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Abstract

We argue that paygo rates are determined by a representative agent and a benevolent government jointly maximizing the expected life-time utility of the agent. The distributions of labor and capital income are calculated from national data on real GDP, real wages and the real return to capital since 1950. With uniform risk aversion, predicted rates explain 83% of the variance of observed rates. The globalization of capital markets would lead to convergence of paygo rates. Our results are immune to crises like 2008.

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One of the puzzles of macroeconomic policy analysis is the extent to which the importance of pay-as-you-go retirement systems varies across countries in the developed world. Table 1, which presents effective tax rates for these systems in the largest countries of the OECD, shows that, in 2002, they varied from 5 % in Australia to 36 % in Italy.

Analysts have sought to explain this diversity in different ways. Some have argued that it reflects historical differences, such as differences in the degree of social conflict and the power of unions.[1] Others have suggested that it is the mark of cultural factors, some societies being more risk averse than others, and thus more intent on ensuring the stability of retirement incomes.

We seek to demonstrate that pay-as-you-go (henceforth paygo) effective contribution rates – are the consequence of rational, welfare maximizing decisions by individuals and societies in countries whose underlying economic characteristics are themselves different. Our hypothesis builds on the Aaron (1966) proposition that a society's choice between paygo and funded saving should depend on whether the natural rate of growth is greater or less than the rate of return on capital – paygo being optimal in the first case and funded saving in the second. Aaron's criterion was a knife-edge criterion. We suggest that, in the richer world of stochastic dynamics, it is optimal for societies to choose to rely on both forms of provision (paygo and saving), and that it is the balance of the two that is affected by economic conditions. Simply put, in countries in which labor income is expected to grow slowly and to be subject to recurrent shocks, individuals and society will, ceteris paribus, emphasize personal saving for the provision of retirement income. In countries in which the real return to capital is expected to be low and volatile, they will, on the contrary, put more weight on paygo transfers.

In order to test this approach, we construct a model of how societies and individuals

[1] In seeking exogenous explanations for different attitudes toward social policy in the United States and Europe, Alesina and Glaeser (2004) point, among other factors, to the presence of racial tensions in the United States. In their discussion of the divergent evolution of social security provisions in different countries, Bruno and Sachs (1985) emphasized the nature of union pressures.

determine the levels of paygo and saving in the provision of retirement income. This is a simple, two-period overlapping generations model in which a benevolent public authority and a representative individual jointly choose that paygo tax rate and saving rate which maximize the representative individual's expected life-time utility. The next step is to construct empirical estimates of the dynamic distributions of labor and capital income in each country. Armed with these distributions, we use the model to generate a cross section of predicted values of paygo and saving rates for each country in a reference year, which we take to be 2002. The test of the validity of the model is how well it explains actual, effective paygo commitments in that year.[2] Though the model describes the dynamic behavior of individuals and societies over time, what it explains is differences in effective paygo contribution rates across countries at a given point in time.

The biggest challenge in this exercise is data construction. In order to analyze a society's paygo and saving choices, we must first estimate the distribution of the labor and capital income of a representative individual for sixty or more years – active life plus retirement. Moreover, the variability and higher moments of this distribution are decisively important for the computation of expected utility. In order to estimate these, we would ideally like to have historical data on as many life-cycles as possible. The available macroeconomic data, which only stretch back one hundred years, do not provide direct evidence of more than two or three lifetimes.

To overcome this obstacle, we resort to a Monte-Carlo approach. Using data since the end of World War II, we estimate simple models of the annual dynamics of labor and capital income. We then use the parameters of these models, and bootstrapped estimates of the distributions of their error terms, to simulate as many life-time histories as we need. With these, we compute the expected life-time utility of the representative

[2] We chose 2002 as reference year because it is the first year when comparative and comprehensive data on pension systems in the OECD became available (OECD (2003)). We would like also to test the ability of the model to predict saving rates, but data on life-time saving rates, which are necessarily estimated by cohort rather than by calendar year, exist in only a few countries.

individual corresponding to any pair of paygo tax and saving rates. Our model says that the rates that maximize this expected utility are the rates that society will choose.

We test the model on a subset of the countries of the OECD, focusing on high-income countries which have developed financial markets, and which, though open to trade, are not so small that trade dwarfs domestic production. Specifically, we chose from the 23 developed countries in the OECD in 2003, the eight for which the average value of the ratio of exports plus imports to GDP during the decade of the 1990s was less than 55 percent.[3]

This paper builds on a long literature about the implications of risk and uncertainty for the efficiency of paygo schemes. Merton (1983), Gordon and Varian (1988), Gale (1990), Demange and Laroque (1999, 2000), Demange (2002) and others have shown that a paygo system can enhance welfare in dynamically efficient economies because of the unique opportunity it provides for workers to spread the risk of life-time earnings over different generations. Gottardi and Kubler (2011) extend these analyses and note that the result depends on the degree to which the paygo system reduces capital accumulation. In de Menil, Murtin and Sheshinski (2005), we derived analytical results relating steady state optimal saving and paygo tax rates (when they exist and are unique) to underlying fundamentals. The present paper uses the same model to obtain empirical estimates of a cross section of economically rational tax and saving rates.

More recently, several papers have used models similar to ours to analyze the properties of public policies designed to provide intergenerational risk sharing. Bohn (2009) posits a comprehensive, intergenerational welfare maximization framework, and concludes that social security policies that shift risk from the working years to the the years of retirement are preferable to policies that shift risk in the opposite direction. Thogersen (1998) reaches a similar conclusion in an analysis which focuses on the mean and variance of life-time income in both periods combined. Using a model also

[3]The countries we selected are Australia, France, Germany, Italy, Japan, Spain, the United Kingdom and the United States. The average ratio of exports plus imports to GDP during the 1990s in these eight countries ranges from 18 % in Japan to 53% in the United Kingdom.

similar to the one used here, Wagener (2003) argues that this conclusion follows from the use of an ex-ante utility criterion. He shows that the conclusion is reversed if the income of the representative individual in her working years is taken as given, and utility is maximised over expectations of retirement income. Beetsma and Bovenberg (2009) extend this conclusion to economies in which there coexist both paygo and mandatory funded pension systems. They argue that a fixed replacement rule in the funded pillar provides risk sharing benefits which a defined contribution rule can not. Van Hemmert (2005) analyses state-contingent pension transfers. Gollier (2007) abstracts from the uncertainty of labor income in order to focus on the volatility of the return to saving, and shows that pooled pension funds can of themselves provide intergenerational insurance which the kind of individual saving behavior modeled here can not.

Simulation methods have been increasingly used to estimate the welfare effects of either increasing or down-sizing a paygo system such as that of the United States. Krueger and Kubler (2005) posit an economy populated with representative agents living through a life-cycle of nine stages, who face macroeconomic shocks to labor and capital income. They use Monte-Carlo techniques to compute the expected lifetime utility of each cohort of agents. Their focus is on the Pareto optimality of a single experiment – the introduction of Social Security with a 2% tax rate in the United States in 1935. In their most general cases, they conclude that the experiment was not Pareto improving.

Nikishama and Smetters (2007) emphasize individual diversity (neglected in this study and many of those cited). In their model of the U.S. economy, individuals have different skill levels, and are subject to idiosyncratic shocks. Their model does not allow for macroeconomic shocks to the wage rate and the return to capital. They find that progressively reducing the U.S. paygo system to half the size it began with in 2003 would diminish welfare in the sense of Hicks, unless the down-sizing were accompanied with labor tax reforms that compensated for the insurance against idiosyncratic risk provided by the original paygo system.

Fuster, İmrohoroğlu and İmrohoroğlu (2007) depart from the non-altruistic framework adopted in much of this research, and posit individuals who incorporate the well being of both children and parents in their own decision making. They simulate the effect of a once-and-for-all elimination of Social Security on the welfare of dynasties with different skill and demographic characteristics, and find a majority benefit from the change. Their result depends critically on the elasticity of life-time labor supply to the taxes required to finance Social Security.

Other authors - Dutta, Kappur and Orszag (2000) and Matsen and Thogersen (2004) have used historically observed growth rates and rates of investment return to calculate optimal paygo tax rates and saving rates for different developed countries. However, our Monte-Carlo approach to estimating the relevant moments of these variables is different from theirs. Dutta, Kappur and Orszag (DKO) and Matsen and Thogersen (MT) take decades as representative of life histories.

DKO and MT's "portfolio approach" further reduces the design of a social security system to a decision regarding the optimal weights to be given, in a fixed portfolio of social security assets, to investment in capital and investment in an asset whose rate of return is equal to the growth of the wage bill. They deal only in rates of growth and thus implicitly assume that the real wage bill follows a random walk with a drift. They do not allow for the possibility that real wages may tend to regress to their long-term trend. As MT themselves point out, in such a world, there is no way to insure against the risk of a bad draw in the lottery for life-time labor income. Their approach thus assumes away one of the principal early arguments in favor of paygo retirement schemes. Our approach is to model the real wage bill as a process of stochastic deviations around a deterministic growth path, and test for the stationarity of that process. When non-stationarity is rejected, as it is in our estimates, paygo can provide intergenerational insurance against the variability of real wage income. We calculate the amount of such insurance which would be optimal for each country.

