A Life-Cycle Model of Entrepreneurial Choice: Understanding Entry into and Exit from Self-Employment*

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Abstract

Data from the 1979 cohort of the National Longitudinal Survey of Youth (NLSY79) show that self-employment (nonfarm and nonprofessional) accounts for as much as 7% of all yearly labor supplied by young white males (aged 20-39 in the period 1979-2000). On the other hand, nearly 30% of the individuals covered by the data have at least one year of experience as a self-employer in the relevant period. The goal of this paper is to develop a coherent framework that accounts for these two contrasting figures, which together indicate the importance of understanding not only entry into but also exit from self-employment. Specifically, I present and estimate a life-cycle model of entrepreneurial choice and wealth accumulation, using a subsample of white males aged 20 to 39 from the NLSY79. In addition, the model includes two basic components of human capital (educational attainment and labor experience) aimed at a better capturing the observed patterns of labor supply, as well as those of income profiles and wealth accumulation over the life cycle. Counterfactual experiments with the use of the estimated model indicate that relaxation of borrowing constraints increases the average duration of self-employment, especially for the non-college-educated, whereas injections of business capital or self-employment-specific human capital only induce entries into self-employment that are of short duration.

Keywords: Labor Force Dynamics; Self-Employment; Entry and Exit; Human Capital; Borrowing Constraints.

JEL classification: J21 (Labor Force and Employment, Size, and Structure);
J24 (Human Capital; Skills; Occupational Choice; Labor Productivity);
L26 (Entrepreneurship).

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1 Introduction

Self-employment constitutes a sizeable portion of the labor force in the United States.[1] Data from the 1979 cohort of the NLSY79 show that self-employment (nonfarm and nonprofessional)[2] accounts for as much as 7% percent of all yearly labor supplied by young white males (aged 20–39 in the period 1979–2000). However, a more noticeable fact is that nearly 30% of individuals included in the data have at least one year of experience as a self-employer in the relevant period. These two contrasting numbers seem to suggest that self-employment is temporary in nature. A natural question that then arises is what determines the duration of self-employment? In this paper, to better understand labor force dynamics, I study this issue of the duration of self-employment by estimating a life-cycle model of entrepreneurial choice and wealth accumulation, using a subsample of white males aged 20 to 39 from the NLSY79, and by conducting counterfactual experiments with the use of the estimated model.[3] The main target of the estimation is to accurately replicate the observed patterns of entry into and exit from self-employment, as well as the patterns of income profiles and wealth accumulation over the life cycle. The counterfactual experiments conducted in this paper involve (i) the relaxation of borrowing constraints, (ii) an injection of business capital and (iii) an injection of self-employment-specific human capital.

My dynamic model is a natural extension of Evans and Jovanovic's (1989) static model of entrepreneurial choice to a competitive labor supply model in a life-cycle framework.[4] In my model, an individual, either non-college- or college-educated, must commence making decisions after he/she finishes schooling. In each period (a calendar year), an individual decides on a mode of employment, after observing shocks to his/her preference and income opportunities, and obtains income from the chosen job. Then he/she determines the amount of

[1] In this study, the empirical counterpart of a person starting a business is that the person becomes his or her own *self-employer* and, therefore, the words "self-employment" and "entrepreneurship" are used interchangeably throughout. The definition of self-employers in US surveys such as the Current Population Survey (CPS) and the National Longitudinal Survey of Youth (NLSY79), which is used in the present study, is "*those who work for profit or fees in their own business, profession, trade or operate a farm.*" I use this definition to describe running a business, instead of an alternative definition that is also widely used (business ownership), because of this paper's emphasis on the labor side of entrepreneurship, as the aim is to highlight the role of human capital in entrepreneurship. In addition, the majority of new businesses are likely to be started by self-employed business owners. Evidence from the Panel Study of Entrepreneurial Dynamics (PSED) indicates that about 75% of business startups involve self-employers: almost half of the nascent entrepreneurs in the PSED plan to start business as the sole legal owner of a new firm, and a quarter of them expect to start partnerships. Only one-fifth of nascent entrepreneurs consider a form of corporation. As the data I use for this study do not contain such information, I may overlook some entrepreneurs who start their business in the form of a corporation, instead counting them as "wage workers". In addition, I may be missing changes in legal status: some successful self-employers may become wage workers when they change the legal form of their firms to a corporation. The data employed in the present study do not include such detailed information.

[2] I exclude professionals (doctors, lawyers and accountants) and farmers from this study. See Subsection 5.1 for details.

[3] One caveat is that no welfare evaluations are provided from these experiments because labor and/or credit market imperfections are not explicitly modeled in the present study. Note also that the analytical framework provided below is a partial equilibrium one: counteractive forces caused by experiments involving changes in market prices are not considered. These are definitely important topics for future research.

[4] I do not explicitly model labor market frictions in a framework of, for example, job search. Rather, the "bare-bones" framework that I adopt is a dynamic model of competitive labor supply, and factors such as possible frictions in the labor market are modeled as unobservable residuals. However, I incorporate financial market "frictions" (in the form of borrowing constraints) into the model (with the word friction placed in double-quotation marks for the reason stated in the previous footnote).

Table 1: Income Differences by Educational Attainment (NLSY79; White Males; Aged 20–39)

	Non-college-educated	College-educated
Mean annual income from self-employment	44978.7	63378.1
(No.Obs.)	(1359)	(720)
Mean annual income from full-time paid employment	28464.6	40500.6
(No.Obs.)	(14019)	(8276)

Note : Monetary values are in terms of year 2000 dollars.

the income from working that is devoted to consumption, and the returns from the accumulated asset. He/she obtains utility from consumption as well as disutility from working. The objective of each individual is to maximize the expected present discounted value of utility over a finite horizon from the first decision period to the last. The main difference between self-employment and paid employment is in the functional forms of the income opportunities. That is, I assume that the functional forms of the individual's income opportunities depend on whether he/she works as a self-employer (that is, "becomes his/her own boss") or is employed by someone else.

