The Optimal Design of Funded Pensions

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Abstract

In many countries, pension funds based on individual accounts have been affected by high operating costs. Contract theory helps to unravel the nature of such problems: managers of pension funds have strong incentives to manipulate market expectations about their capacity through wasteful activities (e.g. promotion). Thus, competition among pension funds entails efficiency losses, due to pension savings attraction efforts, as well as gains, related to investments in asset management skills. Regulations capping fees or costs of pension funds worsen market inefficiency, while a public pension fund competing with private ones improves (at least weakly) it. Taking into account political and commitment constraints affecting public institutions, a quasi-competitive pension scheme - centralizing contribution collection, auctioning the right to manage raised money to competitive fund managers, and affording an opting out choice to households - Pareto-dominates (at least weakly) the market of pension funds.

Keywords: Pension funds, Signaling, Public-private provision mechanism
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1 Introduction

Several countries passed or are currently implementing reforms of their pension systems involving a partial switch from pay-as-you-go (PAYG) to fully funded (FF) plans, e.g Feldstein (2005b). The celebrated report *Averting Old Age Crisis* (The World Bank, 1994) has mustered consensus on the view that old-age retirement schemes should be *multi-pillar*[1]: a mandatory PAYG scheme providing basic pensions; a mandatory FF scheme supplementing them; and possible voluntary savings.

The main argument in favor of a mixed scheme and of the introduction or strengthening of FF pension plans is related to the financial crisis of PAYG systems determined by adverse demographic trends, namely to the opportunity of tax-smoothing policies through capital accumulation or *pre-funding* (Feldstein and Liebman, 2002)[2]. The mainstream approach to pension reform is to create (or strengthen) a financial sector characterized by special operators (the pension funds) and regulated by governmental authorities. Individuals choose pension funds to manage their *individual accounts* and, with certain limitations, asset allocation policy. In the conventional wisdom, competition among pension funds insures the efficient allocation of private (pension) savings and widens individual opportunity to choose preferred risk-return bundles.

Though FF plans based on individual accounts are gathering momentum in many countries, in the traditional institutional framework of the US and of the UK the typical form of FF pensions used to be the defined benefit (DB) company-sponsored plan (Davis, 1995): companies define workers' pension rights and *commit* to finance them. Plans based on individual accounts are very often defined contribution (DC): individuals (mandatorily)

[1]Consensus on the *World Bank's approach* is wide but far from being unanimous, e.g. Kotlikoff (1999). Moreover, some relevant amendments to the multi-pillar approach are justified by the specific features of involved countries: size, development stage, institutional efficiency (Srinivas *et al.*, 2000).

[2]Pension rights are explicit contingent liabilities of the public sector (and/or private institutions) with respect to households. The contingent nature of such liabilities tends to weaken aggregating across households, giving rise to a strong analogy with (public) debt (Sinn, 2000; Valdés-Prieto, 2005). Thus, the argument for pre-funding (within the pension system) follows by tax-burden smoothing considerations, as for public debt management (Missale, 1999, ch. 2 and 3).

contribute to pension funds that commit to pay annuities determined by the financial returns on contributed capital[3]. The trend of the FF pension industry towards DC plans based on individual accounts can be related to the structural change in the economic systems, relying more and more on the mobility of workers among different firms and regions[4]. DB company plans are affected by *portability*[5] and under- funding[6] problems.

Notwithstanding a spreading trend towards DC plans based on individual accounts, these are not free from critiques:

> *"Individual accounts would unquestionably entail administrative costs not present under traditional Social Security. [...] How high those costs would be in reality would depend on a number of factors, including how centralized the system of accounts was and how limited the investment choices were; the level of service provided [...]; the size of the accounts; and the rules and regulations governing them. The higher the administrative costs, the lower the ultimate benefit a worker would receive, all else equal, since more of the funds in the accounts would be consumed by these costs, and less would be left over to pay retirement benefits."*[7]

As other financial industries, pension funds are featured by moderate scale economies. Moreover, a wide consensus identifies important components of high administrative costs

[3]At retirement age, payments of both DB and DC pension funds can take the form of capital (instead of annuities), as well; however, the possibility to obtain capital payments instead of annuities is often limited by law.

[4]Analyzing the trend in G10 countries, the (OECD, 2005b, p. 33) points out that a movement away from DB plans is underway. However, some countries are opting for so called *hybrid* plans: DC plans with a minimum warranted return, involving some DB feature.

[5]Say, limitations to full recognition of acquired pension rights among different DB plans, linked to different technical and institutional problems. These limitations are easily overcome with DC plans based on individual accounts while in DB company plans pension rights are bundled with other aspects of workers' occupational treatment.

[6]Asset management of pension funds sponsored by companies is often used as a tool to manipulate reported budgetary data of sponsors (Bergstresser and Rauh, 2004).

[7]Diamond and Orszag (2004, p. 47). Several contributions investigated this point, e.g. Diamond (2000); Bateman and Mitchell (2004); Dobronogov and Murthi (2005); Mitchell (1996); Sundén (2004); Whitehouse (2000). To illustrate, let us consider that all fees charged by pension funds are measured as a share of managed assets. Assuming a 2% average real rate of return on pension assets, a growth of fees from 0.2% to 0.6% (say, nearly the difference between default-public and market pension funds in Sweden - (Sundén, 2004, p. 4)) reduces the net retirement yield rate of an individual (working for 45 years and experiencing a 1% average real growth of her wage) by 0.4%, and her end-career pension savings by 8.6%. Moreover, losses in terms of yield and savings raise as the rate of return on pension assets increases.

of pension funds in *promotion and marketing* activities, as well as in *switching* costs, that are absent in company pension funds or in PAYG systems (Bateman and Mitchell, 2004; Dobronogov and Murthi, 2005). However, supporters of reforms introducing or widening the role of DC plans based on individual accounts also stress that these costs do not *usually* overweight efficiency benefits of pension plans based on individual accounts, e.g. Feldstein (2005a)[8].

Historical experience shows that the risk of high costs of DC pension plans as well as the risk of underfunding of DB company plans are typically shared between pensioners and the government (either in the form of bail-out of underfunded plans or in the form of warranty of minimum returns to pensioners).

Different policies have been proposed to tackle scale-economies and lessen promotion and switching costs. As first, regulations constraining the working of the market of pension funds have been suggested (James *et al.*, 1999): centralization of contribution collection, limitation of fund manager services (and promotion), constraints to asset allocation policies. These anticompetitive rules would reduce efficiency costs linked to competition amongst fund managers; but, such benefit is balanced by a restriction in the choice freedom of individuals among different risk-return bundles[9]. More recently, some countries have adopted (e.g. Sweden) or are considering (e.g. UK) the introduction of a public pension fund (aiming at increasing competitive pressure on and at providing an alternative to private funds) featured by low fees, risks, and expected revenues (Sundén, 2004; Turner *et al.*, 2006).

The idea of a public pension fund is not new and, indeed, has also been proposed in a relatively extreme version of full *nationalization* or centralization of the funded pillar, in order to benefit of enhanced risk-pooling and low administrative costs of concentrated

[8] Admittedly, this has been a problem in Latin America experience and it is likely to suggest a more cautious approach in transition and small economies, that are featured by limited and inefficient financial markets and institutions (Cangiano *et al.*, 1998; Schiff *et al.*, 2000; Srinivas *et al.*, 2000; Whitehouse, 2000).

[9] A rather limited sacrifice, in the real world: it is, indeed, questionable whether individuals are actually able to choose their preferred risk-return bundle over a life-long time span (Diamond, 2004, 2005). Munnell and Sundén (2002, 2004) provide evidence in this direction analyzing US individual retirement plans.

schemes, e.g. Diamond (2000). The potential huge size of aggregate pension savings suggests caution with respect to the risk of political interference in economy and financial markets that such institutional solution would entail[10]. A problem that can be hardly overcome by regulations, given that governments lack of effective commitment technologies to counter it (Besley and Prat, 2005). Moreover, restricting public fund manager's discretion, to hamper the risk of political interference, is likely to waste the gains of the FF pillar, that are generated by efficient capital allocation.

The theory underlying these policies considers high costs as basically determined by lack of competition, hence by the existence of barriers to entry in the market and, consequently, of extra profits of pension funds. Unless further political constraints are considered, this view cannot explain the long run functioning of the market of pension funds. Moreover, the experience of the last quarter of century has suggested the role of institutional design in warranting the capacity of the FF pension schemes to deliver the good they were conceived for, and in particular of governance and incentive problems (Besley and Prat, 2005). In a broader perspective, the institutional settings adopted to carry out services like pension provision involve specific choices, in terms of sharing of risks and of regulation of incentives of involved players, that heavily affect the their performance (Acemoglu *et al.*, 2003; Prat, 2005).

Following this theoretical perspective, the paper analyzes the optimal institutional design of DC pension plans based on individual accounts considering a market of funds featured by incomplete information and incomplete contracts: the capacity to manage pension savings is non-observable and non-verifiable, but fund managers may indirectly signal it through some costly technology. The two main contributions of this paper are improving our understanding of high administrative costs within a competitive market of pension funds, and exploring possible regulatory or institutional solutions to market

[10]This is a crucial point of the dispute on the institutional setting of the FF scheme. Among others, Diamond (2000) and Feldstein (2005a) expressed influential (and opposed) opinions on the possibility that "public" FF schemes could be *"insulated from political interference"*.

inefficiency.

The simplified setting of our model is characterized by individuals that (mandatorily) contribute to the FF scheme during their working life to obtain a pension in their retirement life. There is an industry of fund managers competing to manage pension savings, that cannot be distinguished on the basis of their investment in skill, which nevertheless affects the expected rate of return they are able to determine. However, assuming that the FF scheme is organized through a competitive market of pension funds, fund managers cannot rely on contracts specifying their skill and need some costly effort, say *promotion*, to affect market expectations about it (Acemoglu *et al.*, 2003). This, in turn, moves market equilibrium away from first-best Pareto-efficiency.