This paper is structured as follows: Section 1 discusses the empirical evidence of diversity in effective paygo provision in the OECD. Section 2 presents a model of how societies and individuals determine paygo tax and saving rates. Section 3 presents our data sources and estimates of the annual dynamics of average earnings and the average return to saving made with macroeconomic data from 1950 through 2002. This section includes a test of the stationarity of the wage process. Section 4 aggregates these annual income components into summary measures of the labor and capital income of the representative individual in the active and retirement years. Section 5 presents the results. We derive the tax and saving rates which maximize the expected utility of the representative individual in each country. We test the ability of these predicted rates to explain the cross-country variation of the effective paygo tax rates in our sample. Our principal result is that our preferred estimates explain 83% of this cross-country variance. This section ends with an attempt to decompose the explained variance, and attribute it to the principal sources of national difference. Section 6 addresses two hypothetical questions: What would the effect on paygo tax rates be of a global convergence of national capital markets? How would paygo tax rates have differed if individuals had anticipated the possibility (but not predicted the occurence) of a crisis like that of 2008? Section 7 concludes.

1 The Diversity of Effective Paygo Rates

Table 1 presents in country alphabetical order the effective paygo tax rates which we seek to explain. A comment is in order about the nature of this variable and the way it is measured. It is well known that social security budgets are often out of balance, that paygo pensions are frequently partially financed out of general revenue, and that, as a consequence, wage tax rates are a poor measure of the importance of a paygo system.

The answer is to construct alternative, effective paygo tax rates. A country's effective rate measures what the wage tax would have to be for the revenue it generates to finance the paygo disbursements to which that country is committed.[4] It measures a country's forward commitment to paygo provision.

Let $\frac{b}{w}$, be the average pension an employee is entitled to at retirement – relative to the then average economy wide wage, and $\frac{p}{e}$ be the ratio of the number of pensioners to the number of active employees at that time, then the effective tax rate required to balance the system is

$$\theta^e = \frac{b}{w}\frac{p}{e}. \tag{1}$$

Appendix A discusses how we estimate $\frac{b}{w}$, the "relative pension level", and $\frac{p}{e}$, the number of retirees per employee, in order to construct effective paygo tax rates.

The salient characteristic of the distribution presented in Table 1 is its diversity. The observations form three distinct clusters. Three countries – Australia, the United Kingdom and the United States – have low effective tax rates. At the other end of the spectrum are Italy and Spain – countries whose effective rates are more than double those of the first group. And, in between, is the third cluster – Germany, Japan and France – with effective rates roughly half way between the top group and the bottom group. What explains this pattern? Cultural and historical differences? Or a shared pattern of common response to differences in underlying economic conditions?

2 The Model

The central issue individuals and societies face in constructing a pension system is how to allocate income between the active years and the retirement years. The standard, two-period, overlapping generations model describes the basic relationships. We

[4] See Disney (2004).

assume that the representative individual saves only for her retirement consumption.[5] Where we depart from the standard model, is that we treat the paygo tax rate as an endogenous, collective decision. We posit the existence of a benevolent authority which sets the tax rate. The representative individual and the tax authority are assumed both to know the distributions of capital and labor income. Together, acting behind a "veil of ignorance", before lifetime income is known, they jointly choose the tax and saving rates that maximize expected life-time utility. They assume that the economy is on the steady state path towards which it is tending when their decision is made.[6]

Let ω_A be the labor income of the representative individual during her active years, and ω_B her pro-rata share of the labor income of the individuals who are working during her retirement years. Each individual provides for her retirement by contributing a portion θ of her labor income during her active years to a balanced paygo system, and by saving and investing an amount S.[7] The budget constraint relating consumption during the active and retirement years, c_A and c_B, to her labor income, her pension, and her saving is:

$$c_A = (1 - \theta)\omega_A - S \tag{2}$$

$$c_B = \theta\omega_B + RS \tag{3}$$

[5]We also assume that all individuals are identical, and thus neglect one of the important rationales for social security – its potential effect on intragenerational redistribution. Our representative agent assumption precludes, for instance, exploring the difference between Bismarkian and Beveridgean paygo systems. Disney and Whitehouse (1993) examine the effect of "opting out" in the U.K. on intragenerational distribution. Pestieau (1999) examines the influence of different paygo formulae on distribution within each cohort. Our representative agent assumption facilitates the analysis of cross-country heterogeneity.

[6]We model a decision making process of a consensual kind, in which societies and individuals base their choices on the expected utility of a representative individual over her entire life-cycle. Galasso and Profeta (2002, 2004) and others focus instead on conflicts between categories of the population, notably between the young and the old. The dynamics in their models depend critically on the demographic structure of the population.

[7]We assume that $0 < \theta < 1$, that liquidity and institutional constraints impose $S > 0$, and that θ and S remain constant throughout the individual's life. As van Hemert (2005) points out, state contingent decisions would improve welfare. Though some governments have enacted state-contingent paygo mechanisms, these are rare. A state contingent pago tax rate would attenuate the volatility of both paygo payments and paygo benefits. To the extent that the volatility of labor income is an important empirical factor, it could enhance the attractiveness of paygo provision.

R is the gross return on the saving of the working years. The model assumes that the individual plans to consume all her saving during retirement, and does not plan to leave a bequest.

We emphasize the fact that labor income (ω_A and ω_B) and R are random variables. The choice[8] of any S and θ by the individual and society therefore entails evaluating the risks associated with that choice. Let

$$V = E[u(c_A)] + \beta E[u(c_B)] \tag{4}$$

be the ex-ante expected utility of the representative individual, where $u(\cdot)$ is the separate utility function applicable to income in each phase of life and β is a discount factor reflecting personal time preference. The tax authority and the individual jointly choose θ and S by maximizing V in (4) subject to (2) and (3). We refer to their choices as θ^* and S^*.

We leave the possible feedback from S to R and ω (through a closed economy aggregate production function, for instance) out of the analysis. One way to interpret this simplification is to argue that free trade determines factor prices up to structural and institutional country-specific effects.[9]

[8]The two-period structure of the model abstracts from much of the complexity of an optimal consumption path. In a dynamic program, the representative agent would choose different levels of saving in each period within her working-age and retirement phases. It is difficult to conjecture how the results would differ within a dynamic setup, as many other factors may intervene. Moreover, the outcome of a dynamic program would not consist of a single saving rate, but of a set of age-specific saving rates. A plausible hypothesis would be that the representative agent would favor high-return, high-risk investments at the beginning of her active life (i.e. higher saving), and conversely, lower-return and lower-risk forms of income subsequently (i.e. lower saving). We see no reason to expect that the average saving rate over her life-time would differ systematically from the one we derive in our simplified model.

[9]We assume that differences in product mix, skill composition and financial institutions cause long-run differences in factor price trends. The important simplifying assumption is that these country-specific effects are not affected by domestic capital accumulation.

3 The Diversity of National Characteristics

The challenge in applying the theory of the preceding section is an empirical one. We seek, for each of the eight countries in our sample, to construct a representation of the life time distribution of labor and capital earnings, derived from information available to the actors at the time they make their decisions. Because our objective is to explain cross-country differences in paygo rates, we derive these distributions, as much as possible, from specifically national data.

We use national dependency rates, national survival functions, national unemployment rates, national growth rates of labor income, national capital market returns, and national measures of the variability of the latter two.

3.1 Data

We posit that for public and private agents setting paygo rates at the beginning of the 21st Century, the relevant history is post-War history. Too much structural change separates the post-War from the pre-War. We also posit that these agents use as much information about the period as possible to extrapolate the future. Our earliest data point is 1950.

We identify the annual return to saving in each country with the total real return on stocks, as measured by the broadest stock index incorporating dividends available in each country, which we obtain from Global Financial Data. Monthly stock indices are averaged to obtain an annual index. Real total annual returns, r_t, are calculated by using the national CPI from IMF (2004) to deflate nominal returns.[10] Section 3.2 explains how we use this data, from 1950 to 2002, to estimate country-specific, average real rates of return to saving, and to obtain country-specific measures of its variability.

[10] We have experimented with using a measure of the return to saving which incorporates returns to bonds as well as to equities. However, the only bond return data we were able to find on a comparable basis for our eight countries was data on the return to government bonds. These are an inadequate measure of the return to corporate bonds. We do not obtain satisfactory results with mixed portofolios of stocks and government bonds.

Paradoxically, data on labor income is not as widely available in our eight countries as data on capital income. The model calls for a measure of average, annual earnings. But comparable date on economy-wide average earnings are only available since 1955 for three of our countries, and since 1960 or up to 1970 for the others. If we were to choose those later starting dates to estimate income expectations, we would lose up to 20 important years of data, and would be limited to a truncated view of income dynamics in each country. Therefore, our preference is to use real annual GDP as a proxy for labor income. GDP data is available from 1950 in all of our eight countries. We let real average annual labor income per employee be $w_t = y_t/e_t$, where y_t is real annual GDP and e_t is total employees.[11] Average annual labor income per member of the labor force is $y_t/l_t = (1 - u_t)w_t$, where l_t is the total labor force and u_t is the unemployment rate.