A key feature of the proposed life-cycle model, which has not been given much attention in the existing literature, is the addition of *human capital* (*educational attainment* and *labor experience*) to the analysis of self-employment. The main motivation for incorporating *labor experience* into the model is to explain the observed increases in incomes from self-employment and paid employment over the life cycle (see Subsubsection 5.2.3 for details). Significant differences between the experiences of the non-college-educated (high-school graduates and dropouts) and the college-educated (those with some college education) in self- and paid employment motivate me to incorporate a variable for *educational attainment* into the model. Table 1 shows that the "college premium" in annual income is almost the same both for self-employment (40.9%) and full-time paid employment (42.3%).

Table 2 displays the differences, other than income, between the non-college-educated and the college-educated. In comparison with the college-educated, non-college-educated workers are more likely to have self-employment experience up to the age of 39 (27.5% and 31.1%, respectively), which is referred to as *Key Fact* (1). In addition, the non-college-educated spend more years in the labor force before they become self-employers for the first time (for the non-college-(college-) educated, 62.7% (74.6%) of first entries into self-employment take place in the first eight decision periods, which is referred to as *Key Fact* (2)). The third item in Table 2 shows that the non-college-educated are more likely to leave self-employment after the first year (*Key Fact* (3)). These numbers seem to suggest that, for the non-college-educated, self-employment is more likely to be a "transitory" option compared to paid employment, whereas for the college-educated, self-employment is more likely to be a "committed" task. Thus, the inclusion of human capital (education as well as experience) in a model that explicitly considers decisions over the life cycle is expected to enhance the measurement of the gains and the opportunity costs associated with occupational decisions

Table 2: Differences in Self-Employment by Educational Attainment (NLSY79; White Males; Aged 20–39)

	Non-college-educated	College-educated
Ever had experience of self-employment (%)	31.78**	27.48
(No.Obs.)	(1199)	(717)
First entry into self-employment occurs within the first eight decision years or less (%)	62.72***	74.62
(No.Obs.)	(381)	(197)
Exit from self-employment in a year (%)	32.28*	28.57
(No.Obs.)	(550)	(287)

Note 1: The data are constructed from the 1979 cohort of the National Longitudinal Survey of Youth (NLSY79). The sample includes 1916 white males. See Section 5 for details of the data.

Note 2: "Non-college-educated" individuals are high school dropouts and high school graduates, and "College- educated" are individuals with some college education and more.

Note 3: "Experience of self-employment ever or never " is measured at the last periods observed in the data.

Note 4: "Decision years" are calendar years during which individuals are in the labor force.

Note 5: The symbols ***, ** and * indicate statistical difference at the 1%, 5% and 10% levels of significance, respectively.

over the life cycle. The above points constitute the major focus of the present study. In constructing the model, I explicitly consider heterogeneity among individuals that is not observable in the data. More specifically, through the assumption of an exogenously given (discrete) distribution of an unobserved "type" variable, I am able to take into account possible unobserved differences among individuals that may affect decisions on labor supply, as well as wealth accumulation.

Given the richness of the structural life-cycle model presented below, there will be no closed-form solution for the optimal path of decisions over time. Therefore, to empirically implement the model, it is first solved numerically. Using the decision rules described in Section 4, I simulate the data and use the simulated maximum likelihood (SML) method to estimate the model parameters. The empirical data I use for the study are from the NLSY79. The proposed life-cycle model yields plausible parameter estimates and has a good fit to the main empirical patterns of entry into and exit from self-employment, as well as the age profiles of the labor supplies, income and net worth. The estimation results show that nonpecuniary benefits from continuing self-employment are relatively large, which results in the observed persistence of individuals being self-employed. Using the estimates of the life-cycle model, I perform the three aforementioned counterfactual experiments. As my approach explicitly solves an optimization problem and thus makes predictions about how individuals behave, I can quantify the effects on entrepreneurial decisions as well as the outcomes of the alternative values of the parameters.

The first experiment is to relax the borrowing constraints for all individuals. I find that a moderate relaxation of the borrowing constraints has large impacts on the formulation and continuation of self-employed businesses. Specifically, with $30,000 as a lower bound on asset holdings (compared to the estimated lower bound of between $10,000 and $18,000 for most of the state variables), the average percentage of time over which self-employment accounts for all yearly labor supplies (over the years covered in the actual data) increases by nearly 50% (from 7% to 11%) for individuals in their thirties. At the same time, the corresponding percentage for nonemployment decreases, whereas that for full-time paid employment does not change much. However, for the individuals in their twenties, the results show the opposite effects. Thus, for individuals in their thirties, the indirect effect of the relaxation of borrowing constraints, which makes individuals more likely to choose nonemployment, is dominated by the direct effect that improves consumption smoothing over time and hence makes individuals more eager to become self-employed, despite the fact that it is a riskier choice than wage employment. For individuals in their twenties, in contrast, the indirect effect dominates the direct effect. It is also found that the average duration of self-employment becomes longer as a result of the relaxation of borrowing constraints. Nearly 90% of self-employers continue to be self-employed in the following year, whereas in the actual data, only 78% continue to be self-employed. This is caused by "selection" effects: individuals who are less able as self-employers choose to stay nonemployed instead. Focusing on educational differences, I find that the effects of relaxing the borrowing constraints are larger for the non-college-educated.

