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Abstract

We investigate the effects of self-control preferences on household life cycle decisions, macroeconomic outcomes, and the roles they play in determining optimal means testing of public old-age pensions. To that end, we develop a stochastic overlapping generations model with heterogeneous households that have Gul-Pesendorfer self-control preferences. First, we show that in economies with higher self-control costs lifetime savings diminish, while labor supply and retirement are postponed to later ages. Hence, the fiscal burden to fund the public pension system increases. Second, we examine the effects of increasing self-control costs in the context of age pension means testing with alternative taper rates at which the pension benefit is withdrawn. We show that there is a negative relationship between self-control costs and taper rates, i.e., populations with higher self-control costs prefer lower taper rates. We find that if self-control costs are sufficiently high, a universal pension with a zero taper rate may be optimal.

Keywords: Self-control preferences, Public pensions, Progressivity, Labor supply, Life-cycle, Stochastic OLG model

JEL Classification: C68, D15, D91, H2, H55, J22

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1 Introduction

The field of economics continuously grapples with understanding the complexities of human decision-making, especially in the context of inter-temporal household behaviour. Traditional economic models presume preferences without temptation or self-control costs, adept at allocating resources to maximize their utility over their lifetimes. However, behavioural economics increasingly scrutinizes deviations from this assumption. There is a growing acknowledgment that households frequently exhibit forms of myopia or present bias, often failing to optimally distribute resources over time, leading to inadequate retirement savings. This present bias not only underscores the necessity for public old-age pensions but also shapes the efficacy of specific design elements, such as means testing, which makes pension benefits contingent on household private retirement income and assets.[1]

In this study, we focus on one facet of present bias known as self-control preferences, as delineated by Gul and Pesendorfer [2001] and Gul and Pesendorfer [2004]. Self-control preferences encapsulate individuals who grapple with the temptation of prioritizing short-term gains over long-term welfare. Resisting this temptation necessitates a costly exercise of self-control discipline. Self-control preferences are a time consistent form of present bias, meaning that an agent with self-control preferences can still plan future consumption and savings without being subject to preference reversals. Given the inherent challenge of saving for retirement amidst self-control costs, as documented by Choi et al. [2011] and more recently by Rey-Ares et al. [2021] and Cobb-Clark et al. [2022], households with such preferences may place greater value on publicly-provided old-age pensions over private savings. Additionally, governmental attempts to curb pension expenditure through means testing might yield unexpected outcomes due to altered household savings behaviour.

[1] Several countries, including Australia, South Africa and Denmark, apply some form of means test to their public old-age pension. Chomik et al. [2015] provide some cross-country comparison of means tested pensions, discuss modelling literature studying pension means testing, and in a non-technical way, explain how it works and what its trade-offs are. In brief, the key advantage of pension means testing is that the public benefit is targeted to those with the greater need for financial support in their old age, hence reducing the fiscal cost of the pension program compared with a similar sized pension that is offered universally. However, means-testing the pension (increasing pension progressivity) can create additional distortions to household behaviour over the life cycle, as some households will find it optimal to limit their asset accumulations, with faster drawdowns at older ages, to qualify for public pensions.

This paper has a dual objective. Firstly, we investigate how self-control preferences impact life cycle household behaviour concerning consumption, saving, labor supply, and retirement decisions within a specific pension framework. Secondly, we assess the effects of self-control preferences on the optimality of pension means testing, considering its impacts on heterogeneous households.[2]

To undertake this analysis, we develop a stochastic overlapping generations (OLG), dynamic general equilibrium model featuring heterogeneous households and self-control preferences. In our model, households make decisions regarding consumption and saving as well as labor supply and retirement. Hence, in each period, households can allocate their time between labor and leisure, and their income between consumption and saving. Households have heterogeneous earning capacities, with their labor productivity determined by their age, educational attainment, and idiosyncratic shocks. They also face longevity risk. The government provides an old-age pension to older households.

We initially solve a benchmark economy, where households do not have self-control costs. We calibrate the model with household survey data and pension policy in Australia, modelling the current income test applied to old-age pensions. Then, we use the model to examine the long run effects of increasing self-control temptation cost on household economic decisions over the life cycle. Next, we examine how self-controlled preferences influence the optimality of pension means testing, using household long-run welfare calculations as a metric. Finally, we consider a variation in the specification of household preferences by providing an additional source of temptation via leisure. Our results are robust to this model extension.

Our findings regarding the first objective indicate that in economies characterized by households with higher self-control costs, lifetime savings diminish due to the present period bias in decision making by households. Similarly, households' present period bias leads to labor supply and retirement being postponed in such economies. Consequently, the fiscal burden of the pension system increases compared to economies where agents do not face self-control utility. Regarding the second objective, we show that in economies where self-control problems are pronounced, a lower or zero taper rate on pension means

[2]We focus on the key parameter of any means test – the taper rate at which pension benefits are withdrawn conditional on private retirement incomes and savings, determining pension progressivity (i.e., a higher taper rate increases pension progressivity). Our optimality analysis is based on expected aggregate life time utility.

testing is preferable. This contrasts with models with no self-control utility, where a higher taper rate is deemed optimal.[3] Populations grappling with significant self-control costs face sensitivity to the pension taper rate, affecting both their savings behaviour and labor supply, particularly at older ages.

Moreover, as populations with self-control costs tend to save less for retirement, they become increasingly reliant on the age pension. Consequently, the cost of providing means-tested pensions can be substantially higher, up to 15 per cent, compared to scenarios without such costs. While means-tested pensions are generally less costly than universal pensions, the savings derived from means testing are less pronounced in economies with higher self-control costs for households. Considering both behavioural and fiscal implications, populations experiencing significant self-control costs favour lower taper rates. In cases where self-control costs are particularly high, a universal pension (independent of private retirement income) emerges as the optimal long-term preferred pension scheme.

Related Literature We contribute to several stands of literature, studying implications of myopia and self-control costs on intertemporal household decisions in the context of public policy and specifically pensions. An early study of present bias as a justification for public pensions is Feldstein [1985], which, using a 2-period life-cycle model, finds that a social security system can be optimal if a population is myopically discounting the future. An alternative approach using time-inconsistent preferences, where the agent's time preferences themselves change over time, was initially used by Phelps and Pollack [1968] to model intergenerational savings and applied to an agent's life cycle in Laibson [1997]. Although time inconsistent preferences are a less subjective approach than ascribing myopia to an agent, welfare analysis is nevertheless complicated by the fact that agents do not have a single set of preferences over their life cycle. Applying time inconsistent preferences to a procrastination problem, O'Donoghue and Rabin [1999] drew a distinction between naive myopes, who do not recognise that they are myopic, and sophisticated myopes, who are aware and adjust their behaviour accordingly.

Imrohoroglu et al. [2003], using an OLG model of the US economy, study whether time-inconsistency in preferences would justify old-age social security. They show that the existence of an unfunded social security system would still reduce capital, output and

[3] This result of a very high taper rate in models with standard preferences is supported by various researchers as documented by Chomik et al. [2015].

welfare if the household preferences were time-inconsistent, but the welfare cost of a social security system is smaller than for a similar economy with time-consistent preferences. If the degree of time inconsistency is sufficiently strong, a social security system may even be welfare improving in the long run. Similarly, Fehr et al. [2008] develop an OLG model with cyclers and myopes where myopes have time inconsistent preferences, extended to account for elastic labor supply and idiosyncratic labor productivity shock to study privatizations of old age social security.

Other authors have appealed to notions of limited self-control. Thaler and Shefrin [1981] develop a theory of finite self-control to explain why households sometimes choose commitment devices (such as opening low-interest Christmas accounts) that otherwise would be sub-optimal. Under this theory, an agent is presumed to have multiple selves; a "doing" self who generally has power over her actions and who only cares about utility in the short run, and a "planning" self who values long run utility and can take limited steps to restrict the doing self's choice set in the future, such as purchase an asset for retirement.

In contrast to the previous literature, the seminal contributions of Gul and Pesendorfer [2001] and Gul and Pesendorfer [2004] provide an alternative self-control theory of consumer behaviour, which is also based on the time-consistent framework for agent's preferences. However, instead of the multiple selves of Thaler and Shefrin [1981], Gul and Pesendorfer develop a measure of preference for commitment and a measure of self-control, which generate different preference rankings for consumption choices.

Several studies have documented the presence of self-control costs. For example, Ameriks et al. [2007] explore the relationship between self-control problems and wealth using data on highly educated adults and find that self-control problems are smaller for older respondents. Exploiting the link between self-control preferences and incentive to hold illiquid assets, Bucciol [2012] uses a method of simulated moments approach to jointly estimate the parameters of the utility function of households, finding evidence of small but statistically significant self-control costs. A different approach is taken by Huang et al. [2015], who find that one important implication of self-control preferences is that households' preference for consumption is influenced by their wealth level. They find evidence for the presence of statistically and economically significant levels of temptation.

For applications to public pensions, Kumru and Thanopoulos [2008] and Bucciol [2011] incorporate the Gul and Pesendorfer self-control preferences (with agents tempted each period to consume their entire savings) in a dynamic general equilibrium OLG model calibrated to the US to study social security privatization. They show that the welfare loss associated with pay-as-you-go social security system can be much smaller than under the standard assumption of exponential discounting. Such social security system could even be preferred in the long run if the costs of self-control are sufficiently high. Kumru and Thanopoulos [2011], using a similar model, study the long run welfare effects of privatizing social security pensions combined with the introduction of mandatory private retirement accounts. Similarly, they show that higher self-control temptation may alter the long run preference for full privatization of social security. A more recent note on pension means testing and temptation is provided by Kumru et al. [2019], using a model applied to PAYG (pay as you go) pensions in the US. In our paper, we create a very general, heterogeneous agent general equilibrium OLG model, which is estimated using household survey, and pension policy data in Australia. Our model allows for household heterogeneity, elastic labor supply and endogenous retirement, which are important channels for the analysis self-control problems affecting the effects of publicly funded pensions that means testing, as studied in this paper.[4]

With growing interest in the means testing of public pensions, there have been several studies that investigate its economy-wide effects on household economic behaviour and welfare, and macroeconomic and fiscal aggregates, using OLG models with standard preferences without self-control. These papers include, for example, Kudrna and Woodland

[4]Note that self-control preferences have been studied in the context of another public policy domain – optimal income taxation. Krusell et al. [2010] study optimal capital income taxation and show that, within a class of Ramsey tax schemes, a negative tax or savings subsidy improves welfare when agents have self-control problems. Tran [2018] extends this analysis by endogenizing labor supply and showed that this extension introduces an intra-temporal channel for temptation distortions through consumption-leisure trade-offs. In a recent paper, Arvaniti and Sjögren [2023] also use Gul and Pesendorfer self-control preferences but in a model with two ability types and asymmetric information, and where people have self-control problems which relate to a consumption good. They showed a linear commodity tax complemented by a positive marginal labor income tax rate improves welfare. In our paper, we focus on public pension means testing, which directly alters pension progressivity, but also indirectly, there is an endogenous adjustment in the income tax schedule captured in our model, hence changing the level of income taxation (i.e., higher (lower) pension taper rate, increasing (reducing) pension progressivity, generates lower (higher) average income tax rate).

[2011], Kudrna et al. [2022] and Wheadon et al. [2024] for Australia; Sefton and van de Ven [2009] for the UK; Kitao [2014] for the US; and Fehr and Uhde [2014] for Germany. However, there has been relatively little attention given to the optimal structure of a social security or pension system (i.e., optimal pension means test) when households have self-control preferences. One exception is Bouchard St-Amand and Garon [2015] who use a theoretical 3-period life-cycle model to study the extent to which a social security system should be redistributive. They find that when populations have proportions of individuals with self-control preferences a less redistributive system is preferred and there is a higher willingness to pay for the pension system. We employ a more comprehensive OLG model with self-control preferences and focus on pension means testing via changes to a single parameter – the pension taper rate.

In this paper, we extend the previous analyses of pension means testing/targeting by comparing welfare outcomes between universal and means-tested pensions in economies with and without self-control preferences, when the maximum pension benefit is fixed, and when retirement is endogenous. When the size of the maximum pension benefit is fixed, the cost of the pension scheme to policymaker and ultimately to taxpayers is affected by changes to the pension taper rate, providing an additional channel through which the means-testing can affect welfare outcomes. In addition, we consider the sensitivity of the welfare outcomes to changes in the intensity of self-control costs.

The rest of the paper is structured as follows. In the next section, we introduce the self-control preferences and, using a simple life-cycle model, we illustrate how means-testing the pension can affect the retirement savings decisions of households with self-control preferences. In Section 3, we develop a general equilibrium OLG model with heterogeneous households that is calibrated to Australian micro-level and macro-level data. In Section 4, we examine the long run effects of changes to self-control temptation on household behaviour over the life cycle and how the intensity of self-control impacts the long run optimality of pension means test. In Section 5, we consider an extension of our results to an alternative specification of the model, in relation to household preferences. Section 6 provides some concluding thoughts.

2 Self-Control Preferences in a Simple Life-Cycle Model

Before moving to a full analysis of the role of self-control preferences in a detailed overlapping generations model, this section provides an introduction to the main ideas using a simple three-period, life cycle model. To that end, we first provide an overview of self-control preferences. We then introduce our simple model and analyze the effect of self-control on saving for retirement. Finally, we introduce a means-tested age pension and undertake some simulations to show how the severity of self-control and the severity of the means test interact.

2.1 Gul and Pesendorfer Preferences

As developed in Gul and Pesendorfer [2004], self-control preferences describe an agent faces a temptation to deviate from their optimal choice (which we here denote by the set x_1) by some alternative option (denoted by the set x_2). For example the agent may desire a healthy snack, but be tempted by an unhealthier alternative, or they may prefer smooth consumption over their life-cycle, but face a temptation to over-consume and under-save while young. An agent facing a temptation to choose x_2 over x_1 has a preference over choice sets that may be represented as $B_1\{x_1\} \succ B_2\{x_1, x_2\}$. While ordinarily, B_2 should weakly dominate B_1, it may not if the presence of x_2 causes the agent to succumb to temptation or require them to exercise a costly form of self control.

