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Andrés Dean
Universidad de la República

Sebastian Fleitas
University of Leuven and CEPR

Mariana Zerpa
University of Leuven and IZA

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IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Dynamic Incentives in Retirement Earnings-Replacement Benefits*

Many defined-benefit pension systems in developed and developing countries use a small set of final years of earnings to compute pension benefits. This provides dynamic incentives to report higher earnings in the final years of the career. In this paper, we document the responses of self-employed and employed workers to these incentives, using social security administrative records and household surveys from Uruguay. We implement event studies that leverage the use of a 10-year benefit-calculation window, combined with the discrete change in the probability of retirement at the minimum retirement age. We find that reported earnings of self-employed workers and employees of small firms start increasing sharply 10 years prior to minimum retirement age, reaching a 3% increase on average. This is not the case for employees of large firms, where earnings underreporting is less prevalent. These responses are not explained by changes in total earnings or hours of work, as reported in household surveys, suggesting a change in reporting behavior. Back of the envelope calculations for the self-employed bound the cost of these responses between 1.9% and 2.6% of the total cost of pensions for this group.

JEL Classification: J26, H26, H55, O15, O17

Keywords: earnings replacement benefits, social security, tax compliance

Corresponding author:
Mariana Zerpa
Department of Economics
University of Leuven
Naamsestraat 69
3000 Leuven
Belgium

E-mail: mariana.zerpa@kuleuven.be

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1 Introduction

In defined-benefit pension systems, benefits are typically calculated using a measure of individual average earnings for a number of years before retirement. Many pension systems use a small set of final (or highest) years of earnings, which has the advantage of avoiding the penalization of workers for years of low-earnings, unemployment and/or informality. It is also less costly in terms of information requirements. However, it creates dynamic incentives to increase reported earnings during the final years of work. The potential costs of these behavioral responses are well-know to economists (Gruber, 2016), and have been present in news coverage and policy discussions.[1] Still, the empirical evidence on behavioral responses to these incentives is remarkably scarce, with the exception of Fitzpatrick (2017), who documents this behavior for public education pension schemes in the US. To the best of our knowledge, there is no evidence on whether behavioral responses to such incentives occur in country-wide private-sector pension systems, whether there are real or reported earnings changes, or whether self-employed workers and employees respond differently given the different incentives and restrictions they face.

This paper aims to fill this gap in the literature by studying the responses of self-employed and employed workers to the dynamic incentives of a 10-year retirement-benefit calculation window in a country-wide social security system. We use matched employer-employee social security administrative records from Uruguay, where private-sector worker retirement benefits are calculated considering the average earnings reported in the final ten years of work. Uruguay is of particular interest for several reasons. First, the 10-year window is representative of other systems. Many developing countries and many public sector and occupation-specific pension systems in developed countries use a small set of years before the time of retirement for benefit calculation.[2] Second,

[1]For example, the issue is pointed out in Jonathan Gruber's widely used public finance textbook (Gruber, 2016, pp. 371-372): "if the averaging period is too short, it can have perverse incentives for behavior by older workers." Gruber then cites two examples, one about subway drivers in Boston and the other about civil servant pensions in Brazil, where problems related to overwork and earnings-spiking in the final years of work led to policy changes that extended the reference earnings period for retirement-benefit computation. Additionally, earnings spiking in the final years of work has been a topic of news attention and policy actions in many local and state civil servant pension schemes in the US (e.g., CST Editorial Board, 2019; Illinois Education Association, 2019).

[2]Five other Latin American countries use the final or best 10 years of earnings in benefit calculation, and another 9 use shorter windows (OECD/IDB/The World Bank, 2014). In Africa, occupational public sector schemes frequently use a short period of final years. For example, civil servants pension schemes in Uganda and Mauritius use the last salary (Stewart and Yermo, 2009). In developed countries, short benefit calculation windows were common until recently and are still widely used in the public sector. Five European countries were using windows of 5 to 15 years in their national retirement systems until the mid-2000s (OECD, 2005). Many state and local civil servant pension plans in the U.S. use windows of 3 to 5 years, and similar periods are used in many European public sector pension schemes. In France, the

Uruguay has a well-established contributory retirement system, where these dynamic incentives affect all private-sector workers, and where the availability of high quality social security records in the last two decades allows us to evaluate these responses at a full-country scale. Finally, policy variation across cohorts and groups allows us to evaluate the potential of regulatory measures to mitigate behavioral responses.

For workers to change their behavior in response to the benefit-calculation window requires not only the presence of incentives, but also the opportunity to take advantage of them. Self-employed workers are likely more able to take advantage of such incentives, because they face lower costs of manipulating reported earnings. Reporting and accounting responses are often less costly than real responses, such as changing hours of work (Slemrod, 1992). Self-employed earnings are typically not subject to third-party reporting and are difficult to monitor by the authorities. Similar arguments can be made for earnings of employees in small firms, which usually have lower productivity and are more prone to informal employment and tax evasion than large firms (Slemrod, 2019; Kleven et al., 2011). These two groups are of key interest because they pose important unresolved challenges for social security systems. For example, the *OECD Pension at a Glance 2019* report characterizes the self-employed as a particularly challenging group, because they tend to have lower levels of contribution to and benefits from social security than dependent workers, and identifying and monitoring their labor income is difficult (OECD, 2019).[3]

This paper has three main goals related to dynamic incentives in the Uruguayan pension system. The first goal is to document the behavioral responses to these incentives from self-employed and employed workers. Second, we aim to assess the margins at which these responses operate, and to tie them to the presence of underreporting of earnings. The third goal is to understand the cost increases to the social security system generated by these dynamic incentives.

We begin by presenting a stylized dynamic model of tax compliance. We use a three-period model, with two periods of work (years before and during the retirement benefit calculation window), and a period of retirement. In the periods of work, the individual chooses the level of reported earnings subject to a minimum contribution base. The model servers two purposes. First,

use of the final 6 months as reference earnings for public pensions is currently under debate (Breeden, 2019).

[3]Self-employment represents a significant share of the employed population in developed countries, and it is even more prevalent in the developing world. It represents 15% of the total employment in OECD countries, 27% in LAC countries, and 76% in least developed countries (The World Bank, 2019).

it shows the conditions under which workers have incentives to increase reported earnings in final years of work. Second, the model shows the sources of heterogeneity in reporting behavior and margins of response to these dynamic incentives.

We use monthly employer-employee individual-level administrative records from Uruguay's social security system between 1996 and 2016, supplemented with household surveys for the same period. The main goal of our empirical analysis is to assess whether workers respond to the incentives embedded in the social security system by strategically increasing reported earnings in the benefit calculation window. Our approach leverages the presence of the ten-year window for benefit calculation, combined with the fact that the probability of retirement increases sharply after the minimum retirement age of 60 years old. This implies that each worker's benefit calculation window starts on or after, but not before, age 50. We conduct age-event studies of reported earnings from five years before until eight years into the 10-year window prior to minimum retirement age, flexibly controlling for the effects of time, industry and firm size. We focus on male workers, whose minimum retirement age is fixed throughout the sample period and who are more likely to achieve eligibility for retirement when they are 60 years old.

Preview of Results We first focus on self-employed workers, who are most likely to be able to take advantage of these incentives. We find that self-employed reported earnings are flat in the years leading to the start of the benefit calculation window, and start increasing sharply in the years that follow. By age 54, their reported earnings are on average about 3% above age-49 reported earnings. This is mostly explained by intensive margin responses, i.e. increases in reported earnings by individuals who already report more than the minimum contribution base. We also find that the magnitude of these responses are larger for self-employed individuals with stronger incentives (frequent reporters), and for those who are not subject to regulations that limit the frequency and magnitude of changes to reported earnings. Thus, our results suggest that such regulations are effective at mitigating dynamic responses to the benefit calculation window.

Then, we turn our attention to employed workers. Although they face the same incentives as the self-employed, employees are less likely to be able to respond to these incentives. Consistent with this, our results do not show an increase in reported earnings after the start of the benefit calculation window for the full sample of employees. However, small firms are more prone to underreporting earnings because they are more difficult to monitor. Thus, we expect employees of these firms to have the possibility to increase their reported earnings in the benefit calculation window. Indeed, we find evidence of increases in reported earnings among employees of firms with less than 10 workers, of a similar in magnitude to those we find for self-employed workers.

Finally, we evaluate whether these changes in reported earnings are explained by changes in reporting behavior or real labor supply responses. To this end, we use data on total earnings and work hours from household surveys, where individuals have no incentive to misreport earnings differentially after the start of the retirement-benefit calculation window. We find no evidence of increased hours of work or total earnings; on the contrary, if anything the evidence points towards a small decrease in total earnings as workers age. This suggests that the responses to the dynamic incentives of the retirement benefit calculation, in terms of reported earnings to social security, are entirely explained by a change in misreporting behavior.

Potential challenges to identification in this setting could come from changes in productivity or hours of work with age. Two sets of findings from our results alleviate this concern. First, we find that reported earnings of self-employed and employed workers are flat in the years leading to the beginning of the benefit calculation window. Thus, any confounding changes in productivity or labor supply would have to start just after age 50, which seems implausible. Second, our analysis of earnings and hours of work reported in household surveys provides direct evidence that neither of them increases after the start of the benefit calculation window.

Finally, we provide back-of-the-envelope calculations of the implied cost of these responses to the social security system. We quantify the cost of the responses of a representative self-employed worker, under two alternative scenarios of counterfactual reported earnings in the absence of these responses. In the first scenario, we assume that the responses are entirely driven by over-reporting in the final 10 years of work; in the second scenario, we assume that they are entirely driven by under-reporting before the final 10 years of work. These two scenarios provide bounds for the estimates of the costs. Both scenarios yield similar conclusions, with an estimated increase in net expenditures on retirement benefits of between 1.9% and 2.6% per self-employed worker.

Related literature This paper contributes to two strands of literature. First, a recent literature has started to document responses to the dynamic incentives embedded in the computation of earnings-replacement benefits in pension systems (Fitzpatrick, 2017; Mannino and Cooperman, 2015). Our paper is most related to Fitzpatrick (2017), who provides evidence of increases in teachers' earnings as a response to Illinois's 4-year benefit-calculation window, and shows that these responses are sensitive to a policy that increases the costs to employers of earnings spiking. So far, this literature has focused on public education pension schemes in the US. That setting is characterized by short benefit-calculation windows, very stable employment relationships, and collective-bargaining between employers and employees. In that context, employers and employees may be more able and willing to cooperate to defer compensation until after retirement if that can increase total rents due to political economy considerations (Glaeser and Ponzetto, 2014), even if workers' valuation of an increase in retirement benefits is well below its cost (Fitzpatrick, 2015). We contribute to this literature by documenting reported earnings responses in a country-wide private-sector retirement system, by stressing the differences between self-employed and employed workers, and by discussing the extent of real and underreporting responses.

Second, we contribute to the literature on tax avoidance and reported earnings responses to taxes and transfers. Previous work has found stronger responses among the self-employed and employees of small firms. For example, Saez (2010) shows evidence of bunching of self-employed reported earnings at kink points of the budget constraint generated by the earned income tax credit, while such behavior is not observed in employee reported earnings. Kuka (2014) shows that these effects are only observed in tax data, and that real responses observed in surveys are very small. Additionally, Kleven et al. (2011) show problems of reporting for the group of self-employed and employees in small firms distinguishing real and reporting behavior using supplement administrative records with data from audits. We contribute to this literature by showing that defined-benefit pensions are another setting where self-employed and small-firm employee reported earnings responses are observed, and where these responses represent changes in reporting behavior rather than real labor supply responses.[4]

[4]Our paper also relates to a broader literature that analyzes the implications of retirement benefits in the design of pension systems. A stream of this literature evaluates the role of income replacement on the retirement decision (Asch, Haider and Zissimopoulos, 2005; Van Soest and Vonkova, 2014; Bissonnette and Van Soest, 2015; Manoli and Weber, 2016; Biasi, 2019); another stream addresses the interaction between retirement and labor supply (Blundell, French and Tetlow, 2016, offer an excellent summary); and a third stream discusses dynamic optimization problems in labor supply responses to the Social Security Earnings Test (Baker and Benjamin, 1999; Friedberg, 2000; Song and Manchester, 2007; Haider and Loughran, 2008; Gelber et al., 2020). We contribute to this literature by providing evidence of responses to dynamic incentives, studying an alternative source of potential effects on labor supply, and highlighting another channel that could potentially affect retirement timing choices.

The rest of the paper is organized as follows. We begin by presenting the institutional background in Section 2. We present the conceptual framework in Section 3. Section 4 presents the data and descriptive evidence. Section 5 discusses the empirical strategy and results; we begin by discussing the evidence on self-employed reported earnings, then present an analysis of the reported earnings of employees, and finish by providing evidence from household surveys. In Section 6, we provide calculations of implied costs to the social security system, and Section 7 concludes.

2 Institutional Background

In this section, we summarize the key elements of the institutional setting that are relevant for our analysis. A more detailed account of the setting is provided in Online Appendix A. We focus on self-employed workers (business owners of sole proprietorship firms) and private-sector employees in Uruguay who contribute to social security.[5] Private sector workers must be registered with and contribute to Uruguay's social security administration, *Banco de Previsión Social* (BPS), which gives them access to social security and social insurance coverage.[6]

Self-employed workers are subject to the same social security system as employees, although with some specific regulations. While employee earnings are reported to BPS by employers, who are responsible for paying employer and employee payroll taxes, self-employed workers must self-report their own earnings. They can decide how much earnings to report, subject to a minimum contribution base that is quite low (below the national minimum wage for a full-time worker). These reported self-employment earnings are used as a base for the calculation of payroll taxes (22.625% of reported earnings) and, when the time comes, retirement benefits.[7]

To qualify for retirement, workers must be at least 60 years old and have contributed to social security for a minimum of 30 years of service. We focus on men only, because women are less

[5]Uruguay is an upper-middle income country (high income in recent years) with a well established contributory social security system. The labor market exhibits a moderate rate of unregistered employment, of between around 40% in the 1990s to 25% of the employed population in recent years.

[6]Exceptions to this are workers in occupation-specific retirement schemes: bank employees, notaries and members of other professional associations with university degrees, which are administered separately. In this paper we focus on workers subject to the general private-sector workers social security scheme, so we exclude public sector workers, notaries, bank employees, and university graduates in independent exercise of liberal professions. We also exclude rural and construction workers, who are subject to specific contribution regulations.

[7]In addition to payroll taxes, workers and employers make additional contributions for health insurance and, since 2007, an income tax. Considerations about the income tax are unlikely to be relevant in the decision on the level of earnings to report to the social security administration for self-employed workers, since for most of them their earnings are well below the exemption threshold.

likely to achieve the required years of service by age 60, and their minimum retirement age was earlier for some years. As shown in Section 4.2, the probability of retirement increases sharply at the minimum retirement age.

Retirement benefits from the contributory defined-benefit social security system are calculated as the product of the reference average pre-retirement earnings and a replacement rate. Replacement rates are incremental with age at retirement and years of service, with a minimum of 45% (at age 60 with 30 years of service) and a maximum of 82.5% (at age 70 with 50 years of service). There is also a minimum and a maximum retirement benefit.[8]

The reference average pre-retirement earnings is calculated as the average of the inflation-adjusted reported earnings of the final 10 years of work, as long as this does not exceed the average of the highest 20 years of earnings plus 5%. If the average earnings of the final 10 years of work is less than the average of the highest 20 years of earnings, the latter is used. This design of the benefit calculation introduces an incentive to report higher earnings in the 10 final years of work to increase the reference average pre-retirement earnings and thus retirement benefits.

