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OPTIMAL COMPULSION WHEN BEHAVIORAL BIASES VARY AND THE STATE ERRS

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Optimal compulsion when behavioral biases vary and the State errs[1]

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Abstract

When behavioral biases have varying sizes, and the State seeks to correct behavior through compulsion, the question is how to design optimal compulsion. One argument is that compulsion should rise with the size of the bias to be "cured". A contrary argument is that since compulsion affects actions, and recommended actions are independent from the bias, compulsion should not depend on the bias. This puzzle is solved for the case where individuals are affected by a bias that leads them to under-save, acknowledging that the planner predicts each individual's optimal action with error. Since only low-bias individuals are willing to correct the planner's mistakes when mandated to save too little, but are not able to do so in the opposite direction due to a costly spread, the optimal amount of compulsion rises with the bias. As an application, the paper explores a behavioral rationale for a Maximum for Taxable Earnings (MTE). It finds that if (1) the State's information is limited to current earnings; (2) earnings do not influence the earnings ratio for old age; and (3) the bias falls only at the highest earnings quintile, then a MTE near the 80th percentile of the earnings distribution is optimal.

JEL classification: H55, H53, H24
Keywords: Behavioral Bias, Compulsion, Optimal Policy, Time-inconsistency, Overoptimism, Pensions, Maximum Taxable Earnings.

[1] We appreciate comments from participants at seminars at CESifo (Munich) in May 2010, Catholic University of Chile (Santiago) in March 2010 and at the annual meeting of Chilean Economists in September 2010. Comments from participants at the CESifo Area Conference on Employment and Social Protection, May 14-15, 2010 were useful for this paper.
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1. Introduction

Many heavy smokers, drinkers and spenders regret their behavior later on, when there is no free turnaround to recover what has been lost. These biases affect different individuals to different degrees, and the "correct" behavior is difficult to predict. Therefore, public policies aimed to correct such biased behaviors can do more harm than good, for many or even for most individuals. But laissez-faire may also do worse than a modest amount of blind compulsion.

The question tackled in this paper is how should a benevolent planner vary his policy, which is the amount of compulsion, taking into account his own errors when estimating each person's optimal action, and when assessing the size of the bias for each individual.

A natural rule of thumb is that compulsion should be targeted to those with large behavioral biases, and that others should be exempt. Indeed, Saint-Paul (2009) asserts that since behavioral biases are essentially a matter of the poor, compulsion should be targeted to the poor alone. However, this rule-of-thumb is not straight-forward. A benevolent planner would try to reach through compulsion the optimal action for the individual in the absence of bias, no matter how large that bias is. Thus, the optimal action would not depend on each individual's level of bias, precisely because the bias is what needs to be set aside. If the planner can achieve an adjustment in the individual's behavior by making the optimal action compulsory, it follows that the amount of compulsion should not depend on the level of bias.

This paper proceeds in two steps. First, it identifies conditions under which the optimal amount of compulsion is independent from the level of bias. Under such conditions the same amount of compulsion applies independently of the size of the bias, and targeting to highly biased individuals alone would be suboptimal. The critical condition turns out to be that the planner is able to predict accurately each individual's optimal action. In that case, the planner's mistakes in assessing each individual's amount of bias do not matter.

Second, the paper identifies optimal policy in the realistic case where the planner also errs in assessing each individual's optimal action. These mistakes make compulsion less efficient, creating scope for voluntary action. Indeed, Beveridge argued that "the State in organizing security should (…) leave room and encouragement for voluntary action by each individual to provide more than that minimum for himself and his family" (Beveridge, 1942, p. 7).[1] In this paper free action (no compulsion, or laissez-faire) is valued instrumentally, as the means for avoiding the inefficiencies created by the planner's mistakes.

For incomplete information scenarios, the optimal level of compulsion *does depend* on the predicted bias for each individual. Let us illustrate with an example, where a planner seeks to increase saving for old age because some bias leads many to save less than optimal. On average, the planner knows that he might mistakenly force some individuals to oversave, while others might be required to save too little relative to their bias-free needs. When compulsion is set higher than what the individual deems optimal, the individual does not counteract over-saving if the cost of consumer credit is prohibitive. In contrast, when the mandatory saving rate is set below what the biased individual would have chosen freely, the individual can respond in two ways: if her bias is small, she can be relied upon to repair most of the planner's mistake by

[1] The literature on why a wider scope for free action is desirable includes Regan (1983) and Zamir (1998). On paternalism and the value of individual freedom, see also Burrows (1993) and Buchanan (1959).

raising her voluntary savings. However, if her bias is large, she will not repair the mistake and will indulge in her biased behavior.

Therefore, the planner's cost of under-predicting the optimal mandatory saving rate is larger when the individual's bias is larger. In contrast, the cost of mandating the individual to oversave is independent from the size of the bias that affects each individual. This asymmetry leads the optimizing planner to cut the compulsory contribution rate for individuals whose bias is predicted to be low. Thus, the optimal amount of compulsion should rise with the bias. Note that this rationale fades as the planner predicts the optimal action more accurately. The precision of the predicted bias is important too. As this precision falls, the conditioning of compulsion on the predicted level of bias is reduced gradually under optimal policy, and is eventually eliminated.

The last part of this paper applies these general results to a long-standing issue in pension economics. Imagine that higher earnings are correlated with a smaller bias regarding old-age savings, and therefore high earners are less affected by insufficient compulsory saving. The previous results suggest that it would be optimal to reduce the compulsory contribution rate on high earners. This might support a "behavioral rationale" for the well-known policy that sets a "maximum on taxable earnings". In about 80% of countries, the compulsory contribution rate for old-age pensions includes a smaller marginal rate on earnings above some threshold, which is designated as the "maximum on taxable earnings" (MTE).

Table 1 reports the MTE for a sample of 60 countries in 2008, expressed as a ratio of GDP per capita. The observed ratios are diverse: nearly a fifth of the countries set a MTE below their own GDP per capita; a fifth go to the opposite extreme and set no limit at all. The middle 60% exhibits a median MTE equal to 2.26 times GDP per capita. This ratio is 2.33 for the U.S.A. About 83% of the sample with a finite MTE reduces the marginal contribution rate by at least 75% as the MTE is surpassed.

The size of the MTE is also at the crux of an old debate between the Beveridgian and the Bismarckian designs for contributory old-age pensions that are not redistributive. Beveridge's (1942) prescription was a contributory system of flat old-age benefits financed with a flat *amount* of contributions per worker.[2] This implies a MTE equal to the minimum wage, at the lower end of the feasible range for MTEs. In contrast, Bismarck's (1887) prescription was a single contribution rate applied to all earners, which implies an unbounded MTE. When the MTE is set at a mid-point, its size tells the degree of "Bismarckianess" of the pensions system.

Demand for mid-point MTEs runs strong among modern policymakers. For example, the 2004 Report of the UK Pension Commission posited that "there is a social interest in ensuring that people of modest or average means (e.g. those up to *the 75th percentile of earnings*) have made provision which they would consider adequate, but that above some level of income (say above *the 90th percentile*) a purely individualist approach is appropriate." (Report, p. 129)[3]. That Commission posits that the MTE should be defined in terms of relative earnings.

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[2] Not to be confused with systems where a *proportional* tax on earnings finances a flat benefit for the old. Such a redistributive and non-contributory system was mistakenly labeled as "Beveridgean" by Cremer et al (2007).
[3] This Report is available at www.pensionscommission.org.uk

How does this paper contribute to this debate? First, a disclaimer: there are three main benevolent rationales to adopt or change a MTE: fiscal, market-structure, and behavioral. [4] Fiscal rationales for a MTE are outlined in section 3.6, and market-structure rationales are summarized section 7. Since assumptions are made to set them aside, this paper's contribution to this debate relates only to behavioral rationales for a MTE.

There is empirical backing for the hypothesis that high earners have a lower bias on average. For example, Stango and Zinman use the 1983 Survey of Consumer Finances in the U.S.A. to measure "exponential growth bias" and find that its size is significantly lower for the highest earnings quintile (2009, Table IV). We have found no empirical evidence on the link between earnings in the first phase of life and net earnings in old age.

However, a detailed examination fails to support in general the behavioral argument for creating a finite MTE. A modern State observes each individual's current taxable earnings, age, occupation, rural/urban status, education, marital status, wealth, gender and other socio-demographic attributes. Let us assume that anti-discrimination legislation does not preclude a State from conditioning the compulsory contribution rate on at least one of the attributes with impact, apart from earnings. For example, in Switzerland the mandatory contribution rate for old age-savings depends on age, and in many countries it also depends on occupational sector and on labor market status. Therefore, conditioning the amount of compulsion on current earnings alone is inefficient. Recently, Stango and Zinman (2009, Table IV) found that the size of "exponential growth bias" is strongly influenced by education, after controlling for the impact of the current earnings quintile and gender. Thus, the Beveridgian and the Bismarckian extremes, and intermediate levels for the MTE, make suboptimal use of information.

Next, the paper explores optimal policy for an informationally constrained State, who is limited to observe current earnings. If current earnings quintile is the only predictor of both the bias and net earnings in old age, the paper shows finds that the optimal dependence of the contribution rate on current earnings depends on the impact of earnings on the optimal age-earnings ratio for old age. For example, if a higher salary induces earlier retirement by enough, it reduces the overall earnings obtained in the second phase of life, and this increases desired savings for old age. If this link is important, it influences the optimal schedule that connects the contribution rate and current earnings. Indeed, a strong impact of this type may convert the optimal MTE into a Lower Earnings Limit. Therefore, an MTE may be suboptimal even for a State subject to these informational limitations.

However, in the subcase where earnings have a negligible influence on the desired age-earnings ratio for old age, the inability to observe data other than current earnings brings the MTE approach close to optimality. For example, if the bias is falt for most earnings quintiles, except for the highest where the bias falls, as in the data for the U.S.A. then the informational limitations make an MTE optimal at the 80th percentile of the earnings distribution. For the Beveridgean system to be optimal, the predicted bias would need to fall continuously as

[4] Gill, Packard and Yermo (2005, p. 230-232) contribute 2 other benevolent arguments in support of a MTE. First, they posit that personal investments such as owner-occupied housing and prepayment of expensive consumer credit, provide higher returns than the purchase of pension rights even under full funding. Second, they argue that for low earners compulsion is *not* costly, because high-return personal investments are denied to them anyway by non-divisibility thresholds. If less compulsion allowed some high earners to accumulate enough savings to overcome those thresholds, the opportunity cost of compulsion would be larger for high than for low earners.

earnings rise above the minimum salary. For the Bismarckian system to be optimal, all workers need to be equally biased, including those in the highest earnings quintile.