Gul and Pesendorfer [2004] developed a utility function to describe this preference relationship. The function involves two components: a commitment utility function (denoted u), which ranks consumption choices by the commitment utility, and a temptation function (denoted v) which ranks consumption choices according to how tempting they are to the agent.[5] In the example given above $u(x_1) > u(x_2)$, but $v(x_1) < v(x_2)$. The self-control utility function is given as

$$U(x, B) = \max_{x \in B} \left[u(x) + v(x) - \max_{\tilde{x} \in B}(v(\tilde{x})) \right]. \tag{1}$$

The function differs from a typical utility function by the addition of the expression $v(x) - \max_{\tilde{x} \in B}(v(\tilde{x}))$ which reduces the agents utility if there is a more tempting alternative available they do not choose, and which may cause them to switch to a more tempting alternative.

[5]Functions u and v each satisfy Von Neumann–Morgenstern properties.

If the agent faces choice set B_1, it is obvious that they will choose x_1 and achieve utility $u(x_1)$. Faced with choice set B_2, they can choose either to resist temptation and consume x_1 or succumb to temptation and consume x_2. It can be shown from Equation 1 that the agent will resist temptation provided that $u(x_1) + v(x_1) \geq u(x_2) + v(x_2)$, otherwise they will succumb. If the agent succumbs to temptation, their utility will be given by $u(x_2)$, which is less than $u(x_1)$. However, if the agent resists temptation and chooses x_1 their utility will be given by $u(x_1) + v(x_1) - v(x_2)$, which is also less than $u(x_1)$. In either case the inclusion of x_2 in the choice set reduces the agent's utility. In either case the addition of the the tempting alternative into the choice set leaves the agent worse off. An agent facing temptation may therefore place value on devices that limit their choice sets to minimise their access to tempting alternatives.

While this example illustrates how self control preferences apply with a binary choice between two sets in a static environment, it can also be applied in dynamic models such as when an agent faces temptation not to save for the future but rather consume their entire income. We now consider the impact of a means-tested public pension on an agent who faces self-control preferences.

2.2 A Simple Life-Cycle Model

We construct a life-cycle model to explore how the presence of self-control preferences affects an agent's consumption-savings decisions under different pension designs. We first analyze how the presence of self-control affects households allocations in the absence of a pension. We then analyze the agent's response when we introduce an asset-tested age pension system.[6]

2.2.1 Model Structure

We consider an endowment economy with a representative agent who lives for three periods. These periods correspond to the agent being young, middle aged and old. The agent's problem is to choose a consumption plan that optimally allocates their resources to maximise their lifetime utility. However, the agent has self-control preferences and is

[6] This model is kept very simple for expository purposes. However, the model developed in the next section is much more comprehensive.

tempted to increase their consumption in the short run at the expense of long run utility. The agent's lifetime utility function is represented as

$$U = \sum_{t=1}^{3} \beta^{t-1} \left(u(c_t) + v(c_t) - \max_{\tilde{c}_t \in C_t} v(\tilde{c}_t) \right), \tag{2}$$

where c_t represents consumption in period t, $u(c_t)$ is the commitment utility from consumption, $v(c_t)$ is the temptation utility function, β is the time discount factor, and C_t is the agent's feasible consumption set in period t. Both $u(c)$ and $v(c)$ are assumed to be monotonically increasing and concave functions for $c \geq 0$, meaning that $u'(c) > 0$, $u''(c) < 0$, $v'(c) > 0$ and $v''(c) < 0$. We also assume that $u(0) = -\infty$.

The endowment received in period one can be allocated to either consumption or saving. Anything they save earns interest at rate r each period. The period t budget constraint is represented by

$$c_1 + s_1 = A, \tag{3}$$

$$c_2 + s_2 = (1 + r)s_1, \tag{4}$$

$$c_3 = (1 + r)s_2. \tag{5}$$

We assume that agents cannot borrow and consumption is strictly positive, so the following non-negativity constraints are required:

$$c_t \geq 0, \quad s_t \geq 0. \tag{6}$$

The single-period budget constraints can be combined as a single inter-temporal budget constraint

$$0 = A - \sum_{t=1}^{3} \frac{c_t}{(1 + r)^{t-1}}. \tag{7}$$

The agent's self-control costs in the model are derived as follows. Since the marginal temptation utility of consumption is assumed to be positive (i.e., $v'(c) > 0$), the value of $\tilde{c}_t$ that maximises $v(\tilde{c}_t)$ is the maximum possible value of $\tilde{c}_t$; the agent is tempted to consume all they possibly can in each period without thought to the future. In the context of this model, this is the value of their accumulated saving each period. Thus, the feasible consumption sets are obtained from the period budget constraints above as $C_1 = [0, A]$, $C_2 = [0, (1 + r)s_1]$ and $C_3 = [0, (1 + r)s_2)]$.

This implies that the self-control costs in periods 1 and 2 may be expressed as $v(\tilde{c_1}) = v(A)$ and $v(\tilde{c_2}) = v((1 + r)s_1)$. In the final period, the agent does not save and consume all their remaining assets, so the agent will not face any self-control costs. Using these self-control costs derived for each period, the agent's utility function from Equation (7) may be re-written as

$$U = (u(c_1) + v(c_1) - v(A)) + \beta\left(u(c_2) + v(c_2) - v((1+r)s_1)\right) + \beta^2 u(c_3). \tag{8}$$

Maximization of the lifetime utility function in Equation (8) subject to the budget constraint in Equation (7) yields the following first order conditions:

$$\frac{u'(c_2^*) + v'(c_2^*)}{u'(c_3^*)} = \beta(1+r) \tag{9}$$

and

$$\frac{u'(c_1^*) + v'(c_1^*) + \beta(1+r)v'((1+r)s_1^*)}{u'(c_2^*) + v'(c_2^*)} = \beta(1+r). \tag{10}$$

From Equation (9), it can be shown that a self-control utility function will lead to lower consumption in the third and final period, relative to the previous period, than would be the case under a standard preference function. To see why, consider a counterfactual utility function where $v(\cdot) \equiv 0$. In that case, the first order condition for optimality would be $\frac{u'(\hat{c}_2)}{u'(\hat{c}_3)} = \beta(1+r)$. However, since $v'(c_2) > 0$, it follows that $\frac{u'(c_2^*)}{u'(c_3^*)} < \beta(1+r)$ which, given the concavity of the utility function, implies that $\frac{c_2^*}{c_3^*} > \frac{\hat{c}_2}{\hat{c}_3}$. Since the budget constraint is unchanged, we conclude that an agent with self-control preferences will consume less in the third period than a similar agent who does not experience self-control preferences. Since the temptation function appears in both the numerator and denominator of Equation (10), it is ambiguous whether or not the presence of self-control costs will lead to a higher or lower consumption in the second period relative to the first, than would be the case under standard preferences.

2.2.2 Introducing a Means-Tested Pension

We now consider the effect of introducing a means-tested age pension in our framework. In addition to their endowment in period 1, the agent may also receives a pension at the commencement of the final period. The pension is means tested based upon the agent's asset level at the end of the second period, s_2, which is also the incoming asset level in period 3, denoted here as a_3. The pension received is based on the formula

$$p(a_3) = \begin{cases} p^m - \phi a_3 & \text{if } 0 < a_3 < p^m/\phi \\ 0 & \text{otherwise,} \end{cases}$$

where p^m is the maximum pension that can be received and ϕ is the taper (withdrawal) rate at which the pension is withdrawn as the asset level increases, and where a_3 the agent's asset holding at the beginning of period 3.[7]

The inclusion of the age pension system requires amendments to the budget constraint for period 3 to

$$c_3 = (1 + r)a_3 + p(a_3) \tag{11}$$

and the combined inter-temporal budget constraint is now

$$0 = A + \frac{p(a_3)}{(1 + r)^2} - \sum_{t=1}^{3} \frac{c_t}{(1 + r)^{t-1}}. \tag{12}$$

The feasible consumption set for period 3 becomes $C_3 = [0, (1 + r)a_3 + p(a_3)]$. The maximum level of consumption comprises the age pension, the incoming assets level and the asset income accruing that period. The role of self-control preferences remain qualitatively the same when computing the updated first order conditions, where the means-tested age pension plays an important role. Rather than analysing the self-control effect on optimal allocations using comparative statics, we illustrate the roles of both self-control preferences and the means-tested age pension system via simulations.

2.3 Model Simulations and Discussion

We illustrate numerically the role played by self-control preferences in our model economy. We present results with and without a means-tests age pension system. We also consider households with and without self-control costs.

To simplify the simulation analysis, we impose some additional restrictions on the model. We also assign values to parameters in order to compute numerical solutions to the model.[8] The functional form for the commitment utility function is specified as $u(c) = \ln(c)$, which satisfies the previously stated conditions for the function $u(c)$. Following a number of other papers, including Bucciol [2011], Bouchard St-Amand and Garon [2015], and Arvaniti and Sjögren [2023], we assume that the temptation utility function is proportional to commitment utility so that $v(c) = \lambda u(c)$, where $\lambda \geq 0$ is a

[7] We have introduced the asset level at the beginning of period 3, a_3, to be the same as the asset level at the end of period 2 (saving), s_2. This doubling up of notation is for expositional purposes to make it clear that the pension payment in period 3 depends on the incoming asset in that period.

[8] In the next section we present a comprehensive calibration strategy.

coefficient that represents the intensity of the preference control cost. If $\lambda = 0$, the role of $v(c)$ vanishes and so there are no self-control costs, while $\lambda > 0$ implies the existence of self-control issues. A higher value for λ implies a stronger temptation.

For the purposes of the numerical analysis, we choose $\beta = 0.8$ for the discount rate and, for simplicity, the interest rate r is assumed to be 0. The maximum pension level is set to $p^m = 1$. To focus attention on the role of self-control preferences, we compare results for an agent without self-control preferences ($\lambda = 0$), which we sometimes refer to as having standard preferences, to one with strong self-control issues ($\lambda = 0.25$).

We solve the model numerically using the functional forms and parameter values specified above. We solve three model scenarios for the pension system. Firstly, a universal pension system ($\phi = 0$), secondly a pension system with $\phi = 0.5$, and thirdly a model economy without a pension system.

Any pension the agent is entitled to will be received and consumed in the third period. The effect of the pension on household behaviour is likely to be different depending on the wealth of the agent. We consider values for the initial endowment ranging from zero to an upper bound level $\bar{A}$. We choose the upper bound to be 20, such that there are no changes in optimal behavior for higher initial values of the endowment.

First, consider the two cases where the self-control cost is zero ($\lambda = 0$) or positive ($\lambda = 0.25$) in a model economy with no age pension. In this setup, the optimal consumption allocation each period is a fixed fraction of A. The optimal shares are presented in Table 1. As expected, an agent with self-control preferences will consume more while young and less while old, when comparing the allocations to an agent without temptation (standard preferences). The agent with self-control preferences will allocate 46.5 per cent of their endowment to consumption in period 1, while an agent without self-control preferences will allocate only 41 per cent. In their final period, agent with self-control preferences will have only 21 per cent of their wealth remaining to consume, rather than the 26 per cent they would have, had they not been tempted. Second period consumption is similar for both types of agents, though the share is slightly higher for agents who did not have self-control preferences than those with self-control preferences.

Second, we now consider the case where the exists an age pension that is means tested based on the agent's level of assets in period 3, as specified further above. As above, our primary interest is to analyze how the degree of self-control costs affects savings at

Table 1: Life-Cycle Consumption: No Pension

Consumption by Period Percent of Endowment, No Pension			
	Period 1 (Young)	Period 2 (Middle Age)	Period 3 (Old)
Standard Preferences ($\lambda = 0$)	41.0	32.8	26.2
Self-control Preferences ($\lambda = 0.25$)	46.5	32.6	20.9

retirement age.

As a benchmark scenario, we initially consider the effect of introducing a means-tested pension to agents with standard preferences. Figure 1 shows retirement savings for different levels of the initial endowment, under different pension regimes.

In the absence of a pension system, the agent's savings are a fixed proportion of their initial endowment. If a universal pension is applied, then the agent will save less for their retirement than otherwise, regardless of the level of the endowment. Furthermore, if the agent's endowment is small enough, they will choose not to save at all and rely entirely on the pension system. The threshold level of the endowment below which they will choose not to save is approximately 2.8.

If the means-tested pension is applied instead, the endowment threshold below which the agent chooses not to save for retirement doubles to around 5.6. If the agents endowment is above this threshold they will save for retirement, though they will save less than otherwise as their saving reduces the pension they receive. However, if the agent is sufficiently wealthy, they will find that it is optimal to forego the means-tested pension altogether and rely on their savings alone. This is reflected in the discontinuity that occurs when the level of the initial endowment is $A = 10$, which is the threshold level of endowment for receiving any pension. If $A < 10$ it is optimal for the agent to have low/no savings in order be eligible for an age pension. If $A > 10$ then the agent optimally chooses to save more and as they are not eligible for the pension.