The second and the third experiments involve direct forces: injections of business capital and self-employment-specific human capital. I find that both counterfactual changes induce more individuals to enter into self-employment, although they make the average duration of self-employment shorter. The results from the three counterfactual experiments show that the relaxation of borrowing constraints encourages entries into self-employment of longer duration, whereas both types of injection only induce entries of short duration. In conclusion, the relaxation of borrowing constraints would be the most effective means of determining the duration of self-employment.

The rest of this paper is organized as follows. Following the review of the related literature in the next section, Section 3 presents a structural model for entrepreneurial choice and wealth accumulation over the life cycle. Because of the richness of the model, it does not permit an analytical solution. Thus, Section 4 explains how the model is numerically solved. Then, I describe the data used for the estimation in Section 5. After the method of estimation is described in Section 6, Section 7 presents the estimation results, followed by discussions of the model fit and the implications of the parameter estimates. Then, Section 8 outlines the results from the three counterfactual experiments. Section 9 concludes the paper.

2 Related Literature

The literature on self-employment and entrepreneurship is vast. Here, I confine my attention to the studies that are closely related to this paper.[5]

[5] A related area of the literature involves the study of entrepreneurship in the presence of borrowing constraints (and precautionary saving) to better explain the observed heavy right tail of the aggregate

The main focus of the literature has been on examining the significance of borrowing constraints in the formation of business startups. In particular, much effort has been devoted to studying whether borrowing constraints deter entry into self-employment. There are two different (although not necessarily mutually exclusive) approaches to this issue. One is to provide probit estimates of the effect of assets on entry into self-employment, and the other is to explicitly consider a behavioral model of entrepreneurial choice. In both approaches, different specifications and different data are used by different authors. A seminal study by Evans and Jovanovics (1989),[6] which belongs to the second approach,[7] concluded (among other things) that borrowing constraints are significant in preventing some individuals from entering self-employment: a counterfactual experiment showed that the average probability of someone becoming a self-employer would increase by 34% if the borrowing constraints were removed.[8] The study by Evans and Jovanovic (1989) stimulated successive studies. Most of them belong in the category of the first approach (probit models). In many cases, statistically significant positive coefficients for wealth were found, which were interpreted as an indication of the existence of borrowing constraints. Many of the recent studies using the first approach have carefully treated endogeneity of wealth using instrumental variables: the possible correlation between, for example, unobserved ability as a self-employer and wealth accumulation may cause the positive relationship even if there are no borrowing constraints.[9] However, a recent study by Hurst and Lusardi (2004), using data from the Panel Study of Income Dynamics (PSID), challenged this conclusion by finding that the positive effect occurs only for the top percentiles of the wealth distribution, whereas for other percentiles, there is little evidence of a positive relationship between assets and entry into self-employment.[10]

Partly in response to Hurst and Lusardi's (2004) results and partly with the intent of improving on Evans and Jovanovics's (1989) *static* model, two recent studies, belonging to the second approach (behavioral models), by Buera (2008a) and Mondragon-Velez (2006)

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wealth distribution in the US. The common idea is that when borrowing constraints are added in a model economy when businesses are starting up, this creates a more skewed wealth distribution than does the precautionary savings motive alone. See, e.g., Quadrini (1999, 2000), Castañdeda, Díaz-Giménez and Ríos-Rull (2003), Cagetti and De Nardi (2006) and Terajima (2006). For other issues on self-employment in macro contexts, see, e.g., Li (2002), Fernández-Villaverde, Galdón-Sánchez and Carranza (2003) and Meh (2008). In particular, Li (2002) compared several alternative credit programs, and found that income subsidy programs and programs that target poor and capable entrepreneurs are most effective in promoting entrepreneurial activity. In contrast to the present study, the focus of these papers was not on explaining transitions (entry into and exit from self-employment) at the individual level in a life-cycle framework. Whereas I study entry into and exit from self-employment over the life cycle, this is out of scope for the above papers because they consider stationary equilibriums.

[6] Evans and Leighton (1989) is a companion paper that is the first study reporting empirical findings on the dynamic aspects of self-employment, making use of longitudinal data.

[7] For studies that use behavioral dynamic models with financial market imperfections to analyze different issues from the present study, see, e.g., Rosenzweig and Wolpin (1993) and Fafchamps and Pender (1997) (farmers in developing countries), Keane and Wolpin (2001) (financing for higher education), Redon (2006) (job search), Pavan (2008) (collateralized debt in consumption smoothing) and Schündeln (2006) (small manufacturing firms in developing countries).

[8] In a follow-up paper, Xu (1998) corrected the puzzling finding in Evans and Jovanovic (1989) that (unobserved) entrepreneurial ability and wealth are negatively correlated. Xu (1998) pointed out the negative correlation resulted from a downward bias in the original data, because a positive correlation was found with less biased wealth data.

[9] See, e.g., Holtz-Eakin, Joulfaian and Rosen (1994a,b), Blanchflower and Oswald (1998) and Dunn and Holtz-Eakin (2000).

[10] More specifically, Hurst and Lusardi (2004) documented the nonmonotonic relationship by considering a polynomial of wealth in the probit equation. In addition, they checked the result with changes in housing prices as an instrumental variable.

estimated structural parameters of a *dynamic* model of entrepreneurial choice. In their dynamic models, asset accumulation is endogenously determined (model individuals decide on how much they consume and save in each period). Buera (2008a) involved a synthesis that offered both analytical characterization in a continuous-time setting and structural estimation, motivated the nonmonotonic relationship found by Hurst and Lusardi (2004). First, by assuming (unobserved) heterogeneity of entrepreneurial skill among individuals, Buera (2008a) derived a nonmonotonic (hump-shaped) relationship between the level of net worth and the likelihood of self-employment. This occurs because, if an individual has accumulated a large amount of wealth, it is likely that he/she can earn more as a wage worker than as a self-employer and thus he/she is less motivated to enter into self-employment. Then, using the PSID, Buera found that welfare costs (measured by consumption) are larger for individuals who are able as self-employers but have insufficient amounts of accumulated wealth than they are for the rest of the population, which implied that borrowing constraints are significant in deterring entry into self-employment.