Our theory of high administrative costs of pension funds affords an assessment of possible public policies aiming at reducing the inefficiency of the competitive market of the pension funds. In our model, high administrative costs arise because a costly effort is required to fund managers to signal they invested in skill, thus more productive. Therefore, regulations constraining fees or promotion costs of fund managers would hinder signaling, and in turn destroy the very incentive to invest in skill. Thus, the market equilibrium induced by these policies is Pareto-dominated by the second-best efficient equilibrium of the market of pension funds without any policy.

A thorough investigation of possible solutions to market inefficiency requires a (simple) theory of the functioning of public institutions. In a framework explicitly accounting for problems determined by political agency and imperfect policy commitment, adding a public pension fund to the market of private funds improves the social welfare proportionally to its market share, because it reduces management fees. However, because of the convexity of average costs, the extent of efficiency improvement cannot affect the whole market unless multiple public pension funds are introduced.

In search of an optimal balance between the potential benefits of public provision and its costs, a crucial observation is that FF pension schemes integrate two main technological

and economic phases (Besley and Prat, 2003, 2005): *financing* (i.e. contribution attraction) and *investment* (i.e. asset allocation and management). Investment requires specific and high value expertise and it is the driver of capital allocation efficiency of FF plans; conversely, financing is featured by relevant scale economies and it is likely to introduce perverse incentives, as observed, diverting fund managers from pursuing efficiency (James *et al.*, 1999; Feldstein, 2005a).

A *quasi-competitive pension scheme* unbundling financing and investment is, therefore, considered: financing is centralized, and the right to manage the collected money is allocated to private fund managers either by the public agency collecting the money, through a *public procurement mechanism*, or by households (if they opt out of the public agency service). The public procurement mechanism employed by the national agency to allot money works as a commitment technology to select the right incentives of the fund managers (namely, to increase actual rate of return on pension savings), neglecting wasteful activities[11]. Under contract incompleteness, and political and commitment constraints limiting the functioning of the national agency, the quasi-competitive pension scheme Pareto-dominates (at least weakly) the market of pension funds that integrates financing and investment (also considering the case one of the funds in the market is public).

The paper is organized as follows. In Section 2 a simple model of the economy is presented. Section 3, then, analyzes the competitive market of pension funds, and in particular establishes its second-best Pareto-efficiency. Section 4 assesses possible public policies in terms of social welfare, and shows that a quasi-competitive pension scheme weakly Pareto-dominates the market of pension funds. Section 5 concludes.

[11] A similar mechanism is used to manage the French PAYG reserve fund (*Fonds de réserve pour les retraites*) that begun its operation in 2004 (FRR, 2006). Greco (2002) proposed this mechanism for small and transition countries.

2 The Model

The economy is made by an infinite number of identical households of mass 1. The utility function of the representative household, $u^h = v(w - s) + p_i^h$, is increasing in its exogenous income, w and its pension p_i^h, and decreasing in mandatory contribution to the (funded) pension scheme, s. The pension is determined by a defined contribution rule, $p_i^h = r_i \cdot s \cdot (1 - \omega_i)$, as the capitalization of contribution invested through the pension-fund manager $i \in I$, $r_i \in [0, +\infty)$, net of the asset management fee, ω_i. The timing of pension financial investment requires that, during the accumulation period, administrative costs (hence, management fees ω_i) are paid out of workers contributions, the remaining money $(s \cdot (1 - \omega_i))$ is actually invested in the pension accumulation plan, yielding r_i for each unit of invested capital[12].

Two alternative institutional pension schemes are henceforth considered. In the *competitive market of pension funds*, households can choose one of the (potentially infinite) fund managers (FMs in Figure 1) that are freely allowed to enter the market: $i \in I_c \equiv \{1, ..., n\}$. In the *quasi-competitive pension scheme*, households are enrolled in a public pension scheme managed by a national agency (NA in Figure 1), but they can opt out of this scheme and choose a pension fund in the competitive market (again, $i \in I_c$).

Whenever households choose a pension fund, the gross rate of return on pension savings, r_i, is a random variable distributed following the probability function $F(r \mid \theta_i)$ (twice continuously differentiable), that depends on the investment in skill of the fund manager: $\theta_i \in \{0, 1\}$. The probability function is assumed to be identically and independently distributed across fund managers, and to be featured by first order stochastic

[12]The underlying and fairly mild assumption is that the financial cost of borrowing money to cover (hence, to postpone) administrative costs during the accumulation period is higher (or equal) than the rate of return of capital accumulated in the pension scheme. Therefore, actual capital accumulation in the pension scheme is $s \cdot (1 - \omega_i)$. Moreover, in the very simple structure of this model, we do not take into account the rather complex structures of pension-fund fees and their links with actual administrative costs Diamond (2000); Dobronogov and Murthi (2005).

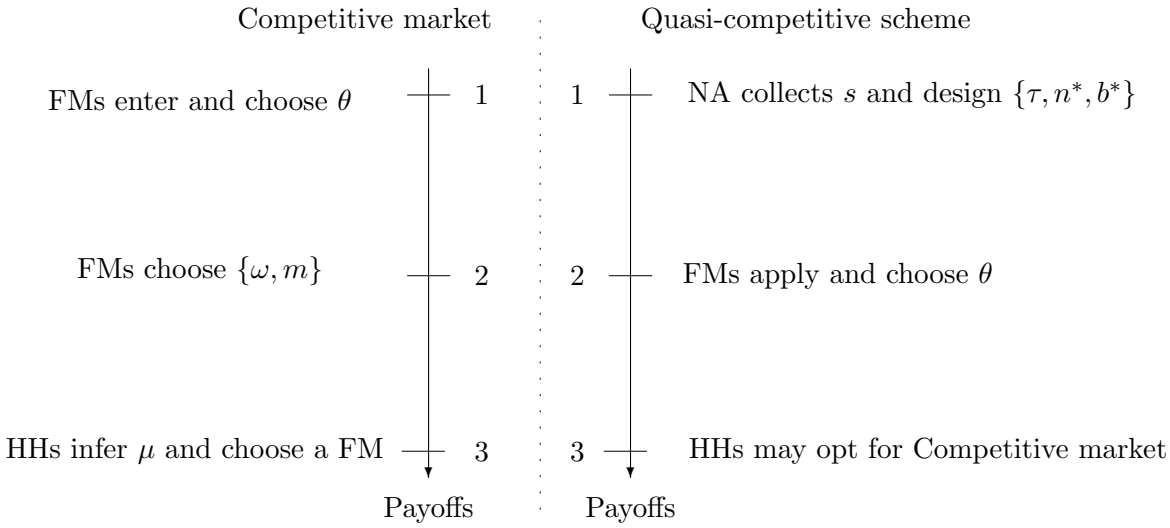

Figure 1: *Alternative funded pension schemes*

dominance: higher skill raises the probability of high rates of return on managed assets ($F(r \mid 0) > F(r \mid 1)$). Hence, the expected return is higher for high-skill fund managers than for low-skill ones: $E(r \mid 1) > E(r \mid 0)$. The rate of return that is provided by the national agency within the quasi-competitive pension scheme depends on the specific features of such institution (Section 4.3).

3 A competitive market of pension funds

We analyze a competitive market of pension funds in a long run perspective: households may switch between pension funds along their working life to maximize the expected pension; fund managers, operating on the market, make non-negative profits; and new fund managers may enter the market, whenever this involves making positive profits[13]. In our simple model of pension funds' market - taking the form of a sequential game (Figure 1), imposing a long run perspective is equivalent to requiring the *sequential rationality* of households and fund managers.

[13]In our setting, switching costs play no role. However, these are empirically relevant (Dobronogov and Murthi, 2005). The effect of switching costs in our framework is not straightforward given that these are likely to reduce the contestability (hence, the efficiency) of the market of pension funds.

At the first stage, fund managers enter the market, choosing their skill level ($\theta_i \in \{0,1\}$), that implies a fixed cost $C(\theta_i)$, namely: being a good (high-skill) fund manager entails a positive cost $C(1) = C \in (0, c \cdot s^2)$; conversely, no fixed cost is associated to entry in the market as bad (unskilled) fund manager ($C(0) = 0$). Moreover, the fund manager $i \in I_c$ has to pay a marginal cost $2 \cdot c \cdot b_i$ to manage an asset mass of measure $b_i \in [0, s]$ (i.e. the fund manager's market share).

At the second stage, having observed the number of fund managers that entered the market, each of them organizes a retail branch of her business, ensuring suitable *promotional effort* to attract contributions from households. In our view, promotion, $m_i \in \Re_+$, represents a host of different activities - such as, marketing, creative accounting, herding in portfolio management - involving efficiency losses in the form of costs overrun (or, possibly, in the form of reduced effective rate of return). Hence, we assume that fund-manager-$\{i\}$'s fixed costs of promotion are $c(\theta_i, m_i) = \gamma(\theta_i) \cdot m_i$, with $\gamma(1) = \gamma > 0$ and $\gamma(0) = \gamma + \delta$ (with $\delta > 0$), hence the cost of promotion is increasing in effort m_i, and satisfies the *single crossing* condition, $\partial_{m_i} c(0, m_i) - \partial_{m_i} c(1, m_i) = \delta > 0$.

The single crossing assumption on promotion costs is relatively mild: it implies that high-skill fund managers find it less costly to produce the same promotion effort than low-skill ones. A first argument supporting such assumption is that real-world governmental authorities control activities of fund managers conveying (soft) information about their true skill to households. Thus, low-skill fund managers are likely to incur higher expenditures to spread among people the impression they are good. Moreover, regulation may involve prudential behaviors and investments that could be more easily met by high-skill, relying on higher productivity, than low-skill.

In other terms, though promotion activities *per se* do not convey hard information to households about actual capacity of fund managers, our single crossing assumption on promotion costs implies that - whenever information is not fully available to all households - promotion actually affects the market perception (beliefs) about fund-manager's skill.

Each fund manager $i \in I_c$ maximizes her profit

$$\pi(\omega_i, m_i; \theta_i) = \omega_i \cdot b_i - c \cdot b_i^2 - C(\theta_i) - \gamma(\theta_i) \cdot m_i$$

implementing a promotional effort m_i (to signal her skill) and fixing her asset management fee ω_i. Fund manager's profit is a function of her market share b_i that, in turn, depends on her strategy ($\{\omega_i, m_i\}$), on the strategies of competing fund managers ($\{\omega_j, m_j\}_{j \in I_c/\{i\}}$), and on households' beliefs about fund managers' skills. Given that insurance markets are incomplete, fund managers who do not cover their costs, in some specific contingency, fail if such case materializes. Thus, the minimum *credible* fee that a fund manager can propose to households has to cover average costs: whenever proposed fee is below average costs, households anticipate that fund-manager's loss will be covered by reductions in the return of asset management.