In contrast with the benchmark case just considered, the optimal saving plans for agents with self-control preferences ($\lambda = 0.25$) are presented in Figure 2. Regardless of their endowment level, an agent saves less for retirement if they have self-control preferences than if they have standard preferences. As for the previous case with $\lambda = 0$, if a

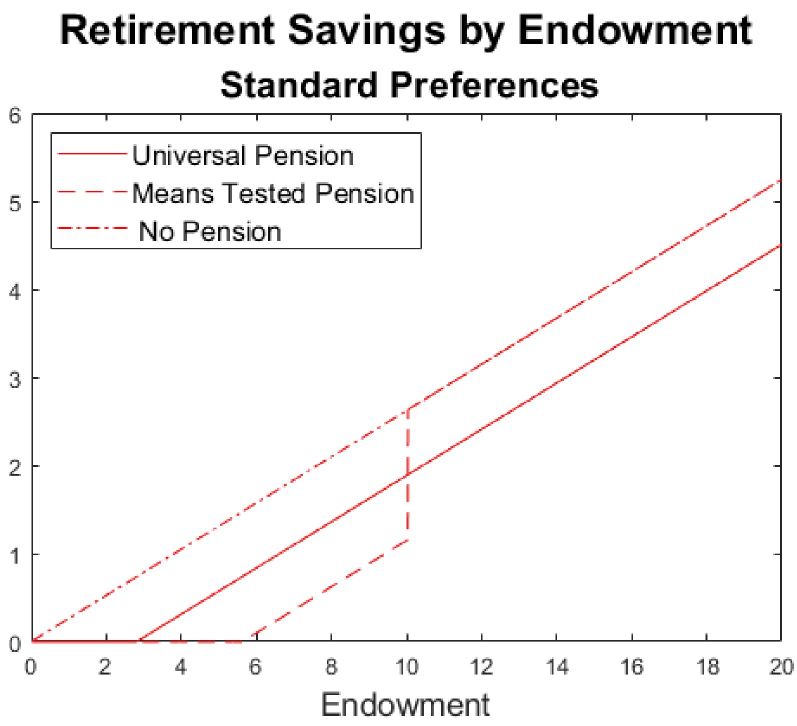

Figure 1: Retirement Savings in the Simple Model: Standard Preferences

universal pension is offered, there is an endowment threshold below which an agent will not save. For the agent with self-control preferences this threshold is 4, which is much higher than threshold of an agent without self-control preferences. Also as before, the threshold endowment doubles when a means-tested pension replaces a universal one, and so with a means-tested pension the threshold below which an agent will not save is 8. The threshold level of the endowment at which an agent chooses not to receive the pension is also higher for an agent with self-control preferences, at 13 rather than 10.

At any level of the initial endowment, an agent will save less for retirement if they have self-control preferences than if they have standard preferences, regardless of the pension regime. Conversely, if a means-tested pension is applied, an agent with self-control preferences will receive at least as high a pension as an agent with standard preferences for any given endowment level, as shown in Figure 3. This supports the intuition that a means-tested pension offered to a population with self-control preferences will be more expensive than one offered to a similar population without self-control costs.

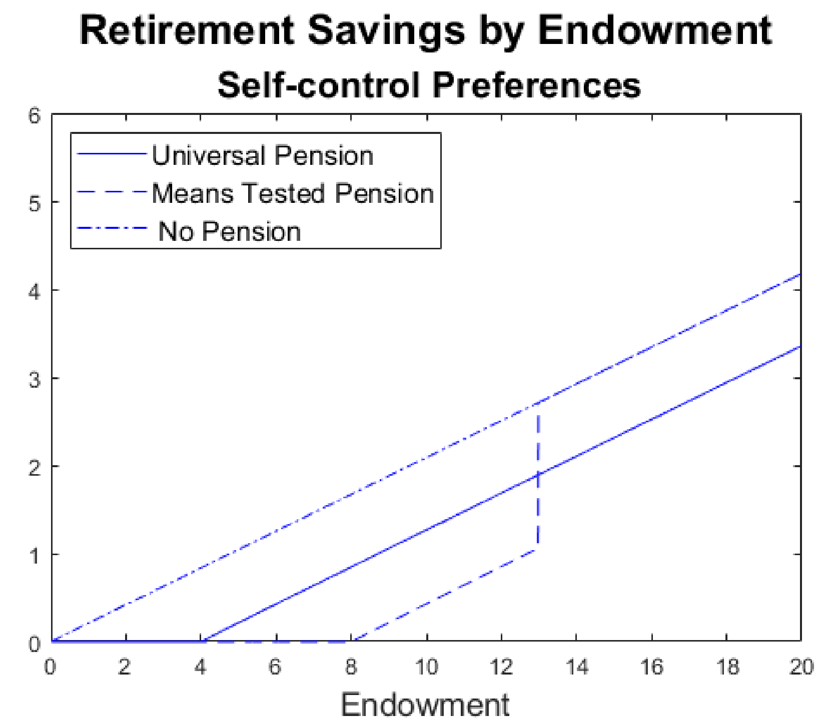

Figure 2: Retirement Savings in the Simple Model: Self-Control Preferences

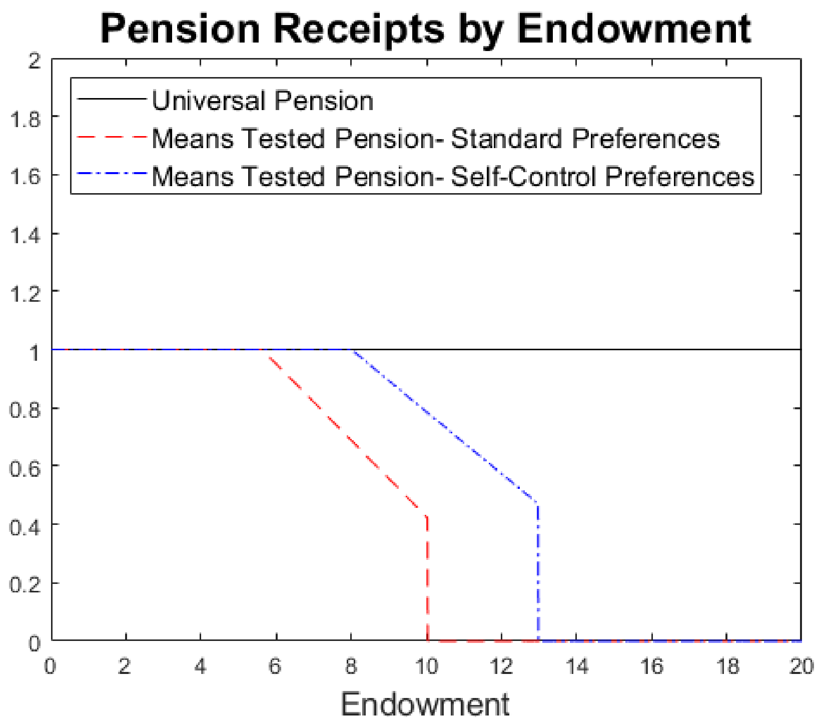

Figure 3: Pension Receipts in the Simple Model

2.4 Summary

This simple life-cycle framework illustrates how an agent with self-control preferences responds differently from an agent with standard preferences without temptation and self-control costs. This difference arises whether or not there is a means-tested pension.

However, since their responses to the pension can differ depending upon their initial endowment, we need to consider the distribution of household incomes (here initial endowments) in order to effectively compare the costs and benefits of means-testing the age pension. This simple model also does not consider the cost of providing the pension, but rather treats the pension as a boon at an old age provided by an exogenous benefactor government. In the following sections, we develop and apply a detailed overlapping generations model with heterogeneous households, uncertain labor income, endogenous labor supply and retirement to address these, and other, issues and to evaluate the role of the severity of agents' self-control in determining the dynamic general equilibrium for the economy, and life cycle behaviour and welfare of agents. Of particular interest is the interaction of the effects of means-testing pensions and the intensity of self-control.

3 Dynamic Stochastic Equilibrium Model

In this section, we develop a general equilibrium overlapping generations (OLG) model to fully explore the interaction of self-control preferences with pension means testing. Our primary focus is on the outcomes for household behaviors, aggregates, and welfare. Following related pension literature that studied the role of self-control preferences, such as Kumru and Thanopoulos [2011], the model developed here incorporates the Gul and Pesendorfer preferences with self-control temptation and idiosyncratic labor income shocks within heterogeneous households. It also includes endogenous labor supply and retirement decisions. The model considers overlapping generations of households with different skill types that make consumption and labor supply decisions over the life cycle, subject to varying degrees of self-control costs. Additionally, it features a representative firm producing a single output good, a government that collects progressive income taxes and provides a means-tested pension to retirees, and an overseas sector.

Below, we provide a detailed description of the model and then outline the calibration of our benchmark economy.

3.1 Households

3.1.1 Demographics and Distributional Measure of Households

The model consists of a mass one of finitely lived single-person households born in period $j = 1$, where the total population grows at a constant rate n per period. In every period, households face an externally-given age-dependent survival probability (ψ_j) and they live up to a maximum of J periods.

The demographic structure is assumed to be stationary, where the fertility rate (of newborn cohorts) gives the total population growth rate n, with (time-invariant) population (cohort) shares (weights) given by $\eta_j = \eta_{j-1}\psi_j/(1+n)$.

At $j = 1$, each household is assigned a permanent skill type $m \in \mathcal{M} = \{1, ..., M\}$ according to the probability distribution $\tilde{\omega}_m$. Household assets are restricted throughout the life cycle to be non-negative, i.e., $a_j \geq 0$. Households are born with zero assets but they can save for the next period $a_{j+1} \in \mathcal{A} = [0, \infty]$. In every period, households are subject to a labor productivity shock $\zeta_j \in \mathcal{E}$, with a transition probability $\pi(\zeta_{j+1}|\zeta_j)$. The individual state vector at each age j is given by

$$x_j = (m, a_j, \zeta_j) \quad \in \quad \mathcal{X} = \mathcal{M} \times \mathcal{A} \times \mathcal{E},$$

where $a_j \in \mathcal{A}$ denotes assets at the beginning of age $j \in \mathcal{J} = \{1, \ldots, J\}$. The assets of agents who do not survive, are distributed among agents of their same skill type m.

We can now define distributional measure of households. Let $\Omega(x_j)$ be the corresponding cumulative measure to $\omega(x_j)$, so that

$$\omega(x_1) = \int_{\mathcal{M}\times\mathcal{E}} d\Omega(x_1) = 1, \tag{13}$$

holds for the initial distributional measure of households at $j = 1$, where $x_1 = (m, 0, \zeta_1)$. Let $\mathbf{1}_{k=s}$ be an indicator function that returns 1 if $k = s$ and 0 if $k \neq s$. Then, the law of motion for the measure of households at age j follows:

$$\omega(x_{j+1}) = \frac{\psi_{j+1}}{1+n} \int_{\mathcal{X}} \mathbf{1}_{a_{j+1}=a_{j+1}(x_j)} \times \pi(\zeta_{j+1}|\zeta_j) d\Omega(x_j). \tag{14}$$

Note that in the model description below, the state index x is omitted to ease the exposition, and agents are distinguished only according to their age j.

3.1.2 Time Endowment and Labor Productivity

Households are endowed with one unit of time each period, which can be allocated between leisure (l) and labor supply ($h = 1 - l$), and with a given labor productivity over the life cycle.

Each household's labor productivity comprises two components, one deterministic and the other stochastic. The deterministic component depends on the household's age and skill type, and is denoted by $\bar{e}_{jm}$, which can be interpreted as the average productivity for that age cohort and skill type. The stochastic component (ζ_j), is assumed to exhibit time persistence and follow a Markov process. Thus, the two components imply that the productivity of an agent of age j and skill level m is given by $e_{jm} = \zeta_j \bar{e}_{jm}$.

Consequently, the effective wage rate facing an agent of age j and skill m is given by $w_{jm} = we_{jm}$, where w is the market wage rate per efficiency unit of labor. The agent j's labor earnings are therefore given by $w_j h_j$.[9]

3.1.3 Preferences

Households derive utility from consumption (c) and leisure (l) each period. Utility is time-separable. Households are assumed to have self-control preferences and face temptation to consume their wealth each period. Although household utility is a function of both consumption and leisure, households may face temptation with regard to consumption and savings only.[10]

The per-period utility function is assumed to have the form

$$U(c_j, l_j) = u(c_j, l_j) + v(c_j, l_j) - \max_{\tilde{c_j} \in B_j} v(\tilde{c_j}|l_j)), \tag{15}$$

where $u(c, l)$ is commitment (standard per-period) utility that household derives from its consumption and leisure each period, and $v(c|l)$ represents temptation utility conditional

[9]Since it is assumed that the productivity shock ζ_j follows a Markov stochastic process, it follows that the agent's productivity e_j and effective wage rate w_j are also stochastic and follow Markov processes. Thus, agents have idiosyncratic productivity and labor earnings risks over their life cycle that are assumed to be uninsurable and, hence, need to be taken into account in making their life-cycle decisions.

[10]This approach assumes that households are able to enter into a one-period contract to supply labor to the firm before they experience temptation. In practice, this means that a household is tempted to consume all their available funds each period, conditional on their level of income in that period. In Section 5, we relax this assumption by allowing agents to face temptation over both consumption and leisure.

upon the level of leisure, l_j. If $v(\cdot) \equiv 0$ then $U(c_j, l_j) = u(c_j, l_j)$, and therefore, there is no self-control problem. In this model, we have taken the view that consumers with self-control issues will wish to maximize the temptation function with respect to current consumption, so that the temptation function is assumed to be conditional on the commitment choice of leisure. The agent chooses the largest feasible value of consumption in the per j budget set by choosing not to save for the future (as explained further below).

The expected life-time utility (of the new-born household) is

$$U = E \sum_{j=1}^{J} \psi_j \beta^j U(c_j, l_j), \tag{16}$$

where ψ_j is the household's age-dependent survival probability and β is the subjective discount factor.

3.1.4 Household Problem

At the beginning of each period, and given the state space, households observe the market wage rate, interest rate, and the tax and pension systems, and solve the following dynamic programming problem

$$V(x_j) = \max_{c_j, l_j, a_{j+1}} \left(u(c_j, l_j) + v(c_j, l_j) - \max_{\tilde{c}_j \in B_j} v(\tilde{c}_j | l_j) + E[\beta \psi_j V(x_{j+1}) | x_j] \right), \tag{17}$$

subject to per-period budget and feasibility constraints

$$(1+g)a_{j+1} = (1+r)a_j + we_j h_j + p(y_j) + b - f^y t(y_j) - (1+\tau_c)c_j, \tag{18}$$

$$c_j \geq 0, \quad 1 \geq l_j \geq 0, \quad h_j = 1 - l_j, \tag{19}$$

$$a_1 = 0, \quad a_j \geq 0. \tag{20}$$

As indicated, households choose consumption c_j, labor supply h_j (leisure l_j) and savings a_{j+1}, given the current state space x_j, effective wage rate we_j, unintended bequests received b, the consumption tax rate τ_c and the income tax and pension functions denoted by $t(y_j)$ and $p(y_j)$, with the income tax scalar f^y that is used to balance the government budget, defined in the government subsection below. Note that both the tax and pension functions depend on personal income comprising labor earnings and asset income, i.e., $y_j = we_j h_j + ra_j$.[11]

[11] Further note that term g accounts for a constant economic growth rate (defined when discussing the production sector below), and that the (accidental) bequest redistribution b (constant at each age but different within each skill type) is defined in the steady state equilibrium subsection.