Section 2 reviews briefly the literature on benevolent compulsion. Section 3 presents a simple model for excessive optimism, the behavioral bias used in this paper. Section 4 explores the case of a planner whose informational resources allow accurate prediction of the optimal action. Section 5 defines and simulates optimal policy for States with realistic amounts of informational resources, and obtains the main results. Section 6 discusses application to the optimal Maximum Taxable Earnings in old-age pensions policy. Section 7 suggests directions for future research.

2. Brief review of the literature that rationalizes benevolent compulsion

Altruism leads people to vote for policies that alleviate poverty. However, if old-age poverty attracts subsidies, then some of the young that have modest earnings may engage in under-saving to benefit from those subsidies. Compulsion has been justified as a policy that prevents this response (Hayek 1960 p. 286, Musgrave 1968, Kotlikoff 1987). This argument is also referred to as the "savings moral hazard" or "rational prodigality" hypothesis. However, compulsory savings may drive consumption of the young poor too close to subsistence levels, an outcome that would contradict the presumed altruism of voters (Valdés-Prieto, 2000). Indeed, the recent literature has shown that when a negative income tax is available, the State should never use compulsion to counteract savings moral hazard, because compulsion deepens distortions to the labor choices of the young poor (Homburg, 2006).

Time-inconsistency is a more robust argument for compulsion. Several branches of time-inconsistency theory are relevant for old-age saving. The "hyperbolic discounting", "finite horizons" and "procrastination" branches stress that people appear to have great concern for immediate consumption, neglecting distant consumption, and this leads them to under-save. The difference between these branches lies in the way they model preference for future consumption. Under "hyperbolic discounting", the discount factor falls steeply at first and then flattens out. (Laibson 1997, Imrohoroglu et al 2003, Fehr et al 2008). In the "finite horizon" branch, the discount factor is constant for several periods up to some moving horizon, beyond which it drops abruptly to zero (Feldstein 1985, Docquier 2002, Caliendo and Aadland 2007). In "procrastination" models, hyperbolic discounting is supplemented by a second aspect of preferences: the individual is hopeful (naively) that her own degree of hyperbolic discounting will diminish in the future (O'Donoghue and Rabin, 2001).

A fourth branch of time-inconsistency is "unrealistic optimism" (Weinstein1980, Scheier, Carver and Bridges 1994), also referred to as "overconfidence" (Malmendier and Tate 2005, Caliendo and Huang 2008) in a burgeoning finance literature. In this case, individuals suffer from an optimistic bias when projecting their future budget sets, not their future preferences. This bias can take several forms. Expenses at old age, such as health costs, may be projected to be lower than they are. In the same way, the young may anticipate higher earnings when old than they should. Evidence in favor of unrealistic optimism has been offered by Quadrel et al (1993), Weinstein and Klein (1996), and Puri and Robinson (2007). In Germany the SAVE survey found a large bias in expected lifetime: women aged 35-75 underestimate their life by about five years, while men aged 35-70 do so by about four years (Steffen 2009, fig. 4.6). The model presented below belongs to this branch of time-inconsistency.

Finally let us review the empirical backing for the hypothesis that high earners have a lower bias on average had empirical backing. This backing may be different for each specific model for the bias. As mentioned, Stango and Zinman (2009) use the 1983 Survey of Consumer Finances to measure "exponential growth bias" and find its size is negatively correlated with current earnings. Bhandari and Deaves (2006) use survey evidence for 2,000 Canadian employees to measure a bias defined as the difference between knowledge perception and actual knowledge, and find it is weakly *positively* correlated with current earnings (Table 3). Puri and Robinson (2007) define "extreme optimism" as belonging to the right-most 5% of individuals in the distribution of differences between self-reported life expectancy and that implied by statistical tables. They find that "extreme" optimists have short planning horizons and save less than "moderate optimists", who display prudent financial habits. Unfortunately, they do not report the demographics of extreme optimists.

3. A simple behavioral model for compulsory contributions

We use a model in which individuals are affected by an overconfidence bias, which a benevolent planner tries to correct. In this model individuals can only limit the effects of compulsion by reducing voluntary savings, and also by accruing expensive consumer debt.

3.1 The labor market

The life cycle is collapsed into two separate periods, the active phase and old age. Each period lasts 30 years with active age beginning at age 20, and old age at age 50. Define:

y_a = net earnings in the active phase.
y_p^e = expected net earnings in old age. It is net from health expenses in old age.
$\psi^e \equiv y_p^e / y_a$ = net productivity ratio when old, as expected by the individual in her active phase. To simplify, assume that each individual considers that her estimate is perfectly accurate.

The supply of hours of labor at each age is set institutionally, so it is inelastic to wages. The model focuses on the impact of a behavioral bias. Define:

ψ = productivity ratio when old.
$b \equiv \psi^e - \psi$ = size of the behavioral bias suffered by this particular individual.

If $\psi^e > \psi$, the individual suffers an overconfidence bias. Note that the bias b is defined as a proportion of net earnings in the active phase. If each individual's bias were redefined as an absolute amount, i.e. as the difference between y_p^e and y_p^e, and this absolute bias is assumed to grow with earnings at a less than proportional rate in section 6, the results of that section do not change.

Ageing is represented by $\psi^e < 1$ and $\psi < 1$.

3.2 The contributory old-age pensions system

The compulsory pensions system is described by two formulae: one for benefits and another for the contribution amount. The *average* contribution rate for any given individual is $\theta \equiv C(y_a)/y_a$, where $C(y_a)$ is the contribution amount when reported earnings is y_a.

Other branches of social insurance, such as health insurance and unemployment insurance, usually create an extra tax on covered earnings because the marginal benefit from extra contributions is smaller than the marginal contribution, in expected present value. Define:

$t_a =$ net tax rate on covered earnings levied by other branches social insurance. This tax is net from any marginal benefits supplied directly by those branches to the individual.

Turn now to the pension benefit formula. Define:

$\rho_c =$ internal rate of return paid by the contributory pensions system to each generation of participants. This rate governs the link between individual benefits and contributions.

With two-period lives, the amount of the pension benefit is simply the contribution times the gross rate of return, or $(\theta \cdot y_a)\cdot(1+\rho_c)$. It is assumed that the compulsory pensions system is fully funded. This implies:

(1) $$\rho_c = r \cdot (1-\tau_{PF}) = r_{PF}$$

where r is the pre-tax rate of return paid out in the capital market, and τ_{PF} is the tax rate levied on the capital income of the pension fund (interest, dividends and net capital gains)[5].

3.3 The individual's budget constraint

To obtain each period's budget constraint, define:

F = stock of voluntary financial savings at the end of the active phase.

r = pre-tax rate of interest paid on voluntary (financial) savings ($F>0$).

τ_S = tax rate levied on the return from voluntary saving.

$r(+) \equiv r \cdot (1-\tau_S)$ = after-tax rate of interest paid to voluntary saving deposits ($F>0$).

$r(-) \equiv r(+) + s$ = rate of interest paid on consumer loans ($F<0$). Positive administration and marketing costs imply that $r(-) > r(+)$, being s the net interest spread[6].

Positive administrative and marketing costs in financial intermediation, and a positive interest rate r, guarantee that s is positive. A positive spread creates a kink in the budget constraint that limits the range where perfect substitution between compulsory and voluntary saving applies. Because of the spread $s > 0$, many individuals choose not to use consumer credit to undo mandatory contributions. The period budget constraints perceived when young are:

(2a) $$c_a = y_a \cdot (1-\theta - t_a) - F$$

---

[5] The tax rate τ_{PF} should be interpreted as the sum of the personal income tax rate with the portion of the corporate tax rate that cannot be deducted from personal taxes (Feldstein and Liebman 2002).

[6] The authorities add interest income to the taxable base, but do not allow interest paid in loans to be deducted from the taxable income. In addition, fiscal incentives for voluntary saving for old age channeled through the financial market are not affected in any way by interest paid in consumer loans.

(2b) $c_p = \psi^e \cdot y_a + \theta \cdot y_a \cdot (1 + r_{PF}) + F \cdot [1 + nr(F)]$

where *nr(F) = r(-)* if $F \geq 0$ and *nr(F) = r(+)* if $F < 0$.

The fact that this kink in the budget constraint limits consumer credit and not excessive saving is important for optimal compulsion, because the only planner's mistake that can be repaired by the individual is insufficient compulsory saving, and not excessive compulsory saving.

3.4 Individual optimization in the active phase

The individual maximizes lifetime utility, which is assumed to be additively separable across phases of life. The individual solves the following standard problem (P1) in the active phase:

$$Max_{\{F\}}\ U \equiv u(c_a) + \beta \cdot u(c_p)$$

$$subject\ to$$

$$(A) \qquad c_a = y_a \cdot (1 - t_a - \theta) - F$$

$$(B) \qquad c_p = \psi^e \cdot y_a + \theta \cdot y_a \cdot (1 + r_{PF}) + F \cdot [1 + nr(F)]$$

where $u' > 0$, $u'' < 0$.

The choice of F^* is standard, determined by preferences (discount factor β and intertemporal elasticity of substitution σ), by the spread *s* that governs the net return *nr(F)*, and by the distribution of earnings in the life cycle perceived by the individual, given by her own perceived net old-age earnings ratio ψ^e. However, the planner's unbiased estimate of productivity ratio when old, defined as ψ^p, does *not* influence voluntary saving F^*. This discrepancy is the basis for benevolent policy.

3.6 A Maximum for Taxable Earnings

This section introduces material useful for the subsequent application of the general discussion to the policy that sets the maximum taxable earnings. In all countries identified in Table 1, the contribution formula for active (young) workers is a two-bracket continuous linear rule:

$$(3) \qquad C(y_a) \equiv \begin{cases} \chi_1 \cdot y_a & if\ \ y_a < MTE \\ \chi_1 \cdot MTE + \chi_2 \cdot (y_a - MTE) & if\ \ not \end{cases}$$

