An Analysis of the Australian Social Security System using a Life-Cycle Model of Labor Supply with Asset Accumulation and Human Capital*

Preliminary and incomplete

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February 15, 2016

Abstract

This paper examines the long term effects of the changes in the generosity of the social security system on the labor supply over the lifecycle and the time of retirement. To capture the effects on both the intensive and extensive margins we estimate a structural dynamic model of labor supply and consumption-savings decisions in presence of human capital accumulation process using the Australian panel data. We quantify the differences between the effects of anticipated and unanticipated policy changes, and study how the effects of the latter vary with the age of the agent when the new policy is put in effect.

Keywords: Labor supply, human capital accumulation, retirement, structural dynamic model

JEL codes: J22, J24, J26, C63

*This paper uses unit record data from the Household, Income and Labor Dynamics in Australia (HILDA) Survey. The HILDA Project was initiated and is funded by the Australian Government Department of Families, Housing, Community Services and Indigenous Affairs (FaHCSIA) and is managed by the Melbourne Institute of Applied Economic and Social Research (Melbourne Institute). The findings and views reported in this paper, however, are those of the author and should not be attributed to either FaHCSIA or the Melbourne Institute.

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1 Introduction

The Australian Social Security system combines a defined contribution pension scheme with an income support system for seniors with relatively low income/assets. The Australian system has been praised as one of the best in the world by the OECD and other international organizations. Participation in the defined contribution scheme, known as "Superannuation", is mandatory. Employers must contribute an amount equal to a fraction of workers' salaries to the scheme (this is currently $9\frac{1}{2}\%$) and employees are required to contribute at least a certain fraction as well. Contributions are managed by a large number of designated private investment funds ("super funds"), and workers can take the accumulated balance as a lump sum or annuity at retirement.

In contrast to the US Social Security System, the Australian system takes Social Security taxes and payments off of the government budget, as well as removing unfunded Social Security obligations from the intergenerational accounts. However, in contrast to a completely privatized system, the Aged Pension provides fairly generous income insurance for those who accumulate inadequate assets to finance retirement. A measure of the success of the privately run defined contribution scheme is that government spending on the Aged Pension is only 2.9% of GDP, less than half than OECD average (**?**).

A nice feature of our data is that the generosity up the Aged Pension was substantially increased in 2009-10. This change can plausibly be viewed as unanticipated. The change in rules provides us with a nice source of variation to help identify and validate the model.

Our analysis is based on a life-cycle labor supply model that incorporates several key features: asset accumulation, liquidity constraints, human capital accumulation via learning by doing, and a discrete choice of hours involving several possible levels. Of course we also include the superannuation and Aged Pension rules, as well as retirement decisions. The model is novel, as there are no published life-cycle labor supply models that include both human capital and assets while also accounting for discreteness of hours, liquidity constraints and retirement decisions.

Our primary data source is the longitudinal study "Household, Income and Labor Dynamics in Australia Survey" (HILDA) which contains social and economic information on roughly 20,000 households collected annually since 2001. The main focus of the survey is on family composition, income and labor supply, it also includes several reoccurring additional modules that collect information on wealth and superannuation, among other things.

We estimate the model with the method of simulated moments (MSM), **?**, using a sample of men aged 19 to 85. Our estimation approach matches life-cycle profiles of hours of work, proportions choosing each of the discrete levels of labor supply, wage and wage dispersion, wealth profile, superannuation balance, and transition rates between employment and unemployment separately for each education level.

The simulated moments are based on the the numerical solution of the dynamic programming problem. The combination of continuous choice of consumption with the discrete choice of labor supply complicates the numerical solution by rendering the problem non-convex. As a result, first order conditions alone can not be used to characterize the optimal behavior, and slow global optimization algorithms have to be deployed.

To deal with these complications, we use the discrete-continuous generalization of the endogenous grid point method (DC-EGM), **?**, which is a significantly faster and not less accurate method for solving the problems of this type. This paper is the first application of the EGM ideas first introduced by **?** and extended by **?** to an empirical model like ours. We make two other technical contributions: One is a much more convenient way to define the human capital state variable in dynamic models. The second is the first application of the smooth simulation algorithm of Bruins et al (2015) to a dynamic structural model.

Our model implies a pattern of labor supply elasticities with age that is broadly consistent with the much simpler life-cycle model in Imai and Keane (2004).[1]. For instance, the Frisch elasticity is about 0.30 for high school types below age 45, but it grows to roughly 1.0 at age 60. Similarly, if we look at the effect of unanticipated permanent wage decreases, Marshallian elasticities are quite small prior to age 50, but grow to about 0.40 at age 55, 0.75 at age 60 and 1.2 at age 65.

Our results imply that increases in the generosity of the Aged pension would have very modest effects on labor supply over the life-cycle. For instance, a 25% increase in the pension grant amount (holding means testing fixed) reduces labor supply of high school type workers by only 1% at age 60, and by even less at earlier ages. Even at age 65 and onward, the drop in labor supply is only about 5%.

A reduction in the wealth exemption for the aged pension seems to have trivial effects on hours of work. For instance, a 50% cut in the exemption has essentially no effect on hours prior to age 65, and raises hours from age 65 onward by only about 0.6% to 1.6% depending on age and education. This is presumably because workers can respond by saving somewhat less prior to retirement.

Finally, we simulate a 10% increase in the magnitude of superannuation payments for a given level of contributions (in partial equilibrium this could be thought of as increasing the employer

[1]Theirs' was the first structural life-cycle model to include both assets and endogenous human capital, but they assumed continuous hours and assumed interior solutions, ignored liquidity constraints, and did not model retirement or social security

match amount). This policy leads to negligible effects on labor supply prior to age 65, and very modest reductions in labor supply from 65 onward (e.g., about 1.0% for college workers and 0.25% for high school and dropout workers). These effects are presumably small because the policy is in effect an increase in the wage rate, so it has conflicting income and substitution effects.

The outline of the paper is as follows. In Section 2 we describe institutional features on the Australian superannuation and aged pension system. In Section 3 we present our model. In Section 4 we discuss the DC-EGM solution method. In section 5 we describe the data. Section 6 discusses the estimation method and the moments that we fit. Section 7 presents our estimation results. In Section 8 we describe the fit of the model. Section 9 presents our policy simulations. Section 10 concludes.

2 The Social Security System in Australia

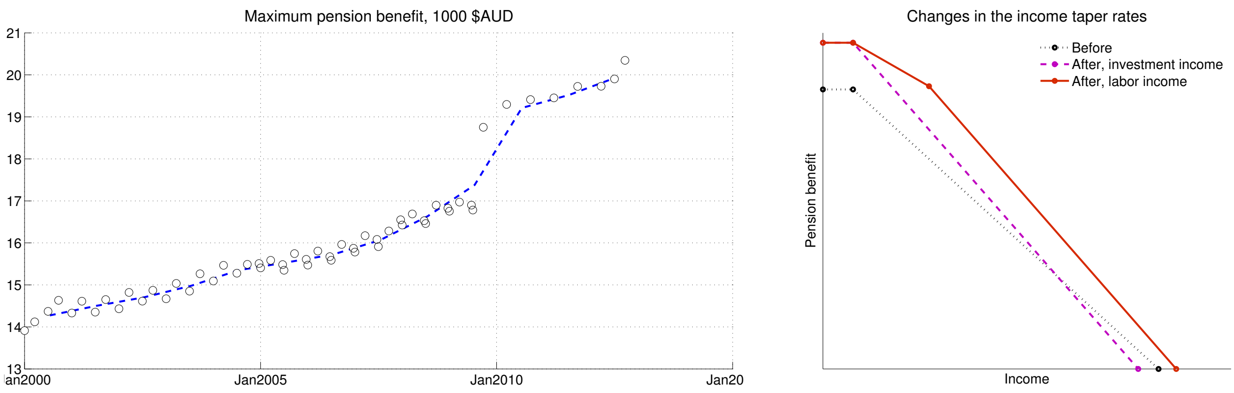
The Australian social security system was introduced in 1908 as an old-age and disability pensions scheme. It has since developed into a large collection of modern income support programs (?). Three characteristic features have been maintained throughout its growth; namely, the prevalence of means tests, the use of funding from general revenue, and a strong emphasis on economic and social participation (?). The Australian model of social security differs markedly from many other countries, but is widely accepted as one of the best systems in the world.[2]