We subject the model and the results to a thorough sensitivity analysis by reestimating the relevant distributions with the available data on labor earnings.[12] We report in Appendix C that when the models are estimated on identical but shorter sample periods, the GDP based estimations and the wage based estimations both support the central hypothesis, and are each similar to the other. But when GDP data going back to 1950 is used, the explanatory power of the model increases.

Both the earnings based models and the GDP based models provide country-specific estimates of the trend rate of growth of real labor earnings per employee, and country-specific measures of their variability. Functional forms are discussed in Section 3.2. Data on national unemployment rates is taken from OECD (2016).

Rational paygo decisions also depend on projected dependency rates, which vary

[11] We obtain real GDP and total employees data from OECD (2005). We extend both series back to 1950 using historical data from Mitchell (2003, 2005). Dutta et al. (2000), Matsen and Thogersen (2004) and others also use GDP as a proxy for labor income.

[12] For seven of the countries in the sample, we take total annual labor earnings and total employment from OECD (2016). In the case of the U.K., we are able to extend the length of the sample by using the employment series in Bank of England (2016). Total annual earnings include both overtime and part-time earnings. Initial dates are 1955 for France, the United Kingdom and the United States; 1960 for Italy and Japan; 1961 for Spain; 1964 for Australia; and 1970 for Germany. Annual nominal earnings are deflated by the CPI series in IMF (2004).

significantly from country to country as a function of demographic trends, trends in labor participation, and country-specific institutional arrangements.[13] We also use country-specific life-tables, taken from United Nations (2015), to derive the national survival functions which condition the estimation of life-time expected utility by the representative individuals in each country (See Eq. 17).

There is one important parameter for which we do not have national data, namely the relative rate of risk aversion (RRA). Our strategy is to seek to explain national differences in paygo rates without appealing to differences in tastes. The question nonetheless remains: at what value should we fix the common relative rate of risk aversion (assumed to be constant) in our estimations of national expected utility?[14]

A value of 5 is frequently used in empirical macroeconomic work. The length of the planning horizon in pension decisions suggests, however, that a higher rate of risk aversion should apply in this case.[15]

We report results with values of RRA ranging from 5 to 20, but our preferred value is 12. This is half way between the Beetsma and Schotman (2001) survey result of 6 and the value of 18 used by Krueger and Kubler (2005) in their study of U.S. social security.

[13]We calculate expected national dependency rates from OECD (2016) demographic and labor force participation data for the periods 2042-2062. See Appendix A. We treat d as non-random, but, as a referee has pointed out, projections of its future level are, in fact, very uncertain. Estimating a different probability distribution of d for each country would be challenging, but would constitute a useful variant of our model.

[14]In a study based on portfolio allocation evidence, Friend and Blume (1975) infer values of RRA between 2 and 3. Eisenhauer and Ventura (2003) and Guiso and Paiella (2008), analyzing individual responses to a lottery proposed by the Bank of Italy, report relative rates of risk aversion between 4.5 and 14. Beetsma and Schotman (2001) derive estimates in the neighborhood of 6 from responses to a popular Dutch television quiz program. Campbell (2003) uses national financial data similar to ours to estimate consumption-based asset pricing models, and finds implied values of RRA between 50 and 600 for several of the countries in our sample.

[15]In empirical studies, the commonly adopted value of the relative risk aversion parameter is based on Arrow's derivation of the *certainty equivalent* premium paid for a fair lottery with small positive and negative (equal) payoffs (the premium is equal to half the risk aversion parameter times the squared payoff). When a lottery is played n times it can be shown that the premium is approximately n times its value in the one-shot lottery. In our context, the working lifetime phase stretches over many years. An investment with uncertain returns kept for many years is like a lottery with a positive drift (otherwise a risk-averse individual would not invest in such a lottery) played many times. Risk increases in proportion to the number of years. In this context, it is reasonable to adopt a significantly larger risk aversion parameter compared to one used for a one-time investment.

3.2 Annual Dynamics

We model average annual earnings per employee w_t as varying around a growth path which converges to a country-specific, long-run trend. Differences in these trend growth rates are in principle one of the differences conditioning the relative desirability of paygo and funded saving across countries. In order to estimate these trends, and the variability of earnings around them, without bias and efficiently, we must take account of a possible phenomenon of convergence. We allow for this possibility by including slow-down effects represented by the function $f(t)$ in our equation for the real wage:

$$\ln w_t = a + gt + f(t) + x_t \tag{5}$$

$$\lim_{t\to\infty} f(t) = 0$$

where g is the rate of growth on the long-term exponential growth path toward which w_t converges, $w_1 = 1$, and x_t is the innovation on annual wages.[16] Though different specifications of the function f were tested, the simple exponential form $\mu e^{\rho t}$ was selected for all countries.

We assume that, when predicting her life-time earnings, the representative agent takes average unemployment experience into account, and projects the average annual earnings of persons in the labor force[17], $y_t/l_t = (1 - u_t)w_t$. We therefore complete our annual model with the simplest possible representation of the unemployment rate, u_t, which we model as the sum of a constant mean $\overline{u}$ and an innovation ζ_t.

$$u_t = \overline{u} + \zeta_t \tag{6}$$

[16]Setting $w_1 = 1$ at the beginning of the active life of each cohort ensures that every cohort in every country, no matter when it is born, views and analyzes its life-time prospects in the same way as every other.

[17]This is equivalent to assuming that the earnings of the employed are shared mutually with the unemployed. Empirical tests of an earlier version of our model, which incorporated the volatility potentially introduced by the random nature of individual unemployment experience, concluded that random individual unemployment experience does not have a significant effect on paygo decisions. This version abstracts from that potential volatility.

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We represent the log-returns to equity simply as the sum of a constant mean return $\bar{r}$ and an innovation ϵ_t.[18]

$$\ln(1 + r_t) = \bar{r} + \epsilon_t \tag{7}$$

Though we treat the long-term trend of wages and the long term return on investment as independent of one another, we allow for cyclical interaction between the deviations from long-term values of both factor incomes. We model this interaction with an estimated vector auto-correlation of errors from each income generating process. The wage income process and the variability of investment returns in "normal" times are estimated with data from 1950 through 2002 (we discuss the implications of low probability crises like that of 2008 in Appendix D).

Table 2 and the first four columns of Table 3 describe the results we obtain when we estimate equations (5) and (7). Table 2 shows that, with the non-linear trend specification just mentioned, residuals x_t pass stationarity tests for all countries at a 5% confidence level and for most countries at a 1% confidence level. This implies, as we emphasized in the introduction, that a paygo system is capable of providing intergenerational insurance against the variability of real wages.

Table 3 shows that country-to-country differences in the mean and variability of real investment returns dwarf differences in the growth and variability of wages. The contrast between Italy – where the real return to investment averages 4.1% and has a coefficient of variation of 6.0 – and the United States – where it averages 7.5% and has a coefficient of variation of 1.8 – is striking. The coefficient of variation for Spain resembles that of Italy. The coefficient of variation for the United Kingdom resembles that of the United States. The other countries lie in between.

Our discussion so far has not yet taken account of serial and cross correlations in the dynamics of wage and investment returns. We estimate a first-order VAR process

[18] In the equation which follows, we define $\bar{r}$ as the expectation of $\ln(1 + r_t)$.

to model the dynamic interaction between x_t and ϵ_t. Specifically, we suppose that

$$\begin{pmatrix} x_t \\ \epsilon_t \end{pmatrix} = \begin{bmatrix} \rho_{x_t x_{t-1}} & \rho_{x_t \epsilon_{t-1}} \\ \rho_{\epsilon_t x_{t-1}} & \rho_{\epsilon_t \epsilon_{t-1}} \end{bmatrix} \begin{pmatrix} x_{t-1} \\ \epsilon_{t-1} \end{pmatrix} + \begin{pmatrix} \eta_t \\ \upsilon_t \end{pmatrix} \tag{8}$$

where η_t and υ_t are two white noises. Results are presented in columns 5-8 of Table 3. We find a significant degree of serial correlation of wage innovations - which is consistent with the existence of a business cycle - in all countries (between 0.58 in Spain and 0.85 in the United States). We also find moderate but significant serial correlation of investment returns in four countries with volatile stock markets (Germany, Italy, Japan and Spain). The United States exhibits a significant negative correlation between wage innovations in one year and real stock market returns in the following year. We interpret this lagged, negative feedback as reflecting the dynamics of profit margins over the business cycle.[19]

If annual capital returns are serially uncorrelated, the variability of their sum benefits from the Law of Large numbers. Positive serial correlation will, on the other hand, amplify the variability of the sum.

4 Life-time income dynamics

The purpose of this section is to show how the annual income histories which we simulate below can be condensed into summary measures of income in the active and retirement years.

[19]Investigating this dynamic further would take us far afield from the focus of our study. Suffice it to say that other scholars analyzing comparable databases have found a similar negative, delayed cross correlation. See Bottazi et al. (1996) in their macroeconomic study of international portfolio decisions.