At the third stage, each household observes the number of fund-managers, n, and their strategies, $\{\omega_j, m_j\}_{j \in I_c}$, infers the probability that each of them invested in high skill, $\{\mu(\omega_j, m_j)\}_{j \in I_c}$, and then chooses the fund managing its pension savings. The market share of the fund manager $i \in I_c$ is determined as the sum of all households opting for it: $b_i = \int_0^1 b_i^h dh$, where

$$b_i^h \equiv \begin{cases} s & if \quad E(p_i) > E(p_j) \\ s_i^h \in [0, s] & if \quad E(p_i) = E(p_j) \\ 0 & if \quad E(p_i) < E(p_j) \end{cases}$$

for any $i \neq j$, with $i, j \in I_c$[14]. Whenever households are unable to distinguish between $k \in \mathbb{N}$ (with $k \geq 2$) fund managers, they are assumed to uniformly distribute among them;

[14]For a given skill, each household chooses the fund manager with lower management fee

$$b_i^h \mid_{\theta_i = \theta_j} \equiv \begin{cases} s & if \quad \omega_i < \omega_j \\ s_i^h \in [0, s] & if \quad \omega_i = \omega_j \\ 0 & if \quad \omega_i > \omega_j \end{cases}$$

for any $i \neq j$, with $i, j \in I_c$.

thus, the market share is equal for all the concerned managers: $b = \frac{s}{k}$. Furthermore, any fund manager may ration her service with respect to potential market share, $\bar{b}_i < b_i$.

3.1 Complete information benchmark

Under complete information, households are able to discriminate fund managers by skill. Thus, promotion is useless and, since it increases fixed costs, fund managers optimally fix it to zero ($m_i = 0$) whatever their skill: hence, the payoff function of high-skill fund managers is $\pi_i(1, \omega_i, 0, b_i) = \omega_i \cdot b_i - c \cdot b_i^2 - C$; while for low-skill fund managers it is $\pi_j(0, \omega_j, 0, b_j) = \omega_i \cdot b_i - c \cdot b_i^2$.

Let $n^* \in \mathbb{N}$ be the number of fund managers operating on the market and $\lambda^* \in [0, 1]$ be the share of high-skill ones, at the equilibrium. Moreover,

$$b^* \equiv argmin\left\{c \cdot b + \frac{C}{b}\right\} = \sqrt{\frac{C}{c}}$$

is the minimum efficient scale of asset management. Under complete information, an equilibrium of the competitive market of pension funds corresponds to a subgame perfect equilibrium of the sequential game describing the market, and it is such that (Lemma 8 in the Appendix): all fund managers price at their marginal cost, low-skill ones serve a trivial (or zero-measure) market share ($\omega(0) = b(0) = 0$), and high-skill serve the minimum efficient market share ($b(1) = b^*$, thus $\omega(1) = \omega^* = 2 \cdot \sqrt{c \cdot C}$). Therefore, in equilibrium (provided that it exists), all fund managers with the same skill propose the same price and households distribute uniformly among them.

Now, household's (equilibrium) choice between low- and high-skill fund manager can be featured. Throughout the paper, we assume that the sufficient condition

$$E(r \mid 1) \cdot \left(1 - 2 \cdot \sqrt{c \cdot C \cdot \left(1 + \frac{\gamma}{\delta}\right)}\right) > E(r \mid 0) \tag{1}$$

holds, insuring that high-skill technology is sufficiently *cheap*, as compared to the gain in

increased (expected) return. Thus, each household strictly prefers an high-skill manager to a low-skill one[15].

On these grounds, the existence and features of market equilibrium can be established[16].

Proposition 1 *Under complete information and (1), a Pareto-efficient market equilibrium exists, with n^* high-skill fund managers, if and only if $\frac{s}{b^*} = n^* \in \mathbb{N}$.*

Proof. See the Appendix. ■

The necessary and sufficient condition in Proposition 1 warrants that the minimum efficient market share is compatible with the existence of the (full information) equilibrium. In the following, we will assume that it is satisfied, observing that - given other parameters - an appropriate choice of the mandatory contribution s is sufficient to afford it. Moreover, given that the market of pension funds is contestable by potential new entrants, the complete-information equilibrium is first-best Pareto-efficient.

3.2 A competitive market under incomplete information

Many features of the competitive market of pension funds highlight that fund managers' skills can hardly be considered as a contractible or even observable (Diamond, 2000). Under fund managers' unobservable and unverifiable skills, the complete information equilibrium (involving no promotion effort) is easily shown to be incentive incompatible: assuming that n^* fund managers play the complete information equilibrium strategy ($\theta = 1$ -

[15]Conversely, when the fixed cost associated to high-skill ($C > 0$) is excessively high with respect to the expected return differential, each household strictly prefers a low-skill manager to an high-skill one: investing in high-skill technology implies an inefficient allocation of resources. Let us also remark that in the case of complete information, a condition $E(r \mid 1) \cdot (1 - 2 \cdot \sqrt{c \cdot C}) > E(r \mid 0)$ - less restrictive than (1) - would be sufficient. However, when asymmetric information is introduced fund managers implement strategies that increase their fixed costs (to signal their skill) and a stronger sufficient condition - say, (1) - is required.

[16]The concept of uniqueness does not make an economic sense in the considered framework. There is an infinite number of subgame perfect equilibria, given the infinite number of potential entrants. However, all these equilibria share the common features established in Proposition 1 and Lemma 8 (in the Appendix).

at the first stage, and $\omega(1) = \omega^*$ - at the second stage), other fund managers would make positive profits by entering the market, choosing low-skill (thus, saving on entrance investment), and pooling with high-skill at the second stage ($\omega(0) = \omega^*$). Thus, by classical *lemon-market* argument, we have

Proposition 2 *Under incomplete information and assuming that promotion is forbidden, a Pareto-inefficient market equilibrium exists, with an infinite number of low-skill fund managers.*

However, once entered the market, fund managers that invested in skill may *signal* their higher productivity to households through promotional activities, entailing higher fixed costs. To proceed in the analysis of this signaling game, let us recall its timing:

1. (potential) fund managers enter the market, and choose the level of investment in skill ($\theta_i \in \{0, 1\}$, for any $i \in I_c$);

2. having observed the number of fund managers operating on the market, each of them chooses a fee-and-promotion vector ($\{\omega_i, m_i\}$, for any $i \in I_c$);

3. having observed the number of fund managers, and their fees-and-promotion vectors, households choose one of them to manage their pension savings, consistently with its beliefs about the probability that each fund manager invested in skill ($\{\mu(\omega_i, m_i)\}_{i \in I_c}$).

As usual, the solution is worked out by backward induction. At the end of the first stage, the number of fund managers operating on the market, n^*, and the share of them choosing high-skill, λ^* is determined. Thus, the second and third stages of the game can be treated as a standard signaling game in which types (here, skills) are exogenously determined. For given first-stage choices (thus, given n^* and λ^*), the equilibria of the sub-game made by stages two and three can be characterized by the vector of *subgame strategies* of fund

managers, $\{\omega_i, m_i\}_{i=1}^{n^*}$, the beliefs of households (and fund managers), and the choice of households (i.e. the market share of each fund manager $\{b_i\}_{i=1}^{n^*}$).

Subgame equilibria, as usual in standard signaling games, can be pooling, when fund managers play the same subgame strategy $\{\omega^p, m^p\}$ independently of their skill, or separating, when high-skill and low-skill fund managers play different strategies. Let us remark that, in the *subgame pooling equilibrium* households do not distinguish among fund managers, hence all fund managers have the same market share. Conversely, in the case of *subgame separating equilibrium* households choose high-skill fund managers provided that the fee they charge is sufficiently low (also with respect to low-skill managers' fees).

A subgame equilibrium is part of a *perfect Bayesian equilibrium* of the whole game only if at the first stage - anticipating the subgame equilibrium - no fund manager (including potential ones) is willing to deviate with respect to her equilibrium strategy (determining the number of entrants, n^*, and the share of high-skill, λ^*) and households' equilibrium beliefs are consistent with the share of high-skill fund managers.

3.2.1 Subgame pooling equilibria

Given n^* and $\lambda^* \in (0, 1)$ (determined by first-stage moves of fund managers), a subgame pooling equilibrium - assuming that it exists - is featured by the subgame strategy $\{\omega^p, m^p\}$ implemented by all the n^* fund managers operating on the market, and a belief μ^p that households (and fund managers) share about the probability that a given fund manager operating on the market is high-skill (provided that she plays the equilibrium strategy). The expected return warranted by asset management of any fund manager, in the subgame pooling equilibrium, is

$$E(r) = \mu^p \cdot E(r \mid 1) + (1 - \mu^p) \cdot E(r \mid 0)$$

thus, households distribute uniformly among fund managers ($b_i = b^p$).

Is a subgame pooling equilibrium part of a perfect Bayesian equilibrium of the game? Let us remark that low- and high-skill fund managers have the same fixed cost when promotion effort is $m^s = \frac{C}{\delta}$. Thus, given the subgame pooling equilibrium strategy, $\{\omega^p, m^p\}$, and the individual market share, b^p, low-skill fund managers' profit is strictly greater than high-skill one, whenever $m^p < m^s$. Conversely, low-skill fund managers' profit is strictly smaller than high-skill one, whenever $m^p > m^s$; and the profit of the two types is the same when $m^p = m^s$.

By these considerations, the subgame pooling equilibrium can be represented in the space of fund-managers subgame strategies as shown in Figure 2. Given the market share, b^p, underlying the subgame pooling equilibrium, the slope of the iso-profit functions is constant and given by

$$d_m\omega \mid_\theta = \frac{\gamma(\theta)}{b^p}$$

thus, $d_m\omega \mid_1 < d_m\omega \mid_0$ for any subgame pooling equilibrium strategy $\{\omega^p, m^p\}$; while the intercept of profit function is $c \cdot b^p + \frac{C}{b^p}$, for high-skill fund managers, and $c \cdot b^p$, for low-skill ones.