Australia's retirement income system consists of two parts. The first component is the "superannuation" system. This system involves mandatory employer contributions paid into individual pension accounts known as "super funds". The mandatory contribution rate was 9% from July 1, 2002 through June 30, 2013, which covers the bulk of our sample period.[3] The private pension funds into which retirement funds are contributed (i.e., the "super funds") are closely regulated. There may also be additional voluntary contributions from employers, employees or the self-employed. These voluntary contributions to the superannuation system are encouraged by tax concessions.

The second component of the retirement system is the means-tested "Age Pension" that is paid from general government revenue. The age pension is paid from the age of 65 (gradually rising to 67 by 2023) conditional on fulfilling residency requirements. The benefits, which are targeted

[2] The Mercer Global Pension Index, which compares adequacy, sustainability and integrity of retirement income systems around the world, gives Australia the third highest rating (?).

[3] A guaranteed superannuation contribution rate for employers was introduced by the Keating government in 1992, at an initial rate of 3% that was set to increase gradually over time. By the period from July 1, 2000 through June 30, 2002 the rate was 8%. As noted in the text, the rate was then held fixed for 11 years, before being increased to 9.25% on July 1, 2013, and to 9.5% on July 1, 2014.



Notes: The left panel shows the size of maximum age pension benefit between 2000 and 2012. The dots are the actual levels introduced, and the dotted line shows annual weighted averages. The right panel shows the changes in the taper rates and thresholds for the income test introduced in the reform in 2009. Shown are amounts for single home owners.

Figure 1: The changes in age pension by the 2009 pension reform.

by means tests to people whose income and assets fall below certain thresholds, are calculated according to

$$\text{pension} = \max\Big\{0, \text{full benefit} - \max\{\text{income test}, \text{asset test}\}\Big\}.$$

Both the income test and the asset test reduce the maximum pension payment by a certain fraction (referred to as taper rate) of every dollar received above the income threshold or accumulated above the asset threshold,

$$\begin{aligned} \text{income test} &= \max\Big\{0, \text{income taper rate} \cdot (\text{income} - \text{income threshold})\}\Big\}, \\ \text{asset test} &= \max\Big\{0, \text{asset taper rate} \cdot (\text{wealth} - \text{asset threshold})\}\Big\}. \end{aligned}$$

The thresholds are not very restrictive and around 70% of age-eligible residents received at least a partial pension benefit in 2012 (**?**).[4]

Age Pension benefits are indexed to the maximum of price and wage growth twice each year, and the means-tests thresholds are adjusted annually to changes in the price level. Age Pension payments are maintained at 27.7% of male average weekly earnings or adjusted for increases in the CPI or the Pensioner and Beneficiaries Cost of Living Index (PBCI), whichever is the higher.

[4]Different sources of income are treated differently under the income test: returns to financial investments are "deemed" at a fixed progressive rate, while incomes from long term income stream products (e.g. annuities) are reduced by returns of capital. Wealth is also treated differentially for the purpose of the asset test. Financial assets are assessed at their market value, while income stream products are assessed at their residual value. Most notably, a residential home is not included in the asset test. Our model largely disregards these details.

In 2009 the Australian government introduced several substantial changes in the old age pension rules. In particular, (a) the full pension benefit was increased by \$1689 per year, (b) the taper rate in the income test was increased from 40% to 50%, (c) the first \$500 earned fortnightly (\$13,000 annually) was subject to a special taper rate of %25 (**?**).[5] The three policy changes illustrated in Figure **??** came into effect in September 2009.

At age 65 the amounts accumulated in the superannuation system can be accessed by individuals. Although retirees can take superannuation in the form of retirement income streams (i.e., annuities), around half of superannuation assets are withdrawn as lump sums, and most of the rest is transferred to phased withdrawal products that have no longevity protection and no upper limit on spending (**?**).

3 The model

In this section, we present a life-cycle model of an individual decision maker who optimally decides how much of his current assets to consume and how many hours of labor to supply in each year of his life after completing schooling. Working positive hours leads to an accumulation of human capital through work experience (learning by doing), which affects the hourly wage the individual is offered. The dynamics of the human capital accumulation process are specific to the individuals' education and unobserved heterogeneity type. Retirement is endogenous and not necessarily an absorbing state.

In each year starting at age $t = t_0$, and up to a maximum age $t = T = 100$, the agent chooses consumption c_t and hours of work h_t. The amount of consumption may not exceed the level of wealth M_t (measured in the beginning of the period) by more than a fixed amount a_0 denoting the credit constraint. Both M_t and a_0 are measured in \$AUD1000, and we set $a_0 = 20$.

The choice of hours is restricted to six discrete levels given by

$$\begin{aligned} h_t \in H &= \{h^{(0)}, h^{(1)}, h^{(2)}, h^{(3)}, h^{(4)}, h^{(5)}\} \\ &= \{0, 1000, 2000, 2250, 2500, 3000\} \text{ hours per year} \\ &= \{0, 20, 40, 45, 50, 60\} \text{ hours per week.} \end{aligned} \tag{1}$$

We found that these six levels provide the best fit to the observed wage distribution, using the algorithm in ****.

At the time that the labor supply decision is made, workers are assumed to know the offer wage

[5] The reform also introduced a gradual increase of the eligibility age, which is planned to reach 67 in 2023, and some other minor changes that we leave out in this paper.

rate up to a a log-normally distributed idiosyncratic wage shock $\varepsilon_t^{wage} \sim lnN(0, \sigma_t^{wage})$. The deterministic part of the observed hourly wage rate $wage_t$ is given by the product of human capital K_t and the rental price of a unit of human capital R_t. Thus we have:

$$wage_t = K_t \cdot R_t \cdot \varepsilon_t^{wage}. \tag{2}$$

We assume the market for human capital is perfect, so all workers face the same human capital rental price R_t. We assume this is constant over time and so it is normalized to one. We also allow for the variance of wage to be non-constant over the life cycle, $\sigma_t^{wage} = \varsigma_0 + \varsigma_1 t + \varsigma_2 t^2$.

Human capital K_t is a deterministic function of age and work experience $\mathcal{E}_t$, conditional on an individuals' *type* $\tau = (\tau_{edu}, \tau_{uh})$. The type consists of observed education $\tau_{edu} \in \{1, \ldots, J^{edu}\}$ as well as an unobserved heterogeneity component $\tau_{uh} \in \{1, \ldots, J^{uh}\}$. We estimate the model with $J^{edu} = 3$ levels of education, namely high school graduates, high school dropouts and college graduates. Following **?** we assume that the unobserved heterogeneity also takes the form of discrete "types". We allow for $J^{uh} = 2$ unobserved types within each education level, and we label these the 'high' and 'low' type. Both the observed education level and the latent type affect the accumulation dynamics of human capital and its initial stock at the start of ones' career.