4.1 Average wage income

Redefine ω_A as the average wage income of the representative individual in a specific life history or trajectory. In a similar manner, redefine ω_B as her share of the wages on the same trajectory of the individuals who will be working when she is retired. Though ω_A and ω_B are given for any specified trajectory, ex-ante, before a specific trajectory has been drawn, they are random variables.

For the moment, assume that the maximum length of a working period is T years and the maximum length of retirement is also T (we will introduce survival probabilities later). Then[20] :

$$\omega_A = \sum_{t=1}^{T} \frac{(1-u_t)w_t}{T} \tag{9}$$

Let p_t be the number of retired persons, and recall that y_t represents the wage bill. Then:

$$\omega_B = \sum_{t=T+1}^{2T} \frac{y_t/p_t}{T} \tag{10}$$

Noting that one can decompose

$$\frac{y_t}{p_t} = \frac{y_t}{e_t}\frac{e_t}{l_t}\frac{l_t}{p_t} \tag{11}$$

where e_t is total employment, l_t the labor force, $w_t = y_t/e_t$ is average annual earnings per employee, $e_t/l_t = 1 - u_t$, and $l_t/p_t = 1/d_t$, with d_t the dependency ratio (or ratio of retirees to the active labor force), one can rewrite (11) as

$$\omega_B = \sum_{t=T+1}^{2T} \frac{(1-u_t)w_t/d_t}{T} \tag{12}$$

The dependency ratio, d_t, differs from country to country because of differences in the

[20]In the following expression, w_t stands for the real wage of the representative individual in the t-th year of her active life. We assume (for lack of better information) that this wage does not depend on seniority, and, therefore, that the representative individual earns the economy-wide average wage rate every year.

growth rate of the population and differences (due to custom, fertility and mortality) in the ratio of retirement years to active years. On any given historical trajectory, d_t varies as demographic patterns change. But, on a steady state path, d_t is necessarily constant.[21]

4.2 Average investment income

Consider now the computation of the average, life-time return to saving. We assume, for simplicity, that the purpose of saving is exclusively to provide income during retirement, and we focus on the rate at which annual saving can be transformed into a retirement annuity. If the representative individual saves S every year of her active life, she will have accumulated

$$F = S \sum_{t=1}^{T} \prod_{\tau=t}^{T} (1 + r_\tau) \tag{13}$$

by the time she retires.[22] That sum will purchase an annuity A, which we assume satisfies the following "fair value" constraint:

$$F = A \sum_{t=T+1}^{2T} \frac{\sigma_t}{\prod_{\tau=T+1}^{t} (1 + r_\tau)} \tag{14}$$

with σ_t being the representative individual's probability of survival to age t.

[21]The dependency rates used in our simulations are computed from OECD demographic and labor force participation data for the periods 2042-2062. The projected averages for this period are: Australia – 0.27; France – 0.35; Germany – 0.45; Italy – 0.47; Japan – 0.39; Spain – 0.44; U.K. – 0.29; and U.S.A. – 0.24. See Appendix A.

[22]We focus on her potential saving, conditional on survival. We account for the probability of survival below.

We can write the resulting annuity as[23]

$$A = \left[\frac{\sum_{t=1}^{T} \prod_{\tau=t}^{T} (1 + r_\tau)}{\sum_{t=T+1}^{2T} \frac{\sigma_t}{\prod_{\tau=T+1}^{t} (1+r_\tau)}} \right] S \tag{15}$$

or

$$A = RS \tag{16}$$

with R equal to the expression in brackets in (15). Note that R measures both accumulation and annuitization. It is, as before, a random variable.

4.3 Expected utility

With these empirical definitions of ω_A, ω_B and R, the budget constraints 2 and 3 can be interpreted as depicting the relationship between average consumption during the representative individual's active years and average consumption during her retirement years. Our central hypothesis is that, in each country, the representative individual and the tax authority jointly choose the paygo tax rate and the saving rate, θ^* and S^*, which maximize the representative individual's ex-ante, expected life-time utility.

In calculating this expected utility, the individual and the tax authority take account of the fact that the individual will enjoy it conditional on her continuing to be alive[24], and that a positive rate of time preference, δ, leads her to discount more distant instantaneous utilities more heavily. The probability of survival, σ_t, and the rate of time preference will affect the weight attributed to more distant utilities in the same manner.

[23]In writing (15) and (16), we do not mean to imply that actuarial markets are broadly prevalent or widely used in our eight OECD countries. We simply assume that, when projecting her retirement income, the representative agent takes account of the fact that her retirement fund will continue to grow, conditional on her survival, after she stops contributing to it. This also allows us to assume that total accidental bequests are zero.

[24]We take the probability of survival as exogenously given. Pestieau, Ponthiere and Sato (2008) argue that survival rates are a function of spending on health, which in turn depends on pension provisions.

The planner's maximand can therefore be written:[25]

$$V = E\left[\sum_{t=1}^{T}\frac{\sigma_t}{(1+\delta)^t}u(c_A)+\sum_{t=T+1}^{2T}\frac{\sigma_t}{(1+\delta)^t}u(c_B)\right] \tag{17}$$

We assume that $u(c)$ is characterised by a constant relative risk aversion (RRA).[26] θ^* and S^* are the values which maximize V in (17).

5 Results

We now use equations (4), (5), (7) and (8) to simulate many life histories of w_t, r_t and u_t (we chose to generate 1000). For each history, we draw values at random from empirical distributions of η_t, v_t, and the unemployment innovations ζ_t[27] constructed by boot-strapping our estimates of these error terms.

We then proceed to compute θ^* and S^*, using the algorithm described in Appendix B. We focus on our model predictions of θ^*. Appendix B presents a full table of values of θ^* and S^* based on a range of different assumptions regarding RRA.

Table 4 presents the values of θ^* which we obtain from these simulations when RRA = 12 and RRA = 5, and compares them with the values of effective tax rates, θ^e, reported in Table 1. We discuss both results in the next section.

[25] In order to remain within the framework of a two-period model, we have to make the simplifying assumption that income and consumption in the active years and income and consumption in the retirement years are equal every year to their respective average values.

[26] T is the maximum length of the representative agent's active years and retirement years. We lack the institutional, national information which would allow us to attribute a different value for this parameter to each country. Realized, average terms depend on the survival function. The assumption we apply to all countries is that T = 40. We also assume δ = .02. We have tested that results are not sensitive to these assumptions.

[27] Unemployment innovations ζ_t are the difference between the unemployment rate u_t and its mean (eq. 6). We restrict the estimation of the empirical distribution of unemployment innovations to the period 1980-2002 to avoid difficulties associated with the secular increase in unemployment rates in Europe after the first oil shock.

5.1 Testing the Model

The test of our rational, economic model is the degree to which θ^* predicts actual values of θ^e in a cross-section regression,

$$\theta_k^e = \theta_k^* + \varepsilon_k, \tag{18}$$

where k is a country index. We use two different sets of estimates of θ^* to test the hypothesis. The set to which we devote our main focus is the one in which GDP is a proxy for labor earnings, and samples in all countries begin in 1950. In the other, we use actual, annual data for labor earnings, and are, therefore, confined to sample periods which begin variously in 1955, 1960, 1961, 1964 and 1970. In both cases, we test the hypothesis twice, once under the assumption that RRA = 12, and once under the assumption RRA = 5. The GDP based results are presented in this section. Appendix C presents the earnings based results and compares them with the GDP based results. In all cases, the test supports our central hypothesis, but the support is strongest with the GDP based data and longer sample periods.

In Figure 1, we plot the GDP-based predicted rational rates based on RRA = 12, θ^*, on the horizontal axis and the effective rates, θ^e, on the vertical axis. There is clearly a strong relationship between the variables. $\overline{R}^2$ of the linear regression drawn in the Figure is 83$\%$. This result confirms our basic hypothesis that objective, economic differences explain the diverse pattern of effective paygo tax rates in our sample.

However, the regression implies that actual rates are too sensitive to predicted rates. The estimated slope, 3.7, far exceeds the theoretical value of 1.0 in equation (18). We conjecture that omitted variables cause the underlying relationship to be non-linear. The argument is that high paygo rates and low saving rates are correlated with weak regulatory infrastructure – poor policing of insider trading, inadequate protection of minority stockholder rights, etc. When capital markets provide low and variable returns, these institutional weaknesses also tend to be present, and to cause reliance on paygo provision to be even higher than it otherwise would be.

