Dynastic Precautionary Savings*

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Abstract

This paper demonstrates that parents accumulate savings to insure their children against income risk. I refer to these as *dynastic precautionary savings*. Using a sample of matched parent-child pairs from the Panel Study of Income Dynamics, I test for dynastic precautionary savings by examining the response of parental consumption to the child's permanent income uncertainty. I exploit variation in permanent income risk across age and industry-occupation groups to confirm that higher uncertainty in the child's permanent income depresses parental consumption. In particular, I find that the elasticity of parental consumption to child's permanent income risk ranges between -0.08 and -0.06, and is of similar magnitude to the elasticity of parental consumption to own income risk. Motivated by the empirical evidence, I analyze the implications of dynastic precautionary saving in a quantitative model of altruistically linked overlapping generations in which parents and children interact strategically. I argue that strategic interactions are important for generating the observed dynastic precautionary behavior. I use the model to *(i)* examine the size and timing of inter-vivos transfers and bequest, and *(ii)* perform counterfactual experiments to isolate the contribution of dynastic precautionary savings to wealth accumulation and intergenerational transfers.

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1 Introduction

The age profile of expenditures of retired parents is backloaded. Explanations such as uncertain lifespans and medical expenses, or increasing monetary transfers from children are partial contributors, but a substantial gap remains. Section 2.4 contains a detailed discussion of these observations. This paper proposes decreasing income uncertainty of children as a justification for the consumption pattern of retired parents. The argument derives from the theory of precautionary saving, according to which, when faced with income uncertainty, individuals postpone current consumption in favor of accumulating precautionary savings as insurance against bad income realizations. As uncertainty resolves over time, consumption increases, thus generating a consumption profile that is backloaded over age. For parents in the data, this backloading postdates the resolution of uncertainty in their own income stream, but coincides with times at which their children are in the beginning or prime of their careers and still resolving their income risk. In the face of this uncertainty, altruistic parents sacrifice current consumption to accumulate savings to insure their children. I refer to these as *dynastic precautionary savings*. Over time, as children's income uncertainty resolves, that form of savings declines, increasing the consumption of retired parents.

In this paper, I seek evidence on dynastic precautionary savings using parent-child pairs from the Panel Study of Income Dynamics (PSID). In particular, I examine how a parent's consumption responds to the uncertainty of his child's permanent income. To that end, I first propose a measure of permanent income uncertainty closely related to the theoretical definition of permanent income. Second, I conduct a regression analysis of the effect of dynastic uncertainty on parental consumption on the sample of matched parents and children. I find a negative and statistically significant relationship, which I interpret as evidence for dynastic precautionary saving. I then build a model of altruistically linked overlapping generations in which parents engage in dynastic precautionary saving. I use the model to verify the plausibility of the empirical estimates, and to conduct counterfactual experiments and evaluate policy proposals.

The measure of income uncertainty considered in this paper is defined as the standard deviation of the forecast error of permanent income. This measure is meant to capture the fact that when individuals make consumption decisions, they are uncertain about the evolution of their entire future income stream. Therefore, it is the uncertainty about permanent income that is relevant for their choices. I assume that individuals' forecasts make rational use of the same conditioning information available to the econometrician. Intuitively, the higher the uncertainty, the more difficult it is to forecast earnings accurately, which translates into a larger standard deviation of the forecast error.

Because of issues such as sample attrition and measurement error in income, I focus on the properties of permanent income uncertainty across age and work sectors (a sector is defined as an industry-occupation pair), instead of individual level. I find that permanent income uncertainty is decreasing over age. On average, more than half of it is resolved by the age of 40. Moreover, there is substantial variation across sectors, both in terms of the level of uncertainty and the speed at which it resolves with age. I assign permanent income uncertainty measures to both parents and children based on their age and the sector in which they work in a given year. The consumption data used in the estimation is drawn directly from the PSID for the later years, while for the earlier waves I use the Consumer Expenditure Survey (CEX) to impute total consumption based on an inverted food demand equation.

From the variation in permanent income uncertainty across age and sectors, I find that parental consumption indeed responds negatively to the child's permanent income uncertainty. In particular, the elasticity of parental consumption to dynastic uncertainty is -0.081. This magnitude implies that parents of children younger than 40 consume on average $\$2,945$ less per year because at that stage most of children's income uncertainty is yet to be resolved. Building on the heterogeneity of permanent income risk across sectors, the regression result implies that parents of children working in riskier sectors have a lower consumption. For example, when comparing two otherwise identical parents of two otherwise identical children, with the only difference being that the child of one of them is a services worker while the child of the other one works in the finance sector, I find that the consumption of the latter parent is on average 7% lower because of the dynastic uncertainty difference.

I take a number of steps to address several endogeneity concerns. Firstly, I explore the sensitivity of the results to controlling for health status, as it may be the case that mortality risk is correlated with the sector in which an individual works. Secondly, it may be the case that children who know that their parents accumulate dynastic precautionary savings choose to work in riskier sectors. I examine the impact of such selection issues by *(i)* excluding from the sample the parent-child pairs in which the child is self-employed and *(ii)* controlling for the initial sector of the child. In this last case an additional source of identification is given by the changes in a child's sector over the career. I find that while the estimates of dynastic precautionary savings are approximately 1 percentage point lower under these specifications, the effect is still significant. In addition to these exercises, I also verify the robustness of the results to a series of alternative specifications which include controlling for the importance of the bequest motive, macroeconomic and local labor market conditions, as well as using different consumption and permanent income uncertainty measures.

Motivated by the empirical evidence, I explore the implications of dynastic precautionary saving in a partial equilibrium model of altruistically linked overlapping generations. I use the model to *(i)* evaluate the plausibility of the empirical estimates, and *(ii)* perform counterfactual experiments to isolate the contribution of dynastic precautionary savings to wealth accumulation and intergenerational transfers. There are three ingredients required for dynastic precautionary savings to emerge in a model: income risk, incomplete markets, and altruism à la Barro (1974), with the parent placing a weight on the child's utility from consumption.[1]

In light of existing evidence on imperfect risk-sharing within and between families, I model the decision making process between the parent and the child as a non-cooperative game without commitment. In my framework, individuals work in sectors characterized by different degrees of permanent income uncertainty. Each period, parents and children decide individually, but sequentially, how much to consume and save. In addition, altruistic parents can provide monetary support to their children through explicit financial transfers while they are alive (inter-vivos transfers), and by leaving an inheritance upon their death. The model enables clear predictions about the wealth position of overlapping generations, as well as the size and timing of inter-vivos transfers, both of which are relevant for counterfactual experiments. The allocations of interest are given by the Markov-perfect equilibrium of the parent-child repeated game.

The calibrated model can reproduce the characteristics of the age profile of parental consumption. In particular, the consumption of retired parents is backloaded, which is a clear indicator of dynastic precautionary saving, as in the model there are no other precautionary motives after retirement. I repeat the empirical exercise with model generated data and find that the response of parental consumption to both own income risk and child's income risk is of similar magnitude as in the data. In particular, the model estimates fall well within the 95% confidence interval of the empirical estimates.

I examine the effect of the strategic interactions between parents and children by solving a version of the model in which these are absent. In the alternative model, the parent makes all consumption-saving decisions for the family while he is alive. Consequently, the wealth position of different generations and the size of intergenerational transfers are indeterminate. In this framework, the dynastic precautionary saving motive is more important than the precautionary motive, contrary to the empirical evidence.

The model with strategic interactions between parents and children also accounts reasonably well for the age pattern of inter-vivos transfers and the fraction of parents making such transfers, as well as for the size of end-of-life bequest. I use the model to quantify the contribution of dynastic precautionary savings to wealth accumulation and intergenerational transfers. I find that a little over one fourth of aggregate wealth is held for dynastic precautionary reasons, and that most of the effect of dynastic uncertainty on parental consumption materializes in delayed rather than bequeathed consumption. Moreover, dynastic uncertainty is the main driver of intergenerational transfers. Lastly, the model predicts that parents' dynastic precautionary savings account for one fourth of children's insurance against income shocks.

[1]The direction of altruism (i.e. from parent to child, from child to parent or two-sided) is not essential. What matters is that the form of altruism considered extends the budget constraint across generations. Note that models with warm-glow bequest do not generate dynastic precautionary saving behavior in response to the child's income risk, as the parent only derives utility from the amount bequeathed.

Related literature This paper is related to three strands of literature. Firstly, it adds to the research aimed at understanding household consumption-saving behavior over the life cycle, and especially at older age. This literature advances two main drivers of saving at older age: bequest motives and precautionary saving motives for mortality and medical risk. However, there is no consensus regarding the strength of these two motives, nor their relative contribution in shaping consumption and savings late in life. Papers like Hubbard et al. (1995), Palumbo (1999), Nardi et al. (2010) or Kopecky and Koreshkova (2014) find that, given the significant medical spending risk faced by retirees, models without bequest motives can match well the wealth dynamics of middle-class retirees. While this suggests that bequest motives are relatively negligible, Kopczuk and Lupton (2007), Ameriks et al. (2011), Lockwood (2014) and De Nardi et al. (2016) conclude that bequest motives are important drivers of retirees' choices. The saving motive analyzed in this paper falls under the umbrella of the bequest motive broadly defined. However, unlike in the previously mentioned papers in which parental altruism can only manifest in the form of end-of-life bequests, here dynastic precautionary savings can also materialize in the form of inter-vivos transfers. Ameriks et al. (2016) and Luo (2016) examine the effects of such transfers on late-in-life wealth accumulation, and find that parents save in order to help when their descendants most need it, rather than at the end of life.

Secondly, this paper is related to the vast literature on precautionary savings. Some notable examples are Kimball (1990), Carroll and Samwick (1997), Gourinchas and Parker (2002), Cagetti (2003), Kennickell and Lusardi (2005) and Hurst et al. (2010).[2] The closest concept to dynastic precautionary savings is the idea of precautionary bequests introduced by Strawczynski (1994). He shows that government intervention is a substitute for bequests that are intended to hedge the future generation against risk. In his paper, agents live for one period and children are born when the parent dies, which means that there is essentially no difference between his framework and the recursive formulation of the problem of an infinitely lived agent. The subjective discount factor is relabeled as degree of altruism and precautionary savings are relabeled as precautionary bequest. In this paper, I allow individuals to have both precautionary and dynastic precautionary saving motives at the same time.

Thirdly, this paper complements the literature that analyzes the insurance role of the family. Examples with rich empirical content are Altonji et al. (1996) who strongly reject family risk sharing, McGarry (1999) who finds that inter-vivos transfers are negatively correlated with the recipient's current income, flowing disproportionately to less well-off children, McGarry (2016) who strengthens this conclusion with much richer data and adds events such as job loss and divorce as strong predictors of parental transfers, Attanasio et al. (2015) who find evidence of partial insurance within family networks, and Ameriks et al. (2016) who designed and fielded a new survey to measure transfers

[2] See Carroll and Kimball (2008) for a review of this literature.

from parents to descendants.

More recently, there has been a revived interest in studying dynamic models of families, especially those that depart from the full commitment assumption.[3] My paper complements these efforts. While this departure is attractive from the perspective of studying more realistic environments and obtaining richer predictions, it raises several challenges, especially if one is interested in environments in which altruistically linked agents can save individually, as it is the case in this paper. Barczyk and Kredler (2014) discuss these challenges at length. They propose a continuous time framework for studying such environments, which they subsequently use in Barczyk and Kredler (2016) to analyze the role of family in evaluating long-term-care policies. Fahle (2015) also studies long-term care arrangements of the elderly in a dynamic model of the family, but assumes children do not save. Kaplan (2012) studies a model of young workers who have the option to move in and out of the parental home. He shows that this option is a valuable insurance channel against labor market risk, which facilitates the pursuit of jobs with the potential for high earnings growth. His paper assumes parents cannot commit to transfers, but makes the simplifying assumption that they cannot save either. Nishiyama (2002) uses a setting with imperfectly altruistic overlapping households to analyze the role of inter-vivos transfers in shaping the wealth distribution, but rules out the possibility that transfers are used for saving. Differentely from the previous papers, in which the parent child interaction is non-cooperative and without commitment, Mommaerts (2015) studies the effect of informal on insurance demand in a cooperative model of the family with limited commitment. In my model, parents and children can save individually and there is no commitment, but I make an assumption on the timing of their non-cooperative interaction to deal with some of the concerns outlined by Barczyk and Kredler (2014).

The rest of the paper is organized as follows. Section 2 contains the empirical exercise of the paper. Section 3 explores dynastic precautionary savings further, in a quantitative model. Section 4 concludes and discusses several avenues for extending this work.

2 Evidence on Dynastic Precautionary Savings

In this section I provide empirical evidence on the existence of dynastic precautionary savings. The empirical exercise is aimed at exploring whether the consumption of parents responds to the resolution of their children's earnings uncertainty.[4] To capture that

[3] Altig and Davis (1992) and Altig and Davis (1993), among others, are examples that assume full commitment. Ameriks et al. (2016) and Luo (2016) bypass such considerations by assuming that parents derive warm-glow utility both from bequests and from inter-vivos transfers.

[4] I focus on earnings rather than consumption uncertainty because the latter is endogenous to individuals' (dynastic) precautionary behavior. Specifically, high (dynastic) precautionary savings translate not only in lower current consumption, but also in lower expected consumption uncertainty.

uncertainty, I focus on how labor earnings risk is dictated by workers' age, industry and occupation.

2.1 Measuring Permanent Income Uncertainty

I begin with the measure of permanent income risk. In the life cycle framework, individuals maximize an intertemporal utility function subject to a lifetime budget constraint, which specifies that permanent consumption cannot exceed permanent income. The uncertainty about an individual's own permanent income triggers the accumulation of precautionary wealth. When the pure life cycle framework is enriched with altruism à la Barro (1974) (i.e. the parent places a weight on the child's utility from consumption), uncertainty about the permanent income of future generations becomes relevant and it triggers the accumulation of dynastic precautionary wealth.

I define permanent income uncertainty as the *standard deviation of the forecast error of lifetime earnings*. Intuitively, the higher the uncertainty the more difficult it is for an individual to forecast earnings accurately, which translates into a larger standard deviation of the forecast error. I only focus on the human capital component of permanent income, since individual assets are known at the time the consumption-saving decision is made. For simplicity, I abstract from the uncertainty associated to forecasting interest rates (interest rates are used for discounting the future income stream).[5]

Income uncertainty at individual level

I now describe the measure of permanent income risk of an individual i, who earns labor income from age $\underline{H}$ to age H. At age $h \in [\underline{H}, H]$ the permanent income of the individual is the discounted sum of his remaining income stream, $\left\{y_j^i\right\}_{j=h}^{H}$, and it is equal to

$$Y_h^i \equiv y_h^i + \frac{y_{h+1}^i}{R} + \frac{y_{h+2}^i}{R^2} + ... + \frac{y_H^i}{R^{H-h}} = \sum_{j=h}^{H} \frac{y_j^i}{R^{j-h}} \tag{1}$$

[5] I measure permanent income uncertainty directly, without imposing any restrictions on the statistical properties of the forecast errors. Alternatively, it can be assumed, as it is often the case in the literature, that shocks to current income can be decomposed into a permanent component z_h (persistent or random walk) and a transitory component ε_h (usually iid) as follows:

$$\begin{aligned} \tilde{y}_h &= z_h + \varepsilon_h \\ z_h &= \rho z_{h-1} + \eta_h \end{aligned}$$

with $\varepsilon_h \sim \left(0, \sigma_\varepsilon^2\right)$ and $\eta_h \sim \left(0, \sigma_\eta\right)$. The parameters ρ, σ_ε^2 and σ_η^2 can then be used to calculate the standard deviation of the forecast error of lifetime earnings as I define it (see Carroll and Samwick (1997) and Feigenbaum and Li (2012) for estimates of these parameters at individual level, and Guvenen (2007), Karahan and Ozkan (2013) and Guvenen and Smith (2014), among others, for estimates at population level, i.e. for certain demographic groups). In fact, this is the procedure I implement in Section 3 of this paper. Therefore, the measure of permanent income uncertainty that I define is not to be confused with the standard deviation of the permanent component of current income, σ_η. The latter is only a component of the standard deviation of the forecast error of lifetime earnings.

where R is the gross risk-free interest rate fixed at population level (i.e. not individual specific) and constant over time. Assuming that current income y_h^i is observed at the beginning of age h, the individual is uncertain about the income stream from age $h+1$ onward, $\left\{y_j^i\right\}_{j=h+1}^{H}$, which he forecasts using the information set available at age h, denoted by $\mathcal{I}_h^i$ (to be defined later).[6] Let $\hat{y}_{j,h}^i = \mathbb{E}\left(y_j^i|\mathcal{I}_h^i\right)$ be the predicted labor earnings at age $j = h+1, \ldots, H$, based on information set $\mathcal{I}_h^i$. I assume labor earnings are predicted according to the following projection equation

$$y_j^i = \underbrace{\mathbb{E}\left(y_j^i|\mathcal{I}_h^i\right)}_{\hat{y}_{j,h}^i} + e_{j,h}^i \tag{2}$$

where $e_{j,h}^i$ is the forecast error and is orthogonal to $\mathcal{I}_h^i$.

The predicted lifetime labor income as of age h is the discounted sum of the predicted income stream and it is equal to

$$\hat{Y}_h^i \equiv \hat{y}_{h,h}^i + \frac{\hat{y}_{h+1,h}^i}{R} + \frac{\hat{y}_{h+2,h}^i}{R^2} + \ldots + \frac{\hat{y}_{H,h}^i}{R^{H-h}} = \sum_{j=h}^{H} \frac{\hat{y}_{j,h}^i}{R^{j-h}} \tag{3}$$

where $\hat{y}_{h,h}^i \equiv y_h^i$, by assumption. Therefore, the error in forecasting lifetime labor earnings as of age h is the difference between realized and predicted permanent income, $Y_h^i - \hat{Y}_h^i$, and it is equal to

$$\mathcal{E}_h^i \equiv \frac{e_{h+1,h}^i}{R} + \frac{e_{h+2,h}^i}{R^2} + \ldots + \frac{e_{H,h}^i}{R^{H-h}} = \sum_{j=h+1}^{H} \frac{e_{j,h}^i}{R^{j-h}} \tag{4}$$

The permanent income uncertainty for individual i at age h, denoted by $\text{Std}_i\left(\mathcal{E}_h^i\right)$, is defined as the standard deviation of this forecast error and is equal to

$$\text{Std}_i\left(\mathcal{E}_h^i\right) = \left(\sum_{j=h+1}^{H} \frac{\text{Var}_i\left(e_{j,h}^i\right)}{R^{2(j-h)}} + 2\sum_{j=h+1}^{H-1} \frac{1}{R^{j-h}} \sum_{k=j+1}^{H} \frac{\text{Cov}_i\left(e_{j,h}^i; e_{k,h}^i\right)}{R^{k-h}}\right)^{\frac{1}{2}} \tag{5}$$

The derivation of this result can be found in Section A.1 of Appendix A.

Income uncertainty at sector level

The measure of uncertainty previously described is an estimate and is subject to severe attenuation bias as predictor of behavior. Therefore, I follow the literature on

[6] The assumption that y_h^i is observed at the beginning of age h is analogous to the recursive formulation of the life cycle model in which current labor income is a state variable.

precautionary savings and project it on influencing factors such as industry and occupation.[7] That is, I construct the measure of income uncertainty previously described at sector level, where a sector s is an industry-occupation pair. The permanent income uncertainty for an individual of age h working in sector s is then equal to

$$\text{Std}_s\left(\mathcal{E}_h^i\right) = \left(\sum_{j=h+1}^{H} \frac{\text{Var}_s\left(e_{j,h}^i\right)}{R^{2(j-h)}} + 2\sum_{j=h+1}^{H-1} \frac{1}{R^{j-h}} \sum_{k=j+1}^{H} \frac{\text{Cov}_s\left(e_{j,h}^i; e_{k,h}^i\right)}{R^{k-h}}\right)^{\frac{1}{2}} \tag{6}$$

where the generic term $\text{Var}_s\left(e_{j,h}^i\right)$ is the cross-sectional variance of the forecast errors of all individuals of age h who are forecasting age $j > h$ earnings and are in sector s at the time of the forecast. Similarly, the generic term $\text{Cov}_s\left(e_{j,h}^i; e_{k,h}^i\right)$ is the cross-sectional covariance of the forecast errors of age j and age k earnings, made by age h individuals working in sector s at the time of the forecast. Note that this measure allows for sector changes over the career. What matters is the sector in which an individual is at the time the forecast is made.

Projecting individual level uncertainty on sectors mitigates the bias introduced by potential measurement error in earnings in the survey. If existent, measurement error ultimately shows up in the forecast errors used to calculate the permanent income uncertainty, and affects the distribution of permanent income risk across individuals of a given age, which is one of the main sources of variation used to identify dynastic precautionary savings. If, given age, measurement error is assumed to be independent and identically distributed across sectors, and uncorrelated with the true forecast error of labor earnings, then measuring permanent income uncertainty at sector level preserves the distribution of permanent income uncertainty across sectors. The formal discussion of this argument is deferred to Section A.2 of the Appendix.

The content of the information set $\mathcal{I}_h$

To compute the forecast error of lifetime earnings a stand must be taken on the content of the information set $\mathcal{I}_h$ used to predict labor earnings at ages $j > h$. I assume that individuals' expectations make rational use of the same conditioning information available to the econometrician. In the benchmark case I employ a rather parsimonious structure of the information set by including characteristics of the individual that are know with certainty at the time the future income stream is predicted. In particular, I assume that age j labor earnings y_j predicted by an individual i of age $h = \underline{H}, \ldots, j-1$

[7] See, for example, Carroll and Samwick (1998) and Kennickell and Lusardi (2005), among others. Additional reasons for "instrumenting" are sample attrition and the fact that the PSID is not long enough to observe two generations (parents and children) over their entire career. This would render extremely noisy estimates of individual level variances and covariances.

and working in sector s are given by

$$y_j^i = \underbrace{\theta_0 + g\left(\boldsymbol{\theta}_1, \mathbf{X}_h^i\right) + \theta_3 \boldsymbol{t}_j}_{\hat{y}_{j,h}} + e_{j,h}^i \tag{7}$$

where the function g is linear in the vector of observables $\mathbf{X}_h^i$. The latter includes current and lagged income, an age polynomial, dummies for current educational attainment, marital status, race and family size. Current and lagged income y_h^i and y_{h-1}^i are included to control for the persistence of income over time. Omitting them would result in larger forecast errors, as individuals on a steep income profile would mechanically translate high observed income into a large forecast error. Finally, $\boldsymbol{t}_j$ is a time trend for the year when the individual is of age j and is meant to capture the effects of aggregate economic growth on future income. I estimate equation (7) for each sector s and use the errors $e_{j,h}^i$ to compute the sector level permanent income uncertainty as described in equation (6).

The contents of $\mathcal{I}_h$ enumerated above include information that is available with certainty to both the individual and the econometrician. However, in reality it is possible that households plan ahead and know more than the econometrician about their future self, especially when the forecast horizon is small. In a first robustness exercise, I augment $\mathcal{I}_h$ with a vector of demographics $\mathbf{X}_j^i$ that are available in the survey and are likely to be known in advance by the individual. These include marital status, family size and educational attainment at the projection horizon j. Additionally, Guvenen (2009) finds evidence income growth rates are individual specific. To the extent individuals learn about their specific slopes over time, failing to account for this magnifies forecast errors. In a second robustness exercise, I attempt to control for the effect of individual specific growth rates by augmenting $\mathcal{I}_h$ with the last forecast error of an individual.[8]

2.2 Data description

Having laid out the theoretical framework for measuring permanent income uncertainty, I now turn to describing the data sets used in the analysis. The data are drawn from two sources: the Panel Study of Income Dynamics (PSID) and the Consumer Expenditure Survey (CEX). I use the PSID to construct the sector level permanent income risk measure previously described, and to form parent-child pairs for the main estimation. I use the CEX to impute total consumption in the years in which the PSID only collected information on food consumption and housing.

Sample selection. The main data source is the PSID, which contains longitudinal information on a representative sample of US individuals and families. The PSID started

[8] For example, for an individual who is 23 and predicts age 24 income, the last forecast error he made (and is aware of at the time of the forecast) was at 22, when predicting age 23 income.

in 1968, collecting information on a sample of approximately 5,000 households. In the following years both the original families and their splitoffs (children moving out of the parent household) have been followed. This is the essential feature of the survey that makes it suitable for the analysis in this paper. The PSID data were collected annually until 1996 and biennially starting in 1997. However, retrospective information on labor income in the past two years is collected in each of the biennial waves, so there are no gaps in labor income induced by this change in survey frequency.

To estimate the profile of income uncertainty I use all the waves of the survey, from 1968 to 2013. I apply fairly standard criteria when constructing the sample. First, I exclude households from the Survey of Economic Opportunity sample (low-income supplemental sample) and latino sample to avoid any selection issues. Second, since the uncertainty measure previously defined refers to the human capital component of permanent income, I focus on individuals of working age, so I restrict the sample to heads of age between 22 and 65 who are either employed or not employed. Third, I exclude the observations with top coded annual earnings and I winsorize the earnings variable at the 99^{th} percentile to minimize the bias caused by outliers and measurement error. I express earnings in 1996 US dollars. Fourth, a stand must be taken regarding the treatment of respondents with zero earnings. Eliminating them would shut down the uncertainty that comes from the extensive margin, thus underestimating the true uncertainty of permanent income. Instead, I impute labor earnings for such observations based on an estimated transfer function, which is discussed in detail in Section A.3 of Appendix A.[9]. Finally, I drop all entries with missing information in labor earnings and any of the demographic characteristics used in estimating equation (7), as well as all individuals with fewer than 3 observations. The resulting sample has 126,476 observations corresponding to 9,046 individuals.

A sector s is defined as an industry-occupation pair, with the exception of the 'unemployment sector' which includes all individuals that are not employed at the time they make the income forecast. Starting from 8 major industry groups listed in the first column of Table 1, I expand along 5 major occupation groups listed in the top row of the table. I aggregate some occupations further based on the distribution of annual labor earnings as summarized by the coefficient of variation. The procedure yields a total of 17 sectors (16 sectors in Table 1, plus the 'unemployment sector').[10] In forecasting permanent income, an individual is assigned to a sector based on his industry and occupation at the time the forecast is made.[11] This allows for transition between sectors over the

[9]I use the same estimated transfer function to impute earnings for observations with positive annual labor earnings smaller than $200, which are likely to be measured with error

[10]For a more detailed discussion of the sector classification, see Section A.4 in Appendix A. Tables 13 and 14 in Section A.4 report descriptive statistics regarding the sector size and earnings distribution in each sector.