Work experience $\mathcal{E}_t \in [0, 1]$ is defined as the fraction of total available time that is devoted to work up to and including period $t - 1$. This is equal to $t \cdot h^{(5)}$. It will be very convenient to use work experience $\mathcal{E}_t$, which is bounded to the unit interval, rather than human capital K_t, as a state variable in the model. Variable $\mathcal{E}_t$ also has a convenient deterministic rule of motion given by the following recursive expression:

$$\mathcal{E}_{t+1} = \begin{cases} \frac{h_t}{h^{(5)}}, & \text{if } t = 0, \\ \frac{1}{t+1}\left(\mathcal{E}_t t + \frac{h_t}{h^{(5)}}\right), & \text{if } t > 0. \end{cases} \tag{3}$$

The human capital production function is given by

$$K_{t+1}(\tau) = \exp\left[\eta_0^{edu}(\tau_{edu}) + \eta_0^{uh}(\tau_{uh}) + \eta_1 t + \eta_2 t^2 + \eta_3(\tau_{edu}) \cdot \mathcal{E}_t t + \eta_4(\tau_{edu}) \cdot (\mathcal{E}_t t)^2\right], \tag{4}$$

where $\mathcal{E}_t t$ can be interpreted as work experience measured in maximum-hours-equivalent time periods, and the η (with various sub- and superscripts) are parameters to be estimated by type. In particular, the initial level of human capital is determined by the sum of the education specific intercept $\eta_0^{edu}(\tau_{edu})$ and the unobserved type specific intercept $\eta_0^{uh}(\tau_{uh})$. The production technology of human capital from experience, governed by $\eta_3(\tau_{edu})$ and $\eta_4(\tau_{edu})$, is also education level specific.

At each age t the agent derives instantaneous utility from consumption $u(c_t)$ and disutility $v_t(h_t, \tau_{uh})$ from working. The agent also takes into account the value of possibly leaving a bequest $w(M_t - c_t)$, discounted by the probability $1 - \delta_t$ of death before the start of period $t + 1$ (see Appendix for the details of how the survival probability δ_t is specified). Preferences are additively separable both within period and over time. Future utility is discounted with discount factor $\beta(\tau_{edu})$ which is education level specific.

Denote by $V_t(X_t)$ the highest attainable discounted expected utility over the remaining life cycle, conditional on the state $X_t = (M_t, \mathcal{E}_t, \tau)$ of the decision maker at period t. Then the intertemporal decision problem is characterized by the *Bellman equation*

$$V_t(X_t) = \max_{0 \le c_t \le M_t + a_0, h_t \in H_t(\tau)} \Big\{ u(c_t) - v_t(h_t, \tau_{uh}) + \delta_t \beta(\tau_{edu}) E\big[V_{t+1}(X_{t+1}) \,|X_t, c_t, h_t\,\big] + (1 - \delta_t) w(M_t - c_t) \Big\}, \tag{5}$$

which gives rise to the optimal decision rules

$$\begin{aligned} c_t^\star(X_t) &: \; X_t \to [0, M_t + a_0], \\ h_t^\star(X_t) &: \; X_t \to H_t(\tau) \subset H, \end{aligned} \tag{6}$$

that solve the maximization problem in (**??**) in each point of the state space X_t. Thus, $c_t^\star(X_t)$ and $h_t^\star(X_t)$ map the state space into the feasible choices of consumption and labor supply. We impose some additional restrictions on the set of feasible hours choices $H_t(\tau)$ that differentiate it from the set H of all discrete hours levels listed in (**??**). First, we assume that working is not feasible after the maximum retirement age 85, i.e. $H_t(\tau) = \{h^{(0)}\}$ for $t > 85$. Second, we impose a minimum level of next period consumption equal to $c_{min} = 100$\$AUD per year, and disallow the choice of zero hours (i.e. $h^{(0)} \notin H_t(\tau)$) if optimal consumption in the next period would then be below c_{min}. Third, we assume *college students* do not work until they reach the age of 22, so $H_t(\tau) = \{h^{(0)}\}$ for $t \le 22$ and $\tau_{edu} =$ college.

The complete specification of the intertemporal budget constraint is given by

$$\begin{aligned} M_{t+1} = (M_t - c_t)(1 + r) &+ h_t \cdot wage_{t+1} \\ &+ tr_{t+1} \cdot \mathbb{1}\{t + 1 \le 22\} \\ &+ pens_{t+1} \cdot \mathbb{1}\{t + 1 \ge 65\} \\ &+ super_{t+1} \cdot \mathbb{1}\{t + 1 = 65\}, \end{aligned} \tag{7}$$

where the first component is assets carried over from the previous period with interest rate r (which we fixed at 4%); the second component is wage earnings; the third is transfers from parents (which agents receive at young ages); the fourth is the Aged Pension received from age 65; and the fifth is the superannuation lump sum payment that is received once at age 65. We use $\mathbb{1}\{\cdot\}$ to denote the indicator function.

A key point is that the wage in period $t+1$ is dependent on period $t+1$ human capital according to (??), and on work experience in period t according to (??). Therefore, the deterministic part of the wage is known at the time when hours are chosen. However, note that in (7) we attribute to period $t+1$ the wage income resulting from the labor supply decision made in period t. This is equivalent to assuming that the labor supply decision is made before the wage shock is realized. As a result, the wage shock must be integrated over when forming the Bellman equation. [6]

The expectation in (??) is normally taken over the transition probabilities of the state process, but because (??) and (??) are deterministic expressions, and an individuals' type τ does not change with age, all three components of our state vector X_t evolve deterministically. Consequently, the expectation in (??) is only taken over idiosyncratic wage shocks (as well as taste shocks to be introduced in the next section).

The non-labor income terms in (??) are specified as follows. The Aged Pension $pens_t$ is modeled using a smoothed version of the means tested pension equation, including both the income and asset tests, that is estimated from the data (see Appendix for details). This is:

$$\begin{aligned} pens_t = \mathcal{M}_\nu \Big(& 10,826.40 + 1249.67 \cdot \mathbb{1}\{year \geq 2010\} \\ & - \mathcal{M}_\nu \big[0, \mathcal{M}_\nu \big(0.26906 \cdot wage_t, 0.00402 \cdot (M'_t - 140,326.90)\big)\big], 0 \Big), \end{aligned} \tag{8}$$

where $\mathcal{M}_\nu(x,y) = \nu \cdot log\big(\exp(x/\nu) + \exp(y/\nu)\big)$ is a smooth maximum function[7] with smoothing parameter $\nu = 0.1$ (maximum error is $log(2)\nu = 69.315$\$AUD per year). The variable M'_t is wealth for the purpose of the asset test, which is given by

$$M'_{t+1} = (M_t - c_t)(1+r) + h_t \cdot wage_{t+1} + super_{t+1} \cdot \mathbb{1}\{t+1 = 65\}. \tag{9}$$

Here $super_t$ denotes the one-time full withdrawal of funds from the superannuation account

[6]More precisely, we adopt the following timing convention. At the start of each period $t+1$ the agent has a known amount of assets $(1+r)(M_t - c_t)$ carried over from period t. Then the labor supply decision h_t is made, which is followed by the realization of the wage shock ε^{wage}_{t+1}. Next, current total resources M_{t+1} are determined according to (??). Once M_{t+1} is known, the consumption decision c_{t+1} is made. To avoid the need to compute an expectation over wage shocks within the period, we attribute the labor supply decision to the previous period and re-label it accordingly. This modification is completed by discounting the deterministic disutility of work $w_t(h_t)$, a detail that is performed in the code but ignored in the text for notation simplicity.