The objective function (17) comprises the temptation-adjusted utility function, with households being tempted to maximize $v(c_j|l_j)$ by choosing the highest level of feasible current consumption without regard to the future, given the current leisure choice. Examination of the period j budget constraint (18) reveals that this is achieved by choosing zero assets to be carried forward ($a_{j+1} = 0$).

3.2 Production

We assume a perfectly competitive production sector with a representative firm that produces a single composite good, using both capital and labor. The production function is given by

$$Y = F(K, H, A), \tag{21}$$

where A represents multi-factor productivity, K is aggregate capital and H is aggregate (efficiency weighted) labor supply. Multi-factor productivity A is assumed to grow at a constant rate g each period. The firm is a price taker for both labor and capital and chooses the level of labor and capital demand to satisfy the profit maximising conditions

$$F_K(K, H, A) = r + \delta, \tag{22}$$

$$F_H(K, H, A) = w, \tag{23}$$

where $F_K()$ and $F_H()$ denote the marginal products with respect to K and H, w is the market wage rate per efficiency unit of labor, r is the prevailing interest rate, and δ is the depreciation rate of capital.

3.3 Government

There are two types of government expenditure in this model: public consumption (G), which is assumed to be a fixed proportion of output (Y), and the age pension, which is provided to households of a predetermined pension eligibility age ($j \geq J_p$). The pension is subject to an income test, with the pension benefit $p(y)$ expressed as

$$p(y) = \begin{cases} p^m & \text{if} \quad y < \eta_1, \\ p^m - \phi(y - \eta_1) & \text{if} \quad \eta_1 \leq y < p^m/\phi + \eta_1, \\ 0 & \text{if} \quad y \geq p^m/\phi + \eta_1, \end{cases} \tag{24}$$

where p^m is the maximum pension benefit that a household receive if their total private income is below the threshold η_1. The tape rate is $\phi \in [0, 1]$, and the income test applies to the combined income from both labor supply (if households still work) and savings, i.e., $y_j = w_j h_j + r a_j$ for $j \geq J_p$. The total pension expenditure is then given as $P = \sum_{j=J_p}^{J} \int_{\mathcal{X}} p(y(x_j)) d\Omega(x_j)$.

Government Budget Constraint To fund these outlays, the government collects a proportional tax of rate τ_c on household consumption, and a progressive income tax on the combined household labor and asset income, denoted by $t(y) = t(wh + ra)$. Hence, the government budget constraint is expressed as

$$\tau_c \int_{\mathcal{X}} c(x_j) d\Omega(x_j) + f^y \int_{\mathcal{X}} t(y(x_j)) d\Omega(x_j) = G + P, \tag{25}$$

where f^y is the income tax scalar that is assumed to adjust to maintain (25) in balance. Accordingly, the total income tax is $f^y t(y)$.

3.4 External Sector

The model comprises a small open economy, with free international movement of capital and the domestic interest rate set at the world interest rate $r = r^w$. Overseas investors will supply (absorb) capital (K^F) should domestic supply of capital ($\int_{\mathcal{X}} a(x_j) d\Omega(x_j)$) fall short of (exceed) domestic demand for capital at the world rate. The balance of payments condition is

$$X - rK^F = \Delta K^F, \tag{26}$$

where the left-hand side is the balance on the current account (equal to net export X minus interest payments abroad) and the right-hand side is the net change in foreign assets.

3.5 Equilibrium

Given the government fiscal and pension policy, a stationary recursive, steady state equilibrium is a set of value functions $\{V(x_j)\}_{j=1}^{J}$, household decision rules $\{c_j(x_j), l_j(x_j), a_{j+1}(x_j)\}_{j=1}^{J}$, distribution of bequests $\{b(x_j)\}_{j=1}^{J}$, and time-invariant measure of households $\{\omega(x_j)\}_{j=1}^{J}$ such that the following conditions are satisfied.

1. Households choose consumption/saving and leisure/labor by maximizing the value function in (17) subject to the household budget constraint in (18), borrowing and time constraints and non-negativity constraints on consumption and leisure in (19) and (20).

2. Firms choose the level of capital and labor to maximise profits, consistent with their marginal productivities described in (22) and (23).

3. Government budget constraint in (25) (with the specified progressive income tax and means tested pension benefits) is balanced by the income tax scalar f^y that applies to (proportionally shifts up or down) the income tax schedule $t(y)$.

4. The laws of motion in (13) and (14) for the measure of households hold.

5. Unintended bequests satisfy:

$$(1+n)\int_{\mathcal{X}} b(x_j)d\Omega(x_j) = \int_{\mathcal{X}} (1-\psi_{j+1})(1+r)a_{j+1}(x_j)d\Omega(x_j). \tag{27}$$

6. The market wage rate (w) is such that (efficiency weighted) demand for labor equals aggregate household labor supply given by

$$H = \int_{\mathcal{X}} h(x_j)d\Omega(x_j). \tag{28}$$

7. The supply of foreign capital (K^F) freely adjusts in our small open economy with $r = r^w$ to ensure that the capital market clears:

$$K = \int_{\mathcal{X}} a(x_j)d\Omega(x_j) + K^F. \tag{29}$$

8. The goods market clears:

$$Y = \int_{\mathcal{X}} c(x_j)d\Omega(x_j) + I + G + X, \tag{30}$$

where output good produced is equal to the sum of aggregate expenditures on household consumption, firm's investment $I = (ng + n + g + \delta)K$, government consumption, and net export $X = (ng + n + g - r)K^F$.

3.6 Calibration of Benchmark Economy

The model is calibrated to Australia, utilizing household survey HILDA data and fiscal and pension policy rules. In this benchmark economy, we assume that households do not face self-control costs ($\lambda = 0$). We relax this self-control cost assumption in the next section.

Demographics Each period in the model is assumed to be 1 year, with agents living for a maximum of $J = 70$ periods. We assume that agents enter the model economy at age 21 and face uncertain survival probability every period. Age dependant survival rates (ψ_j) are based on 2014-16 life tables from Australian Bureau of Statistics [2017], and we assume that the survival rate to age $J+1$ is 0. The population growth rate, n, is assumed to be 1.1 per cent each period, which is based on an average of past and projected growth rates in Australia (derived from Australian Bureau of Statistics [2018a]).

Endowments Households are randomly allocated into different skill types, which are based on educational attainment of full time workers derived from waves 1-16 of the HILDA survey (for documentation, see Summerfield et al. [2017]). We consider five skill categories ($M = 5$): not completed high school, completed high school only, achieved a certificate or diploma, completed a bachelors degree, or completed a postgraduate degree, and derive the probability distribution (by skill type) $\tilde{\omega}_m$ from the 16 waves of the survey for the population aged 20 to 60.

We then use the HILDA survey to estimate the average wage of households in each skill group at each age.[12] These average wage profiles are then smoothed to create synthetic profiles for expected productivity of workers by age in each education group (for further details, see Appendix A.1).

Each household has an expected productivity outcome based on their age and skill type, but they are also subject to idiosyncratic labor productivity shocks. We simulate these using a Markov process in which the agent can realize one of five productivity outcomes. In a Markov process, the probability of each realisation depends only on the realisation in the previous period. To estimate the vector of realisations and the trans-

[12] We restrict the data to households in the survey in which the main income earner is a full time worker. As indicated, we also restrict the sample to workers between the age of 20 and 60, and we are comparing wages across a 16 year period.

ition matrix, we use the detrended wage data from HILDA. We restrict the sample to observations where two or more consecutive wages were observed, dividing each observation by its expected value given the individuals age and education, and then sorting the standardised observations into quintiles. The transition matrix is calculated from the conditional probabilities of an observation being in each quintile based on the previous observation for that worker (for further details, see Appendix A.1).

Preferences Agents value consumption and leisure according to the standard CRRA utility function (their commitment utility):

$$u(c, l) = \frac{(c^{\gamma} l^{1-\gamma})^{1-\sigma}}{1-\sigma}, \tag{31}$$

where γ represents the consumption weight and σ is the relative risk aversion coefficient. We calibrate γ to 0.385, to match the average time allocated to labor at 0.33. We follow the conventional literature (e.g., Conesa et al. [2009] and Tran and Woodland [2014]) and set $\sigma = 4$. The discount factor $\beta = 0.9895$ is calibrated to match the consumption share of GDP of 0.55 (derived from Australian Bureau of Statistics [2018b]).

As described in Section 2 and following the standard practice in the literature, we assume the temptation function to be proportional to the commitment utility:

$$v(c, l) = \lambda u(c, l), \tag{32}$$

where the value of λ determines the strength of the temptation function and the cost of self-control. If $\lambda = 0$, there is no self-control cost and agents have standard preferences. $\lambda > 0$ implies a cost to exercising self-control that increases with the value of λ.[13] As indicated, the benchmark equilibrium assumes $\lambda = 0$. In the next section, we consider several values for self-control costs ranging from 0 to 0.4. Note that estimates for the value of λ are generally in the range of 0.05 to 0.2, see for example Bucciol [2012] and Huang et al. [2015].

Production The production function assumes the Cobb-Douglas functional form:

$$F(K, H, A) = AK^{\alpha} H^{1-\alpha}, \tag{33}$$

[13]This approach is standard in the literature, see for example Kumru and Thanopoulos [2008] , Krusell et al. [2010], Bucciol [2011], and Arvaniti and Sjögren [2023].

where the parameter α represents the cost share of capital and is calibrated to 0.3424 to match the capital to GDP ratio at 3.2. The capital depreciation rate ($\delta = 0.0571$) is calibrated to target the investment share of GDP at 0.25. Multi-factor productivity A is assumed grow at a constant rate of 1% each period ($g = 0.01$). Moment statistics for the capital to GDP ratio and investment share of GDP represent the average data counterparts for the Australian economy over the 5 years to September 2018 (derived from Australian Bureau of Statistics [2018b]).

Government Government consumption is assumed to be constant, targeting a fixed proportion of output of $G = 0.184Y$ (derived from Australian Bureau of Statistics [2018b]).

The age pension function, $p(y)$, includes the three income test parameters – maximum age pension p^m, income threshold or disregard η_1, and taper rate ϕ – all set to their 2018 values of the Australian age pension system. The pension eligibility age is set at 67 and the maximum pension is $19,980, which in the benchmark model produces pension outlays approximately 2.9% of GDP (derived from Australian Government [2018]).[14]

The government has two sources of revenue in this model. The first is a 10% tax on consumption, $\tau_c = 0.1$. The second source of revenue corresponds to income taxes. The government imposes a progressive income tax schedule $t(y)$ on the combined labor and asset incomes. For the income tax, there is a schedule of marginal tax rates and the thresholds of which are based on correspond to the Australian income tax rate schedule.[15] As indicated previously, the marginal (and average) income tax rates are adjusted proportionally by the income tax scalar f^y to maintain the government budget in balance. In the benchmark model, we set $f^y = 0.91$ for the model to match income tax revenue to GDP ratio of 0.135 (also derived from Australian Government [2018]).

External Sector The world interest rate r^w is assumed to be a constant 5% per period. Since the model economy is a small open economy, this is also set as the domestic rate. In order to keep the domestic interest rate constant, foreign capital inflows/outflows will adjust to offset any shortfall/excess in domestic savings and investment. Since on a balanced growth path $\Delta K^F = (gn+g+n)K^F$, it follows from Equation 26 that the share of foreign

[14]Note that in Australia, there are different maximum pension levels for singles and couples. The figure chosen for p^m is in between the two levels.

[15]Further details on the tax schedule are provided in Appendix A.2.

owned capital is anchored by r, n, g and X. We assume in the benchmark calibration that foreign owned capital is 18.4% of the capital stock (derived from Australian Bureau of Statistics [2018b]), which generates net exports X at 17% of GDP.

Summary of Calibration The model's parameters, their values for the benchmark economy, and macroeconomic targets (discussed above) are listed and summarized in Table 2.[16]

[16]Further details on the calibration, including an outline of our computational algorithm, are provided in Appendix A and Appendix B respectively.

Table 2: Parameters of Benchmark Model

	Demography		
n	Population growth rate	0.011	ABS Data
ψ_j	Survival probabilities		2014-16 ABS Life Tables
J	Maximum lifespan	70 periods	Corresponds to age 90
J_p	Pension age	47 periods	Corresponds to age 67
	Macroeconomic targets		
K/Y	Capital/GDP	3.2	ABS Data
K^F/Y	Foreign capital/Capital	0.184	ABS Data
C/Y	Consumption/GDP	0.549	ABS data
G/Y	Government consumption/GDP	0.184	ABS Data
I/Y	Investment/GDP	0.25	ABS Data
$ITAX/Y$	Income tax revenue/GDP	0.135	ABS Data
	Households		
β	Subjective discount factor	0.9895	To match C/Y
γ	Share parameter for consumption	0.385	To match average time allocated to labor
σ	Inverse inter-temporal elasticity of substitution	4	Related literature
λ	Self-control temptation	0	Assumed - benchmark case
	Production		
g	Productivity growth rate	0.01	ABS Data
α	Cost share parameter for capital	0.3428	To match K/Y
δ	Capital depreciation rate	0.0571	To match I/Y
r^w	Interest rate	0.05	
	Government		
$t(y)$	Income tax schedule		2017/18 income tax function defined in Appendix A.2
f^y	Income tax scalar	0.91	To match $ITAX/Y$
τ_c	Consumption tax rate	0.1	Statutory rate
p^m	Maximum Pension	$\$19,747$	Statutory rate
η_1	Income test threshold	$\$4,472$	Statutory rate
ϕ	Income taper rate	0.5	Statutory rate - benchmark case

4 Quantitative Analysis of Self-Control Preferences and Taper Rate Dynamics

In this section, we report model outcomes for the benchmark economy described in the previous section, along with counterfactual scenarios where agents face different degrees of self-control costs and alternative age pension systems. We begin by examining agents' life-cycle behavior and the macroeconomic consequences of increasing self-control temptation costs. We then explore the responsiveness of different types of agents (in terms of skill type and temptation cost) to alterations in the pension system by adjusting the pension taper rate ϕ making pension benefits more or less progressive.