We take advantage of the features of this institutional setting to study whether self-employed and employed workers report higher earnings in the final years of work, in order to increase their retirement benefits. The key elements of the setting for our empirical strategy are the 10-year benefit-calculation window and the minimum retirement age of 60. In addition, some regulatory differences between groups of self-employed workers provide variation that allows us to study whether different types of restrictions to their earnings reporting are effective at mitigating earnings increases in the benefit calculation window. These regulations are discussed in Section 5 and Online Appendix A.

3 Conceptual framework

In this section, we present a simple and stylized model of individual decisions in the presence of pension benefits that are a function of reported earnings in the final years of work. The model has three time periods; in periods 1 and 2 individuals work, and in period 3 they are retired. Period

[8]The current social security system has two pillars: a defined-benefit pillar, administered by BPS, and a defined-contribution individual savings accounts pillar. The last 15 cohorts in our sample are subject to this two-pillar system, while the first 15 cohorts are subject to a purely defined-benefit *transition* regime. Even in the *two-pillar* regime, most workers can expect to receive a larger share of their retirement benefits from the defined-benefit pillar, especially those with lower lifetime reported earnings. More details about the two regimes are provided in Online Appendix A.

1 represents the years when reported earnings do not affect retirement benefits, and period 2 is represents the years in the retirement benefit-calculation window.[9] We assume that the individual retires at the end of period 2, and this decision is exogenous to the model.[10]

We consider an individual i deciding the level of earnings to report to the social security administration in each of the two working periods (w_{i1} and w_{i2}). In each period of works, the individual is endowed with exogenous pre-tax total earnings Z_i. The model could be extended to account for endogenous labor supply; however, we discuss evidence in Section 5.3 that shows that labor supply responses are not present in our setting. An individual reporting w_{it} earnings contributes τw_{it} in payroll taxes, with τ being the tax rate over reported earnings. There is a minimum contribution base of $\bar{w}$ that applies for both periods ($w_{i1}, w_{i2} \geq \bar{w}$ for all i). If the individual reports less than their true earnings, there is an expected cost $f(Z_i, w_{it})$, which we assume to be a weakly increasing function of total earnings ($\frac{\partial f(\cdot)}{\partial Z_i} \geq 0$), and a weakly decreasing function of reported earnings ($\frac{\partial f(\cdot)}{\partial w_{it}} \leq 0$).[11]

Under these assumptions, expected consumption in the first and second period is given by $c_{it} = Z_i - \tau w_{it} - f(Z_i, w_{it})$. Consumption in the third period is given by $c_{i3} = p(w_{i2})$, where $p(w_{i2})$ is income from retirement benefits. Pension benefits are assumed to be weakly increasing in reported earnings in the second period ($\frac{\partial p(\cdot)}{\partial w_{i2}} \geq 0$).[12] We assume there is no saving or borrowing except through the pension system.[13]

[9]Each period is meant to represent each of the groups of years that are in the corresponding case in terms of how contributions affect lifetime income. We make this assumption for ease of notation. The results can be extended to more than three periods.

[10]It is possible that retirement age may also change as a response to the design of the benefit calculation window. Optimal reporting responses can increase the effective replacement rate of pension benefits relative to lifetime earnings, which could affect the optimal retirement age through income and substitution effects. The modeling of retirement age responses is beyond the scope of this paper, and our identification strategy avoids dealing with this issue by relying on the minimum retirement age as an exogenous shifter of the likelihood of retirement.

[11]We allow the functional form of this function to be general in how it depends on these two arguments. For example, it is common in the tax evasion literature to express the probability of detection as a function of evaded earnings: $f(Z_i, w_{it}) = f(Z_i - w_{it})$. This implies that an unreported dollar has the same probability of detection regardless of income. However, the amount of evaded earnings is not observed by the authorities. Detection may be more likely if a larger proportion of income is under-reported, in which case we would have $f(Z_i, w_{it}) = f((Z_i - w_{it})/Z_i)$ (Slemrod, 2019). It is also possible that the authorities may be more likely to audit firms with higher revenue, which would imply that a dollar of evasion has a higher probability of being noticed for workers with higher total earnings.

[12]In Uruguay, for some individuals pension benefits may also dependent on reported earnings in period 1 because of the computation method discussed in Section 2. In this sense, there are also dynamic incentives 20 years before retirement (assuming the final 20 years of work are the years with highest earnings). However, these incentives are less salient to individuals and their effects more discounted over time. Given the lower importance of those incentives and data restrictions, we focus on the incentives in the final 10 years of work. In this sense, we can interpret the model as the additional incentives to increase reported earnings in period 2.

[13]The model can be extended to allow for savings or borrowing. We assume that individuals have higher expected

Utility in each period is given by $U(c_{it})$, with $\frac{\partial U(\cdot)}{\partial c_{it}} > 0$, $\frac{\partial^2 U(\cdot)}{\partial c_{it}^2} < 0$. The individual problem is:

$$\max_{w_{i1}, w_{i2}} V(w_{i1}, w_{i2}, Z_i) = \sum_{t=1}^{3} (\frac{1}{1+r})^{t-1} U(c_{it})$$

subject to: $\tau w_{it} + f(Z_i, w_{it}) \leq Z_i$ and $w_{it} \geq \bar{w}$ for all i and $t = 1, 2$.

To keep the notation simple, and given that there is no borrowing or saving, we assume that the sum of the taxes and the penalization is always strictly less than the total earnings than the individual receives each period ($\tau w_{it} + f(Z_i, w_{it}) < Z_i$). The first order conditions of this problem provide the optimal solution for reported earnings in periods 1 and 2, which we discuss as follows.

First period The condition for the optimal reported earnings in period 1, w_{i1}^*, is given by:

$$\lambda_1 = 0,\ w_{i1}^* > \bar{w} : \quad \underbrace{\tau}_{\substack{\text{marginal cost} \\ \text{of reporting \$1}}} \quad = \quad \underbrace{-\frac{\partial f(Z_i, w_{i1})}{\partial w_{i1}}}_{\substack{\text{marginal benefit} \\ \text{of } \downarrow \text{ expected penalty}}} \qquad [\text{or } \lambda_1 > 0 :\ w_{i1}^* = \bar{w}\,]$$

Intuitively, this condition states that the optimal level of reported earnings is the one that equalizes the marginal cost of reporting one dollar (τ) in period 1 to its marginal benefit, expressed in terms of the expected reduction in the cost of misreporting earnings. If the optimal reported earnings are lower or equal than the minimum contribution base, and thus the value of relaxing the constraint is positive ($\lambda_1 > 0$), the individual reports the minimum ($w_{i1}^* = \bar{w}$). Thus, in period 1, optimal reported earnings are independent of the retirement benefit calculation.

This optimal condition also highlights that heterogeneity in total earnings (Z_i) introduces heterogeneity in optimal reported earnings in Period 1. Individuals with low earnings and low probability of enforcement will report the legal minimum in earnings. The sign of the cross-partial derivative of the evasion cost function with respect to total and reported earnings ($\frac{\partial^2 f(\cdot)}{\partial w \partial Z}$) determines where in the income distribution individuals gain more from reporting an additional dollar of earnings. If this cross-derivative is positive, higher-earnings workers face a steeper penalty as a function of reported earnings, and benefit more for reporting and additional dollar of earnings. Higher-income workers may face a steeper penalty function if, for example, the regulator

utility from investing their savings through the pension system rather than private savings, given the generosity of the pension system or the different risks associated to these options. Additionally, in the empirical part of the paper we do not have information about savings or borrowing, so we focus our model on the reported earnings decision.

monitors with higher probability higher-income individuals (compared to the lower-income individuals) when they report low earnings, but monitors them with a similar probability when they report high earnings.

Second period Optimal reported earnings in the second period (w_{i2}^*) are given by the following condition:

$$\lambda_2 = 0,\ w_{i2}^* > \bar{w} : \underbrace{\tau \frac{\partial U(Z_i - \tau w_{i2} - f(Z_i, w_{i2}))}{\partial w_{i2}}}_{\substack{\text{marginal utility cost} \\ \text{of contributing \$1}}} =$$

$$\underbrace{-\frac{\partial f(Z_i, w_{i2})}{\partial w_2} \frac{\partial U(Z_i - \tau w_{i2} - f(Z_i, w_{i2}))}{\partial w_{i2}}}_{\substack{\text{marginal utility benefit} \\ \text{of } \downarrow \text{ expected penalty}}} + \underbrace{\beta \frac{\partial p(w_{i2})}{\partial w_{i2}} \frac{\partial U(p(w_{i2}))}{\partial w_{i2}}}_{\substack{\text{marginal utility benefit} \\ \text{of } \uparrow \text{ pension}}}$$

$$[\, \text{or } \lambda_2 > 0 : w_{i2}^* = \bar{w} \,]$$

This condition shows that in period 2, during the benefit calculation window, individuals maximize their utility by choosing the level of reported earnings that equalizes the marginal utility cost of reporting an extra dollar to its marginal utility benefit, which is the sum of the reduction in evasion cost plus the marginal utility benefit from increased pension benefits in period 3.

These conditions imply that reported earnings in period 2 are weakly higher than in period 1, and that there are two margins of response. In the extensive margin, individuals who report the minimum in period 1 but are close to the margin, will report more than the minimum in period 2. In the intensive margin, those reporting more than the minimum contribution base in period 1 will report higher earnings in period 2 if they have positive marginal utility from the increase in pension benefits (since p is a weakly increasing function of $p(w_{i2})$ and marginal utility is increasing in consumption). However, not everyone will increase reported earnings in the second period. As in the first period, some individuals will find it optimal to report the minimum contribution base. Others may derive no additional utility from increasing reported earnings in period 2, because they may be at a point where the pension benefit function is flat.[14]

[14] In the institutional setting of our empirical application, there is a minimum and a maximum retirement benefit. Individuals with very low optimal reported earnings in period 1 may still be below the minimum pension even if they

Finally, the model can be extended to reflect other potential sources of heterogeneity, such as costs of evasion $f(Z, w)$, including for example perceptions about the probability of enforcement, and time preferences (represented by r). Another possible extension to the model is to allow for a cost of changing reported earnings; this could serve to illustrate administrative or regulatory costs of adjustment for self-employed workers, which we introduce in the heterogeneity analysis in our empirical application, or to represent in a simplified manner the costs of adjustment of reported earnings faced by dependent workers. A more realistic representation of the situation of employees would require directly modeling the representative-agent bargaining between workers and employers.

4 Data and Descriptive Statistics

4.1 Data sources

Social security records Our main empirical analysis is based on matched employer-employee individual-level administrative records from Uruguay's social security system. The dataset contains the work histories between April 1996 and March 2016 of a random sample of 300,000 workers (approx. 15% of Uruguayan labor force) who were registered in social security at least one month during the period. The data were provided by Uruguay's social security administration (BPS). The structure of the data is an unbalanced panel of workers, containing information on monthly earnings, contribution scheme, personal attributes of the worker (gender, date of birth), information about each firm (legal type, number of employees, 5-digit ISIC industry codes).

We include in our samples only workers registered with the main social security contribution scheme ("Industria y Comercio"), which includes workers in private-sector firms in the secondary and tertiary sectors. Thus, we exclude public sector workers, and workers subject to especial rural and construction social security contribution schemes. The sample does not include university graduates working independently as free-lance professionals, who contribute to a separate retirement scheme.[15]

increase reported earnings in period 2, while individuals with high earnings may hit the benefit ceiling with the optimal reported earnings of period 1.

[15]Using a longitudinal survey, de Melo et al. (2019) estimate that in 2015, 73% of individuals between ages 40 and 60 have ever contributed to BPS, while 20% have never contributed to any pension scheme, and the remaining 7% have contributed to occupation-specific pension schemes.

We restrict our samples to male workers born between April 1, 1941 and April 1, 1971 (30 birth-year cohorts), and observations between ages 45 and 57. These restrictions imply that the cohorts in our sample are potentially observed at least one year between ages 45 and 57, and do not enter the sample after age 55. We adjust earnings to thousands of Uruguayan Pesos (UY$) of December 2015 using the consumer price index. For reference, in December 2015, the exchange rate was about 30 UY$ per USD. We drop observations with reported earnings below the 5th percentile or above the 95th percentile, and observations with missing data on any of the variables we use in the empirical analysis.

Self-employed workers. Our main analysis sample consists of self-employed workers, defined as working owners of sole proprietorship firms. We restrict the sample to workers who do not report employment and self-employment simultaneously, and who report positive self-employment earnings for at least 6 months in our sample period. This leaves us with a sample of 5,350 registered independent workers in the whole period, or 299,572 observations. A typical self-employed worker in this sample is observed reporting positive self-employment earnings 70% of the time we could potentially observe them.[16]

Employees. We similarly construct a sample of employees who have positive reported earnings for at least 6 months in our sample period. We exclude employees who ever report self-employment earnings in the sample period, so that the two samples do not overlap. This leaves us with a sample of 12,895 registered workers and 669,950 observations. A typical employee is observed with positive reported earnings 66% of the time we could potentially observe them.

Household surveys We supplement our analysis with information from household surveys (*Encuesta Continua de Hogares*, or ECH), conducted by the National Statistics Institute (INE). These consist of annual cross-sections that are representative of the working age population, for the years 1996 to 2016. Survey respondents report the total earnings and usual working hours of

[16]Note that given our cohort and age restrictions, not all individuals are potentially observed for the whole sample period. We define the proportion of time observed as the number of months observed divided by the maximum number of months an individual could potentially be in our sample given his birth cohort. In one of our heterogeneity analyses, we further restrict the sample to individuals reporting positive self-employment earnings for at least 70% of the number of months we could potentially observe them, as an attempt to identify the workers that are most likely to rely solely on self-employment as their main income source. Results are robust to these sample definitions.

household members, so this data source allows us to discuss the difference between total earnings and reported earnings to social security, and also assess responses in terms of labor supply. We identify formal self-employed workers as those who report working for themselves as their main occupation, and report having social security coverage. Similarly, we identify formal employees as those reported working for an employer and having social security coverage. We drop from the sample workers in the primary sector (agriculture, cattle, mining) or construction, and those whose occupation is reported as government or armed forces. This gives us a sample of 7,153 observations for self-employed workers, and a sample of 28,971 observations for employees.

4.2 Descriptive statistics

Table 1 reports summary statistics for the samples described above. We begin by reporting summary statistics for self-employed workers in the social security records. Self-employed individuals mostly work in small firms, with 65% having no employees. 37% of observations are in the trade, restaurants and hotels sector, followed by services (26%), transport, communications and energy (19%), and manufacturing (18%). Their average reported earnings are 9,430 UY$ per month, equivalent to about 314 US$, or 1.3 times the minimum contribution base. In one third of observations, self-employed workers are reporting exactly the minimum contribution base.

Table 1 also shows summary statistics of social security records for dependent employees. The average worker in this sample earns 26,900 UY$ (897 US$), 2.8 times the average reported earnings of self-employed workers. Although it is possible that part of this difference is explained by productivity differences, it is suggestive of underreporting of earnings by self-employed workers. They are more likely to work in larger firm, and they are more likely to work in services than self-employed workers. Those working in small firms (less than 10 employees) have substantially lower average reported earnings, but still 1.8 times the average for self-employed workers.