However, in Buera's (2008a) model, as in many studies on self-employment and entrepreneurship, human capital is not incorporated: instead, talent that augments entrepreneurial income is treated as unobserved, determined in the beginning and permanently fixed. Considering that the human capital literature has devoted much effort to studying how education and experience enhance one's market wage in paid employment, it is surprising that most of the literature on self-employment does not focus on human capital, instead treating a pool of current and future self-employers as homogenous (except for unobservable factors).[11] This simplification may cause the effect of entrepreneurial skills on self-employment performance to be overstated. This is because human capital may be correlated with important (unobserved) factors such as borrowing constraints, resulting in omitted variable biases. To capture the effects of observed and unobserved characteristics on entrepreneurial choice and wealth accumulation as precisely as possible, the level of human capital should be considered in relation to earnings opportunities not just from paid employment, but also from self-employment.

With the intent of improving on Buera's (2008a) formulation, Mondragon-Velez (2006) incorporated human capital accumulation into a dynamic framework to better capture the benefits and opportunity costs of self-employment, and then estimated the model to replicate earnings and fractions of self-employers by age–education groups. Mondragon-Velez (2006) augmented Buera's (2008a) nonmonotonic (hump-shaped) relationship between the probability of transition to self-employment and accumulated wealth: because the opportunity cost of self-employment (wage increases owing to the accumulation of human capital) becomes larger as the individual becomes older, a larger scale of business capital is necessary to attract an individual into self-employment. In this way, the relationship between the propensity to be a self-employer and accumulated wealth is nonmonotonic, consistent with Hurst and Lusardi (2004). However, Mondragon-Velez (2006) stated that the significance of borrowing constraints may still hold because tight values for borrowing constraints better replicate the skewness of the wealth distribution observed in many US data sets.

In this paper, adopting the second approach (behavioral models), I focus on an impor-

[11] There are a few exceptions, for example, Bates (1990) and Kawaguchi (2003) focused on the effects of human capital on self-employment. By estimating a logit model, Bates found that owner schooling (years of education) is the most significant human capital variable that explains the longevity of small businesses: businesses owned by college-educated individuals survived longer than businesses owned by other individuals. By considering a two-period model of human capital accumulation under income risk, Kawaguchi (2003) found that experience–earnings profiles are flatter for self-employed workers than for wage workers.

tant aspect of self-employment to which Buera (2008a) and Mondragon-Velez (2006) did not pay attention: *exit* from self-employment.[12] In Buera's (2008a) model, an individual remains a self-employer once he/she becomes one, because the author did not incorporate uncertainty into his model. When he estimated his dynamic model, Buera (2008a) used only cross-sectional information on income and the ratios of entrepreneurs to wage workers. Mondragon-Velez (2006) did not focus much on the dynamic aspects of entrepreneurship, although his model is potentially able to do so. In addition, Mondragon-Velez (2006) used age as a dynamic component in the human capital function rather than (endogenously) accumulated experience, and did not include nonemployment as a labor-supply choice. Hence, he did not distinguish between self-employment experience and wage experience. In the present study, because my life-cycle model allows exit from self-employment, I can examine the dynamic aspects of self-employment over the life cycle and, hence, the effects of borrowing constraints on entry into and exit from self-employment. In addition, I can conduct additional experiments to the relaxation of the borrowing constraints that have not considered by either Buera (2008a) or Mondragon-Velez (2006). Being able to conduct a variety of counterfactual/policy experiments is the main benefit from estimating a behavioral model. To the best of my knowledge, there are no studies using a structural model that investigate entry into self-employment and exit from self-employment. I do not focus on the nonmonotonic (hump-shaped) relationship between net worth and the likelihood of self-employment partly because the data I use are different from the data used by Hurst and Lusardi (2004), Buera (2008a) and Mondragon-Velez (2006).

In a study analogous to the present study, Schjerning (2006) focused on entry into and exit from entrepreneurship by developing and calibrating an infinite-horizon model of occupational choice and wealth accumulation. In addition, his dynamic model incorporated human capital accumulation. Schjerning's (2006) calibration exercises yielded a number of interesting predictions. There are two important differences between his model and the one in the present study. First, whereas Schjerning (2006) assumes the stationarity of the model environment, I employ a finite-horizon (life-cycle) model so that I can consider life-cycle aspects pf labor suppy and wealth accumulation. Second, in my fomulation, switching costs are modeled as nonpecuniary terms in the utility function.

3 Model Strucuture

In this section, I present a life-cycle model of an individual's decisions on entrepreneurial choice and on wealth accumulation. The general structure is a standard one that can been seen as a natural extension of Evans and Jovanovic's (1989) static model of entrepreneurial choice: in each calender year, an individual, after observing shocks to his preference and income opportunities, decides on the mode of employment and obtains income from the job. He then determines the amount of consumption out of the sum of the income from working and the returns from the accumulated asset, obtaining utility from consumption as well as disutility from working. The objective of the individual is to maximize the expected present

[12] Using the 1976–2006 March Current Population Survey (CPS), Rissman (2007) calibrated a model to generate steady-state transition rates across three employment states (self-employment, paid employment and unemployment). Rissman's (2007) results suggested that startup costs are not important determinants of the steady-state level of self-employment because a doubling of business startup costs had very little effect on the simulated transition rates. By its nature, Rissman's (2007) model is not a life-cycle model. In addition, Rissman (2007) abstracted from wealth accumulation and did not incorporate borrowing constraints into his model.

discounted value of utility over a finite horizon from the first decision period to the last. The rest of this section gives a formal description of the model.