4.1 Implications of Increasing Self-Control Temptation

In this subsection, the focus is on the analysis of the behavioral implications (for key household variables over the life cycle) and macroeconomic outcomes when agents face different levels of self-control costs (λ), while maintaining the benchmark pension system with a taper rate of $\phi = 0.5$.

4.1.1 Life-Cycle Effects

We now document and analyze how individual decisions on consumption, savings, and labor supply over the life cycle vary for agents with self-control preferences and varying degrees of self-control costs and temptation. Note that our model accounts for two types of effects on household behavior – direct effects of increasing λ representing household temptation preference for consumption; and indirect (or feedback) effects via macroeconomic outcomes and automatic fiscal and pension adjustments. The latter are discussed in the next subsection.

Our results show that the key indirect effect on household behaviour arising from higher self-control costs is due to budget-equilibrating adjustments in the income tax scalar. This scalar would need to be increased significantly in economies with a high self-control parameter λ, because of lower savings and increased pension expenditure, despite keeping the pension taper rate at $\phi = 0.5$.

Savings Figure 4 depicts average household saving patterns over the life cycle in economies of workers with varying self-control costs, with λ ranging from zero to 0.4. Note that $\lambda = 0$ represents the benchmark economy where agents do not have self-control costs over consumption.

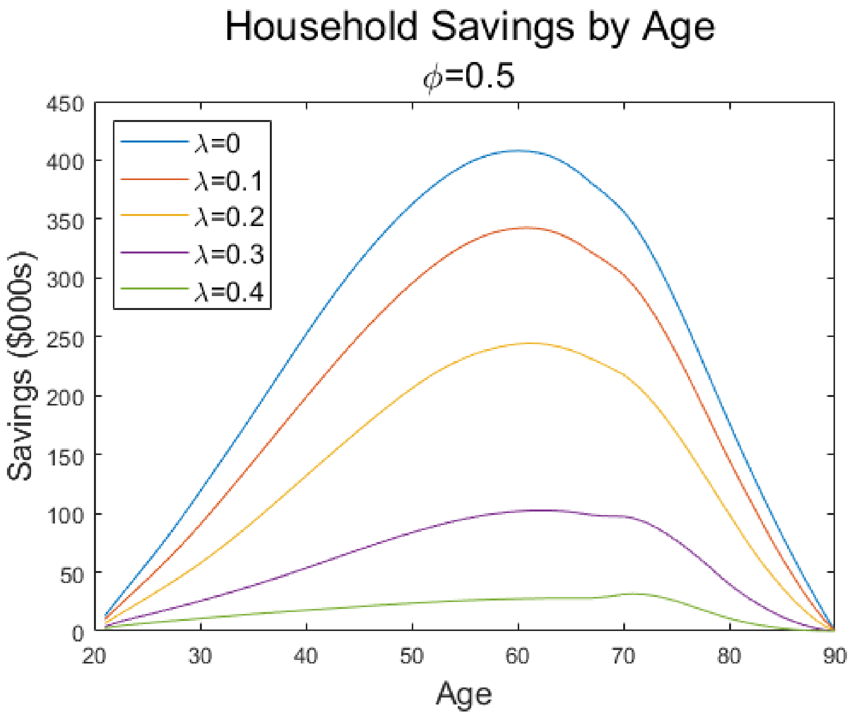

Figure 4: Average Savings over the Life Cycle

As shown, households with higher self-control costs tend to save less over their life cycle compared to those with lower self-control cost. As self-control costs increase, the reduction in savings becomes more significant, which is driven by a preference for higher current consumption over savings. This result has also been provided by Kumru and Thanopoulos [2008], Bucciol [2011] and Tran [2018].

However, in our framework, the indirect effect plays an important role. First, higher self-control costs imply a more costly age pension scheme financed with higher taxes. Second, there will be lower financial incomes due to lower savings. Both indirect effects make the decrease in average savings more pronounced. In addition, agents without self-control costs typically reach their asset peak at age of 60, whereas for those with the highest self-control cost ($\lambda = 0.4$) the peak is at the age of 71.

Consumption Figure 5 displays average consumption patterns over the life-cycle for agents with different self-control costs indicated by parameter λ. Note that consumption profiles over the life cycle in Figure 5 are typically hump-shaped, following age-patterns of labor productivity of workers and falling survival probabilities at older ages.[17]

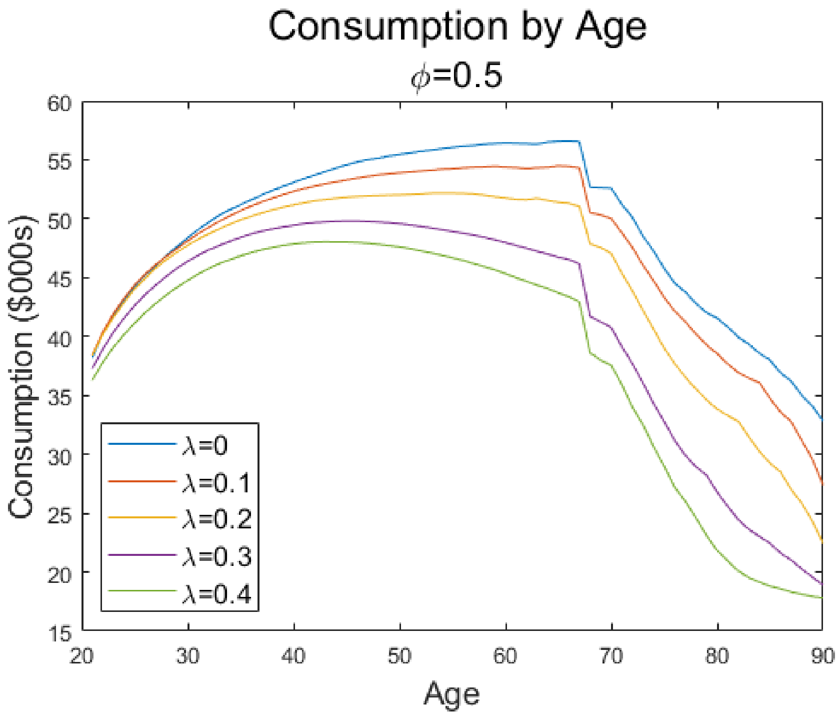

Figure 5: Average Consumption over the Life Cycle

Examination of Figure 5 reveals that increasing self-control costs λ leads to: consumption peaked at younger ages; more pronounced hump-shaped consumption; and lower older-age consumption in particular.[18] Even at younger ages, average consumption is found to be lower in economies with higher λ, despite the temptation preferences for consumption when young. They simply cannot afford that desired consumption because of the increased income tax scalar that, in our model, balances the government budget constraint. More importantly, reduced life cycle savings in economies with very high λ imply much financial income and therefore lower consumption at older ages.

[17] In household surveys, average consumption typically increases during early working years, then stabilizes, and eventually decreases in retirement – i.e., life cycle patterns replicated in Figure 5.

[18] Specifically, workers with higher self-control costs exhibit a flatter consumption pattern, which begins to decline at earlier ages. For workers with the highest self-control cost, $\lambda = 0.4$, consumption peaks at age 43, followed by a decline. In contrast, workers without self-control costs reach peak consumption at age 66. The consumption gap widens with age as self-control costs increase, with a less pronounced decline at retirement for workers without self-control costs – a decrease of 6.8% compared to a 10% decrease for those with the highest self-control cost, $\lambda = 0.4$.

Labor Supply In our model, we allow for labor supply to be endogenous at the intensive (hours worked) and extensive (endogenous retirement) margins. The impacts of increasing $\lambda = 0.4$ on these labor supply channels are depicted in Figure 6, where we present labor supply as the share of time endowment (normalized to one) allocated to work (averaged across all skill types).

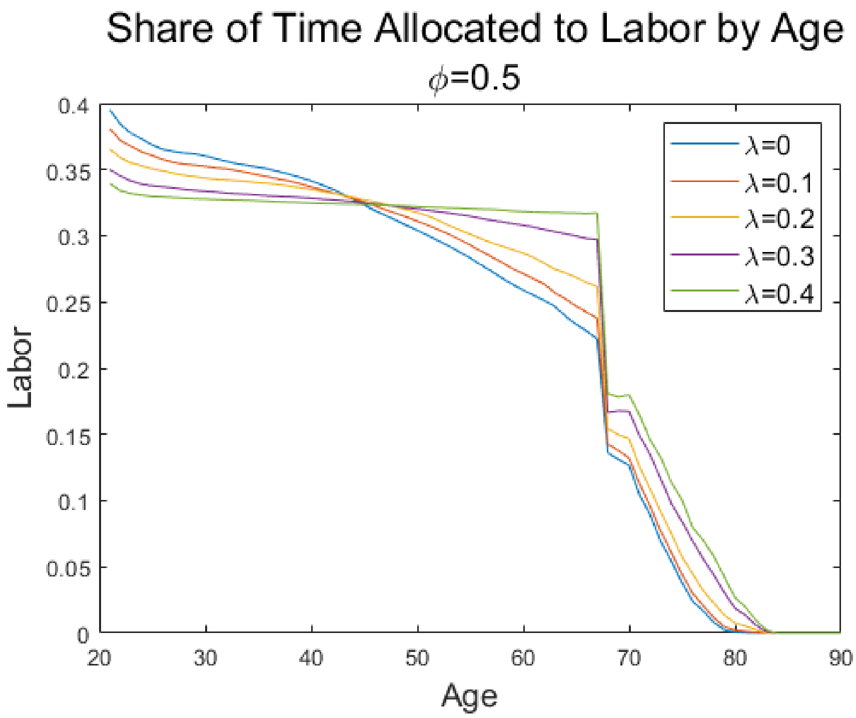

Figure 6: Average Labor Supply over the Life Cycle

As shown, labor supply decreases at older working ages due to a declining labor productivity, with a notable reduction at age 67 when workers become eligible for the means-tested age pension. What is perhaps more interesting is how this profile changes in economies with high self-control costs. First, workers with positive self-control costs allocate less time to labor in their early years (ages 21-44) compared to those without self-control costs. However, this trend reverses from age 44 onwards, resulting in a 'back-loaded' labor supply pattern.

This 'back-loaded' labor supply pattern can be attributed to several factors. Since self-control agents do not save much when young compared to agents without self-control costs, there is not much need for working at early stages of the life-cycle. However, as workers age and retirement get closer, agents with a lower financial income (due to lower saving when young) need to increase their working time to compensate their lower savings for retirement. Consequently, workers with higher self-control costs may initially choose to work fewer hours, increasing their labor supply later in life when the need for higher income becomes more pressing.

Second, the labor supply decline at age 67 is found to be more pronounced for workers with higher self-control temptation over consumption (for example, decreasing by 43% for $\lambda = 0.4$) than those without self-control costs (decreasing by 39% for $\lambda = 0$). Although we keep the benchmark taper rate unchanged here at $\phi = 0.5$, this effect can be explained by 'automatic' adjustments in pension benefits where for many households, particularly those of higher skill types, the pension means test becomes binding, generating additional labor supply distortions.

In the next subsection, we show how aggregate effects change in economies with increasing self-control costs.

4.1.2 Macroeconomic Implications (with Benchmark Taper Rate)

Table 3 presents the effects of changing the intensity of self-control temptation (by increasing λ from 0.02 to 0.4) on selected macroeconomic and fiscal outcomes, relative to the benchmark model with no self-control costs, both with the taper rate of 0.5. Results are reported as the percentage change relative to the benchmark solution (some results are reported as a percentage point, p.p., as stated in the table). Compared to the life-cycle effects discussed above, we have now added two additional cases with low values of λ below one, in order to show how quantitatively significant (for the economy) are only small deviations from our benchmark solution based on households having zero self-control costs.[19]

The key findings from Table 3 can be summarized as follows. As we increase self-control costs by increasing λ, average consumption and household savings further decline,

[19] Note that these relative values are derived from more detailed outcomes from the benchmark model and all other counterfactuals are provided in Appendix C. Specifically, for this sub-section, the relevant results are reported in Table C.2, where we report the level values from solutions, including $\lambda = 0$ and six self-control alternatives $\lambda = 0.02, 0.05, 0.1, 0.2, 0.3, 0.4$, while maintaining the benchmark taper rate at 0.5. Note that the level values in C.2 are derived by aggregating the (mean) life cycle profiles in figures above that at each age are multiplied by cohort shares (that are falling with age). For example, the reported value for consumption of 50.18 in the first column of Table C.2 relates to average consumption of 50,180 in the calibrated benchmark economy, while around 17% of those aged 65 to 85 continue to provide labor supply (outcome for the aged labor force participation rate (LFPR)).

Table 3: Macroeconomic Effects of Increasing Self-control Temptation*

Variable	$\lambda = 0.02$	$\lambda = 0.05$	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$
Consumption	-0.44	-1.20	-2.59	-6.32	-12.40	-16.80
Domestic Savings	-3.18	-8.57	-18.45	-43.63	-76.30	-92.69
Labor Supply	0.02	0.08	0.26	1.00	2.07	2.61
Aged LFPR (p.p.)[a]	0.41	1.09	2.96	10.99	30.43	43.74
Pension Outlays	0.74	2.01	4.19	9.43	14.43	15.26
Income Tax Revenue	0.25	0.70	1.43	2.84	1.61	-2.12
Tax Base ($t(y)$)	-0.80	-2.19	-4.79	-11.91	-24.34	-33.99
Tax Scalar (f^y)[b]	1.65	4.18	8.41	17.21	26.56	32.30

*Percentage or percentage point (p.p.) change relative to benchmark with $\lambda = 0$ and $\phi = 0.5$; [a]Labor force participation rate (of those aged 65-85); [b]Computed to balance government budget.

while the aged labor participation rate, pension expenditure and the government budget-equilibrating tax scalar all further increase, compared to the benchmark solution where agents do not face self control over consumption. These effects are far more pronounced for very high temptation levels, with the average consumption decline and required income tax hike by 16.8% and 32.3%, respectively, when the case with $\lambda = 0.4$ is compared to the benchmark solution. However, even for lower values of self-control costs, e.g., when λ is set at 0.05, the effects on consumption and household savings (financial wealth) show significant declines by 1.2% and 8.57%, respectively.