In the last four columns of Table 1, we present summary statistics for formal self-employed and employed workers observed in the household surveys. While for the full sample of employees, reported earnings in administrative records are higher than in household surveys, among employees working in small firms this is reversed. The contrast is even more stark for the self-employed. Average reported earnings of self-employed workers to social security are 35% of the average earnings of dependent workers, while in household surveys formal self-employed workers report slightly higher average total earnings than formal employees. This suggests that earnings of self-employed workers are substantially underreported to the social security administration, and also those of employees of small firms to a lesser extent. Self-employed workers also report having more employees in household surveys than what we observe in social security records; this difference could be related to informal employment, i.e. having employees that are not registered with the social security administration. Most self-employed and employed workers report working full time, with an average work schedule of 50 and 48 hours per week, respectively.

Figure 1 shows the histogram and cumulative distribution function of the retirement age for the unrestricted sample of male workers who we observe retiring in the social security records. We identify retirement as the first time we have a record of retirement benefits for a worker. There is a very sharp jump in the probability of retirement at age 60. Less than 10% retire before this age (which could be explained by early retirement arrangements, disability retirement, and measurement error). In the years that follow the minimum retirement age, the cumulative percentage of workers that have retired increases rapidly, and by age 62.4 already 50% have retired. The average observed retirement age in this sample is 63.5. This observation, combined with the way retirement benefits are calculated, motivate our use of age 50 as the threshold at which we expect to observe increases in earnings reported to social security in order to increase expected retirement benefits.

4.3 Descriptive evidence

Before presenting our regression framework, we begin by motivating our analysis with some descriptive evidence. Given the minimum retirement age of 60, each individual's actual 10-year retirement benefit calculation window starts at or after, but not before, their 50th birthday. If the predictions of our model are correct, we expect average reported self-employment earnings to start increasing at age 50, and to continue increasing until at least age 55, when most individuals should have approached the start of their expected benefit-calculation window.

In Figure 2, we plot the average reported earnings of self-employed and employed workers by age, normalized to equal 1 at age 49. While reported earnings of both groups of workers look fairly stable in the years leading to age 50, the reported earnings of self-employed workers start increasing at age 50, while those of employed workers continue on a very slightly decreasing path.

This evidence is consistent with self-employed workers having more flexibility to respond to the incentives created by the retirement system, since they report their own earnings and can more easily avoid monitoring from the social security administration.

5 Identifying the responses of reported earnings to the benefit calculation window

In this section, we go beyond the descriptive analysis discussed above, and present evidence of changes in reported earnings controlling for potential confounding factors, including time, sector and firm-size effects. We begin by studying self-employed reported earnings. We then study the reported earnings of employed workers, and narrow down on groups of workers who are more likely to be able to respond. Finally, we use data from household surveys to show that responses are due to changes in misreporting behavior rather than real labor supply responses.

5.1 Event study of self-employed reported earnings

We start the empirical analysis by focusing on self-employed workers, who have both the incentives to change their reported earnings and the opportunity to do so, since they report their own earnings and can more easily avoid monitoring from the social security administration. In Section 3 we show that the self-employed should respond to the incentives of the retirement system by increasing their reported earnings after the start of the benefit-calculation window. In this section, we present evidence that self-employed workers respond to these incentives as the model predicts.

In what follows, we implement an event study framework, where the "event" is turning 50, which is the minimum age at which the benefit-calculation window starts. In this setting, it is key to control for changes in earnings over time, since time is mechanically correlated with age. We do this by estimating a fully dynamic event study of reported earnings around age 50 with time fixed effects. We include observations between ages 45 and 57, i.e. up to 5 years before and 8 years after the minimum starting date of the benefit calculation window. We estimate the following model:

$$Y_{it} = \sum_{b=-5}^{-2} \mu_b 1[\text{Years Window}_{it} = b] + \sum_{a=0}^{7} \mu_a 1[\text{Years Window} = a] + \delta_t + \gamma X_{it} + \varepsilon_{it} \qquad (1)$$

Y_{it} is the outcome variable for individual i in period t; our main outcome variable is reported earnings to social security, expressed as the ratio over the age-49 average reported earnings, so that estimates can be interpreted as percent changes. Years Window_{it} is the number of years since the individual's 50th birthday, i.e. since the start of the 10-year benefit calculation window leading to minimum retirement age. The set of parameters μ_b are changes in reported earnings with age before the start of the benefit calculation window, and the set of μ_a represent changes in reported earnings after the start of the 10-year window, relative to earnings in the omitted age group (age 49). We control flexibly for time effects by including dummy variables for each month-year (γ_t). We also control for firm-size categories and economic sector of the firm (2-digit ISIC codes), and interactions of calendar year with firm size and sector. We report two-way cluster robust standard errors, clustered by individual and by age.

Figure 3 shows the estimates from this event study, and illustrates the main result of the paper: reported earnings of self-employed workers start increasing at age 50. In the first four years (ages 50-53), reported earnings increase on average 1% relative to age 49, and by ages 54 to 57 they are on average close to 3 percentage points above average earnings just before age 50. The timing of the increases is consistent with a ramp-up period after the start of the 10-year window before the *minimum* retirement age (i.e. after age 50), and a stabilization after the start of the 10-year window before the *average* retirement age (dashed line).

Part of this ramp-up of the effects can be explained by the gradual increase of the share of retired individuals following the minimum retirement age. The estimates presented in Figure 3 are *intent-to-treat* (ITT) effects, because we are considering how many years into the benefit-calculation window a person would be *if they retire at the minimum retirement age*. In order to approximate the *treatment-on-the-treated* (ATT) effects, we can use the proportion of people who retire at each age, presented in Figure 1. The implied ATT effects are 2.4% at ages 50 to 53, and 4.5% at ages 55 to 57.[17] Thus, the dispersion in retirement age explains a relevant part of the ramp-up of the effects, but not all. The remaining increase in the effects as workers age can have multiple explanations, including for example time preferences (discounting of future retirement benefits when workers are further away from retirement), an increase in the salience of the potential benefits as workers

[17] The ATT effect at ages 50-53 of 2.4%, is obtained by dividing the average estimated ITT effect of 1% relative to age-49 reported earnings, by the increase in the probability of being retired 10 years later, at ages 60-63, which is 39 percentage points. Doing a similar calculation for ages 54 to 57 gives us an implied ATT of 4.5% (2.8% ITT divided by 64% change in the cumulative probability of being retired).

approach retirement age, or heterogeneity of responses (with stronger responses among workers who delay retirement).

The results in Figure 3 confirm that there is no trend in reported earnings in the years leading to age 50. The main identifying assumption in this empirical approach is that individuals in each age group are on average identical, conditional on the set of controls. Thus, all differences in reported earnings across age groups are assumed to come from the dynamic incentives of the pension system. The main challenge to identification in this setting comes from the fact that productivity, and therefore wages, may also change with experience and therefore could be confounded with age. The event study allows us to partially test this identifying restriction, by showing that there are no age effects before the start of the benefit-calculation window. Therefore, if there were any confounding changes in earnings with age, they would have to happen only after age 50 and not before, which seems implausible.[18]

Robustness In Table 2, Panel A, we present estimates of a more parsimonious version of the event study model and show its sensitivity to the control variables included in the model. We estimate the following model:

$$Y_{it} = \alpha \text{Age}_{it}^{45-48} + \beta \text{Age}_{it}^{50-53} + \lambda \text{Age}_{it}^{54-57} + \delta_t + \gamma X_{it} + \varepsilon_{it} \tag{2}$$

To show that our main takeaways do not depend on the particular set of controls used, we start by only including time effects (column 1). We then add firm size and 2-digit industry code dummies to account for any composition changes that may happen as workers age (column 2). Finally, we show the results after adding the full set of interactions between year and firm size and industry dummies (column 3), which is the same set of controls we use in the fully dynamic event study. The results are very robust across these specifications. The estimates of our preferred specification (column 3) indicate that, between the ages of 50 and 53, reported earnings increase by 1% relative to age-49 reported earnings, and by 2.8% at ages 54 to 57, relative to age-49 reported earnings.

[18]Implicitly, we are also assuming that an individual's birth cohort has no effect on earnings. It is a well known problem that, without further assumptions, it is not possible to simultaneously identify age, time, and cohort effects, due to their multicollinearity. In our setting, age effects are the main object of interest, and time effects are of primary importance, because of the long period of time considered and the presence of business cycles. The concern for cohort effects is mitigated by the fact that we find no age effects before the start of the benefit-calculation window, to the extent that there is no reason to think that cohorts would start having an impact only after age 50.

In Panel B of Table 2, we show the estimates of the following model with linear age trends:

$$Y_{it} = \varphi_0 \text{Age trend}_{it} + \varphi_1 1[\text{Age}_{it} \geq 50] + \varphi_2 1[\text{Age}_{it} \geq 50]\text{Age trend}_{it} + \delta_t + \gamma X_{it} + \varepsilon_{it} \tag{3}$$

where Age trend_{it} is age centered at 50, and $[\text{Age}_{it} \geq 50]$ is an indicator for age being greater or equal than 50 years old. This specification allows for the possibility of a linear age-trend in reported earnings, and identifies responses to the benefit calculation window as deviations from this trend after age 50. The identifying assumptions are that reported earnings grow linearly with age (within the age-window considered) and that, in the absence of responses to the retirement benefit calculation, the trend observed before would continue after age 50. The results of our preferred specification (column 3) show that there is no significant age trend before age 50. The estimated discrete change at age 50 is 0.3 percentage points, and the break in the trend is estimated to add 0.5 percentage points of earnings per year after age 50, relative to average age-49 earnings. The cumulative effect of these estimates over a 10-year benefit-calculation window imply a total increase of 4.3% in reported earnings, relative to the average at age 49.

We present additional robustness checks in Online Appendix B. First, we discuss the results of the event studies when the dependent variable is expressed as the ratio of reported earnings over the value of the minimum contribution base. This allows us to test the sensitivity of the estimates to changes in the minimum contribution base, and at the same time provides an alternative way of expressing the magnitude of the effects. The results follow the same patterns as our main results. At ages 50 to 53, self-employed reported earnings increase 1.1 percentage points of the minimum contribution base, and that by ages 54-57 they are larger than age-49 reported earnings by 3.4 percentage points.

Additionally, we compare the behavior of self-employed and employed workers in difference-in-differences analysis. This specification identifies the differential responses among self-employed workers to the benefit calculation window, relative to those of employed workers. This allows for the presence of other unobserved changes in reported earnings with age, under the assumption that these changes are common to all workers. The results of this analysis (presented in Online Appendix B, confirm our findings from the event study analysis of self-employed earnings, with only small changes in our estimated responses for the self-employed. The estimated differential increase in self-employed reported earnings at ages at ages 50-53 is 1.5 percentage point, and it is 2.2 percentage points at ages 50-54. We come back to the behavior of employees in next subsections.

Minimum contribution base and margins of response Our model predicts "extensive margin" responses from workers who report the minimum contribution base (MCB), and "intensive margin" responses from workers who are already reporting above the MCB. We conduct additional event studies to evaluate responses in these two margins. We discuss here the main takeaways from this analysis, while a more detailed discussion and the full results are provided in Online Appendix C. First, we estimate an event study where the outcome is a binary variable for reporting the MCB, and find that the proportion of self-employed reporting the minimum decreases by only about 1 percentage point (3%) after the start of the benefit-calculation window. When we estimate an event study of reported earnings, conditional on reporting earnings above the MCB when first entering the sample. We find changes in reported earnings that are larger than our estimates for the full sample. These results suggest that most of the responses of self-employed workers seem to come from the intensive margin, i.e. from workers who are already reporting above minimum earnings.

Heterogeneity among the self-employed Next, we explore heterogeneity of responses across groups that have different incentives and flexibility to respond, due to specific institutional regulations. The results are also provided in Online Appendix C. First, we find larger responses from frequent self-employment earnings reporters. We expect this group to benefit the most from adjusting their reporting earnings, because they are more likely to rely on self-employment as their main source of earnings and to meet the years of service requirements for retirement. By ages 54-57, their reported earnings are 4% higher than at age 49. Second, explore the effects of regulations affecting *transition* cohorts, who are limited in terms of the frequency and the magnitude of increases in reported earnings. We find that these restrictions delay and reduce their magnitude of responses. The cohorts who are not subject to these restrictions (*two-pillar* cohorts) have responses that are about twice our baseline estimates of the average effects for the full sample. Finally, we study the heterogeneity of responses among self-employed workers who are employers themselves, whose reported earnings are tied to the earnings they report for their employees. While this regulation is effective at increasing their baseline level of reported earnings, we do not find evidence that they are less responsive to the dynamic incentives of the benefit-calculation window.

Taken together, these results confirm that both incentives and opportunity to respond matter. We find stronger responses among workers who frequently report self-employment earnings, who have more clear incentives. We also find stronger responses among workers who have more flexibility to respond, i.e. those who are not subject to regulations that limit the frequency and magnitude of changes in reported earnings.

5.2 Reported earnings of employees

Do employee earnings also respond to the incentives of the benefit calculation window? Employees face the same retirement system incentives as self-employed workers, but their cost of increasing reported earnings in the benefit-calculation window is larger. Thus, we would expect employee earnings to have smaller responses, if any at all. To evaluate this, we estimate event study and regression models on our sample of dependent workers analogous to the ones we estimated for self-employed workers. We start with the full sample of employed workers, and then focus on employees of small firms, which are more prone to earnings underreporting.

For the full sample of employees, we show the estimates of the event study of reported earnings in Figure 4, Panel A. We do not find clear evidence of an increase in reported earnings of employed workers in the 10-year window before retirement. The estimated changes in reported earnings with age are small, and seem to show a slightly decreasing trend until age 53. After that, there is a small increase that brings earnings to about the same or slightly higher level than before age 50. The estimates of the regression models of equations 2 and 3, presented in Table 3, yield a similar conclusion.

Employees of firms more prone to earnings underreporting Previous literature has found stronger tax evasion and income misreporting responses among small firms (Kleven et al., 2011). Earnings misreporting and informal arrangements between employers and employees are more likely to happen in these firms, which tend to have lower productivity and are less likely to be closely monitored by the tax authorities. In Figure 4, Panels B and C, we estimate separate event studies for employees of small (<10 workers) and larger firms, respectively. We find that reported earnings of employees at small firms increase in the benefit-calculation window, in a similar proportion to what we observe for the self-employed (around 1% after age 50 and 3% after age 54). Reassuringly, our findings show that employees working at larger firms do not exhibit any significant increases in reported earnings in the benefit calculation window. In Table 3, we show the robustness of these results in specifications of the semi-parametric and linear-trend regression models, where we include the full sample and fully interact all parameters of the models with an indicator for working in a small firm.[19]

Responses among workers with stable employment In Online Appendix D, we study the subsample of workers with more stable employment relationships, where long-term arrangements between workers and employers on real and reported earnings increases are more plausible. We find evidence that the reported earnings of these workers increase after age 50, above an underlying linear age-premium observed before that age.