[7]$\mathcal{M}_\nu(x,y) \to max(x,y)$ when $\nu \to 0$.

at age 65. Modeling superannuation withdrawal decisions is beyond the scope of this paper. Therefore we assume that the whole accumulated amount of superannuation is taken out by the agents as a lump sum at age 65 (the earliest age it can be withdrawn without additional taxes). [What percent of people do this?].

Our model also abstracts from voluntary contributions to the superannuation account. Thus, the accumulated balance is a deterministic function of the amount of labor supplied throughout the life cycle. This information is summarized by the amount of accumulated human capital. Thus, we model the superannuation amount as a linear function of human capital with a type specific slope

$$super_t = \rho_0 + \rho_1(\tau_{edu}) \cdot K_t, t = 65. \tag{10}$$

The parameters of (10) are estimated structurally. Finally, the transfer from parents at young ages tr_t is uniform across types, and is estimated as a single parameter.

We now turn to the specification of preferences. We use a constant relative risk aversion specification for the utility of consumption and the bequest motive.

$$u(c_t) = \frac{c_t^{1-\zeta} - 1}{1-\zeta}, \tag{11}$$

$$w(B_t) = b_{scale} \cdot \frac{(B_t + a_0)^{1-\xi} - a_0^{1-\xi}}{1-\xi}, \tag{12}$$

where $B_t = M_t - c_t$ denotes bequeathed wealth, and $b_{scale} > 0$, $\zeta > 0$ and $\xi > 0$ are parameters to be estimated. Because we assume the credit constraint $c_t \leq M_t + a_0$ holds in every period, the power in $w(B_t)$ is taken for non-negative numbers only. Both $u(c_t)$ and $w(B_t)$ nest log specifications when $\zeta = 1$ or $\xi = 1$.

The disutility of work $v_t(h_t, \tau_{uh})$ is given by a vector of constants associated with each of the discrete levels of hours $\gamma = (\gamma^{(1)}, \ldots, \gamma^{(5)})$. These coefficients are allow to vary with age and the unobserved heterogeneity type. Thus we have:

$$v_t(h_t) = \mathbb{1}\{h_t > 0\} \cdot \kappa_{type}(\tau_{uh}) \cdot \kappa_{age}(t) \cdot \gamma(h_t), \tag{13}$$

where $\gamma(h_t) = \gamma^{(i)} \Leftrightarrow h_t = h^{(i)}$, $i \in \{1, \ldots, 5\}$, and the type specific parameters are given by

$$\kappa_{type}(\tau_{uh}) = 1 + \kappa_1 \cdot \mathbb{1}\{\tau_{uh} = \text{low}\}, \tag{14}$$

$$\kappa_{age}(t) = 1 + \kappa_2(t-40)^2 \cdot \mathbb{1}\{t > 40\} + \kappa_3(t-25) \cdot \mathbb{1}\{t < 25\}. \tag{15}$$

Because we abstract from job availability and involuntary job loss, the parameters $\gamma^{(1)}, \ldots, \gamma^{(5)}$

will reflect not only the disutility of working the associated level of hours, but also the extent to which jobs with each level of hours are available. (These are structural parameters from the point of view of an individual decision maker, although they are determined by technology and the equilibrium of the economy).

4 Numerical solution method: The DC-EGM Algorithm

We solve the model using a generalization of the endogenous grid point method (EGM) developed by **?**. While the original method applied to a model with a single state variable and a single continuous choice variable, it was generalized by **?** to apply to models with mixed discrete-continuous choice variables as well as multiple state variables. We refer to this as the "DC-EGM" method. As with the original EGM, the main idea is to construct a grid of state points where arbitrarily chosen actions satisfy the first order conditions of the problem, and therefore are likely to be optimal. In fact, these points are optimal in convex problems for which the method was originally developed. In other words, instead of looking for optimal actions on a fixed grid over the state space, the method starts with a grid over the action space, which is mapped point-by-point into the *endogenous* grid over the state using the (analytically) inverted Euler equation.

As noted by **?**, problems containing mixed discrete and continuous choices are in general non-convex, and therefore solution methods for such problems can not rely solely on first order conditions of optimality. Identifying and filtering out redundant solutions of the Euler equation is the primary concern of DC-EGM method. **?** also show how the value functions of a simple model of consumption-saving and dichotomous retirement choice acquire kinks at the points of wealth where the decision maker is indifferent between the two discrete options. Derivatives of the value function change discontinuously at these kinks, leading to discontinuities and multiple solutions of the Euler equation. These multiple solutions correspond to multiple local maxima in the maximization problem in Bellman equation. At the level of wealth where the global maximum changes from one local maximum to another, the optimal consumption makes a discontinuous jump, inducing a discontinuous change in marginal utility and a corresponding kink in the value function. **?** show how these "secondary" kinks multiply and accumulate through time in deterministic problems, as well as problems with "too little" choice-specific randomness. However, in the presence of a random component of utility associated with each of the discrete choices, the kinks in the value functions are smoothed, and even though the problem remains non-convex in general, accumulation of kinks is significantly dampen.

Thus, following **?** we assume that the choice of hours in our model is dependent on additional state variables that are not observed by the econometrician. The influence of these state variables can be accounted for by adding random components to the deterministic utilities of hours, which we label *taste shocks*. Denote these taste shocks $\varepsilon_t = (\varepsilon_t^{(0)}, \dots, \varepsilon_t^{(5)}) \in \mathbb{R}^6$, so that $\varepsilon_t^{(i)}$ is associated with supplying $h_t^{(i)}$ hours of labor. We assume that the random variables ε_t have independent multivariate extreme value distributions with a common scale parameter λ. They are also independent of ε_t^{wage} and across time.

The intertemporal decision problem (**??**) (modified by inclusion of taste shocks) can then be re-written in terms of discrete choice specific deterministic value functions $U(X_t, h_t)$ as

$$\begin{aligned} U_t(X_t, h_t) = &\max_{0 \le c_t \le M_t + a_0} \Big\{ u(c_t) - v_t(h_t, \tau_{uh}) + (1-\delta_t) w(M_t - c_t) \\ &+ \delta_t \beta(\tau_{edu}) E\big[\max_{h_{t+1} \in H_{t+1}(\tau)} \{U_{t+1}(X_{t+1}, h_{t+1}) + \lambda \varepsilon_{t+1}(h_{t+1})\} \,|X_t, c_t, h_t \,\big] \Big\} = \\ &= \max_{0 \le c_t \le M_t + a_0} \Big\{ u(c_t) - v_t(h_t, \tau_{uh}) + (1-\delta_t) w(M_t - c_t) \\ &+ \delta_t \beta(\tau_{edu}) \mathop{\mathcal{LS}_\lambda}_{h_{t+1} \in H_{t+1}(\tau)} \Big(E\big[U_{t+1}(X_{t+1}, h_{t+1}) \,|X_t, c_t, h_t \,\big]\Big) \Big\}, \end{aligned} \tag{16}$$