[11]For example, if an individual works as a construction worker at 25, his forecast errors as of age 25 will enter the measure of income uncertainty of construction workers of age 25. If at 26 he works as a transportation worker, his forecast errors as of age 26 enter the measure of income uncertainty of

course of a worker's career.

Table 1: Sector definition

Industry/Occupation	Executive and professional specialty occupations	Technicians and administrative support	Sales and services occupations	Production, operators, fabricators, and laborers	Farming, forestry and fishing occupations
Agriculture and Mining	Sector 1				
Construction	Sector 2			Sector 3	
Manufacturing	Sector 4	Sector 5	Sector 4	Sector 5	
Transp. and Utilities	Sector 6		Sector 7		
Trade	Sector 8	Sector 9	Sector 10	Sector 9	
Finance	Sector 11				
Services	Sector 12	Sector 13	Sector 14	Sector 15	
Public administration	Sector 16				

Notes: Table entries are labels allocated to each sector. The unemployment sector is labeled Sector 0.

Parent-child pairs. I test for the existence of dynastic precautionary savings on a sample of matched pairs of parents and children, constructed using the PSID Family Identification Mapping System. If a parent has $n > 1$ children, I treat that as n parent-child pairs. There is a possibility that this affects the estimation results via two channels. Firstly, parents of multiple children working in different sectors can hedge against dynastic uncertainty, biasing the estimates downwards. I explore the extent to which this is true by repeating the empirical exercise on the sample of parents with one child only. Secondly, errors might be serially correlated between such pairs, contaminating the standard errors and implicitly the inference. I account for this by clustering the standard errors at parent level.

The analysis requires demographic and economic information for both parent and matched child (e.g. parent and child income, parent and child sector, just to name a few). Therefore, I restrict the sample to those pairs in which the child is a splitoff.[12] In addition, given that the income uncertainty measure constructed here refers to heads that are at least 22 years old, I drop those pairs in which the splitoff child is not a head or is younger than 22. I also drop those pairs for which the age difference between the parent and the child is lower than 20 years or which have fewer than 4 entries in the sample. The resulting sample has 1525 parent-child pairs observed between 4 and 21 times over the sample period. The oldest child is 59 years old, while the age of parents ranges between 42 and 80 years old.

transportation workers of age 26.

[12] A splitoff child is a child who moved out from the parent's house and established his own household. Therefore, his demographic and economic information is collected separately from the parent's.

Consumption series. The empirical exercise in this paper requires data on consumption or savings. PSID collected information on household wealth across 11 interview waves. Researchers who use this information define savings as the change in wealth net of debt between two time periods (for example Dynan et al. (2004)). The measure thus obtained is rather noisy and limited to the ten existing wealth supplements. Instead, I choose to focus on consumption expenditure. This decision is motivated both by the fact that consumption data is arguably less noisy, and by the fact that in some models of dynastic precautionary saving the wealth position of different generations is not identified.

With this approach, I face the problem that in the early waves of PSID information about consumption is limited to spending on food and rent. To overcome this, I follow the strategy of Blundell et al. (2008), who use the CEX to estimate the demand for food (available in both surveys) as a function of total consumption expenditure, relative prices and household characteristics, and then invert it to obtain a measure of total consumption expenditure in PSID. Since CEX data is only available starting 1980, I am able to construct the PSID measure of total consumption from 1981 until 2003 (calendar years 1980-2002), with breaks in 1988 and 1989 when PSID did not collect any information of food expenditure. The details of the procedure are discussed in Section A.5 of Appendix A. For the survey years 2005-2011, the consumption information in PSID is rich and consistent enough in terms of the categories to be used on its own. To aggregate the consumption categories collected in the PSID, I use the guidelines in Andreski et al. (2014).

I construct two measures of consumption expenditure. The first one includes only expenditure on non-durable consumption goods and services (food, utilities, personal care, transportation, health, education, etc.), and is the benchmark measure. The second measure of consumption also includes expenditure on durables (furniture, jewelry, cars, etc.). I examine both measures because expenditure on durables might affect utility for more than one period.

2.3 Uncertainty characterization

I now turn to characterizing the age profile of permanent income uncertainty. I estimate the projection equation (7) at the sector level using log annual labor earnings of the head as the dependent variable. That is, for each sector s and for all $h < j$ I run the following regression

$$\ln y_j^i = \underbrace{\tilde{\theta}_0 + \tilde{\boldsymbol{\theta}}_1 \mathbf{X}_h^i + \tilde{\theta}_3 \boldsymbol{t}_j}_{\ln \hat{y}_{j,h}} + \varepsilon_{j,h}^i \tag{8}$$

where the contents of $\mathbf{X}_h^i$ and $\boldsymbol{t}_j$ are as previously described. The residuals $\varepsilon_{j,h}^i$ obtained from this regression are used to construct the forecast errors $e_{j,h}^i$ from equation (7) according to[13]

$$e^i_{j,h} = \exp\left(\ln \hat{y}_{j,h}\right)\left(\exp\left(\varepsilon^i_{j,h}\right) - 1\right) \tag{9}$$

The forecast errors $e^i_{j,h}$ are then used to compute the permanent income uncertainty measure as described in equation (6), using $R = 1.04$ for discounting.

I begin by examining the income uncertainty estimated under the baseline information set. Because the uncertainty measure defined in equation (6) is unit of measurement dependent (in particular, $\text{Std}_s\left(\mathcal{E}^i_h\right)$ is measured in US dollars), in what follows I report the standard deviation of the forecast error divided by expected permanent income, $\hat{Y}_{h,s}$. Expected permanent income is calculated as

$$\hat{Y}_{h,s} = \sum_{j=h}^{H} \frac{\mathbb{E}_s\left(y^i_j | \mathcal{I}^i_h\right)}{R^{j-h}} = \sum_{j=h}^{H} \frac{\hat{y}_{j,h}}{R^{j-h}} \tag{10}$$

where $\hat{y}_{j,h}$ is defined in equation (7). The expected permanent income is computed under the assumption that $H = 80$. Individuals between 66 and 80 years old are treated as retired and thus not subject to labor income risk.[14] Their income stream is given by the social security income of the head.[15]

The average age profile of income uncertainty relative to permanent income is displayed in Figure 1. Permanent income uncertainty is high when the individual is young and it declines during the twenties and thirties. By the age of 40 approximately half of the relative uncertainty is resolved. Afterwards, uncertainty decreases at a lower pace with only an extra 15% being resolved until mid fifties. As retirement age approaches, the resolution of uncertainty accelerates. The figure implies that relative permanent income uncertainty is very high, with an average over age and sectors of 56%. A similar magnitude is implied by a calibrated income process with relatively standard parameter values, as will be shown in Section 3. The age profiles at sector level are displayed in Figures 12-13 in Appendix A. The correlation between permanent income uncertainty and permanent income across sectors is 0.61, meaning that sectors that are subject to high risk also exhibit high levels of permanent income.

The fact that uncertainty is downward sloping over age is not an artifact of the narrowing forecast horizon. Figure 2 displays the relative standard deviation of labor earnings forecasts, from the 1-year-ahead up to the 10-year-ahead forecast, by age.

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[13] If $y = \hat{y} + e$ and $\ln y = \ln \hat{y} + \varepsilon$, then

$$\begin{aligned} e &= y - \hat{y} = \exp(\ln y) - \exp(\ln \hat{y}) = \exp(\ln \hat{y} + \varepsilon) - \exp(\ln \hat{y}) \\ &= \exp(\ln \hat{y}) \exp(\varepsilon) - \exp(\ln \hat{y}) = \exp(\ln \hat{y})(\exp(\varepsilon) - 1) \end{aligned}$$

[14] 77% of the entries of age between 66 and 80 years old are retired. The rest of 23% are either employed or unemployed.

[15] A retired individual is assigned to the sector in which he last worked before retirement age.

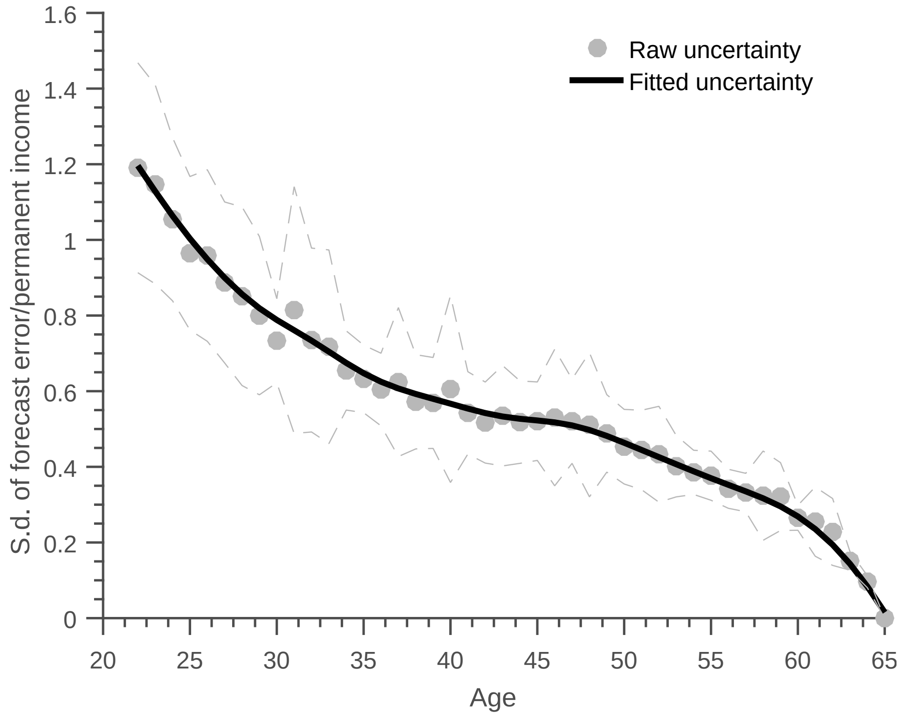

Figure 1: Age Profile of Income Uncertainty Relative to Permanent Income - baseline information set

Notes: The 'Raw uncertainty' is obtained by averaging over the age profiles of uncertainty at sector level weighted by the number of observations in each sector (Table 14 in Appendix A). The 'Fitted uncertainty' line is obtained by fitting a local linear regression with bandwidth equal to 2 to the 'Raw uncertainty' measure. Lastly, the dotted gray lines are the 95% confidence interval.

Specifically, the figure reports the average over sectors s of $\frac{\sqrt{\text{Var}_s\left(e^i_{j,h}\right)}}{\mathbb{E}_s\left(y^i_j|\mathcal{I}^i_h\right)}$, where the forecast horizon is $j-h \in [1, 10]$ and the age at which the forecast is made is $h \in [22, 55]$. The fact that each of the lines in the figure is upward sloping shows that the longer the forecast horizon is, the less precise the forecasts are. However, at older ages forecasts become more precise, as implied by the lower relative standard deviations.

I perform two robustness exercises with respect to the information set on which income forecasts are based and find very small effects. First, using a richer information set in forecasting income reduces measured permanent income uncertainty, on average, by approximately 2%. The difference is largest in the early twenties, with a reduction of 4%. Second, using past forecast errors in forecasting future income has almost no effect on the measured permanent income uncertainty.

I exploit differences in uncertainty across age and sectors to estimate the effect of own and dynastic uncertainty on parental consumption. This is a fruitful strategy insofar as there is enough variation in the level of permanent income uncertainty across sectors and in the speed at which it resolves over age. To verify this, Figure 3 displays the coefficient of variation across sectors, by age, of the level of permanent income uncertainty

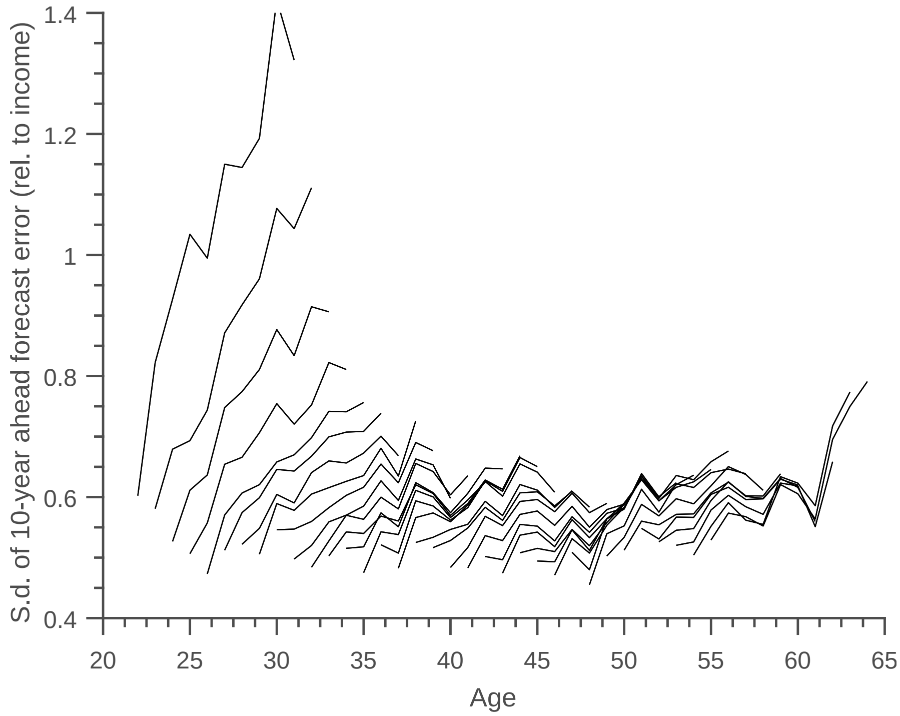

Figure 2: Relative Standard Deviation of the 10-year-ahead Earnings Forecasts, by Age

Notes: The lines in the figure are relative standard deviations of labor earnings forecasts, from 1-year to 10-years-ahead, by age.

in gray and the 1-year change in permanent income uncertainty in black for the baseline information set. Variation across sectors in the level of income risk is roughly constant across age groups, averaging at 36% and suggesting that level differences in risk between different sectors are an important source of identification at all ages. For the slopes of the permanent income risk the average over age is 22%. There is little variation across sectors in the speed at which uncertainty resolves in the twenties, suggesting that rapid resolution of uncertainty early in the career is a feature common to all industries and occupations.

Under altruism, current generations internalize the income uncertainty of future generations. This means that parents close to retirement, who face little to no income risk of their own, are still subject to income risk pertaining to their children's permanent income. Moreover, even early in their careers, forward looking parents face more income risk than that associated to their own permanent income. This acts towards flattening out the uncertainty profile over the working life of an individual with children (and an active bequest motive), giving scope for precautionary saving, dynastic and for own insurance, until later in life.

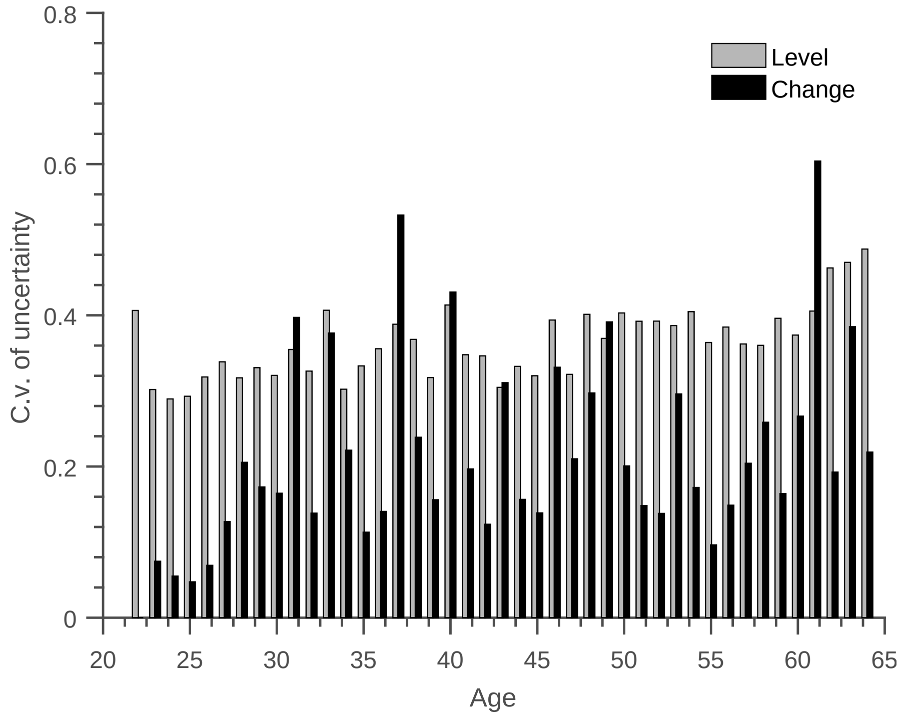

Figure 3: Coefficient of Variation of Income Uncertainty across Sectors, by Age

Notes: The gray bars represent the coefficient of variation of permanent income risk as defined in equation (6) across the 17 sectors, by age. The black bars represent the coffiecient of variation of the 1-year change in permanent income uncertainty calculated as the ratio between the permanent income risk at age h and permanent income risk at age $h-1$.

2.4 Empirical Estimation

A standard precautionary saving argument implies that one's consumption responds negatively to uncertainty related to the permanent income. Extending this argument to include intergenerational considerations of the type entailed by altruism à la Barro (1974) implies that parental consumption responds negatively to uncertainty related to the child's permanent income.[16]

Life-cycle consumption patterns for parents

I begin my analysis of the relationship between parental consumption and dynastic uncertainty with an examination of the age profile of consumption expenditure of parents. To that end, I estimate the following regression on the sample of respondents with chil-

[16] This can occur through one or two channels, depending on how the parent-child interaction is modeled. For example, in a dynamic version of Barro's setup, where the parent makes all the decisions for the family while alive and there are no strategic interactions between the two parties, the child's income is an extension of the parent's income and appears directly in the family's budget constraint. In setups in which the parent and the child make decisions separately, with or without strategic interactions, the parent is subject to fluctuations in the child's income through the weight placed on the child's utility from consumption.

dren:[17]

$$\ln C_{it} = \beta_0 + \boldsymbol{\beta}_{age} f\left(Age_{it}\right) + \boldsymbol{\beta}_c Coh_i + \beta_t D_t + \boldsymbol{\beta}_x \mathbf{X}_{it} + \varepsilon_{it} \tag{11}$$

where C_{it} is the equivalized consumption expenditure of household i during year t,[18] $f\left(Age_{it}\right)$ is a quartic polynomial in the age of the household head, Coh_i is a vector of 10-year cohort dummies, D_t is a vector of year dummies and $\mathbf{X}_{it}$ is a vector of demographic and economic characteristics of the household that includes a college dummy, a race dummy, dummies for family size, and a dummy for weather the head of the household is working or not. The latter controls for the fact that retired or unemployed households have different consumption preferences or needs.[19] Finally, ε_{it} is a residual that captures all individual effects such as measurement error, initial wealth, etc.

The left panel of Figure 4 displays the estimated age profile of parental consumption (i.e. the fourth-order age polynomial). Results are only shown for consumption of non-durables and services, but total consumption expenditure exhibits a similar pattern. The consumption profile has the hump-shaped pattern over the working life that has been previously documented, with the peak occurring in the forties (see, for example, Gourinchas and Parker (2002)). The new feature is the consumption backloading late in life, which suggests that there is a precautionary motive at play in this stage of the life cycle.[20] This pattern in consumption is observed after retirement age (the assumption is that retirement occurs around age 65), when presumably the uncertainty related to own permanent income is resolved. However, it is possible that even though at this stage parents are no longer subject to risk in their own income, they still face the uncertainty pertaining to the permanent income of their children. The fact that the latter is still resolving would shape the consumption profile of parents as in the figure.

Naturally, risk in children's income is not the only type of uncertainty elderly face. Two other sources that have been previously examined in the literature are uncertain medical expenses (see Nardi et al. (2016) for a survey). While the two do resolve with age, generating a backloaded consumption profile, they affect all individuals, which means that the consumption of non-parents should exhibit the same pattern.[21] To verify whether this is the case, I run the same regression on the sample of non-parent house-

[17] A respondent is classified as parent if any of following criteria is met: *(1)* respondent has positive number of total births, *(2)* respondent reported having a child under 18 living in the household in any wave of the survey. All other respondents are classified as non-parents.

[18] Equivalized consumption is obtained by dividing household consumption by the OECD equivalence scale. The OECD equivalence scale is defined as $ES = 1 + 0.7 \times (\text{number of adult members} - 1) + 0.5 \times$ number of children.

[19] For example, Aguiar and Hurst (2013) show that inputs into market work are an important driving force of life cycle consumption expenditure.

[20] A precautionary saving argument says that, when faced with income risk, individuals postpone current consumption in favor of accumulating precautionary savings. As uncertainty resolves, consumption starts increasing, therefore displaying a backloaded pattern.

[21] One could argue that uncertainty about the lifespan or medical expenses affects the two groups differently. In particular, medical evidence suggests that women who have had children tend to live longer (see Barha et al. (2016)).

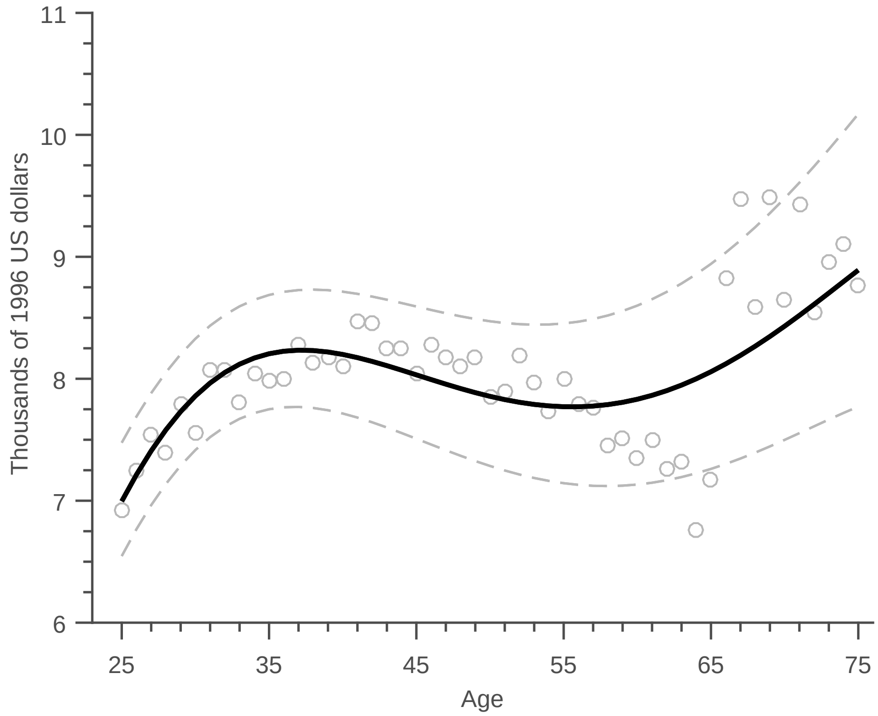

Figure 4: Age Profile of Consumption Expenditure of Parents

Notes: The figure shows the age profile of consumption of non-durables and services for parents in the black solid line, together with the 95% confidence interval in the gray dashed lines. The profiles are constructed using the estimates of $\boldsymbol{\beta}_{age}$ from equation (11). The scatter plot is the nonparametric profile. The sample has $57,980$ observations.

holds, and plot the average age profile of consumption of non-parents in Figure 5. The figure shows that the consumption of non-parents continues to decline after retirement, albeit at a lower rate. Note, however, that the results for non-parents are noisier, especially at older age. This is a consequence of the fact that the sample of non-parents is very small. In particular, the sample of parents is 7.5 times higher than the one of non-parents. Conditional on individuals being older than 60, there are 13 times more parents than non-parents.

The difference between the consumption profiles of parents and non-parents late in life could potentially be justified by increasing monetary transfers from children to their parents. This is unlikely to be the sole, or even the main driver. Data on monetary transfers between parents and their children from the PSID Family Rosters and Transfers Module shows that only 5.2% of respondents report having received monetary transfers from their children. This fraction is increasing in age (albeit with large fluctuations), but conditional on positive transfers there is no trend in the amount transfered.

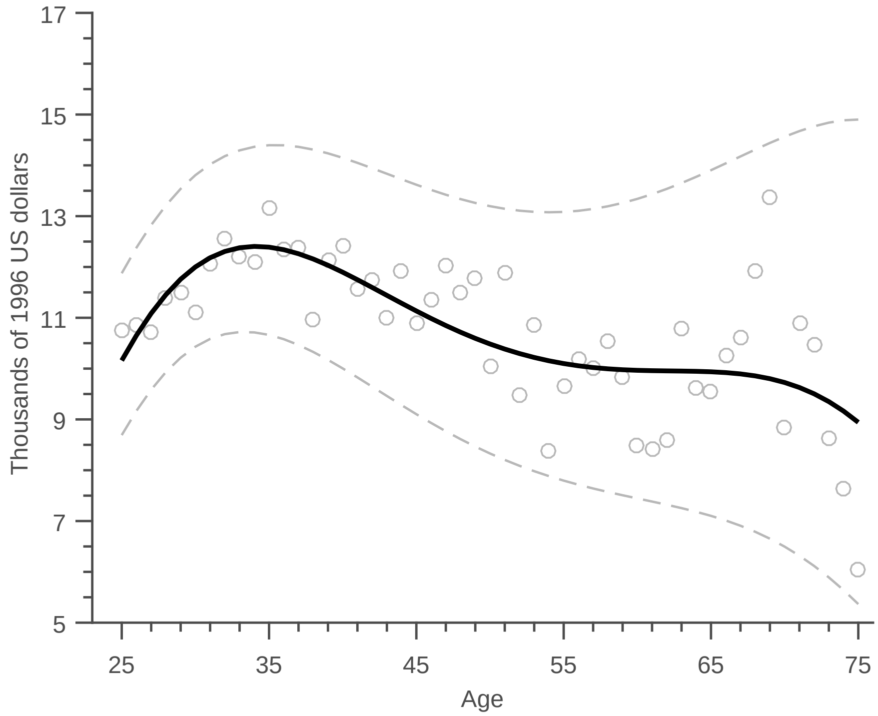

Figure 5: Age Profile of Consumption Expenditure of Non-Parents

Notes: The figure shows the age profile of consumption of non-durables and services for non-parents in the black solid line, together with the 95% confidence interval in the gray dashed lines. The profiles are constructed using the estimates of $\boldsymbol{\beta}_{age}$ from equation (11). The scatter plot is the nonparametric profile. The sample has $7,730$ observations.