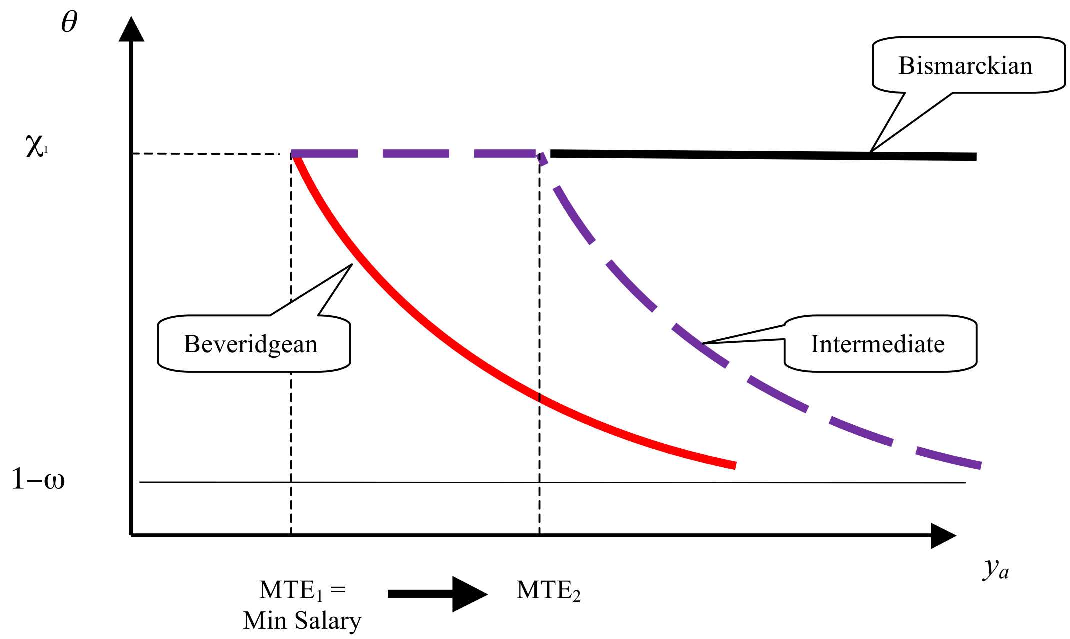
where χ_i is the marginal contribution rate in bracket i, y_a is covered earnings and MTE is the Maximum Taxable Earnings. This is the earnings threshold above which the second marginal contribution rate applies. The evidence given in the Introduction shows that only concave cases where $\chi_1 > \chi_2$ are observed. Let us define as ω the proportion by which the marginal contribution rate is reduced when the threshold MTE is surpassed. Therefore $\chi_2 \equiv (1-\omega) \cdot \chi_1$ with $\omega > 0$. In most countries the marginal contribution is cut by 100% when the threshold MTE is surpassed, so $\omega = 1$, $\chi_2 = 0$ and (3) collapses into $C(y_a) \equiv \chi_1 \cdot Min\ (y_a; MTE)$.

The *average* contribution rate for any given individual is $\theta \equiv C(y_a) / y_a$ or equivalently

$$(4) \qquad \theta(y_a) = \chi_1 \cdot Min\left[1; (1/y_a) \cdot MTE \cdot \omega + (1-\omega)\right]$$

Equation (4) reveals that when covered earnings y_a exceeds the MTE, θ falls as y_a rises. Figure 1 shows how the functional form in (4) spans both the Beveridgean and Bismarckian extremes when the MTE rises from the minimum salary to very high levels (Valdés-Prieto 2002, p. 46).

Figure 1: Changing the MTE moves schemes from Beveridgean to Bismarckian



A finite MTE may also have a number of possible fiscal effects. The next paragraphs identifies most of them –some taken from by Whitman (2009) – and subsequently indicate how further assumptions allow the elimination of that specific fiscal effect.

First, other branches of social insurance, such as health insurance and unemployment insurance, usually create the extra tax t_a on covered earnings, because the marginal benefit from extra contributions is expected to be smaller than the marginal contribution in present value. Fiscal neutrality requires the revenue from t_a to be independent from the contribution rate θ, and therefore from (χ_1,MTE,ω). One requirement for this is that the amount of labor supplied to covered jobs is independent from t_a, which requires labor supply to be inelastic to real wages. For simplicity, we assume that to be the case in this model.

Second, the base for t_a may be subject to its own MTE. This MTE may be shared with the MTE for old old-age contributions, or may be an independent threshold, in the extreme one for each other branch of social insurance. To avoid fiscal interactions, it is assumed here that the MTE for other branches of social insurance is indefinitely large. Therefore, although t_a is applied to y_a in full, the tax revenue from t_a is independent from the MTE for old-age pensions.

Third, the base and rate of non-contributory subsidies for the old must be independent from the contribution rate θ. This assumption is inappropriate when the non-contributory benefit formula withdraws the benefit in response to larger contributory pensions. For this reason, this paper assumes implicitly that non-contributory benefits are either flat (universal) or not available. The second case is appropriate for populations with earnings above the average, which comes close to where the UK's Commission suggests placing the MTE (between the 75th and the 90th percentiles of the earnings distribution). Of course, this second case precludes application of this paper's results to the lower end of the earnings distribution, where subsidies are significant.

Fourth, the degree of pay-as-you-go finance allows the MTE to create a further impact. For example, under pay-as-you-go an increase in the MTE creates a cash surplus, and increases the hidden pension debt during a large number of years. This fiscal consequence could determine the desired level of the MTE, depending on the direction of desirable intergenerational redistribution. To put aside this fiscal rationale for choosing the MTE, it is assumed that the compulsory pensions system is fully funded.

Fifth, consider τ_S, the tax rate on the returns earned by voluntary saving. If fiscal incentives for voluntary old-age saving are generous, τ_S is low relatively to τ_{PF}. In the opposite case where $\tau_{PF} < \tau_S$, the after-tax return earned by the fully-funded compulsory pensions system exceeds the one earned by independent voluntary saving for old age. In this case the MTE would have a further fiscal consequence: it would limit access of high earners to those fiscal incentives. To prevent the MTE from having such fiscal consequences, it is assumed that $\tau_{PF} = \tau_S$.

4. Optimal compulsion in extreme informational scenarios

This and next section show that the planner's choice of optimal compulsion depends critically on the information he possesses about the individual's preferences and opportunities. The planner's optimal contribution rate is identified in three scenarios, which differ by the amount of information the planner has. In all scenarios, the planner is supposed to know t_a, r and τ_S because they are common to all individuals, and to know θ because it is set by himself.

4.1 Optimal compulsion for third-best information

The scenario designated here as "third-best" is the one where the planner has the least information. The planner does not have information about each individual´s personal circumstances, parametrized in section 3 by ψ^e, s, β and σ.

Imagine that the planner suspects that there is a correlation between personalized earnings and each individual's degree of overconfidence b, and of other (as posited by Saint-Paul, 2009). However, this knowledge is useless if personalized earnings y_a are not observed by the authorities. For example, this occurs when employers do not break down reported contributions by worker, say because of the lack of a national identification number, or because of costly or inefficient administration. Thus, in the third-best scenario the planner is ignorant of each individual's degree of overconfidence b.

In such a case the compulsory contribution formula must be uniform. There are two uniform options, and its combinations. One is a flat compulsory contribution amount per employed person (Beveridge), and the other is a single contribution rate that applies to the full payroll (Bismarck).

However, a Beveridgean flat contribution is viable only if the authorities can observe personnel movements and hours hired to each employee. If not, a flat contribution would allow employers to minimize contributions by underreporting the number of employees. Even when the planner observes the number of workers, but there is a minimum number of hours of work that must be met before a worker causes a compulsory contribution, employers can evade by underreporting the number of their employees that work hours above the threshold. It is precisely in the third-best informational setting where the planner is unlikely to have access to information about personnel movements and hours worked by each employee. If the set of employers free to underreport is large enough, the only feasible design is Bismarckian.[7]

There is no scope for a finite MTE either, because lifetime personalized earnings y_a are not observed by the authorities. This immediately establishes the following:

PROPOSITION 1:
With third-best information, the only feasible MTE is indefinitely large, as in the Bismarckian design.

The only remaining issue is how to determine the size of the Birmarckian contribution rate θ. In this scenario the planner may still use surveys, or other means, to determine the joint distribution of the unbiased old-age net earnings ratio ψ in the population and the degree of overconfidence b, together with other personal preferences and circumstances information, which can be summarized in density $h(\psi^e, b, s, \beta, \sigma)$.

A best "one size fits all" contribution rate takes into account that the planner is averse to the risk that insufficient compulsion cuts unbiased welfare. He is also averse to the risk that excessive compulsion reduces welfare, especially below laissez-faire levels, which is a possibility illustrated in section 4.2. The planner's aversion to these outcomes is represented by a constant relative risk aversion function with parameter $\eta \geq 0$. As the coefficient η rises, the planner cares more about the utility losses caused. Consequently, the planner should choose θ by maximizing:

$$(5) \qquad W^u(\theta) \equiv \int \frac{\left[u(c_a) + \beta \cdot u(c_p)\right]^{-\eta}}{1-\eta} \cdot h(\psi^e, b, s, \beta, \sigma) d\psi^e db ds d\beta d\sigma$$
$$subject \;\; to \quad (c_a, c_b) = ArgMax(P1)$$

4.2 Optimal compulsion for first-best information

he "first-best" informational scenario is defined as one where the planner has access to very detailed information about each individual that allows him to estimate very accurately the unbiased net earnings ratio when old or each individual (ψ). Specifically, the planner knows preference parameters such as the utility discount factor β and the elasticity of intertemporal substitution σ, and knows the spread s on each individual's consumer credit (and in a more general model, the return of private investment opportunities). The planner also observes active life earnings, y_a. It will be shown that accurate estimation of the bias b is not important for the first-best scenario.

[7] This informational scenario also has implications for the benefit formula. The authorities have administrative resources that at most allow observation of earnings in the last few years before the pension starts. Only years-of-service formulae based on the last few earnings are feasible, along with flat benefits and. This informational setting is incompatible with an actuarial benefit formula based on lifetime contributions or lifetime earnings.

4.2.a The first-best personalized contribution rate

The benevolent planner solves P1 using his realistic, unbiased estimate for the individuals's productivity ratio when old, ψ^p. The planner seeks to correct the bias by forcing the individual to save what her unbiased self would have liked. Nevertheless, he is aware that the individual can react to the mandate by reducing voluntary savings, which he cannot control.

In this informational scenario, the planner's decision can be modeled as in Valdés-Prieto (2002). The planner maximizes the individual's unbiased welfare, W^u, subject to her budget constraint and to her response in terms of voluntary saving (the solution to P1). The planner solves the following problem (P2), separately for each individual:

$$Max_{\{\theta\}} \quad W^u(\theta) \equiv u(c_a) + \beta \cdot u(c_p) \qquad where$$
$$(A) \qquad c_a = y_a \cdot (1 - t_a - \theta) - F^{biased}$$
$$(B) \qquad c_p = \psi^p \cdot y_a + \theta \cdot y_a \cdot (1 + r_{PF}) + F^{biased} \cdot [1 + nr(F^{biased})]$$
$$(C) \qquad F^{biased} = Arg\ Max_{\{F\}} \left\{ u(c_a^{biased}) + \beta \cdot u(c_p^{biased}) \right\}$$
$$subject\ to$$
$$(C1) \qquad c_a^{biased} = y_a \cdot (1 - t_a - \theta) - F$$
$$(C2) \qquad c_p^{biased} = \psi^e \cdot y_a + \theta \cdot y_a \cdot (1 + r_{PF}) + F \cdot [1 + nr(F)]$$

Note that lines (B) and (C2) use different assessments for the net productivity ratio when old. The planner's unbiased ψ^e in (B) reflects the ability of the authority to exactly predict earnings when old. In contrast, (C2) uses the biased ratio ψ^e $(\equiv \psi^p + b)$ because the individual chooses voluntary saving by relying on her own (biased) assessment of net productivity ratio when old. b is a ratio, hence may be called a "proportional" bias. Note that b is predicted with full accuracy in (P2).