3.1 Timeline, Choice and State Variables

The discrete decision periods are assumed to be *calender years*, indexed by t. The individual's sequential decision-making problem begins one year after when he has completed his education ($t = 1$)[13] and ends at $t = T$. I denote his age in decision period t by $age_t \in \{\underline{age}, ..., \overline{age}\}$, where $\underline{age}$ is the first year after he completed schooling[14] and $\overline{age}$ is the last decision period. I assume the retirement age is 65 for all individuals so that I set $\overline{age} = 64$. Two variables that characterize the individual's *permanent* heterogeneity are (i) his level of completed schooling (denoted by *educ*) and (ii) his type (denoted by *type*). Throughout this section, the dependence of variables on *educ* and *type* notionally suppressed.

At the beginning of each decision period t, the individual first observes shocks

$$\widetilde{\epsilon}_t^l = (\widetilde{\epsilon}_t^{ls}, \widetilde{\epsilon}_t^{lw}) \in \mathbb{R}^2$$

to his preference u_t (more precisely to labor disutility; see below) where $\widetilde{\epsilon}_t^l$ is distributed according to $N(0, \Sigma^l)$, and shocks

$$\widetilde{\epsilon}_t^y = (\widetilde{\epsilon}_t^{ys}, \widetilde{\epsilon}_t^{yw}) \in \mathbb{R}^2$$

to his earnings opportunities for the current period y_t (see Subsection 3.3 below for details), where $\widetilde{\epsilon}_t^y$ is distributed according to $N(0, \Sigma^y)$. I assume that $\widetilde{\epsilon}_t^l$ and $\widetilde{\epsilon}_t^y$ are serially uncorrelated and independently distributed.

After observing the shocks and the potential amount of business scale in his self-employment, he decides on the mode of employment (non-employed, paid-employed or self-employed). If he has decided to work for a paid job, he can choose full or part-time. For self-employment, he can only choose to work or not to work.[15] Specifically, a choice element of labor is written by

$$\begin{aligned} l_t = (l_t^s, l_t^w) \in & \{Zero, SE\} \\ & \times \{Zero, \textit{Part-time } PE, \textit{Full-time } PE\} \end{aligned}$$

and as a result of labor choice he obtains income from working.[16,17] Since I assume that full-time work is equivalent to working for 2000 hours and part-time work is to 1000 hours,

[13] In this study, I do not model schooling decisions and assume that the individual's education level is exogenously given. This simplifying assumption may lead to overstatement of college premium in self-employment because the schooling decision may be partly motivated by some unobservable factors that relate to productivity in self-employment.

[14] In the data, the starting age varies among individuals as a result of differences in last years of schooling. I exclulded those individuals whose first period is 14 years, or 26 years old or older. Following Imai and Keane (2004), I assume that the earliest age when decisions start is 20. So, the first age ranges from 20 to 25 in the constructed data. See B.2 in Appendix B for details.

[15] The reason why I do not distinguish between full- and part-time self-employment is that the number of individuals choosing part-time self-employment in each age is small. See B.4.2 in Appendix B for details. Notice here that by definition I am excluding such issues as "overwork" and "flexibility" on hours worked in self-employment.

[16] Note that he makes a decision, observing a vector of earnings "offer." In other words, the value for all income alternatives have already "realized" when he is making a decision.

[17] Campbell and DeNardi (2007) find that a large proportion of nascent entrepreneurs are employed in the wage and salary sector at the time they are starting their own business.

I occasionally use the alternative notation:

$$l_t = (l_t^s, l_t^w) \in \{0,\ 2000\} \times \{0{,}1000, 2000\}.$$

He also determines how much to save for next period out of the sum of the current income and the accumulated asset (denoted by $\Delta a_{t+1} = a_{t+1} - a_t$, where a_t is the amount of financial net worth in age t). The residual is consumption, c_t. I assume that he chooses an absolute change in financial net worth for next period from a discretized set $\{\underline{\Delta a}, ..., \overline{\Delta a}\}$, that is

$$\Delta a_{t+1} \in \{\underline{\Delta a}, ..., \overline{\Delta a}\}.$$

He obtains per-period utility from consumption as well as gets disutility from working: $u_t = u(c_t, l_t^s, l_t^w; \epsilon_t^{ls}, \epsilon_t^{lw})$. The objective of the individual is to maximize the expected present discounted value of utility over a finite horizon from the first decision age to the last (see next subsection).

Beside age index age_t itself, there are five moving state variables in each decision age t: (i) whether he has ever experienced self-employment until period $t-1$, h_t^s, (ii) how many years he has been a self-employer *in a row*, τ_t^s, (iii) accumulated labor experience in paid-employment, h_t^w, (iv) labor experience in paid-employment in the previous period, l_{t-1}^w,[18] and (v) financial net worth, a_t. The initial values for labor experience, (h_1^s, h_1^w) and for net worth, a_1, are exogenously given.