5.3 True labor supply responses or changes in reporting behavior?

So far, we have shown evidence of increased reported earnings of self-employed workers and employees of small firms during the retirement benefit-calculation window. In this section, we show evidence that these responses are purely changes in underreporting behavior, rather than real increases in labor supply or total earnings. With this purpose, we estimate the same event study and regression models of Equations 1-3 in our household survey samples of self-employed workers and employees of small firms. The outcome variables in this analysis are total earnings and hours of work. The comparison of changes in earnings with age across the two sources–administrative records and household surveys–allows us to understand changes in tax-non compliance as a response to the incentives of the social security system.[20] In addition, by looking at

[19]Our result of reporting responses among employees of small firms is also consistent with the findings of Bergolo and Cruces (2014). They study the effects of an expansion of formal-work benefits in Uruguay, and find reported earnings responses only among employees of small firms.

[20]In household surveys, there can also be measurement error earnings; although incentives to misreport are lower than in administrative administrative data, the cost of misreporting is also lower (Hurst, Li and Pugsley, 2014). However, there is no reason to change misreporting behavior specifically after age 50.

hours of work as an outcome, we can directly test whether there are changes in labor supply after age 50, and hours of work are less likely to be reported with error than earnings.

The results of the fully dynamic event studies are presented in Figure 5. Panel A presents results for the sample of self-employed workers, while Panel B shows results for employees of small firms.[21] The outcome variable is total earnings in the plots on the left, and hours of work per week in the plots on the right. We do not find significant increases in total earnings or hours of work after age 50 for self-employed or employed workers. If anything, there seems to be a slight decrease in both earnings and hours of work as workers get closer to retirement age, although the estimates are not statistically significantly different from zero. Similar conclusions are obtained from the models presented in Table 4.

These findings suggest that self-employed workers and employees of small firms do not respond to the dynamic incentives of the retirement system by changing their true earnings or hours of work. What we find in the previous sections can therefore be understood as a pure change in their reporting behavior to the social security administration. This is consistent with suggestive evidence of underreporting of earnings for these two groups, discussed in Section 4.2. If anything, there is some indication that total earnings have a tendency to decrease with age in the sample age-range. If this is the case, then our estimates using reported earnings to social security may somewhat underestimate the actual increase in the share of earnings reported to social security.

6 Back-of-the-envelope calculation of costs

In this section, we present approximate "back-of-the-envelope" calculations of the implied costs to the social security system of the responses of self-employed workers to the dynamic incentives embedded in the retirement benefit calculation window. While for clarity of the exposition we focus on the self-employed here, the computation for employees working in small firms is analogous, since the estimated responses are very similar.

The main challenge to evaluate the costs of these responses is that we do not know what would be the reporting behavior of self-employed workers in the absence of these dynamic incentives (e.g., with benefits based on average lifetime reported earnings). We assume two extreme case

[21] We have also conducted the same analysis for the full sample of employees, and the results, available upon request, are virtually identical.

scenarios in order to bound the costs, with the actual behavior likely being within this range.

6.1 Computation of costs under counterfactual reporting

In this subsection, we present a simple model to compute the costs for each sceneario. Let r be the real interest rate, RR the replacement rate of benefits to reported earnings and τ the payroll tax rate. T_1, T_2 and T_3 denote the number of years in periods 1, 2 and 3, respectively, as described in the model presented in Section 3. We assume that years service (formal work) are continuous until retirement. Finally, we use the percent increase of reported earnings in the benefit calculation window, relative to reported earnings before this period. Therefore, the ratio $\frac{w_2-w_1}{w_1}$ is the main parameter of interest to be taken from our estimates. We approximate it with λ from Equation 2 in the computations below.

Scenario 1: over-reporting in the benefit-calculation window In the first scenario, we assume that, in the absence of the benefit-calculation window, self-employed workers would report the same earnings that we observe them reporting during the years before the 10-year benefit-calculation window. This means that workers respond to the benefit calculation window by over-reporting earnings (relative to what they would report in the counterfactual) in those last ten years. If this is the case, this behavior imposes a cost to the social security administration through overspending in retirement benefits for self-employed workers, but it also increases payroll tax revenues during the 10 years of increased reported earnings.

The average increase in expenditures per self-employed worker discounted to the moment of retirement is given by the sum over the duration of period 3 (expected life expectancy at retirement) of the discounted value of the increase in retirement payouts. The increase in payouts is given by the replacement rate times the increase in period 2 reported earnings relative to period 1: $\Delta\text{Expend}_{\text{S1}} = \sum_{i=1}^{T_3} \frac{1}{(1+r)^{i-1}} \times RR \times (w_2 - w_1)$. The average increase in tax revenues per self-employed worker is given by the sum across the years in the benefit calculation window (period 2) of the updated value of the increase in paid payroll taxes: $\Delta\text{Revenue}_{\text{S1}} = \sum_{t=1}^{T_2} (1+r)^t \times \tau \times (w_2 - w_1)$. Thus, the net cost to the social security system, as a percentage of expenditure in self-employed pensions, is given by:

$$\Delta\text{Cost}_{\text{S1}} = \frac{\mathbf{\Delta Expend_{S1} - \Delta Revenue_{S1}}}{\textbf{Expend. SE pensions}} \quad = \quad \left(1 - \frac{\sum_{t=1}^{T_2} (1+r)^t \times \tau}{\sum_{i=1}^{T_3} \frac{1}{(1+r)^{i-1}} \times RR}\right) \times \frac{\lambda}{1+\lambda}$$

Scenario 2: underreporting before the benefit-calculation window In the second scenario, we assume that the increase in reported earnings in the benefit-calculation window is explained by an underreporting of earnings in the years before this 10-year window. Reported earnings in the 10 years before retirement are as they would have been in the absence of responses to the dynamic incentives of the benefit calculation window. In this case, the cost to the social security administration comes exclusively through a loss of revenues during the years of work outside of the benefit calculation window (for example, 20 years for a person with 30 years of service at the time of retirement).

The net change in payroll tax revenues, updated to the time of retirement, is the sum across years in period 1 of the updated value of forgone payroll tax revenues due to the decrease in reported earnings: $\Delta\text{Revenue}_{\text{S2}} = \sum_{t=1}^{T_1} (1+r)^{T_2+t} \times \tau \times (w_1 - w_2)$. Thus, the net cost to the social security as a percentage of total expenditures in self-employed pensions is:

$$\Delta\text{Cost}_{\text{S2}} = \frac{\mathbf{-\Delta Revenue_{S2}}}{\textbf{Expend. SE pensions}} = \frac{\sum_{t=1}^{T_1} (1+r)^{T_2+t} \times \tau}{\sum_{i=1}^{T_3} \frac{1}{(1+r)^{i-1}} \times RR} \times \frac{\lambda}{1+\lambda}$$

Parameterization We calibrate our formulas with the values of the parameters in the institutional setting. The parameters used are presented in the top panel of Table 6. The number of years in period 2, $T_2 = 10$, and the payroll tax rate, $\tau = 22.625\%$, are determined by the regulations (see Section 2). We assume a composed real interest rate of 2 percent, which is about the average real interest rate in the last 30 years; we also present the results with alternative values of the interest rate of 0 and 4%. The number of years in period 1 (T_1), is the total number of years of service minus the last 10. The number of years in period 3 (T_3) is the male life expectancy at the age of retirement.[22] For the replacement rate, we use the statutory replacement rates for the retirement

[22]We use life expectancy at three different ages of retirement considered, for a person that was 60 years old in 2019, published by Banco Central del Uruguay (2019).

age and years of service considered (de Melo et al., 2019).

Finally, we use our estimate of λ from the empirical analysis to approximate the percent increase of reported earnings due to the presence of a 10-year benefit-calculation window. Given that the average retirement age is 63.5, we use the estimated increase in reported earnings at ages 54 to 57, relative to reported earnings at age 49 (λ from Equation 2) as our estimate of the increase in reported earnings in the 10-year benefit-calculation window for the average self-employed retiree. This estimate is an increase of 2.8 percentage points in reported earnings. In this sense λ, combined with the parameters of the institutional setting and assumptions about counterfactual behavior, is a sufficient statistic, in the spirit of Saez (2001) and Chetty (2009), to compute the costs of responses to the benefit calculation window.

6.2 Counterfactual results

The results for each scenario are presented in the last two rows of Table 6. Under Scenario 1, we estimate that the net social security expenditures increase by 2% per self-employed worker who retires at the average retirement age of 63. In the second scenario, the estimated net cost is slightly larger. Our point estimate for retirement at age 63 is an increase of 2.5% in the cost per self-employed retiree.

For each scenario, we also present estimates for retirement at ages 60 (minimum retirement age) and 65, for a person that has accumulated 30 years of service at age 60. The estimated costs in both scenarios vary little with retirement age and implied years of service, given the 2% interest rate. In scenario 1, the sensitivity to retirement age is very small because the effects of differences in life expectancy and replacement rates practically offset each other. In scenario 2, there is some more variation with retirement age, with estimates that range from 2.3% for a person retiring at age 60 with 30 years of service, to 2.6% for retirement at age 65 with 35 years of service.

Robustness We study the robustness of the estimated costs to the real interest rate. The estimated net cost in scenario 1 is decreasing with the interest rate, as future expenditures are discounted at a higher rate. In scenario 2, using a higher interest rate increases the estimated cost, because past forgone revenues have a higher present value. Overall, the results are robust to reasonable ranges for the interest rate.

In sum, our estimates suggest that responses to the benefit-calculation window increase the net cost of providing retirement benefits to the self-employed by between 1.9% and 2.6%. The estimated costs are relatively larger the longer retirement is delayed, and in the scenario where responses operate through a decrease in reported earnings in the period before the benefit-calculation window (scenario 2), although these differences are relatively small.

7 Final remarks

Many developed and developing countries, or subsystems in these countries, take into account reported earnings in a small set of final years of work in the computation of pension benefits. This decision introduces dynamic incentives for individuals to shift reported earnings towards the final years of their careers to increase their pension benefits. The presence of responses to these dynamic incentives is not trivial, since workers may have optimization frictions and may face high costs of changing their reporting behavior in their final years of work. In this paper, we use matched employer-employee social security administrative records from Uruguay, to study the earnings-reporting behavior of self-employed and employed workers.

In our event study analysis, we find that reported earnings of self-employed workers and those of employees of small firms start increasing 10 years before the minimum retirement age, while this is not observed for employees of larger firms. Furthermore, we find that these changes in reported earnings are not true labor supply responses but rather changes in reporting behavior. Self-employed workers are a group that is particularly likely to take advantage of these incentives, because their earnings reporting is not mediated by employers with whom to bargain and are more prone to misreporting. Small firms are also prone to misreporting employee earnings, and this fact together with a closer employment relationship may facilitate responses from employees of small firms.

Our estimations imply that these behavioral responses impose substantial costs to the retirement system, increasing expenditures in self-employment retirement benefits by 1.9% to 2.6%. To the best of our knowledge, this is the first paper to document the responses of reported earnings to this type of dynamic incentives in a country-wide pension system.

There may be reasons to use short retirement benefit calculation windows in defined-benefit retirement systems, including incomplete information about individuals' earnings histories, or the goal to protect workers against negative employment shocks or informality spells. However, the costs induced by the dynamic incentives they create should be included in the discussion about the design of pension benefit calculation.

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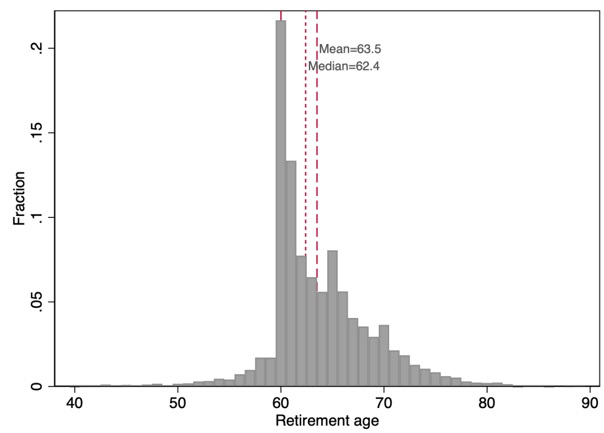
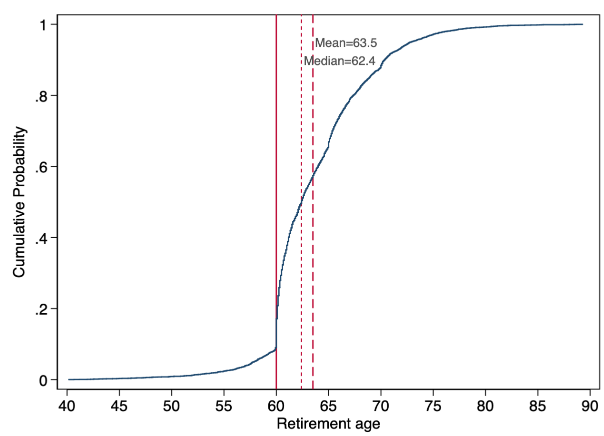
Figures and Tables

Figure 1: Retirement age histogram and empirical CDF



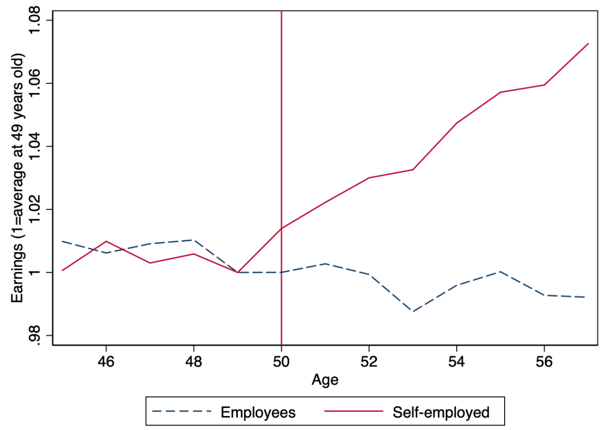
(a) Retirement age histogram



(b) Retirement age empirical CDF

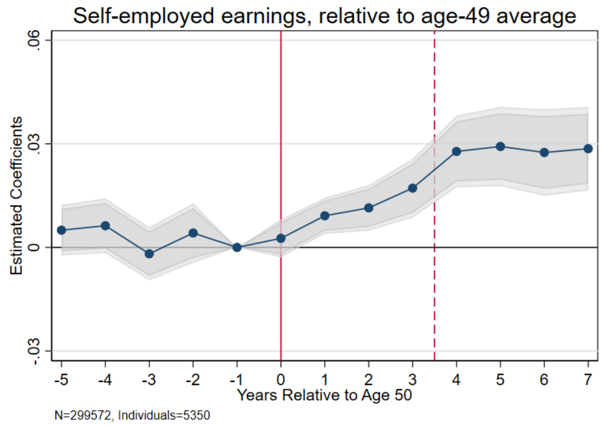
Notes: The figure on the top panel (a) shows the histogram of age of retirement for all the workers in our sample that are observed retiring between 1996 and 2016. The figure on the bottom (b) shows the empirical cumulative distribution function of retirement age. The sample includes self-employed and employed workers reporting earnings to social security between April 1996 and April 2016.