From (B) and (C2) and from $F = F^{biased}$ from (C) it follows that:

(6) $\quad c_p^{biased} - c_p = \left(\psi^e - \psi^p\right) y_a \equiv b \cdot y_a$ Thus, if $b > 0$, then $c_p < c_p^{biased}$.

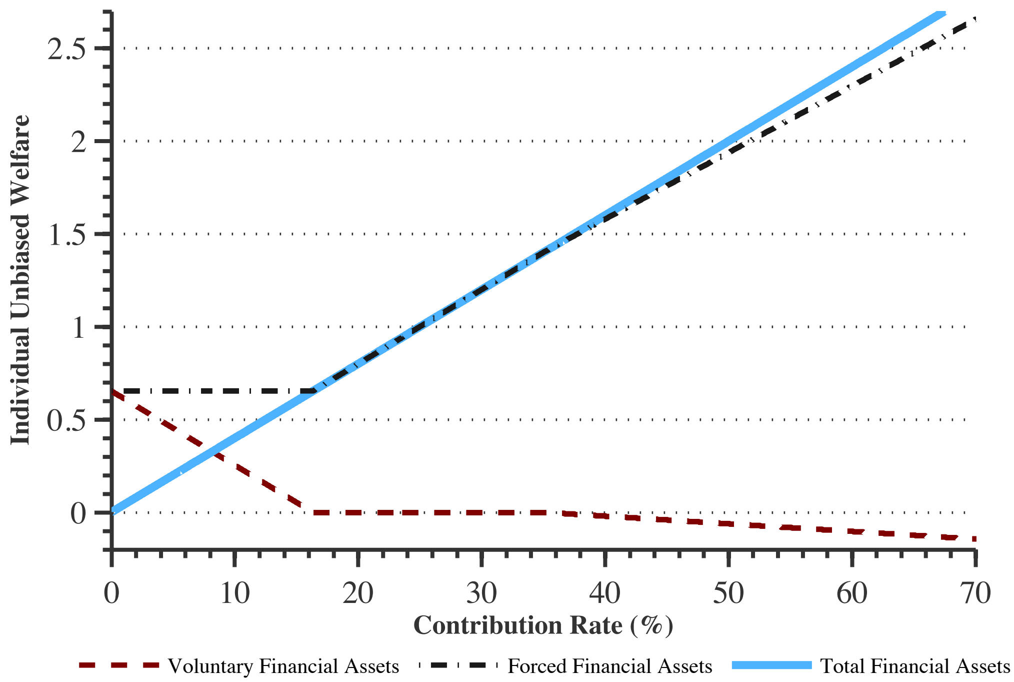
This confirms that an overconfident individual plans to consume more when old than she will actually consume[8]. The planner predicts this surprise and adjusts θ to help the improvident. Figure 1 describes the planner's problem in the first-best scenario, by reporting the amount of voluntary saving chosen by an individual, as a function of the compulsory contribution rate θ. The figure is obtained with the parameter assumptions in the Appendix, for a specific value of the bias b of 0.20 (old age earnings is over predicted by 20% of active age earninsg).

Figure 2 shows that at low contribution rates, voluntary saving is substituted perfectly for mandatory saving. This is a standard result, because in this model, the link between contributions and benefits is the same in both types of saving ($\tau_{PF} = \tau_S$ and full funding of compulsory savings, as assumed in section 3.6). In this illustration, voluntary assets fall to zero when the contribution rate comes close to 16%. For higher contributions rates, total saving rises.

[8] In a simple two-period life model, this negative income shock is perceived just at the end of her active phase. However, with a more realistic number of periods, the shock would be spread out over different ages.

For contribution rates above a number close to 36% in the illustration, total saving rises more slowly, because the individual chooses to leave the corner with $F = 0$ and takes some consumer

Figure 2: Voluntary, Compulsory and Total Saving in response to θ, first-best



credit, which carries the obligation to pay the spread s. Since this spread reduces wealth, substitution between compulsory saving and consumer debt is imperfect. Although this simulation assumes that the spread s is merely 10% per annum (it is much larger in many emerging countries), it still creates a very wide range of contribution rates where voluntary saving is zero. In this illustration this range is about 20 percentage points wide.

4.2.b How the bias affects the first-best amount of compulsion

This subsection comes back to the rationale for a MTE. The hypothesis analyzed is that the optimal amount of compulsion for an individual becomes smaller as the estimated bias b decreases (Gill et al 2005, Saint-Paul 2009).

As shown by (P2), the planner needs to estimate each individual's bias. Assume that the planner does observe a number of individual attributes, say because a personal identification number for workers allows employers to report personalized contributions and administration of personalized records is efficient enough. The planner may invest in surveys to to estimate the relationship between each individual's degree of overconfidence (the bias b) and her earnings y_a and other attributes z_a such as age, gender, residence area, type of job, etc.. Through this method or others, the planner comes to learn the following relation that predicts each individual's bias:

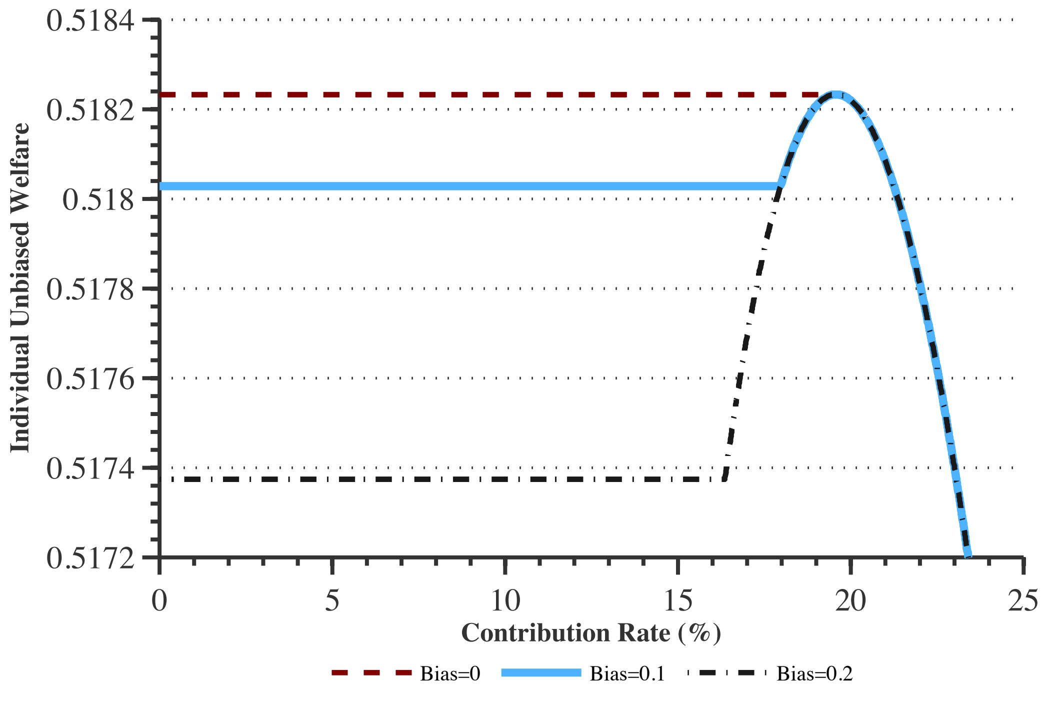
(7) $$b = B(y_a, z_a) + \varepsilon \quad ; \quad Var(\varepsilon) > 0; \quad E(\varepsilon) = 0.$$

where b is the actual bias and $B(y_a,z_a)$ is the predicted bias for an individual with earnings y_a and other attributes z_a.[9] The error term ε summarizes the impact of variation across individuals in $(\psi^e, s, \beta, \sigma)$ within the subset that shares a common set of observable variables (y_a,z_a), and $Var(\varepsilon)$ measures one aspect of the planner's ignorance.

The case of zero variance for ε is analyzed first. Figure 3 shows unbiased individual welfare for different levels of the actual and predicted bias (these coincide for $Var(\varepsilon) = 0$, as shown by (7)). For a zero bias ($b = 0$, $Var(\varepsilon) = 0$), the level of unbiased welfare is represented by the higher dashed lines. In this case compulsion is irrelevant as long as the contribution rate θ is below the voluntary saving rate in the absence of compulsion. In the case of zero bias, the first-best amount of compulsion is not unique, because there is perfect substitution between voluntary and compulsory saving in the fiscally neutral setting analyzed in this paper. In this case it is incorrect to assert that the *only* best policy is no compulsion ($\theta^* = 0$).[10]

For a positive bias ($b > 0$), and $Var(\varepsilon) = 0$, Figure 3 shows that a well-chosen compulsory rate raises unbiased welfare above the level attained in laissez-faire, which is the level attained when the compulsory contribution rate is zero. It also shows that when the compulsory contribution becomes large enough, the individual is forced to save "too much" in the sense that her unbiased welfare falls steeply. Since unbiased welfare can fall below the laissez-faire level, the range of contribution rates in which benevolent first-best social insurance is justified is finite.[11]

Figure 3: Unbiased Welfare versus contribution rate for different actual biases



[9] Saint-Paul (2009) suggests that $\partial B/\partial y_a < 0$.
[10] The same result obtains for cases with $b < 0$ (unjustified pessimism, leading to oversaving). Since compulsory saving is unable to help the individual, these cases are represented in Figure 3 by the line for $b = 0$. She chooses some point in the right-hand side of the curve. Her unbiased welfare falls as her degree of pessimism rises.
[11] For very large contribution rates, where the individual responds by issuing consumer debt, the negative wealth effect caused by the cost of spread s creates a kink in the curve in Figure 3, in the rightmost range.

Three lessons follow from figure 3. First, compulsion does not improve unbiased welfare if the contribution rate is small enough, due to perfect substitution of compulsory for voluntary actions. Second, the size of the actual bias affects the size of the smallest contribution rate at which unbiased welfare can be improved by compulsion. This "smallest effective contribution rate" is inversely proportional to the actual degree of overconfidence *b*, because the size of actual *b* or ψ^e influences *the individual's* decision. Third, for contribution rates above the "smallest effective contribution rate", the size of the actual bias *does not* influence the individual's decision (the amount of voluntary saving F^*), because it is already at the corner, and thus is fixed (at zero in this model).

However, and critical for this paper's results, optimal compulsion θ is independent from the size of the actual bias. Figure 3 shows clearly that the size of the actual bias *b* does not affect *the planner's* decision in this informational scenario. It follows that the predicted bias *B*, and thus (y_a, z_a) are irrelevant for policy. The intuition is that the planner's optimal compulsion is always equal to the voluntary saving rate in the absence of bias, regardless of the size of the actual bias.

Of course, this result obtains only because the planner never errs in determining the individual's optimal total saving in the absence of bias. This requires first-best information, i.e. planner knowledge of each individual's true (ψ, s, β, σ).