Let us remark that, for relatively high fees and low promotion efforts (region μ^p of Figure 2), fund-managers earn non-negative profits independently of their skill: strategies in this region are candidate to be part of potential subgame pooling equilibria. For intermediate fees and promotion efforts below m^s (region $\mu = 0$), only low-skill fund-managers earn non-negative profits, while high-skill managers would incur in negative profits, thus strategies in this region are not compatible with subgame pooling equilibria. The same argument holds for intermediate fees and promotion effort above m^s (region $\mu = 1$), where low-skill fund managers would make negative profits and high-skill fund managers make non-negative profits. Finally, for low fees and relatively high promotion effort (blank region), no fund manager can operate and these strategies cannot be part of any equilibrium.

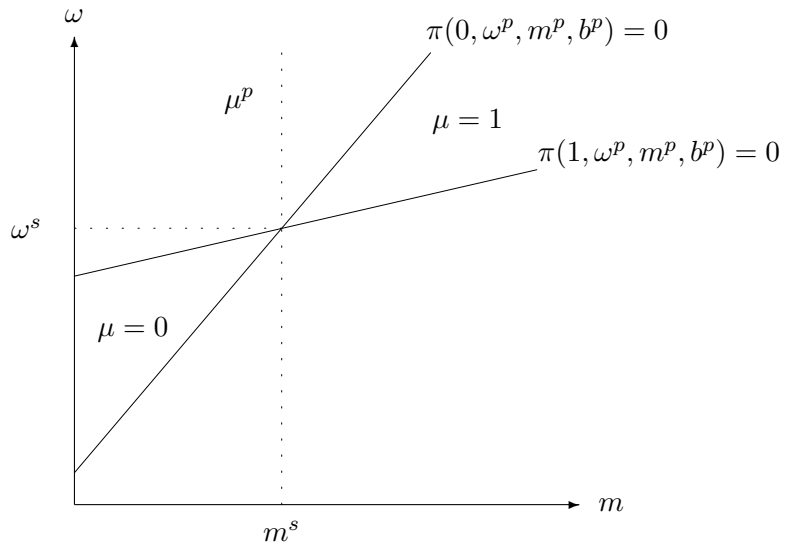

Figure 2: *Households' beliefs and fund managers' strategies*

With these specifications, we have

Lemma 3 *A pooling equilibrium of the subgame, made by stages two and three of the competitive market of pension funds, is never part of a perfect Bayesian equilibrium.*

Proof. See the Appendix. ■

The intuition of Lemma 3 is that a subgame pooling equilibrium cannot be part of the overall equilibrium of the market of pension funds, given that any fund manager, at the first stage, can deviate investing in skill and implementing, at the second stage, a fee-and-promotion subgame strategy in the region $\mu = 1$ of Figure 2. In other terms, investments in skill (at stage one) and promotion (at stage two) are complement.

3.2.2 Second-best market efficiency

In a subgame separating equilibrium, investment in promotion is useless for low-skill fund managers, hence they have no fixed costs. As already underlined, m^s is the promotion effort equalizing fixed costs of low- and high-skill. When fund managers implement such

level of effort, the minimum efficient scale of asset management is

$$b^s = \sqrt{\frac{C}{c} \cdot \left(1 + \frac{\gamma}{\delta}\right)}$$

and the fee covering the corresponding (minimum) average cost (which insures zero profits) is

$$\omega^s = 2\sqrt{c \cdot C \cdot \left(1 + \frac{\gamma}{\delta}\right)}$$

With these specifications, the following Lemma characterizes the necessary conditions for a subgame separating equilibrium to be part of an equilibrium of the market of pension funds.

Lemma 4 *If a separating equilibrium of the subgame, made by stages two and three of the competitive market of pension funds, is part of a perfect Bayesian equilibrium, then: fee-and-promotion subgame strategy is* $\{0, 0\}$*, for low-skill fund managers, and* $\{\omega^s, m^s\}$*, for high-skill ones; households' beliefs are* $\mu(0, 0) = 0$ *and* $\mu(\omega^s, m^s) = 1$*, on-the-equilibrium path, and*

$$\mu(\omega', m') = \begin{cases} 0 & if \quad \pi(0, \omega', m', b') > 0 > \pi(1, \omega', m', b') \\ \mu' \in [0, \bar{\mu}] & if \quad \pi(0, \omega', m', b') \geq 0 \quad and \quad \pi(1, \omega', m', b') \geq 0 \\ 1 & if \quad \pi(0, \omega', m', b') < 0 < \pi(1, \omega', m', b') \end{cases}$$

off-the-equilibrium path, where $\bar{\mu} = \min\left\{1, \frac{E(r|1) \cdot \frac{1-\omega^s}{1-\omega'} - E(r|0)}{E(r|1) - E(r|0)}\right\}$*; moreover, low-skill fund managers serve a trivial market share, and high-skill ones serve a market share* b^s*.*

Proof. See the Appendix. ■

The condition imposed by Lemma 4 on households' beliefs *out of the equilibrium* insures that households would not find profitable to choose a deviating fund manager to manage

their pension savings[17]. Therefore, fund managers do not find profitable to deviate, and - by this way - the consistency between equilibrium beliefs (in the subgame made by stages three and two) and fund managers' equilibrium strategies (namely, the choice of skill at stage one) is warranted.

By condition (1), in a subgame separating equilibrium at stages two and three households never choose low-skill fund managers, thus a perfect Bayesian equilibrium of the game must be such that at the first stage fund managers that enter the market invest in skill. By the same argument of Proposition 1, the sufficient and necessary condition for the existence of second-best efficient market equilibrium[18] is found (with $n^s < n^*$)

Proposition 5 *Under incomplete information and (1), a market equilibrium exists, with* n^s *high-skill fund managers, if and only if* $\frac{s}{b^s(1)} = n^s \in \mathbb{N}$.

Assuming that high-skill is always a worthy investment in social terms - condition (1), asymmetric information without any signaling technology determines a stark inefficiency result, by forcing high-skill managers (that necessarily have to bear fixed costs) out of the market. However, following the traditional idea of signaling models, some costly activities (here, promotion) can be undertaken by good managers to signal their capacity.

4 Efficiency-enhancing public policies?

In our model, market equilibrium is second-best efficient: signaling corrects fund managers' incentives under asymmetric information, enticing them to invest in skill. However, signaling involves a welfare loss with respect to complete information, that can be mea-

[17] The upper bound to the beliefs of households observing off-the-equilibrium path behaviors implies that $[\mu' \cdot E(r \mid 1) + (1-\mu') \cdot E(r \mid 0)] \cdot (1-\omega') \leq E(r \mid 1) \cdot (1-\omega^s)$. This *refinement* of the subgame separating equilibrium derives by the sequential rationality involved in the concept of perfect Bayesian equilibrium applied to the market of pension funds. Moreover, by condition (1), $\bar{\mu}$ is always strictly positive.

[18] Also under asymmetric information: equilibrium existence requires compatibility between minimum efficient scale and stable market configuration (i.e. a finite number of operating fund managers); an infinite multiplicity of (identical) equilibria are possible.

sured in terms of lost expected pension

$$\Delta E(p|_s^*) = E(p^*) - E(p^s) = E(r \mid 1) \cdot s \cdot (\omega^s - \omega^*) > 0 \tag{2}$$

with $\omega^s - \omega^* = 2 \cdot \sqrt{c \cdot C} \cdot \left(\sqrt{1 + \frac{\gamma}{\delta}} - 1\right)$; where $E(p^*) = E(r \mid 1) \cdot s \cdot (1 - \omega^*)$ is the expected pension in first-best market equilibrium and $E(p^s) = E(r \mid 1) \cdot s \cdot (1 - \omega^s)$ is the expected pension in second-best market equilibrium.

As stressed in the introduction, the efficiency loss determined by high administrative costs is rather relevant in terms of reduced rates of return on pension savings. As a consequence, economic policy debate on pension funds, in many countries, has particulary focussed on ways to reduce these losses, improving pension funds' performance. As argued, some solutions that have been suggested to enhance the market of pension funds rely on regulations of some aspects of competition among fund managers: cap to management fees; costs regulations, encompassing or hindering promotional activities; or restraints to pension funds' fees by setting up a public pension fund *competing* in the market with private ones[19].

What our simple model can say about these policy proposals? Before answering, it is worth remarking that much of the sound economics grounding the three considered proposals relies on the view that one of the sources of inefficiency of the market of pension funds is imperfect competition. From this point of view, regulating revenues or costs, or introducing a public competitor should enhance market competition tending towards first-best.

In this paper, we formalized an innovative view of the inefficiency disease of the market of pension funds, focusing on incomplete information[20]. There is no doubt that asymmetric information and imperfect competition both affect the working of the real-world market of

[19] A similar mechanism is operating, for example, in Sweden (Sundén, 2004) and it has been proposed for the UK (Turner *et al.*, 2006, chapter 10).

[20] The role of asymmetric information has sometimes been informally evoked in the debate on high costs of pension funds, e.g. Diamond (2000).

pension funds. Though the latter problem seems less deeply rooted: after all, pension funds are part of the wider class of financial markets, and a persistent (long run) situation of low contestability should find some political economy explanation. Conversely, asymmetric information seems to be intimately related to the very nature of funded pensions.

4.1 Inefficient fees or costs regulations

Our model affords an handful assessment of the welfare effect of the first two policy proposals: regulation of revenues or costs. Assuming that these policies are fully effective (say, all fund managers perfectly comply) and the constraints they introduce are binding (say, actually affect the market equilibrium), the two alternative regulations (fees or costs) produce the same effect: fund managers that, at the first stage, invest in skill would be prevented from signaling it to the market (by promotion). Constraints to management fees would restrain financing capacity and, hence, signaling; similarly, limitations to promotional activities would directly cap signaling expenditures. By Proposition 2, limitation to signaling would increase market inefficiency given that only low-skill fund managers would enter the market.