Any individual before observing shocks and starting decisions is, therefore, characterized by

$$\bar{s}_1 = ((h_1^s, \tau_1^s, h_1^w, l_0^w, a_1), (educ,\ type,\ \underline{age})),$$

where $h_1^s = 0$, $\tau_1^s = 0$, $h_1^w = 0$, $l_0^w = \phi$ (null), and a_1 may be positive or negative (or zero). Regarding experience in self-employment, I employ the following transitions:

$$h_{t+1}^s = \begin{cases} 1 \text{ if } \exists t' \leq t \text{ such that } l_{t'}^s = SE \\ 0 \text{ otherwise} \end{cases}$$

for any $t \in \{1, ..., T\}$, and

$$\tau_{t+1}^s = \begin{cases} \tau_t^s + 1 \text{ if } l_t^s = SE \\ \quad 0 \quad \text{otherwise} \end{cases}$$

for any $t \in \{1, ..., T\}$. Regarding labor experience accumulation in paid-employment, I employ the following transitions:

$$h_{t+1}^w = h_t^w + 0.5 \cdot I(l_t^w = Part\text{-}time\ PE) + I(l_t^w = Full\text{-}time\ PE)$$

for any $t \geq 1$, where $I(\cdot)$ is an indicator function that assigns one if the term inside the parenthesis is true and zero otherwise. Notice that two state variables l_{t-1}^w and a_t are also decision variables.

3.2 The Individual's Problem and Constraints

In each decision period t, the individual is assumed to maximize the present discounted value of lifetime utility from the current period to the terminal age. The subjective discount factor

[18] The reason his work status in the previous period, $(\tau_{t-1}^s, l_{t-1}^w)$ is introduced is that the persistence effect in the employment modes is captured to explain better the patterns in the empirical data.

is denoted by $\beta \in (0,1)$. Then, in each period t, he solves

$$\max_{\{l_{t'},\ \Delta a_{t'+1}\}_{t'=t}^{T}} E\left[\sum_{t'=(\underline{age}-19)}^{(\overline{age}-19)} \beta^{t'-t} u_t\right]$$

where $u_t = u(c_t, l_t^s, l_t^w; \epsilon_t^{ls}, \epsilon_t^{lw})$, subject to the budget and borrowing constraints, which are specified in the rest of this subsection.

First, letting y_t denote the earned income, the *budget constraint* is given by

$$c_t + a_{t+1} = y_t + (1-\delta)k_t + (1+r)(a_t - k_t)$$

where $y_t = y_t^w + y_t^s$ and k_t is the amount of business capital invested in the self-employed business, which is positive *if and only if* he worked as a self-employer (see next subsection for details), $\delta \in (0,1)$ is the rate of capital depreciation of business capital, and $r > 0$ is the rate of return from savings, which is assumed to be the same as the unit cost of business capital.[19] The opportunity cost for k_t arises because he could have saved k_t in a bank. Here I assume, as in the standard neoclassical growth model, that business capital, k_t, can be completely divested (cashed out) after production and that there is no additional adjustment cost other than depreciation.[20] In addition, consumption in any period t cannot be below some level, which is called consumption floor and is denoted by $c_{\min}$ (implicitly assumed is the existence of such (unmodeled) public welfare systems as unemployment insurance and bankruptcy protection), so that

$$c_t \geq c_{\min}.$$

Second, he (*as a consumer*) faces the *borrowing constraint* due to (unmodeled) imperfections in the financial market. That is, in each period t, (unmodeled) creditors impose a lower bound that prevents the individual's net financial asset a_{t+1} from falling below a lower bound, $\underline{a}_t$:[21,22]

$$a_{t+1} \geq \underline{a}_{t+1}.$$

Because of this borrowing constraint the individual *cannot always perfectly smooth consumption.*

3.3 Earnings Opportunities

Differences between self-employment and paid-employment are expressed as those in functional forms of earnings opportunities: I assume that functional forms of someone's earnings opportunities depend on whether he works independently ("becomes his own boss") or is

[19] Notice here that the interest rate is not dependent on t. If one wants to consider the time dependency of the interest rate in a consistent manner to a dynamic model, she needs to introduce the individual's forecasting rule in the model. In this paper, I just assume that the individual in the model regards the interest rate as some constant during his life. Hence, I do not consider macro schocks from the aggregate economy, either. For an analysis of the macro effects on self-employment, see Rissman (2003, 2006).

[20] Such papers as Quadrini (2000), Cagetti and De Nardi (2006), Buera (2008a,b), Mondragon-Velez (2006) and Schjerning (2006) that study the role of borrowing constraints in entrepreneurship also employ the same assumption and thus business capital does not constitute a state variable in their models.

[21] The lower bound, $\underline{a}_t$, can be negative. This is motivated by the empirical observations: in most of ages that are covered by the data for estimation, the lower 10% have negative net worth.

[22] I do not allow the individual to default. See Pavan (2008) and Herranz, Krasa and Villamil (2007) for estimable dynamic models that allow for default.

employed by someone else.[23] I begin with the case of paid-employment because it uses a familiar formulation from the existing literature on human capital.

3.3.1 Income from Paid-Employment

Hourly Market Wages Following the literature on human capital (e.g. Ben-Porath (1967) and Mincer (1974)), I assume that the market hourly wage for effective labor is the product of the *rental price* of human capital (R^f for full-time paid-employment and R^p for part-time paid-employment) and the level of (sector-specific) human capital for paid-employment, Ψ_t^w. I assume that $\Psi_t^w$is the product of the deterministic part of the human capital ($\overline{\Psi}_t^w$) and the idiosyncratic productivity shock ($\exp(\epsilon_t^{yw})$):

$$
\begin{aligned}
w_t^j &= R^j \cdot \Psi_t^w \\
&= R^j \overline{\Psi}_t^w \exp(\epsilon_t^{yw}) \ \left(\equiv w^j(\overline{\Psi}_t^w, \epsilon_t^{yw})\right)
\end{aligned}
$$

which leads to the following *Mincerian wage equation*:

$$
\ln w_t^j = \ln R^j + \ln \overline{\Psi}_t^w + \epsilon_t^{yw},
$$

for $j = f, p$.