Estimates exploiting age and sectoral differences

I now present the results of a regression analysis of the effect of dynastic uncertainty on parental consumption. The baseline specification for exploring this effect is

$$\ln c_{p_{it}} = \beta_0^p + \beta_1^p \sigma_{p_{hs}} + \beta_2^p \sigma_{c_{hs}} + \mathbf{X}_{p_{it}} \beta_3^p + \mathbf{X}_{c_{it}} \beta_4^p + \epsilon_{p_{it}} \tag{12}$$

where $c_{p_{it}}$ is the logarithm of the consumption of parent household i in year t, $\sigma_{p_{hs}}$ is the permanent income uncertainty of the parent and is assigned based on the age h and the sector s in which the head of the parent household i is in year t, while $\sigma_{c_{hs}}$ is the permanent income uncertainty of the child, assigned based on the age h and the sector s in which the child of the parent i is in year t.[22,23] The permanent income uncertainty is as described in equation (6) and is expressed in logarithm, to facilitate the interpretation of the estimated coefficients as elasticities. $\mathbf{X}_{p_{it}}$ and $\mathbf{X}_{c_{it}}$ are vectors of demographic

[22] I assume that uncertainty profiles previously documented are time-invariant. This is mainly because of data limitations, as the survey is not long enough to fully observe two generations.

[23] A parent with n children appears in the sample as n parent-child pairs. Because in this case it is very likely that residuals are correlated within the family of a parent i with multiple children, I report standard errors clustered at parent level.

and economic controls included to deal with various selection concerns. They contain, for the parent and the child, respectively: a full set of age dummies meant to capture consumption patterns that stem from pure life cycle considerations, dummies for marital status, race, gender, educational attainment, family size, as well as permanent income $\hat{Y}_{hs}$ (as defined in equation (10)) and wealth holdings.[24,25] These controls not only shape consumption, but are also potential determinants of occupation and industry choices.

There is still a measurement error concern regarding the estimation, even after expressing income risk and permanent income at sector level. Equation (12) is estimated using the measures of consumption discussed in section 2.2 on the left hand side. Due to the imputation procedure in the early years of the survey, as well as potential misreporting of consumption in the later years, these might be measured with error. I assume that the measurement error in the consumption variables is multiplicative in levels and uncorrelated with the explanatory variables.[26]

Measured permanent income risk is a function of an individual's age and sector. It is natural to ask whether a specification in which age and sector enter freely significantly dominates the restricted specification in equation (12). A likelihood-ratio test fails to reject the null of the restricted model, in which age and sector are relevant in the sense dictated by equation (6), in favor of the unrestricted model.[27]

Because models of two-sided altruism, as well as various setups of models of one-sided altruism, imply that child's consumption also responds to the parent's permanent income uncertainty (in addition to that of own income), I estimate the following analogous specification for the child

$$\ln c_{c_{it}} = \beta_0^c + \beta_1^c \sigma_{p_{hs}} + \beta_2^c \sigma_{c_{hs}} + \mathbf{X}_{p_{it}} \beta_3^c + \mathbf{X}_{c_{it}} \beta_4^c + \epsilon_{c_{it}} \tag{13}$$

where the dependent variable is the logarithm child's consumption $c_{c_{it}}$ and the dependent variables are the same as in the parent's regression.

The estimation results are presented in Table 2. The first two columns display the estimated coefficients in regression equations (12) and (13) when the dependent variable is consumption expenditure on non-durables and services. The next two columns display the same results, but with consumption augmented to include expenditure on durables,

[24] In the years that are not covered in the wealth supplement I impute household wealth holdings by using a budget constraint equation and the series for consumption. Because 34.64% of children and 12.44% of parents have zero or negative wealth, wealth controls are in levels. Taking logarithm would amount to dropping 39.86% of the sample. For comparison purposes, I also express permanent income in levels.

[25] I control for permanent labor income and wealth to capture potential non-homotheticity of preferences. However, it is possible that wealth holdings reflect past precautionary saving behavior. For robustness, I also estimate equation (12) without wealth controls and obtain similar results.

[26] Under this assumption the estimates are consistent, but the inference is subject to Type I error, which hopefully the large sample size takes care of.

[27] To perform the likelihood-ratio test, I estimate with maximum likelihood equation (12) and an augmented equation in which I add interaction terms between age and sector dummies, for both the parent and the child. The likelihood ratio is 1962.99 and the corresponding critical value at 5% is 1190.69.

health and education.

Of main interest in this paper is the estimate of β_2^p, which captures the strength of the dynastic precautionary saving motive. Regardless of the consumption measure considered, after controlling for an extensive set of covariates, the response of parental consumption to the uncertainty in the child's permanent income is negative and statistically significant. In particular, a 10% increase in dynastic uncertainty is associated with a 0.81% decrease in parent's consumption of non-durables and services, and a 0.76% decrease of his total consumption. A back of the envelope calculation suggest that parents of children younger than 40 consume, on average, $2,945 less per year because at that stage most of their children's permanent income uncertainty is yet to be resolved.

To better grasp the magnitude of the estimates of the dynastic precautionary motive, consider the case of three identical parents whose children are identical, except for the sector in which they work. In particular, the first child is a services worker (sector 15), the second is a construction worker (sector 3) and the third works in the finance sector (sector 11).[28] The left panel of Figure 6 shows how the corresponding levels of dynastic uncertainty vary with the age of the child. Irrespective of age, services workers have the lowest income risk among the three categories. Construction workers face higher income uncertainty, but the speed of resolution is slightly higher than that of services workers. Lastly, individuals in the finance sector have the highest level of income risk and very little of it is resolved over time.

The differences in parental consumption (of non-durables and services) implied by the estimates in Table 2 are plotted in the right panel of Figure 6. For every age of the child, the consumption of the parent of the services worker is normalized to zero, and the consumption of the other two parents is expressed relative to his consumption.[29] The figure reveals that the annual consumption of the parent of the construction worker is between 4 and 1% lower that that of the parent of the services worker, depending on the age of the child. The consumption gap between the two parents decreases with the child's age, due to the fact that uncertainty differences between the two sectors are smaller at older age. The relative consumption of the parent of the child working in the finance sector is even lower, with the gap fluctuating between 6 and 8.5%. Since permanent income risk in the finance sector resolves at a low speed, the consumption gap between the two parents does not close, even when the child is 50 years old.

The estimates of β_1^p and β_2^c capture the strength of the precautionary saving motive from one's own permanent income uncertainty and are both negative and statistically significant. Note however that precautionary saving appears to be stronger for the child than for the parent ($\hat{\beta}_1^p = -0.089$ and $\hat{\beta}_2^c = -0.163$). The reason for this difference might lie in the age composition of the two groups, as children in the sample are a younger group than the parents (22-59 vs. 42-80). Gourinchas and Parker (2002) show that

[28]Here, identical means fixing all elements of $\mathbf{X}_p$ and $\mathbf{X}_c$.

[29]The relative parental consumption gap is given by $-0.081 \times \left[\ln \text{Std}_{s'}\left(\mathcal{E}_h^i\right) - \ln \text{Std}_{15}\left(\mathcal{E}_h^i\right)\right]$, $s' \in \{3, 11\}$.

Table 2: Regression of Consumption on Permanent Income Uncertainty

	Non-durables and services		Total consumption	
	Parent's consumption	Child's consumption	Parent's consumption	Child's consumption
Parent's uncertainty	-0.089** (0.033)	-0.039 (0.025)	-0.081** (0.030)	-0.043 (0.025)
Child's uncertainty	-0.081* (0.034)	-0.163** (0.038)	-0.076* (0.033)	-0.149** (0.038)
$\mathbf{X}_p$				
Marital status	0.246** (0.057)	-0.024 (0.047)	0.251** (0.058)	-0.039 (0.046)
Race	0.132** (0.049)	-0.017 (0.056)	0.132** (0.049)	-0.026 (0.056)
Educ: some college	0.247** (0.030)	0.150** (0.026)	0.247** (0.030)	0.159** (0.026)
Educ: college degree	0.271** (0.024)	0.066** (0.021)	0.271** (0.024)	0.076** (0.021)
Permanent income	0.114** (0.011)	0.063** (0.010)	0.114** (0.013)	0.061** (0.010)
Asset holdings	0.036** (0.003)	0.012** (0.002)	0.036** (0.003)	0.012** (0.002)
$\mathbf{X}_c$				
Marital status	-0.053* (0.023)	0.173** (0.028)	-0.066** (0.023)	0.177** (0.028)
Gender	-0.019 (0.023)	0.288** (0.030)	-0.019 (0.022)	0.296** (0.030)
Educ: some college	0.092** (0.021)	0.093** (0.025)	0.091** (0.021)	0.095** (0.025)
Educ: college degree	0.164** (0.023)	0.171** (0.022)	0.164** (0.021)	0.172** (0.022)
Permanent income	0.014* (0.006)	0.068** (0.006)	0.014* (0.006)	0.066** (0.006)
Asset holdings	0.011** (0.004)	0.049** (0.006)	0.011** (0.004)	0.047** (0.006)
Constant	10.225** (0.413)	11.469** (0.464)	9.833** (0.404)	11.468** (0.463)
R^2	0.288	0.268	0.284	0.276
Sample size	8,851	8,330	8,861	8,323

Notes: Table entries are coefficient estimates from equations (12)-(13). The income, consumption and wealth variables are measured in 1996 dollars. Other explanatory variables are (for both parent and child): full set age age and family size dummies (coefficients are omitted for space considerations), dummy for marital status (1 if married), race (1 if white), gender (1 if male), education (relative to the high-school degree group). Robust standard errors clustered at parent and child level, respectively, are in parenthesis. * significant at 5%; ** significant at 1%

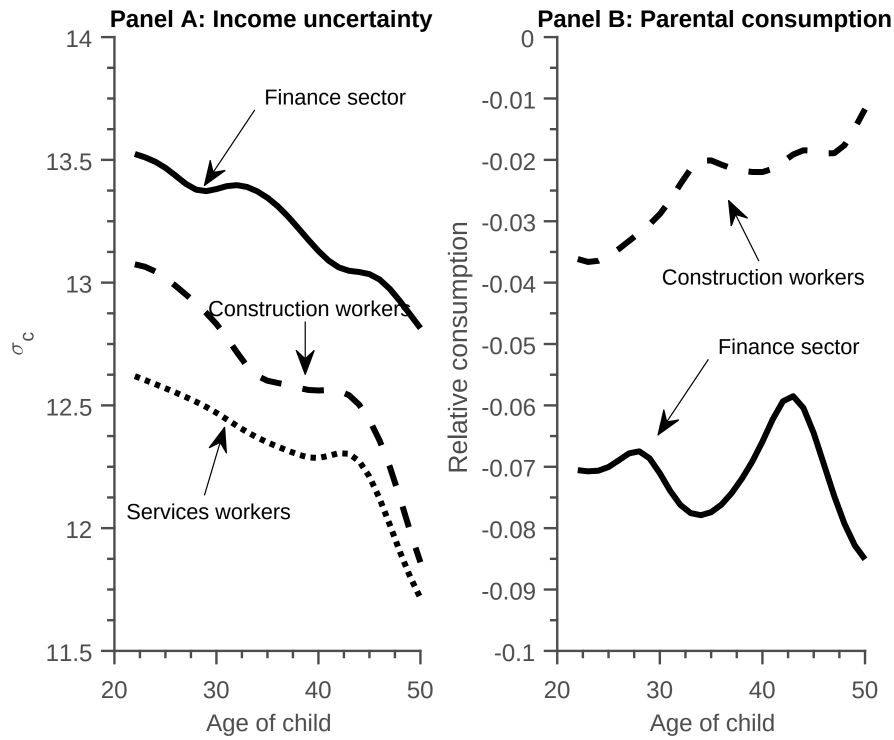

Figure 6: Regression Implied Consumption Gap

buffer saving is particularly important early in life, until about mid forties. Comparing the estimates of β_1^p and β_2^p under both consumption measures reveals that the effect of child's income risk on parental consumption is almost as large as the effect of parent's own income risk, suggesting that the dynastic precautionary motive is as important as the precautionary one. Lastly, the estimate of β_1^c captures the response of child's consumption to the parent's permanent income uncertainty. While negative, this effect is not statistically significant.

A natural question to ask, which has implications for issues like intergenerational mobility, is whether dynastic precautionary saving occurs throughout the income distribution, or is it just the rich parents who can provide such a security blanket for their children. To explore this, I stratify parents into rich or poor, based on weather the sum between their permanent income (as defined in equation (10)) and wealth holdings is above or below the median, and I estimate equation (12) for each of the two groups. The first two columns in Table 3 show the estimated effect of income uncertainty on parental consumption, by parent's wealth. Richer parents have a stronger (dynastic) precautionary motive, but while apparently economically large, the difference is not statistically significant. The last two columns of Table 3 report the same coefficients, but stratified by the child's wealth, and show that parents of poor children have a stronger dynastic precautionary motive. With caveat of the difference not being statistically significant, parents of richer children appear to be less responsive to their own income risk.

Since the purpose of dynastic precautionary saving is to insure children against bad

Table 3: Response of Parental Consumption to Income Uncertainty by Wealth

	Parent's wealth		Child's wealth	
	Poor parent	Rich parent	Poor child	Rich child
Parent's uncertainty	-0.069*	-0.179*	-0.110*	-0.077*
	(0.034)	(0.070)	(0.042)	(0.035)
Child's uncertainty	-0.027	-0.113**	-0.197**	0.004
	(0.051)	(0.043)	(0.044)	(0.064)

Notes: Table entries are coefficient estimates from equation (12). The dependent variable is parental consumption of non-durables and services. Robust standard errors clustered at parent level are in parenthesis. * significant at 5%; ** significant at 1%

income realizations, an alternative exploration of this phenomenon is to look at how children's income risk influences parental transfers. This approach is likely to bias downwards the estimated strength of the saving motive for two reasons. Firstly, parents tend to make transfers in the event bad income realizations actually occur (McGarry (2016)), so a large buffer stock of savings does not necessarily translate into a monetary transfer. Secondly, uncertainty about children's income gives parents an incentive to delay transfers until uncertainty is resolved (Altig and Davis (1992)), so instances of high uncertainty in the child's income might not be accompanied by a monetary transfer. Nevertheless, a positive association between parental transfers and dynastic uncertainty would certainly be in support of dynastic precautionary savings. To test whether this is the case, I make use of the 2013 PSID Family Rosters and Transfers Module, where parents report monetary transfers to children. Since parents report the total amount transfered to their children, who may work in different sectors, I restrict the sample to parents who participated in the survey module and only have one child.[30] I find that both the probability of making a transfer and the amount transfered are positively correlated with children's income risk. In particular, a 10% increase in the child's income risk is associated with a 1.29 percentage points increase in the likelihood of a transfer and a 3.87% increase in the amount transfered.

I now turn to discussing several endogeneity concerns that might plague the results presented thus far, as well as robustness of the findings to alternative specifications.

Health status

One potential concern for identification is that working in certain occupations and industries has consequences for workers' health status and implicitly their life expectancy (mortality risk). As previously discussed, such precautionary motives also depress consumption. Johnson et al. (1999) use the U.S. National Longitudinal Mortality Study to

[30]This is small sample, with only 226 parent-child pairs, so the test does not have a lot of power.

show that mortality differences among occupations are almost completely accounted for by adjustments for income and education. I control for both of these factors in the main estimation, so if their argument is true there should not be any residual differences plaguing the estimates. On the other hand, Heimer et al. (2015) show that individuals have subjective mortality beliefs that correlate with their savings behavior even after controlling for socioeconomic factors.

I address this issue directly by augmenting vectors $\mathbf{X}_p$ and $\mathbf{X}_c$ to include dummies for the health status of the parent and the child, respectively. Health status is classified as: *(i)* excellent or very good, *(ii)* good or fair, or *(iii)* poor, the latter being the baseline group in the estimation. Table 4 reports the results for the parent's equation (see Table 15 in Appendix A.6 for the results from the child's regression).[31] The point estimates of both precautionary and dynastic precautionary motives are slightly lower when controlling for health status, but not statistically different from the corresponding baseline estimates.

Table 4: Importance of Health Status

	Non-durable parental consumption		Total parental consumption	
	Baseline	Health controls	Baseline	Health controls
Parent's uncertainty	-0.089** (0.033)	-0.079** (0.029)	-0.081** (0.030)	-0.072** (0.027)
Child's uncertainty	-0.081* (0.034)	-0.068 (0.035)	-0.076* (0.033)	-0.063 (0.034)
$\mathbf{X}_p$				
Excellent health	– –	0.204* (0.092)	– –	0.209* (0.092)
Good health	– –	0.215* (0.092)	– –	0.219* (0.093)
$\mathbf{X}_c$				
Excellent health	– –	0.185 (0.097)	– –	0.178 (0.093)
Good health	– –	0.143 (0.095)	– –	0.143 (0.092)

Notes: Table entries are coefficient estimates from equation (12). The set of covariates from the baseline estimation is augmented to include dummy variables for weather the parent and the child are in excellent and very good, good and fair or poor health condition. The latter is the omitted dummy. Robust standard errors clustered at parent level are in parenthesis. * significant at 5%; ** significant at 1%

Heterogeneity of the bequest motive

[31] For space considerations, in this and all subsequent robustness exercises, I only report the estimates of interest for the discussion.

The controls included in the specifications (12)-(13) are meant to capture several saving motives at play over the life cycle such as life cycle saving, precautionary and dynastic precautionary saving or saving for bequest. While the first three are accounted for by the age and uncertainty variables, controlling for a pure bequest motive is less straightforward, as there is limited direct information on its strength. This is important in the context of this analysis for various reasons. For example, parents who have a bequest motive may want to accumulate larger precautionary and dynastic precautionary savings to increase the likelihood that there will be a bequest. Or, if upon controlling for the strength of the bequest motive there is no more role for dynastic precautionary savings, it could be inferred that a warm-glow model of bequest is a more appropriate description of household behavior.

I try to account for the heterogeneity of the bequest motive by estimating three alternative specifications. In the first two I employ a proxy for the bequest motive, while in the third one I use a direct measure of its strength. Firstly, I follow the literature and use presence of children as a proxy for the strength of the bequest motive (see Hurd (1987) among the earlier papers, and Lockwood (2012) more recently). To that end, I augment the sample of parent-child pairs with the sample of non-parents used in the estimation of the consumption profile in Figure 5. I reestimate equation (12) with the new sample, allowing parents and non-parents to have a different intercept. Secondly, I estimate equation (12) with the original sample and use dummies for the number of children as proxy for the strength of the bequest motive.

Panel A of Table 5 shows the results exploiting differences between parents and non-parents in the first row, and when the number of children is the proxy in the second row. Results are for consumption of non-durables and services as dependent variable (see Table 16 in Appendix A.6 for total consumption as dependent variable). The first two entries in each row are the coefficients on the two uncertainty measures (own and child's). The second row also reports the estimated coefficients on the dummies for number of children. The more children the parent has, the less he consumes, which I interpret as a stronger bequest motive. The magnitude of the estimates of both precautionary and dynastic precautionary motives is robust to these controls.

In a third specification, I make use of some limited direct information on the strength of the bequest motive in PSID. In particular, in 2007 the respondents were asked the following question: *Some people think that leaving an estate or inheritance to their children or other relatives is very important, while others do not. Would you say this is very important, quite important, not important, or not at all important?* I augment the set of controls in equation (12) with a dummy variable that is equal to 1 if the parent reports that leaving an estate is very important or quite important (39% of the sample), and 0 otherwise.[32] The estimation results are reported in Panel B of Table 5. The magnitude of the coefficients on

[32]I assume the attitude towards bequest of an individual expressed in the 2007 interview is time invariant and impute the same value in other years.

the uncertainty measures hardly change and parents who report that leaving an estate is important consume slightly less than their counterparts who believe the opposite, but the coefficient is not statistically significant.

Table 5: Importance of the Bequest Motive

	Parent's uncertainty	Child's uncertainty	$n = 2$	$n = 3$	$n = 4$	$n \geq 5$	$b = 1$
			Panel A. Proxy for the bequest motive				
Bequest proxy: parent vs non-parent	-0.098** (0.032)	-0.082* (0.033)	– –	– –	– –	– –	– –
Bequest proxy: number of children	-0.075 (0.040)	-0.081* (0.034)	-0.055** (0.019)	-0.058* (0.029)	0.051 (0.035)	-0.265** (0.077)	– –
			Panel B. Direct measure of the bequest motive				
How important it is leaving an estate?	-0.089** (0.035)	-0.083* (0.034)	– –	– –	– –	– –	-0.008 (0.020)

Notes: Table entries are coefficient estimates of the effect of parent's and child's uncertainty on parent's consumption of non-durables and services for various controls for the strength of the bequest motive. *Panel A*: The first row reports estimates of equation (12) when a dummy variable equal to 1 if the respondent is a parent and zero otherwise is used as proxy for the bequest motive. In the second row the number of children is used as proxy, with the reference group being number of children = 1 (parent has one adult child). *Panel B* The strength of the bequest motive is captured with a dummy variable that is equal to 1 if leaving an estate is important and 0 otherwise. Robust standard errors clustered at parent level are in parenthesis. * significant at 5%; ** significant at 1%

Selection into risky sectors

Individuals' attitude towards risk is a problem for identifying exogenous variations in uncertainty across households. This is a well known fact in the precautionary savings literature and it also applies to the exercise in this paper, to the extent that attitudes towards risk are not captured by other covariates. Parents/children who are more risk tolerant may choose to work in sectors with a riskier income stream. At the same time, they also hold less precautionary savings, rendering their consumption less responsive to uncertainty resolution. If this is the case, then the precautionary motive is even bigger than what I estimate.

An additional concern for identification here is the fact that children who know that their parents accumulate savings choose to work in riskier sectors. If that is indeed the case, then by including child fixed effects in the estimation the argument in this paper would imply that changes in the child's sector should be followed by changes in the parent's consumption. However, for a given parent-child pair, over the entire duration of the sample there are on average 3 sector transitions on the side of the child, which is not nearly enough variation to pick up any effect.

I perform two types of exercises to further address this concern. Firstly, I estimate the probability that a child moves from a low risk to a high risk sector conditional on his parent being unemployed. The parent's employment status is arguably exogenous to the child's sector assignment. Therefore, if children whose parents have lost their jobs are less likely to move to riskier sectors, then this type of selection is indeed a concern. To verify the extent to which this is true I estimate:

$$\Pr\left(switch_{t,t+1} | emp\_parent_t, \mathbf{X_t}\right) = \alpha + \beta \times emp\_parent_t + \Phi\left(\mathbf{X_t}\gamma\right) \tag{14}$$

where $switch_{t,t+1}$ is an indicator variable equal to 1 if between two consecutive periods the child moved from a low risk to a high risk sector, emp_parent_t is an indicator variable equal to 1 if the parent is unemployed at time t and $\mathbf{X_t}$ is a vector of controls for the child's age, marital status, educational attainment and family size, as well as year dummies. I estimate equation (14) as a linear probability model, as well as a probit model. Irrespective of the specification, the point estimate of β is actually positive, but very small and never significantly different from zero, suggesting that the parent's inability to provide insurance because of a job loss does not influence the child's sector choice.

Secondly, I estimate two other versions of equation (12). In the first one, I exclude from the sample the pairs in which the child is self-employed.[33] Presumably this is a group in which self-selection is likely to occur. Results are reported in the column labeled 'No self-employed' in Table 6. The response of parental consumption to the child's permanent income risk is still negative and significant, and its magnitude barely changes. In the second, I augment the vector of covariates $\mathbf{X}_c$ with dummies for the child's initial sector. In this case, identification of the dynastic precautionary motive comes from differences in the level and speed of resolution of the uncertainty faced by children working in different sectors, as well as from sector changes over time.[34] Results are in Table 6, in the column labeled 'Initial sector'. In this case the estimated dynastic precautionary motive is slightly smaller, but is not statistically different from the baseline estimate.

Other robustness tests

As additional robustness check, Table 7 reports the estimates of the effect of parent's and child's income uncertainty on parental consumption under alternative specifica-

[33]There are 923 such pairs in the sample, amounting to 10% of the initial sample size.

[34]The average number of times a child changes sector in the sample is 3.

Table 6: Importance of Selection

	Non-durable parental consumption			Total parental consumption		
	Baseline	No self-employed	Initial sector	Baseline	No self-employed	Initial sector
Parent's uncertainty	-0.089** (0.033)	-0.079* (0.031)	-0.083** (0.029)	-0.081** (0.030)	-0.070* (0.028)	-0.076** (0.027)
Child's uncertainty	-0.081* (0.033)	-0.083* (0.036)	-0.066 (0.035)	-0.076* (0.033)	-0.081* (0.036)	-0.065 (0.035)

Notes: Table entries are coefficient estimates from equation (12). The 'Baseline' column reproduces the estimates of β_1^p and β_2^p from Table 2. The 'No self-employed column' displays the estimates of β_1^p and β_2^p when self-employed children are excluded from the sample. The 'Initial sector' column shows the estimates of β_1^p and β_2^p when the child's initial sector is included in the set of controls. Robust standard errors clustered at parent level are in parenthesis. * significant at 5%; ** significant at 1%

tions. Each row in the table shows results from a different regression. For comparison purposes, the first row reproduces the estimates of interest from the baseline estimation in Table 2.

Firstly, I examine the degree to which the consumption imputation procedure biases downwards the estimates of (dynastic) precautionary motives. Food consumption is a necessity, making it less likely to respond to income risk. Intuitively, parents who postpone consumption in favor of (dynastic) precautionary savings probably do not postpone food consumption, but rather more elastic consumption categories. In the early waves of PSID, total consumption is imputed based on an inverted food demand equation and might inherit its inelastic properties. The second row in Table 7 shows that the estimated effect of own and dynastic income risk on parental food consumption is smaller than the effect on total consumption, but the difference is not statistically significant. I also explore the effect of the imputation procedure by using in the estimation only the later years, in which PSID collected information on consumption.[35] The third row of the table shows the estimated precautionary and dynastic precautionary motives, which are not statistically different from those estimated with the full sample.