As indicated earlier, there are two channels – direct and indirect – affecting the macroeconomic outcomes in our model when agents face different levels of self-control costs. In an environment where individuals face higher self-control costs, average household savings are low because of (i) increased preference for current consumption, directly reducing life cycle savings, and (ii) lower financial income with a higher tax burden (i.e., increased tax scalar applied to benchmark tax schedule), as the government now faces a higher pension expenditure.

In our model, labor supply increases with higher self-control costs, particularly at older ages because of insufficient retirement savings. Much lower retirement wealth also implies higher government pension benefits and coverage, leading to increased pension expenditure, which, together with a declining income tax base, requires an increase in the income tax rates as self-control costs increase.

In summary, economies where agents have higher self-control costs would experience worsening macroeconomic and fiscal outcomes, due to the direct and indirect channels described above amplifying each other.

4.2 Implications of Increasing Self-control Costs in Combination with Alternative Taper Rates

We now proceed to the analysis of increasing self-control costs via changing parameter λ through a wide spectrum of values, combined with also changing the pension taper rate ϕ. The key objective is to examine how higher self-control costs λ affect steady state optimality of pension means testing, where our optimality measure is based on maximizing average lifetime utility – expected lifetime welfare. We begin this subsection by briefly outlining key macroeconomic implications of combinations of λ and ϕ, and then by reporting the welfare implications for the examined combinations.

4.2.1 Macroeconomic Implications

Tables 4 and 5 report the macroeconomic and fiscal outcomes for different levels of self-control costs ($\lambda = 0, 0.02, 0.05, 0.1, 0.2, 0.3, 0.4$), with a universal pension system ($\phi = 0$) and a regressive system ($\phi = 1$), respectively. Outcomes are reported as percentage changes relative to the benchmark model solution described earlier (with $\lambda = 0$ and $\phi = .5$).[20]

Several observations can be made from comparing the macroeconomic effects in the two tables. First, we examine the role of the degree of means testing in the special case where households are not subject to self-control costs and temptation. For $\lambda = 0$ (i.e., standard agent framework without self-control costs), the reduced pension taper (here implying universal pensions) significantly increases the pension expenditure, while the higher taper rate reduces the pension costs. This is as one would expect. What may be more interesting is that a reduction of 0.5 in the taper rate from the benchmark rate generates a far more significant increase in the pension costs (41.95 per cent higher that

[20] As already indicated above, these relative results are derived from more detailed outputs with the level values reported in Appendix C and Tables C.2, C.3 and C.4 for the taper rates at 0.5, 0 and 1.

Table 4: Macroeconomic Effects of Increasing Self-control Costs with Low Pension Taper Rate ($\phi = 0$)*

Variable	$\lambda = 0$	$\lambda = 0.02$	$\lambda = 0.05$	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$
Consumption	-1.05	-1.48	-2.20	-3.49	-7.45	-13.45	-16.87
Domestic Savings	-8.39	-11.63	-17.02	-26.67	-53.11	-82.90	-94.27
Labor Supply	1.31	1.39	1.54	1.90	3.05	4.46	5.06
Aged LFPR (p.p.)[a]	22.40	22.94	23.90	25.56	31.31	41.30	46.97
Pension Outlays	41.95	41.95	41.95	41.95	41.95	41.95	41.95
Income Tax Revenue	9.27	9.43	9.66	10.05	10.26	7.03	3.41
Tax Base ($t(y)$)	-0.14	-0.96	-2.34	-4.87	-12.84	-25.82	-33.51
Tax Scalar (f^y)[b]	1.05	2.70	5.19	9.34	18.23	27.29	31.99

*Percentage or percentage point (p.p.) changes relative to benchmark with $\lambda = 0$ and $\phi = 0.5$; [a]Labor force participation rate (of those aged 65-85); [b]Computed to balance government budget.

Table 5: Macroeconomic Effects of Increasing Self-control Costs with High Pension Taper Rate ($\phi = 1$)*

Variable	$\lambda = 0$	$\lambda = 0.02$	$\lambda = 0.05$	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$
Consumption	0.80	0.29	-0.54	-2.08	-6.21	-12.54	-16.79
Domestic Savings	0.65	-2.88	-8.54	-19.04	-45.35	-77.84	-92.82
Labor Supply	0.79	0.80	0.81	0.91	1.38	2.14	2.52
Aged LFPR (p.p.)[a]	3.89	3.90	4.12	5.23	11.43	28.14	40.68
Pension Outlays	-17.44	-15.98	-13.64	-9.42	0.94	11.95	15.38
Income Tax Revenue	-2.16	-1.78	-1.18	-0.18	1.85	1.29	-2.03
Tax Base ($t(y)$)	1.33	0.40	-1.13	-4.02	-11.87	-24.68	-33.86
Tax Scalar (f^y)[b]	-0.25	1.44	4.02	8.34	17.39	26.94	32.48

*Percentage or percentage point (p.p.) changes relative to benchmark with $\lambda = 0$ and $\phi = 0.5$; [a]Labor force participation rate (of those aged 65-85); [b]Computed to balance government budget.

the benchmark, as shown in Table 4) than the cost reduction due to a 0.5 increased taper rate scenario (17.44 per cent lower than the benchmark, as shown in Table 5). This is partly due to the pension design with income threshold up to which the taper does not apply, but also labor supply and old-age savings disincentives generated by the means test and increased pension progressivity due to the higher taper rate. The universal (more means tested) pension case has negative (positive) impacts on long-run consumption and household assets. For the universal pension case, these negative effects can be explained by disincentives (to work and save) faced by working age populations, combined with implied income tax hike to support universal pensions.

In the case of the regressive pension system (Table 5), when there is no temptation cost, the aggregate consumption level increases by 0.8%, accompanied by higher labor supply and savings, which positively affect financial income. As workers save more, there is also a decrease in pension costs, leading to a direct reduction in taxes, which reinforces higher consumption. As we move to economies where agents face higher self-control costs, workers save less, impacting financial income and, therefore, lowering consumption. Households work more to mitigate the lower financial income and higher taxes required to finance a more generous pension, as more agents now qualify due to their lower savings.

Second, we now compare the columns with different self-control costs (increasing λ) of the two tables. As shown in Table 4, the pension outlay on universal pension benefits is determined independently of λ. In contrast, increasing λ has significant impact on the change in pension outlays under the more stringent (progressive) means test with $\phi = 1$. As reported in Table 5, the pension cost would be roughly 17% lower under $\lambda = 0$, but it would increase by about 15% under $\lambda = 0.4$. Importantly, when comparing the effects on average consumption and household assets between the two tables, the differences seem to be very significant (positive for $\phi = 1$ when compared to $\phi = 0$) only for low values of λ. For high values of λ, these differences almost completely disappear. In fact, $\lambda = 0.4$ requires an income tax hike that is greater under $\phi = 1$ than $\phi = 0$. Nevertheless, aged labor supply participation rate increases significantly for high values of λ, which is also the case under a very progressive pension system with $\phi = 1$ (with life cycle labor effects depicted by Figures C.2 and C.3 discussed in Appendix C.2).

In summary, the macroeconomic effects of increasing λ across the two pension systems indicate that there are further distortions in economies with the higher taper rate (and particularly when λ is high). Furthermore, as displayed in Figures C.2 and C.3, these distortions are particularly important for households at older ages (pension-age-eligible households), facing a more significant labor supply disincentive (drop) upon pension eligibility age from higher pension taper rates.

4.2.2 Welfare Implications

Lastly, we examine the welfare effects of altering the taper rate in the presence of different degrees of self-control costs. Table 6 presents the expected lifetime utility values (averaged over the five skill types) for each pension setting, from a universal pension system ($\phi = 0$) to a fully tapered system ($\phi = 1$), across a wide spectrum of self-control costs (λ).

The maximum value for expected lifetime utility under each setup is highlighted in bold.[21] For populations without self-control costs, the best scenario for maximizing expected utility is found to be the income-tested pension with $\phi = 1$, representing the highest possible taper rate. Among populations with self-control costs, the same policy remains optimal as long as the self-control cost (λ) remains relatively low. However, as self-control costs increase – e.g. to $\lambda = 0.2$ – a high taper rate no longer yields the highest expected utility. Instead, a lower taper rate of $\phi = 0.25$ emerges as the preferred option for households. When agents face the highest examined temptation cost ($\lambda = 0.4$), the universal pension policy with $\phi = 0$ becomes the optimal choice for maximizing average utility.

Table 6: Expected Lifetime Utility Values

Taper Rate	Temptation Parameter (λ)						
ϕ	0.00	0.02	0.05	0.10	0.20	0.30	0.40
0.00	-0.4683	-0.4759	-0.4875	-0.5067	-0.5479	-0.5899	**-0.6116**
0.25	-0.4640	-0.4717	-0.4832	-0.5026	**-0.5428**	**-0.5863**	-0.6117
0.50	-0.4634	-0.4710	-0.4828	-0.5024	-0.5432	-0.5865	-0.6131
0.75	-0.4630	-0.4707	-0.4825	-0.5025	-0.5436	-0.5874	-0.6140
1.00	**-0.4623**	**-0.4701**	**-0.4820**	**-0.5021**	-0.5440	-0.5882	-0.6139

Populations with lower self-control costs generally prefer an income-tested pension with a high taper rate. However, as self-control costs rise, a lower taper rate and eventually

[21] Note that we only evaluated the taper rates of 0, .25, .5, .75 and 1.

universal pension become more favorable. This preference shift can be attributed to two factors: the higher fiscal cost of a means-tested pension due to lower private retirement incomes among those with higher self-control costs, and the increased value of a public pension as an alternative to private savings for populations with self-control costs.

The higher fiscal burden of the age pension channel arising from higher self-control costs is explained as follows. When the same income test is applied to different populations, the total cost to the government of providing the pension is higher in populations with higher self-control costs, as they tend to save much less compared to households with no self-control costs. As shown in Table 4, while the fiscal costs of providing universal pensions are capped (at the same level irrespective of increasing self-control costs), they are found to increase significantly in economies with means-tested pensions and higher λ (as depicted in Tables 3 and 5 for the taper rates of 0.5 and 1, respectively).

For households with self-control preferences, changes to the means test can impact welfare in an additional way. Saving for retirement is costly, especially as the self-control parameter (λ) increases. Households with self-control costs may value the age pension more because it reduces the need for them to save for retirement, thereby lowering welfare costs typically associated with less progressive or universal pension provisions. On the other hand, a higher taper rate (implying a more progressive pension system) generates additional behavioral distortions for those with high self-control costs at older ages (that is when these households tend to work and save (or dis-saves more slowly than those without self-control costs), as shown in Figures 4 and 6. For the life-cycle labor supply effects, see comparisons across three pension system with varying taper rates in Figures 6, C.2, and C.3, with the strongest distortion in older age labor supply under the strict means tested case with the taper rate of 1.

Overall, we find that populations with no or low self-control costs prefer an income-tested pension with a high taper rate, but the optimal taper rate tends to be lower amongst (economies of) populations with high self-control costs. If self-control costs are sufficiently high, households may prefer a universal pension to a means-tested pension.[22]

[22]Interestingly, these welfare findings are mostly consistent across different skill types of households, as shown in Table C.5 of Appendix C.3.

5 Temptation over Both Consumption and Leisure

In this section, we undertake a model extension to allow for a change in the specification of self-control preferences. Specifically, we relax the previous assumption that self-control cost were on consumption only, and now allow households to face temptation with respect to both consumption and leisure. We find that our results are consistent with our previous model specification.

5.1 Model Extension

Expanding the model specification to allow agents to experience temptation over current leisure, the updated maximization problem described in Equation 17 is rewritten as

$$V_j(x) = \max_{c \in B, l \in [0,1]} \left(u(c,l) + v(c,l) + E[\beta \omega_j V_{j+1}(x')] - \max_{\tilde{c} \in B, \tilde{l} \in [0,1]} v(\tilde{c}, \tilde{l}) \right), \quad (34)$$

where the temptation utility function is a linear transformation of the commitment utility, i.e., $v(c,l) = \lambda u(c,l)$.

We solve for the optimal allocations and compute the expected life time utility considering a range of self-control values (λ ranging from 0 to 0.4) and different pension systems.[23] We analyze the effect on lifetime utility, savings, labor supply and consumption.

5.2 Welfare Effects

We report the discounted life time utility in Table 7, values in bold indicate the highest utility level for each value of the self-control cost. As expected, the discounted life-time utility is now slightly lower compared to the case where agents face self-control over consumption only. However, the results are broadly consistent with the outcomes from the baseline economy (see Table 6). When agents face a lower temptation cost ($\lambda \leq 0.1$), agents would be better off with a pension system where the taper rate is one. When agents have a higher self-control cost, they would prefer an economy with a lower taper rate.

[23] We follow the same calibration procedure as described in Section 3.

Table 7: Expected Lifetime Utility: Temptation over Consumption and Leisure

	Temptation Level (λ)						
Taper Rate (ϕ)	0.00	0.02	0.05	0.10	0.20	0.30	0.40
0.00	-0.4683	-0.4763	-0.4885	-0.5088	-0.5529	-0.5971	**-0.6160**
0.25	-0.4640	-0.4722	-0.4843	-0.5047	**-0.5478**	-0.5945	-0.6166
0.50	-0.4634	-0.4715	-0.4838	-0.5046	-0.5481	**-0.5945**	-0.6180
0.75	-0.4630	-0.4712	-0.4836	-0.5048	-0.5485	-0.5959	-0.6190
1.00	**-0.4623**	**-0.4705**	**-0.4831**	**-0.5043**	-0.5491	-0.5965	-0.6188

5.3 Life-Cycle effects

We display outcomes for savings in Figure 7. Over the life cycle, savings are slightly lower when the temptation applies to both consumption and leisure rather than consumption only. We also report results when the self-control cost is zero. When agents display self-control over leisure, they supply less labor and pay more taxes to finance a broader pension system, and therefore their decline in earnings explain the lower level in savings.

