_t(s_t, d_t) = \begin{cases} u(d_T, s_T) + \Lambda(s_T), t = T, \\ u(d_t, s_t) + \rho_t \beta \sum_{s_{t+1}\in S} \log\left(\sum_{d_{t+1}\in D(s_{t+1})} \exp\{v_{t+1}(d_{t+1}, s_{t+1})\} \right) p(s_{t+1} \mid s_t, d_t), t < T. \end{cases} \tag{3}$$

Given the panel of observations $\left\{d_t^a, ps_t^a, e_t^a, sp_t^a, nw_t^a, aw_t^a\right\}_{t\in\{T_0^a-1,..,T^a\},a\in\{1,..,A\}}$ which originates in the collection of the Norwegian register data files organized by the Statistics Norway and available at the Frisch Centre for Economic Research, and describe the sample of 200 921 single and full households, the likelihood function based on the choice $P_t(d_t \mid s_t)$ and transition $p(s_t \mid s_{t-1}, d_{t-1})$ probabilities

$$L(\theta)=\prod_{a=1}^{A}\left[\sum_{(h,m)\in HM^a} p_0(h_{T_0^a-1}, m_{T_0^a-1}, \theta)\prod_{t=T_0^a}^{T^a} P_t(d_t^a \mid s_t^a, \theta)\cdot p(s_t^a \mid s_{t-1}^a, d_{t-1}^a, \theta)\right] \tag{4}$$

$$p_0(m_{T_0^a-1}, h_{T_0^a-1}, \theta)=p_0(h_{T_0^a-1})\cdot p_0(m_{T_0^a-1}\mid h_{T_0^a-1}),\ \ s_t^a=\left(ps_t^a, h_t, m_t, e_t^a, sp_t^a, nw_t^a, aw_t^a\right)$$

is constructed by aggregating the probability mass along all trajectories $(h,m)=(h_{T_0},..,h_T,m_{T_0},..,m_T)$ of the latent health and job match processes which are consistent with the available observations: $(h,m)\in HM^a$. Probabilities $p_0(m_{T_0^a-1}, h_{T_0^a-1}, \theta)$ define the initial conditions.

Section 3 of the paper describes the assumed dependence structure of the controlled Markovian transition probability for the state process $\left\{p(s_t \mid s_{t-1}, d_{t-1})\right\}$ and reports the obtained estimates for the agents' beliefs with respect to evolvement of all the state variable. In particular, health status h_t and the job match m_t are modelled as simple Markov chains (jointly independent of the rest of the transitions) with uniform across individuals' transition probability matrices, spouse existing probabilities $p(sp_t \mid sp_{t-1})$ are exogenous and sample specific. When they are not verifiable from the rest of the state variables, the individual AFP eligibility conditions are predicted with two simple logit models responsible respectively for the eligibility status at the AFP age and on the later years. The transition probability $p(aw_t \mid ps_t, aw_{t-1})$ distribution of the aggregated wage becomes degenerate after the estimated recursive expression (motion rule) is assumed deterministic due to its extremely tight fit. The short term indicator of the income profile nw_t follows a simple dichotomous motion pattern described with a logit model.

Section 4 describes the assumed structure of the agents' preferences and reports the structural estimates of the discount factor (0.91235 with the standard error 0.0009) and the parameters in the likelihood function. The deterministic part $u(d_t, s_t)$ of the utility function $U(d_t, s_t)$ has

the additive form with constant relative risk aversion λ with respect to household disposable income (estimated at the level of 0.67393 with standard error 0.03001) and linear leisure. Other coefficients of the utility function are estimated as[f]

$$
\begin{aligned}
u(d_t, s_t) = u(I, L) = & \underset{(0.00426)}{0.17147} \cdot \frac{(Tx(I))^{\lambda} - 1}{\lambda} \\
& + \left[\underset{(0.57728)}{29.3224} \cdot \xi(h_t = 1) + \underset{(0.02073)}{0.26551} \cdot sp_t - \underset{(0.01838)}{0.61363} \cdot \xi(\text{female}) \right] \cdot L \\
& + \sum_{k=0}^{7} c_k \cdot \xi(ps_{t+1} = k).
\end{aligned} \tag{5}
$$

With no reliable data leisure $L = L(d_t, s_t) = L(ps_{t+1})$, it is simplified to three constant levels which correspond to different labour market states. In contrast, the incomes of the households are calculated in a complicated manner as a sum of at most four sources (earned income, pension, social security benefits and other additional incomes, income from a spouse) which come into play in the relevant states ps_{t+1}. The sources are predicted on the basis of all the state variables as reported in the Appendix for the first paper.