Figure 2: Age-earnings profiles of self-employed and employed workers



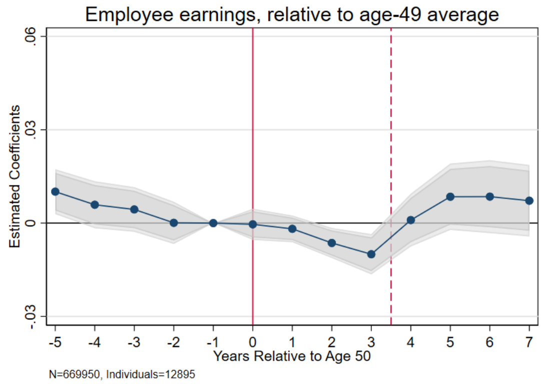
Notes: The graph shows the average monthly earnings reported to the Social Security Administration of self-employed and employed workers by age, normalized to 1 at age 49. The sample includes all observations for self-employed and employed workers ages 45 to 57, reporting earnings for at least 1 month between April 1996 and March 2016.

Figure 3: Event Study of self-employed reported earnings to Social Security

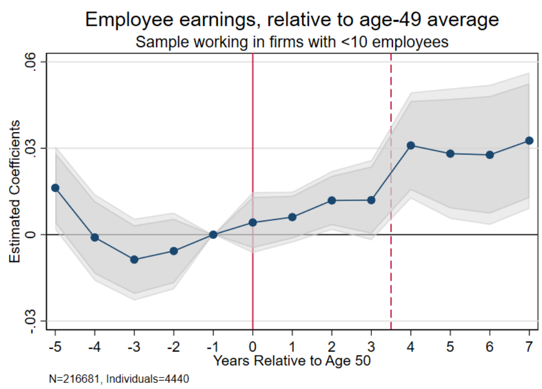


Notes: The plot shows estimates of the coefficients of age dummies in equation 1, with the shaded area illustrating 95% (light gray) and 90% (dark gray) confidence intervals based on two-way cluster robust standard errors by individual and age. The outcome variable is Reported Earnings to social security, expressed as a ratio of sample average age 49 earnings. The sample includes self-employed workers ages 45 to 57, reporting earnings to social security for at least 6 months, between April 1996 and April 2016.

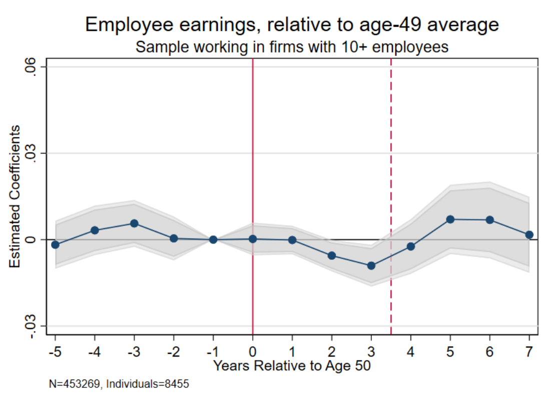
Figure 4: Event Study of employee earnings reported to Social Security



Panel A. Full sample of employees



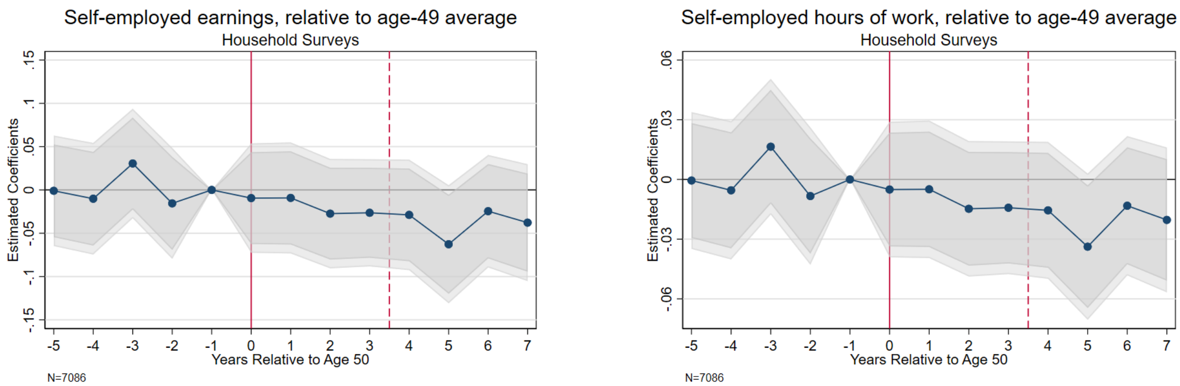
Panel B. Employees of small firms (<10 workers)



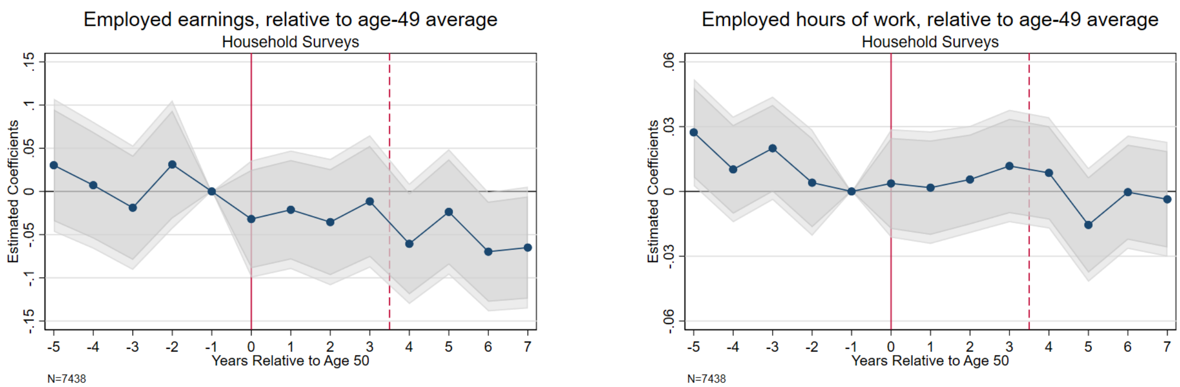
Panel C. Employees of larger firms (10+ workers)

Notes: The plots show estimates of the coefficients of age dummies in equation 1, with the shaded area illustrating 95% (light gray) and 90% (dark gray) confidence intervals based on two-way cluster robust standard errors by individual and age. The outcome variable is Reported Earnings to social security as a ratio of average sample age 49 earnings. The samples include workers ages 45 to 57, employed at any firm (Panel A), firms with less than 10 employees (Panel B), and firms with 10+ employees (Panel C), reporting earnings to social security for at least 6 months, between April 1996 and April 2016.

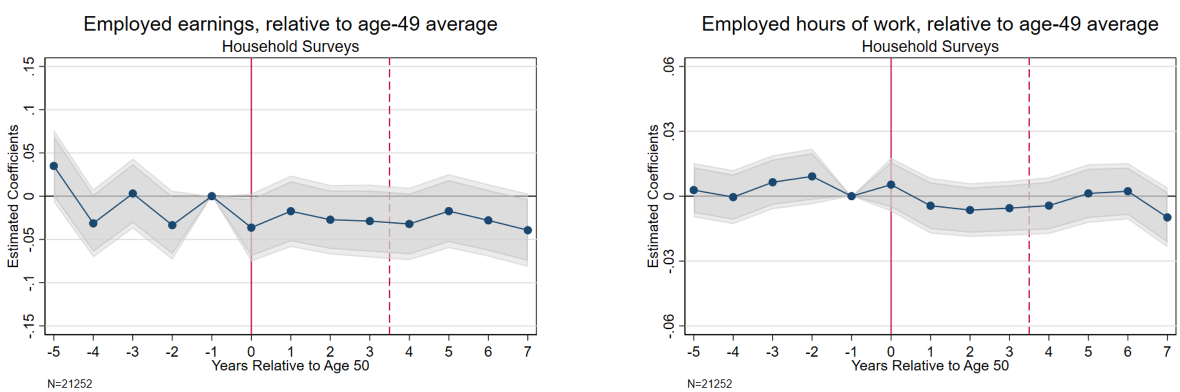
Figure 5: Event Studies of earnings and hours of work in household surveys



Panel A. Self-employed workers



Panel B. Employees of small firms (<10 workers)



Panel C. Employees of larger firms (10+ workers)

Notes: Each plot shows estimates of the coefficients of age dummies in equation 1, with the shaded area illustrating 95% (light gray) and 90% (dark gray) confidence intervals based on robust standard errors. The outcome variable for the plots on the left is total self-employed earnings relative to the sample average before age 50, while the outcome in the plots on the right is total self-employed hours of work per week. The sample includes workers ages 45 to 57 who are self-employed as their main job (Panel A), or who are employees in firms with less than 10 workers (Panel B), in household surveys (ECH) 1996 to 2016.

Table 1: Descriptive Statistics

	Social Security Data				Household Surveys			
	Self-employed		Employees		Self-employed		Employees	
	mean	sd	mean	sd	mean	sd	mean	sd
Reported earnings (1,000 UY$)	9.43	5.49	26.90	18.54	25.91	21.06	23.73	18.54
– If employed at small firm			17.26	12.28			18.29	14.55
Rep. earnings/Self-emp. min.	1.28	0.70						
Reports self-empl. min.	0.34	0.47						
Prop. time reporting earnings	0.70	0.28	0.66	0.27				
Hours of work per week					50.29	14.84	48.45	10.23
Age	51.14	3.69	50.94	3.68	50.91	3.66	50.68	3.70
No employees	0.65	0.48	0.00	0.00	0.55	0.50	0.00	0.00
Firm size < 5 workers	0.28	0.45	0.19	0.39	0.40	0.49	0.13	0.34
Firm size 5-9 workers	0.04	0.21	0.12	0.33	0.06	0.23	0.13	0.33
Firm size $\geq$10 workers	0.02	0.13	0.69	0.46	0.00	0.00	0.74	0.44
Manufacturing	0.18	0.39	0.16	0.36	0.19	0.39	0.31	0.46
Retail, Restaurants, Hotels	0.37	0.48	0.31	0.46	0.42	0.49	0.24	0.43
Transport, Communications, Energy	0.19	0.39	0.11	0.32	0.19	0.39	0.23	0.42
Services , Other	0.26	0.44	0.41	0.49	0.20	0.40	0.23	0.42
Observations	299,572		669,950		7153		28971	
Individuals	5,350		12,895		7153		28971	

Notes: Data from employment administrative records (BPS) between April 1996 and April 2016. Details about each sample are provided in Section 4.

Table 2: Regression estimates of changes in self-employed reported earnings

Outcome:	Self-Employed reported earnings/age 49 average		
	(1)	(2)	(3)
Panel A. Semi-parametric specification			
Age≤48	-0.001	0.004	0.003
	(0.006)	(0.004)	(0.004)
Age 50-53	0.008**	0.010***	0.010***
	(0.003)	(0.003)	(0.003)
Age≥54	0.027***	0.030***	0.028***
	(0.007)	(0.006)	(0.005)
Panel B. Parametric specification with linear age trend			
Age trend	0.003	-0.001	-0.001
	(0.002)	(0.002)	(0.001)
Age≥50	-0.006***	0.001	0.003***
	(0.001)	(0.001)	(0.001)
Age≥50 x Age trend	0.002	0.006**	0.005**
	(0.003)	(0.002)	(0.002)
Observations	299572	299572	299572
Individuals	5350	5350	5350
Time FE	Yes	Yes	Yes
Firm size FE		Yes	Yes
Industry FE		Yes	Yes
Year # Firm size FE			Yes
Year # Industry FE			Yes

Notes: Data from BPS employment administrative records between April 1996 and April 2016. The outcome variable is Reported Earnings to social security as a ratio of average sample age 49 earnings. The sample includes self-employed workers ages 45 to 57 reporting earnings to social security for at least 6 months. Two-way cluster robust standard errors by individual and age in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 3: Regression estimates of changes in employee reported earnings

Outcome:	Employee reported earnings/age 49 average					
	All Employees			Interactions firm <10 workers		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Semi-parametric specification						
Age≤48	0.008	0.005	0.005	0.012**	0.002	0.002
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)
Age 50-53	-0.010***	-0.005*	-0.005*	-0.017***	-0.004	-0.003
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)
Age≥54	-0.009	0.007	0.006	-0.018**	0.004	0.003
	(0.006)	(0.005)	(0.005)	(0.007)	(0.006)	(0.006)
Small firm x Age≤48				-0.036***	-0.005	-0.002
				(0.010)	(0.009)	(0.009)
Small firm x Age 50-53				0.040***	0.013**	0.012**
				(0.007)	(0.005)	(0.005)
Small firm x Age≥54				0.085***	0.033**	0.027*
				(0.014)	(0.012)	(0.012)
Panel B. Parametric specification with linear age trend						
Age trend	-0.003**	-0.003*	-0.003*	-0.004**	-0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Age≥50	-0.007***	-0.004***	-0.004***	-0.013***	-0.006***	-0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Age≥50 x Age trend	0.003	0.005**	0.004**	0.003	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Small firm x Age trend				0.012***	-0.003	-0.004
				(0.003)	(0.004)	(0.003)
Small firm x Age≥50				0.017***	0.017***	0.017***
				(0.001)	(0.000)	(0.001)
Small firm x Age≥50 x Age trend				-0.000	0.008	0.008
				(0.004)	(0.005)	(0.005)
Observations	669950	669950	669950	669950	669950	669950
Individuals	12895	12895	12895	12895	12895	12895
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm size FE		Yes	Yes		Yes	Yes
Industry FE		Yes	Yes		Yes	Yes
Year # Firm size FE			Yes			Yes
Year # Industry FE			Yes			Yes

Notes: Data from BPS employment administrative records between April 1996 and April 2016.The outcome variable is Reported Earnings to social security as a ratio of average sample age 49 earnings. The sample includes employees ages 45 to 57 reporting earnings to social security for at least 6 months. Two-way cluster robust standard errors by individual and age in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 4: Self-employed total earnings and hours of work in household surveys

Outcome:	Total earnings			Hours of work		
	(1)	(2)	(3)	(1)	(2)	(3)
Panel A. Semi-parametric specification						
Age≤48	-0.024	-0.028	-0.028	0.004	0.001	0.002
	(0.030)	(0.028)	(0.028)	(0.014)	(0.014)	(0.014)
Age 50-53	-0.032	-0.033	-0.035	-0.009	-0.010	-0.010
	(0.030)	(0.028)	(0.028)	(0.014)	(0.014)	(0.014)
Age≥54	-0.051*	-0.046	-0.052*	-0.020	-0.023	-0.021
	(0.030)	(0.028)	(0.028)	(0.015)	(0.014)	(0.014)
Panel B. Parametric specification with linear age trend						
Age trend	0.015*	0.015*	0.014*	0.000	-0.001	-0.001
	(0.008)	(0.008)	(0.008)	(0.004)	(0.004)	(0.004)
Age≥50	-0.055*	-0.054*	-0.050*	-0.010	-0.004	-0.005
	(0.031)	(0.030)	(0.030)	(0.015)	(0.015)	(0.015)
Age≥50 x Age trend	-0.019**	-0.017**	-0.017**	-0.003	-0.002	-0.001
	(0.009)	(0.009)	(0.009)	(0.004)	(0.004)	(0.004)
Observations	7153	7153	7153	7153	7153	7153
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm size FE		Yes	Yes		Yes	Yes
Industry FE		Yes	Yes		Yes	Yes
Time # Firm size FE			Yes			Yes
Time # Industry FE			Yes			Yes

Notes: Data from Encuesta Continua de Hogares from April 1996 until March 2016. The outcome variable is total individual earnings as a ratio of average sample age 49 earnings in the first three columns, and hours of work per week in main employment in the last three columns. The sample includes formal self-employed workers ages 45 to 57. Robust standard errors in parentheses. * $p<0.1$, ** $p<0.05$, *** $p<0.01$