Annual Income Annual income from paid-employment, y_t^w, is then the hourly market wage multiplied by hours worked. Specifically, it is given by

$$
y_t^w = \begin{cases} w_t^f \cdot 2000 \text{ if } l_t^w \text{ is ``full-time''} \\ w_t^p \cdot 1000 \text{ if } l_t^s \text{ is ``part-time''} \\ \quad 0 \quad\quad \text{ if } l_t^s \text{ is ``zero''}, \end{cases}
$$

where the variation in income reflects only the variation in hourly market wages.[24]

3.3.2 Income from Self-Employment

Entrepreneurial Production Function I assume that production contribution by the individual as a self-employer separable from that by other individuals who work with him (if any). The individual's production ability when he works as a self-employer is assumed to be captured by following the Harrod-Neutral Cobb-Douglas *entrepreneurial production function*:

$$
\begin{aligned}
y_t^s &= f([\overline{\Psi}_t^s l_t^s], k_t, \epsilon_t^{ys}; \alpha) \\
&= [\overline{\Psi}_t^s l_t^s]^{1-\alpha} {k_t}^{\alpha} \exp(\epsilon_t^{ys}),
\end{aligned}
$$

which leads to

$$
\ln y_t^s = (1-\alpha) \ln[\overline{\Psi}_t^s l_t^s] + \alpha \ln k_t + \epsilon_t^{ys},
$$

[23] In the present study, I assume away one important difference that a self-employed worker has to pay fringe benefits out of his earnings while a wage worker receives these as part of earnings, but they are not added into the earnings data of the wage worker. I also do not consider business transfers. See Holmes and Schmitz (1990,1995) for this issue.

[24] This is also the way of constructing data on income from paid-employment. See Appendix B.4.4.

where $\overline{\Psi}_t^s$ is the (deterministic) value of human capital for self-employment, l_t^s is hours worked for self-employment, k_t is business capital, and $\alpha \in (0, 1)$ is a constant.[25] Following the human capital literature on *heterogenous skills* (e.g. Willis and Rosen (1979), Heckman and Sedlacek (1985), and Keane and Wolpin (1997)) I distinguish the (deterministic) value of human capital for self-employment ($\overline{\Psi}_t^s$) and that for paid-employment ($\overline{\Psi}_t^w$). The difference is, however, that, I assume that there does not exist a price of human capital for self-employment (such R^f and R^p as in the case of paid-employment) because the lack of the market for it.[26] Notice also that different from paid employment, the idiosyncratic productivity shock ($\exp(\epsilon_t^{ys})$) is not multiplied by deterministic part of the human capital ($\overline{\Psi}_t^s$) only but by the component including the scale of business, k_t.

Now, I assume, following Evans and Jovanovic (1989), Buera (2008a,b), Mondragon-Velez (2006) and many others in the literature on entrepreneurship, that the individual (*as a self-employer*) faces the following *borrowing constraint*:

$$0 \leq k_t \leq a_t - \underline{a}_t.$$

Notice here that if the borrowing constraint is binding, then accumulated net worth a_t determines the level of business capital (together with the lower bound for financial net worth, $\underline{a}_t$). Or, anticipating this, he may be able to overcome the borrowing constraint by accumulating enough amount of wealth beforehand. This is the mechanism of how wealth accumulation may affect entrepreneurial choice *through the presence of the borrowing constraint*. Even if an individual anticipates that the borrowing constraint is not likely to bind, wealth accumulation may matter to entrepreneurial choice *though precautionary saving motive*: if income from self-employment fluctuates more than from paid-employment, then it gives potential and current self-employers.

Annual Income Since I have judged that information on business capital k_t is not reliable enough[27] due to the small number of observations in the NLSY79 and the ambiguity of the definition of "business capital" in early processes of business formation, I follow Evans and Jovanovic (1989) to substitute the chosen k_t into the entrepreneurial production function in the following way. When he has decided works as a self-employer with $l_t^s = 2000$ hours worked, he chooses his business capital k_t by solving

$$\max_{k_t \in [0, a_t - \underline{a}_t]} \exp(\epsilon_t^{ys})[\overline{\Psi}_t^s l_t^s]^{1-\alpha} k_t^\alpha - (1 + r)k_t,$$

subject to the borrowing constraint above, so that the chosen amount of business capital is

$$k_t^\$ = k_t^\$(2000, \epsilon_t^{ys}, a_t) = \min\{k_t^*(2000; \epsilon_t^{ys}), a_t - \underline{a}_t\}.$$

[25] In the present study, when estimating the model, I capture heterogeneity in α by considering differences in the level of schooling. This is because, as Mondragon-Velez (2007) points out in other dataset, there are significant differences in industries of self-employers by the level of schooling. See A.4 in Appendix A for details.

[26] An alternative modeling for the entrepreneurial production function would be to assume homegenous human capital ($\overline{\Psi}_t \equiv \overline{\Psi}_t^s \equiv \overline{\Psi}_t^w$) and thus

$$\begin{aligned} y_t^s &= f([\overline{\Psi}_t l_t^s], k_t; \omega, \alpha) \\ &= \omega \cdot [\overline{\Psi}_t l_t^s]^{1-\alpha} {k_t}^\alpha \end{aligned}$$

where ω is assumed to be related to *entrepreneurial/managerial talent* (see e.g. Lucas (1978)). Notice that in my model, "entrepreneurial/managerial talent" is incorporated in $\overline{\Psi}_t^s$.