These results extend also to the general case with projection error, $Var(\varepsilon) > 0$. In this case the three cases shown in Figure 3 can be interpreted as consequences of three different values for ε. Since the optimal θ is the same for all values for ε, and the planner maximizes a weighted average of the unbiased individual welfares that result for each value for ε, it follows that the optimal θ is the same for any distribution of ε. One corollary is that the size of *error ε, and of* $Var(\varepsilon)$ are irrelevant for policy, i.e. for the optimal θ. Again, this result obtains because the planner does not err when determining the individual's optimal total saving in the absence of bias.

Coming back to the MTE, is there any consequence for the optimal size of the MTE? According to definition (4), a given goal for the personalized θ can be achieved with a set of permutations of the parameters (χ_1, ω, MTE). This suggests that any finite MTE is equally acceptable, since the optimal θ can be reached by adjusting (χ_1, ω). However, if there are constraints on parameters (χ_1, ω), imposition of a finite MTE might be an obstacle to efficient choice of the personalized contribution rate by the planner, in response to different (ψ, s, β, σ). To avoid this potential obstacle, the MTE should be indefinitely large. Summarizing,

PROPOSITION 2:
With first-best information regarding optimal actions, and in the absence of fiscal consequences,
a) The hypothesis that the optimal amount of compulsion for an individual is smaller when her actual or predicted bias is smaller, is false.
b) The optimal personalized contribution rate is independent from each individual's bias, and errors in estimating these biases are irrelevant for policy.
c)The optimal MTE is indefinitely large, as in the Bismarckian design.

Thus, the Bismarckian design is best under both first-best and third-best information.

5. Optimal compulsion for intermediate informational scenarios

The "second-best" informational scenario is defined here by an intermediate degree of information asymmetry faced by the planner regarding his unbiased estimate of the bias-free saving rate, determined at least by the net earnings ratio when old for each individual (ψ). His informational resources do not allow him to know exactly the values of *(ψ, s, β, σ)* for each individual, To model this realistic case, define:

$$(8) \qquad \psi = \psi^{p}(y_a, z_a) + \delta \quad ; \quad Var(\delta) > 0; \quad E(\delta) = 0.$$

where ψ is the *actual* old-age net earnings ratio, ψ^p is the old-age net earnings ratio *predicted* by the planner using the information available and δ is the planner's error in predicting the old-age net earnings ratio.

Since the planner also predicts the bias b with error (recall equation (7)), the issue to be explored is how optimal policy varies in response to different values of the two types of planner mistakes, measured by *Var(δ)* and *Var(ε)*.

5.1 The second-best contribution rate for *Var(ε)* = 0.

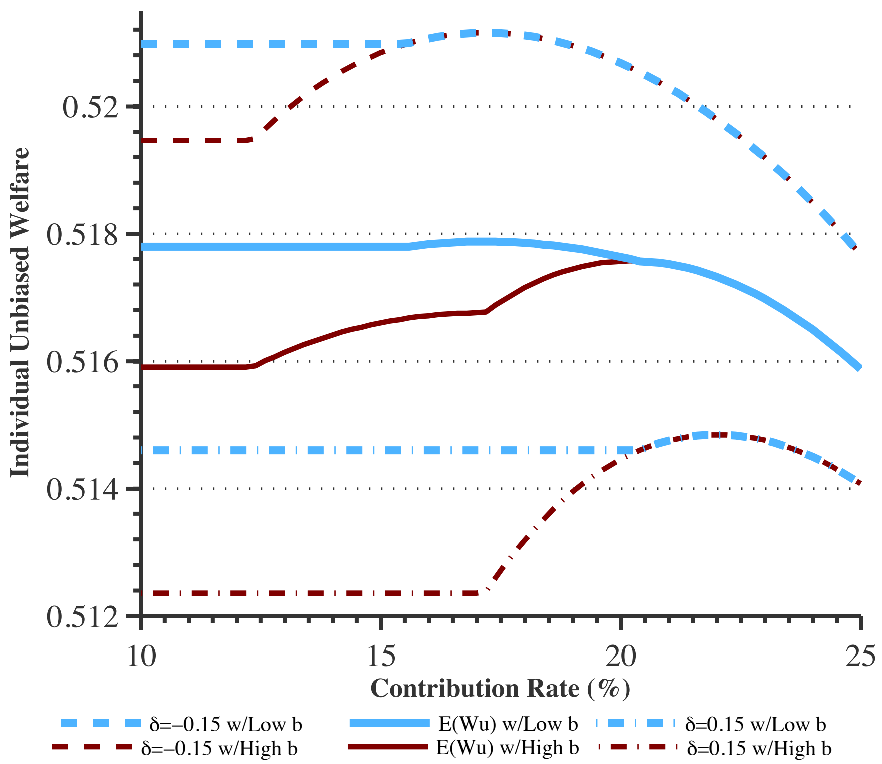
In this informational scenario, the planner faces significant uncertainty about the value of the individual's old-age net earnings ratio, but predicts her bias accurately.

A positive error δ > 0 leads the planner to underpredict net earnings in old age (note $\psi^{p} = \psi - \delta$), and in turn overpredict the voluntary savings F^* desired by the individual for old age. Therefore, for δ > 0 the naive planner would impose a compulsory contribution rate θ that is above her optimum. Conversely, a negative error δ < 0 leads the planner to impose a contribution rate that is lower than optimal.

Figure 4 illustrates the case where δ follows a bimodal distribution, with values 0.15 or -0.15 with probability 0.5. The planner predicts a central value for ψ equal to 0.6, but knows the actual value could be either 0.75 or 0.45. Lighter lines show the case for low bias (b = 0.1), whereas the darker lines show higher bias (b = 0.3). In this case the planner makes no mistake when predicting the bias. The higher dashed lines represent the lifetime welfare the individual would face when the planner underpredicts ψ; similarly, the dash-dotted lines represent the individual lifetime welfare when the planner overpredicts ψ. The middle lines show expected welfare as seen by the planner. He simply averages the vertical values of welfare, for each value of θ. In the Bernoulli distribution depicted, expected welfare for low values of θ is simply welfare for the high value of the old-age earnings ratio multiplied by 0.5 plus a constant. This constant reflects the fact that in response to low contributions, the individual with low old-age earnings ratio raises her voluntary savings to achieve the same total amount of savings, and the same welfare, that would have prevailed under laissez-faire.

When the bias b is known to be small, the mistakes made by the planner when predicting ψ have asymmetric impacts: an excessive contribution rate imposes higher expected costs than an insufficient one. An excessive contribution rate leads to oversaving, because given the costly spread *s,* the individual prefers not to adjust by issuing consumer debt. Thus, excessive compulsory contributions reduce welfare. On the other side, because the bias *b* is small, the amount of total saving is close to optimal. Therefore, it is best for the planner to err from below than from above, when setting the contribution rate for a low-bias individual. This is clear in figure 4, in the light lines corresponding to low bias. It can be seen that the planner would impose considerable damage by setting a high contribution rate (above 17.5% in the figure) if he had underpredicted ψ, whereas the individual would be little affected by a low contribution rate if the planner had overpredicted ψ. The highest expected welfare seen by the planner is reached at a relatively low contribution rate. Indeed, it is reached exactly at the same contribution rate that would have prevailed if the planner *had known accurately* the net earnings ratio in old age of the low-bias individual and had ignored the case of high net earnings ratio.

Figure 4: Optimal policy based on low-bias individuals' corrections to the planner's mistakes
(Welfare and expected welfare when δ is bimodal and the bias varies)



Now check the case where the bias *b* is large in Figure 4. Again, an excessive contribution rate leads to oversaving, because of the costly spread *s*. Also again, an insufficient contribution rate permits the individual to adjust total savings by adding voluntary saving. However, as individuals only add voluntary saving to make total savings coherent with their biased preferences, for highly biased individuals that have low age-earnings ratios, total savings remain well below optimal (in figure 4, the line for an age-earnings ratio of 0.45 and high bias finishes its flat portion at a contribution rate of only 17%). Therefore, the planner faces comparable costs from oversaving and undersaving, as shown by the expected welfare line for the low bias case. The optimizing planner reacts to this by choosing a relatively higher contribution rate (about 20.5% in figure 4) when the bias is high.

Summarizing, for *Var(ε)* = 0 and *Var(δ)* > 0, a higher bias *b* leads the planner to raise the compulsory contribution rate θ. This is not because the planner thinks that a higher bias warrants more compulsion on a benevolent basis, as in Saint-Paul (2009). The argument is more nuanced: it is the planner's response to the fact that a more biased individual is less able to *cover up the planner's mistakes* when he errs in providing sufficient amount of compulsion. The result evaporates if the net earnings ratio for old age is known accurately (figure 3), showing that the targeting argument is wrong.

Further analysis of figure 4 shows that for bimodal distributions of the age-earnings ratio in old age, the expected welfare for the planner has two local maxima for intermediate levels of the bias, indicating a non-convex region and a discrete jump in θ* in response to certain changes in the predicted bias. This implies that some first derivatives of this function may not exist.

To check the argument, we simulated problem P3 presented in section 5.2 below, simplified to insure that *Var(ε)* = 0. In contrast to the Bernoulli distribution depicted in figure 4, we generated 200 values for *δ* taken from a uniform distribution. We then created 200 identical individuals differing only in their assigned *δ*, and optimized θ for several known values for the bias *b*. To avoid results from being influenced by the particular sample of *δ*, we repeated this experiment 100 times for each value of bias *b*, and averaged the optimal θs [12]. An important result (not shown) is that expected welfare has a single local optimum for θ in this stochastic setting, for all values of *b* and *Var(δ)*. This result suggests that unless the distribution of δ exhibits abrupt jumps, as for figure 4, non-convex regions do not exist and standard comparative statics can be applied.

Table 2 presents the results of these simulations and report how the optimal contribution rate varies with the bias *b,* for scenarios that differ in the size of *Var(δ)*.

Table No. 2 : Optimal compulsory contribution as function of a bias that is accurately predicted

(*Var(ε)* = 0; The planner's prediction about the old-age net earnings ratio is ψ^P = 0.60 and the error in this prediction is δ ~ U(–D,D) with variance is $D^2/3$)

Predicted bias B (=b, Var(ε) = 0)	Optimal θ	
	$Var(\delta) = (0.1)^2/3$	$Var(\delta) = (0.2)^2/3$
0.001	0.1800	0.1632
0.05	0.1883	0.1707
0.10	0.1967	0.1818
0.15	0.1968	0.1933
0.20	0.1968	0.1995
0.25	0.1968	0.1995
0.30	0.1968	0.1995
0.40	0.1968	0.1995

Source: Authors' simulations based on P3 and parameters in the Appendix.