Finally, Section 5 presents a practical application of the estimated model, namely the analysis of substitution between the disability and early retirement exit routes from the Norwegian labour market. The question stated is "What fraction of the AFP pensioners would be able to retire with disability pension if the former option was not available?" The performed simulation of a complete elimination of the early retirement system shows that between 4.88% and 7.99% of otherwise early retirees end up with the disability benefit in the ages of 64-66 years.

The paper is finalized by a short conclusion and two appendices which describe the estimation strategy of the model and the technique used for predicting counterfactual household incomes respectively.

Paper 2. Quality of structural dynamic models and unexpected policy change

Abstract: This paper overviews the measures of goodness of fit of the structural dynamic models estimated on the labour market data, generalizes a popular McFadden's rho coefficient for the use in the structural dynamic models of discrete choice and suggests a general

[f] Indicator function $\xi(\bullet)$ returns unity if the condition is satisfied and zero otherwise, $Tx(\bullet)$ is a mapping from before tax household incomes to disposable household incomes.

framework for the testing of stability of the structural estimates based on the unexpected changes of the institutional settings. Suggested approaches are applied for testing the quality of the dynamic model of health and retirement estimated in (Iskhakov, 2008). The results indicate a reasonable fit of this model, but also reveal some restrictions in the application of the proposed quality measures.

The second paper contains six sections including the introduction and the conclusions, which occupy 25 pages and which are followed by an appendix. Preceded by the introduction which provides a short overview of the existing approaches used in judging the quality of structural dynamic models, Section 2 develops the generalization of the static McFadden's goodness of fit rho coefficient for the dynamic models of discrete choice. Generalization builds on the two common approaches for the formulation of the restricted benchmark specifications of the likelihood used in standard logit models which correspond to the direct approximation of the choice and transition probabilities in the structural dynamic case. In standard notation, the frequency based and uniform approximations of the choice probabilities are given by

$$P^{freq}(d \mid s) = \frac{N\left\{(d_t^a, s_t^a) : d_t^a = d, s_t^a = s\right\}}{N\left\{(d_t^a, s_t^a) : s_t^a = s\right\}}, \tag{6}$$

$$P^{uniform}(d_t \mid s_t) = \frac{1}{\left|D(s_t)\right|}, \tag{7}$$

and similarly for the transition probabilities by

$$p^{freq}(s_{t+1} \mid s_t, d_t) = \frac{N\left\{s_{t+1}^a : s_{t+1}^a = s_{t+1}\right\}}{N\left\{(d_t^a, s_t^a) : s_t^a = s_t, d_t^a = d_t\right\}}, \tag{8}$$

$$p^{uniform}(s_{t+1} \mid s_t, d_t) = \frac{1}{\left|S\right|}, \tag{9}$$

where $N\{\bullet\}$ denotes the number of elements in the collection described by the properties in the brackets and $|\bullet|$ denotes the number of elements in a set.

Section 3 reports 9 proposed measures of goodness of fit calculated for different combinations of the used probability approximations. The results range from modest 9.12% when only the choice probabilities are approximated to substantial 79.064% when both choice and transition

probabilities are approximated with uniform distributions. Most reasonable approximations lead to the fit coefficient 53.129% which reflects very reasonable fit of the model.