However, in a world of incomplete contracts, implementing regulations to management fees and promotional activities could bring to very different results, because of effectiveness of regulations and costs of enforcing them. Intuitively, capping management fees should be easier and more effective than preventing all possible activities that are related to promotion. Under such different setting, constraints to management fees are likely to be effective, hindering signaling and increasing market inefficiency. As regards limitations to expenditures for promotional activities (as marketing), fund managers may elude regulations and, thus, implementing signaling, reaching second-best efficiency (Proposition 5). In turn, this would imply that regulation is ineffective in curbing administrative costs or, even worst, regulations - by inducing fund managers to elusion practices - could increase the marginal cost of promotional activities (say, γ), and in turn could bring to second-best

efficient equilibria Pareto-dominated by the market of pension funds in absence of any public regulation of promotional activities.

Our model also suggests a possible direction to improve regulation and, thus, market efficiency affecting promotion technology. Given the cost technology of fund management and skill investment, the efficiency loss (2) is decreasing in the difference between the marginal cost of promotion for low- and high-skill fund managers (δ). As δ grows, market equilibrium tends to move towards first-best efficiency ($\Delta E(p|_*^s)$ decreases). A richer model would be necessary to investigate the potential role of government in the optimal (say, cost-minimizing) selection of signals by market players (Bernheim and Redding, 2001). To illustrate the intuition: promotional activities directly conveying (soft) information about fund manager skill should be allowed, and governmental authorities should control the correspondence between claimed and true data; promotional activities less directly related with the pension business should be discouraged, thus inducing an optimal selection of signals by high-skill fund managers. In our model, these mechanisms would completely solve the problem. In more complex settings and in the real world, public monitoring is costly and raises typical political economy concerns.

4.2 A public pension fund competing in the market

The third policy - the public pension fund, competing with private ones - requires to be more specific about the *skill of the public fund manager*. To illustrate, in the case of the Swedish market of pension funds, often considered a success case, the public pension fund plays a crucial role as default option for households: aiming at warranting low risk but also fairly good returns. Thus, the benchmark for the performance of the public fund manager is (legally) fixed at the top-25% rates-of-return of private funds (Sundén, 2004, p. 3). In our bare setting, this would be equivalent to consider that the public fund is set up to be high-skill!

Is such a policy *credible*? The answer hinges on people's confidence in the capacity of

the public institutions to pursue public interest. To catch this point, we need a simple theory of public institutions explicitly considering that there is a political agency problem and that households are aware of it. Households are assumed to know the ex ante probability that the public fund is benevolent (i.e. it implements a socially optimum policy), $\alpha \in [0, 1]$, representing the degree of credibility of such institution. Therefore, households expect that, with a probability $1 - \alpha$, the public fund is self-interested and maximizes the fund's profit[21]. Moreover, we assume that the nature of the public fund is determined before market competition begins and it can act as a Stackelberg leader.

4.2.1 Observable nature of public fund manager

As a benchmark, let us first consider that the nature of the public fund is observable. A benevolent public fund manager would always invest in skill, given that (1) holds, thus incurring in fixed costs C. Given that public fund type is observable, being public is a *credible* and *free* signal to the market, thus the public fund manager does not need investing in promotional activities. Moreover, the public fund will charge a fee that is always equal to its average costs[22], $\omega^g = c \cdot b^g + \frac{C}{b^g}$, and would choose its market share, b^g, to maximize the social welfare.

Private fund managers will play the same game they played in absence of the public fund, competing on the market share that is left after public fund chooses its optimal policy: $s - b^g$. Thus, if an equilibrium still exists, the only difference with the case of pure private market is in the number of operating private fund managers. Therefore, the best policy for the the (benevolent) public fund manager is to choose the market share, b^g, maximizing the social welfare or, equivalently, the total saving on management fees

$$b^g \cdot (\omega^s - \omega^g) = b^g \cdot \omega^s - c \cdot b^{g2} - C$$

[21] The underlying idea is that public pension fund profit is the stake that is divided between government's officials.

[22] We are here excluding, as it seems to be the case in reality, that the public fund is allowed to cover losses with transfers by government.

thus, the optimal policy for the benevolent public fund manager is $b^g = b^s$ and $\omega^g = c \cdot b^s + \frac{C}{b^s}$.

Given that a single public fund manager competing with private fund managers can efficiently serve just b^s, say $\frac{1}{n^s}$ of the entire market, the welfare effect of the introduction of the public fund, measured in terms of increase of the average (expected) pension with respect to the second-best in absence of it, is

$$\Delta E(p_s^{s+g}) = E(p^{s+g}) - E(p^s) = \frac{E(r \mid 1) \cdot s \cdot (\omega^s - \omega^g)}{n^s} > 0$$

with $\omega^s - \omega^g = \sqrt{c \cdot C} \cdot \frac{\gamma}{\sqrt{\delta} \cdot \sqrt{\delta + \gamma}}$; where $E(p^{s+g}) = E(r \mid 1) \cdot [b^s \cdot (1 - \omega^g) + (s - b^s) \cdot (1 - \omega^s)]$ is the (average) expected pension in the second-best market equilibrium with the public pension fund and $E(p^s) = E(r \mid 1) \cdot s \cdot (1 - \omega^s)$ is the expected pension in the second-best market equilibrium (without the public pension fund). $\Delta E(p_s^{s+g})$ increases as the market share, b^s, grows and the differential between marginal costs of promotion for low and high skill fund managers, δ, dwindles.

If the public fund is self-interested (and perceived as such by households) it will have the same incentives of other (private) fund managers. Thus, households would choose the public fund to manage their savings only if they receive credible signals that it invested in skill. Assuming that public and private financial and signaling technologies are similar, the only way to communicate this is by investing in promotion, thus increasing fixed costs. Therefore, the self-interested public fund manager would serve a market share b^s and would charge a fee ω^s as other fund managers.

4.2.2 Unobservable nature of the public fund manager

Let us turn to consider the main case in which households cannot observe the type (benevolent or self-interested) of the public fund manger, but have an exogenous belief - say, linked to the working of the political system and public institutions - about the probability that

it is benevolent, α. Then, the following result can be established

Proposition 6 *Under incomplete information and (1), a competitive market of pension funds with a public pension fund weakly Pareto-dominates a market without it.*

Proof. See the Appendix. ■

The intuition of the proof is that the self-interested public fund manager would mimick the benevolent one, by offering a contract with a fee ω^g and zero promotion, and would not invest in skill. Households rationally anticipate this, but as far as the probability that the public fund manager is benevolent is sufficiently high, say above the threshold

$$\bar{\alpha} = \frac{E(r \mid 1) \cdot \frac{1-\omega^s}{1-\omega^g} - E(r \mid 0)}{E(r \mid 1) - E(r \mid 0)}$$

(that takes values between zero and one, whenever (1) holds), the expected pension that the public fund provides, considering the uncertainty about the institutional nature of it, is higher than the one of private fund managers. Thus, for $\alpha \geq \bar{\alpha}$ the introduction of a public fund in the competitive market of pension funds (weakly) improves the expected pension (and, hence, expected social welfare).

When $\alpha < \bar{\alpha}$, the expected pension of the public fund is lower than private ones, hence households would choose private fund managers, and the only strategy that the public fund can implement to attract pension savings - independently of its type - is to signal investment in skill through promotion. Hence, for a low level of credibility of the public fund, this policy tool cannot improve expected social welfare but it does not worsen it. Therefore, the expected improvement in social welfare

$$\Delta E(p_s^{s+g}|\alpha) = \begin{cases} \Delta E(p_s^{s+g}) - (1-\alpha) \cdot \frac{(E(r|1)-E(r|0)) \cdot s \cdot (1-\omega^g)}{n^s} & \alpha \geq \bar{\alpha} \\ 0 & \alpha < \bar{\alpha} \end{cases}$$

declines with public fund credibility, reaching a minimum of zero for $\alpha \leq \bar{\alpha}$.

Contrary to what we observed in the case of price or cost capping, a public pension fund - also taking into account political agency problems - may improve the social welfare by restraining management fees. Furthermore, competition between public and private funds affords households an effective tool to keep their pension at least at the same level that the competitive market of pension funds would reach in absence of the public fund.

However, the capacity of the public fund to improve social welfare is limited by the second-best efficient market share. The way the public pension funds affords a Pareto-improvement in the competitive market of pension funds, say by reducing the management fees without limiting too much the expected return (related to political agency concerns), brings us to the following consideration: efficiency could be enhanced even more by multiplying the number of public pension funds, thus allowing them to operate at their minimum efficient scale (given that fixed costs exclude promotion), b^*, that in turn would restrain management fees at their minimum efficient level (for fund managers that invested in skill), ω^*.

Moreover, the public pension fund improves social welfare just by substituting one of private pension funds that, because of the signaling game, may be more costly whereas the public pension fund could rely on public institution credibility (if sufficiently high) to avoid costly investments in signalling. Along these considerations we would reach the provocative view of a quasi-market of pension funds: say, a *de facto* nationalization by substituting private funds with multiple public funds competing among each others! The assessment of this view would require a thorough investigation of the working of public institutions that is out of the reach of our analysis.

4.3 A quasi-competitive pension scheme

All considered proposals fail to intervene on the very mechanism generating high costs and fees: bad incentives created by competition among fund managers to *attract* contributions (Acemoglu *et al.*, 2003). All FF pension schemes based on individual accounts, requiring

households to choose their fund manager, foster costly signaling too.

A radically different approach to solve the problem of incentive selection is explored in this section. The *quasi-competitive pension scheme* is based on the idea that public institutions may have enhanced contracting technologies with respect to single households. Again we assess this intuition in a framework explicitly taking into account that public institutions are affected by political agency problems and that commitment capacity may be limited.

The quasi-competitive pension scheme is structured as follows:

1. All households are enrolled in a public pension scheme managed by a national agency that collects households' pension savings, s, and allocate the rights to manage a number of predetermined shares of them to private fund managers through a public procurement mechanism.

2. Private fund managers observe the public procurement mechanism and decide whether to participate or not and their investment in skill.

3. Households may opt out of the public scheme and allocate their pension savings directly to private fund managers operating on a competitive market.