Table 2 reveals that optimal compulsion indeed rises with the bias. This is because the planner takes advantage of the fact that the less biased individual does better in covering up his

[12] For consistency, we used the same *δ* error matrix generated when computing optimal θ for other values of bias *b*.

mistakes. Table 2 shows also that when the planner is more uncertain about his own knowledge about the optimal action, he chooses to start compulsion at a substantially smaller level. However, optimal compulsion for large biases is slightly larger when uncertainty about the optimal action is slightly larger.[13]

Sensitivity analysis was performed for two other levels of the old-age net earnings ratio, ψ^p = 0.50 and ψ^p = 0.70. The qualitative results are the same as in Table 2. Of course, as expected the whole schedule of optimal contribution rates rises for ψ^p = 0.50 and falls for ψ^p = 0.70. This shift occurs because a lower old-age net earnings ratio increases the optimal saving rate. Moreover, the size of this shift is substantial. For example, for a predicted bias of 0.20 and $Var(\delta) = (0.1)^2/3$, an increase in ψ^p from 0.50 to 0.60 and then to 0.70 cuts the optimal contribution rate from 0.2129 to 0.1968 and then to 0.1806 for a total of 3.23 percentage points. Other simulations find that the results in Table 2 are insensitive to inequality aversion (η).

5.2 The second-best contribution rate for $Var(\varepsilon) > 0$.

In this most realistic among informational scenarios, the planner predicts each individual's optimal action with error, and also predicts each individual's bias with error. This paper assumes that these errors are independent.

The basic elements of section 5.1 apply here. On its own, a positive error $\delta > 0$ in predicting the individual's old-age net earnings leads the planner to impose a contribution rate θ that is below the optimum for her, and a negative error $\delta < 0$ leads to impose excessive contributions. The additional element to take into account is that the size of the predicted bias B may be mediated by the variance of the planner's error in projecting the bias, $Var(\varepsilon)$.

Consider first the case where the level of the predicted bias B is small. Recall from section 5.1 that for low $Var(\varepsilon)$ the planner's mistakes have asymmetric impacts on the individual's welfare, and the optimizing planner reacts to that asymmetry by reducing the contribution rate. However, as $Var(\varepsilon)$ grows:

i-. It is more likely that the actual bias is significantly larger than the predicted bias (a large positive ε applies). The highly biased individual fails to compensate an insufficient contribution rate with a higher amount of voluntary saving. Therefore, the cost for the planner of his prediction error regarding the old-age net earnings ratio is substantial if $\delta > 0$, maybe as substantial as if $\delta < 0$. The asymmetry in welfare costs of raising compulsory θ is smaller than with $Var(\varepsilon) = 0$.

ii-. It is also more likely that the actual bias is significantly smaller than the predicted bias (a large negative ε applies). Since the predicted bias B is small, a large negative ε implies that the individual is likely to suffer unjustified *pessimism* ($b < 0$), which leads to oversaving. However, compulsory saving is unable to help this individual. Therefore, the sign of the

[13] The sensitivity of optimal compulsion to increases in the bias varies. For small errors about the optimal action (for smaller $Var(\delta)$), the sensitivity is initially large and falls rapidly. In contrast, for larger errors about the optimal action, this sensitivity rises initially and only falls after the bias surpasses 0.15 in this illustration. In all cases, the influence of the bias on the optimal contribution tapers off as the bias exceeds 0.30. This indicates that the asymmetry of the impact of a mistake by the planner becomes almost constant for large biases.

planner's mistake in predicting her old-age net earnings ratio does not affect her welfare loss, because she always compensates by adjusting her voluntary saving to reach the same desired level of oversaving. Thus, there is no further cost for the planner' in raising compulsory θ. Again, the asymmetry in welfare costs is smaller than with $Var(\varepsilon) = 0$.

Summing up, when the level of the predicted bias B is small, the degree of symmetry faced by the planner, in the costs of raising compulsory θ, rises as $Var(\varepsilon)$ grows. Therefore he raises θ when $Var(\varepsilon)$ grows.

Now consider the case where the predicted bias B is large. Recall that in this case and for low $Var(\varepsilon)$, the planner's mistakes have symmetric impacts on the individual's welfare, and the planner reacts to this symmetry by avoiding cuts to the contribution rate. As $Var(\varepsilon)$ grows:

i.- It is more likely that the actual bias is significantly larger than the predicted bias. Again, the highly biased individual fails to compensate the planner's mistake. The asymmetry in welfare costs remains modest.

ii.- It is also more likely that the actual bias is significantly smaller than the predicted bias. However, since the predicted bias B is now large, the large negative ε is still compatible with substantial unjustified *optimism* ($b > 0$), and with undersaving. Compulsory saving does help this individual. However, she is unable to compensate undercompulsion by the planner. Since her unbiased self also suffers if the planner imposes excessive contributions, the asymmetry in welfare costs remains modest.

Summing up, when the predicted bias B is large, the planner faces a degree of symmetry that is similar to the case where the bias is predicted accurately. In other words, the size of $Var(\varepsilon)$ matters little when the predicted bias B is large.

Putting all together, the optimizing planner reacts to a larger prediction error for the bias (higher $Var(\varepsilon)$) by reducing his response to the size of the predicted bias B. As $Var(\varepsilon)$ grows, the contribution rate imposed on high earners should grow to be same as imposed on low earners.

5.3 Analytical framework

The discussion in sections 5.1 and 5.2 can be formalized with the following analytical framework: The planner solves problem P3 below, where $d(\delta)$ and $e(\varepsilon)$ are two error density distributions:

$$\underset{\{\theta / y_a, z_a\}}{Max} \quad W^u(\theta) \equiv \iint \frac{\left[u(c_a) + \beta \cdot u(c_p)\right]^{1-\eta}}{1-\eta} d(\delta) e(\varepsilon) d\delta d\varepsilon \qquad \textit{where}$$

$$(A) \qquad c_a = y_a \cdot (1 - t_a - \theta) - F^{biased}$$

$$(B) \qquad c_p = (\psi^p(y_a, z_a) + \delta) \cdot y_a + \theta \cdot y_a \cdot (1 + r_{PF}) + F^{biased} \cdot [1 + nr(F^{biased})]$$

$$(C) \qquad F^{biased} = Arg \underset{\{F\}}{Max} \left\{ u(c_a^{biased}) + \beta \cdot u(c_p^{biased}) \right\}$$

subject to

$$(C1) \qquad c_a^{biased} = y_a \cdot (1 - t_a - \theta) - F$$

$$(C2) \qquad c_p^{biased} = (\psi^p(y_a, z_a) + \delta + B(y_a, z_a) + \varepsilon) \cdot y_a + \theta \cdot y_a \cdot (1 + r_{PF}) + F \cdot [1 + nr(F)]$$

When the planner predicts the bias with no error, density *e(ε)* collapses into a single mass point and the problem faced in section 5.1 is recovered. When the planner predicts the true old-age earnings ratio accurately, density *d(δ)* collapses into a single mass point. If both errors disappear, the first-best informational scenario is recovered (section 4.2). In the other direction, when the planner and predicts neither the optimal action nor the bias, the third-best informational scenario is recovered (section 4.1).

Table 3 uses simulations to solve P3 numerically, to determine how the optimal contribution rate changes with the level of the predicted bias *B* in scenarios where the bias error ε has positive variance, as opposed to the scenarios where its variance is zero, as in Table 2. Simulations are conducted the same way as in Table 2: for both δ and ε, we create 200 random values from a uniform distribution. Robustness of the optimal contribution rate to the prediction error for the optimal action *Var(δ)* is reported too.

Table No. 3 : Optimal compulsory contribution and the predicted bias, for positive *Var(ε)*

(The two prediction errors made by the planner are assumed to distribute uniform and independently. For the bias, ε ~ U(–0.15,0.15) and for the true old-age earnings ratio, δ ~U(–D,D) with D = 0.1 and 0.2; The planner's prediction about the old-age earnings ratio is $\psi^p = 0.60$)

Predicted bias B *Var(ε)*=$(0.15)^2/3$	Optimal θ	
	Var(δ) = $(0.1)^2/3$	*Var(δ)* = $(0.2)^2/3$
0.001	0.1927	0.1775
0.05	0.1940	0.1828
0.10	0.1948	0.1900
0.15	0.1958	0.1945
0.20	0.1965	0.1971
0.25	0.1968	0.1987
0.30	0.1968	0.1994
0.40	0.1968	0.1995

Source: Authors' simulations based on parameters in Appendix.

Table 3 reveals that in the presence of planner errors about the bias, optimal compulsion also rises with the predicted bias.[14] However, the level of optimal compulsion starts higher than in Table 2, where the bias was predicted with full accuracy. In this case the planner is uncertain of the degree of bias each individual faces, so he prefers to mandate a higher contribution rate in case the individual has a higher bias than predicted. This is so because the effect of a mistake on the optimal contribution rate is not symmetric, since it creates a larger cost for the more biased individual. Here, the optimal contribution rate is not centered on the median individual, but shifts to a more biased individual. Finally, the sensitivity of the optimal contribution rate to the predicted bias first rises and then falls, as the predicted bias rises. This remains true for all values of the prediction error about the optimal action, $Var(\delta)$. Again, for large predicted biases, the errors in predicting the bias do not influence optimal compulsion.[15]

By comparing Tables 2 and 3, it can also be seen that for a given level of $Var(\delta)$, a higher $Var(\varepsilon)$ raises the optimal contribution rate when the level of the predicted bias is low. This confirms the reasoning presented in section 5.2. For the reason s explained there, the increase is almost nil for a high level of the predicted bias. Still, Table 3 reveals additional subtleties, such as the existence of a range of intermediate values for the predicted bias in which an increase in $Var(\varepsilon)$ reduces slightly the optimal contribution rate.

The results of section 5 are summarized as follows:

PROPOSITION 3: *In second-best informational scenarios where each individual's bias and true old-age earnings ratio are predicted with error, and in the absence of fiscal consequences,*

a) The hypothesis that the optimal amount of compulsion is smaller for individuals for whom the planner predicts a smaller bias B is correct, if the precision in predicting each individual's old-age earnings ratio is held constant.

b) For low-predicted-bias individuals, the optimal amount of compulsion falls as the precision in predicting each individual's old-age earnings ratio rises, holding each individual's predicted bias constant.

Proof: Simulations of P3, summarized in Tables 2 and 3 and sensitivity analyses.

Proposition 3 says that for a planner with intermediate informational resources, the optimal contribution rate θ can depend on the predicted bias B. This is in contrast to optimal policy for planners with extreme informational resources. However, this dependence is significant only for large $Var(\delta)$ and low $Var(\varepsilon)$. Otherwise, this dependence is slight or irrelevant for policy.

Another lesson from the analytical framework is that optimal compulsion for an individual depends on the levels for that individual of the predictor variables used by the planner, denoted (y_a, z_a). This dependence occurs through the prediction rules in equations (7) and (8). There can be conflicting influences. For example, if in a given population higher earnings on average reduces old-age net earnings (say, through earlier retirement not compensated by higher salary) and also reduces the bias, optimal compulsion rises on the first count and falls on the second, with an ambiguous net result. This is the basis for next section's results.