We therefore estimate the following Poisson relationship:

$$\theta_k^e = \exp(a + b\theta_k^*) + \varepsilon_k \tag{19}$$

Predicted and actual values are plotted in Figure 2. In the Poisson model, the estimated slope is 1.0 when θ_k^* is low, and increases as it rises.[28] The Poisson model is our preferred model.[29]

5.2 Decomposition of Explained Variance

Though we have only one explanatory variable in our model, it is constructed as a composite of many elements. We now ask how much each element contributes to the explanatory power of the model. To that purpose, we run a number of counter-factual simulations in which we remove these elements, one at a time, and evaluate the resulting reduction in explained variance. At each stage, the way we remove the particular element's contribution to explained variance is by attributing its value in one country to all of the countries. For instance, we consider what happens to the model's ability to explain cross-country variation, when we attribute U.S. capital market characteristics – or French labor market characteristics – to each of the other seven countries. We take the reduction in explained cross-country variance of each counter-factual simulation to be a heuristic measure of the contribution of the removed element to total explained variance.[30] The results are presented in Tables 5 and 6. Table 5 analyzes the results of standardizing capital market characteristics, and Table 6 of standardizing labor market

[28]In the Poisson model, the slope is 1.0 at θ_k^* = 7, and 2.7 at θ_k^* = 12.

[29]Although the F-test of the linear model and the Chi-square test of the Poisson model are not strictly comparable, a RMSE corrected for degrees of freedom, computed for the Poisson case (4.2), is smaller than the RMSE of the linear estimate (5.0).

[30]The highly non-linear character of the model means that we can not attribute particular significance to combinations of these individual measures.

characteristics.[31]

The Tables elicit three general observations, which can be made before we examine the details:

- Understanding the stochastic structure of the environment in which individuals and societies plan for retirement is critical to understanding those decisions. The stochastic nature of our model is not just a refinement; it is its central feature.

- Differences in capital market characteristics account for more of the cross-country variance of paygo levels than any other factor (with the projected dependency rate being a close second). The reason is clear. The volatility of capital market shocks is, in general, two orders of magnitude greater than that of labor market shocks, and it varies dramatically from country to country. The striking feature of this result is that it is very different from what the early theorists of paygo systems expected. They focussed on the volatility of labor earnings. One of their central points was that a paygo system may be pareto improving, even when the economy is dynamically efficient, because it allows agents to insure against the volatility of labor earnings.

- The magnitude of the effects of different national characteristics depends importantly on what we assume the relative rate of risk aversion to be. This observation follows naturally from the first, above. If stochastic structure is important, then the lens through which individuals evaluate stochastic events – their utility function – is central.

Table 5 analyzes the contribution of capital markets to paygo differences. If we focus on the left half of the table, where RRA = 12, we see that the volatility of cap-

[31] In both Tables 5 and 6, we have set the cross-VAR coefficients of Eq. (8) equal to zero before simulating rational paygo rates. We do this because our purpose is to identify separately the effects of capital market innovations and labor market innovations. Non-zero cross-effects would cause them to be comingled in ways that vary from country to country. As it turns out, the estimates used as a base of comparison in these tables are similar to the "rational paygo rates" presented in Table 4. Eliminating cross effects has only a marginal impact on every country except the United States. For consistency, we use these estimates with no cross-effects also to simulate standardizing the dependency rate, d.

ital market shocks accounts for about a quarter of the explained variance.[32] Volatility proves to be more important than differences in mean expected return. Fixing that everywhere at its U.S. value reduces explained variance by only 4%. We conjecture that what lies behind this result is a) the striking extent of the differences in the variability of capital returns from country to country, and b) the sensitivity of expected utility to this variability.

If we turn to the right side of Table 5, where RRA = 5, we see that the explanatory importance of capital market variability appears even greater there. In that case, differences in the volatility of returns account for 70% of the explained variance, whereas differences in mean expected return account for barely 1% of explained variance.[33] What is perhaps even more striking is the magnitude of the shift away from paygo triggered by improvements in capital market volatility. Whether RRA = 12 or 5, the preference of all countries for saving increases when capital market volatility decreases. But the drop in θ^* associated with lower volatility is much larger when RRA = 5.[34]

Table 6 analyzes the contribution to paygo differences of factors which affect implicit paygo returns. The first thing one notices is the insignificance of the variability of labor earnings, whether RRA = 12 or 5. When we attribute the relatively low volatility of these earnings in France to the other countries, explained variance is effectively unchanged, which implies that this factor is not a significant contributor to cross-country variance. Similarly, when we attribute the French trend rate of growth of labor income, g, to other countries, explained variance is again effectively unchanged (This result is not shown in the table.) Admittedly, our prior for that simulation was ambiguous, because the multiplicative nature of the wage rate error term (see Eq. 5)

[32] In column 3, the reduction in explained variance when this volatility is set everywhere equal to U.S. values, is 22%, which is about a quarter of the total explained variance, 85%.

[33] Part but not all of the striking drop in variance explained is a reflection of the sharp drop in the rational rates of Germany and Japan. The same calculations excluding Germany and Japan attribute almost 50% of the variance explained to the remaining capital shocks.

[34] Lower volatility causes the average rational paygo rate to drop from 9.1 to 4.7 when RRA = 5 (Compare col. 6 with col. 5). The drop is more moderate, from 12.6 to 10.5, if RRA =12 (Compare col. 3 with col. 2).

implies that increasing g, and thus raising the implicit return of paygo, also increases the amplitude of wage shocks, and raises the volatility of that return.

The dominant influence on the labor income side is that of the dependency rate, d, which agents expect will prevail when the current generation retires. This parameter, which we treat as non-random, figures directly and importantly in calculations of the implicit return of paygo. Table 6 shows that its marginal contribution is 29% of explained variance when RRA = 12, and 11% of explained variance when RRA = 5.[35]

What is particularly striking about the dependency rate is the direction of its effect on rational paygo rates. Reducing d appears to have both an income and a substitution effect. When the substitution effect dominates, an increase in expected d creates an incentive for society to lower θ^*. Agents expect a larger number of claimants for future pensions, and, therefore, other things being equal, reduced pensions. When the income effect dominates, increasing d – though it reduces the expected return of paygo for the representative individual – causes θ^* to rise. In Table 6, when risk aversion is high and RRA = 12, the income effect dominates in every country. When RRA = 5, the substitution effect dominates in Australia, the United Kingdom and the U.S., and the income effect continues to prevail, but more moderately, in the remaining countries.

Higher risk aversion appears to cause individuals and society to protect the relative stability of retirement income that paygo provides. The return to saving is highly volatile in all countries, much more so in some than in others. Paygo provides a less volatile alternative. Thus, when individuals are very risk averse, a drop in the implicit return of paygo causes them to want more of it.

Which value of RRA best describes sensitivity to risk in the developed countries in our sample? The argument in Section 3.1 that the length of the planning horizon implies greater sensitivity to risk, weighs in favor of higher values of RRA. Moreover, the evidence in Appendix C is that higher values of RRA, specifically $RRA = 12$,

[35]We find, in simulations not reported here, that standardizing the survival functions has only a minor effect on rational paygo rates. Differences in life expectancy per se appear to have less effect on pension decisions than fertility and the many institutional and other factors affecting dependency.

contribute to a more powerful explanation of the cross-country variation of effective rates. In our judgment, we understand the logic of pension planning in our countries better, if we attribute high relative rates of risk aversion to them. When RRA is on the high end of the acceptable range, we can more clearly identify the pension implications of the factor which most differentiates one developed country from another – the stochastic characteristics of its capital markets. The fact that high values imply under certain circumstances a desire to defend the stability of paygo in spite of its declining internal return does not alter our judgment.

6 Further Results

In this section, we use the rational, economic model (maintaining RRA = 12), to consider alternative economic scenarios. We ask how paygo rates may be influenced by the integration of national capital markets, and by a new awareness of the low but significant probability of crises like that of 2008. In each case, we modify the relevant assumptions, rerun the algorithm described in Appendix B, and compare the new predictions with our previous "normal" rates.

6.1 The integration of financial markets

If the capital markets of the large OECD countries were to become fully integrated, what would the consequences be for national patterns of paygo tax rates?

We address the issue by performing the following thought experiment. Suppose that our eight countries continue to have distinct and separate labor markets, but that they share a common, pooled capital market. Assume further, for simplicity, that the stochastic characteristics of the return to investment in that pooled capital market are the same as those we have observed for the United States. The simulations presented in Table 5 closely approximate this scenario. In Table 7, col. 3, we go one step further, and completely replace each country's own distribution of capital returns and its own VAR coefficient measuring the serial correlation of investment returns ($\rho_{\epsilon_t \epsilon_{t-1}}$ in equation (8)) with that of the United States.[36] Not surprisingly, the pattern of retirement provision converges in the eight countries. The cross-country standard deviation of the predicted rational rates goes down from 2.8 in the standard set of results (where VAR cross-effects are muted) to 0.5 in the integration experiment results. Access to the relative stability of a global capital market would bring about declines in paygo rates which vary commensurately with the previous volatility of national capital markets.