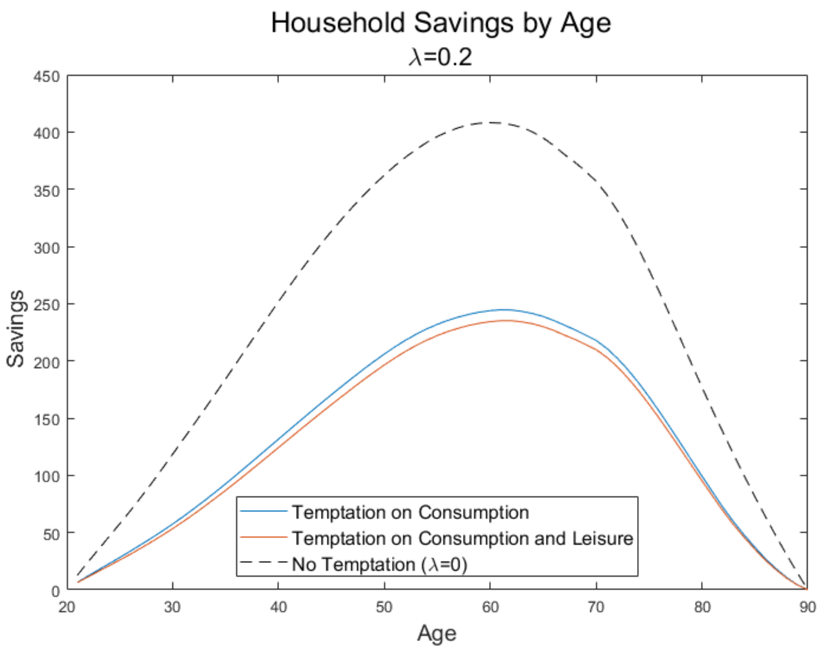

Figure 7: Savings by Age: Comparison of Temptation Types

In terms of labor supply, households supply slightly less labor while young, compared to the case where temptation is only on consumption. As agents age and haven't much savings (compared to the cases where there is no self-control costs or there is self-control on consumption only), agents increase their labor supply when getting old, to compensate their lower financial income, higher tax payments, lower wealth to finance their retirement, making the back-loaded labor supply profile discussed earlier even stronger. Results are displayed in Figure 8.

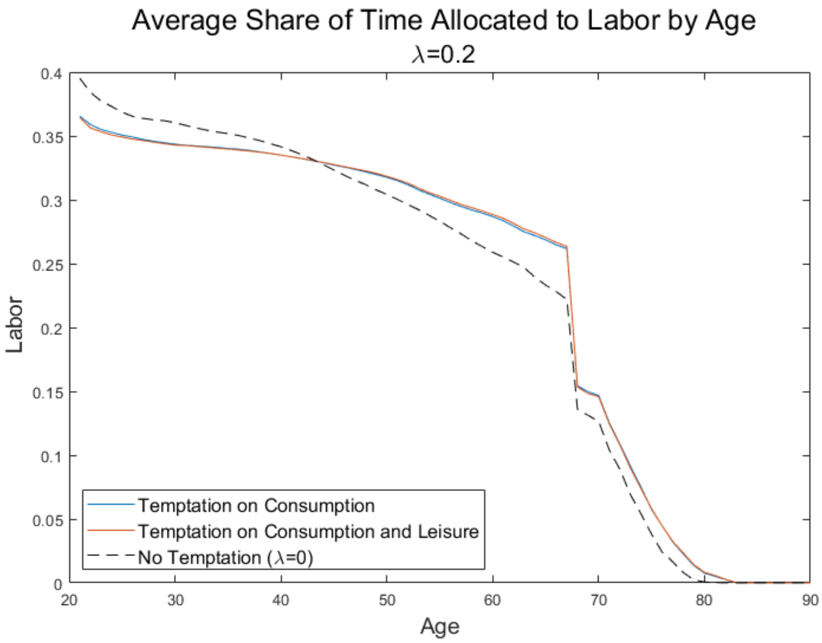

Figure 8: Labor Supply by Age: Comparison of Temptation Types

As agents supply less labor when young, and save less for retirement, their overall earnings decline over time, having a direct negative impact on consumption. In this case, consumption is slightly lower over the life cycle when households are tempted by leisure. The consumption pattern is depicted in Figure 9.

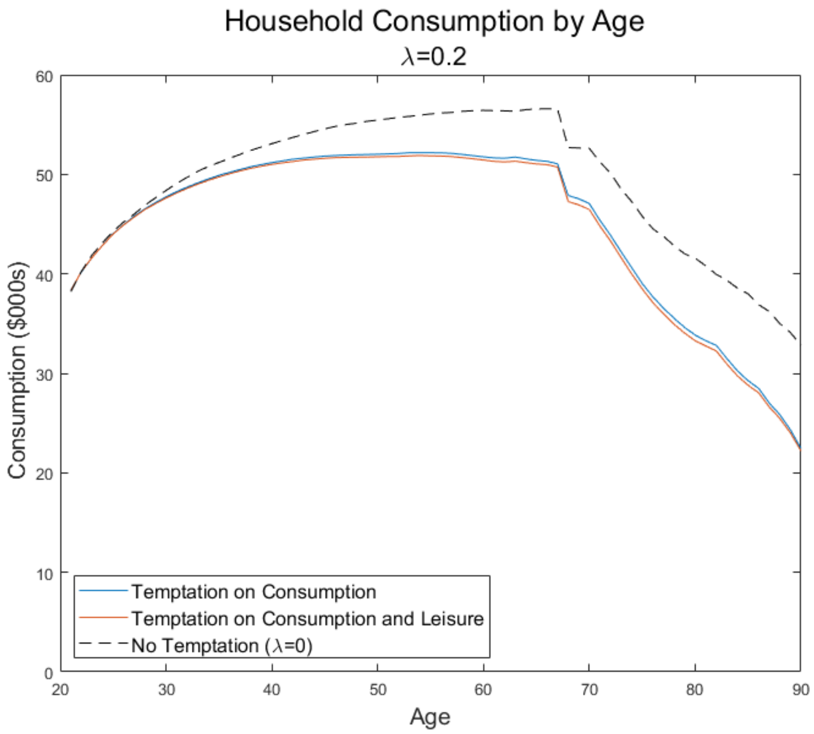

Figure 9: Consumption by Age: Comparison of Temptation Types

We find that the outcomes for savings, labor supply and consumption over the life cycle are generally similar regardless of whether the temptation is applied to both consumption and leisure or consumption only.

6 Conclusion

In this paper, we have employed an overlapping generations model of a small open economy to consider how the presence and degree of self-control preferences change the saving, labor supply and consumption decisions of households. In addition, we have examined the resulting impact of self-control preferences on the means-testing of the age pension, household behaviour and welfare. The paper contributes to the literature on retirement income policies and temptation, by considering less explored topics on the effects of means testing of publicly provided old-age pensions for populations with self-control preferences.

The first main focus of the paper is on the role of self-control preferences on household choices. Over the life cycle, households drawn from populations with self-control preferences save less than households with standard preferences, and higher self-control costs are associated with lower savings. Additionally, and importantly, these households defer their labor supply to later ages in the life cycle and tend to delay retirement. A significant finding of the paper is that the savings behaviour of households with self-control preferences is both a response to temptation, and an anticipation of it. Since households experience self-control costs as dis-utility, they will choose behaviour that reduces their need to exercise self-control in subsequent periods. Consequently, households with high self-control costs save less throughout their life-cycle not only because they face increased temptation to draw down their savings each period, but also because their present savings will increase their self-control costs in the future.

The second main focus of the paper is on the role of self-control preferences when the government provides a mean-tested age pension to older agents. Within this model, applying an income test to the age pension increases the savings of households, as many of them have to self-finance their retirement and, over the life cycle, face a lower tax rate as pension costs fall. Our paper also examines the impacts of combining higher self-control costs with different taper rates. In economies with high self-control costs, distortions from higher taper rate on the pension become more pronounced, with the difference in household savings between high and zero taper almost disappearing when self-control costs are very high (see Tables 4 and 5).

These effects of self-control preferences under different pension means testing settings have welfare implications. Increased eligibility for the pension puts additional pressure on government spending on the pension, requiring higher tax rates, which weighs upon household consumption and utility. However, the need for households to increase their savings in response to higher taper rates also directly reduces the utility of households. We find that an income tested pension with a very high taper rate of 1 is the policy that maximises expected utility in economies with no or low self-control costs. On the other hand, as the cost of self-control rises households may prefer pension systems with lower taper rates. If self-control costs are sufficiently high, a universal pension with a zero taper rate generates the optimal long run welfare outcome.

Throughout this paper, we have considered populations which have self-control preferences of different intensities in order to analyse the effect of means-testing the age pension when self-control costs are both high and low. We remained agnostic as to which value of λ is appropriate, or whether there may be heterogeneity in self-control costs, and these issues remain areas for further study. Future research could also consider the role that mandatory private pension schemes, such as Australia's Superannuation Guarantee, would have on the optimal design of (the combination of) a private pension mandate and a means-tested age pension in a population with temptation.

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Appendices

In these appendices, we provide more details of (A) model calibration, (B) computational algorithm and (C) further results for Section 4.

Appendix A Calibration

Appendix A.1 Labor Efficiency and Shocks

We use data drawn from the Household, Income and Labour Dynamics in Australia (HILDA) longitudinal survey (see Summerfield et al. [2017] for more details) to estimate of labor productivity and other key life cycle profiles for our model calibration. HILDA is an Australian household panel survey with focus on families, income, employment and well-being, and contains detailed information on individuals' current labor market activity including labor force status, earnings and hours worked, and employment and unemployment histories. We use data from the first 16 waves of HILDA surveys.

Estimation of Labor Efficiency. Each individual was allocated to one of 5 education groups, based upon their reported educational achievement. The five education groups are individuals reporting that they: (1) did not complete high school, (2) completed high school, (3) complete a certificate, diploma or advanced diploma level tertiary qualification, (4) completed a bachelor degree, and (5) completed a graduate diploma or certificate, or a post graduate degree.

We restricted the sample to full time workers over the age of 20. An individual is considered to be a full time worker if they were reported as such ($esdtl = 1$) and if their reported wage is positive. The series $wsce$ (gross weekly wage) was used as the wage measure. There were $40,746$ individuals surveyed over this period, though not all were surveyed each year. At high ages there were limited data for full time wages of older workers, and the average wages become quite volatile. We therefore restricted the data in the estimations to households between the ages of 20 and 60. The education types and estimated share of households of each type, along with their median wages, are presented in Table A.1.

To estimate expected efficiency units by age and skill type, we constructed age-based expected wage profiles for agents in each educational group. This was done in several

Education Group	Per cent of Households	Median Full Time Weekly Salary wsce	HILDA Category edhigh1
1 - Didn't Finish High School	18.7	$930	9 - Year 11 or below
2 - Finished High School	15.5	$944	8 - Year 12
3 - Some Post High School Qualification	35.1	$1100	5 - Cert. III or IV 4 - Adv. Diploma, diploma
4 - Bachelor Degree	18.1	$1350	3 - Bachelor or honours
5 - Graduate or Postgrad. Degree	12.7	$1534	2 - Grad. Diploma, grad. certificate 1 - Postgrad. - Masters or doctorate

Table A.1: Household Skill Types

stages. We initially estimated a time trend and de-trended the wages reported by individuals across the 16 years over which wage data was collected. We then used the de-trended data to estimate smooth profiles for the expected wages of each of the groups at various ages by estimating the regression equation

$$\overline{e}_j(j,m) = \beta_0 + \beta_1 ln(j) + \beta_2 ln(j)^2 + \beta_3 ln(j)^3 + \beta_4 D_m + \beta_5 D_m ln(j). \tag{A.1}$$

In the above equation, the deterministic weekly wage of the individual is conditional on their age (j) and education type $m \in \{1, ..., 5\}$, where D_m is a dummy variable indicating the individual's education type and the β_i are parameters. Figure A.1 shows plots of the estimated wage profiles.

These estimated expected wage profiles ($\overline{w}_{jm}$) are used as a benchmark against which to index the expected productivity of the each type at each age ($\bar{e}_{jm}$). The bottom educational type of worker at age 21 is assumed to have 1 efficiency unit in expectation, with the remaining workers' expected productivity scaled accordingly. For the purposes of calibrating the model, a linear decline in productivity is imposed on all income groups once the agent reaches the age of 75 over 10 years. Agents above [the age of 85 are assumed to be unproductive.

Estimation of Productivity Shocks and Transition Matrix. Although agents deterministic productivity ($\bar{e}_{jm}$) is determined by their age and education type, each agent faces income uncertainty each period, as explained in Section 3. The mobility of individuals across different quintiles of labor efficiency from one age to the next is captured by Markov transition matrices. A single wage scale vector (ζ) defining the quintiles and a transition probability matrix (T) were estimated for all agents regardless of their education type, and from the de-trended wage data set.

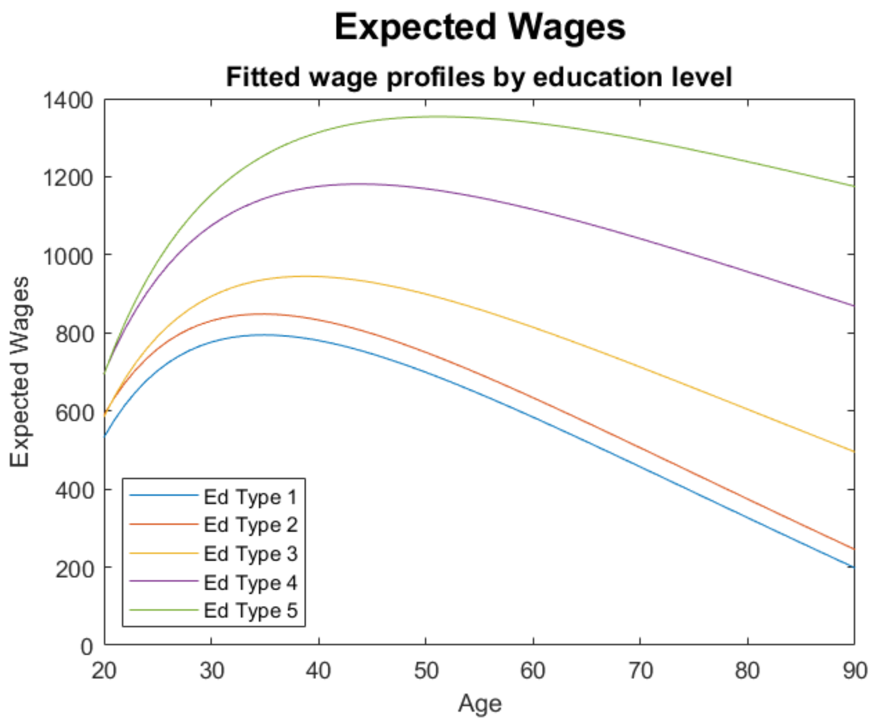

Figure A.1: Wage Profiles by Education Type

The sample was restricted to observations where two or more consecutive full time wages were observed. Each wage observation was divided by the expected wage for that agent given their age and education type. This created a standardized set of wages which were then allocated into one of five bins based on their quintile. The elements of vector ζ are the mean standardized wages in each quintile, while the transition matrix T is calculated by the observed likelihood of the agents wage being allocated to bin y in period $t+1$ after being in bin x in period t, for each possibly combination of x and y.