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[14] Expected welfare also has a single local optimum for θ, for all values of b, $Var(\delta)$ and η considered.

[15] Sensitivity analysis for $\psi^p = 0.50$ and $\psi^p = 0.70$, preserve the qualitative results of Table 3. The results are also insensitive to inequality aversion (η).

6. An application: the optimal Maximum on Taxable Earnings

As explained in the *Introduction*, an important standing issue in pension economics is whether the optimal contribution rate θ for each individual should be reduced if her level of current earnings surpasses a finite threshold (this threshold is the "maximum taxable earnings" or MTE). Specifically, is it likely that optimal policy includes a finite MTE and a positive ω, as defined in section 3.6?

The answer resides in the link between the optimal contribution rate θ defined by problem P3, and current taxable earnings y_a. According to problem P3, this link relies on two functions, $\psi^p(y_a,z_a)$ and $B(y_a,z_a)$. Recall that the first function connects the predicted net earnings ratio when old (ψ^p) – which is the determinant of the bias-free saving rate or optimal action which we focus on - with current earnings y_a and other observables z_a such as gender, education, age, employment status, health, homeownership, industry, occupation (including self-employment), etc. The second function connects the predicted bias (B) with the same observables.

Assume that a State's informational resources allow it to observe several of the z_a. Assume also that at least one of the observed z_a has a non-zero impact on the predicted net earnings ratio when old or on the predicted bias ($\psi^p{}_{2k} \neq 0$ or $B_{2k} \neq 0$ for at least one attribute k). Then, it is not optimal policy to set a triplet (MTE, ω, χ_1), because it is based on current earnings alone. The triplet ignores the other determinants z_a , so it has lower predictive ability than what is feasible at no extra cost. Under optimal policy, the individual's contribution rate depends on all observable socio-demographic attributes that have an impact on the predicted net earnings ratio when old and on the predicted bias. This is not a mere theoretical possibility, at least in the case of the predicted bias B. Stango and Zinman (2009, Table IV) find that the size of "exponential growth bias" is strongly and significantly influenced by gender and education, after controlling for the impact of the current wage quintile.[16]

Of course, anti-discrimination jurisprudence or legislation is likely to preclude a State from conditioning the compulsory contribution rate for old age on some of the k attributes with impact, such as gender. However, conditioning on other attributes such as occupational sector is common, and conditioning on educational attainment may be less constrained if adequately supported. Thus, the concept of a MTE is almost surely suboptimal for a State with modern informational resources.

This result has several policy implications. First, the Beveridgian and Bismarckian designs and all intermediate levels for the MTE are obsolete for a modern State. Second, further complexities appear, especially with educational attainment. For example, in societies undergoing long-run economic growth based on education, the link between educational attainment (one of the z_a) and the predicted bias B, on the one hand, and the optimal action as proxied by the predicted net earnings ratio when old (ψ^p), on the other, has different implications depending on the sign of these links. If more education increases the bias B, as occurs for the bias measured with Canadian data by Bhandari and Deaves (2006), and the

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[16] Other controls such as employment status, health, homeownership, industry and occupation (including self-employment) may also be significant, but the authors did not publish the coefficients for them.

predicted net earnings ratio when old (ψ^p) is not affected by education, then the MTE should rise over time as absolute educational levels rise. However, if more education reduces the bias, as for the bias measured by Stango and Zinman (2009), the MTE should fall over time. Similar options appear when taking into account the impact of education on the predicted net earnings ratio when old (ψ^p).

An informationally constrained State

Now consider the case of a State whose informational resources are limited to observe current earnings y_a alone, while all the z_a are unobservable. Although historical evidence shows that many societies condition the contribution rate on the occupational sector, this informational situation may be realistic within an occupational sector.[17] The question is whether the optimal link between the contribution rate and current taxable earnings has a functional form that can be adjusted to be close enough to the one imposed by the MTE approach. Note that y_a could be expressed by the individual's percentile position in the earnings distribution.

The answer is not obvious because equation (4) in section 3.6 shows that the MTE approach imposes a very specific functional form on this link. As summarized in section 3.6, the MTE approach simply applies a constant contribution rate ($\theta'(y_a) = 0$) to earners below the MTE, and a falling contribution rate for high earners, as depicted in Figure 1:

(9) $\theta'(y_a) = \chi_1 \cdot MTE \cdot (-1/y_a^2) \cdot \omega < 0$ for $y_a >$ MTE.

How does the MTE approach or schedule compare with the optimal schedule? To answer, let us define the solution $\hat{\theta}$ to problem P3 as a function of earnings y_a in this case as $\hat{\theta} \equiv \theta(\psi^p(y_a), B(y_a))$. This implies that in differentiable regions:

(10) $\hat{\theta}'(y_a) \equiv \theta_1 \cdot \psi_1^p + \theta_2 \cdot B_1$.

Table 3 shows that the optimal θ rises when the predicted bias (*B*) rises, but does so asymptotically until a fixed value is reached. Thus, $\theta_2 \geq 0$ and is closer to zero for high levels of the bias B. The sensitivity analysis for Table 3 also showed that the optimal contribution rate θ falls unambiguously when the predicted net earnings ratio when old (ψ^p) rises, so $\theta_1 < 0$. Assume also that $B_1 \leq 0$, as in the evidence by Stango and Zinman (2009), where the higher earnings quintile has a lower bias B but the bias remains flat as earnings changes across the other quintiles. This implies:

(11) $sign\{\hat{\theta}'(y_a)\} = (-) \cdot (\psi_1^p) + (0 \to +) \cdot (0 \to -) \ = ?$

There is potential for a substantial difference between the signs in equations (11) and (9), where the latter follows from the MTE approach. Concretely, the optimal contribution rate may rise

[17] Similar results obtain for a much more unusual case, where the State does observe some of the z_a but the only socio-demographic attribute that has an impact on the predicted net earnings ratio and the predicted bias is current earnings y_a , so that ($\psi^p_{2k} = 0$ and $B_{2k} = 0$ for all *k* attributes z_a.

with taxable earnings, which is not allowed by the MTE approach. This increase can happen if high earnings are correlated with smaller net earnings when old (say, due to a wealth effect causing earlier retirement and lower earnings in the second phase of life). Combined with the fact that smaller net earnings in old age necessitate a higher saving rate, this yields a larger optimal compulsory contribution rate for high earners, *ceteris paribus*. In other words, $\psi^p{}_1 < 0$ if the wealth effect of earnings on the retirement age dominates the substitution effect. Of course, this effect may or may not be compensated by the effect of higher earnings on the predicted bias B, compounded by the impact of the predicted bias on the optimal contribution rate. The point is that the overall sign is uncertain from general principles and depends on empirical detail.

The MTE approach also imposes a specific *curvature* on the link between the optimal contribution rate θ and earnings y_a. Indeed, equation (4) implies that for y_a < MTE, $\theta''(y_a) = 0$, and that for y_a > MTE: curvature is:

$$(12) \qquad \theta''(y_a) = 2/(y_a)^3 \cdot \chi_1 \cdot \omega \cdot MTE \qquad > 0 \,.$$

In contrast, in the optimal schedule, curvature is set by:

$$(13) \qquad \hat{\theta}'' \equiv \theta_{11}(\psi_1^p)^2 + \theta_1\psi_{11}^p + 2\theta_{12}\psi_1^p B_1 + \theta_{22}(B_1)^2 + \theta_2 B_{11}$$

The sign of (13) is not fixed and may vary. Since optimal policy does not impose a specific curvature, constraint (12) on the curvature of the link between the contribution rate and earnings is not warranted in general by the theory presented in this paper, even for an informationally constrained State which can only measure current earnings y_a at the individual level. The MTE approach is inefficient if the impact of earnings on the desired age-earnings ratio for old age is negative enough.

Finally, consider a further subcase, where empirical evidence for the country shows that earnings has a negligible influence on the desired age-earnings ratio for old age. In this subcase $\psi^p{}_1 \approx 0$ and $\psi^p{}_{11} \approx 0$. Equations (10) and (11) imply that the MTE approach offers the optimal sign in the range of earnings where y_a > MTE. In the other range of earnings, the evidence by Stango and Zinman (2009) shows that the bias remains flat as earnings changes across quintiles other than the highest, so $B_1 = 0$ in that range. Therefore, according to (10) it is optimal to have $\theta'(y_a) = 0$ for y_a < MTE, which is exactly what the MTE approach offers. This evidence suggests that the optimal threshold between the two regions is near the 80th percentile in the earnings distribution.

Regarding curvature, the result for this subcase is mixed. In the region where y_a < MTE, $B_1 = 0$ and $B_{11} = 0$, which implies that the optimal curvature according to (13) is $\hat{\theta}'' \equiv 0$, which is the one offered by the MTE approach. However, in the region y_a > MTE the optimal curvature is $\hat{\theta}'' \equiv \theta_{22}(B_1)^2 + \theta_2 B_{11}$. We know that $\theta_2 > 0$, but the results of Table 3 suggest that the sign of θ_{22} varies. Moreover, there is no empirical evidence on the sign of B_{11}. Therefore, there is no presumption of optimality for the positive curvature offered by the MTE approach in (12).

Some policy lessons

The results in this section allow a brief evaluation of the recommendation by the UK Pensions Commission in 2004, which is to set the MTE between the 75th and the 90th percentile of the earnings distribution,. Stango and Zinman's empirical work (2009) found that, indeed, only the highest quintile of earners have detectably lower bias in U.S.A. data for 1983 (in their case, a lower exponential growth bias), apparently supporting the suggested position for the MTE. However, these authors also find that the size of the bias is strongly influenced by gender and education. Conditioning on the latter can survive antidiscrimination jurisprudence and legislation. It is certainly inefficient to use only one result and not the other.

This paper shows that is also important to verify the other function that controls the size of a MTE, which connects current earnings y_a with the predicted net earnings ratio when old (ψ^p). This connection may cancel the effect of the link between earnings and the predicted bias. For example, if high earnings cause significantly earlier retirement on average, dominating the substitution effect, high earnings leads to smaller net earnings when old. This would imply that the optimal action and the optimal compulsory contribution rate rises with earnings, making the optimal ω negative and converting the threshold MTE into a Lower Earnings Limit. The UK Pensions Commission did not verify this possibility.

Still, in the case of a State whose informational resources are limited to observe current earnings y_a alone, while all the z_a are unobservable, and in the further subcase where earnings has a negligible influence on the desired age-earnings ratio for old age, the recommendation by the UK Pensions Commission is correct: the MTE approach is close to optimal and the evidence for the U.S.A. suggests that the optimal MTE is close to the 80th percentile of the current earnings distribution.