A completely different exercise involves assuming that the representative agent eliminates financial markets completely from her retirement planning. We do this in Table 7, col. 4, by imposing the constraint $S = 0$ in all countries. This thought experiment leaves all the other cross-country differences (dependency, wage distributions, long-term wage growth trend) full room to play out. Deprived of saving, agents choose higher paygo rates in all countries. The exercise shows how much capital markets (in this case their absence) influence desired paygo rates.[37]

6.2 Global Crises

We have assumed that in 2002 individuals and the pension authority did not allow for the possibility of crises like that which unfolded in 2008. If they had, would they have made the pension commitments implicit in the predictions of section 5? Clearly, the realization of such a possibility would have reduced expectations of life-time utility. But, even though faced with a more somber future, each society would still have had to choose the best possible balance between paygo and saving. Would awareness of

[36] The radical nature of this hypothetical exercise should be emphasized. It abstracts from all of the institutional differences that characterized OECD capital markets in the second half of the twentieth Century. It also assumes away national heterogeneity of capital. For the real rate of return to be identical across countries, they would all have to share a common capital market. In addition, those which had common currencies or were linked by fixed exchange rates would have to share a common inflation rate. Currency depreciation would have to exactly compensate for inflation differences between countries with floating rates.

[37] This exercise was suggested by an anonymous referee. There is some convergence of paygo rates, but it is not as stark as in the integration of financial markets case. The coefficient of variation (last row in Table 7) drops by 76% in the integration of financial markets exercise (compare col. 3 to col. 2) and by 40% when the representative agent forgoes any access to capital markets (compare col. 4 to col. 2).

the possibility of a crisis have affected those calculations? Our analysis in Appendix D suggests that paygo rates would not have been fundamentally altered.

7 Conclusion

The central result of this paper is that a rational economic, and consensual model of how societies set paygo tax rates replicates the diverse pattern of effective paygo rates in large OECD countries at the beginning of the 21st Century. The model is a simple, two-period OLG model, in which a representative individual and a benevolent tax authority jointly choose the tax rate and the saving rate which maximize the expected life-time utility of the representative individual. We assume that the individual and the tax authority both have complete knowledge of the distribution of labor and capital income over the individual's lifetime. We construct this distribution by estimating annual equations for the wage rate and the return to capital, and using them to simulate large numbers of life histories. Taking expectations over these life histories, we compute the expected life-time utility of the representative individual as a function of the paygo tax and saving rates. The model predicts that society will choose the tax and saving rate which maximize the individual's expected life-time utility. Though the model assumes that every agent expects the paygo budget to be balanced over her lifetime, its focus is more on pension provision than pension financing.

We find that societies in which capital markets are relatively stable, and offer rates of return well in excess of the rate of growth of labor income, tend to have moderate paygo tax rates. By contrast, societies in which capital markets are relatively volatile, choose higher paygo tax rates. These considerations – the most important of which are differences in the volatility of the return to capital – explain approximately 83% of the cross-section variance of observed effective paygo tax rates in 2002. The results point to the importance for pensions of reducing capital market volatility. Allowing for the possibility of extreme events, like those of 2008, does not change our conclusions. Among the many questions calling for future research, one of the central ones has to do with the effect of the distributional characteristics of paygo systems in a heterogeneous population. Addressing such questions will require the use of substantially more disaggregated models.

A Constructing Estimates of Effective Paygo Tax Rates in 2002

Following Disney (2004), we write the effective tax rate as

$$\theta^e = \frac{b}{w}\frac{p}{e}. \tag{A-1}$$

Of the two parameters on the right hand side, the more difficult to estimate is $\frac{b}{w}$, "the relative pension level", because it depends on numerous, detailed, country-specific regulations. We use estimates of this parameter first published in 2003 in a new OECD publication, Pensions at a Glance. Noting that laws in effect at a given moment generally entail future commitments to increases or reductions of benefits spread out over many years, the OECD computes, on the basis of legislation in effect in 2002, the average pension which an employee who entered the labor force that year, and subsequently fulfilled all relevant working requirements, would be entitled to at the statutory retirement age. To the extent that a social security system is contributory, different individuals (all of whom have met all the work requirements) will receive different pensions, because of differences in their life-time earnings. The OECD therefore bases its projection of pension entitlements on what it projects the range of life-term earnings to be. It then averages these entitlements, and presents this average "relative pension level" as a percentage of its projection of the economy wide average wage during the years when the individual in question will be in retirement.

The forward looking nature of the OECD measure of the relative pension level, $\frac{b}{w}$, requires for consistency that our measure of $\frac{p}{e}$ also be forward looking. It should reflect the balance between retirees and workers for the duration of the retirement of the cohort whose entitlements we are estimating. We base our estimate of $\frac{p}{e}$ in each country on OECD projections of the number of retirees and the number of active employees in each country between 2042 and 2062.

We adjust for the statutory nature of the OECD's measure of relative pension levels by recognizing that many individuals who are working at the time they retire will nonetheless not receive a full, potential pension, because they have incurred spells of maternity leave, unemployment, or other interruptions from active work. We estimate that the average, normal pension is 20 % lower than the potential level calculated by the OECD.[38] As in Disney (2004), we further argue that persons who were not em-

[38] OECD (2003) presents projected pension levels for men and not for women. Though, in all the countries in our sample, statutory pension provisions are the same for women as for men, the actual pensions women

ployed during the last decade of their working lives receive half of a normal pension, this additional discount corresponding to average widow and survivor provisions.

The effective tax rates thus obtained are not current tax rates. They reflect the future commitments that legislation currently in effect implies for the cohort entering employment, and measure the burden of those commitments on those who will be employed during this cohort's retirement. Their forward looking nature corresponds to the forward looking nature of the collective decision process hypothesized in our model.

B Simulation Algorithm

We construct measures of the rational, economic paygo tax rates which our model predicts by using the annual equations for labor and capital income estimated in section 3 to simulate numerous life cycle histories. The algorithm has seven steps:

1. To simulate each life cycle j, we draw a full history, $0 < t < 2T$, from the empirical distributions of $\widehat{\eta}_t$, $\hat{v}_t$ and $\widehat{\zeta_t}$. We use the first two to construct a sample of innovations $\left(x_t^{(j)}, \epsilon_t^{(j)}\right)_{2T \geq t \geq 0}$ using the vector auto-regression (8).

2. Capital returns are simply deduced from (7), whereas annual wages in the steady-state regime are given by

$$\ln w_t^{(j)} = \hat{a} + \hat{g}t + x_t^{(j)} \tag{20}$$

   The convergence of earnings is assumed completed.

3. Using (9) and (12), we compute $\omega_A^{(j)}, \omega_B^{(j)}$. We use (15) and (16) to compute $R^{(j)}$.

4. We select values of the saving and tax rates (θ, S), and compute $c_A^{(j)}$, $c_B^{(j)}$ and the lifetime utility associated with that history and those values of (θ, S), $\sum_{t=1}^{T} \frac{\sigma_t}{(1+\delta)^t} u(c_A^j) + \sum_{t=T+1}^{2T} \frac{\sigma_t}{(1+\delta)^t} u(c_B^j)$.

5. We go to step 1 and loop 1000 times.

6. We compute expected utility V for each pair (θ, S), using (17).

receive are lower than those received by men, because their annual earnings are lower. Much of our discount corresponds to the lower average career earnings of women.

7. We scan over the space $0 < \theta, S < 1$, allowing each variable to increase in steps of 0.001. The values θ^* and S^*which maximize V are the values which the model predicts that society and the individual will adopt.[39]

The values of S^* and θ^* depends on RRA. Table B1 displays the values obtained when RRA varies between 5 and 20. As RRA rises and societies become more risk averse, they increasingly avoid the volatility of capital markets, and rely more on paygo. θ^* rises, and S^* falls.

C Estimations Using Data on Average Annual Earnings.

In sections 3 through 6, we construct measures of rational paygo rates using GDP as a proxy for earnings. This makes it possible to start our estimates of the underlying annual models in 1950, prior to the availability of comparable earnings series. In this appendix, we compare the results above with the results we obtain when we use actual, average annual earnings data.

Working with a range of starting dates increases the difficulty of estimating the convergence function in equation (5). In the five of the eight cases in which the sample period starts more than ten years later than previously,[40] actual and trend growth are too collinear to allow simultaneous estimation of the trend and the convergence function. Hence, we constrain g in (5) to be equal to the actual rate of growth between 1973 (the first oil shock) and 2002 for the three countries which earnings data is available from 1955 onwards and between 1980 and 2002 for the other countries. We then estimate the convergence function conditional on that prior, and use the values of the residuals of the wage equation (5) along with those of the return to capital equation (7) to estimate the coefficients of the VAR (8), and to extract the i.i.d. series which drive annual income in each country. All eight real wage equations pass the same stationarity tests to which the GDP based data were subjected.[41] The fact that the wage and capital innovations jointly determine the error terms in the wage and capital return equations means that when wage data is only available for a shorter period, capital return data

[39]We also use this simulation algorithm to calculate quasi confidence intervals, conditional on the choice of RRA, for the values of θ^* and S^* obtained. We take the maximum value of the expected life-time utility of the representative agent in each country, and trace pairs of paygo tax and saving rates that cause expected utility to be 99% of that maximum value. The exercise shows that the estimated utility function is relatively flat, and that variations of +/- 10% of θ^* are within this 99% confidence interval.

[40]See Table C1 for starting dates.

[41]Detailed results are available upon request.

can also only be used for that shorter period. The counterpart to these shortcomings is that the earnings data directly measures labor earnings, rather than a proxy for labor earnings.