The resulting estimates of ζ and T are:

$$\zeta = \begin{bmatrix} 0.51 \\ 0.72 \\ 0.88 \\ 1.10 \\ 1.79 \end{bmatrix}, \tag{A.2}$$

and

$$T = \begin{bmatrix} 0.66 & 0.23 & 0.07 & 0.03 & 0.01 \\ 0.19 & 0.51 & 0.22 & 0.06 & 0.01 \\ 0.06 & 0.20 & 0.50 & 0.19 & 0.04 \\ 0.02 & 0.07 & 0.18 & 0.58 & 0.15 \\ 0.01 & 0.01 & 0.04 & 0.16 & 0.77 \end{bmatrix}. \tag{A.3}$$

Appendix A.2 Progressive Income Taxes

The progressive income tax function is based on the 2018-19 Australian income tax schedule and is given by

$$\mathcal{T}(y) = \begin{cases} 54,097 + 0.450(y - 180,000), & y > 180,000 \\ 20,797 + 0.370(y - 90,000), & 180,000 > y > 90,000 \\ 3,572 + 0.325(y - 37,000), & 90,000 > y > 37,000 \\ 0.190(y - 18,200), & 37,000 > y > 18,200 \\ 0 & 18,200 > y, \end{cases} \tag{A.4}$$

where y is taxable income from both labor earnings and interest receipts.[24] In addition, a 2 per cent medicare levy is applied to taxable income. The tax schedule is proportionally adjusted to ensure that the government budget remains in balance. Accordingly, all non-zero marginal tax rates alter proportionately, while the tax bracket income thresholds remain unchanged.

Appendix B Computational Algorithm

The code for the computations is written using the MATLAB software. Our algorithm applies the iterative Gauss-Seidel computational method initially recommended by Auerbach and Kotlikoff [1987] and used frequently in the literature. The solution of the household optimization problems is complicated by the fact that the means test for the age pension causes the budget set to be non-convex, as is well known. Indeed, these potential numerical issues arise even in standard linear means-test cases. We avoid such problems by creating a grid over leisure and future assets (consumption being determined by the

[24] https://atotaxcalculator.com.au/ato-tax-rates retrieved December 2019.

budget constraint), evaluate the expected value function at each such grid point, and then choose the grid point that yield the greatest value for the objective function. Unless the grids are too coarse, this method (while computationally time-consuming) will find the globally optimal solution (up to an approximation, of course) and avoid the possibility of local maxima.

Appendix C Further Results for Section 4

In this appendix, we provide additional and more-detailed effects of increasing self-control costs in combination with thee benchmark and alternative pension taper rates.

Appendix C.1 Macroeconomic Outcomes

In Tables below, we present more detailed macroeconomic and fiscal outcomes (in levels) for different self-control costs (with increasing λ) and under three different pension systems with the benchmark taper $\phi = 0.5$ (Table C.2), reduced taper $\phi = 0$ (Table C.3), and increased taper $\phi = 1$ (Table C.4).[25]

The macroeconomic results presented in Section 4 in Tables 3, 4, and 5 (as percentage or percentage point changes relative to the benchmark model) are all derived from the tables below, using the first column of Table C.2 as the benchmark case.

[25] Note that monetary variables (e.g., consumption, household assets) are cohort-weighted averages expressed in units of 1,000 Australian dollars. As indicated, in the benchmark model, we target several macroeconomic ratios, e.g. the consumption to output ratio of 0.545 or the pension cost to output ratio of approximately 0.029, which can be derived from the first column of Table C.2.

Table C.2: Macroeconomic Outcomes of Increasing Self-control Temptation with Benchmark Pension Taper Rate ($\phi = 0.5$)

Variable	$\lambda = 0$	$\lambda = 0.02$	$\lambda = 0.05$	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$
Consumption	50.18	49.96	49.58	48.88	47.01	43.96	41.75
Domestic Savings	239.36	231.76	218.85	195.20	134.92	56.72	17.49
Labor Supply	27.09	27.10	27.11	27.16	27.36	27.65	27.80
Aged LFPR	17.29	17.70	18.38	20.25	28.28	47.72	61.03
Pension Outlays	2.70	2.72	2.75	2.81	2.95	3.09	3.11
Income Tax Revenue	12.32	12.35	12.41	12.50	12.67	12.52	12.06
Tax Base ($t(y)$)	13.48	13.38	13.19	12.84	11.88	10.20	8.90
Tax Scalar (f^y)	0.91	0.92	0.94	0.97	1.07	1.23	1.36
Output	92.05	92.03	91.99	91.89	91.46	89.60	87.25

Table C.3: Macroeconomic Outcomes of Increasing Self-control Temptation with Reduced Pension Taper Rate ($\phi = 0$)

Variable	$\lambda = 0$	$\lambda = 0.02$	$\lambda = 0.05$	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$
Consumption	49.65	49.44	49.08	48.43	46.44	43.43	41.71
Domestic Savings	219.28	211.53	198.62	175.52	112.24	40.93	13.72
Labor Supply	27.45	27.47	27.51	27.61	27.92	28.30	28.46
Aged LFPR	39.69	40.22	41.19	42.84	48.60	58.59	64.25
Pension Outlays	3.83	3.83	3.83	3.83	3.83	3.83	3.83
Income Tax Revenue	13.47	13.49	13.51	13.56	13.59	13.19	12.74
Tax Base ($t(y)$)	13.47	13.36	13.17	12.83	11.75	10.00	8.97
Tax Scalar (f^y)	1.00	1.01	1.03	1.06	1.16	1.32	1.42
Output	92.22	92.22	92.21	92.18	91.66	89.45	87.42

Table C.4: Macroeconomic Outcomes of Increasing Self-control Temptation with Increased Pension Taper Rate ($\phi = 1$)

Variable	$\lambda = 0$	$\lambda = 0.02$	$\lambda = 0.05$	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$
Consumption	50.58	50.33	49.91	49.14	47.06	43.89	41.75
Domestic Savings	240.91	232.46	218.91	193.78	130.82	53.05	17.18
Labor Supply	27.30	27.31	27.31	27.34	27.47	27.67	27.77
Aged LFPR	21.18	21.19	21.40	22.52	28.72	45.43	57.97
Pension Outlays	2.23	2.27	2.33	2.44	2.72	3.02	3.11
Income Tax Revenue	12.06	12.10	12.18	12.30	12.55	12.48	12.07
Tax Base ($t(y)$)	13.66	13.54	13.33	12.94	11.88	10.16	8.92
Tax Scalar (f^y)	0.88	0.89	0.91	0.95	1.06	1.23	1.35
Output	92.76	92.72	92.63	92.46	91.78	89.64	87.28

Appendix C.2 Life-Cycle Labor Supply Effects

The life cycle effects on labor supply under different self-control costs (λ) for the two alternative pension designs with universal pensions ($\phi = 0$) and the strict means tested regime ($\phi = 1$) are depicted in Figures C.2 and C.3, respectively.

As already shown in the main text (Figure 6 for the case with the benchmark taper rate of $\phi = 0.5$). Higher self-control costs are associated with lower hours worked while young but higher hours worked at middle-working and older ages. Recall that as households with high self-control costs generally have lower savings, they rely more upon labor income to sustain consumption levels as they age, and this is reflected in profiles of hours over their working lives. The higher levels of time allocated to labor amongst middle-aged and older households with self-control preferences reflects the lower level of savings accumulated by these households over their life cycles.

Older households with higher self-control costs work longer hours both prior to the pension age and after reaching the pension age, but the pension availability (at age 67) causes a larger fall in their hours worked, compared to households without self-control costs. Importantly when comparing the two figures with universal and strict means tested pension systems, the labor supply, particularly amongst older households, appears to be more sensitive to changes in the taper rate in economies with high self-control costs. With lower savings, these households have less non-labor income and their expected pension receipts are more likely affected by their labor income.

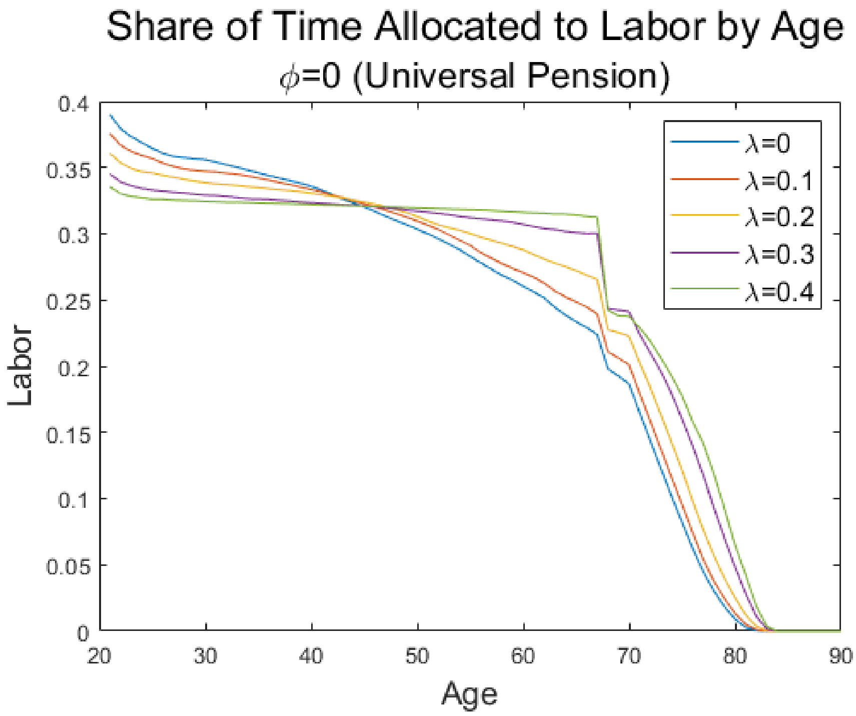

Figure C.2: Time Allocated to Labor by Age: $\phi = 0.0$

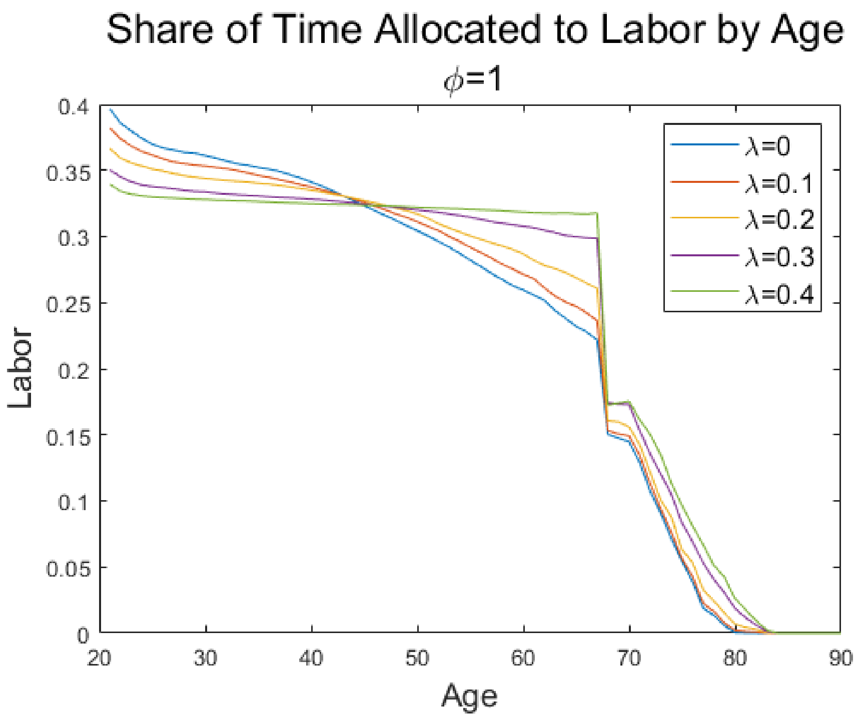

Figure C.3: Time Allocated to Labor by Age: $\phi = 1.0$

Appendix C.3 Distributional Welfare Effects

As shown in the main paper, economies of populations with no or low self-control costs prefer an income-tested pension with a high taper rate, but in economies with high self-control costs, the optimal choice for taper rate tends to be lower. If self-control costs are sufficiently high, households may prefer a universal pension to an income tested pension. In Table C.5, we show the preferred taper rate by skill types, with the findings consistent for these different skill groups. The same taper rate maximises expected utility for all household types within the population with standard preferences (no self-control costs). With some minor exceptions, this is also mostly true for the economies of populations with self-control preferences. There are generally only small differences in preferred taper rate across skill/educational type.

Table C.5: Preferred Taper Rate by Education Type

	Temptation Parameter (λ)						
Education Type	0.00	0.02	0.05	0.10	0.20	0.30	0.40
Type 1	1.00	1.00	1.00	1.00	0.25	0.25	0.25
Type 2	1.00	1.00	1.00	1.00	0.25	0.25	0.25
Type 3	1.00	1.00	1.00	0.25	0.25	0.25	0.00
Type 4	1.00	1.00	1.00	1.00	0.25	0.25	0.00
Type 5	1.00	1.00	1.00	1.00	0.50	0.50	0.00