where $\varepsilon_t(h_t) = \varepsilon_t^{(i)} \Leftrightarrow h_t = h^{(i)}$, $i \in \{0, \dots, 5\}$, and $\mathcal{LS}_\lambda(x_1, \dots, x_k)$ is logsum function, which is a multivariate version of the smooth maximum function $\mathcal{M}_\nu(x, y)$. Similar to (**??**), the solution to (**??**) gives rise to the optimal decision rules

$$\begin{aligned} &c_t^\star(X_t): \; X_t \to [0, M_t + a_0], \\ &h_t^\star(X_t): \; X_t \to \Big(P_t(h^{(0)}), \dots, P_t(h^{(6)})\Big), P_t(h_t) = 0 \;\forall h_t \notin H_t(\tau), \end{aligned} \tag{17}$$

where $P_t(h^{(i)})$ is the choice probability of supplying $h^{(i)}$ hours of labor at period t, given by

$$P_t(h^{(i)}) = \frac{\exp\big(U_t(X_t, h^{(i)})/\lambda\big)}{\sum_{h_t' \in H_t(\tau)} \exp\big(U_t(X_t, h_t')/\lambda\big)}. \tag{18}$$

The DC-EGM algorithm is centered around the Euler equation which remains a necessary condition even in presence of discrete choice (**?**). The Euler equation for the model is given by (see derivation in the Appendix):

XXX

The DC-EGM proceeds in the following way.

Step 0.

Step 1.

Table 1: Estimates of the preference parameters.

Parameter	Description	Estimate	Std.Err.
ζ	CRRA coefficient in consumption	1.01210	
γ_1	Disutility of working 1000 hours (20 per week)	0.59976	
γ_2	Disutility of working 2000 hours (40 per week)	0.53505	
γ_3	Disutility of working 2250 hours (45 per week)	1.06416	
γ_4	Disutility of working 2500 hours (50 per week)	1.05970	
γ_5	Disutility of working 3000 hours (60 per week)	1.50886	
$\kappa_1(\tau = \text{low})$	Correction coefficient for low type with disutility of work	0.65397	
κ_2	Quadratic coefficient on age for older workers	0.00158	
κ_3	Linear coefficient on age for young workers	0.05	**
ξ	CRRA coefficient in utility of bequest	0.03323	
b_{scale}	Scale multiplicator of the utility of bequest	0.01842	
$\beta(\tau = \text{hs})$	Discount factor, highschool	0.96154	**
$\beta(\tau = \text{dr})$	Discount factor, dropouts	0.96154	**
$\beta(\tau = \text{cl})$	Discount factor, college	0.96154	**
λ	Scale of EV taste shocks	0.335	**

Notes: The table presents the preliminary results obtained through estimation of subsets of parameters and calibration (marked with **).

Step 2.

Notably, none of these steps involves solving an optimization problem or computing solutions of an equation. This is the primary advantage of the DC-EGM algorithm, which allows for fast and accurate solution of the dynamic programming problem. For the more detailed description of the method, see **?**.

5 Data

6 Estimation method and Moments

7 Estimation results

The model has been estimated using the *** algorithm. Preliminary estimates are reported in Tables 1 to 4. These estimates are preliminary, both because the search algorithm has not yet fully converged, and because we have left quite a few parameters fixed at their initial calibrated values. We also have not yet calculated standard errors (as we will wait until we have the final estimates).

Table 2: Estimates of the parameters of human capital accumulation process.

Parameter	Description	Estimate	Std.Err.
$\eta_0(\tau = \text{cl})$	Constant for college	2.71840	
$\eta_0(\tau = \text{hs})$	Constant for high school	2.68287	
$\eta_0(\tau = \text{dr})$	Constant for dropouts	2.79407	
$\eta_0(\tau = \text{low})$	Constant for low type	-0.85986	
η_1	Age (time index)	0.02464	
η_2	Age (time index) square	-0.00074	
$\eta_3(\tau = \text{cl})$	Work experience for college	0.0435	**
$\eta_3(\tau = \text{hs})$	Work experience for high school	0.025	**
$\eta_3(\tau = \text{dr})$	Work experience for dropout	0.01	**
$\eta_4(\tau = \text{hs})$	Work experience square for high school	-0.000025	**
$\eta_4(\tau = \text{dr})$	Work experience square for dropout	0.0	**
$\eta_4(\tau = \text{cl})$	Work experience square for college	-0.0002	**

Notes: The table presents the preliminary results obtained through estimation of subsets of parameters and calibration (marked with **).

Table **??** contains estimates of the preference parameters. The CRRA parameter for consumption in equation (11), ***, is estimated to be very close to 1.0, which implies utility is close to logarithmic in consumption. In simple versions of the life-cycle model this would imply that income and substitution effects of wages on labor supply roughly cancel. But this is not necessarily the case here, given that we have endogenous human capital and pensions that are a nonlinear function of earnings.

The dis-utility of work hours parameters from equation (13), ***, imply that dis-utility is non-monotonically increasing in hours. The estimated dis-utility of working 40 hours per week is slightly less than that of working 20, and the estimated dis-utility of working 50 hours per week is slightly less than that of working 45. However, recall that in our model the *** reflect not only the dis-utility of working the associated level of hours, but also the extent to which jobs with each level of hours are available. The additional dis-utility of work parameters from equations 12-13 (kappa 1 to 3) imply that the "low" type has a dis-utility of work 2/3 greater than the "high" type. The dis-utility of work is also increasing with age after age 40.

Note that the discount factor is fixed at the initial value of 0.95, and the scale of the EV errors is fixed at 0.335.

Table **??** contains estimates of the human capital production function parameters. Note that the "low" type has a substantially lower production function intercept. Human capital has an inverted U-shaped path in age. Unfortunately, we have not yet moved the experience parameters

Table 3: Estimates of the other transition parameters.

Parameter	Description	Estimate	Std.Err.
ς_0	St.dev. in shock distribution: constant	0.55634	
ς_1	St.dev. in shock distribution: age	−0.00308	
ς_2	St.dev. in shock distribution: age square	0.000087	
$tr1$	Transfer from parents	10.0	**
ρ_0	Superannuation: constan	0.0	**
$\rho_1(\tau = \text{cl})$	Superannuation: human capital | college	6.0	**
$\rho_1(\tau = \text{hs})$	Superannuation: human capital | high school	4.275	**
$\rho_1(\tau = \text{dr})$	Superannuation: human capital | dropouts	7.95	**

Notes: The table presents the preliminary results obtained through estimation of subsets of parameters and calibration (marked with **).

Table 4: Estimates of the initial conditions parameters.

Parameter	Description	Estimate	Std.Err.
w0mu	Initial wealth mu	0.0	**
w0sigma	Initial wealth sigma	0.15	**
prH_hs	High type proportion | high school	0.79622	
prH_dr	High type proportion | dropout	0.69308	
prH_cl	High type proportion | college	0.88631	

Notes: The table presents the preliminary results obtained through estimation of subsets of parameters and calibration (marked with **).

from the starting values.

Table **??** contains estimates of the parameters *** that determine how the standard deviation of the wage shocks vary with age (see equation 2). The estimates imply a U-shaped path. The superannuation process parameters are estimated from the HILDA data and held fixed.

Table **??** contains estimates of the type proportions conditional on education. As expected, the probability of being the "high" type is increasing in education.