Table 5: Employee total earnings and hours of work in household surveys

Outcome:	Total earnings			Hours of work		
	(1)	(2)	(3)	(1)	(2)	(3)
Panel A. Semi-parametric specification						
Age≤48	-0.013	-0.008	-0.004	0.005	0.008*	0.008*
	(0.016)	(0.015)	(0.015)	(0.005)	(0.005)	(0.005)
Age 50-53	-0.034**	-0.031**	-0.028*	-0.000	0.001	0.001
	(0.016)	(0.015)	(0.015)	(0.005)	(0.005)	(0.005)
Age≥54	-0.046***	-0.037**	-0.035**	-0.004	-0.001	-0.001
	(0.016)	(0.015)	(0.015)	(0.005)	(0.005)	(0.005)
Panel B. Parametric specification with linear age trend						
Age trend	-0.007	-0.005	-0.006	-0.001	-0.001	-0.001
	(0.004)	(0.004)	(0.004)	(0.001)	(0.001)	(0.001)
Age≥50	0.001	-0.008	-0.005	-0.000	-0.000	-0.001
	(0.017)	(0.016)	(0.016)	(0.005)	(0.005)	(0.005)
Age≥50 x Age trend	0.005	0.003	0.005	-0.000	0.001	0.000
	(0.005)	(0.005)	(0.005)	(0.002)	(0.001)	(0.001)
Observations	28971	28971	28971	28971	28971	28971
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm size FE		Yes	Yes		Yes	Yes
Industry FE		Yes	Yes		Yes	Yes
Year # Firm size FE			Yes			Yes
Year # Industry FE			Yes			Yes

Notes: Data from Encuesta Continua de Hogares from April 1996 until March 2016. The outcome variable is total individual earnings as a ratio of average sample age 49 earnings in the first three columns, and hours of work per week in main employment in the last three columns. The sample includes data from Encuesta Continua de Hogares on formal employed workers ages 45 to 57. Robust standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 6: Back-of-the-Envelope Estimated Cost

Retirement age:	60	63	65
Panel A. Parameters			
Service years	30	33	35
Replacement rate	0.45	0.54	0.6
Years period 1 (T_1)	20	23	25
Years period 2 (T_2)	10	10	10
Years period 3 (T_3)	22	20	19
Payroll tax rate(τ)	0.22625	0.22625	0.22625
Panel B. Estimated increase in net cost per self-employed retiree			
Interest rate = 0.02			
Scenario 1	0.019	0.020	0.020
Scenario 2	0.023	0.025	0.026
Interest rate = 0.00			
Estimations Scenario 1:	0.021	0.022	0.022
Estimations Scenario 2:	0.012	0.013	0.014
Interest rate = 0.04			
Estimations Scenario 1:	0.016	0.017	0.018
Estimations Scenario 2:	0.042	0.046	0.048

Notes: The last two rows present estimates of the net increase in total expenditure in social security per self-employed retiree from dynamic responses to the 10-year retirement benefit calculation window, given the parameters presented above. The methodology for each of the two scenarios is described in Section 6. Each column presents the parameters and estimates for a person who retires at the age indicated in the column heading, who accumulates 30 years of service by age 60. The replacement rates are statutory for the corresponding retirement age and years of service. Years in period 3 (in retirement) equal the life expectancy at the age of retirement for a person who is age 60 in 2019, obtained from Banco Central del Uruguay (2019).

A Appendix

A On-line Appendix A: Additional details about the institutional background

Uruguay has a well established contributory social security system that gives formal workers (i.e. those registered and contributing payroll taxes) access to contributory retirement benefits, as well as other social insurance programs (unemployment insurance, workers compensation, disability insurance, maternity and paternity leave, health insurance) and employment protections. The social security system for private-sector workers is administered by *Banco de Previsión Social* (BPS), Uruguay's social security administration, which collects payroll taxes and distributes benefits.[23] There is a proportion of unregistered workers (informal employment) that is comparable to many transition economies and low in the Latin American context; it declined from 40% to 25% during our study period. There is also payroll tax evasion through the underreporting of earnings; 10% of formal employees state in household surveys that their earnings are under-reported to the social security administration, and this proportion is higher for individuals with low earnings and working in small firms (Bergolo and Cruces, 2014).

Reporting and taxation of earnings Employee earnings are reported by employers, who are responsible for collecting and paying to BPS the employer (7.625%) and employee (15.125%) payroll taxes. The law treats self-employed business owners as subject to the same social security system as employed workers, although with some specific regulations. Self-employed workers report their own earnings to BPS and must pay a 22.625% payroll tax on the reported earnings.[24] They cannot report less than a minimum contribution base (MCB) that is adjusted yearly with the national average salary. In 2019, the MCB was 12,094 UY$ (or 318 US$) per month, which is 77% of the minimum wage for a full-time employee. Those who employ other workers have a higher minimum contribution base and cannot report earnings below those of their highest paid employee.

Since 2007 there is an income tax, with marginal tax rates of between 10% and 36% depending

[23]There are specific retirement schemes for certain occupations that are administered separately, such as police and military personnel, bank employees, and notaries and members of other professional associations with university degrees. In this paper we focus on workers subject to the general private-sector social security scheme.

[24]In addition, workers and employers also contribute an additional percentage to finance the health insurance program. Self-employed workers contribute an equivalent of the cost of coverage for the worker and his/her dependents.

on total annual earnings brackets. However, it is unlikely that the income tax plays an important role in most self-employed workers' decisions on the level of earnings to report to the social security administration. Monthly earnings must be above UY$ 36,000 (952 UY$) to start paying any income tax; as a reference, this is more than two standard deviations above the average reported earnings by the self-employed to the social security administration, and 33% above the average total monthly earnings they report in household surveys.

Minimum retirement age and conditions for retiring To qualify for what is called *ordinary* retirement, workers must be at least 60 years old and have contributed to social security for a minimum of 30 years of service. Workers who do not satisfy the required years of service may be eligible for *old age* retirement at age 65 with at least 25 years of service, or other combinations of fewer years of service and more years of age, up to age 70 and 15 years of service. In this study we focus on men, whose minimum retirement age remained constant throughout our sample period.[25]

In our data for the period 1996 to 2016, over 20% of male retirees started receiving benefits at age 60, and 50% were receiving benefits by age 62.4 (see Figure 1). Later retirement may be voluntary or due to insufficient accumulated years of service. Using administrative data and macroeconomic projections, de Melo et al. (2019) estimate that 52.4% of men in the total population of 40-60 years of age in 2015 would satisfy the required years of service to be eligible for retirement by age 60, and another 19.6% will be eligible by age 70. 28% will not be eligible for retirement under the contributory scheme; those with low income receive a non-contributory *old age pension*.

Social security reforms and defined-benefit pensions The current social security system originated in reform that took effect in April 1996 (Act 16713/1995). The workers older than 40 on April 1, 1996 would be covered *transition* defined-benefit regime. We denominate these cohorts ***transition cohorts*** hereafter. For the younger cohorts, the reform created a *two-pillar* system, part *defined-benefit* and part *defined-contribution* (private individual retirement savings accounts). We call these younger cohorts ***two-pillar cohorts*** hereafter. Our sample includes workers in both groups of

[25]Before the social security reform that took effect in 1996, the minimum retirement age was 60 for men and 55 for women. The reform stipulated gradual increases of the minimum retirement age of women, reaching age 60 by 2003. It increased the required years of contributions from 30 to 35, and established the minimum age for retirement due to old age at 70 years old, for both men and women. Due to the small proportion of people that would meet all these requirements, a law that took effect in 2009 relaxed some of these criteria: the minimum years of service was reduced back to 30 years, and the minimum age for *old age* retirement was reduced to 65 as it is now.

cohorts. As a consequence of how contributions are distributed between the two pillars, and the relative generosity of the defined-benefit pillar, most workers in the two-pillar system can expect to receive a larger share of their retirement benefits from the defined-benefit pillar, especially those with lower lifetime reported earnings.[26]

Benefit computation Retirement benefits in both the transition regime and the defined-benefit pillar of the two-pillar regime, are calculated as the product of a statutory replacement rate and a reference pre-retirement average reported earnings. The latter is calculated as the average of (inflation updated) reported earnings in the final 10 years of work, as long as this does not exceed the average of the highest 20 years of earnings plus 5%. If the average earnings of the final 10 years of work is less than the average of the highest 20 years of earnings, the latter is used. This design of benefit calculation using a window of the final 10-years introduces an incentive to report higher earnings in this window to increase retirement benefits.

Statutory replacement rates are incremental with age at retirement and years of service. Conditional on retiring with 30 years of service, the replacement rate goes from a minimum of 45% at age 60, to a maximum of 65% at age 70. The maximum replacement rate is 82.5%, and can be obtained by a person that retires at age 70 with at least 50 years of service. There is also a minimum retirement benefit, which has been increased over time. With the minimum retirement benefit, effective replacement rates can be higher for retirees with very low average reported earnings. However, it should be noted that minimum retirement benefits are subject to political decisions and are very difficult to predict for the future for active workers deciding how much to report to social security. There is also a ceiling for defined-benefit retirement benefits.

Regulatory sources of heterogeneity among the self-employed There are two main sources of heterogeneity in the flexibility that the self-employed have to increase their reported earnings in the

[26]In the two-pillar system, employer contributions go to the defined-benefit pillar, while worker contributions are distributed the following way: the first UY$ 58,000 in 2019 values (US$ 1,500) of reported earnings contribute to the defined-benefit pillar (administered by BPS), and any additional earnings above that threshold contribute to the defined-contribution pillar (administered by a retirement savings fund of their choice). Individuals with monthly earnings below the threshold of UY$ 58,000 have the option to contribute half of their reported earnings to the defined-contribution pillar and the other half to the defined-benefit pillar. There was a subsidy (matched contribution from the government) to induce individuals to opt for this option, and approximately 70% of individuals in this earnings range did (Castiñeiras et al., 2017). The defined-contribution pillar also has a maximum level of earnings for mandatory contributions, above which contributions are optional.

final 10 years of work: differences between *transition* and *two-pillar* cohorts, on one hand, and differences between firms with and without employees, on the other. A summary of all these regulations is provided in Table A.1. In our empirical analysis, we use the variation in regulation between these groups to study if the limitations imposed on transition cohorts and self-employed workers with employees mitigate their responses.

Table A.1: Contribution regulations for self-employed workers (sole-proprietorship firms)

	Cohorts in Two-Pillar Regime		Cohorts in Transition Regime	
	Without employees	With employees	Without employees	With employees
Minimum reported monthly earnings	Category 1 (11 BFC)	Max of Cat. 2 (15 BFC) or max employee earnings	Category 1 (11 BFC)	Max of Cat. 2 (15 BFC) or max employee earnings
Maximum reported monthly earnings	No limit		Category 10 (60 BFC)	
Rules for first choice of category (at firm opening)	Can choose any category		Must choose among first 3 categories (up to 20 BFC).	
Rules for change of category	Can change to any category once a year		Choice to upgrade to next category after reporting for at least 3 years in the same category	

Notes: Source: Asesoría Tributaria y Recaudación (2004). Two-pillar regime cohorts are those below age 40 by April 1, 1996. Transition regime cohorts were age 40 or above and had not met the requirements to retire by April 1, 1996. BFC refers to a standard contribution basis, which is updated annually to account for changes in national average salary.

The main difference between *transition* and *two-pillar* cohorts is that the law establishes some restrictions to changes in reported earnings for transition cohorts that may limit the scope of responses among this group. Transition cohorts can change their reported earnings once every three years, and these increases are topped. Two-pillar cohorts can change their reported earnings every year, and they have no limit as to how much to report.[27] Self-employed workers who have employees have a higher minimum contribution base and, most importantly, cannot report earnings that are below the highest paid employee in the firm.

[27]Self-employment earnings are reported by choosing a category within scale of earnings levels, where the first category is the minimum contribution base and the tenth and top category is the maximum that transition cohorts can report. Two-pillar cohorts can report any level of earnings above the minimum, including earnings above the tenth category. Transition cohorts can only change their reported after being three years in the same category, and can only move up one category at a time.

B On-line Appendix B: Additional robustness checks for reported self-employed earnings

B.1 Reported earnings as a ratio of the minimum contribution base

To distinguish age effects from time effects, our empirical strategy relies on variation over time in average reported earnings by workers of any age within our sample, which identifies the time fixed effects. Any changes over time that may affect reported earnings should be controlled for by the inclusion of time dummies. An example of such a change that could affect the level of reported earnings is a change in the value of the minimum contribution base for the self-employed, which was changing over time as a result of changes in average wages in the economy. This variable could thus capture changes in reported earnings due to the binding nature of this legal minimum, on one hand, and because it reflects changes in earnings over the business cycle, on the other.

To check whether these changes are correctly captured in our models and are not biasing our results, we estimate the same models as in equations 1 to 3, but we now transform our outcome variable to be the ratio of reported earnings over the value of the legal minimum for self-employed reported earnings. The results of this exercise, presented in Table B.1, follow the same patterns as our main results, which implies that our models are correctly controlling for the effects of changes in the minimum contribution base over time. These results also allow us to give another sense of the magnitude of the estimated effects. In our preferred semi-parametric specification, the results indicate that self-employed reported earnings increase after age 50 by 1.1% of the minimum contribution base, and that by ages 54-57 they are larger than age-49 reported earnings by 3.4% of the minimum.

Table B.1: Robustness to measuring earnings as ratio of minimum contribution base

Outcome:	Self-Employed reported earnings/legal min		
	(1)	(2)	(3)
Panel A. Semi-parametric specification			
Age≤48	-0.002	0.004	0.002
	(0.007)	(0.005)	(0.005)
Age 50-53	0.009**	0.012***	0.011***
	(0.003)	(0.004)	(0.003)
Age≥54	0.034***	0.037***	0.034***
	(0.009)	(0.007)	(0.007)
Panel B. Parametric specification with linear age trend			
Age trend	0.004	-0.001	-0.001
	(0.002)	(0.002)	(0.002)
Age≥50	-0.008***	0.001	0.002*
	(0.001)	(0.001)	(0.001)
Age≥50 x Age trend	0.002	0.007**	0.006**
	(0.003)	(0.003)	(0.002)
Observations	299572	299572	299572
Individuals	5350	5350	5350
Time FE	Yes	Yes	Yes
Firm size FE		Yes	Yes
Industry FE		Yes	Yes
Year # Firm size FE			Yes
Year # Industry FE			Yes

Notes: The outcome variable is Reported Earnings to social security as a ratio of the minimum contribution base at the time. The sample includes self-employed workers ages 45 to 57 reporting earnings to social security at least 70% time, between April 1996 and April 2016. Two-way cluster robust standard errors by individual and age in parentheses. * p<0.1, ** p<0.05, *** p<0.01

B.2 Difference-in-differences between self-employed and employed workers

In this section, we provide a complementary strategy for identifying the responses of self-employed workers to the benefit calculation window, based on a difference-in-differences comparison between self-employed and employed workers. This strategy allows us to relax the assumption of our event study that there are no unobserved factors that affect reported earnings and are correlated with age. Instead, here we assume that, if such unobserved factors exist, they are common to self-employed and employed workers. If this is the case, we can use employees as a control group for the self-employed.