Secondly, I explore whether the hedging option for parents with multiple children working in different sectors could translate into a smaller measured dynastic precautionary motive. To that end, I estimate equation (12) on the sample of parents with only one child.[36] For these parents, hedging is not an option. Results are in the fourth row of Table 7. While the point estimate of response of parental consumption to dynastic risk is a bit higher, it is not statistically different from the baseline coefficient.

[35]In this case, the sample size is halved.

[36]This sample is 3.5 times smaller than the baseline sample.

Thirdly, in the last two rows of the table I verify the sensitivity of the results to estimating permanent income uncertainty based on a richer information set (as discussed in Section 2.1), as well as to controlling for time and geography dummies in an attempt to address the concern that macroeconomic conditions or location can affect not only consumption behavior, but also sector level income risk. The results are robust to these considerations.

Table 7: Other Robustness Tests

	Coefficient on parent's risk	Coefficient on child's risk
1. Baseline	-0.089** (0.033)	-0.081* (0.033)
2. Effect on food consumption	-0.041 (0.022)	-0.009 (0.025)
3. Consumption in later years	-0.139** (0.043)	-0.022 (0.039)
4. Parents with one child	-0.047 (0.055)	-0.136* (0.057)
5. Income forecast with rich information set	-0.075** (0.029)	-0.075* (0.036)
6. Time and geography	-0.070* (0.031)	-0.074* (0.033)

Notes: Table entries are coefficient estimates of β_1^p and β_2^p from equation (12). Geography dummies correspond to the Census-Bureau designated division in which the parent/child resides. Robust standard errors clustered at parent level are in parenthesis. * significant at 5%; ** significant at 1%

3 Model

Following the empirics in the previous section, which provide evidence that over the life cycle individuals engage in dynastic precautionary saving, it is a natural progression to think about the implications of this phenomenon. Firstly, dynastic precautionary savings inform the choice of preference parameters, such as risk aversion and intergenerational altruism. Both these parameters are at the heart of dynamic models, but their range of estimates is extremely wide. Secondly, dynastic precautionary savings are relevant for evaluating the welfare gains from social security policies for which they are substitutes. However, without a structural model, these issues cannot be addressed.

In this section, I develop a quantitative model of altruistically linked overlapping generations in which parents accumulate dynastic precautionary savings. Motivated by the empirical results, I model altruism as one-sided, from the parent to his child. In this framework, a parent and a child decide individually how much to save and consume. In addition, the parent also makes monetary transfers to the child. I model the decision making process between the parent and the child as non-cooperative and without commitment. This modeling choice is appealing in light of the existing empirical evidence on imperfect risk-sharing within and between families.[37] In addition, it enables clear predictions regarding the wealth position of overlapping generations, as well as the size and timing of inter-vivos transfers, both of which are relevant objects for counterfactual experiments. However, it has a major downside in that without additional assumptions on the timing of the parent-child interaction, such a model has a large set of Markov equilibria.[38] Moreover, even with such assumptions, the model is very computationally intensive, limiting the features that can be embeded in the analysis. The details of the model are outlined below.

3.1 Environment

Demographics. Agents are economically active (i.e. earn income and make decisions) from age of 22 until the end of age 79, when they die. Figure 7 shows the life cycle of two overlapping generations. When an individual turns 29 his child is born. However, it is not until the parent turns 51 that his child becomes economically active. At 65 an individual retires. The generations overlap such that at every point in time only two generations are economically active, represented by 29 parent-child pairs indexed by the age of the parent and that of the child. A parent and his child overlap for 29 years.

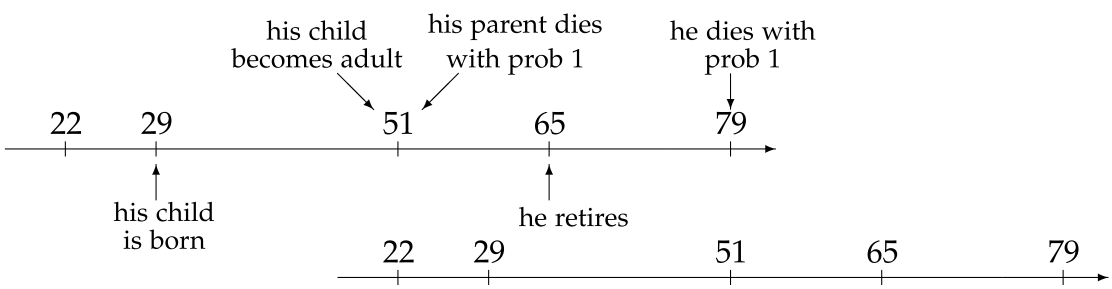

Figure 7: Life Cycle of Individuals

Altruism. The parent is altruistic towards the child in the spirit of Barro (1974). In particular, he places a weight γ on the utility of the adult child. Upon the death of the parent, the household wealth is bequeathed to the child. Altruism towards the young child (younger than 22) is not explicitly modeled.

[37] Using the PSID, Altonji et al. (1996) show that risk-sharing is incomplete within and between families. Attanasio et al. (2015) argue that while the family network has large insurance potential, no such insurance occurs on average.

[38] An illustrative two period example can be found in Lindbeck and Weibull (1988).

Household income. Household members can earn labor and asset income. An individual supplies labor inelastically to a sector s for the first 44 periods of his economic life and earns stochastic labor income y. Labor earnings are age-dependent. Individuals retire at the of age 65 and earn constant pension benefit $\Phi(\cdot)$ for the remaining of their life. They hold a single asset (bond) a issued by the government and face a borrowing constraint. Asset income depends on the asset holdings and the gross interest rate R.

Government. The government levies a proportional tax τ on individuals' labor earnings. The tax revenue and newly issued bonds B' are used to finance government expenditure G, which has no welfare enhancing role, to pay interest on previously issued bonds and to finance retirees' pension income. The government runs a balanced budget:

$$G + SS + RB = B' + \tau \bar{Y},$$

where $\bar{Y}$ denotes aggregate labor earnings of working individuals and SS denotes aggregate pension payments to retirees.

Timing. To avoid the multiplicity of equilibria in the parent-child interaction, I impose a particular extensive form of their stage game and focus in the Markov-perfect equilibrium (MPE) of this sequential stage game. The timing of the model is as follows: in the beginning of the period labor earnings shocks realize and are known both to the parent and his child. In the first stage, the parent chooses his consumption c_p, next period wealth holdings a'_p, and the monetary transfer to the child g_p. Given the parent's choices, in the second stage the child makes his own consumption-saving decision (c_c, a'_c). Given prices, this timing protocol guarantees a unique equilibrium of the parent-child stage game. Moreover, since it is unlikely for parents to be able to force children to adhere to a particular consumption path beyond the influence induced by their choice of transfers, this timing could be an accurate description of how these interactions take place in reality.

State variables. The state variables of a parent of age $h_p \in \{51, 52, \ldots, 79\}$ are: beginning of period wealth of the parent $a_p \in A$ and of the child $a_c \in A$, realized earnings for both the parent and the child $y_p, y_c \in Y$, as well as the sectors in which the two work $s_p, s_c \in S$. The value function of a parent household of age h_p is denoted as $V^p_{h_p}(\tilde{s}_p)$, where $\tilde{s}_p = (a_p, a_c, y_p, y_c, s_p, s_c)$. The state variables of a child of age $h_c \in \{22, 23, \ldots, 50\}$ are: own beginning of period wealth $a_c \in A$, realized earnings for both the parent and the child $y_p, y_c \in Y$, the sectors of the two $s_p, s_c \in S$, as well as the parent's first stage choice of transfers g_p and savings a'_p. The value function of a child of age h_c is denoted as $V^c_{h_c}(\tilde{s}_c)$, where $\tilde{s}_c = \left(a_c, y_c, y_p, g_p, a'_p, s_p, s_c\right)$.

Decision problems

The problem of a working parent-child pair. In the second stage, given $\tilde{s}_c = \left(a_c, y_c, y_p, g_p, a'_p, s_p, s_c\right)$ the child of age h_c solves

$$
\begin{aligned}
V^c_{h_c}\left(\tilde{s}_c\right) \quad &= \quad \max_{c_c, a'_c} u\left(c_c\right) + \beta \mathbb{E} V^c_{h_c+1}\left(\tilde{s}'_c | \mathbf{y}, \mathbf{s}\right) \\
&\text{s.t.} \quad c_c + a'_c = (1-\tau)\, y_c + R a_c + g_p \\
&\qquad a'_c \geq \underline{A}_{h_c}
\end{aligned}
$$

where $\tilde{s}'_c = \left(a'_c, y'_c, y'_p, g'^{\star}_p, a''^{\star}_p, s'_p, s'_c\right)$, $\mathbf{s} = \left(s_p, s_c\right)$ and $\mathbf{y} = \left(y_p, y_c\right)$. Next period transfer $g'^{\star}_p$ and parental savings $a''^{\star}_p$ are equilibrium objects. Call the resulting optimal policy function $c^{\star}_c\left(h_c, \tilde{s}_c\right)$. In the first stage, given $\tilde{s}_p = \left(a_p, a_c, y_p, y_c, s_p, s_c\right)$, the parent of age h_p solves

$$
\begin{aligned}
V^p_{h_p}\left(\tilde{s}_p\right) \quad &= \quad \max_{c_p, a'_p, g_p} u\left(c_p\right) + \gamma u\left(c^{\star}_c\left(h_c, a_c, y_c, y_p, g_p, a'_p, s_p, s_c\right)\right) + \beta \mathbb{E} V^p_{h_p+1}\left(\tilde{s}'_p | \mathbf{y}, \mathbf{s}\right) \\
&\text{s.t.} \quad c_p + a'_p + g_p = (1-\tau)\, y_p + R a_p \\
&\qquad a'_p \geq \underline{A}_{h_p}, g_p \geq 0
\end{aligned}
$$

where $\tilde{s}'_p = \left(a'_p, a'^{\star}_c\left(h_c, a_c, y_c, y_p, g_p, a'_p, s_p, s_c\right), y'_p, y'_c, s'_p, s'_c\right)$. The expectation is taken over all possible sector and income transitions, for the parent and the child, as both of them are in the labor market in the following year.

The problem of a retired parent-child pair. At the end of age $H_{ret} = 65$ the parent retires and starts earning constant income $\Phi\left(\hat{y}_p\right)$, which is a function of predicted career earnings. In the second stage, given $\tilde{s}_c = \left(a_c, y_c, \hat{y}_p, g_p, a'_p, \hat{s}_p, s_c\right)$ the child of age h_c solves

$$
\begin{aligned}
V^c_{h_c}\left(\tilde{s}_c\right) \quad &= \quad \max_{c_c, a'_c} u\left(c_c\right) + \beta \mathbb{E} V^c_{h_c+1}\left(\tilde{s}'_c | y_c, s_c\right) \\
&\text{s.t.} \quad c_c + a'_c = (1-\tau)\, y_c + R a_c + g_p \\
&\qquad a'_c \geq \underline{A}_{h_c}
\end{aligned}
$$

where $\tilde{s}'_c = \left(a'_c, y'_c, \hat{y}_p, g'^{\star}_p, a''^{\star}_p, \hat{s}_p, s'_c\right)$. Call the resulting optimal policy function $c^{\star}_c\left(h_c, \tilde{s}_c\right)$. In the first stage, given $\tilde{s}_p = \left(a_p, a_c, \hat{y}_p, y_c, \hat{s}_p, s_c\right)$, the problem of a retired parent of age $h_p = H_{ret} + 1, \ldots, H - 1$ is

$$
\begin{aligned}
V^p_{h_p}\left(\tilde{s}_p\right) &= \max_{c_p, a'_p, g_p} u\left(c_p\right) + \gamma u\left(c^\star_c\left(h_c, a_c, y_c, \hat{y}_p, g_p, a'_p, \hat{s}_p, s_c\right)\right) + \beta \mathbb{E} V^p_{h_p+1}\left(\tilde{s}'_p | y_c, s_c\right) \\
\text{s.t.} \quad & c_p + a'_p + g_p = \Phi\left(\hat{y}_p\right) + R a_p \\
& a'_p \geq \underline{A}_{h_p}, g_p \geq 0
\end{aligned}
$$

where $\tilde{s}'_p = \left(a'_p, a'^\star_c\left(h_c, a_c, y_c, \hat{y}_p, g_p, a'_p, \hat{s}_p, s_c\right), \hat{y}_p, y'_c, \hat{s}_p, s'_c\right)$. Only the child is in the labor force, so the expectation is taken only with respect to y_c and s_c.

The problem of a terminal parent-child pair. At the end of age H the parent dies. In the following period his child becomes a parent and his own child starts earning income. The second stage problem of the child is

$$
\begin{aligned}
V^c_{50}\left(\tilde{s}_c\right) &= \max_{c_c, a'_c} u\left(c_c\right) + \beta \mathbb{E} V^p_{51}\left(\tilde{s}'_p | \mathbf{y}, \mathbf{s}\right) \\
\text{s.t.} \quad & c_c + a'_c = (1-\tau) y_c + R a_c + g_p \\
& a'_c \geq \underline{A}_{h_c}
\end{aligned}
$$

where $\tilde{s}'_p = \left(a'_c + a'_p, 0, y'_p, y'_c, s'_p, s'_c\right)$, $\mathbf{y} = \left(y_c, y'_p\right)$ and $\mathbf{s} = \left(s_c, s'_p\right)$. This allows for intergenerational correlation in sectors and income processes. I assume that young adults (age 22) have no assets. In the first stage, given $\tilde{s}_p = \left(a_p, a_c, \hat{y}_p, y_c, \hat{s}_p, s_c\right)$, the terminal parent solves

$$
\begin{aligned}
V^p_{79}\left(\tilde{s}_p\right) &= \max_{c_p, a'_p, g_p} u\left(c_p\right) + \gamma u\left(c^\star_c\left(h_c, a_c, y_c, , \hat{y}_p, g_p, a'_p, \hat{s}_p, s_c\right)\right) + \beta\gamma \mathbb{E} V^p_{51}\left(\tilde{s}'_p | \mathbf{y}, \mathbf{s}\right) \\
\text{s.t.} \quad & c_p + a'_p + g_p = \Phi\left(\hat{y}_p\right) + R a_p \\
& a'_p \geq \underline{A}_{h_p}, g_p \geq 0
\end{aligned}
$$

where $\tilde{s}'_p = \left(a'_p + a'^\star_c\left(h_c, a_c, y_c, \hat{y}_p, g_p, a'_p, \hat{s}_p, s_c\right), 0, y'_p, y'_c, s'_p, s'_c\right)$.

Equilibrium definition and properties

A steady-state recursive equilibrium, which is also a Markov-Perfect equilibrium, is a collection of value functions $V_{h_p}\left(\tilde{s}_p\right)$ and $V_{h_c}\left(\tilde{s}_c\right)$, policy functions $c_p\left(h_p, \tilde{s}_p\right)$, $a'_p\left(h_p, \tilde{s}_p\right)$, $g_p\left(h_p, \tilde{s}_p\right)$, $c_c\left(h_c, \tilde{s}_c\right)$ and $a'_c\left(h_c, \tilde{s}_c\right)$, measures of households $f\left(h_p, \tilde{s}_p\right)$ and $f\left(h_c, \tilde{s}_p\right)$, and aggregate bond holdings B such that: *(i)* given the payoff relevant state vectors, in each repetition of the parent-child stage game the parent decides optimally how much to consume, save and transfer to the child, after which the child makes an optimal consumption-saving choice of his own, *(ii)* the bond market clears, *(iii)* the government's budget is balanced and *(iv)* the measure of households is invariant. Details on the computational algorithm are in Section B.1 in Appendix B.

This setup has two important properties. Firstly, for a given interest rate R, the timing assumption guarantees that in each stage game the equilibrium is unique. Secondly, the setup features strategic behavior of the type encountered in the 'Samaritan's dilemma', with the child pursuing a consumption plan that exploits the parent's altruism.[39] To mitigate this, the parent only makes transfers to the child if the latter would be otherwise constrained. When they occur, transfers are set such that $u'\left(c_p\right) = \gamma u'\left(c_c\right)$. Section B.2 in Appendix B discusses these two points in more detail.

3.2 Parameter values

Labor earnings. Individuals can work in one of two sectors: a sector with low permanent income risk and a sector with high permanent income risk. They can transition between the two sectors over their career. To calibrate the transition probabilities, I aggregate the 17 sectors from Section 2 into two groups based on whether average income uncertainty a specific sector is below or above the average uncertainty over all sectors.[40] Transition probabilities are given by the empirical average switching rates between sectors and are equal to

$$\mathbf{P_s} = \begin{bmatrix} p_{ll} & p_{lh} \\ p_{hl} & p_{hh} \end{bmatrix} = \begin{bmatrix} 0.921 & 0.079 \\ 0.113 & 0.887 \end{bmatrix}$$

In the matrix $\mathbf{P_s}$ the generic element $p_{ss'}$, with $s, s' \in \{l, h\}$, is the probability of switching to sector s' if currently working in sector s. I allow for correlation between the sector of a parent and that of his child. In particular, the sector a child first works in is correlated with his parent's sector at the time the child enters the labor market.[41] I use the sample of parent-child pairs to estimate the probability that if the parent works in sector $s_p \in \{l, h\}$, the child works in sector $s_c \in \{l, h\}$. These probabilities are

$$\mathbf{P_s^{ig}} = \begin{bmatrix} \hat{p}_{ll} & \hat{p}_{lh} \\ \hat{p}_{hl} & \hat{p}_{hh} \end{bmatrix} = \begin{bmatrix} 0.647 & 0.353 \\ 0.493 & 0.507 \end{bmatrix}$$

where the generic element $\hat{p}_{s_p s_c}$, with $s_p, s_c \in \{l, h\}$, is the probability that if the parent works in sector s_p then his 22 year old child begins his career in sector s_c.

I assume log labor earnings have two age-dependent components. The first is a

[39] In the steady state 1.4% of children are constrained. If the transfer option would be removed unanticipatedly, then 23.3% of children would find themselves constrained.

[40] The low income uncertainty group contains sectors $\{2, 3, 4, 5, 6, 7, 9, 11, 13, 15, 16\}$ and covers approximately 60% of the sample, while the high risk group includes sectors $\{0, 1, 8, 10, 12, 14\}$.

[41] This is to capture the fact that some children work in family businesses, or their parents use their contacts, often in the workplace, to find them jobs.

deterministic component which is common to all individuals of age h, irrespective of the sector in which they work. The second is an idiosyncratic component capturing labor income risk at sector level. Therefore, log earnings of an individual i of age $h \in [22, 65]$ working in sector s are given by

$$\ln y_{hs}^{i} = \underbrace{f(h)}_{\text{deterministic}} + \underbrace{\tilde{y}_{hs}^{i}}_{\text{idiosyncratic}} \tag{15}$$

The deterministic component is a quartic age polynomial obtained from reestimating equation (11) with log annual labor income of the head as the dependent variable. Average labor earnings are hump-shaped over the life cycle, increasing by 43% until they peak in the forties, and then decreasing by 38% by retirement age.

In what concerns the idiosyncratic component, the goal is to feed in the model the sector level age profile of permanent income uncertainty estimated with the PSID data. To that end, I assume that, for a given sector s, the idiosyncratic component of log earnings follows an AR(1) process

$$\tilde{y}_{hs}^{i} = \rho_s \tilde{y}_{h-1,s}^{i} + \epsilon_{hs}^{i}, \ \epsilon_{hs} \sim \left(0, \sigma_{hs}^{2}\right) \tag{16}$$

with sector specific persistence ρ_s and age and sector specific variance σ_{hs}^2, $h = 22, \ldots, 65$.[42] I calibrate parameters ρ_s and σ_{hs}^2 such that, for each sector, the relative permanent income risk implied by the decomposition (15)-(16) matches the empirical profile of uncertainty relative to permanent income. Since for each sector there are only 44 data moments, estimating a fully non-parametric variance age profile is virtually impossible. Instead, I assume that the variance of the idiosyncratic component is a cubic polynomial in age. Section B.3 in Appendix B discusses the estimation procedure in more detail.

The left panel of Figure 8 displays the fit of the estimation, for each of the two sectors. The right panel of the figure shows how the variance in each sector varies with age. The average variance is 0.696 in the low risk sector and 0.088 in the high risk sector. The estimated persistence parameters are 0.908 and 0.947, respectively. Both the persistence and the variance of the income process are larger for the high risk sector. While these parameters are estimated based on a different set of moments than it is common in the literature, the resulting values are comparable with existing ones.

Pension benefits. In a realistic analysis of retirement, pension benefits would be based on career (lifetime) average earnings. In terms of modeling, that requires introducing a new continuous state variable for each member of the family to what already is a large state space. To avoid that, I set pension benefits as a function of predicted lifetime average earnings, as in Guvenen et al. (2013). To that end, I first simulate the lifetime labor

[42] Karahan and Ozkan (2013) provide evidence for age dependence of income process parameters. While such patterns are not very strong for the persistence parameter, they are for the variance.

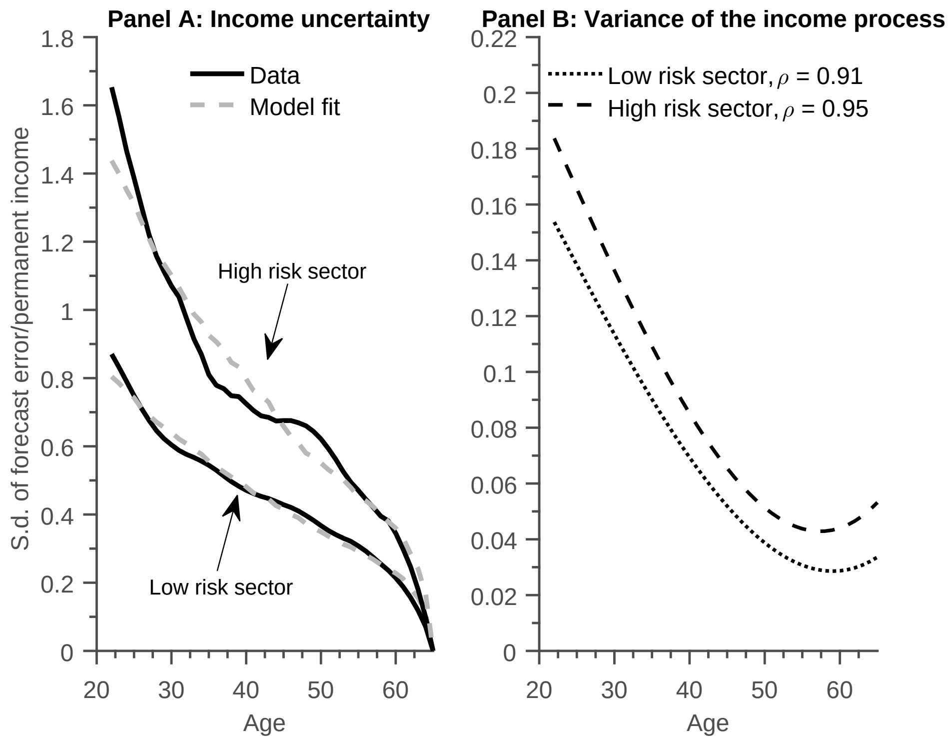

Figure 8: Parameters of the Income Process and Uncertainty Fit

Notes: The figure shows the estimated parameters of the income processes for the two sectors in the right panel and the fit of the estimation in the left panel. The variance is assumed to be a cubic polynomial in age: $\sigma^2_{hs} = a_s + b_s \frac{h}{10} + c_s \left(\frac{h}{10}\right)^2 + d_s \left(\frac{h}{10}\right)^3$, $s \in \{l, h\}$. For the low income sector the coefficients are: $a_l = 0.159$, $b_l = -0.051$, $c_l = 10^{-5}$, $d_l = 0.001$. For the high income sector the coefficients are: $a_h = 0.190$, $b_h = -0.061$, $c_h = 10^{-5}$, $d_h = 0.002$.

earnings profile of 10,000 individuals and compute average earnings for each of them. I then regress average earnings on earnings in the last period of working life and use the estimated coefficients to predict the career average earnings of an individual, given earnings right before retirement. Letting $\hat{y}$ denote an individual's predicted lifetime average earnings and $\bar{y}$ denote average earnings in the economy, the individual's pension benefit is determined as follows:

$$\Phi(\hat{y}) = a\bar{y} + b\hat{y}$$

where $a = 0.168$ captures the insurance component of retirement income and $b = 0.355$ captures the private returns to lifetime earnings. The values of these two parameters are taken from Guvenen et al. (2013), who use the information reported by OECD for the US in "Pensions at a Glance 2007: Retirement Income Systems in OECD Countries".

Borrowing limit. I set the borrowing limit $\underline{A}_h$ to zero, but explore the sensitivity of the results under the natural borrowing limit. Irrespective of the type of borrowing limit considered, parents are not allowed to borrow against the income of future generations.

Preferences. Household utility is CRRA with the relative risk aversion equal to 2. Following the literature on quantitative macroeconomic models with heterogeneous households and incomplete markets, I set the discount factor β to 0.959 to match an average wealth to average income ratio of 6.218.[43] I calibrate the altruism coefficient γ to target the average ratio between parent's and child's consumption, as measured in the sample of parent-child pairs used in the empirical analysis. Recall that a parent who makes positive transfers sets them such that $u'\left(c_p\right) = \gamma u'\left(c_c\right)$, so the ratio between the consumption of a parent and that of his child is directly influenced by the weight that parents place on their children's utility.[44] The calibrated value for γ is 0.201. There is a wide range of values for this parameter in the literature, from 0.04 in Kaplan (2012) to 0.63 in Nishiyama (2002). The value I use falls close to the middle of this range.

Government and interest rate. The proportional tax rate is set to 24.6%, which corresponds to the net personal average tax rate for the US, as reported in the OECD Tax Database.[45] Government spending is set such that in the steady state the interest rate is 4% annually.

3.3 Results

I now discuss the quantitative results. Firstly, I examine the model's performance in matching the empirical evidence on parental help, both from an ex-ante perspective via dynastic precautionary savings, and from an ex-post perspective through intergenerational transfers and end-of-life bequest. Secondly, I use the model to evaluate the contribution of dynastic precautionary savings to consumption backloading and aggregate wealth.

Model fit

Age profile of consumption and the distribution of wealth. I begin with examining the model implied age profile of consumption, displayed in Figure 9. Qualitatively, consumption over the life-cycle displays similar patterns as those documented in Figure 4 in terms of the backloading after retirement. In the model, this is solely a reflection of

[43]This target is computed by averaging the respective ratios between 2001 and 2013, interval during which the average wealth to average income ratio has been relatively stable. The yearly ratios are calculated using moments from the Survey of Consumer Finances reported on the Rios-Rull and Kuhn (2016) project webpage.