The underlying assumption of the quasi-competitive scheme is that the national agency can design a mechanism allocating collected savings to private fund managers participating to the public procurement mechanism, involving a payment that can be linked to the long-term performance of fund managers[23]. Here is the major divide between the competitive market of pension funds and the quasi-competitive pension scheme: private fund managers (competing to attract pension savings) cannot write credible contracts with workers to link their fees to asset management performance[24], in bad contingencies (r low) they would

[23] An equivalent way to put it is to consider that government can tax with sufficiently rich instruments the private managers operating on the market.

[24] Or, equivalently, high-skill fund managers cannot design credible contracts allowing them to signal their skill through management fees instead of promotion (that would reduce the main source of pension-fund market inefficiency).

fail and households' pension would necessarily be determined as residual claim (i.e. gross return on invested assets less operating and fixed costs of failed manager).

Conversely, the national agency is able to design contracts with single fund managers allowing also for their default, given that it is able to pool such risks and compensate them on aggregate. In other terms, the national agency is able to commit to optimal payment functions linking the contingent profit of fund managers to their performance; as a consequence, some fund managers fail in some states of the world and the national agency is the residual claimant of failed fund managers.

In the following, we consider three potential limits affecting the capacity of the national agency to improve the social welfare, with respect to the competitive market of pension funds. As first, the capacity of the national agency to rely on tax-financed revenues is limited by the fact that each unit of tax revenues (that, in this setting, finances private fund managers' profits) has a social marginal cost equal to $1 + \phi$, with $\phi > 0$ (because of taxation distortion and/or different social weighting of private profits with respect to consumers' surplus). Moreover, the functioning of the national agency is affected by a political agency constraint: again in the form of exogenous probability that the national agency is benevolent, α; thus, with probability $1 - \alpha$, the national agency is captured by the sector of the fund managers and pursue the task to maximize their aggregated profits. Finally, the national agency capacity to link the payment function rewarding fund managers to their performance may be limited by commitment problems.

4.3.1 Observable nature of the national agency

A benevolent national agency will adopt an optimal mechanism implementing the social optimum under the information and taxation constraints (assuming away commitment problems). The national agency maximizes a social welfare function given by the sum of households' expected welfare and private fund managers' expected profits, net of the cost of taxation. By condition (1), the optimal mechanism has to induce some fund

managers' to participate and to invest in skill: the first-best optimal number of (high-skill) fund managers is $n^* = \frac{s}{b^*}$, where b^* is the efficient operative scale of pension-savings management[25].

The public procurement mechanism implies a payment from the national agency to each fund manager, $i \in \mathcal{I}$, actually managing a lot b^* of pension savings that, without loss of generality, we assume made by two parts: a fixed part covering variable and fixed costs, $c \cdot b^{*2} + C$[26], that is observable and verifiable, and a variable part that depends on fund managers' performance, $\tau_i(\mathbf{r})$ (with $\mathbf{r}$ the vector of rates of return obtained by fund managers), that we assume unverifiable.

The non-contingent part of public procurement payment covers total costs of fund managers that invested in skill, thus the net contingent profit of each fund manager is given by $\pi(\mathbf{r}, \theta_i) = C - C(\theta_i) + \tau_i(\mathbf{r})$. Therefore, whenever the performance of a fund manager that invested in skill implies that the performance-related payment is negative, the concerned fund manager fails and its assets and liabilities are taken by national agency acting as residual claimant.

Under these specifications, the program of the national agency is[27]

$$\begin{aligned} \max_{\{\tau_i(\mathbf{r})\}_{i\in\mathcal{I},\mathbf{r}\in\mathcal{R}_+^{n^*}}} & \sum_{i\in\mathcal{I}} b^* E(r_i \mid \mathbf{1}) \cdot (1-\omega^*) - \phi \cdot \sum_{i\in\mathcal{I}} E(\tau_i(\mathbf{r}) \mid \mathbf{1}) \\ & s.t. \\ & E(\tau_i(\mathbf{r}) \mid \mathbf{1}) \geq 0 \qquad \forall i \in \mathcal{I} \\ & E(\tau_i(\mathbf{r}) \mid \mathbf{1}) \geq C + E(\tau_i(\mathbf{r}) \mid 0, \mathbf{1}_{-i}) \qquad \forall i \in \mathcal{I} \end{aligned} \tag{3}$$

[25] Whenever the mechanism is able to correctly induce self-selection of fund managers, it is well possible that more than n^* high-skill fund managers apply to manage a part of pension savings. In such a case, we assume that government randomly select just n^* fund managers. In the following, we just exclude this situation and let $\mathcal{I}$ be the optimal set of fund managers that participate to the public procurement mechanism.

[26] To illustrate, this part is subtracted by pension savings and is paid before the fund manager performance is known.

[27] To lighten the notation let $E(. \mid \mathbf{1}) = \int_0^\infty ... \int_0^\infty (.) \cdot \prod_{j\in\mathcal{I}} f(r_j|1) \cdot dr_j$ and $E(. \mid 0, \mathbf{1}_{-i}) = \int_0^\infty ... \int_0^\infty (.) \cdot \prod_{j\in\mathcal{I}/\{i\}} f(r_j|1) \cdot dr_j \cdot f(r_i|0) \cdot dr_i$.

where the first constraint insures participation of fund managers that invested in skill, and the second constraint insures incentive-compatibility. By the first order conditions of the program, the first constraint is always binding and the second constraint is never, thus the national agency does not extract - on average - tax revenues to finance the mechanism.

The mechanism designed by the national agency implements the first best Pareto-efficient allocation, thus households would never opt out of the public scheme. Given the allocation mechanism underlying the public procurement scheme, that is trivially determined by the simple structure of the problem, many different payment functions can implement it.

What happens when the national agency is self-interested (and households observe it)? Now the agency is willing to extract the maximum surplus by the households, thus the participation constraints of the latter are binding: unless the national agency designs a policy that credibly provides households with at least the same pension they would get in the competitive market, they would opt out of the public scheme. But, as investment in skill is not verifiable, assuming that a self-interested national agency has no way to prove that the designed public procurement mechanism induces the right level of investment in skill, households would always opt out.

4.3.2 Unobservable nature of the national agency

Let us turn to consider the case in which the national agency continues to face no limitation as regards commitment capacity, but its very nature (benevolent or self-interested) is no more observable or verifiable. Thus we have

Proposition 7 *Under incomplete information and (1), a quasi-competitive pension scheme weakly Pareto-dominates a competitive market of pension funds (with or without a public pension fund).*

Proof. See the Appendix. ■

Now, the self-interested national agency may mimick the benevolent one, by consequently choosing the observable features of the public procurement mechanism. As argued, the contingent part of the payment is assumed to be non-verifiable. Therefore, the self-interested national agency chooses n^* fund managers with profit function $\pi(\mathbf{r}, \theta_i) = C - C(\theta_i) + \tau_i(\mathbf{r})$. In this case, the objective function of the national agency is defined as the difference between the total profit of pension fund managers and the total cost of taxation, hence: $\sum_{i\in\mathcal{I}}(C - C(\theta_i)) - \phi \cdot \sum_{i\in\mathcal{I}} E(\tau_i(\mathbf{r}) \mid \theta)$.

Given the number of fund managers and the investment in skill that the optimal contract induces, also for the self-interested national agency it is an optimal policy to reduce as much as possible the expected cost of taxation, namely to put it to zero. However, the public agency does not implement the optimal investment in skill given that it would entail a cost that, in the objective function of the self-interested public agency, does not yield any benefit.

Also in this case, households anticipate this behavior of the self-interested national agency and they nevertheless prefer to remain in the public scheme if the expected pension so determined is higher than the one offered on the competitive market of pension funds. This happens for a sufficiently high probability that the national agency is, actually, benevolent. Let

$$\tilde{\alpha} = \frac{E(r \mid 1) \cdot \frac{1-\omega^s}{1-\omega^*} - E(r \mid 0)}{E(r \mid 1) - E(r \mid 0)}$$

be the threshold level of public institution's credibility such that for higher values, households remain in the public scheme and for lower levels they opt out. $\tilde{\alpha}$, takes values between zero and one whenever (1) holds. When the credibility is low ($\alpha < \tilde{\alpha}$) the national agency, either benevolent or self-interested has no credible strategy to convince households that the designed mechanism affords a proper selection of incentives for fund managers inducing investment in skill.

The capacity of the quasi-competitive pension scheme to outperform the market of pension funds, also in the case this is improved by a public pension fund, relies on the capacity of the national agency to determine an optimal sharing of pension savings among fund managers thus exploiting the efficiency gains of reaching minimum efficient scales of fund management. The expected gain in terms of pension is

$$\Delta E(p^p_{s+g}|\alpha) = \begin{cases} \Delta E(p^*_s) - (1-\alpha)\cdot(E(r|1) - E(r|0))\cdot s\cdot(1-\omega^*) - \Delta E(p^{s+g}_s|\alpha) & \alpha \geq \bar{\alpha} \\ \Delta E(p^*_s) - (1-\alpha)\cdot(E(r|1) - E(r|0))\cdot s\cdot(1-\omega^*) & \alpha \in [\tilde{\alpha}, \bar{\alpha}) \\ 0 & \alpha < \tilde{\alpha} \end{cases}$$

Given that ω^g, the fee chosen by the public fund competing with the private ones is not the minimum efficient fee (because the market size is not the minimum efficient one), say ω^*, that conversely is applied by the national agency in the framework of the quasi-competitive pension scheme, then it can easily be checked that $\bar{\alpha} > \tilde{\alpha}$. In other terms, the credibility of the public institutions with respect to the objective of pursuing the public interest that is required by a quasi-private pension scheme is lower than what is needed to the public fund competing in the private market to afford an increase of the expected pension (thus, an improvement of the social welfare).

The result is rather intuitive given that the quasi-competitive mechanism relies on the full power of the public mechanisms, while the public fund is a rather restrained policy tool. Thus, for high credibility levels the public scheme Pareto-dominates a market that optimally allows for a public pension fund competing with private ones. For intermediate credibility levels ($\alpha \in [\bar{\alpha}, \tilde{\alpha})$), a public pension fund cannot improve on a pure private market of pension funds but the public scheme does. And for low credibility levels, the quasi-competitive scheme cannot improve on the market of pension funds: the expected pension of the public scheme is low and people opt out.