In Table C1, we compare rational paygo rates obtained from this earnings data with the rational paygo rates derived in the text from GDP data. The two series display similar cross-section characteristics. Each one, on its own, explains almost 80% of the cross-section variance of effective rates presented in Table 1. The last two lines of the table present the adjusted Root Mean Square Error of the linear and Poisson regressions of effective on rational rates.

D The Implications of 2008

We examine the possible effects on paygo tax rates of incorporating the previously ignored probability of a crisis. Using Barro and Ursua (2008) and Barro (2009), we infer a binomial variable with a known probability of realization which simultaneously generates two outcomes - a decline of GDP (our proxy for wage income) and a drop in the return to capital.[42] In steps 1 and 2 of the algorithm in Appendix B, we add draws from this binomial distribution to the values of $\widehat{x}_t$ and $\widehat{\varepsilon}_t$ derived from the population of shocks previously estimated from data from 1950 to 2002. Each of the eight countries is characterised by its own population of "normal" shocks $\widehat{x}_t$ and $\widehat{\varepsilon}_t$.The binomial distribution describing crises, which is added to those "normal" shocks, is the same across countries (we only have one estimate), but we continue to simulate independent life histories for each country.

Examination of Table D1 suggests that incorporating the expectation of low probability crises does not substantially change the calculus of rational individuals and authorities. The new predicted paygo tax rates are similar to the old, though they are everywhere slightly higher. Though expected utility declines, the trade-off between paygo and saving remains substantially the same.

[42]Specifically, we refer to the data in Barro and Ursua (2008) on macroeconomic crises since 1870. According to Table 8 p.279, 70 crises have taken place in 17 OECD countries in the 136 years of history examined, implying a probability of crisis equal to 3.0%. The corresponding average decline in GDP per capita was 17.4% (Table 9 p.283). We estimate the shock to the stock price to be 22.9%, which is the average decline among OECD countries during GDP crises as calculated from Table C2 p.323.

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Table 1: Effective Paygo Tax Rates

	Effective Tax Rates
Australia	4.8
France	18.4
Germany	19.1
Italy	36.3
Japan	18.8
Spain	33.5
United Kingdom	10.9
United States	8.7

Source: OECD (2003), OECD labour force participation projections and authors' calculations.

Table 2: Unit Root Test Applied to Wage Innovations (five lags)

	Augmented Dickey-Fuller Statistics	Phillips-Perron Statistics
Australia	-3.67***	-3.81***
France	-3.70***	-3.37***
Germany	-2.53**	-2.62***
Italy	-2.55**	-2.65***
Japan	-2.01**	-2.67***
Spain	-2.17**	-4.82***
United Kingdom	-2.93***	-2.39**
United States	-2.65***	-2.06***

Note: *** (resp. **) represent significance at the 1% (resp. 5%) level. Critical values at the 1% and 5% levels are respectively equal to -2.61 and -1.95 for augmented Dickey-Fuller statistics and for Phillips-Perron statistics. The stationarity tests results presented in this table are based on wage series constructed using GDP as a proxy for annual labor earnings. Wage series using OECD (2016) data on actual labor earnings were also tested for stationarity and are discussed in Appendix C.

Source: Authors' calculations.

Table 3: Annual Statistics

	$\hat{g}$	$\hat{\sigma}_x$	$\hat{E}_r$	$\hat{\sigma}_r/\hat{E}_r$	$\rho_{x_t x_{t-1}}$	$\rho_{x_t \epsilon_{t-1}}$	$\rho_{\epsilon_t x_{t-1}}$	$\rho_{\epsilon_t \epsilon_{t-1}}$
Australia	1.40%	0.049	6.38%	2.58	0.59***	0.04	-1.06**	0.18
					(0.12)	(0.03)	(0.46)	(0.14)
France	1.59%	0.015	6.81%	2.74	0.67***	0.00	-3.36*	0.17
					(0.11)	(0.01)	(1.76)	(0.14)
Germany	1.96%	0.030	7.55%	2.58	0.75***	0.02	0.93	0.33**
					(0.11)	(0.02)	(0.92)	(0.14)
Italy	1.93%	0.030	4.12%	5.98	0.72***	0.01	-0.21	0.35**
					(0.11)	(0.01)	(1.20)	(0.14)
Japan	1.90%	0.056	8.21%	2.48	0.76***	0.01	-0.06	0.31**
					(0.10)	(0.03)	(0.52)	(0.14)
Spain	1.60%	0.034	5.59%	3.79	0.58***	0.03	-0.70	0.59***
					(0.12)	(0.02)	(0.80)	(0.12)
United Kingdom	1.94%	0.034	6.78%	2.41	0.84***	0.03	-1.15*	0.20
					(0.08)	(0.02)	(0.66)	(0.14)
United States	1.25%	0.028	7.45%	1.84	0.85***	0.00	-1.88***	0.17
					(0.09)	(0.02)	(0.68)	(0.14)

Note: Standard errors appear in parentheses. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively. This table presents estimates of coefficients in equations (5), (7) and (8). Wage series are constructed using GDP as a proxy for annual labor earnings. $\hat{g}$ is the estimate of the long-term growth rate of wages. $\hat{\sigma}_x$ and $\hat{\sigma}_r$ are empirical estimates of the standard deviation of innovations x_t and ϵ_t. $\hat{E}_r$ is the empirical estimate of the expectation of $ln(1+r_t)$. The estimates of the four VAR coefficients are reported in columns 5-8.
Source: Authors' calculations.

Table 4: Effective and Predicted Paygo Tax Rates

	Effective Tax	Predicted Paygo Tax	
		RRA=12	RRA=5
Australia	4.8	10.8	7.0
France	18.4	12.4	8.3
Germany	19.1	14.7	11.6
Italy	36.3	16.6	15.2
Japan	18.8	12.5	8.5
Spain	33.5	16.7	14.2
United Kingdom	10.9	9.2	5.5
United States	8.7	11.3	9.4
R^2	-	83%	78%

Note: Predicted paygo tax rates, generated by Monte-Carlo simulations with 1000 replications, assuming a relative risk aversion coefficient of 12 in column 2 and 5 in column 3. The last row reports the R^2 of the linear regression of effective tax rates (column 1) on predicted rational paygo tax rates.
Source: Authors' calculations.

Table 5: Capital Return Effects

	Effective Tax	Predicted Tax - RRA = 12			Predicted Tax - RRA = 5			$\hat{E}_r$
		Base of Comparison	Same ν_t & $\rho_{\epsilon_t \epsilon_{t-1}}$	Same $\hat{E}_r$	Base of Comparison	Same ν_t & $\rho_{\epsilon_t \epsilon_{t-1}}$	Same $\hat{E}_r$	
Australia	4.8	11.1	10.4	10.1	7.8	5.9	5.5	6.38%
France	18.4	12.3	10.0	11.6	8.0	3.4	6.8	6.81%
Germany	19.1	13.6	8.9	13.6	9.2	0.8	9.4	7.55%
Italy	36.3	16.6	15.7	15.0	15.3	12.7	11.6	4.12%
Japan	18.8	12.6	8.5	13.1	8.6	0.6	9.8	8.21%
Spain	33.5	16.8	13.0	16.0	14.7	5.7	12.9	5.59%
United Kingdom	10.9	9.6	9.1	9.0	6.4	5.1	5.1	6.78%
United States	8.7	8.3	8.3	8.3	3.0	3.0	3.0	7.45%
R^2	-	85%	64%	82%	82%	25%	81%	
R^2 : Reduction	-	-	22%	4%	-	57%	1%	
Average	18.8	12.6	10.5	12.1	9.1	4.7	8.0	
Std. Dev.	10.5	2.8	2.4	2.6	3.8	3.6	3.2	
Std. Dev./Avg.	0.56	0.23	0.23	0.22	0.42	0.77	0.40	

Note: Predicted paygo tax rates, generated by Monte-Carlo simulations with 1000 replications, after setting cross-VAR coefficients to 0, assuming a relative risk aversion coefficient of 12 in columns 2-4 and 5 in columns 5-7. ν_t and $\rho_{\epsilon_t \epsilon_{t-1}}$ are the return white noise and VAR serial correlation coefficient in eq. (8). $\hat{E}_r$ is the empirical estimate of the expectation of $ln(1+r_t)$ in eq. (7). R^2 is the R-squared of the linear regression of effective tax rates (column 1) on predicted rational paygo tax rates. The row R^2 *: Reduction* reports the drop in explained variance in columns 3-4 relative to column 2 and in columns 6-7 relative to column 5. Std. Dev. and Avg. respectively stand for the standard deviation and the average of the paygo tax rates.
Source: Authors' calculations.