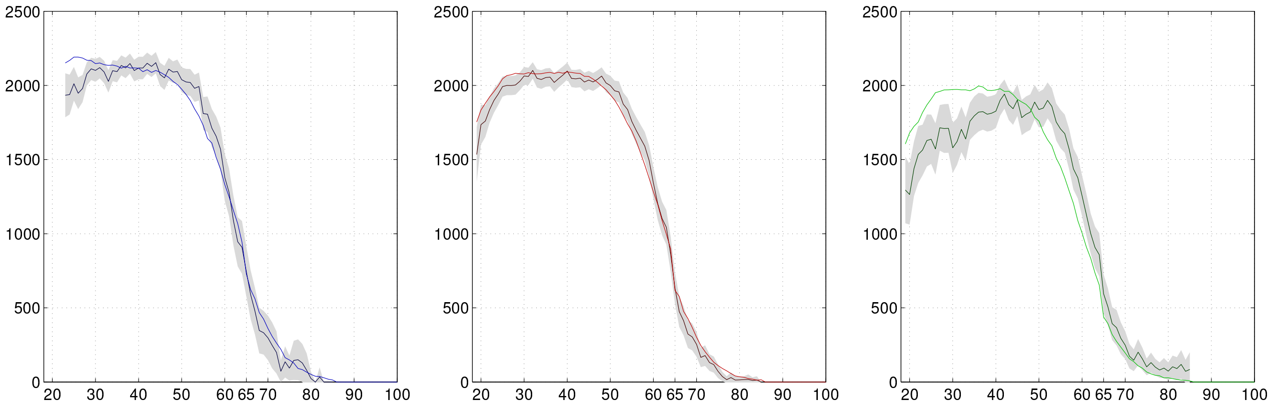
8 Fit of the Model

In this section we describe the fit of the model to several key dimensions of the data. These are hours, employment, wages, assets and bequests.

Figure **??** shows the fit of the model to average annual hours over the life-cycle. The average includes both working and non-working individuals. Notice that the model provides a good fit to the life-cycle path of hours for high school workers. In particular it captures that hours rise at

Figure 2: Fitted hours of labor supply by age.

(a) College graduates (b) Highschool graduates (c) Highschool dropouts



Notes: The plots show simulated life cycle profiles of hours of labor supply for the three education groups against the profiles observed in the data. The profiles observed in the data are shown with the bands of 1.96 standard deviations of the means.

young ages, then stay very flat from the late 20s through the late 40s, and then decline steeply in the 50s and 60s.

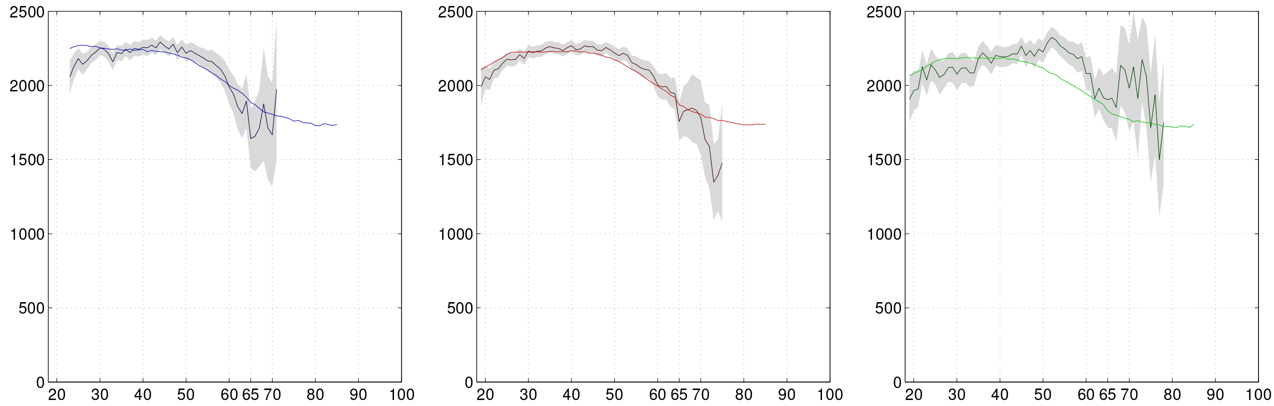
The fit for college workers is not quite as good because the model predicts their hours are too high at young ages (i.e., their hours are flat right from the beginning). Clearly the model fits the dropouts less well than the other two groups. Although it gets the basic shape of their life-cycle hours path correct, it predicts too high a level of hours prior to 40, and too quick a drop in hours in the 50s.

Figures **??** and **??** decompose total hours into the extensive margin (i.e., employment) and the intensive margin (i.e., hours conditional on employment). The model captures the nature of this decomposition quite well for all three groups. As we see in Figure **??**, hours conditional on employment are quite flat over the life-cycle for all three education groups. For example, for high school workers, average hours are about 2250 per year at age 40, and they only drop to about 1800 hours per year at age 70. As we see in Figure **??** it is sharp drops in employment after age 50 that account for most of the declines in total hours that we see in Figure **??**.

Recall that in our model agents can choose to work 20, 40, 45, 50 or 60 hours per week (where these values were chosen because they provide a good fit to the observed bunching of hours in the data). Figure 4 reports how the model fits the number of high school workers at each hours level. The model provides a very good fit to the distribution of workers to hours levels by age with one notable exception. Specifically, in the data we see that when people reach their late 50s and 60s there is a jump in the number who work part-time (i.e., 20 hour per week). At

Figure 3: Fitted hours conditional on working by age.

(a) College graduates (b) Highschool graduates (c) Highschool dropouts



Notes: The plots show simulated life cycle profiles of hours of labor supply conditional on working for the three education groups against the profiles observed in the data. The profiles observed in the data are shown with the bands of 1.96 standard deviations of the means.

the same time, there is a drop in the number of people who work 40 hours per week. Thus, it appears as if a sizable number of people transition from 40 to 20 hours per week before they retire. The model fails to generate this pattern, and hence, in the late 50s and 60s, it understates the number of people working 20 hours per week and overstates the number working 40 hours per week. The same pattern holds for all three groups, so we relegate the results for the college and dropout groups to the online appendix.

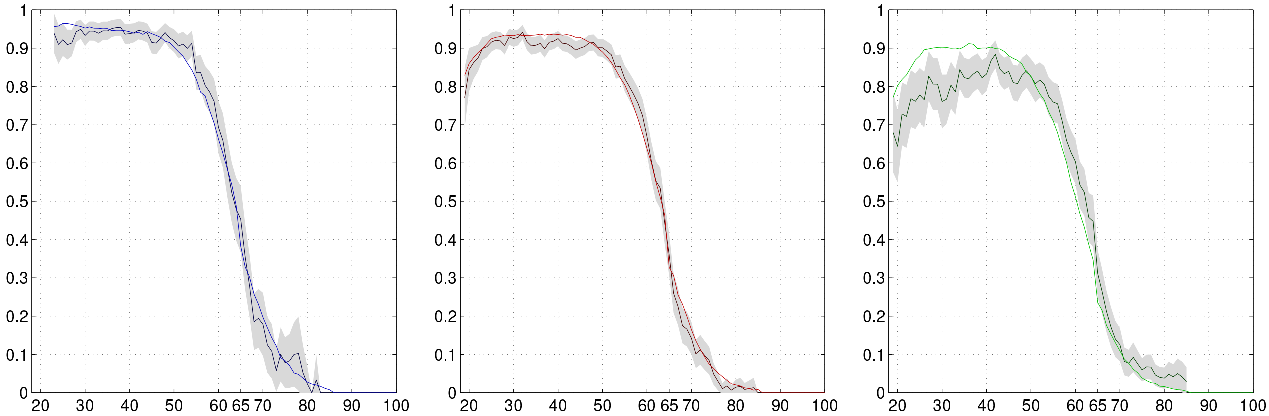
Figure 5 reports the fit of the model to the average wage of employed workers by education and age. One can see details of the life-cycle wage path for each education that the model fails to fit precisely. However, the big picture is that the life-cycle wage paths are very different for the three education groups. For dropouts wages only rise very slightly from when workers first enter the labor market until their life cycle peak. But for college workers wages roughly double. The high school workers are in between. The model does a very good job of capture the broad differences between the three education groups. Obviously this is primarily because the estimates imply greater returns to experience for model educated workers.