4.3.3 Introducing commitment constraints

Proposition 7 is grounded on the assumption that the national agency within a quasi-competitive mechanism can perfectly commit to the optimal payment functions. In real world, public procurement mechanisms are often affected by time consistency, renegotiation, or collusion concerns. In the following, we focus on two limits related to time-consistency of optimal payment functions. As first, government (through the national agency) could be ex post concerned with the fact that too many fund managers may fail in some particularly averse contingencies, and thus could deviate from the optimal payment if it involves allowing such failures. In a long run perspective, fund managers and households would anticipate such time-inconsistent behavior and, in turn, a truly optimal payment function should be robust against it. Conversely, if the optimal payment function involves high payments in some contingencies, government could ex post consider it too much generous. Again, fund managers would anticipate it.

Introducing commitment problems may reduce the capacity of the quasi-competitive mechanism of outperforming the competitive market of pension funds. To illustrate this issue, in this section we consider an extreme case of commitment limits to the public scheme: as first, the national agency cannot credibly act as residual claimant, thus the payment function has always to afford non-negative contingent profits to fund managers; moreover, contingent profits of fund managers are limited by an upper non-contingent bound, $\bar{\tau}$. It is worth to remark that, by introducing the considered lower bound, the contracts that the national agency is able to implement through the public procurement mechanism have the same limitation featuring contracts between pension funds and households in the competitive market.

Therefore, the program (3) of the benevolent national agency has to satisfy two addi-

tional constraints[28]

$$\tau_i(\mathbf{r}) \geq 0 \tag{4}$$

$$\bar{\tau} \geq \tau_i(\mathbf{r}) \tag{5}$$

for all $i \in \mathcal{I}$ and $\mathbf{r} \in \mathcal{R}_+^{n^*}$. By the first order conditions of this new program the participation constraint is proven to be always non-binding ($E(\tau_i(\mathbf{r}) \mid \mathbf{1}) > 0$) and the incentive constraint to be always binding ($E(\tau_i(\mathbf{r}) \mid \mathbf{1}) = C + E(\tau_i(\mathbf{r}) \mid 0, \mathbf{1}_{-i})$), because of the commitment constraint (4) - see Lemma 9 in the Appendix.

The commitment constraints (namely, the lower bound) involve an efficiency loss with respect to the first best due to the fact that the incentive constraint of the program (3), under the commitment constraint (4), is always binding and requires a non-binding participation constraint, that in turn involves net tax-financing to the scheme, to provide positive profits to fund managers participating to public procurement.

As a consequence, the scope for a welfare enhancing quasi-competitive scheme is reduced, because of a divergence between the net benefit of the public scheme perceived by future pensioners, say the expected pension

$$(\alpha \cdot E(r|1) + (1-\alpha) \cdot E(r|0)) \cdot s \cdot (1-\omega^*)$$

and the net benefit for society as a whole, that is equal to the expected pension net of taxes

$$(\alpha \cdot E(r|1) + (1-\alpha) \cdot E(r|0)) \cdot s \cdot (1-\omega^*) - \alpha \cdot \phi \cdot n^* \cdot E(\tau^*(\mathbf{r})|\mathbf{1}) \tag{6}$$

where $E(\tau^*(\mathbf{r})|\mathbf{1})$ is the optimal expected payment solving the program (3) under constraints (4) and (5).

[28]The program of the self-interested national agency is not modified given that it has no interest in provide incentives to fund managers to invest in skills.

Unless we consider that taxes financing the public procurement payment are collected only from households enrolled in the public scheme (and that they rationally understand it), they continue to consider profitable to stay in the public scheme as far as the credibility of the national agency is above $\tilde{\alpha}$, and to opt out when it is below this level. However, for credibility of national agency managing the public scheme below[29]

$$\tilde{\alpha}^c = \frac{E(r \mid 1) \cdot \frac{1-\omega^s}{1-\omega^*} - E(r \mid 0)}{E(r \mid 1) - E(r \mid 0) - \phi \cdot \frac{E(\tau^*(\mathbf{r})|\mathbf{1})}{b^* \cdot (1-\omega^*)}}$$

the net social welfare is lower than what is obtained through the competitive market of pension funds, $E(r|1) \cdot s \cdot (1-\omega^*)$. Let us observe that $\tilde{\alpha}^c > \tilde{\alpha}$ whenever the marginal cost of taxation is higher than one ($\phi > 0$). Therefore, for all $\alpha \in (\tilde{\alpha}, \tilde{\alpha}^c)$ the quasi-competitive scheme under commitment constraints strictly reduces the expected social welfare as compared to the market of pension funds, while for higher public credibility the expected social welfare increases and for lower public credibility households opt out of the public scheme. Hence, Proposition 7 does no more hold: the quasi-competitive scheme does not Pareto-dominate (nor it is Pareto-dominated by) the market of pension funds.

The mechanics of such negative results, that is determined by the divergence between private benefits of future pensioners and social welfare, suggest a *minor* amendment to the quasi-competitive scheme restoring our main result established in Proposition 7: let the performance-related payment be financed just by households enrolled in the public scheme, say as an extension of management fees. Under this specification, the net benefit that households obtain from the public scheme becomes

$$(\alpha \cdot E(r|1) + (1-\alpha) \cdot E(r|0)) \cdot s \cdot (1-\omega^*) - \alpha \cdot (1+\phi) \cdot n^* \cdot E(\tau^*(\mathbf{r})|\mathbf{1}) \tag{7}$$

[29]For the sake of simplicity we just consider that the alternative is the competitive market of pension funds, without any public fund competing in it. Let us also remark that, for $\phi \cdot n^* \cdot \bar{\tau} \leq \Delta E(p_s^*)$ (where $\phi \cdot n^* \cdot \bar{\tau}$ is the maximum tax cost of the performance-related payment), $\tilde{\alpha}^c < 1$ hence the public procurement mechanism improves on the competitive market for some feasible α.

the entire cost[30] of additional financing to the public procurement scheme is borne by future pensioners. Therefore, now households out out of the public scheme for credibility levels below

$$\tilde{\alpha}^C = \frac{E(r \mid 1) \cdot \frac{1-\omega^s}{1-\omega^*} - E(r \mid 0)}{E(r \mid 1) - E(r \mid 0) - (1+\phi) \cdot \frac{E(\tau^*(\mathbf{r})|\mathbf{1})}{b^* \cdot (1-\omega^*)}}$$

Let us remark that $\tilde{\alpha}^C > \tilde{\alpha}^c$: for credibility levels between these two values, the expected social welfare could be increased, with respect to the quasi-competitive scheme, by another mechanism forcing households to stay in the public scheme. However, the most important point is that for these values the market of pension funds delivers a worst result. Therefore, the Proposition 7 is restored: restricting the financing of the payment function to be supported just by future pensioners, the quasi-competitive mechanism again weakly Pareto-dominates the market of pension funds.

5 Conclusion

The economic literature on mandatory funded pensions has informally argued that high administrative costs of pension funds based on individual accounts originate by imperfect competition and asymmetric information. On this ground, policy proposals have been suggested aiming at restraining the rise of costs and fees (by directly limiting fees and costs or by increasing the competitive pressure through a public pension fund). Imperfect competition may be rather relevant to explain this phenomenon in the start up phase of markets of pension funds. However, in the long run it seems that this financial sector should converge towards a competitive setting. The empirical assessment of this prediction is still poor and further research is probably required on this point. Nevertheless, existing empirical analysis on the structure and determinants of administrative costs and fees

[30] Here ϕ represents higher weight that a benevolent national agency would attribute to the consumers' surplus, with respect to private funds' profits, rather than efficiency costs of taxation.

seems to show that imperfect competition is only a part of the story, probably not the most important one.

To explore the role of incomplete information in determining high costs and fees of pension funds, we considered a model in which fund managers' management skill is not observable or verifiable. In this setting, a competitive market of pension funds fails to reach first-best. If good managers cannot signal their capacity to the market, a stark version of the traditional lemon-market argument applies: only bad managers stay on the market in equilibrium, given that good fund managers are unable to cover fixed costs of investment in skill. If good managers are able to signal their skill through some costly promotional activity (as we observe in real-world markets of pension funds), then the efficiency of market equilibrium improves, though first-best cannot be reached because of deadweight losses determined by promotion costs.

On this ground, policies directly restraining management fees or costs are deemed to increase market inefficiency, rather than reducing it. Conversely, also taking into account political agency problems, a public fund competing in the market of pension funds is likely to improve the social welfare, by reducing management fees for the portion of the market it is able to serve. However, this solution is limited by the fact that public-private competition hinders an optimal management scale for the public pension fund. Then, we considered a radically different approach relying on the observation that the main problem of the pension funds' market is related to the competition for pensions' contribution attraction.

We defined a quasi-competitive scheme which is conceived as a tool to select fund managers' incentives, relying on the full power of collective mechanisms. A national agency is charged to collect pension savings and to allot them to private fund managers through a public procurement mechanism. Fund managers, then, decide to participate or not and whether they invest in skill. Finally, households may opt out of the public scheme, which insures that the results obtained in it cannot drop below what the market could

deliver. Our main result is that this quasi-competitive pension scheme determines an higher (or not lower) social welfare than the market of pension funds also taking into account political agency and commitment problems. As argued with a simple example, commitment issues are very important to correctly design the functioning of the public procurement mechanism and afford an effective mechanism that is likely to improve on the market of pension funds. However, we argued that this - as the political agency problem - is not a prohibitive constraint on the way of the optimal design of funded pensions, though first best results are, in general, unreachable.

Admittedly, our bare analysis leaves unexplored many important issues. Two crucial extensions should focus on the analysis of dynamics and of the way moral hazard affects asset management (after fund skill has been determined). As regards model dynamics, one could imagine that the mere repetition of the game could create a scope for reputation equilibria: high-skill fund managers could signal their capacity by the simple observation of past rates of return. This intuitive result could not be robust to two features of the considered market: first, investment in skill has to be repeated during time rather often (e.g. investments to keep an high management standard); moreover, this feature is likely to foster entrance of new fund managers as far as profits arise on the market.