Table 6: Labor Return Effects

	Effective Tax	Predicted Tax - RRA = 12			Predicted Tax - RRA = 5			d
		Base of Comparison	Same η_t & $\rho_{x_t x_{t-1}}$	Same d	Base of Comparison	Same η_t & $\rho_{x_t x_{t-1}}$	Same d	
Australia	4.8	11.1	11.1	12.4	7.8	7.7	7.2	27.4%
France	18.4	12.3	12.3	12.3	8.0	8.0	8.0	35.0%
Germany	19.1	13.6	13.6	11.7	9.2	9.2	9.0	44.8%
Italy	36.3	16.6	16.6	13.5	15.3	15.3	13.2	47.0%
Japan	18.8	12.6	12.5	11.8	8.6	8.6	8.5	39.2%
Spain	33.5	16.8	16.8	14.3	14.7	14.7	13.2	44.4%
United Kingdom	10.9	9.6	9.5	10.5	6.4	6.3	5.9	29.3%
United States	8.7	8.3	8.2	9.2	3.0	3.0	0.5	23.9%
R^2	-	85%	85%	56%	82%	83%	72%	
R^2 : Reduction	-	-	1%	29%	-	-1%	11%	
Average	18.8	12.6	12.6	12.0	9.1	9.1	8.2	
Std. Dev.	10.5	2.8	2.9	1.5	3.8	3.8	3.8	
Std. Dev./Avg.	0.56	0.23	0.23	0.13	0.42	0.42	0.47	

Note: Predicted paygo tax rates, generated by Monte-Carlo simulations with 1000 replications, after setting cross-VAR coefficients to 0, assuming a relative risk aversion coefficient of 12 in columns 2-4 and 5 in columns 5-7. η_t and $\rho_{x_t x_{t-1}}$ are the labor white noise and VAR serial correlation coefficient in eq. (8). d is the dependency rate. R^2 is the R-squared of the linear regression of effective tax rates (column 1) on predicted rational paygo tax rates. The row R^2 *: Reduction* reports the drop in explained variance in columns 3-4 relative to column 2 and in columns 6-7 relative to column 5. Std. Dev. and Avg. respectively stand for the standard deviation and the average of the paygo tax rates.
Source: Authors' calculations.

Table 7: Integration of financial markets (RRA=12)

	Effective Tax	Base of Comparison	U.S. Capital Market	$S = 0$
Australia	4.8	11.1	8.8	14.0
France	18.4	12.3	9.0	15.9
Germany	19.1	13.6	9.1	17.2
Italy	36.3	16.6	9.5	17.9
Japan	18.8	12.6	9.4	16.1
Spain	33.5	16.8	9.6	18.7
United Kingdom	10.9	9.6	8.2	12.4
United States	8.7	8.3	8.3	13.1
Std. Dev.	10.5	2.8	0.5	2.1
Std. Dev./Avg.	0.56	0.23	0.05	0.14

Note: Predicted paygo tax rates, generated by Monte-Carlo simulations with 1000 replications, after setting cross-VAR coefficients to 0, assuming a relative risk aversion coefficient of 12. In column 3, ν_t and $\rho_{\epsilon_t \epsilon_{t-1}}$ (eq. 8) and $\hat{E}_r$ (eq. 7) are everywhere set equal to their values in the U.S. This simulation combines together the assumptions of the simulations of column 3 and column 4 of Table 5. Std. Dev. and Avg. respectively stand for the standard deviation and the average of the paygo tax rates.
Source: Authors' calculations.

Table B1: Predicted Rational Paygo and Saving Rates (in percent) for different RRA

	Effective Tax	Predicted Tax/Predicted Saving Rate					
		RRA=5	8	10	12	15	20
Australia	4.8	7	9.4	10.3	10.8	11.2	11.8
		5.1	3.1	2.4	2	1.6	1.1
France	18.4	8.3	10.9	11.8	12.4	13	13.4
		4.9	3	2.4	1.9	1.5	1.1
Germany	19.1	11.6	13.7	14.3	14.7	15.1	15.4
		3.6	2.1	1.7	1.4	1.1	0.8
Italy	36.3	15.2	16.2	16.4	16.6	16.7	16.8
		2.1	1.2	1	0.8	0.6	0.4
Japan	18.8	8.5	11	11.9	12.5	13.1	13.7
		4.6	2.9	2.3	1.9	1.5	1.1
Spain	33.5	14.2	15.9	16.3	16.7	16.9	17
		2.8	1.6	1.3	1	0.8	0.5
United Kingdom	10.9	5.5	7.8	8.7	9.2	9.7	10.1
		4.9	3	2.3	1.9	1.5	1.1
United States	8.7	9.4	10.6	11	11.3	11.5	11.8
		3	1.8	1.4	1.1	0.9	0.6
R^2	-	78%	82%	83%	83%	84%	82%

Note: Predicted paygo tax rates, generated by Monte-Carlo simulations with 1000 replications, assuming a relative risk aversion coefficient varying from 5 in column 2 to 20 in column 7. The last row reports the R^2 of the linear regression of effective tax rates (column 1) on predicted rational paygo tax rates.
Source: Authors' calculations.

Table C1: Predicted PaygoTax Rates : Comparison of GDP and Earnings Based Estimates

	RRA = 12		RRA = 5	
	GDP Based	Earnings Based	GDP Based	Earnings Based
Australia (1964)	11.6	13.6	8.8	8.1
France (1955)	13.9	14.1	11.9	10.6
Germany (1970)	16.5	16.6	16.0	10.1
Italy (1960)	17.8	20.1	18.3	19.2
Japan (1960)	14.9	14.0	14.1	8.2
Spain (1961)	17.7	17.1	16.8	14.3
United Kingdom (1955)	9.7	12.4	6.7	10.7
United States (1955)	12.1	12.6	11.6	7.4
R^2	79%	79%	74%	77%
RMSE, Linear	5.6	5.6	6.1	5.8
RMSE, Poisson	4.3	6.2	4.9	6.6

Note: Predicted paygo tax rates, generated by Monte-Carlo simulations with 1000 replications, assuming a relative risk aversion coefficient of 12 in columns 1-2 and 5 in columns 3-4. The sample period goes from the year indicated under each country to 2002. The estimates in columns 1 and 3 are the smaller-sample counterparts of the predicted, rational rates presented in table 4. R^2 is the R-squared of the linear regression of effective tax rates on predicted rational paygo tax rates. The last two rows report the Root Mean Square Error in the linear regression (eq. 18) and in the Poisson regression (eq. 19).

Source: Authors' calculations.

Table D1: Predicted PaygoTax Rates with and without Accounting for the Risk of a Crisis (RRA=12)

	Paygo Rate Assuming no Crisis	Paygo Tax Rate with Possible Crisis
Australia	10.8	11.5
France	12.4	12.9
Germany	14.7	15.1
Italy	16.6	16.8
Japan	12.5	13.0
Spain	16.7	16.9
United Kingdom	9.2	9.9
United States	11.3	11.7

Note: Column 1 reports the predicted rational tax rates shown in Table 4, column 2. Crises have a binomial probability distribution and are added to the national stochastic processes summarized in Table 3. The predicted rational rates in the crisis experiment are presented in column 2.
Source: Barro and Ursua (2009) and authors' calculations.

Figure 1 : Linear Model

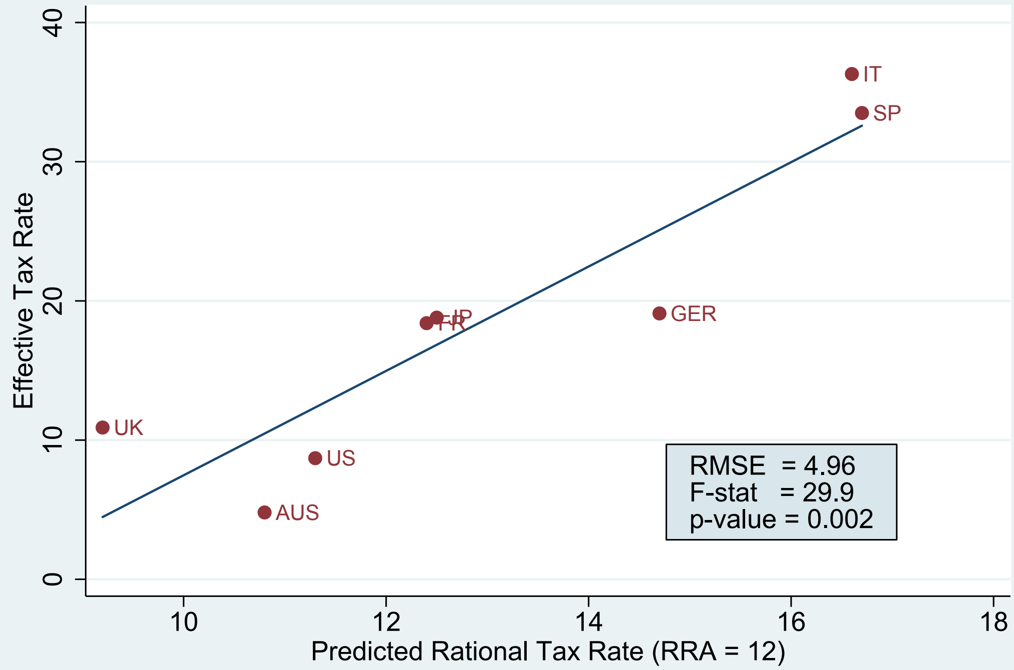

Figure 2 : Poisson Model