We estimate the following fully dynamic difference-in-differences study:

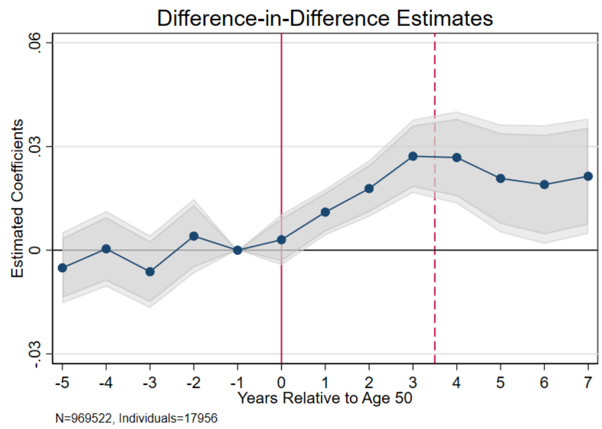
$$
\begin{aligned}
Y_{it} = & \sum_{b=-5}^{-2} \nu_b 1[\text{Years Window}_{it} = b] + \sum_{a=0}^{7} \nu_a 1[\text{Years Window} = a] \\
& + \sum_{b=-5}^{-2} \mu_b \text{Self-empl}_i 1[\text{Years Window}_{it} = b] + \sum_{a=0}^{7} \mu_a \text{Self-empl}_i 1[\text{Years Window} = a] \\
& + \delta_t + \xi_t \text{Self-empl}_i + \gamma X_{it} + \varepsilon_{it} \qquad \text{(B.1)}
\end{aligned}
$$

where the Self-empl_i is an indicator variable for self-employed workers, and all control variables are interacted with this indicator.

The identifying assumptions in this model are that employees' reported earnings do not respond to the incentives of the retirement system, and that self-employed and employed workers would have similar changes in reported earnings as they age. If the first assumption is not satisfied, this model identifies the differential responses of self-employed workers to the benefit-calculation window, above any responses there may be among employees.

The estimates of this model are presented in Figure B.1. The estimated effects before the start of the benefit-calculation window are all close to zero and not statistically significant. This indicates that, at least before age 50, changes in reported earnings with age among self-employed and employed workers have similar slopes. Immediately after the start of the benefit-calculation window, the earnings of self-employed workers increase above those of employed workers, similar to what we had found in our event study for the self-employed.

Figure B.1: Dynamic difference-in-differences study of reported earnings of self-employed and employed workers



Notes: The plot shows estimates of the coefficients of age dummies in equation 1, with the shaded area illustrating 95% (light gray) and 90% (dark gray) confidence intervals based on two-way cluster robust standard errors by individual and age. The outcome variable is Reported Earnings to social security as a ratio of average sample age 49 earnings. The sample includes self-employed and employed workers ages 45 to 57, reporting earnings to social security for at least 6 months, between April 1996 and April 2016.

We also estimate difference-in-differences versions of our more parsimonious semi-parametric and age-trend models, with different sets of controls.[28] The results are presented in Table B.2. The estimated effects in the semi-parametric model are very similar to our main results from the analogous model for the self-employed, and they are robust across specifications. With the most flexible set of controls, the estimated effect is somewhat larger at ages 50 to 53 (1.5 percentage points), and slightly smaller at ages 54 to 57 (2.2 percentage points), compared to our event study estimates. The model with age trends allows us to assess the presence of different age trends between employees and self-employed workers before age 50, which we reject. The results of this model are consistent with a shift upward in the reported earnings of the self-employed after the start of the benefit-calculation window.

[28] We estimate the following equations:

$$Y_{it} = \theta_0 \text{Age}_{it}^{45-48} + \theta_1 \text{Age}_{it}^{50-53} + \theta_2 \text{Age}_{it}^{54-57} + \kappa_0 \text{Self-empl}_i \text{Age}_{it}^{45-48} + \kappa_1 \text{Self-empl}_i \text{Age}_{it}^{50-53} + \kappa_2 \text{Self-empl}_i \text{Age}_{it}^{54-57} + \xi_t + \psi_t \text{Self-empl}_i + \gamma X_{it} + \varepsilon_{it} \quad \text{(B.2)}$$

$$Y_{it} = \eta_0 \text{Age trend}_{it} + \eta_1 1[\text{Age}_{it} \geq 50] + \eta_2 1[\text{Age}_{it} \geq 50]\text{Age trend}_{it} + \zeta_0 \text{Self-empl}_i \text{Age trend}_{it} + \zeta_1 \text{Self-empl}_i 1[\text{Age}_{it} \geq 50] + \zeta_2 \text{Self-empl}_i 1[\text{Age}_{it} \geq 50]\text{Age trend}_{it} + \delta_t + \xi_t \text{Self-empl}_i + \gamma X_{it} + \varepsilon_{it} \quad \text{(B.3)}$$

Table B.2: Difference-in-differences estimates of changes in reported earnings

Outcome:	Reported earnings/age 49 average		
	(1)	(2)	(3)
Panel A. Semi-parametric specification			
Self-employed x Age≤48	-0.009	-0.001	-0.002
	(0.008)	(0.006)	(0.006)
Self-employed x Age 50-53	0.018***	0.015***	0.015***
	(0.005)	(0.005)	(0.004)
Self-employed x Age≥54	0.036***	0.023**	0.022**
	(0.009)	(0.008)	(0.008)
Panel B. Parametric specification with linear age trend			
Self-employed x Age trend	0.006**	0.002	0.002
	(0.003)	(0.002)	(0.002)
Self-employed x Age≥50	0.000	0.005**	0.007***
	(0.001)	(0.002)	(0.002)
Self-employed x Age≥50 x Age trend	-0.001	0.001	0.001
	(0.003)	(0.003)	(0.003)
Observations	969522	969522	969522
Individuals	17956	17956	17956
Time FE	Yes	Yes	Yes
Firm size FE		Yes	Yes
Industry FE		Yes	Yes
Year # Firm size FE			Yes
Year # Industry FE			Yes

Notes: Data from BPS employment administrative records between April 1996 and April 2016. The outcome variable is Reported Earnings to social security as a ratio of average sample age 49 earnings. The sample includes self-employed workers ages 45 to 57 reporting earnings to social security for at least 6 months, between April 1996 and April 2016. Two-way cluster robust standard errors by individual and age in parentheses. * p<0.1, ** p<0.05, *** p<0.01

C On-line Appendix C: Heterogeneity and margins of response for self-employed workers

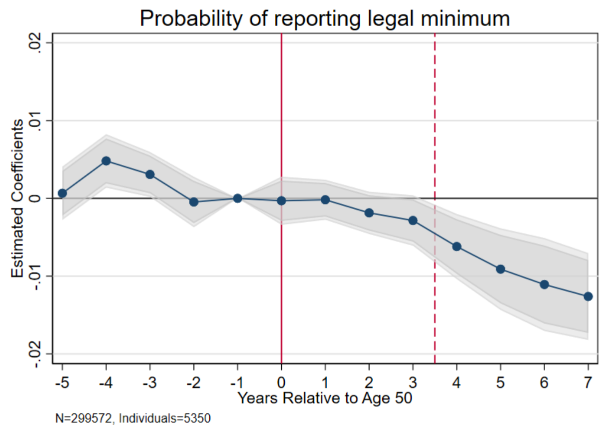
This section discusses margins of response and heterogeneity analyses among different groups of self-employed workers. We begin by studying the extensive and intensive margins of responses that our model predicts. Then, we explore heterogeneity of responses across groups that have different incentives and flexibility to respond due to specific institutional regulations.

C.1 Margins of response

Probability of reporting minimum earnings We begin by testing if the probability of reporting the minimum contribution base changes after age 50. Figure C.1 shows the results of an event study (linear probability model) where the outcome variable is an indicator that takes the value of 1 if reported earnings are equal to the minimum contribution base (MCB) at the time of reporting. The graph shows evidence of a decrease in the proportion of self-employed workers reporting the MCB after age 50, with effects that are increasing in magnitude with age and reach over a 1 percentage point decrease in the last years of the age window considered. This is a rather small effect considering that over one third of observations of reported self-employment earnings are at the MCB (it implies a decrease of 3% in the proportion reporting the MCB). There is also some variation in the probability of reporting minimum earnings before age 50, although this variation does not appear to be a downward trend.

In the first three columns of Table C.1, we present estimates of the semi-paramentric (Panel A) and age-trend models (Panel B). The results in Panel A suggest there is a decrease of 1 percentage point in the probability the minimum after age 54. In Panel B, there is no evidence of a pre-existing trend in reported earnings. The non-statistically significant negative age-trend after age 50 and the positive intercept are consistent with the pattern observed in Figure C.1, given that the decrease only starts in the second half of the post-age-50 period.

Figure C.1: Event Study of likelihood of reporting earnings equal to the minimum contribution base



Notes: The plot shows estimates of the coefficients of age dummies in equation 1, with the bars illustrating 95% confidence intervals based on two-way cluster robust standard errors by individual and age. The outcome variable is an indicator variable that is 1 if reported earnings to social security are equal to the minimum contribution base. The sample includes self-employed workers ages 45 to 57 reporting earnings to social security for at least 6 months, between April 1996 and April 2016.

Intensive margin responses To assess intensive margin responses, we estimate the reported earnings models separately for the sample of workers who report earnings above the MCB in the first in-sample observation. The results are presented in the last three columns of Table C.1. The estimated coefficients for the two age groups above age 50 are slightly larger than those of the full sample of self-employed workers shown in Table 2 in the paper. In this case, the changes in reported earnings in our preferred specification (column 6) are of 1.1 percentage points at ages 50-53, and 3.4 percentage points at ages 54-57. These results, taken together with those discussed in the previous paragraph, suggest that most of the responses of self-employed workers to the incentives of the retirement-benefit calculation window seem to come from the intensive margin, i.e. from workers who are already reporting above minimum earnings.

Table C.1: Minimum contribution base and margins of response

Outcome:	Reports Minimum			Self-Employed reported earnings/age 49 average		
	All self-employed			Report earnings>min when 1st observed		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Semi-parametric specification						
Age≤48	0.004	0.002	0.002	0.009	0.005	0.001
	(0.003)	(0.002)	(0.002)	(0.008)	(0.006)	(0.006)
Age 50-53	0.000	-0.003**	-0.001	0.009*	0.010**	0.011**
	(0.002)	(0.001)	(0.001)	(0.004)	(0.004)	(0.004)
Age≥54	-0.003	-0.009***	-0.010***	0.037***	0.030***	0.034***
	(0.004)	(0.003)	(0.003)	(0.011)	(0.009)	(0.008)
Panel B. Parametric specification with linear age trend						
Age trend	-0.002	0.000	-0.000	-0.002	-0.000	0.001
	(0.001)	(0.001)	(0.001)	(0.003)	(0.002)	(0.002)
Age≥50	0.003***	-0.002*	0.002***	-0.007***	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Age≥50 x Age trend	0.001	-0.001	-0.002	0.008**	0.005	0.004
	(0.002)	(0.001)	(0.001)	(0.004)	(0.003)	(0.003)
Observations	299572	299572	299572	185431	185431	185431
Individuals	5350	5350	5350	3501	3501	3501
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm size FE		Yes	Yes		Yes	Yes
Industry FE		Yes	Yes		Yes	Yes
Year # Firm size FE			Yes			Yes
Year # Industry FE			Yes			Yes

Notes: Data from BPS administrative records between April 1996 and April 2016. In the first three columns, the outcome variable is an indicator for reported earnings equal to the minimum contribution base, and the sample includes self-employed workers ages 45 to 57 reporting earnings to social security for at least 6 months between April 1996 and April 2016. In the last three columns, the outcome variable is reported earnings, expressed as a ratio of sample average earnings at age 49, and the sample includes self-employed workers ages 45 to 57 reporting earnings to social security for at least 6 months, who report earnings above the minimum when they first enter the sample. Two-way cluster robust standard errors by individual and age in parentheses. * p<0.1, ** p<0.05, *** p<0.01

C.2 Frequent self-employment reporters

As observed in the summary statistics (Table 1 in the paper), there is considerable dispersion in the frequency of reporting of self-employment earnings. Some workers only report earnings for a few periods, which may have to do with self-employment not being their main source of income or with a weak attachment to formal employment. Because qualifying for retirement benefits require workers to have reported earnings for at least 30 years, workers with infrequent reported earnings are less likely to be eligible for retirement even when they achieve the minimum retirement age. We would thus expect workers with a stronger attachment to formal self-employment to have stronger responses to the dynamic incentives of the retirement-benefit calculation formula. To assess this, we estimate the empirical models on the sample of self-employed workers who report earnings at least 70% of the time they can potentially be in our sample.

The results of the non-parametric event study are presented in Figure C.2, and the estimates of the semi-parametric model with different sets of controls are presented in the first three columns of Table C.2. The results are qualitatively very similar to the results presented for the full sample of self-employed workers, but the estimated responses are indeed larger in the sample of frequent reporters. At ages 50-53 and 54-57, reported earnings are 1.7 and 4 percentage points higher than at age 49, respectively. Estimates of the parametric model with linear age trend for this sample of self-employed workers are presented in the first three columns Table C.3.

Figure C.2: Event study of self-employed earnings, sample reporting frequently to Social Security

Notes: The plot shows estimates of the coefficients of age dummies in equation 1, with the shaded area illustrating 95% (light gray) and 90% (dark gray) confidence intervals. The outcome variable is Reported Earnings to social security as a ratio of average sample age 49 earnings. The sample includes self-employed workers ages 45 to 57, reporting earnings to social security at least 70% of the time, between April 1996 and April 2016. Two-way cluster robust standard errors by individual and age in parentheses. * $p<0.1$, ** $p<0.05$, *** $p<0.01$

C.3 Impacts of regulations

Next, we explore the heterogeneity of responses across groups that have different flexibility to respond due to specific institutional regulations. The goal of this empirical analysis is to understand whether the regulatory restrictions that apply to certain groups, are effective at mitigating the responses of these groups to the incentives of the retirement system.

As discussed in Section 2 of the paper and in Online Appendix A, there are some regulatory differences between *transition* and *two-pillar* cohorts, as well as specific regulations for self-employed workers with employees. These regulations are summarized in Table A.1 of Online Appendix A. We are interested in the differential effects of age after the start of the retirement calculation window for the groups that are subject to stringer regulatory restrictions. To estimate these differential effects, we extend the models presented in the paper by introducing interactions with indicators for individuals subject to these regulatory restrictions.

Transition and two-pillar regime cohorts Our sample includes 30 birth cohorts; the first 15 cohorts are in the *transition* regime, and the other 15 are in the *two-pillar* system. The law established more restrictions for *transition* cohorts to respond to the dynamic incentives of the retirement system: they can only change their reported earnings every three years, and they have limits to both the increase in the reported earnings and the maximum earnings they can report. On the other hand, the cohorts that are in the *two-pillar* system can more freely respond to these dynamic incentives, since they can change their reported earnings yearly without any restrictions. To study whether the cohorts in the transition regime behave differently from those in the two-pillar regime, we extend the semi-parametric model of equation 2 in the paper as follows:

$$
\begin{aligned}
Y_{it} = {} & \rho_0 \text{Age}_{it}^{45-48} + \rho_1 \text{Age}_{it}^{50-53} + \rho_2 \text{Age}_{it}^{54-57} \\
& + \pi_0 \text{Age}_{it}^{45-48} \text{Transition}_i + \pi_1 \text{Age}_{it}^{50-53} \text{Transition}_i + \pi_2 \text{Age}_{it}^{54-57} \text{Transition}_i \\
& + \delta_t + \xi_t \text{Transition}_i + \gamma X_{it} + \varepsilon_{it} \qquad \text{(C.1)}
\end{aligned}
$$

where the indicator variable Transition_i indicates that individual i is in a *transition* cohort, and all control variables are interacted with this indicator so that the model is saturated.