[44]In particular, under the CRRA utility assumption with relative risk aversion σ, the intra-temporal optimality condition for positive transfers is $c_p^{-\sigma} = \gamma c_c^{-\sigma}$ or, equivalently, $\ln \frac{c_p}{c_c} = -\frac{1}{\sigma} \ln \gamma$. The altruism parameter γ is set such that the model implied average of $\ln \frac{c_p}{c_c}$ matches its empirical counterpart, which is equal to 0.171. The empirical moment is calculated based on the sample of parent-child pairs in which the parent is older than 51 and the child is older than 22, as in the model.

[45]Net personal average tax rate is the term used when the personal income tax and employee social security contributions net of cash benefits are expressed as a percentage of gross wage earnings. The value is an average over the 2000-2015 horizon.

dynastic precautionary savings. After retirement, which occurs at age 65, parents' income is no longer subject to risk, but their children's income still is. The resolution of children's permanent income stimulates parental consumption and generates the back-loaded consumption profile. Note however that, while the model matches the level of average consumption over the life-cycle ($7,929 in the model versus $7,998 in the data), it understates the consumption of the young and overstates the consumption of the old.

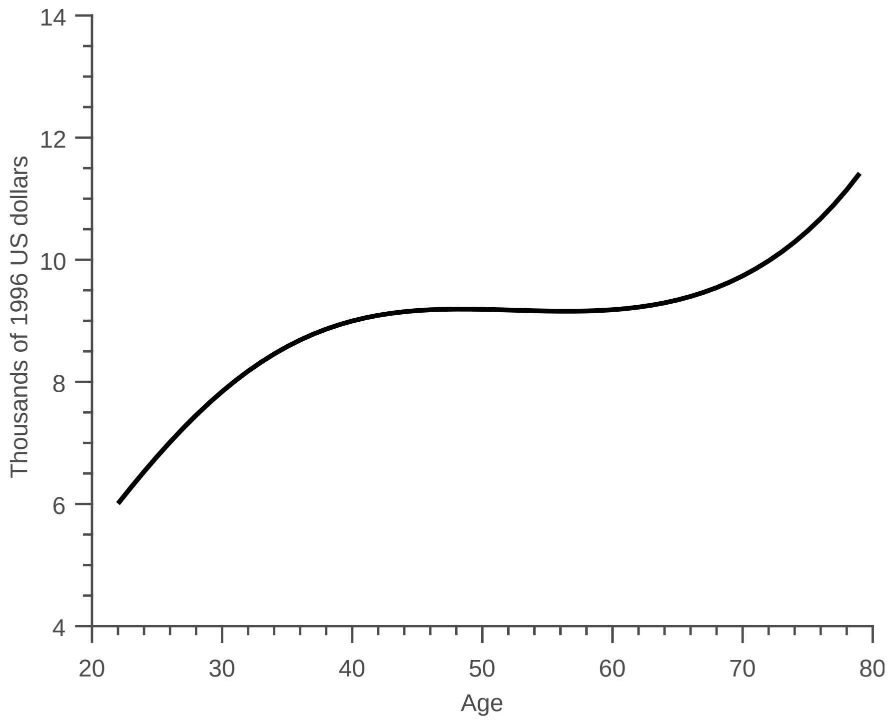

Figure 9: Model Implied Age Profile of Consumption

Notes: The figure shows the model implied average age profile of consumption, obtained by estimating equation (11) with model generated data.

Since the model is meant to paint a picture of various motives for which individuals hold wealth, it is desirable that it generates a distribution of wealth that resembles the US data. This is largely the case, as shown in Table 8, which compares quintiles of cross-sectional wealth and after-tax income found in the model and in the data. The data moments, calculated from the Survey of Consumer Finances, are taken from Rios-Rull and Kuhn (2016).

Model regression. I now repeat the regression analysis in Section 2 with model generated data to determine the model implied elasticities of consumption with respect to permanent income uncertainty. Precautionary and dynastic precautionary savings inform the choice of behavioral parameters such as risk aversion and intergenerational altruism. The purpose of this exercise is to verify whether standard calibration of these parameters is able to deliver consumption responses to both own and child's income risk consistent with those documented in the previous section. To that end, I simulate $10,000$

Table 8: Characteristics of the Wealth and Income Distribution

	Quintiles				
	Q1	Q2	Q3	Q4	Q5
Wealth distribution					
US data	-0.38	0.94	3.98	10.90	84.50
Model	0.59	1.73	5.68	17.81	74.19
Income distribution					
US data	7.12	10.00	13.62	18.04	51.26
Model	4.56	9.96	12.98	20.93	51.57

parent-child pairs from the steady state of the model, and follow them for as long as the parent is alive. I then estimate the following equation:

$$\ln c_{p_{it}} = \beta^p_{m0} + \beta^p_{m1}\sigma_{p_{hs}} + \beta^p_{m2}\sigma_{c_{hs}} + \mathbf{X}_{p_{it}}\beta^p_{m3} + \mathbf{X}_{c_{it}}\beta^p_{m4} + \epsilon_{p_{it}} \tag{17}$$

where $c_{p_{it}}$ is the logarithm of the consumption of parent household i in year t, $\sigma_{p_{hs}}$ is the permanent income uncertainty of the parent and is assigned based on the age $h \in \{51, \ldots, 79\}$ and the sector $s \in \{l, h\}$ in which the parent i is in year t, while $\sigma_{c_{hs}}$ is the permanent income uncertainty of the child, assigned based on the age $h \in \{22, \ldots, 50\}$ and the sector $s \in \{l, h\}$ in which the child of parent i is in year t. $\mathbf{X}_{p_{it}}$ and $\mathbf{X}_{c_{it}}$ are vectors of controls for the parent and child's permanent labor income and wealth holdings, as well as a full set of age dummies for the parent. Note that in the model all parents are 29 years older than their children, so controlling for the child's age is redundant. Likewise, in the regression with model generated data there are no controls for demographic characteristics other than age, as these are absent from the model.

Table 9 reports the results. Panel A of the table reproduces the empirical estimates of β^p_{m1} and β^p_{m2} from Table 2, for comparison purposes. Panel B reports the corresponding estimates from the model generated sample. The first row of Panel B corresponds to the baseline scenario with no borrowing. As is the case in the data, parental consumption responds negatively to both own and child's permanent income uncertainty. Moreover, the consumption response to own income risk is stronger than the response to the child's income risk, albeit relatively stronger in the model than in the data. However, the model estimates fall well within the 95% confidence interval of the empirical estimates.[46] This is in spite of the fact that the model estimates are based on much less variation across

[46] They even fall within the 90% confidence interval.

sectors than the empirical ones (i.e. 2 sectors in the model versus 17 sectors in the data).[47]

The second row of Panel B explores the sensitivity to the borrowing limit. Following Kaplan and Violante (2014), I assume that in a given year working age individuals can borrow up to 18.5% of average annual income and retired individuals cannot borrow. The option of borrowing provides extra insurance for young adults, reducing the parental response to dynastic uncertainty. However, the overall effect of looser borrowing constraints is quantitatively small. In fact, there is virtually no effect on the strength of parents' precautionary motive as average income is decreasing over the age range in which one is a parent, so very little borrowing is possbile, and borrowing is not allowed after retirement. Finally, the third row of Panel B shows that when individuals cannot switch sectors over the course of their career, (dynastic) precautionary motives are stronger. This is a consequence of the fact that transition between sectors acts as an additional insurance channel. Everything else equal, the parent of a child who is stuck in a high risk sector has to provide more insurance than the parent of a child who might find a job in a low risk sector in the future.

Inter-vivos transfers and bequest. The model makes predictions about the size and timing of intergenerational transfers, which are displayed in Figure 10. Though none of these dimensions are targeted, the model matches them well. The top panel shows the model implied inter-vivos transfers relative to parental wealth in black, and their data counterpart in gray. The data moment is measured from the 2013 PSID Family Rosters and Transfers Module and the dashed lines are the 95% confidence bands.[48] The model matches well the evolution over age of the transfer-to-parental wealth ratio. In particular, the model implied average ratio is 3.06%, while the empirical counterpart is 3.01%.

The bottom panel of Figure 10 shows the model predicted fraction of parents making inter-vivos transfers to their children in black, and the empirical counterpart in gray. In the PSID approximately 24.1% of all parents make inter-vivos transfers. When restricting the sample to parents older than 51, as in the case in the model and is shown in the figure, this share becomes 39.73%, in comparison to 39.15% in the model. While the model predicts that the fraction of parents making transfers decreases over age, the data counterpart does not exhibit any such trend. However, the model implied share is within the 95% confidence interval of the data for almost all age groups.

Lastly, the model predicted bequest-to-aggregate wealth ratio of 0.49% is roughly in line with Gale and Scholz (1994), who estimate bequests to represent 0.88% of net worth. Total intergenerational transfers (end-of-life bequest and inter-vivos transfers) are 1.87%

[47] Including only 2 sectors in the model is largely for computation time reasons.

[48] Monetary transfers to children are directly reported by parents in the module. Wealth is the sum of assets (farm/business assets, checking and savings accounts, real estate other than main home, stocks, vehicles, annuity/IRA and other assets), net of debt value (farm/business debt, real estate debt other than for main home, student loans, medical and legal debt, family loans and other debt), plus the value of home equity. The average transfer-to-parental wealth ratio is calculated for respondents with positive wealth, as the borrowing limit is set to zero in the baseline.

Table 9: Regression Analysis with Model Generated Data

	Coefficient on parent's permanent income risk	Coefficient on child's permanent income risk
	Panel A. Empirical estimates from Table 2	
1. Non-durable consumption	-0.089** [-0.153 -0.025]	-0.081* [-0.147 -0.015]
2. Total consumption	-0.081** [-0.140 -0.023]	-0.076* [-0.140 -0.012]
	Panel B. Model estimates	
1. Baseline	-0.097** (0.012)	-0.067** (0.013)
2. Borrowing allowed	-0.098** (0.012)	-0.064** (0.013)
3. No transition between sectors	-0.157** (0.011)	-0.136** (0.018)

Notes: Table entries are coefficient estimates of the effect of parent's and child's permanent income uncertainty on parental consumption. Panel A reports results from estimating equation (12) with the PSID sample, with the 95% confidence interval in paranthesis. Panel B reports results from estimating equation (17) with model generated data with robust standard errors in parenthesis. * significant at 5%; ** significant at 1%

of aggregate wealth. Gale and Scholz (1994) estimate intended transfers and bequest to be 1.41% of net worth. As a general observation, it appears that in terms of point estimates the model ever so slightly overestimates the size of intergenerational transfers. This may be a consequence of the fact that in the model there is no income growth, while empirically it is observed that income grows over time, reducing parents' incentives to make transfers.

Model without parent-child strategic interactions

The model environment described in Section 3.1 features strategic interactions between parents and children that stem from the lack of commitment regarding intergenerational transfers. While these interactions enable predictions regarding the size and timing of intergenerational transfers, as well as the wealth position of overlapping generations, both of which are objects of interest for the counterfactual experiment, they are not a prerequisite for the accumulation of dynastic precautionary savings. I show this by repeating the analysis in the context of a model of altruism of the type considered in

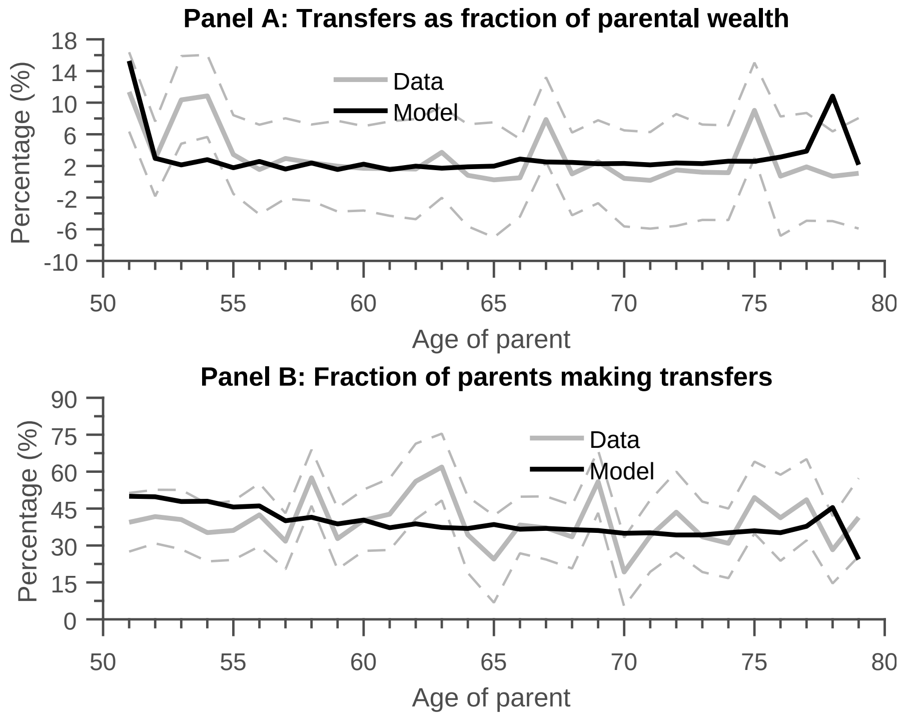

Figure 10: Age Profile of Transfers: Data vs Model

Notes: The top panel of the figure shows the ratio between inter-vivos transfers and parental wealth in the model (solid black line) and the 2013 PSID Family Rosters and Transfers Module (gray solid line). Dashed gray lines are the 95% confidence interval for the data. The bottom panel shows the same objects for the fraction of parents making transfers to their children.

Barro (1974), in which, while alive, the parent makes all consumption-saving decisions of the family. In particular, given $\tilde{s} = \left(a, y_p, y_c, s_p, s_c\right)$, a non-terminal parent of age h_p solves

$$\begin{aligned} V^p_{h_p}\left(\tilde{s}_p\right) &= \max_{c_p, c_c, a'} u\left(c_p\right) + \gamma u\left(c_c\right) + \beta \mathbb{E} V^p_{h_p+1}\left(\tilde{s}' | \mathbf{y}, \mathbf{s}\right) \\ \text{s.t.} \quad & c_p + c_c + a' = (1-\tau)\left(y_p + y_c\right) + Ra \\ & a' \geq \underline{A}_{h_p} \geq 0 \end{aligned}$$

where $\tilde{s}' = \left(a', y'_p, y'_c, s'_p, s'_c\right)$. The expectation is taken over all possible sector and income transitions, for the parent and the child. Note that if the parent is retired his net income is $\Phi\left(\hat{y}_p, \hat{s}_p\right)$, and the expectation is taken only over possible sector and income transitions for the child. A terminal parent with state variables $\tilde{s} = \left(a, \hat{y}_p, y_c, s_p, s_c\right)$ solves

$$\begin{aligned} V^p_{79}\left(\tilde{s}_p\right) &= \max_{c_p, c_c, a'} u\left(c_p\right) + \gamma u\left(c_c\right) + \beta \gamma \mathbb{E} V^p_{51}\left(\tilde{s}'_p | \mathbf{y}, \mathbf{s}\right) \\ \text{s.t.} \quad & c_p + c_c + a' = \Phi\left(\hat{y}_p\right) + (1-\tau)\, y_c + Ra \\ & a' \geq \underline{A}_{h_p} \geq 0 \end{aligned}$$

where $\tilde{s}' = \left(a', y'_p, y'_c, s'_p, s'_c\right)$.

I use the same parameter values as in the baseline framework, except for the discount factor β and the degree of altruism parameter γ, which I recalibrate to match the same moments as the model with strategic interactions.[49] The calibrated values of β and γ are 0.958 and 0.710, respectively. Note that the model with strategic interactions requires a lower degree of altruism to match the same moment. This is a consequence of the fact that children overconsume (relative to what parents would like them to consume) to induce higher transfers from parents in the future, which lowers the parent-child consumption ratio. This more altruistic is the parent, the more severe is the 'overconsumption problem', and therefore the lower is the ratio between parent's and child's consumption.

I repeat the regression analysis in Section 2 with model generated data to determine the elasticities of consumption with respect to permanent income uncertainty implied by the model with no strategic interactions.[50] The first column in Table 10 reports the estimated coefficients. For comparison purposes, the second columns reports the corresponding estimates from the model with strategic interactions, and the third column reports the estimates from the PSID sample. The top panel of the table reports the effect of permanent income risk on parental consumption, while the bottom panel reports the effect of uncertainty on child's consumption.

Note first that in the model without strategic interactions the effect of income uncertainty on parent's and child's consumption is the same. This is a consequence of the fact that in this model the parent sets his child's consumption as a constant fraction of his own consumption. In addition, the effect of child's income uncertainty on consumption is stronger than the effect of parent's income risk. To see why this is the case, recall that in this setup joint family labor income has two components with different degrees of riskiness: parent's income which is less risky and child's income which is more risky.[51] When the riskiness in child's consumption decreases, the effect on the overall riskiness of joint family income is larger than when the riskiness in parent's income decreases by the same magnitude, which translates into a stronger consumption adjustment.[52]

In the model with strategic interactions, on the other hand, the relative importance of the two saving motives is in line with that observed in the PSID. This is because the nature of these strategic interactions is such that the child is pursuing a consumption plan that exploits the parent's altruism. In particular, the child behaves recklessly by

[49]Note that in the model without strategic interactions, child's consumption is always a constant fraction of the parent's consumption, as dictated by the intra-temporal optimality condition $u'\left(c_p\right) = \gamma u'\left(c_c\right)$.

[50]Because the wealth holdings of parents and children are not separately identified, I estimate a slightly modified version of equations (12) and (13), in which I control for joint asset holdings.

[51]The difference in the degree of riskiness comes from the age difference between the parent and the child.

[52]This is true as long as the two income streams are not perfectly correlated, a condition that is satisfied by the parametrization of the model.

overconsuming, to induce transfers from parents in the future. For example, if parents' ability to make transfers would be removed unaticipatedely, approximately 51% of children would hit their borrowing limit, as opposed to 1.6% in the setup with transfers. The parent is aware of this behavior and would want the child to entertain a lower level of consumption than he actually does. This dampens the parent's incentive to provide private insurance via dynastic precautionary savings. At the same time, for a fixed level of the child's consumption, the parent is underconsuming when there are strategic interactions. To ensure that his consumption does not fall by too much relative to this underconsumption level, he responds more to own income risk than in the setup without strategic interactions.

The bottom panel of the table shows that in the setup with strategic interactions the child has to compensate with stronger precautionary saving relative to the setup without strategic interactions, because the parent does not provide as much insurance against the child's income risk. The child is subject to the parent's income risk insofar as it generates fluctuations in transfers, so he mildly insures against that.

Table 10: Regression Analysis with Model Generated Data (comparison)

	Model without strategic interactions $\gamma = 0.710$	Model with strategic interactions $\gamma = 0.201$	Data
	Panel A. Effect of uncertainty on parent's consumption		
Parent's uncertainty	-0.022* (0.009)	-0.097** (0.012)	-0.089** [-0.153 -0.025]
Child's uncertainty	-0.062** (0.009)	-0.067** (0.013)	-0.081* [-0.147 -0.015]
	Panel B. Effect of uncertainty on child's consumption		
Parent's uncertainty	-0.022* (0.009)	-0.019 (0.011)	-0.039 [−0.088 0.010]
Child's uncertainty	-0.062** (0.009)	-0.181** (0.013)	-0.163** [−0.237 − 0.089]

Notes: Table entries are coefficient estimates of the effect of parent's and child's permanent income uncertainty on parental consumption. Panel A reports results from estimating equation (12) with the PSID sample, with the 95% confidence interval in paranthesis. Panel B reports results from estimating equation (17) with model generated data with robust standard errors in parenthesis. * significant at 5%; ** significant at 1%

The comparison of the setups with and without strategic interactions shows that pure precautionary saving motives are stronger where there are strategic interactions, and precautionary motives against the income uncertainty of the other party are dampened. Generally, the estimates from both models are within the 95% confidence interval of the data estimates. However, the relative importance for parents of the dynastic precautionary motive is much closer to the empirical one in the model with strategic interactions. In particular, this model predicts that a 1% increase in parent's own income risk has an effect on parental consumption that is 1.45 times higher than the effect of an equal size increase in the child's income risk. This is closer to the empirical ratio of 1.1 than the prediction of the model without strategic interactions, which generates a ratio of 0.35.

I proceed forward with the model with strategic interactions for two reasons. Firstly, the discussion above suggests that the true model of parental precautionary and dynastic precautionary saving is intermediate, but closer to the setup with strategic interactions. Secondly, in the model without strategic interactions the wealth position of the parent and the child cannot be separately identified, and the timing of intergenerational transfers is indeterminate.[53] This limits the number of counterfactual exercises that can be performed in this environment.

How much dynastic precautionary wealth in aggregate wealth?

Having established that the model with strategic interactions is a good descriptor of parents' dynastic precautionary behavior, I now turn to quantifying the contribution of dynastic precautionary wealth to aggregate wealth. To that end, I perform a decomposition exercise inspired by Gourinchas and Parker (2002), who measure precautionary wealth by comparing aggregate wealth in a pure life-cycle model with income risk and a counterfactual model without income risk. In the setting of this paper, a literal application of this decomposition would amount to shutting down children's income risk in the counterfactual model. This, however, would be wrong because eliminating the risk in children's income not only suppresses parents' dynastic precautionary saving motive, but also children's precautionary saving motive. As a consequence, in the counterfactual model parental wealth holding is significantly lower (i.e. $\approx 70\%$ lower) because *(i)* parents no longer hold dynastic precautionary wealth, which is the effect of interest, and *(ii)* children enter parenthood with lower levels of wealth.

Instead, I apply a two step decomposition. First, I solve a counterfactual model in which I shut down income risk at all ages. The difference between aggregate wealth in the baseline model and aggregate wealth in this counterfactual model is precautionary wealth and dynastic precautionary wealth. Call this quantity $W_{PS,DPS}$. Second, I measure precautionary wealth the same way Gourinchas and Parker (2002) do. Specifically, I solve a counterfactual model in which $\gamma = 0$, which is in fact a pure life-cycle model, and measure precautionary wealth as the difference between aggregate wealth in the model

[53] The reason is that the parent is indifferent between saving one dollar and transferring it to his child the next period, and transferring the dollar in the current period so that the child can save it.

with $\gamma = 0$ and income risk and aggregate wealth in the model with $\gamma = 0$ and no income risk. Call this quantity W_{PS}. Lastly, dynastic precautionary wealth is the difference between $W_{PS,DPS}$ and W_{PS}. According to this definition, dynastic precautionary wealth represents 27% of aggregate wealth, while precautionary wealth accounts for 53%.[54]

These averages obscure significant variation in the relative importance of dynastic precautionary wealth over the life-cycle. In particular, dynastic precautionary wealth accounts for 41% of the wealth holdings of parents and -3% of the wealth holdings of children. To illustrate why the ratio is negative for children, Figure 11 shows the age-profile of wealth in the baseline (dynastic) model and in a pure life-cycle model ($\gamma = 0$). In the dynastic model children overconsume to induce higher transfers from the parents in the future. This translates into undersaving relative to the life-cycle model, as shown in the Figure for the age interval 22-50. Therefore, the absence of a dynastic precautionary motive has two effects on children's wealth: *(i)* a negative effect coming from the fact that children themselves no longer save to insure their own children against income risk and *(ii)* a positive effect coming from the fact that they now have to compensate for the lost insurance from their parents. The second effect dominates quantitatively.

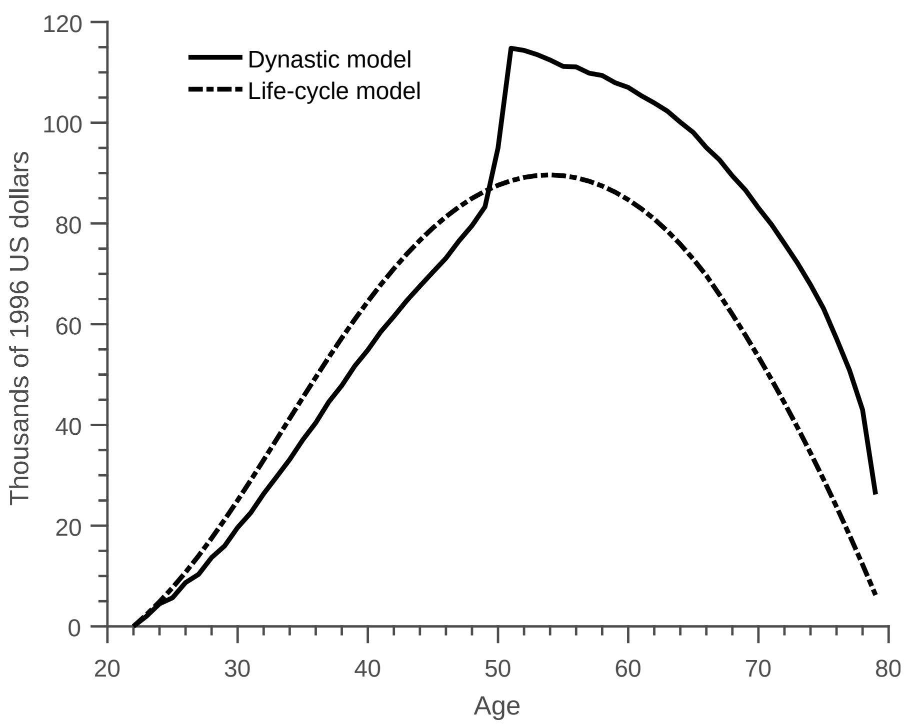

Figure 11: Age Profile of Wealth: Dynastic vs Life-cycle Model

Notes: The figure shows the evolution of wealth over age in the baseline model in the solid black like and a counterfactual model in which $\gamma = 0$ in the dashed black line.

[54]It is worth pointing out that, when expressed as fraction of the aggregate wealth in the pure life-cycle model, precautionary wealth accounts for 64%, which is extremely close to the 62% found by Gourinchas and Parker (2002).

This decomposition is subject to two caveats. First, as is apparent from the discussion above, wealth components might crowd each other out. The decomposition relies on the implicit assumption they do not. Secondly, the measured magnitudes are upper bounds because the model misses on other savings motives, such as those triggered by uncertain medical expenses or survival risk. Accounting for these would increase aggregate wealth and thus lower the relative importance of the dynastic precautionary component.