Another related issue is that fund managers' signals passing through the very fund management policy, say the rate of return, is affected by problems similar to the one analyzed in this paper: fund managers may be very interested in providing the right (short term) signal to the market, e.g. beating the (short term) financial benchmark, and they could waste some opportunities in a longer run perspective. Considering a similar problem, Prat (2005) underlines the role of commitment in incentive selection.

An important implication of our analysis is about the public service nature of mandatory private pensions. The privatization of the mandatory scheme of funded pension is limited by market failure. Namely, asymmetric information affects the functioning of the competitive market of pension funds very deeply. Trying to solve this problem - be

it through heavy regulations of the market of pension funds or through a full-fledged public-private mechanism as the one proposed here - necessarily requires to set up public institutions and rules that, by their very nature, are exposed to the interference of the political system. Which is always intimately true for any public service. Failure to consider the public nature of private pensions brings to overlook the potentially devastating relevance - in terms of economic and fiscal risks - of implicit contingent liabilities that the working of a pension system (be it private or public) involves for the public sector and the whole society.

Appendix

Lemma 8 *Under complete information, if a market equilibrium exists, all fund managers price at their marginal costs; moreover: (1) each low-skill fund manager serves a trivial market share* $b(0) = 0$*; (2) each high-skill fund manager serves the minimum efficient market share* $b(1) = b^*$.

Proof. All fund managers operating on the market in equilibrium earn zero profits, otherwise - at the first stage - other fund managers would enter undercutting them. Thus, low-skill fund managers, in equilibrium, serve a trivial market share - which implies marginal cost pricing, and high-skill fund managers price at their average cost. Remark that, by assumption, $C < c \cdot s^2$, hence $b^* < 1$. Assume, by contradiction, that (at least) the high-skill fund manager $i \in I_c$ has a market share $b_i \neq b^*$. If $b_i > b^*$, the average cost is higher than the minimum. Then, another high-skill fund manager, j, may enter the market and make positive profits: offering a contract to a rationed market share $\bar{b}_j \in [b^*, b_i)$, at a fee $\omega_j \in (c \cdot \bar{b}_j + \frac{C}{\bar{b}_j}, \omega_i)$. Assume, now, that $b_i < b^*$: the average cost is higher than the minimum. If at least another high-skill fund manager j operating on the market has $b_j < b^*$, with fee $\omega_j = c \cdot b_j + \frac{C}{b_j}$, she can make positive profits by an appropriate reduction of her fee, thus attracting a portion of the market share of i. Assume that all fund managers but i operate at the minimum efficient scale (b^*). Then, households served by i (at an higher fee) would opt for others but are rationed: any other high-skill fund manager can make positive profits by increasing fee and widening her market share. Thus, in equilibrium, $b(1) = b^*$ and also high-skill fund managers price at the marginal cost. ■

Proof of Proposition 1. By Lemma 8, low- and high-skill fund managers price at their marginal cost, hence by (1) households always opt for the latter ones that uniformly share the market among them. The sufficient condition is straightforward. For the necessary condition, if $\frac{s}{b^*}$ is not an integer the equilibrium does not exist. Assume, by

contradiction, that it exists: let n^{**} be the (integer) number of high-skilled fund managers operating on the market. By Lemma 8, high-skill fund manager price at their marginal (and average minimum) cost and serve the minimum efficient market share; hence necessarily $n^{**} < \frac{s}{b^*}$, implying that a non-trivial mass $s - n^{**} \cdot b^*$ of households would remain unsatisfied. Thus, any incumbent fund manager could raise her fee and serve the remaining market share. ■

Proof of Lemma 3. Assume, by contradiction, that a subgame pooling equilibrium in stages two and three is part of a perfect Bayesian equilibrium of the competitive market of pension funds. In equilibrium all fund managers earn zero profits, that implies $m^p = m^s$, otherwise the subgame pooling strategy would imply different profits for fund managers with different skills. By the same arguments of Lemma 8, b^p is equal to the minimum efficient scale $\sqrt{\frac{C}{c} \cdot \left(1 + \frac{\gamma}{\delta}\right)}$. However, this cannot be part of a market equilibrium, given that, at the first stage, a fund manager could deviate and make positive profits: entering the market, investing in skill and credibly implementing a strategy $\{\omega', m'\}$ in the neighborhood of $\{\omega^p, m^p\}$ - such that b' is the corresponding minimum efficient scale, and $\pi(1, \omega', m', b') > 0 > \pi(0, \omega', m', b^p)$, thus convincing households that she invested in high skill. ■

Proof of Lemma 4. In a subgame separating equilibrium, high-skill fund managers implement a promotion effort m^s: a lower effort would afford profitable deviations for low-skill fund managers mimicking high-skill; a higher effort would afford profitable deviations for high-skill fund managers undercutting incumbents. Then, fee and market share derive as in Lemma 8. As regards households' beliefs, the condition on beliefs *out of the equilibrium* insures that households would never choose a deviating fund manager proposing them a fee $\omega' < \omega^s$ (i.e. $[\mu' \cdot E(r \mid 1) + (1 - \mu') \cdot E(r \mid 0)] \cdot (1 - \omega') \leq E(r \mid 1) \cdot (1 - \omega^s)$), otherwise a low-skill fund manager could make positive profits by proposing a deviation

with $\{\omega', m'\}$ in a suitable neighborhood of $\{\omega^s, m^s\}$. ■

Proof of Proposition 6. Let us consider, first, that at the incomplete information equilibrium a benevolent public fund manager implements its complete information equilibrium strategy (investing in skill at the first stage, and choosing ω^g and zero promotion at the second stage), and households are willing to choose the public fund. Then a self-interested public fund manager would mimick the benevolent one at the second stage without investing in skill at the first stage. This is an equilibrium if and only if

$$(\alpha \cdot E(r|1) + (1-\alpha) \cdot E(r|0)) \cdot s \cdot (1-\omega^g) \geq E(r|1) \cdot s \cdot (1-\omega^s)$$

or $\alpha \geq \bar{\alpha}$, with

$$\bar{\alpha} = \frac{E(r \mid 1) \cdot \frac{1-\omega^s}{1-\omega^g} - E(r \mid 0)}{E(r \mid 1) - E(r \mid 0)}$$

When $\alpha < \bar{\alpha}$ households are not willing to choose the public fund unless it signals it invested in skill at the first stage. Both benevolent and self-interested fund manager can signal it just by investing in promotion as private fund managers. ■

Proof of Proposition 7. Let us consider, first, the market without the public fund. Remark that households do not opt out of the public scheme if and only if

$$(\alpha \cdot E(r|1) + (1-\alpha) \cdot E(r|0)) \cdot s \cdot (1-\omega^*) \geq E(r|1) \cdot s \cdot (1-\omega^s)$$

or $\alpha \geq \tilde{\alpha}$, with

$$\tilde{\alpha} = \frac{E(r \mid 1) \cdot \frac{1-\omega^s}{1-\omega^*} - E(r \mid 0)}{E(r \mid 1) - E(r \mid 0)}$$

When $\alpha < \tilde{\alpha}$ households opt out. Now remark that, for any α the net revenue provided by

the national agency for each unit of managed savings $((\alpha \cdot E(r|1)+(1-\alpha)\cdot E(r|0))\cdot(1-\omega^*))$ is strictly higher than the one of the public fund competing in the market $((\alpha \cdot E(r|1) + (1-\alpha)\cdot E(r|0))\cdot(1-\omega^g))$. ■

Lemma 9 *Under incomplete information and (1), and assuming that the national agency is constrained by (4), the optimal payment function is such that:* $E(\tau_i(\mathbf{r}) \mid \mathbf{1}) > 0$ *and* $E(\tau_i(\mathbf{r}) \mid \mathbf{1}) = C + E(\tau_i(\mathbf{r}) \mid 0, \mathbf{1}_{-i})$*, for all* $i \in \mathcal{I}$*.*

Proof. If $E(\tau_i(\mathbf{r}) \mid \mathbf{1}) = 0$, by constraint (4) it follows that $\tau_i(\mathbf{r}) = 0$ for all $\mathbf{r} \in \mathcal{R}_+^{n^*}$, then also $E(\tau_i(\mathbf{r}) \mid 0, \mathbf{1}_{-i}) = 0$, implying $E(\tau_i(\mathbf{r}) \mid \mathbf{1}) < C + E(\tau_i(\mathbf{r}) \mid 0, \mathbf{1}_{-i})$. Therefore, $E(\tau_i(\mathbf{r}) \mid \mathbf{1}) > 0$. Let us consider the generic first order condition of the program (3) under constraint (4)

$$-\phi \cdot \prod_{j\in\mathcal{I}} f(r_j|1) + \varepsilon_i \cdot \prod_{j\in\mathcal{I}} f(r_j|1) + \eta_i \cdot (f(r_i|1) - f(r_i|0)) \cdot \prod_{j\in\mathcal{I}/\{i\}} f(r_j|1) + \upsilon_i(\mathbf{r}) - \psi_i(\mathbf{r}) = 0$$

for any $i \in \mathcal{I}$ and any $\mathbf{r} \in \mathcal{R}_+^{n^*}$; with $\varepsilon_i \geq 0$, $\eta_i \geq 0$, $\upsilon_i(\mathbf{r}) \geq 0$, $\psi_i(\mathbf{r}) \geq 0$ the Lagrangian multipliers of respectively the participation constraint, the incentive constraint, and constraints (4) and (5) in program (3). By $E(\tau_i(\mathbf{r}) \mid \mathbf{1}) > 0$, $\varepsilon_i = 0$, then summing first order conditions over $\mathbf{r}$ and dividing the generic first order condition by $\prod_{j\in\mathcal{I}} f(r_j|1)$

$$\eta_i \cdot Big(1 - \frac{f(r_i|0)}{f(r_i|1)}\Big) = \phi - \upsilon_i(\mathbf{r}) + \psi_i(\mathbf{r})$$

If $\eta_i = 0$ then $\upsilon_i(\mathbf{r}) - \psi_i(\mathbf{r}) = \phi > 0$ for all $\mathbf{r} \in \mathcal{R}_+^{n^*}$ that is incompatible with incentive constraint. Thus, $\eta_i > 0$, and the incentive constraint is binding. ■

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