A recommendation made by the Chilean 2006 Presidential Commission on Pension Reform, approved later by Chilean legislators in 2008, can be evaluated as well. The proposal modified the indexing of the MTE. As of 2006, the MTE level covered about 90% of earners at the full rate. From 2009, adjustments in proportion to the change in the Consumer Price Index were replaced by an adjustment in proportion to the change in average taxable earnings during the previous year. This reform blocked the previously planned secular fall in the MTE relative to average earnings and redefined the MTE as a fixed multiple of average current earnings. Curiously, this reform seems to have been proposed on behavioral grounds, since the authorities declared that the change would "help high earners reach a pension in accordance with their earnings".[18,19] (the market-structure rationale may have played a role too, see section 7).

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[18] See p. 360-361 in the Official History of the Law, in http://www.bcn.cl/histley/lfs/hdl-20255/HL20255.pdf

[19] Note that the "high earners" that deserved help were those closely below the 90th percentile of the earnings distribution, and not above, because if not, the Presidential Commission would have also raised the MTE in addition to changing its indexation. A contrary argument, not captured in this paper, is that allowing the MTE to fall further would have helped to attract some self-employed to jobs covered by the mandate to contribute.

Again, this paper finds that this behavioral argument is flawed. First, the MTE concept should be abandoned in favor of a contribution rate conditional on all observables that are compatible with antidiscrimination jurisprudence or legislation, which are many in Chile. Second the link between net earnings ratio in old age and the level of earnings was not verified prior to legislation, as suggested by the theory. Third, even in the subcase where the MTE approach is optimal, no empirical evidence was offered in support of the requirement that the bias does begin to fall for earnings above the chosen fixed multiple of average current earnings.

7. Directions for future research

This paper studies optimal policy when using compulsion to deal with behavioral biases such as excessive optimism about net earnings in old age. The finding is that the optimal use of compulsion is governed by the type and precision of the information on individuals that is available to the planner, with regards to the optimal action and to the bias. In the standard case, more biased individuals should be subject to a higher level of the compulsory action. Although a MTE is close to optimal for a State with constrained informational resources and under some further assumptions, the paper shows how more advanced States can be more efficient.

Parallel research suggests that this result is fragile to how compulsion becomes binding. If the individual has access to other voluntary actions which substitute imperfectly for the compulsory action, and can be less costly than consumer credit, at least for a range of values, the connection can be reversed. For example, Valdes-Prieto (2010) allows individuals to escape excessive compulsory saving by moving to uncovered jobs, and the result is that optimal policy may be to reduce the level of compulsion on more biased individuals.

Regarding the level for maximum taxable earnings, future research should explore in more depth the non-behavioral rationales. Fiscal rationales for a finite MTE, including redistributive and efficiency aspects, are surveyed in section 3.6 and are certainly a major driver of actual MTE policy in a number of countries (Whitman, 2009)

“Market structure” rationales for a MTE are important in countries with compulsory funded pensions, where scale economies and the need to minimize marketing expenditures concentrate administration in only a few organizations. A single state-owned institution or a few large and heavily regulated firms make the critical asset-allocation decisions, while individual security selection is delegated to atomistic subcontractors. In contrast, voluntary financial saving is usually managed by hundreds of medium-sized firms, while non-financial saving is managed by millions of decision-makers, so asset-allocation decisions are more dispersed. Therefore, a higher MTE increases the concentration of financial power, possibly with both antitrust and macroprudential consequences. When compulsory pensions are managed by heavily regulated firms while voluntary saving is managed in a dispersed way by less regulated firms, the size of the MTE also affects the distribution of power between politicians and the private sector. Finally, an increase in the MTE increases the size of the market for these large firms. If market and regulatory conditions allow fees to exceed marginal costs substantially, this increase may create substantial additional profits for the owners of these firms, at the expense of participants, while scale economies and sunk costs limit entry. Lobbying by these firms’ owners may lead to increases in the MTE that outweigh gains based on the behavioral rationale.

General equilibrium effects are also important. Compulsory contributions can affect fiscal revenue even in the fiscally neutral environment specified in section 3.6, because of the following effect (Valdés-Prieto 2010): compulsion raises total savings, and this raises the revenue from capital income taxation. This allows a cut in other tax rates, raising welfare.

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Appendix: Parameter assumptions for the numerical simulations

The parameters used in the simulations presented in this paper are set as follows. First, consider the size of the optimistic bias given by the difference $b \equiv (\psi^e - \psi)$, measured in percentage points of y^c. The limited empirical data on parameter b supplied by Puri and Robinson (2007) suggests that it differs widely across the population. This section follows Valdés-Prieto (2010), who simulates a range of values, with an average bias of 20 percentage points of y^c. The predicted net productivity when old is set at $\psi^p = 0.60$ also measured in percentage points of y^c. This same value is used whether the planner knows the actual value (predicts with no error), or whether he predicts with an error.

The impact of ageing is captured by assuming that even when biased, expectations about net productivity when old always comply with $\psi^e < 1$ and $\psi < 1$. This imposes a restriction on b: $0 \leq b \leq 1 - \psi$. From the numerical range used, it follows that $0 \leq b \leq 0.40$. The qualitative results of the simulations are not sensitive to changes in the value of ψ.

The parameters that underlie earnings are as follows: Individual earnings in the active phase are calculated as $y_a \equiv w \cdot (1 - l_a)$; where w is the wage rate per hour per unit of effective labor fixed at 1; and $(1 - l_a)\ \varepsilon\ (0,1)$ is cumulative hours supplied in the active phase by the individual. Actual individual earnings when old are defined analogously as $y_p \equiv w \cdot (1 - l_p)$; where $(1 - l_p)\ \varepsilon\ (0,1)$ is cumulative hours supplied when old. It is further assumed that l_a and l_p are set institutionally, in the sense that individuals cannot choose l, and that leisure is not valued.

Factor prices are given for an individual. The assumed values are $w = 1$ and $r = 3\%$ per year (after inflation). Labor productivity in the covered sector is set at 10 units when active. The spread in consumer credit is set at 10 percentage points per annum following data for the U.S.A. (Lu, 2008). This implies that $r + s = (1+0.03+0.10)^{30} - 1 = 38.116$ (3,812% per 30-year period).

The tax implicit in contributions to other branches of social insurance, net of marginal benefits, is set at $t_a = 0.15$. The tax rate on the return from voluntary saving is set at $\tau_S = 0.20$. Thus, the after-tax return on voluntary saving is $(1 + 0.03 \cdot (1-0.20))^{30} - 1 = 2.0370$ or 103.70% per 30-year period. The internal rate of return paid by the compulsory and fully-funded pensions system to each generation depends on the tax treatment for pension funds, given by tax rate τ_{PF}. The paper assumes equal tax treatment of mandatory and voluntary saving, so $\rho^c = r(1-\tau_{PF}) = (1+0.03\cdot(1-0.20))^{30}-1 = 2.0370$ (204% per 30-year period).

Regarding preferences, we follow Auerbach and Kotlikoff (1987, p. 27), although labor choices are ignored to simplify:

(10a) $u(c_a) = (1/(1-1/\sigma)) \cdot \left\{ \left[c_a \right]^{1-1/\sigma} - 1 \right\} \qquad \sigma \neq 1$

(10b) $v(c_p) = \beta \cdot (1/(1-1/\sigma)) \cdot \left\{ \left[c_p \right]^{1-1/\sigma} - 1 \right\} \qquad \sigma \neq 1$

where σ and β are taste parameters. The intertemporal elasticity of substitution in consumption, σ, is set at the value suggested by Auerbach and Kotlikoff : $\sigma = 0.25$. 1 is subtracted in the curly bracket to insure that utility is positive for all values of σ, provided that consumption is large enough. In turn, positive utility is needed for the social welfare functions to be operative for all values for the inequality aversion parameter η.

Impatience is set at 1.5% per annum, from the same source. This implies a discount factor β equal to $1/(1+0.015)^{30} = 0.64$ per 30-year period.

For these preferences, the optimal choices D^*, c_a^*/c_p^* and F^*/c_a^* do not depend on labor productivity, so individual results are homothetic.

Table 1: MTEs in 60 contributory earnings-related compulsory pension plans throughout the world (countries ordered by the size of her MTE)

High-income countries and Europe	**Annual MTE for old age/ GDP per capita**	**Other Countries in Americas, Asia, Pacific, and Africa**	**Annual MTE for old age/ GDP per capita**
Group 1: High MTE		***Group 1: High MTE***	
Belgium	No limit	Indonesia	No limit
Denmark (SP)	No limit*	Iran	No limit
Finland	No limit	Malaysia EPF	No limit*
Norway	No limit	Nigeria	No limit
Portugal	No limit	Peru	No limit*
Romania	No limit*	Panama	No limit
Czech Republic	34.572	Yemen	No limit
Poland	32.182*	Colombia	9.365*
Croatia	7.858*	Saudi Arabia	9.166
Israel	5.504	Turkey 2006	3.322
Greece	4.649	China (varies)	up to 3.00
Italy	4.571	Mexico	2.887*
Australia	4.222*	Vietnam	2.598
Germany (West)	3.175	Costa Rica	2.496
Group 2: MTE below the USA's		***Group 2: MTE below the USA's***	
United States	2.328	Uruguay	2.301*
Japan	2.255	Brazil	2.153
Austria	2.058	Chile	2.146*
Bulgaria	1.998	Guatemala	2.058
Spain	1.997	Morocco	1.886
Korea, South	1.907	Argentina	1.779*
France[a]	1.557	Trinidad and Tobago	1.088
Singapore CPF	1.329*	Philippines EPF	0.801*
Canada	1.235	Egypt	0.708
Ukraine	0.927	Thailand	0.539
Hong-Kong, China	0.882*	India PF	0.533
Taiwan, China	0.525	Pakistan	0.502
		Kenya	0.495
Group 3: Above the MTE, the marginal contribution rate is smaller but larger than zero:[b]			
United Kingdom	2.510* (54%)	Ireland	1.936 (73%)
Russia	2.263 (20%)	Sweden	1.733 (63%)
		Hungary	1.646 (72%)
Switzerland	1.994* (50%)	Netherlands	1.421 (23%)

* indicates a fully funded pension plan.

Note a: In most countries the same MTE applies to both worker and employer contributions. The only exception is France, where this table uses the simple average of the MTEs because the difference is small.

Note b: in all countries in Group 3 except Russia, the MTE for the employer is indefinitely large but the MTE for the worker is finite, which is the one reported here. The percentage in the parenthesis is the ratio between the marginal contribution rate above and below the threshold. In the Netherlands and Russia at least one additional threshold is present, at lower earnings.

Source: SSA, Washington D.C., *Social Security Programs Throughout the World* 2008 edition for Europe, 2007 edition for the Americas, 2008 edition for Asia-Pacific and 2009 edition for Africa. See http://www.socialsecurity.gov/policy/docs/progdesc/ssptw/