I now turn to analyzing the contribution of risk in children's income to intergenerational transfers. To that end, I solve a counterfactual model in which children (i.e. individuals of age 22-50), are not subject to income risk, but average income is the same as in the baseline environment.[55] I find that intergenerational transfers are primarily driven by incentives to insure children against income risk. In particular, the dynastic precautionary motive accounts for 97% of total intergenerational transfers. Columns 2 and 3 in Table 11 further decompose the effect on total intergenerational transfers into the effect of inter-vivos transfer and the effect on end-of-life bequest. Almost all inter-vivos transfers are dictated by dynastic precautionary considerations. This shows that the primary role of such transfers is to provide insurance against bad income realizations, as argued by McGarry (1999) and McGarry (2016). A relatively smaller share of end-of-life bequest, albeit not by much, is dictated by incentives to insure future generations against income risk.

Table 11: The Effect of Eliminating Children's Income Risk

	Total transfers	Inter-vivos transfers	End-of-life bequest
Total effect (%)	-97.48	-99.82	-90.80

Notes: Table entries are percentage changes in intergenerational transfers resulting from eliminating dynastic uncertainty. The total effect on intergenerational transfers is further decomposed into the effect of inter-vivos transfer and the effect on end-of-life bequest.

The decomposition above highlights the role of dynastic precautionary savings to provide children with insurance against bad income realizations. If such income realizations occur, dynastic precautionary savings materialize in the form of inter-vivos transfers. From the perspective of parents, these transfers are lost consumption.[56] This begs the question of how much of dynastic precautionary saving translates into lost consumption versus delayed consumption. To answer it, I calculate the share of potential

[55]Note that there is residual dynastic uncertainty in the counterfactual model. When individuals turn 51 and become parents they are again subject to income risk. This is a consequence of the fact that in the dynastic model every individual play every role. However, I conjecture that this has limited quantitative importance, as most of income risk is resolved by age 51.

[56]These transfers do enter parents' welfare though, through the weight placed on children's utility from consumption.

parental consumption that is represented by intergenerational transfers made for insurance purposes, which I define as the share of lost consumption. Transfers made for insurance purposes are the difference between intergenerational transfers in the baseline setup with dynastic risk, and intergenerational transfers in the counterfactual environment with no dynastic risk. Potential consumption, defined as the sum of parental consumption (in the baseline setup with dynastic risk) and transfers made for insurance purposes, is the maximum amount of consumption parents could enjoy if they did not have to compensate children for bad income realizations.

The average share of potential parental consumption that is lost because of parents having to make inter-vivos transfers to compensate for bad income realizations in children's income is 12.6%. This number is larger when children are young and face high income risk, and decreases as their income risk resolves. In general, the share of consumption lost to inter-vivos transfers traces very closely the evolution of children's permanent income risk. If end-of-life bequests are included in the calculation, then the average share of forgone consumption rises to 14.4%.

How much insurance via dynastic precautionary savings?

Dynastic precautionary savings of parents constitute, for children, a form of private insurance against labor market shocks that goes over and above self-insurance through borrowing and saving.[57] Kaplan and Violante (2010) compute the amount of consumption insurance implicit in a calibrated life-cycle model and compare it with the corresponding estimates from US data in Blundell et al. (2008). They find that in the US data there is substantial consumption insurance against permanent income shocks that goes beyond the self-insurance predicted by a life-cycle model. Moreover, the gap between the empirical and the model implied insurance is particularly large for the young. This suggests that incorporating dynastic precautionary savings could improve the fit of the model in terms of how much consumption of the young responds to labor earnings shocks.

In this section, I assess the degree of additional consumption smoothing induced by parents' dynastic precautionary savings. I do this by calculating consumption insurance coefficients against income shocks and comparing them with those implied by the pure life-cycle model, where dynastic precautionary saving is absent. As in Kaplan and Violante (2010), the consumption insurance coefficient against the persistent income shock ϵ_{ih}, defined in equation (16), is calculated as

$$\phi^{\epsilon} = 1 - \frac{\text{Cov}\left(\Delta c_{ih}, \epsilon_{ih}\right)}{\text{Var}\left(\epsilon_{ih}\right)},$$

where c_{ih} denotes the log consumption of individual i of age h, and the variance and

[57] Hayashi et al. (1996) call for future research to be directed at estimating the extent of such insurance.

covariance are taken cross-sectionally over the simulated sample of individuals.[58] The interpretation of the insurance coefficient is intuitive: it captures the share of the (variance of the) persistent shock that does not translate into movements in consumption. I calculate the consumption insurance coefficient for children in the baseline dynastic model and in the counterfactual model with $\gamma = 0$ (i.e. the pure life-cycle model). The difference between these two insurance coefficients is informative on the extent of additional consumption insurance coming from parent's dynastic precautionary savings.

Table 12 shows that the dynastic model generates a consumption insurance coefficient that is 1.35 times larger than in the life-cycle model. In particular, 66% of labor income shocks faced by children are insured when their parents accumulate dynastic precautionary savings, in comparison to only 49% otherwise.[59] This means that, in the dynastic model, consumption insurance through parents' dynastic precautionary savings accounts for a little over one fourth of children's total consumption insurance. The rest is through children's own savings. Dynastic precautionary saving provides additional insurance for children in all sectors, but the added benefit is largest for children in the high risk sector. In particular the consumption insurance for children working in the high-risk sector is 36.4% larger than the life-cycle counterpart, while for children in the low-risk sector it is 33.7% larger.

Table 12: Consumption Insurance Coefficients for Children

	Full sample of children	Children in low-risk sector	Children in high-risk sector
Dynastic model	0.663	0.650	0.680
Life-cycle model	0.492	0.486	0.499

4 Conclusion

In this paper I investigate, empirically and in a quantitative model, the response of parents' consumption to their children's permanent income uncertainty. I find that the latter depresses parental consumption, which suggests that parents engage in precautionary saving against the income risk of their offspring. I refer to this behavior as *dynastic precautionary saving*.

[58] To be consistent with Blundell et al. (2008) and Kaplan and Violante (2010), log consumption is defined as the residual from a quartic age profile.

[59] It is worth pointing out, as a cross-check, that the insurance coefficient found in the life-cycle model is of a similar magnitude to that found by Kaplan and Violante (2010) for the corresponding age group and income shock persistence.

Empirically, I document that the consumption profile of retired parents is backloaded, a feature consistent with precautionary behavior and absent from the consumption profile of non-parents. I hypothesize that this is a reflection of dynastic precautionary savings and test this hypothesis by regressing parental consumption on a measure of child's permanent income uncertainty on a sample of parent-child pairs from the Panel Study of Income Dynamics. The measure of permanent income risk I employ is closely related to the theoretical definition of permanent income and is defined as the standard deviation of the forecast error of permanent income. I exploit variation in income uncertainty across age and industry-occupation groups to confirm that parental consumption indeed responds negatively to the child's permanent income uncertainty.

In light of the empirical evidence for dynastic precautionary savings, I build a quantitative model of altruistically linked overlapping generations that is able to replicate the observed consumption pattern of parents, and deliver a response of parental consumption to child's permanent income risk of similar magnitude as in the data. I use the model to evaluate the contribution of dynastic uncertainty to aggregate parental wealth accumulation and to intergenerational transfers.

Going forward, dynastic precautionary savings could potentially be important in explaining several empirical puzzles: *(i)* It has repeatedly been documented that upon retirement wealth declines slower than the life cycle model predicts, but the reason remains poorly understood. The dynastic precautionary saving motive is still relevant at older ages, when children are in the beginning of their career and face high income uncertainty; *(ii)* There is substantial wealth heterogeneity at retirement, even after controlling for realized lifetime income. Parents of children facing different levels of income risk have different precautionary saving motives, translating into different wealth holdings. These exercises could, in principle, be accommodated by variants of the model in this paper. More broadly, this framework could also be used to study issues related to intergenerational mobility in general and wealth mobility in particular.

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Appendices

A Appendix for Empirical Analysis

A.1 Derivation of Permanent Income Uncertainty $\text{Std}_i\left(\mathcal{E}_h^i\right)$

Permanent income uncertainty of individual i at age h is defined as

$$\text{Std}_i\left(\mathcal{E}_h^i\right) = \left[\text{Var}_i\left(\sum_{j=h+1}^{H} \frac{e_{j,h}^i}{R^{j-h}}\right)\right]^{\frac{1}{2}} = \left[\text{Var}_i\left(\frac{e_{h+1,h}^i}{R} + \frac{e_{h+2,h}^i}{R^2} + ... + \frac{e_{H,h}^i}{R^{H-h}}\right)\right]^{\frac{1}{2}}$$

which is equal to the square root of the sum of all variance and covariance terms. The sum of variances is

$$\sum_{j=h+1}^{H} \frac{\text{Var}_i\left(e_{j,h}^i\right)}{R^{2(j-h)}}$$

For $h+1$ the covariance terms are

$$\underbrace{\frac{2}{R}\left[\frac{\text{Cov}_i\left(e_{h+1,h}^i; e_{h+2,h}^i\right)}{R^2} + \frac{\text{Cov}_i\left(e_{h+1,h}^i; e_{h+3,h}^i\right)}{R^3} + \cdots + \frac{\text{Cov}_i\left(e_{h+1,h}^i; e_{H,h}^i\right)}{R^{H-h}}\right]}_{\frac{2}{R}\sum_{k=h+2}^{H} \frac{\text{Cov}_i\left(e_{h+1,h}^i; e_{k,h}^i\right)}{R^{k-h}}}$$

For $h+2$ the covariance terms are

$$\underbrace{\frac{2}{R^2}\left[\frac{\text{Cov}_i\left(e_{h+2,h}^i; e_{h+3,h}^i\right)}{R^3} + \frac{\text{Cov}_i\left(e_{h+2,h}^i; e_{h+4,h}^i\right)}{R^4} + \cdots + \frac{\text{Cov}_i\left(e_{h+2,h}^i; e_{H,h}^i\right)}{R^{H-h}}\right]}_{\frac{2}{R^2}\sum_{k=h+3}^{H} \frac{\text{Cov}_i\left(e_{h+2,h}^i; e_{k,h}^i\right)}{R^{k-h}}}$$

and so on, with the number of covariance terms decreasing each time. For $H-1$ there is only one covariance term left

$$\frac{2}{R^{H-h-1}}\left[\frac{\text{Cov}_i\left(e_{H-1,h}^i; e_{H,h}^i\right)}{R^{H-h}}\right] = \frac{2}{R^{H-h-1}}\sum_{k=H}^{H} \frac{\text{Cov}_i\left(e_{H-1,h}^i; e_{k,h}^i\right)}{R^{k-h}}$$

Summing all of the above gives

$$\begin{aligned}
\text{Var}_i\left(\mathcal{E}_h^i\right) &= \sum_{j=h+1}^{H}\frac{\text{Var}_i\left(e_{j,h}^i\right)}{R^{2(j-h)}}+\frac{2}{R}\sum_{k=h+2}^{H}\frac{\text{Cov}_i\left(e_{h+1,h}^i;e_{k,h}^i\right)}{R^{k-h}}+\frac{2}{R^2}\sum_{k=h+3}^{H}\frac{\text{Cov}_i\left(e_{h+2,h}^i;e_{k,h}^i\right)}{R^{k-h}} \\
&+ \cdots+\frac{2}{R^{H-h-2}}\sum_{k=H-1}^{H}\frac{\text{Cov}_i\left(e_{H-2,h}^i;e_{k,h}^i\right)}{R^{k-h}}+\frac{2}{R^{H-h-1}}\sum_{k=H}^{H}\frac{\text{Cov}_i\left(e_{H-1,h}^i;e_{k,h}^i\right)}{R^{k-h}} \\
&= \sum_{j=h+1}^{H}\frac{\text{Var}_i\left(e_{j,h}^i\right)}{R^{2(j-h)}}+2\sum_{j=h+1}^{H-1}\frac{1}{R^{j-h}}\sum_{k=j+1}^{H}\frac{\text{Cov}_i\left(e_{j,h}^i;e_{k,h}^i\right)}{R^{k-h}}
\end{aligned}$$

A.2 Measurement Error

Let $\tilde{e}_{j,h}^i = e_{j,h}^i + e_{j,h}^{0,i}$ be the measured forecast error made by the age h individual i in predicting age j income. This is the sum of the true forecast error, $e_{j,h}^i$, and the measurement error $e_{j,h}^{0,i}$. Then the measured variance of the forecast error of permanent income is

$$\begin{aligned}
\tilde{\text{V}}\text{ar}_s\left(\mathcal{E}_h^i\right) &= \sum_{j=h+1}^{H}\frac{\text{Var}_s\left(e_{j,h}^i\right)}{R^{2(j-h)}}+\sum_{j=h+1}^{H}\frac{\overbrace{\text{Var}_s\left(e_{j,h}^{0,i}\right)}^{=\sigma_{0,h}^2\text{ by homoskedasticity}}}{R^{2(j-h)}}+\sum_{j=h+1}^{H}\frac{\overbrace{\text{Cov}_s\left(e_{j,h}^i,e_{j,h}^{0,i}\right)}^{=0\text{ uncorr. with true error}}}{R^{2(j-h)}} \\
&+ 2\sum_{j=h+1}^{H-1}\frac{1}{R^{j-h}}\sum_{k=j+1}^{H}\frac{\text{Cov}_s\left(e_{j,h}^i;e_{k,h}^i\right)}{R^{k-h}}+2\sum_{j=h+1}^{H-1}\frac{1}{R^{j-h}}\sum_{k=j+1}^{H}\frac{\overbrace{\text{Cov}_s\left(e_{j,h}^{0,i};e_{k,h}^{0,i}\right)}^{=0\text{ uncorr. over time}}}{R^{k-h}} \\
&+ 2\sum_{j=h+1}^{H-1}\frac{1}{R^{j-h}}\sum_{k=j+1}^{H}\frac{\overbrace{\text{Cov}_s\left(e_{j,h}^{0,i};e_{k,h}^i\right)}^{=0\text{ uncorr. with true error}}}{R^{k-h}}+2\sum_{j=h+1}^{H-1}\frac{1}{R^{j-h}}\sum_{k=j+1}^{H}\frac{\overbrace{\text{Cov}_s\left(e_{j,h}^i;e_{k,h}^{0,i}\right)}^{=0\text{ uncorr. with true error}}}{R^{k-h}} \\
&= \sum_{j=h+1}^{H}\frac{\text{Var}_s\left(e_{j,h}^i\right)}{R^{2(j-h)}}+\sum_{j=h+1}^{H}\frac{\sigma_{0,h}^2}{R^{2(j-h)}}+2\sum_{j=h+1}^{H-1}\frac{1}{R^{j-h}}\sum_{k=j+1}^{H}\frac{\text{Cov}_s\left(e_{j,h}^i;e_{k,h}^i\right)}{R^{k-h}} \\
&= \text{Var}_s\left(\mathcal{E}_h^i\right)+\sum_{j=h+1}^{H}\frac{\sigma_{0,h}^2}{R^{2(j-h)}}
\end{aligned}$$

Since the term $\sum_{j=h+1}^{H}\frac{\sigma_{0,h}^2}{R^{2(j-h)}}$ is constant across sectors for a fixed h, the distribution of variances of forecast errors of permanent income across sectors is unaffected by the measurement error, except for the mean which increases by exactly $\sum_{j=h+1}^{H}\frac{\sigma_{0,h}^2}{R^{2(j-h)}}$. However, it is the variation across sectors, which is not affected, that is exploited in the main empirical exercise of the paper.

A.3 Zero Earnings Observations

To estimate transfers as a function of labor income I first remove from (head and wife total) transfers the part that is predictable by demographics. To that end I estimate the following specification on the pooled sample:

$$transfer = \alpha_0 + \boldsymbol{\alpha}_1 \mathbf{X} + u$$

where **X** is a vector of observables including employment status, marital status, family size, race, a cubic age polynomial and year dummies. I then project the residual u on labor income:

$$u = \tilde{\alpha}_0 + \tilde{\alpha}_1 \times labor\ earnings + \epsilon_t$$

and set annual labor earnings for zero earnings observations equal to $\tilde{\alpha}_0$. Additionally, I use the results above to impute earnings for observations with positive annual earnings smaller than $200, which are likely to be measured with error.

A.4 Sector Definition

A sector s is an industry-occupation pair. There are 8 industry groups displayed in the first column of Table 1 in the main text and 5 occupation groups listed in the first row of the table. These are aggregated based on the major industries and occupations Census classification. Since the projection equation (7) estimates 13 parameters in its most general specification, there must be at least 14 individuals of each age in each sector. This is why for some industries such as construction or manufacturing occupation groups are aggregated even further. The aggregation is based on the distribution of annual labor earnings as summarized by the coefficient of variation. There is a total of 16 sectors in Table 1. An additional sector, which is an exception from the industry-occupation pair rule, is the 'unemployment sector', containing all individuals that are unemployed at the time they make the income forecast.

Table 13 summarizes some statistics at sector level. Sectors 5 and 12 are the largest, each covering approximately 14% or the sample, while sectors 2 and 15 are the smallest with only 3% of respondents. In light of this discrepancy, it is worth pointing out that sector 12 is at its maximum level of disaggregation, while an alternative disaggregation of sector 5 is not supported by the 'coefficient of variation' criterion. Annual labor earnings are highest in sector 4 and, not surprisingly, lowest for the unemployed.

Lastly, Table 14 reports the number of individuals in each age-sector cell.

A.5 Consumption Imputation Procedure

I impute total consumption in the PSID by using the data available in the CEX. Variations of this technique have been used several times in the literature (for example Skinner

Table 13: Sector statistics

Sector/Statistic	Percentage of sample (%)	Average age	Average log annual labor earnings	St. dev. of log annual labor earnings
Sector 0	6.38	39	7.92	1.84
Sector 1	4.47	41	9.95	1.12
Sector 2	2.81	42	10.49	0.94
Sector 3	5.91	38	10.06	0.93
Sector 4	6.35	42	10.87	0.72
Sector 5	14.01	40	10.28	0.71
Sector 6	4.04	41	10.69	0.67
Sector 7	4.90	41	10.36	0.81
Sector 8	4.50	40	10.46	0.92
Sector 9	4.80	39	10.03	0.79
Sector 10	5.38	39	9.97	0.99
Sector 11	5.03	41	10.51	0.91
Sector 12	13.83	41	10.55	0.88
Sector 13	3.97	39	10.07	0.79
Sector 14	4.57	41	9.63	1.01
Sector 15	2.98	40	9.98	0.89
Sector 16	6.07	40	10.52	0.69

(1987) and Ziliak (1998)). Here, I follow the strategy of Blundell et al. (2008) who estimate the demand for food (available in both surveys) as a function of total consumption, relative prices and household characteristics using the data in CEX, and then invert it to obtain a measure of total consumption in the PSID.

The first step in the imputation procedure is the estimation of the food demand function for individual i at time t:

$$f_{i,t} = Z'_{i,t}\delta + p'_t\theta + \beta\left(D_{i,t}\right)C_{i,t} + \epsilon_{i,t}$$

where f is the log of real food expenditure, Z is a set of household characteristics available in both surveys (a quadratic term in age, education, region, cohort, number of children and race dummies, family size), p is a set of prices (of food, alcohol and tobacco, transport, fuel and utilities), C is the log of total consumption expenditure and ϵ is the error term. The elasticity $\beta(\cdot)$ is allowed to vary with observed household characteristics. To account for potential measurement error in total expenditure, the latter is instrumented with the average hourly wages of the husband and the wife by cohort, year and education level. In both surveys food expenditure is the sum of annual expenditure on food at home and away from home.

In the second step of the imputation procedure, under the assumption of normality of food demand, the function can be inverted to obtain a measure of non-durable and total consumption in the PSID. The food demand is estimated with the sample of CEX male heads with ages between 22 and 80, born between 1921 and 1970. The imputation is done

Table 14: Number of observations

Age/Sector	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
22	191	76	14	154	33	317	45	61	64	133	187	58	96	97	124	63	63
23	247	99	22	190	72	400	61	92	78	180	234	115	208	131	157	84	113
24	295	134	41	225	111	479	83	123	106	202	262	156	318	167	162	100	153
25	322	146	61	257	154	529	94	136	134	217	287	176	371	177	184	113	175
26	305	154	70	269	186	563	116	146	146	246	259	185	443	187	191	120	188
27	281	148	83	277	188	564	126	181	188	213	239	197	501	196	191	113	205
28	274	173	85	286	197	565	138	192	190	208	218	201	541	203	199	126	207
29	269	172	98	275	218	553	150	190	190	199	238	203	522	202	197	122	225
30	262	167	113	270	230	571	140	213	193	210	197	208	527	184	191	117	242
31	285	178	110	280	246	550	155	193	203	195	200	189	554	165	164	117	243
32	263	169	109	274	246	580	167	195	209	188	193	184	579	150	157	103	250
33	240	163	116	259	243	582	168	207	201	197	182	190	559	145	155	107	251
34	244	154	117	237	252	541	166	201	177	196	203	188	532	135	169	126	256
35	225	168	126	238	245	533	166	184	196	195	189	176	547	124	156	130	253
36	220	154	138	221	255	510	159	201	200	184	182	182	534	135	152	101	247
37	238	154	130	210	255	509	159	186	183	167	187	177	504	130	139	118	252
38	211	155	107	226	249	499	170	174	171	163	179	162	530	136	135	110	260
39	222	146	107	196	257	485	173	181	159	173	165	167	516	129	133	108	253
40	196	151	120	183	257	490	162	183	167	167	157	167	514	123	130	112	251
41	177	147	118	172	255	494	160	160	173	173	148	172	497	122	126	128	242
42	176	151	108	198	254	470	158	167	164	162	147	164	493	113	125	113	230
43	190	147	94	202	252	451	149	167	152	148	137	173	480	96	132	110	223
44	175	139	97	193	257	438	144	178	148	138	133	175	478	106	122	102	218
45	172	143	102	180	234	441	146	178	142	136	130	164	473	102	125	96	227
46	169	141	95	175	235	438	136	168	152	131	141	164	470	95	126	78	212
47	166	137	85	163	232	428	139	169	158	124	130	167	454	88	120	71	207
48	158	138	88	148	214	421	139	159	148	127	135	158	429	100	121	74	201
49	164	131	87	138	197	408	132	162	135	121	138	156	410	110	112	72	196
50	137	118	88	152	205	392	127	154	119	104	129	139	415	95	126	66	194
51	131	117	89	141	201	381	119	148	121	100	114	123	407	91	126	62	185
52	132	119	84	130	195	364	113	153	98	95	124	119	385	97	107	59	166
53	119	122	77	122	168	356	108	139	88	82	125	123	371	93	107	70	145
54	135	117	74	113	163	325	104	121	87	85	128	126	350	84	100	65	130
55	148	114	70	100	168	298	96	116	78	83	123	120	337	84	100	61	125
56	126	115	62	89	153	274	91	109	70	84	119	113	328	74	114	59	117
57	101	103	64	89	139	256	81	104	69	85	112	112	308	86	112	61	105
58	85	103	59	89	123	243	78	86	73	77	107	108	282	84	111	53	101
59	115	91	48	82	108	228	75	73	69	69	106	104	269	67	110	53	84
60	105	91	47	74	100	201	62	62	60	73	88	89	240	66	104	49	82
61	94	87	47	62	79	184	40	55	54	66	83	82	210	62	99	49	57
62	88	68	34	49	74	149	37	47	57	51	79	70	160	61	79	42	57
63	83	57	27	34	56	120	35	38	50	50	69	61	132	51	69	35	42
64	76	52	25	32	45	84	28	28	43	42	59	55	118	44	63	31	28
65	62	40	21	18	32	50	13	21	33	29	48	39	95	29	57	25	20

Notes: Table entries are number of observations in each age-sector cell.

on a similarly constructed PSID sample, which does not include the SEO, immigrants

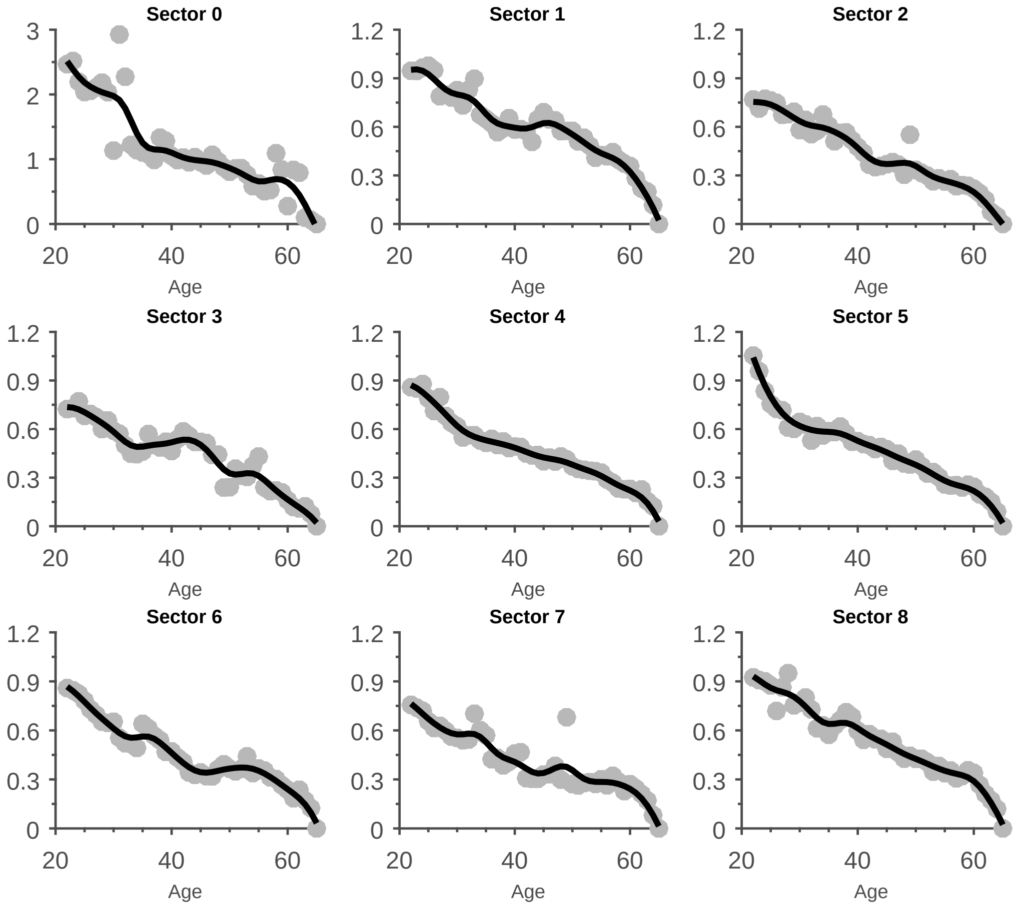


Figure 12: Age Profile of Income Uncertainty Relative to Permanent Income - sector level

Notes: The definition of sectors is in Table 1 in Appendix A.

and latino sub-sample. The latter are excluded to avoid selection issues and allow a one to one mapping between the age profile of savings and the lifetime profile of income uncertainty previously constructed. Since CEX data is only available starting 1980, I am able to construct the PSID measure of total consumption from 1981 until 2003 (calendar years 1980-2002), with breaks in 1988 and 1989 when PSID did not collect information of food expenditure. When inverting the food demand equation, I set the constant term so that the average savings rate in the PSID matches the average savings rate reported in the NIPA Tables for the same horizon of 8.2%.