In this model, parameters denoted with ρ correspond to age effects for the group not subject to the more restrictive regulations (*two-pillar* cohorts). Parameters π are the additional age effects for the *transition* cohorts; the total age effects for this group can be obtained by adding ρ and π for each age-group. The outcome variable is normalized to 1 for each group at age 49. We also present estimates for an analogous extended version of the parametric age-trend model of Equation 3.

The identifying assumption is that the change in reported earnings after the start of the retirement benefit calculation window would be the same for both groups in the absence of the differential regulations that limit the responses of one of the groups. ρ_0 allows us to test for the presence of a trend in reported earnings with age before the start of the benefit calculation window for the omitted group, while π_0 allows us to test whether there is a differential pre-trend for transition cohorts.

The results for the semi-parametric specification are presented in the paper in columns 4 to 6 of Table C.2, where column 6 shows the specification with the most flexible set of controls. The estimated responses of the cohorts in the *two-pillar* regime (base group) are about twice our baseline estimates of the average effects for the full sample. In our preferred specification, at ages 50-53, self-employed reported earnings for the cohorts in the two-pillar system grow by 2.2% relative to the average pre-age 50 reported earnings, and at ages 54-57 they grow by 5.7%. For *transition* cohorts, the estimated effects are 2.5 and 3.3 percentage points smaller, respectively, although only the difference at ages 50-53 is statistically significant. These estimates imply that transition cohorts do not change their reported earnings until age 53, and increase their reported earnings by 2.3% after age 54. The results of the linear age-trend model, presented in the first three columns of Table C.3, are qualitatively and quantitatively similar, but the differences across the two groups are not statistically significant in the model with the full set of controls.

These results suggest that the specific regulations for *transition* cohorts limit their capacity to respond to the incentives of the earnings replacement calculation window.

Self-employed workers with or without employees Another institutional feature that introduces differences across groups in the possibility to respond to these incentives, is the fact that a business owner with employees cannot report earnings that are lower than those of their highest reported pay employee. On average, self-employed workers report earnings that are much lower than those reported for dependent employees, which suggests that this restriction should be binding and self-employed workers who have employees should report to social security earnings that are above what they would optimally report without this restriction.

In our model, if we assume reported earnings for employees to be exogenous to the dynamic retirement incentives, this is equivalent to setting a higher floor to reported earnings of self-employed workers with employees. Therefore, other things equal, we would expect self-employed workers with employees to have smaller increases in reported earnings in the benefit-calculation window.

We extend the semi-parametric model as follows:

$$\begin{aligned} Y_{it} = {} & \rho_0 \text{Age}_{it}^{45-48} + \rho_1 \text{Age}_{it}^{50-53} + \rho_2 \text{Age}_{it}^{54-57} \\ & + \pi_0 \text{Age}_{it}^{45-48} \text{Employer}_i + \pi_1 \text{Age}_{it}^{50-53} \text{Employer}_i + \pi_2 \text{Age}_{it}^{54-57} \text{Employer}_i \\ & + \delta_t + \xi_t \text{Employer}_i + \gamma X_{it} + \varepsilon_{it} \end{aligned} \tag{C.2}$$

where the variable Employer_i indicates that individual i has employees. Because the decision to have employees may change over time, and may even be endogenous to the incentives of the retirement benefit calculation, we construct this variable using the information of the first time the self-employed business owner is observed in our sample and keep it fixed throughout our sample period.

In the last three columns of Tables C.2, we present the estimates of equation C.2. The estimated changes after age 50 for those without employees (base group) are similar to our baseline estimates of the average effects for the full sample. In the semi-parametric model with the full set of controls (Table C.2 column 9), the results indicate that at ages 50-53, self-employed workers without employees report earnings 1% higher than at age 49, and 2.4% larger after age 54. The estimated differential effect for self-employed workers who have employees at age 50-53 is close to zero, while the estimated difference after age 54 is positive (3 percentage points). The results of an analogous model with linear age-trends, presented in the last three columns of Table C.3, reject that there is a positive shift or trend break at age 50. Thus, we cannot conclude that self-employed workers with employees are less responsive to the dynamic incentives of the benefit-calculation window than those without employees.

Taken together, the results presented in this section suggest that some regulations that limit the scope of changes in reported earnings, such as the introduction of limitations and inertia to increases in reported earnings, can be effective at mitigating responses to the dynamic incentives induced by the retirement benefit-calculation formula. We find larger and more statistically significant differences between transition and two-pillar regime cohorts, where the main difference in terms of regulations is that the changes in reported earnings by cohorts in the transition regime are limited in terms of the amount of the increases and their frequency.

Table C.2: Heterogeneity among self-employed workers

Outcome:	Self-Employed reported earnings								
	Sample of frequent self-employed reporters			Interactions transition cohorts			Interactions employees when 1st observed		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Age≤48	-0.001	-0.005	-0.006	0.002	0.007	0.007	-0.024***	0.012**	0.008*
	(0.007)	(0.006)	(0.005)	(0.011)	(0.008)	(0.007)	(0.008)	(0.004)	(0.004)
Age 50-53	0.021***	0.016***	0.017***	0.018**	0.024**	0.022**	0.025***	0.013**	0.010**
	(0.002)	(0.004)	(0.003)	(0.007)	(0.008)	(0.008)	(0.006)	(0.005)	(0.004)
Age≥54	0.040***	0.044***	0.040***	0.042	0.060***	0.057***	0.061***	0.039***	0.024***
	(0.009)	(0.008)	(0.007)	(0.026)	(0.018)	(0.018)	(0.007)	(0.006)	(0.005)
Transition x Age≤48				-0.007	-0.011	-0.011			
				(0.014)	(0.010)	(0.011)			
Transition x Age 50-53				-0.025**	-0.029***	-0.025**			
				(0.009)	(0.010)	(0.009)			
Transition x Age≥54				-0.023	-0.035*	-0.033			
				(0.028)	(0.020)	(0.019)			
Employer x Age≤48							0.020	-0.022**	-0.019*
							(0.012)	(0.010)	(0.009)
Employer x Age 50-53							-0.013*	-0.000	0.006
							(0.007)	(0.006)	(0.006)
Employer x Age≥54							-0.013	0.013	0.030**
							(0.014)	(0.013)	(0.012)
Observations	177587	177587	177587	299572	299572	299571	299572	299572	299570
Individuals	1704	1704	1704	5350	5350	5350	5350	5350	5350
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm size FE		Yes	Yes		Yes	Yes		Yes	Yes
Industry FE		Yes	Yes		Yes	Yes		Yes	Yes
Year # Firm size FE			Yes			Yes			Yes
Year # Industry FE			Yes			Yes			Yes

Notes: Data from BPS administrative records between April 1996 and April 2016. The outcome variable is reported earnings to social security as a ratio of average sample age 49 earnings. The sample in columns includes self-employed workers ages 45 to 57 reporting earnings to social security for at least 6 months, and in columns 1-3 they report earnings at least 70% time. Transition indicates whether a person belongs to a cohort in the fully defined-benefit transition regime. Employees indicates whether the self-employed worker's firm has employees. Two-way cluster robust standard errors by individual and age in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table C.3: Heterogeneity among self-employed workers, age-trends specification

Outcome:	Self-Employed reported earnings								
	Sample of frequent self-employed reporters			Interactions transition cohorts			Interactions employees when 1st observed		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Age trend	0.002	0.002	0.002	0.002	-0.002	-0.002	0.012***	-0.005***	-0.004***
	(0.001)	(0.002)	(0.001)	(0.003)	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)
Age≥50	0.007***	0.002**	0.005***	-0.001	0.007**	0.005**	-0.004	0.004	0.008
	(0.000)	(0.001)	(0.001)	(0.001)	(0.003)	(0.002)	(0.007)	(0.005)	(0.004)
Age≥50 x Age trend	0.003***	0.005**	0.003**	0.005	0.012**	0.011**	-0.003	0.011***	0.008***
	(0.001)	(0.002)	(0.001)	(0.005)	(0.005)	(0.004)	(0.003)	(0.002)	(0.002)
Transition x Age trend				0.004	0.006	0.006			
				(0.004)	(0.003)	(0.004)			
Transition x Age≥50				-0.025***	-0.029***	-0.024***			
				(0.004)	(0.008)	(0.005)			
Transition x Age≥50 x Age tr.				-0.005	-0.009	-0.009			
				(0.007)	(0.006)	(0.005)			
Employer x Age trend							-0.009*	0.011***	0.010***
							(0.004)	(0.003)	(0.003)
Employer x Age≥50							-0.003	-0.012***	-0.012***
							(0.004)	(0.003)	(0.002)
Employer x Age≥50 x Age tr.							0.008	-0.009*	-0.005
							(0.006)	(0.005)	(0.004)
Observations	177587	177587	177587	299572	299572	299571	299572	299572	299570
Individuals	1704	1704	1704	5350	5350	5350	5350	5350	5350
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm size FE		Yes	Yes		Yes	Yes		Yes	Yes
Industry FE		Yes	Yes		Yes	Yes		Yes	Yes
Year # Firm size FE			Yes			Yes			Yes
Year # Industry FE			Yes			Yes			Yes

Notes: Data from BPS administrative records between April 1996 and April 2016. The outcome variable is reported earnings to social security as a ratio of average sample age 49 earnings. The sample in columns includes self-employed workers ages 45 to 57 reporting earnings to social security for at least 6 months, and in columns 1-3 they report earnings at least 70% time. Transition indicates whether a person belongs to a cohort in the fully defined-benefit transition regime. Employees indicates whether the self-employed worker's firm has employees. Two-way cluster robust standard errors by individual and age in parentheses. * p<0.1, ** p<0.05, *** p<0.01

D On-line Appendix D: Responses among workers with stable employment

Unlike self-employed workers, employees' earnings are reported by a third party (employers), which means that any real or reported changes in earnings would have to be negotiated with employers. Most male workers in their 40s and 50s are working full-time, so they have little scope for real labor supply changes. In addition, the degree of misreporting of employee earnings is usually lower than for self-employment. To change reporting behavior, employers and employees would have to have a very long term agreement in which reported worker earnings are lower until the start of the expected benefit-calculation window, and start increasing after that. Because private-sector employment relationships do not usually provide such a long-term employment guarantee, and because of the threat that employees could report misreporting behavior to the social security administration,[29] we expect such agreements to be possible only in situations where there is a long-term trust relationship between the employer and the employee.

Here, we explore the behavior of employees who are more likely to have stable employment relationships, by focusing on the subsample of employees who have reported earnings at least 70% of the time we could potentially observed them in our sample. These workers are more likely to be in stable long-term employment relationships, and are also more likely to satisfy the years of service requirement for retirement. Thus, this is a subsample of employees who have more incentives to increase reported earnings in the benefit calculation window, and they have an employment history that makes them more likely to have long-term agreements with their employers.

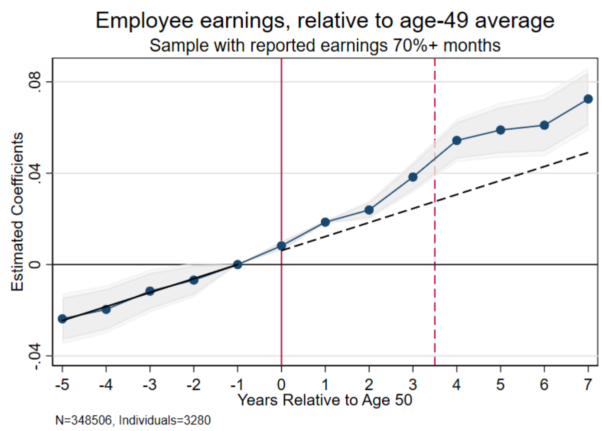
The results of this analysis are presented in Figure D.1 and Table D.1. The changes with age for this sample are quite different to those for the full sample of employees. First, there seems to be a general trend to increase reported earnings with age. Second, the increases are stronger after the start of the retirement-benefit calculation window, and especially after age 54. We include in Figure D.1 a fitted regression line between age and estimated reported earnings changes before age 50 to provide a visual reference of the underlying age-trend.

These results are not conclusive, because of the presence of an increasing trend in the reported

[29] In the Uruguayan labor relations legislation, employers are solely responsible for any misreported earnings. If an employee reports and proves that earnings were under-reported, the employer must back-pay all missed social security contributions, as well as penalties. If earnings were over-reported, i.e. the employee was paid below the level of earnings reported to social security, the employer must pay to the employee the forgone earnings as well as penalties to the social security administration.

earnings of employees with very stable employment histories. However, they suggests the possibility that the earnings of some employees may also increase in the 10-year benefit calculation window as a response to the dynamic incentives of the retirement system. The estimates of the parametric model with linear age trends, presented in Panel B, indicate that, although there is a pre-existing age-trend, after age 50 there is a significant break in this trend, with reported earnings growing at a 67% higher rate.

Figure D.1: Event Study of employee reported earnings to Social Security, sample reporting frequently to Social Security



Notes: The plot shows estimates of the coefficients of age dummies in equation 1, with the shaded area illustrating 95% (light gray) and 90% (dark gray) confidence intervals based on two-way cluster robust standard errors by individual and age. The outcome variable is Reported Earnings to social security as a ratio of average sample age 49 earnings. The sample includes employed workers ages 45 to 57, reporting earnings to social security for at least 6 months, between April 1996 and April 2016.

Table D.1: Reported earnings of employees frequently employed

Outcome:	Reported employee earnings		
	(1)	(2)	(3)
Panel A. Semi-parametric specification			
Age≤48	-0.015**	-0.014**	-0.015**
	(0.006)	(0.006)	(0.006)
Age 50-53	0.027***	0.022***	0.022***
	(0.003)	(0.004)	(0.004)
Age≥54	0.058***	0.062***	0.061***
	(0.006)	(0.006)	(0.007)
Observations	348506	348506	348506
Individuals	3280	3280	3280
Panel B. Parametric specification with linear age trend			
Age trend	0.006***	0.006***	0.006***
	(0.001)	(0.001)	(0.001)
Age≥50	0.010***	0.003***	0.002***
	(0.000)	(0.000)	(0.000)
Age≥50 x Age trend	0.002**	0.004***	0.004***
	(0.001)	(0.000)	(0.000)
Observations	348506	348506	348506
Individuals	3280	3280	3280
Time FE	Yes	Yes	Yes
Firm size FE		Yes	Yes
Industry FE		Yes	Yes
Year # Firm size FE			Yes
Year # Industry FE			Yes

Notes: Data from BPS employment administrative records between April 1996 and April 2016. The outcome variable is reported earnings to social security as a ratio of average sample age 49 earnings. The sample includes employed workers ages 45 to 57 reporting earnings to social security at least 70% time. Two-way cluster robust standard errors by individual and age in parentheses. * p<0.1, ** p<0.05, *** p<0.01