Section 4 of the paper goes beyond the simple goodness of fit coefficients and systematizes four main approaches for testing dynamic models which include in-sample and out-of-sample predictive test as well as in-sample stability test and the test of stability across a policy change. The last one is recognized as the ultimate procedure for assessment of the quality of structural dynamic models. A version of this test applicable for the model estimated in the first paper is formulated in terms of unexpected change in the structure of future consequences of the made decisions. Namely, a reduction in the early retirement age in Norway in 1997 and 1998 which happens during the period when the sample is observed, is used as an unexpected policy change. Three cohorts (born in 1935-1937) were affected by this exogenous change and the behavioural response from these decision makers could be analyzed in the test on stability of the structural estimates on the model.

In Section 5 I apply the described technique for the structural dynamic model of health and retirement. Potential difficulties with identification of the transition probability parameters on the bases of largely reduced sample forces me to consider only the preference parameters in the test. Large standard errors of the estimates of these parameters obtained for all considered simplifications of the utility function, however, indicate that the model fails to provide identification of the parameters using the data in the subsample. Provided overview of the observed in this subsample transitions among the labour market states support this conclusion.

The paper is finalized by a short conclusion and an appendix which contains a very short recapitulation of the structural dynamic model of health and retirement used in the illustrative examples.

Paper 3. Pension reform in Norway: evidence from a structural dynamic model

Abstract: This paper simulates a set of proposed policies from the Norwegian pension reform within a structural dynamic model of health and retirement estimated on the Norwegian labour market data. The paper focuses on the two main elements of the reform, namely the new pension entitlement accrual rules linking benefits more closely to earnings and the new pension benefit drawing rules designed to eliminate the incentives distortions with respect to the time of retirement. The effects of these proposals are investigated in terms of labour market outcomes, social welfare and income distribution. It is shown that while the proposed

pension reform succeeds in urging the older workers to postpone their retirement and induces an increase in total social welfare, individuals in good health who retire early experience a negative change in their discounted utility. In addition, an increase in social welfare is accompanied with an increase in income inequality.

The third paper contains five sections including the introduction and the conclusions which altogether occupy 65 pages. The introduction states the forthcoming difficulties in the financial stability of the social security systems of the Pay-As-You-Go type which are rather urgent for many OECD countries, provides a short description of the pension reform discussion taking place in Norway, and explains the advantages of using a structural dynamic approach for simulating the consequences of the reform measures.

Section 2 of the paper consists of three sub-sections which consequently describe the main events and the documents of the Norwegian pension reform, the existing retirement settings in Norway and the main elements of the proposed new pension system. The chronicle of the pension reform can be followed through a sequence of White papers and reports (Nou 2004:1, 2004; St.Meld. Nr. 12, 2004; Innst. S. Nr. 195, 2005; St.Meld. Nr. 5, 2007; Innst. S. Nr. 168, 2007) which gradually proceeds from agreeing on the general principles of the reform to the detailed rule and quantitative relations. The most recent development in this discussion (Rapport Fra Afp-Utvalget, 2008) from the April of 2008 was publicized after the paper was completed and has thus not been included.

The current Norwegian pension system belongs to the class of defined benefit pay-as-you-go systems. The calculation of the pension benefit is based on so called pension points pp_t which are derived annually from the individual pension providing income with a concave piecewise linear function, and the basic amount G which is corrected on annual bases in accordance to macroeconomic indicators. If T denotes the length of individual working history, the annual pension benefit PB is given by the formulas

$$PB = G + \max(0.7933 \cdot G, SP), \tag{10}$$

$$SP = fpp\left(pp_1, pp_2, .., pp_T\right) \cdot G \cdot \sum_{t=1}^{\min(T,40)} \frac{SPr_t}{40}, \tag{11}$$

$$fpp\left(pp_1, pp_2, .., pp_T\right) = \frac{1}{\min(T,20)} \sum_{t \in T^{best}20} pp_t, \tag{12}$$

where the rate SPr_t was lowered from 0.45 to 0.42 in 1991 and $T^{best\,20}$ denotes the years in which the highest 20 pension points were earned. The early retirement (AFP) scheme which is available for the individuals meeting the eligibility criteria and working at the participating companies, provides an option to retire earlier with the annual pension benefit practically equal to normal pension. In addition, private occupational pension schemes play an important role in the retirement process in Norway.