Savings are defined as after-tax income less consumption expenditure. After-tax income is constructed as total family money income less federal income taxes. Total family money income includes the taxable income and transfers of all members. The taxable income covers labor and asset income. Transfers are not removed from family income because for part of the survey years it is impossible to separate social security income from other forms of transfers (e.g. children aid for unemployed parents). In constructing disposable income I face the complication that PSID stopped determining taxes paid in 1991. To calculate taxes owed for calendar years $1991-2010$ (survey years $1992-2011$)

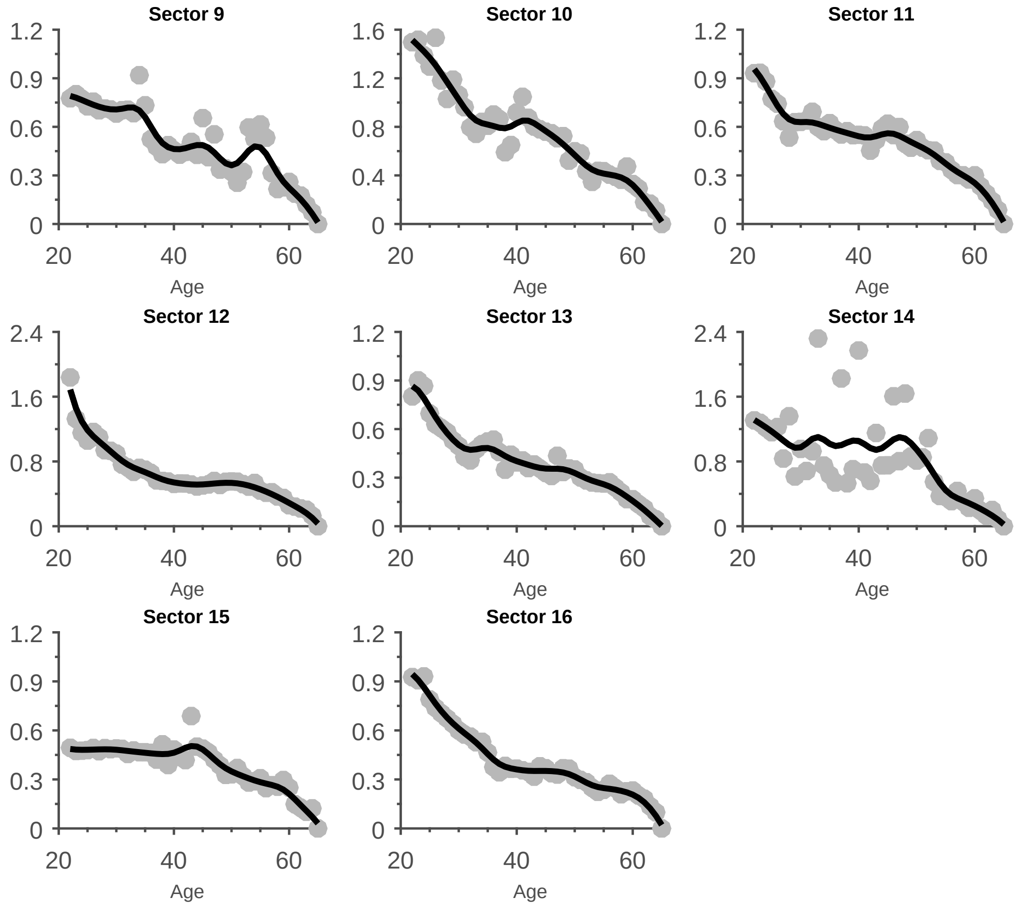


Figure 13: Age Profile of Income Uncertainty Relative to Permanent Income - sector level

Notes: The definition of sectors is in Table 1 in Appendix A.

I use TAXSIM with PSID variables as inputs.

A.6 Additional Empirical Results

Tables 15 and 16 in this section reports some additional empirical results referenced in the main text.

B Appendix for Quantitative Model

B.1 Computational Algorithm

The algorithm to compute a steady-state equilibrium amounts to finding the value functions and the associated decision rules, as well as the stationary measure of households of different ages. The two steps are now further detailed. The algorithm is written for the general case in which the child's age runs from 1 to H_c, the parent's age runs from $H_c + 1$ to H and there is a d periods age difference between parents and children.

Table 15: Importance of Health Status (child's equation)

	Non-durables and services		Total consumption	
	Baseline	Health controls	Baseline	Health controls
Parent's uncertainty	-0.039 (0.025)	-0.035 (0.025)	-0.043 (0.025)	-0.040 (0.025)
Child's uncertainty	-0.163** (0.038)	-0.162** (0.040)	-0.149** (0.038)	-0.148** (0.040)
$\mathbf{X}_p$				
Excellent health	−−	-0.030 (0.048)	−−	-0.040 (0.048)
Good health	−−	0.013 (0.047)	−−	-0.003 (0.047)
$\mathbf{X}_c$				
Excellent health	−−	0.362** (0.101)	−−	0.348** (0.091)
Good health	−−	0.259* (0.101)	−−	0.251** (0.091)

Notes: Table entries are coefficient estimates from equation (13). The set of covariates from the baseline estimation is augmented to include dummy variables for weather the parent and the child are in excellent and very good, good and fair or poor health condition. The latter is the omitted dummy. Robust standard errors clustered at child level are in parenthesis. * significant at 5%; ** significant at 1%

Finding the policy functions

The algorithm for finding the optimal policy functions for the parent $a'_p\left(h_p, a_p, a_c, y_p, y_c, s_p, s_c\right)$, $g_p\left(h_p, a_p, a_c, y_p, y_c, s_p, s_c\right)$ and the child $a'_c\left(h_c, a_c, y_c, g_p, a'_p, y_p, s_p, s_c\right)$, where $h_p = H_c + 1, \ldots, H$ and $h_c = h_p - d$ is as follows:

Step 1. Place a grid on the asset, transfer, labor income and sector spaces spaces. Let NA be the number of notes in the asset space, NG the number of nodes in the transfer space, NY be the number of nodes in the income space and NS the number of sectors. This means the state space has $d \times NA^2 \times NY^2 \times NS^2$ nodes for the parent's value function and $d \times NA^2 \times NY^2 \times NS^2 \times NG$ for the child's value function. The labor income grid and the corresponding age specific transition probabilities are approximated using the algorithm in Tauchen (1986).

Step 2. Initialize value function $V_0^p\left(H_c + 1, a_p, a_c, y_p, y_c, s_p, s_c\right)$, for all $a_p, a_c = 1, \ldots, NA$, $y_p, y_c = 1, \ldots, NY$ and $s_p, s_c = 1, \ldots, NS$.

Step 3. Starting from this guess, iterate backwards over all parent-child age pairs $\left(h_p, h_c\right) \in \left\{\left(H, H_c\right), \left(H-1, H_c - 1\right), \ldots, \left(H_c + 1, 1\right)\right\}$ to update the initial guess to

Table 16: Importance of the Bequest Motive for the Effect on Total Consumption

	Parent's uncertainty	Child's uncertainty	$n=2$	$n=3$	$n=4$	$n\geq 5$	$b=1$
			Panel A. Proxy for the bequest motive				
Bequest proxy: parent vs non-parent	-0.092** (0.031)	-0.077* (0.033)	– –	– –	– –	– –	– –
Bequest proxy: number of children	-0.069 (0.037)	-0.077* (0.034)	-0.069** (0.019)	-0.081** (0.029)	0.016 (0.035)	-0.299** (0.077)	– –
			Panel B. Direct measure of the bequest motive				
How important it is leaving an estate?	-0.081* (0.033)	-0.077* (0.034)	– –	– –	– –	– –	0.015 (0.020)

Notes: Table entries are coefficient estimates of the effect of parent's and child's uncertainty on parent's total consumption for various controls for the strength of the bequest motive. *Panel A*: The first row reports estimates of equation (12) when a dummy variable equal to 1 if the respondent is a parent and zero otherwise is used as proxy for the bequest motive. In the second row the number of children is used as proxy, with the reference group being number of children = 1 (parent has one adult child). *Panel B* The strength of the bequest motive is captured with a dummy variable that is equal to 1 if leaving an estate is important and 0 otherwise. Robust standard errors clustered at parent level are in parenthesis. * significant at 5%; ** significant at 1%

$V_1^p\left(H_c+1, a_p, a_c, y_p, y_c, s_p, s_c\right)$. To that end, for each parent child pair solve the two-stage game backwards, as follows:

Step 3.1 Solve the child's optimization problem to get the policy functions $c_c^{\star}\left(h_c, a_c, y_c, g_p, a_p', y_p, s_p, s_c\right)$ and $a_c'^{\star}\left(h_c, a_c, y_c, g_p, a_p', y_p, s_p, s_c\right)$.

Step 3.2 Given the child's policy function, solve the parent's optimization problem to get policy functions $c_p^{\star}\left(h_p, a_p, a_c, y_p, y_c, s_p, s_c\right)$, $g_p^{\star}\left(h_p, a_p, a_c, y_p, y_c, s_p, s_c\right)$ and $a_p'^{\star}\left(h_p, a_p, a_c, y_p, y_c, s_p, s_c\right)$. Given a_p', the transfer g_p is set as follows: *(i)* if $a_c'^{\star}\left(h_c, a_c, y_c, 0, a_p', y_p, s_p, s_c\right) > \underline{A}_{h_c}$, then $g_p^{\star}\left(h_p, a_p, a_c, y_p, y_c, s_p, s_c\right) = 0$ and *(ii)* if $a_c'^{\star}\left(h_c, a_c, y_c, 0, a_p', y_p, s_p, s_c\right) = \underline{A}_{h_c}$, then $g_p^{\star}\left(h_p, a_p, a_c, y_p, y_c, s_p, s_c\right) = \max\left\{0, \hat{g}_p\right\}$, where $\hat{g}_p$ solves

$$u'\left(y_p + Ra_p - a_p' - g_p\right) - \gamma u'\left(c_c^{\star}\left(h_c, a_c, y_c, g_p, a_p', y_p, s_p, s_c\right)\right) = 0$$

Savings a_p' are then chosen to maximize the parent's value function. Once the parent's policy functions are computed, the child's consumption can be backed out as

$$c_c\left(h_c, a_p, a_c, y_p, y_c, s_p, s_c\right) =$$
$$c_c^{\star}\left(h_c, a_c, y_c, g_p^{\star}\left(h_p, a_p, a_c, y_p, y_c, s_p, s_c\right), a_p'^{\star}\left(h_p, a_p, a_c, y_p, y_c, s_p, s_c\right), y_p, s_p, s_c\right)$$

Step 4. Iterate until V_0 and V_1 are close enough.

Finding the stationary distribution

Let $A = [-\underline{a}, \bar{a}]$, $Y = \left[\underline{y}, \bar{y}\right]$ and $S = [\underline{s}, \bar{s}]$ be the asset, labor efficiency and sector space, respectively. Define $\tilde{S} \equiv A^2 \times Y^2 \times S^2$ as the state space with the generic element $\tilde{s} = \left(a_p, a_c, y_p, y_c, s_p, s_c\right)$. Denote as $\tilde{\mathcal{S}}$ the Borel σ-algebra of the state space, with typical subset $\mathcal{A}^2 \times \mathcal{Y}^2 \times \mathcal{S}^2$. Let $f_h(\tilde{s})$ be a probability measure defined over $\left(\tilde{S}, \tilde{\mathcal{S}}\right)$. $f_h(\tilde{s})$ denotes the measure of households of age h which have state variable s. Denote as $F_h(\tilde{s})$ the corresponding cumulative distribution function. Normalizing to 1 the population of age 1 households, the size of the population of age h can be expressed at any point in time as $f_h\left(\tilde{S}\right) = \int_{\tilde{S}} \mathrm{d}F_h(\tilde{s}) = \frac{1}{(1+v)^{h-1}}$.

In a stationary (partial) equilibrium, the invariant measures for this economy (normalized by the population growth) need to satisfy the following consistency conditions:

The consistency condition for a child household of age $h_c = 1$ is:

$$\begin{aligned} f_1\left(\tilde{s}'\right) &= (1+v) \int_{\tilde{S}} \mathbf{1}_{\left\{a_p' = a_{H_c}'(\tilde{s}) + \frac{a_H'(\tilde{s})}{n}\right\}} \mathbf{1}_{\{a_c'=0\}} \pi^s_{H_c+1}\left(s_p'|s_c\right) \pi^s_{\mathrm{ch}}\left(s_c'|s_p'\right) \\ &\quad \pi^y_{H_c+1}\left(y_p'|y_c, s_p'\right) \pi_{\mathrm{ch}}\left(y_c'|y_p', s_c'\right) \mathrm{d}F_{H_c}(\tilde{s}) \end{aligned}$$

and that for child households of age $h_c = 2, \ldots, H_c$ is:

$$\begin{aligned} f_{h_c}\left(\tilde{s}'\right) &= \frac{1}{1+v} \int_{\tilde{S}} \mathbf{1}_{\left\{a_p' = a_{h_p-1}'(\tilde{s})\right\}} \mathbf{1}_{\left\{a_c' = a_{h_c-1}'(\tilde{s})\right\}} \pi^s_{h_p}\left(s_p'|s_p\right) \pi^s_{h_c}\left(s_c'|s_c\right) \\ &\quad \pi^y_{h_p}\left(y_p'|y_p, s_p'\right) \pi^y_{h_c}\left(y_c'|y_c, s_c'\right) \mathrm{d}F_{h_c-1}(\tilde{s}) \end{aligned}$$

Since every parent household has $n = (1+v)^d$ children, where d is the age difference between parents and children, the measure of parent households of age $h_p = H_c + 1, \ldots, H$ is $f_{h_p}\left(\tilde{s}'\right) = \frac{1}{n} f_{h_c}\left(\tilde{s}'\right)$.

The procedure to find the stationary distribution is as follows:

Step 1. Place a grid on the asset space that is finer than the one used to compute the optimal decision rules. Let NA_m be the number of nodes in the asset space and NY be the number of nodes in the income space.

Step 2. Choose initial discrete density functions $f_0\left(h_c, a_p, a_c, y_p, y_c, s_p, s_c\right)$ over that grid for $h_c = 1, \ldots, H_c$.

Step 3. Set $f_1(\cdot) = 0$.

(a) If $h_c \in \{2, \ldots, h_c\}$, then for all $a_p, a_c, y_p, y_c, s_p, s_c$ do the following:

Step 3.1 Find the indexes j'_p and j'_c on the asset grid that satisfy

$$a_{j'_p} \leq a'_p\left(h_p - 1, a_p, a_c, y_p, y_c, s_p, s_c\right) < a_{j'_p+1}$$

and

$$a_{j'_c} \leq a'_c\left(h_c - 1, a_p, a_c, y_p, y_c, s_p, s_c\right) < a_{j'_c+1}$$

If $a'_p\left(h_p - 1, a_p, a_c, y_p, y_c, s_p, s_c\right) \geq a_{NA_m}$ or $a'_c\left(h_c - 1, a_p, a_c, y_p, y_c, s_p, s_c\right) \geq a_{NA_m}$, set the indexes as $j'_p = NA_m - 1$ and $j'_c = NA_m - 1$.

Step 3.2 Calculate the weights

$$\omega_p = \frac{a'_p\left(h_p - 1, a_p, a_c, y_p, y_c, s_p, s_c\right) - a_{j'_p}}{a_{j'_p+1} - a_{j'_p}}$$

and

$$\omega_c = \frac{a'_c\left(h_c - 1, a_p, a_c, y_p, y_c, s_p, s_c\right) - a_{j'_c}}{a_{j'_c+1} - a_{j'_c}}$$

Step 3.3 For all y'_p, y'_c, s'_p, s'_c, update the distribution as follows

$$\begin{aligned}
&f_1\left(h_c, a_{p,j'_p}, a_{c,j'_c}, y'_p, y'_c, s'_p, s'_c\right) := f_1\left(h_c, a_{p,j'_p}, a_{c,j'_c}, y'_p, y'_c, s'_p, s'_c\right) + \\
&+\frac{1}{1+v}\left(1-\omega_p\right)\left(1-\omega_c\right)\pi^s_{h_p}\left(s'_p|s_p\right)\pi^s_{h_c}\left(s'_c|s_c\right) \\
&\pi^y_{h_p}\left(y'_p|y_p, s'_p\right)\pi^y_{h_c}\left(y'_c|y_c, s'_c\right) f_0\left(h_c - 1, a_p, a_c, y_p, y_c, s_p, s_c\right)
\end{aligned}$$

$$\begin{aligned}
&f_1\left(h_c, a_{p,j'_p}, a_{c,j'_c+1}, y'_p, y'_c, s'_p, s'_c\right) := f_1\left(h_c, a_{p,j'_p}, a_{c,j'_c+1}, y'_p, y'_c, s'_p, s'_c\right) + \\
&+\frac{1}{1+v}\left(1-\omega_p\right)\omega_c\pi^s_{h_p}\left(s'_p|s_p\right)\pi^s_{h_c}\left(s'_c|s_c\right) \\
&\pi^y_{h_p}\left(y'_p|y_p, s'_p\right)\pi^y_{h_c}\left(y'_c|y_c, s'_c\right) f_0\left(h_c - 1, a_p, a_c, y_p, y_c, s_p, s_c\right)
\end{aligned}$$

$$f_1\left(h_c, a_{p,j'_p+1}, a_{c,j'_c}, y'_p, y'_c, s'_p, s'_c\right) := f_1\left(h_c, a_{p,j'_p+1}, a_{c,j'_c}, y'_p, y'_c, s'_p, s'_c\right) +$$
$$+\frac{1}{1+v}\omega_p\left(1-\omega_c\right)\pi^s_{h_p}\left(s'_p|s_p\right)\pi^s_{h_c}\left(s'_c|s_c\right)$$
$$\pi^y_{h_p}\left(y'_p|y_p, s'_p\right)\pi^y_{h_c}\left(y'_c|y_c, s'_c\right)f_0\left(h_c-1, a_p, a_c, y_p, y_c, s_p, s_c\right)$$

and

$$f_1\left(h_c, a_{p,j'_p+1}, a_{c,j'_c+1}, y'_p, y'_c, s'_p, s'_c\right) := f_1\left(h_c, a_{p,j'_p+1}, a_{c,j'_c+1}, y'_p, y'_c, s'_p, s'_c\right) +$$
$$+\frac{1}{1+v}\omega_p\omega_c\pi^s_{h_p}\left(s'_p|s_p\right)\pi^s_{h_c}\left(s'_c|s_c\right)$$
$$\pi^y_{h_p}\left(y'_p|y_p, s'_p\right)\pi^y_{h_c}\left(y'_c|y_c, s'_c\right)f_0\left(h_c-1, a_p, a_c, y_p, y_c, s_p, s_c\right)$$

(b) If $h_c = 1$, then for all $a_p, a_c, y_p, y_c, s_p, s_c$ do the following:

Step 3.1 Find the indexes j'_p and j'_c that satisfy

$$a_{j'_p} \le a'_c\left(H_c, a_p, a_c, y_p, y_c, s_p, s_c\right) + \frac{a'_p\left(H, a_p, a_c, y_p, y_c, s_p, s_c\right)}{n} < a_{j'_p+1}$$

and

$$a_{j'_c} \le 0 < a_{j'_c+1}$$

If $a'_c\left(H_c, a_p, a_c, y_p, y_c, s_p, s_c\right) + \frac{a'_p\left(H, a_p, a_c, y_p, y_c, s_p, s_c\right)}{n} \ge a_{NA_m}$, set the index as $j'_p = NA_m - 1$.

Step 3.2 Calculate the weights

$$\omega_p = \frac{a'_c\left(H_c, a_p, a_c, y_p, y_c, s_p, s_c\right) + \frac{a'_p\left(H, a_p, a_c, y_p, y_c, s_p, s_c\right)}{n} - a_{j'_p}}{a_{j'_p+1} - a_{j'_p}}$$

and

$$\omega_c = \frac{0 - a_{j'_c}}{a_{j'_c+1} - a_{j'_c}}$$

Step 3.3 For y'_p, y'_c, s'_p, s'_c, update the distribution as follows

$$f_1\left(h_c, a_{p,j'_p}, a_{c,j'_c}, y'_p, y'_c, s'_p, s'_c\right) := f_1\left(h_c, a_{p,j'_p}, a_{c,j'_c}, y'_p, y'_c, s'_p, s'_c\right) +$$
$$+\left(1+v\right)\left(1-\omega_p\right)\left(1-\omega_c\right)\pi^s_{H_c+1}\left(s'_p|s_c\right)\pi^s_{\text{ch}}\left(s'_c|s'_p\right)$$
$$\pi^y_{H_c+1}\left(y'_p|y_c, s'_p\right)\pi_{\text{ch}}\left(y'_c|y'_p, s'_c\right)f_0\left(h_c-1, a_p, a_c, y_p, y_c, s_p, s_c\right)$$

$$f_1\left(h_c,a_{p,j_p'},a_{c,j_c'+1},y_p',y_c',s_p',s_c'\right):=f_1\left(h_c,a_{p,j_p'},a_{c,j_c'+1},y_p',y_c',s_p',s_c'\right)+$$
$$+(1+v)\left(1-\omega_p\right)\omega_c\pi^s_{H_c+1}\left(s_p'|s_c\right)\pi^s_{\text{ch}}\left(s_c'|s_p'\right)$$
$$\pi^y_{H_c+1}\left(y_p'|y_c,s_p'\right)\pi_{\text{ch}}\left(y_c'|y_p',s_c'\right)f_0\left(h_c-1,a_p,a_c,y_p,y_c,s_p,s_c\right)$$

$$f_1\left(h_c,a_{p,j_p'+1},a_{c,j_c'},y_p',y_c',s_p',s_c'\right):=f_1\left(h_c,a_{p,j_p'+1},a_{c,j_c'},y_p',y_c',s_p',s_c'\right)+$$
$$+(1+v)\,\omega_p\left(1-\omega_c\right)\pi^s_{H_c+1}\left(s_p'|s_c\right)\pi^s_{\text{ch}}\left(s_c'|s_p'\right)$$
$$\pi^y_{H_c+1}\left(y_p'|y_c,s_p'\right)\pi_{\text{ch}}\left(y_c'|y_p',s_c'\right)f_0\left(h_c-1,a_p,a_c,y_p,y_c,s_p,s_c\right)$$

and

$$f_1\left(h_c,a_{p,j_p'+1},a_{c,j_c'+1},y_p',y_c',s_p',s_c'\right):=f_1\left(h_c,a_{p,j_p'+1},a_{c,j_c'+1},y_p',y_c',s_p',s_c'\right)+$$
$$+(1+v)\,\omega_p\omega_c\pi^s_{H_c+1}\left(s_p'|s_c\right)\pi^s_{\text{ch}}\left(s_c'|s_p'\right)$$
$$\pi^y_{H_c+1}\left(y_p'|y_c,s_p'\right)\pi_{\text{ch}}\left(y_c'|y_p',s_c'\right)f_0\left(h_c-1,a_p,a_c,y_p,y_c,s_p,s_c\right)$$

Step 4. Iterate until f_0 and f_1 are close enough.

B.2 Equilibrium of the model with strategic interactions

This is a two-period example (the parent and the child overlap for two periods) with no income risk and one sector, but the conclusions extend to a multi-period setting with income risk. In the first stage, the parent chooses c_p, a_p' and g_p. In the second stage, given the parent's decision, the child chooses c_c and a_c'. The argument goes about showing that each stage game has a unique equilibrium.

Age 4 parent with age 2 child

In the parent's terminal period the problem of the child (second stage) is:

$$\begin{aligned} V^c\left(2,a_c,y_c,g_p,a_p'\right) &= \max_{c_c,a_c'} u\left(c_c\right)+\beta V^p\left(3,a_p'+a_c',0,y_p',y_c'\right) \\ \text{s.t.} &\quad c_c+a_c'=y_c+Ra_c+g_p \\ &\quad a_c'\geq 0 \end{aligned}$$

The first order condition is

$$u'\left(c_c\right)=\beta V_2^p\left(3,a_p'+a_c',0,y_p',y_c'\right)+\lambda_{a_c}$$

where $\lambda_{a_c}\geq 0$ is the multiplier on the borrowing constraint and V_2^p denotes the derivative of the value function with respect to its second argument. The optimal policy functions are $c_c\left(2, a_c, y_c, g_p, a'_p\right)$ and $a'_c\left(2, a_c, y_c, g_p, a'_p\right)$.

In the first stage the parent solves

$$\begin{aligned} V^p\left(4, a_p, a_c, y_p, y_c\right) &= \max_{c_p, a'_p, g_p} u\left(c_p\right) + \gamma u\left(c_c^\star\left(2, a_c, y_c, g_p, a'_p\right)\right) \\ &+ \beta\gamma V^p\left(3, a'_p + a_c'^\star\left(2, a_c, y_c, g_p, a'_p\right), 0, y'_p, y'_c\right) \\ \text{s.t.} \quad & c_p + a'_p + g_p = y_p + Ra_p \\ & a'_p \geq 0, g_p \geq 0 \end{aligned}$$

given that $u'\left(c_c^\star\left(2, a_c, y_c, g_p, a'_p\right)\right) = \beta V_2^p\left(3, a'_p + a_c'^\star\left(2, a_c, y_c, g_p, a'_p\right), 0, y'_p, y'_c\right) + \lambda_{a_c}$.