Figure 6 reports the fit of the model to the standard deviation (or variance??) of wages. What is notable here is that the variance of wages rises very substantially with age for college workers. For high school and drop out workers the variance is much lower and does not rise very much over the life-cycle. The model captures these differences quite well. Where the model falls short is that it overstates the level of the variance for high school and dropout workers.

Figure 7 reports on the evolution of wealth over the wealth cycle. Overall, the model provides

Figure 4: Fitted fraction of working by age.

(a) College graduates (b) Highschool graduates (c) Highschool dropouts



Notes: The plots show simulated life cycle profiles of working for the three education groups against the profiles observed in the data. The profiles observed in the data are shown with the bands of 1.96 standard deviations of the means.

quite a good fit to the life-cycle wealth paths for all three education groups. Notice that wealth jumps at age 65 with the receipt of superannuation. At age 65 teh mean wealth of college workers is roughly \$1M, that of high school workers is roughly \$600k, and that of dropouts is roughly \$400k. The models fits the age 65 differences in wealth across groups very precisely.

Finally, Figure 8 describes how the model fits transition rates between work and non-work states. The captures the qualitative patterns of how these transition rates vary by age and education, but it is far from getting the magnitudes correct. Looking first at high school workers, the model captures that the work-to-work transition rate is over 90% until the late 50s, and then falls in the 50s and 60s. But the model substantially exaggerates this drop. There is a similar problem of seriously understating the work-to-work transition rate in the 50s and 60s for high school and college workers as well.

Turning to the unemployed-to-unemployed transition rate, during the prime working years it hovers around 50% for college workers, 60% for high school workers, and 70% for dropouts. The model generates this ranking, but seriously understates the magnitudes for all three groups. The model does generate the qualitative pattern that the unemployed-to-unemployed transition rate rises substantially in the 50s and 60s for all three education groups.

Of course, it is well known that dynamic labor supply models have a tendency to understate both work-to-work and unemployed-to-unemployed transition rates, in part due to teh problem of classification error in employment states (see Keane and Sauer (****), Poterba and Summers

(****)). As we abstract from classification error, we do not find it too surprising that we also understate these transition rates.

9 Policy simulations

In this section we look at the predictions of the model with respect to changes in wage rates, as well as changes in the aged pension and superannuation rules.

First, in Figure 9, we report simulated responses to transitory changes in the wage rate. We look at 10% reductions in the wage rate that last for exactly one year. We consider the effect of wage changes that occur at five year intervals from age 25 through 70, in order to see how the effects vary by age. The top panel of Figure 9 reports the effects of transitory wage changes that are fully anticipated, so that we obtain pure Frisch elasticities. The bottom panel reports effects of unanticipated transitory changes. This gives approximate Frisch effects, as the unanticipated wage changes have very small effects on lifetime wealth.

As we see in Figure 9, Our model implies a pattern of labor supply elasticities with age that is broadly consistent with the much simpler life-cycle model in Imai and Keane (2004).[8] For instance, the Frisch elasticity is about 0.30 for high school types below age 45, but it grows to roughly 1.0 at age 60.

Figure 10: Similarly, if we look at the effect of unanticipated permanent wage decreases, Marshallian elasticities are quite small prior to age 50, but grow to about 0.40 at age 55, 0.75 at age 60 and 1.2 at age 65.

Figure 11: Our results imply that increases in the generosity of the Aged pension would have very modest effects on labor supply over the life-cycle. For instance, a 25% increase in the pension grant amount (holding means testing fixed) reduces labor supply of high school type workers by only 1% at age 60, and by even less at earlier ages. Even at age 65 and onward, the drop in labor supply is only about 5%.

Figure 12: A reduction in the wealth exemption for the aged pension seems to have trivial effects on hours of work. For instance, a 50% cut in the exemption has essentially no effect on hours prior to age 65, and raises hours from age 65 onward by only about 0.6% to 1.6% depending on age and education. This is presumably because workers can respond by saving somewhat less prior to retirement.

Figure 13: Next we simulate a 10% increase in the magnitude of superannuation payments for

[8] Theirs' was the first structural life-cycle model to include both assets and endogenous human capital, but they assumed continuous hours and assumed interior solutions, ignored liquidity constraints, and did not model retirement or social security

a given level of contributions (in partial equilibrium this could be thought of as increasing the employer match amount). This policy leads to negligible effects on labor supply prior to age 65, and very modest reductions in labor supply from 65 onward (e.g., about 1.0% for college workers and 0.25% for high school and dropout workers). These impacts are presumably small because the policy is, in effect, an increase in the wage rate, so it has conflicting income and substitution effects.

In our next set of experiments we consider the *ceteris paribus* effects of complete elimination of the superannuation and Aged Pension programs. These experiments are not realistic, as such large policy changes would presumably have non-negligible equilibrium effects if actually implemented. For instance, abstracting from uncertainty and borrowing constraints, superannuation is very much like a 9% wage subsidy, except that these earnings are required to be saved and then paid out (with interest) at age 65. Thus, we would expect the elimination of superannuation to cause a substantial increase in the equilibrium wage rate. Nevertheless, our partial equilibrium experiments are useful to gain insights into the mechanisms through which superannuation and the Aged pension affect *individual* life-cycle behavior, holding the wage rate fixed.

In Figures 14, 15 and 16 we report the effects of eliminating superannuation on hours, wealth and consumption. Consider first the results for the college type (files #214, 226 and 238). Notice that they respond by working only slightly fewer hours prior to age 65 (i.e., only about 0.5%). Given that eliminating super is very similar to a 9% wage cut for those under 65, this is consistent with our earlier finding that the Marshallian elasticity is quite small. On the other hand, eliminating super causes workers to work roughly 10% more hours after age 65. This is consistent with a fairly large income effect.

Next consider consumption. Interestingly, consumption only falls by about 1% or 2% (depending on age). One might have expected a larger drop, given the *effective* wage rate prior to age 65 has fallen by roughly 9%. Thus, it seems that workers respond to elimination of super by working a bit more prior to age 65 and quite a bit more from 65 onward in order to avoid substantial drops in consumption.

Finally, we look at the asset path. Notice that by working slightly more (i.e., 0.5%) and consuming about 1% or 2% less prior to age 65 college workers are able to save about $100k more. This is just voluntary savings (netting out the required superannuation contributions). Under the baseline college workers save about $800k by age 65 (and then the super payment of roughly $200k brings them up to about $1M). Thus, in response to the elimination of superannuation, workers make up roughly half of the age 65 asset decline via increased voluntary saving.[9] To-

[9]Notice that the amount college workers save goes up by about $100k/$800k = 12.5%. Is that consistent with

gether, these results suggest that the superannuation program induces college workers to save roughly 12.5% more prior to age 65, and to work about 10% less after age 65.