Section 2.3 which presents the proposed pension reform measures starts with a classification of the general principles of the reform into two dimensions – those aimed at making the system more direct thus freeing the retirement decision from the incentives distortions, and those aimed at making the system just and more redistributive. All the proposed reform measures are then placed in the space determined by these dimensions, while the existing pension system is shown not to comply them at all. The latter is explained with three major distortions implied by the limited number of years of pension rights accrual, concavity of the relationship between the income and the earned pension points, and the use of only the highest earning years in the pension calculation. Among the proposed pension reform measures I consider four different accrual models which are for convenience expressed as functions of the average lifetime wage earnings. Analysis of the marginal accrual rates reveals the evolution of these models towards the distortion free setting. The notion of actuarial adjustment is shown to be a dual mechanism dealing simultaneously with the reduction of the pension benefit for the longer living cohorts and the increase of the benefit for the individuals choosing to stay in the labour force longer and to retire later than usual. Other quantitatively less important measures of the proposed reform are overviewed in the end of the section.

Section 3 of the paper provides a short summary of the structural model of health and retirement developed and estimated in the first paper, focusing in details on the representation of the pension reform proposals in the restricted terms of the model. The analysis of the fundamental assumptions of the following simulation, the exogenous information and the parameters which are assumed to be invariant throughout the pension reform, and the structure of the model lead to the narrowing of the set of the reform measures tested in the simulation to only the most important, namely new accrual models and new models for drawing of old age pension. Yet, introducing these two elements into the model requires certain adjustments which are described in the rest of the section. Different pension accrual

rules are incorporated into the equations for pension income predictions used in the model with the means of a correction coefficient, which is in turn predicted on the bases of the benefit level under the old rules, gender, spouse existing indicator and the aggregated wage. Different options open for a decision maker in terms of drawing pension are adjusted for the Markovian nature of the model so that instead of the conditioning the benefit level on the age of retirement (as proposed in the reform), the agents face adjusted pension profiles in which the pension levels only depend on the state variables from the previous year. Although the constructed pension profile suffers from being somewhat artificial, the main principle of actuarial adjustment, namely the equality of the net present values of the benefit streams independent of the time of retirement, is satisfied. Special assumptions had to be made about the new early retirement rules which were not yet settled when the paper was completed. These assumptions, however, differ very little from what was agreed upon in April 2008 as described in (Rapport Fra Afp-Utvalget, 2008).

Section 4 of the paper describes the results of the simulations of the Norwegian pension reform with respect to the labour market consequences, social welfare and income inequality. To set a common framework, 7 simulations sets combining different accrual and drawing settings are defined in the beginning of the section. Section 4.1 reviews the labour market implications and reports in a substantial increase in the supply of labour between 62 an 69 accompanied with significant decrease of the number of pensioners in most simulation sets. Differences in responses among the accrual models constitute the small scale adjustments while the large scale effects (up to 23 percent points increase in employment) is due to the new pension drawing rules. Implications for the social welfare and income inequality are described in Section 4.2. I use a simple welfare measure, namely the expected maximum level of the current utility where the maximization is performed over the available choices and the expectation is taken over the stochastic component of the utility. The results indicate a significant increase in welfare in all the simulation sets except the first one when the AFP pension is left unchanged. Differences among the accrual models are again responsible only for the second order effects. Measured with a decile range in income distribution the income inequality is shown to increase quite a lot as a result of the pension reform with the magnitude also growing in time in all simulation sets. Section 4.2 also contains a short individual analysis of the welfare implications which shows that those who lose welfare in the course of the reform do so mainly because of involuntary retirement due to job loss while those who

experience most increase in welfare are healthy individuals continuing to work after the normal retirement age.

The paper is finalized with a short conclusion emphasizing the main implications of the reform, namely the desirable labour market outcome, positive welfare and income inequality effects, certain demand for the early retirement among some individuals and the absence of the long run dynamic behavioural reaction to the reform.

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