The first order condition with respect to a'_p is:

$$u'\left(c_p\right) = \gamma u'\left(c_c^\star\right)\frac{\partial c_c^\star}{\partial a'_p} + \beta\gamma V_2^p\left(3, a'_p + a_c'^\star, 0, y'_p, y'_c\right)\left(1 + \frac{\partial a_c'^\star}{\partial a'_p}\right) + \lambda_{a_p}$$

where λ_{a_p} is the multiplier on the borrowing constraint. From the child's budget constraint we have $\frac{\partial c_c^\star}{\partial a'_p} = -\frac{\partial a_c'^\star}{\partial a'_p}$, so the above becomes

$$\begin{aligned} u'\left(c_p\right) &= \gamma\frac{\partial c_c^\star}{\partial a'_p}\left(u'\left(c_c^\star\right) - \beta V_2^p\left(3, a'_p + a_c'^\star, 0, y'_p, y'_c\right)\right) + \beta\gamma V_2^p\left(3, a'_p + a_c'^\star, 0, y'_p, y'_c\right) + \lambda_{a_p} \\ &= \gamma\frac{\partial c_c^\star}{\partial a'_p}\lambda_{a_c} + \beta\gamma V_2^p\left(3, a'_p + a_c'^\star, 0, y'_p, y'_c\right) + \lambda_{a_p} \end{aligned}$$

The first order condition with respect to g_p is:

$$u'\left(c_p\right) = \gamma u'\left(c_c^\star\right)\frac{\partial c_c^\star}{\partial g_p} + \beta\gamma V_2^p\left(3, a'_p + a_c'^\star, 0, y'_p, y'_c\right)\frac{\partial a_c'^\star}{\partial g_p} + \lambda_g$$

where λ_{g_p} is the multiplier on the non-negativity of transfers constraint. From the child's budget constraint we have $\frac{\partial c_c^\star}{\partial g_p} = 1 - \frac{\partial a_c'^\star}{\partial g_p}$, so the above becomes

$$\begin{aligned} u'\left(c_p\right) &= \gamma u'\left(c_c^\star\right) + \gamma\frac{\partial a_c'^\star}{\partial g_p}\left(\beta V_2^p\left(3, a'_p + a_c'^\star, 0, y'_p, y'_c\right) - u'\left(c_c^\star\right)\right) + \lambda_g \\ &= \gamma u'\left(c_c^\star\right) - \gamma\frac{\partial a_c'^\star}{\partial g_p}\lambda_{a_c} + \lambda_g \end{aligned}$$

Call the resulting optimal policy functions $a'_p\left(4, a_p, a_c, y_p, y_c\right)$ and $g_p\left(4, a_p, a_c, y_p, y_c\right)$.

Age 3 **parent with age** 1 **child**

In the first period the problem of the child (second stage) is:

$$
\begin{aligned}
V^{c}\left(1, a_{c}, y_{c}, g_{p}, a_{p}^{\prime}\right) &= \max_{c_{c}, a_{c}^{\prime}} u\left(c_{c}\right)+\beta V^{c}\left(2, a_{c}^{\prime}, y_{c}^{\prime}, g_{p}^{\prime}\left(4, a_{p}^{\prime}, a_{c}^{\prime}, y_{p}^{\prime}, y_{c}^{\prime}\right), a_{p}^{\prime\prime}\left(4, a_{p}^{\prime}, a_{c}^{\prime}, y_{p}^{\prime}, y_{c}^{\prime}\right)\right) \\
\text{s.t.} \quad & c_{c}+a_{c}^{\prime}=y_{c}+R a_{c}+g_{p} \\
& a_{c}^{\prime} \geq 0
\end{aligned}
$$

The first order condition is

$$
u^{\prime}\left(c_{c}\right)=\beta V_{2}^{c}\left(2, a_{c}^{\prime}, y_{c}^{\prime}, g_{p}^{\prime}, a_{p}^{\prime\prime}\right)+\beta V_{4}^{c}\left(2, a_{c}^{\prime}, y_{c}^{\prime}, g_{p}^{\prime}, a_{p}^{\prime\prime}\right) \frac{\partial g_{p}^{\prime}}{\partial a_{c}^{\prime}}+\beta V_{5}^{c}\left(2, a_{c}^{\prime}, y_{c}^{\prime}, g_{p}^{\prime}, a_{p}^{\prime\prime}\right) \frac{\partial a_{p}^{\prime\prime}}{\partial a_{c}^{\prime}}+\lambda_{a_{c}}
$$

where $\lambda_{a_c} \geq 0$ is the multiplier on the borrowing constraint and V_n^c denotes the derivative of the child's value function with respect to its n^{th} argument. The optimal policy functions are $c_c\left(1, a_c, y_c, g_p, a_p^{\prime}\right)$ and $a_c^{\prime}\left(1, a_c, y_c, g_p, a_p^{\prime}\right)$.

In the first stage the parent solves

$$
\begin{aligned}
V^{p}\left(3, a_{p}, a_{c}, y_{p}, y_{c}\right) &= \max_{c_{p}, a_{p}^{\prime}, g_{p}} u\left(c_{p}\right)+\gamma u\left(c_{c}^{\star}\left(1, a_{c}, y_{c}, g_{p}, a_{p}^{\prime}\right)\right) \\
&+ \beta V^{p}\left(4, a_{p}^{\prime}, a_{c}^{\prime\star}\left(1, a_{c}, y_{c}, g_{p}, a_{p}^{\prime}\right), y_{p}^{\prime}, y_{c}^{\prime}\right) \\
\text{s.t.} \quad & c_{p}+a_{p}^{\prime}+g_{p}=y_{p}+R a_{p} \\
& a_{p}^{\prime} \geq 0, g_{p} \geq 0
\end{aligned}
$$

given that $c_c^{\star}\left(1, a_c, y_c, g_p, a_p^{\prime}\right)$ and $a_c^{\prime\star}\left(1, a_c, y_c, g_p, a_p^{\prime}\right)$ satisfy the child's first order condition and budget constraint.

The first order condition with respect to $a_p^{\prime}$ is:

$$
\begin{aligned}
u^{\prime}\left(c_{p}\right) &= \gamma u^{\prime}\left(c_{c}^{\star}\right) \frac{\partial c_{c}^{\star}}{\partial a_{p}^{\prime}}+\beta V_{2}^{p}\left(4, a_{p}^{\prime}, a_{c}^{\prime\star}\left(1, a_{c}, y_{c}, g_{p}, a_{p}^{\prime}\right), y_{p}^{\prime}, y_{c}^{\prime}\right) \\
&+\beta V_{3}^{p}\left(4, a_{p}^{\prime}, a_{c}^{\prime\star}\left(1, a_{c}, y_{c}, g_{p}, a_{p}^{\prime}\right), y_{p}^{\prime}, y_{c}^{\prime}\right) \frac{\partial a_{c}^{\prime\star}}{\partial a_{p}^{\prime}}+\lambda_{a_{p}}
\end{aligned}
$$

where λ_{a_p} is the multiplier on the borrowing constraint and V_n^p denotes the derivative of the parent's value function with respect to its n^{th} argument.

The first order condition with respect to g_p is:

$$
u^{\prime}\left(c_{p}\right) = \gamma u^{\prime}\left(c_{c}^{\star}\right) \frac{\partial c_{c}^{\star}}{\partial g_{p}}+\beta V_{3}^{p}\left(4, a_{p}^{\prime}, a_{c}^{\prime\star}\left(1, a_{c}, y_{c}, g_{p}, a_{p}^{\prime}\right), y_{p}^{\prime}, y_{c}^{\prime}\right) \frac{\partial a_{c}^{\prime\star}}{\partial g_{p}}+\lambda_{g}
$$

where λ_{g_p} is the multiplier on the non-negativity of transfers constraint. Call the resulting optimal policy functions $a_p^{\prime}\left(4, a_p, a_c, y_p, y_c\right)$ and $g_p\left(4, a_p, a_c, y_p, y_c\right)$.

Uniqueness at interior solution

Age 4 *parent with age* 2 *child*

The envelope condition in the child's problem is

$$\begin{aligned} V_2^c\left(2, a_c, y_c, g_p, a_p'\right) &= u'\left(c_c\right)R \\ &+ \frac{\partial g_p\left(4, a_p, a_c, y_p, y_c\right)}{\partial a_c}\left(u'\left(c_c\right) + \beta V_2^p\left(3, a_p' + a_c', 0, y_p', y_c'\right)\frac{\partial a_c'\left(2, a_c, y_c, g_p, a_p'\right)}{\partial g_p\left(4, a_p, a_c, y_p, y_c\right)}\right) \\ &+ \frac{\partial a_p'\left(4, a_p, a_c, y_p, y_c\right)}{\partial a_c}\beta V_2^p\left(3, a_p' + a_c', 0, y_p', y_c'\right)\left(1 + \frac{\partial a_c'\left(2, a_c, y_c, g_p, a_p'\right)}{\partial a_p'\left(4, a_p, a_c, y_p, y_c\right)}\right) \end{aligned}$$

Updating one period ahead the terms in the second and third row disappear because the parent dies at the end of age 4, so the child's Euler equation at an interior solution is

$$u'\left(c_c\right) = \beta R u'\left(c_c'\right)$$

and has a unique solution by the properties of the utility function.

From the child's problem we also have

$$V_4^c\left(2, a_c, y_c, g_p, a_p'\right) = u'\left(c_c\left(2, a_c, y_c, g_p, a_p'\right)\right)$$

and

$$V_5^c\left(2, a_c, y_c, g_p, a_p'\right) = \beta V_2^p\left(3, a_p' + a_c', 0, y_p', y_c'\right) = \beta R u'\left(c_c'\right)$$

where $c_c' = c_c\left(3, a_p' + a_c', 0, y_p', y_c'\right)$. These will be used later on.

The envelope condition in the parent's problem is

$$V_2^p\left(4, a_p, a_c, y_p, y_c\right) = u'\left(c_p\right)R$$

so the parent's Euler equation at an interior solution is

$$u'\left(c_p\right) = \beta\gamma R u'\left(c_c'\right)$$

which has a unique solution by the properties of the utility function. Therefore, the interior solution in this stage of the game is unique.

From the parent's problem we also have

$$V_3^p\left(4, a_p, a_c, y_p, y_c\right) = \gamma R u'\left(c_c^\star\left(2, a_c, y_c, g_p, a_p'\right)\right)$$

Age 3 *parent with age* 1 *child*

Using the results in the child's problem from above we have

$$\begin{aligned}
V_2^c\left(2,a_c',y_c',g_p',a_p''\right) &= u'\left(c_c\left(2,a_c',y_c',g_p',a_p''\right)\right)R \\
V_4^c\left(2,a_c',y_c',g_p',a_p''\right) &= u'\left(c_c\left(2,a_c',y_c',g_p',a_p''\right)\right) \\
V_5^c\left(2,a_c',y_c',g_p',a_p''\right) &= \beta V_2^p\left(3,a_p''+a_c'',0,y_p'',y_c''\right) = \beta R u'\left(c_c\left(3,a_p''+a_c'',0,y_p'',y_c''\right)\right)
\end{aligned}$$

The envelope condition with respect to a_c in the child's problem is

$$\begin{aligned}
V_2^c\left(1,a_c,y_c,g_p,a_p'\right) &= u'\left(c_c\left(1,a_c,y_c,g_p,a_p'\right)\right)R \\
&\quad+\frac{\partial g_p\left(3,a_p,a_c,y_p,y_c\right)}{\partial a_c}u'\left(c_c\left(1,a_c,y_c,g_p,a_p'\right)\right) \\
&\quad+\frac{\partial a_p'\left(3,a_p,a_c,y_p,y_c\right)}{\partial a_c}\left(\beta V_4^c\left(2,a_c',y_c',g_p',a_p''\right)\frac{\partial g_p'\left(4,a_p',a_c',y_p',y_c'\right)}{\partial a_p'\left(3,a_p,a_c,y_p,y_c\right)}\right. \\
&\quad\left.+\beta V_5^c\left(2,a_c',y_c',g_p',a_p''\right)\frac{\partial a_p''\left(4,a_p',a_c',y_p',y_c'\right)}{\partial a_p'\left(3,a_p,a_c,y_p,y_c\right)}\right)
\end{aligned}$$

When updating one period ahead the terms in the brackets last two rows collapse to $\beta V_2^p\left(3,a_p''+a_c'',0,y_p'',y_c''\right)$ as the parent dies at the end of age 4. Therefore

$$\begin{aligned}
V_2^c\left(2,a_c',y_c',g_p',a_p''\right) &= u'\left(c_c\left(2,a_c',y_c',g_p',a_p''\right)\right)\left(R+\frac{\partial g_p'\left(4,a_p',a_c',y_p',y_c'\right)}{\partial a_c'}\right) \\
&\quad+\frac{\partial a_p''\left(4,a_p',a_c',y_p',y_c'\right)}{\partial a_c'}V_2^p\left(3,a_p''+a_c'',0,y_p'',y_c''\right)
\end{aligned}$$

However, we know from the problem of an age 4 parent with an age 2 child that along the equilibrium path

$$V_2^c\left(2,a_c,y_c,g_p,a_p'\right) = u'\left(c_c\left(2,a_c,y_c,g_p,a_p'\right)\right)R,\ \forall a_c,y_c,g_p,a_p'$$

Therefore, it must be that

$$u'\left(c_c\left(2,a_c',y_c',g_p',a_p''\right)\right)\frac{\partial g_p'\left(4,a_p',a_c',y_p',y_c'\right)}{\partial a_c'}+\frac{\partial a_p''\left(4,a_p',a_c',y_p',y_c'\right)}{\partial a_c'}\beta V_2^p\left(3,a_p''+a_c'',0,y_p'',y_c''\right)=0$$

and

$$V_2^c\left(2,a_c',y_c',g_p',a_p''\right) = u'\left(c_c\left(2,a_c',y_c',g_p',a_p''\right)\right)R$$

The envelope condition with respect to g_p in the child's problem is

$$V_4^c\left(1,a_c,y_c,g_p,a_p'\right) = u'\left(c_c\left(1,a_c,y_c,g_p,a_p'\right)\right)$$

and updating one period ahead we have

$$V_4^c\left(2,a_c',y_c',g_p',a_p''\right) = u'\left(c_c\left(2,a_c',y_c',g_p',a_p''\right)\right)$$

Lastly, the envelope condition with respect to a_p' in the child's problem is

$$\begin{aligned} V_5^c\left(1,a_c,y_c,g_p,a_p'\right) &= \beta V_4^c\left(2,a_c',y_c',g_p',a_p''\right)\frac{\partial g_p'\left(4,a_p',a_c',y_p',y_c'\right)}{\partial a_p'\left(3,a_p,a_c,y_p,y_c\right)} \\ &\quad +\beta V_5^c\left(2,a_c',y_c',g_p',a_p''\right)\frac{\partial a_p''\left(4,a_p',a_c',y_p',y_c'\right)}{\partial a_p'\left(3,a_p,a_c,y_p,y_c\right)} \end{aligned}$$

which collapses to $\beta V_2^p\left(3,a_p''+a_c'',0,y_p'',y_c''\right)$ when updating one period ahead.

Therefore, the child's Euler equation at an interior solution is

$$\begin{aligned} u'\left(c_c\right) &= \beta\left(Ru'\left(c_c'\right)+\underbrace{u'\left(c_c'\right)\frac{\partial g_p'}{\partial a_c'}+\beta V_2^p\left(3,a_p''+a_c'',0,y_p'',y_c''\right)\frac{\partial a_p''}{\partial a_c'}}_{=0 \text{ by the argument on the previous page}}\right) \\ &= \beta Ru'\left(c_c'\right) \end{aligned}$$

where $c_c'=c_c\left(2,a_c',y_c',g_p',a_p''\right)$. This has a unique solution by the properties of the utility function.

For the parent's problem, using the results in the age 4 parent with age 2 child case, we have

$$\begin{aligned} V_2^p\left(4,a_p',a_c',y_p',y_c'\right) &= Ru'\left(c_p\left(4,a_p',a_c',y_p',y_c'\right)\right) \\ V_3^p\left(4,a_p',a_c',y_p',y_c'\right) &= \gamma Ru'\left(c_c\left(2,a_c,y_c,g_p,a_p'\right)\right) \end{aligned}$$

The envelope condition with respect to a_p in the parent's problem is

$$V_2^p\left(3,a_p,a_c,y_p,y_c\right) = u'\left(c_p\right)R$$

which updated one period ahead gives

$$V_2^p\left(4,a_p',a_c'^{\star},y_p',y_c'\right) = Ru'\left(c_p\left(4,a_p',a_c',y_p',y_c'\right)\right)$$

The envelope condition with respect to a_c in the parent's problem is

$$V_3^p\left(3,a_p,a_c,y_p,y_c\right) = \gamma R u'\left(c_c^{\star}\left(1,a_c,y_c,g_p,a_p'\right)\right)$$

and updating one period ahead we have

$$V_3^p\left(4,a_p',a_c',y_p',y_c'\right) = \gamma R u'\left(c_c\left(2,a_c',y_c',g_p',a_p''\right)\right)$$

Therefore, the parent's Euler equation at an interior solution is

$$\begin{aligned} u'\left(c_p\right) &= \gamma u'\left(c_c^{\star}\right)\frac{\partial c_c^{\star}}{\partial a_p'} + \beta R u'\left(c_p'\right) + \beta\frac{\partial a_c'^{\star}}{\partial a_p'}\gamma R u'\left(c_c'\right) \\ &= \gamma\frac{\partial c_c^{\star}}{\partial a_p'}\underbrace{\left(u'\left(c_c^{\star}\right) - \beta R u'\left(c_c'\right)\right)}_{=0 \text{ by child Euler's equation}} + \beta R u'\left(c_p'\right) \\ &= \beta R u'\left(c_p'\right) \end{aligned}$$

which also has a unique solution by the properties of the utility function. Therefore, there is a unique equilibrium in this stage of the game.

Properties of the transfer function

Age 4 *parent with age* 2 *child*

Since the parent makes the first move in the stage game, he can limit the strategic behavior of the child by setting the transfer according to $u'\left(c_p\right) = \gamma u'\left(c_c\right)$, as he would in a setup with no strategic interactions. Comparing it with the first order condition with respect to g_p in this model, this amounts to the parent wanting to set $\frac{\partial c_c^{\star}}{\partial g_p} = 1$ and $\frac{\partial a_c'^{\star}}{\partial g_p} = 0$. In other words, the parent would want to set the transfer such that the kid consumes it all. This way the child can achieve the level of consumption that the parent desires for him. The only scenario in which the child's consumption is below the parent's desired level of consumption for him is when the child is constrained. Otherwise the child consumes at least as much as the parent would want him to consume, so there is no scope for positive transfers. To see this suppose the child is unconstrained, irrespective of the parent's actions. That is $\lambda_{a_c}\left(2,a_c,y_c,g_p,a_p'\right) = 0, \forall g_p, a_p'$ and the child's consumption-saving decision is given by

$$u'\left(c_c\right) - \beta V_2^p\left(3,a_p'+a_c',0,y_p',y_c'\right) = 0$$

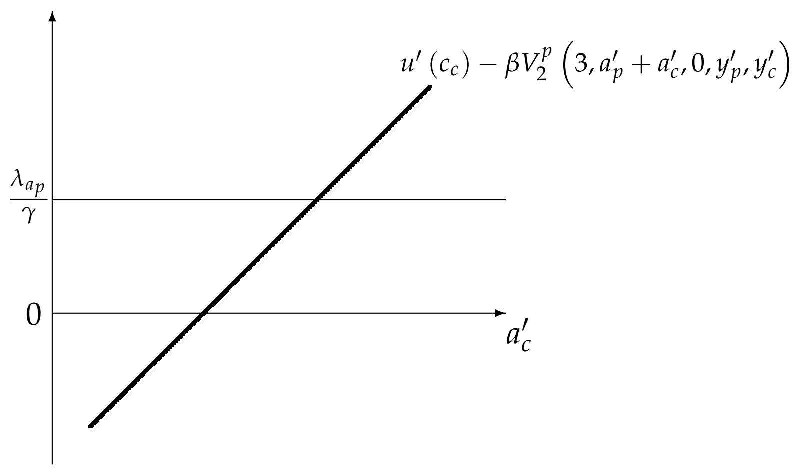
where the right hand side is strictly increasing in a_c' by the properties of the utility function. Suppose now that $g_p > 0$, i.e. $\lambda_g = 0$. Then, from the parent's first order conditions we have

$$\begin{aligned}\beta V_2^p\left(3, a_p' + a_c', 0, y_p', y_c'\right) &= \frac{u'\left(c_p\right) - \lambda_{a_p}}{\gamma} \\ u'\left(c_c\right) &= \frac{u'\left(c_p\right)}{\gamma}\end{aligned}$$

and so

$$u'\left(c_c\right) - \beta V_2^p\left(3, a_p' + a_c', 0, y_p', y_c'\right) = \frac{\lambda_{a_p}}{\gamma} \geq 0$$

The figure below depicts the choice of child's savings both from the child's and from the parent's perspective. It can be seen that the child would choose a level of savings that is weakly below the level that the parent would choose for him and therefore, would consume at least as much as the parent would want him to.



Suppose now that $g_p = 0$, i.e. $\lambda_g > 0$. In this case either the parent does not want to make any additional transfers, which means that the child's consumption must be at the level desired by the parent, or the parent would like to make negative transfers but cannot do so. In principle, if negative transfers were allowed, they would be made by decreasing either the child's consumption or savings, or both. Either way, it has to be the case that the child consumes at lease as much as the parent wants him to.

Therefore, the parent sets transfers as follows. If in the absence of transfers the child is unconstrained, i.e. $a_c'\left(2, a_c, y_c, 0, a_p'\right) > 0$, then transfers are set to zero (in this case, if the parent were to transfer another dollar, part of it would be saved). If in the absence of transfers the child is constrained, i.e. $a_c'\left(2, a_c, y_c, 0, a_p'\right) = 0$, then solve for the g_p that satisfies $u'\left(c_p\right) = \gamma u'\left(c_c\left(2, a_c, y_c, 0, a_p'\right)\right)$.

Age 3 *parent with age* 1 *child*

The age 3 parent sets the transfer following the same argument as at age 4. The crux is that the unconstrained child of age 1 wants to consume at least as much as his parent would like him to consume. This can be seen by analyzing the optimality conditions of the agents. Below are the optimality conditions for saving for unconstrained children of age 1 and 2, respectively:

$$
\begin{aligned}
u'\left(c_c\right) &= \beta V_2^c\left(2, a_c', y_c', g_p', a_p''\right) + \underbrace{\beta V_4^c\left(2, a_c', y_c', g_p', a_p''\right)\frac{\partial g_p'}{\partial a_c'} + \beta V_5^c\left(2, a_c', y_c', g_p', a_p''\right)\frac{\partial a_p''}{\partial a_c'}}_{\text{saving disincentive}} \\
u'\left(c_c\right) &= \beta V_2^p\left(3, a_p' + a_c', 0, y_p', y_c'\right)
\end{aligned}
$$

The benefit of saving is in the RHS of the equations. It can be seen that the age 1 child has an additional incentive for consuming which comes from increased transfers induced in the following period, and the prospect of a higher bequest through increased parental savings. This means that, everything else equal, an age 1 child would like to consume even more than an age 2 child. The later cannot influence the parent's future behavior through his actions as his parent is in the terminal period.

Below are the optimality conditions for saving of parents of age 3 and 4, respectively:

$$
\begin{aligned}
u'\left(c_p\right) &= \gamma u'\left(c_c^\star\right)\frac{\partial c_c^\star}{\partial a_p'} + \beta V_2^p\left(4, a_p', a_c'^\star, y_p', y_c'\right) + \beta V_3^p\left(4, a_p', a_c'^\star, y_p', y_c'\right)\frac{\partial a_c'^\star}{\partial a_p'} + \lambda_{a_p} \\
u'\left(c_p\right) &= \gamma u'\left(c_c^\star\right)\frac{\partial c_c^\star}{\partial a_p'} + \beta\gamma V_2^p\left(3, a_p' + a_c'^\star, 0, y_p', y_c'\right)\left(1 + \frac{\partial a_c'^\star}{\partial a_p'}\right) + \lambda_{a_p}
\end{aligned}
$$

as well as the optimality conditions for transfers of parents of age 3 and 4:

$$
\begin{aligned}
u'\left(c_p\right) &= \gamma u'\left(c_c^\star\right)\frac{\partial c_c^\star}{\partial g_p} + \beta V_3^p\left(4, a_p', a_c'^\star, y_p', y_c'\right)\frac{\partial a_c'^\star}{\partial g_p} + \lambda_g \\
u'\left(c_p\right) &= \gamma u'\left(c_c^\star\right)\frac{\partial c_c^\star}{\partial g_p} + \beta\gamma V_2^p\left(3, a_p' + a_c'^\star, 0, y_p', y_c'\right)\frac{\partial a_c'^\star}{\partial g_p} + \lambda_g
\end{aligned}
$$

By comparing the two sets of equations it can be seen that incentives for saving and transfers for parents do not vary with age, everything else equal, so neither will the desired consumption for their child. However, the child of an age 3 parent would like to consume more than the child of an age 4 parent. But the child of an age 4 parent wants to consume at least as much as his parent wants him to consume. Therefore, it must be that the the age 3 child also wants to consume more than his parent wants him to.

B.3 Parameters of the income process

The permanent income uncertainty profiles for the low and high risk sectors are constructed by averaging over the uncertainty profiles of the component sectors, weighted by the number of observations in each component sector. The variance of the idiosyncratic component of earnings is assumed to be a cubic polynomial in age:

$$\sigma_{hs}^2 = a_s + b_s \frac{h}{10} + c_s \left(\frac{h}{10}\right)^2 + d_s \left(\frac{h}{10}\right)^3$$

Parameters ρ_s, a_s, b_s, c_s, d_s are estimated by minimizing, for each sector, the weighted distance between the empirical age profile of income risk relative to permanent income and that implied by the decomposition (15)-(16) and the polynomial assumption. I use the identity matrix as the weighting matrix. The steps to construct the permanent income risk implied by the parametric assumptions in the model are as follows:

Step 1. Discretize the idiosyncratic component of income using the Tauchen (1986) method.

Step 2. Simulate the earnings path of $5,000$ individuals.

Step 3. Compute forecast errors for the simulated individuals as difference between realized earnings and expected earnings.

Step 4. Use these forecast errors to compute permanent income risk in sector s according to equation (6) and then divide by expected permanent income using gross discount rate $R = 1.04$.