In Figures (files #214, 226 and 238) we look at effects for high school workers. Under the baseline high school workers save about \$520k by age 65, and then the super payment of roughly \$80k brings them up to about \$600k to finance retirement. In the absence of superannuation, their voluntary saving up to age 65 increases by \$60k. They achieve this primarily by reducing consumption by roughly 1% to 1.5% over the period from 35 to 65, slightly raising hours of work prior to age 65 (by about 0.5%), and increasing hours by roughly 2.25% after age 65. Thus, the qualitative pattern is very similar to college workers; but the high school workers make up for a higher percentage of lost savings, and increase hours by less after age 65.

Finally in Figures (files #213, 225 and 237) we look at effects for dropout workers. Under the baseline dropout workers save about \$300k by age 65, and then the super payment of roughly \$100k brings them up to about \$400k to finance retirement. It is interesting that in the data (and simulation) superannuation payments to dropout workers are actually slightly larger than those to high school workers. This may be because dropouts are more likely to work in unionized industries where employers make voluntary extra contributions. In the absence of superannuation, the voluntary saving of dropouts up to age 65 increases by \$80k, and the assets available at age 65 to finance retirement only drop by \$20k or 5%. They achieve this primarily by reducing consumption by roughly 2% prior to age 65, raising hours of work by about 0.8% prior to age 65, and raising increasing hours by roughly 2.5% after age 65.

The pattern that emerges is that more educated workers replace a smaller percentage of the retirement savings (available at age 65) that is lost due to elimination of superannuation. Conversely, the response of college workers is characterized by a much larger increase in labor supply after age 65 than for the less education groups.

In Figures 17, 18 and 19 we report the effects of eliminating the Aged Pension on hours, wealth and consumption. Recall that, in contrast to superannuation, the Aged Pension is a social insurance program to help people over 65 with low assets and income. Consider first the results for the dropout type (files #210, 222 and 234), who should be the most affected by the program. When the aged pension is eliminated, the dropouts are predicted to reduced their consumption prior to age 65 by over 2% at most ages, and to increase labor supply modestly. This enables them to accumulate an additional \$185k by age 65. Nevertheless, hours of work still increase by about 30% after age 65 and consumption falls by roughly 2%. If we look at high school workers

a 1% drop in consumption? Suppose consumption is 92% of income under the baseline, and it drops by 1% to 91%. Then the saving rate will have gone up by $1/8 = 12.5\%$. Thus, a back of the envelop calculation suggests these figures do hang together.

(files #209, 221 and 233) the effects on hours, wealth and consumption are very nearly as large as for dropouts.

Perhaps surprisingly, the effects of eliminating the Aged Pension are quite large even for college workers (files #211, 223 and 235). They are are predicted to reduce their consumption prior to age 65 by over 2% at most ages, although labor supply is essentially unchanged. This enables them to accumulate an addition \$105k by age 65. They then work about 10% more at age 65, and at least 5% more afterwards.

There are two main reasons that college workers respond so strongly to elimination of the Aged Pension. First, the Aged Pension is a consumption insurance program, that mitigates the risk of poverty in old age. Risk averse agents will save less prior to age 65 if they have such consumption insurance available, even if the probability of using it is rather small. Second, as we discussed in Section 2, the rate at which Aged Pension benefits are taxed away with income and assets is very low. Thus, even fairly high income individuals will in fact be eligible for some benefits under the program.

10 Discussion and conclusions

Appendix

A Complete list of model parameters

Table 5: Parameters of the model.

	Symbol|Value	Description
Preference parameters		
1	ζ	CRRA coefficient in consumption
2	γ_1	Disutility of working 1000 hours (20 per week)
3	γ_2	Disutility of working 2000 hours (40 per week)
4	γ_3	Disutility of working 2250 hours (45 per week)
5	γ_4	Disutility of working 2500 hours (50 per week)
6	γ_5	Disutility of working 3000 hours (60 per week)
7	$\kappa_1(\tau = \text{low})$	Correction coefficient for low type with disutility of work
8	κ_2	Quadratic coefficient on age for older workers
9	κ_3	Linear coefficient on age for young workers
10	ξ	CRRA coefficient in utility of bequest
11	b_{scale}	Scale multiplicator of the utility of bequest
12	$\beta(\tau = \text{hs})$	Discount factor, highschool
13	$\beta(\tau = \text{dr})$	Discount factor, dropouts
14	$\beta(\tau = \text{cl})$	Discount factor, college
15	λ	Scale of EV taste shocks
Parameters of state transition (beliefs)		
16	$\eta_0(\tau = \text{hs})$	Human capital: constant for high school
17	$\eta_0(\tau = \text{dr})$	Human capital: constant for dropouts
18	$\eta_0(\tau = \text{cl})$	Human capital: constant for college
19	$\eta_0(\tau = \text{high})$	Human capital: constant for high typ
20	$\eta_0(\tau = \text{low})$	Human capital: constant for low typ
21	η_1	Human capital: ag
22	η_2	Human capital: age squar
23	$\eta_3(\tau = \text{hs})$	Human capital: work experience for high school
24	$\eta_3(\tau = \text{dr})$	Human capital: work experience for dropout
25	$\eta_3(\tau = \text{cl})$	Human capital: work experience for college
26	$\eta_4(\tau = \text{hs})$	Human capital: work experience square for high school
27	$\eta_4(\tau = \text{dr})$	Human capital: work experience square for dropout
28	$\eta_4(\tau = \text{cl})$	Human capital: work experience square for college
29	ς_0	St.dev. in shock distribution: constant
30	ς_1	St.dev. in shock distribution: ag
31	ς_2	St.dev. in shock distribution: age squar
32	$tr1$	Transfer from parents
33	ρ_0	Superannuation lumpsum: constan
34	$\rho_1(\tau = \text{hs})$	Superannuation lumpsum: human capital for high school
35	$\rho_1(\tau = \text{dr})$	Superannuation lumpsum: human capital for dropouts
36	$\rho_1(\tau = \text{cl})$	Superannuation lumpsum: human capital for college
Initial conditions and smooth simulator parameters		
37	w0mu	initial wealth mu
38	w0sigma	initial wealth sigma
39	prH_hs	High type proportion | high school
40	prH_dr	High type proportion | dropout
41	prH_cl	High type proportion | college

Table 5: (continued)

Symbol|Value	Description
Fixed and calibrated parameters	
20	Credit constraint (in $AUD1000)
4%	Interest rate on savings
85	Compulsory retirement age
0.1	Minimum consumption (in $AUD1000) for not working, c_{min}
22	Minimum age of college student working career beginning
22	Maximum age to receive money transfer from parents
65	Minimum age to receive pension benefits
65	The age when lump sum payment of superannuation is received
0.1	Smoothing parameter in smooth maximum function in pension equation, ν
25	Young age threshold in disutility of work moderation multiplier
40	Old age threshold in disutility of work moderation multiplier
0.002	Smooth simulator: scale invariant smoothing parameter for $h^{(0)}$
0.005	Smooth simulator: scale invariant smoothing parameter for $h^{(1)}, \dots, h^{(5)}$

Notes: The table lists all estimated, calibrated and fixed parameters of the dynamic programming model, excluding parameters estimated outside of the model during the first stage of estimation. For the fixed parameters the values are also shown. The counter is displayed only for the structurally estimated parameters.