[27] Evans and Jovanovic (1989) reached the same judgement, stating that "[s]ince our data do not contain precise enough information on how much is invested, ... " (p.814)

where

$$k_t^*(2000, \epsilon_t^{ys}) = \left(\frac{\alpha \cdot \exp(\epsilon_t^{ys})}{1+r}\right)^{\frac{1}{1-\alpha}} [\overline{\Psi}_t^s \cdot 2000]$$

is derived from the first-order condition for the optimal value without the borrowing constraints.[28]

Annual income from self-employment, y_t^s, is thus given by

$$y_t^s = \begin{cases} \exp(\epsilon_t^{ys})[\overline{\Psi}_t^s \cdot 2000]^{1-\alpha}[k_t^\$(2000, \epsilon_t^{ys}, a_t)]^\alpha & \text{if } l_t^s \text{ is "work"} \\ 0 & \text{if } l_t^s \text{ is "zero"}, \end{cases}$$

where, because of the borrowing constraint, the realization is affected by the current net worth, a_t.

4 Solving the Model

Although its structure is not conceptually complicated, the life-cycle model described above does not seem to permit an analytical solution for the optimal decision rule that yields the path, $\{(l_t)^*, (\Delta a_{t+1})^*\}_{t=1}^T$, even if parametric forms for the functions are given. In this section, I explain how my life-cycle model becomes computationally solvable.

4.1 Descretization

Notice that the structural model is presented as a *discrete choice problem*.[29] In the current formulation, the number of grids for absolute change in net worth for next period is 12,[30] so that the choice set contains 72 ($= 6 \times 12$) elements.

Variables that characterize the individual's permanent heterogeneity (*educ*, and *type*) are also discretized. First, education level takes one of two values. That is, $educ = 0$ if the individual is a high-school dropout (his year of schooling is less than 12) or a graduate (his year of schooling is 12), $educ = 1$ if he obtained some college degree (his year of schooling is equal to or greater than 13 and equal to or less than 15) or if he is a college graduate (his year of schooling is equal to or greater than 16). I also assume that *type* takes value 0 or 1.

[28] This operation is justified because I assume that k_t does not appear in a transition equation or it is not a state variable. In Schündeln (2006), who considers adjustment costs of capital but assumes away human capital accumulation, does the same operation for labor input.

[29] Another formulation would allow savings choice to be *continuous*. See, e.g, Cagetti (2003), Imai and Keane (2004), and van der Klaauw and Wolpin (2008), who numerically solve the Euler equation for the optimal consumption/savings path. Obviously, this formulaion would be more demanding in computation.

[30] The set of the actual grids that are used in the current formulation is

$$\{\underline{\Delta a}, ..., \overline{\Delta a}\} = \{\pm\{20000, 10000, 7500, 5000, 1500\}, +500, +40000\}.$$

In constructing the asset space for each period, Starting with $t = 1$ (with 5 grids), I recursively expand grids for next period by adding all $\Delta a \in \{\underline{\Delta a}, ..., \overline{\Delta a}\}$ to all the grids in the current period, starting with the initial period. For those who start working at age 20 the initial grids are set to be $\{-4240, 704, 2424, 6136, 96496\}$, and for others they are $\{-19154, 1840, 5932, 12492, 296400\}$.

4.2 Recursive Formulation

Notice that the problem of the individual can be recast in a recursive formulation. In addition, the dynamic problem ends in a finite horizon. Thus, the model can be solved backward, starting from the terminal decision period T. At this last age, the continuation value is exogenously given as a function of the state variable at that period. I do not normalize it to be zero because if I do so the individual consumes all the income in this last period, which may significantly affect the pattern of the optimal path.[31] The details are as follows.

First, let j-th element of the choice set in each period be denoted by

$$\begin{aligned} d_t^j &\in \{Zero,\ SE\} \\ &\times \{Zero,\ Part\text{-}time\ PE, Full\text{-}time\ PE\} \\ &\times \{\underline{\Delta a}, ..., \overline{\Delta a}\} \end{aligned}$$

and the utility associated with that choice as u_t^j. In addition, letting the state space at t be denoted by S_t, state point in period t, $s_t \in S_t$, is given by

$$s_t = ((h_t^s, \tau_t^s, h_t^w, l_{t-1}^w, a_t), (educ,\ type,\ \underline{age}),\ (\epsilon_t^{ls},\ \epsilon_t^{lw},\ \epsilon_t^{ys},\ \epsilon_t^{yw})),$$

where the generic element of the *predetermined* part of S_t is written by $\overline{S}_t$ whose generic element is

$$\overline{s}_t = ((h_t^s, \tau_t^s, h_t^w, l_{t-1}^w, a_t), (educ,\ type,\ \underline{age})).$$

Note that the part $(h_t^s, \tau_t^s, h_t^w, l_{t-1}^w, a_t)$ is a result of past decisions (up to $t-1$), and that the element ($educ$, $type$, $\underline{age}$) is the part of the state points that is permanently fixed.[32] Note also that actual age age_t is implicitly included in $\overline{s}_t$ because it is determined by t and the age in the first decision period ($\underline{age}$), that is, $age_t = \underline{age} + (t-1)$. Exogenous to the decisions but moving across t's are $(\epsilon_t^l, \epsilon_t^y)$ and age_t.

Thanks to the Bellman representation, the value function at any period t, V_t, is written in a recursive way by

$$\begin{aligned} V_t(s_t) &= \max_{d_t^j} u_t^j + \beta E_t[V_{t+1}(s_{t+1})|s_t] \\ &= \max[V_t^1(s_t), ..., V_t^J(s_t)] \end{aligned}$$

where E_t is the expectations operator at the beginning of period t, and

$$V_t^j(s_t) = u_t^j + \beta E_t[V_{t+1}(s_{t+1})|d_t^j = 1, s_t]$$

for $j = 1, 2, ..., J$. The expectation is taken over the joint distribution of the stochastic shocks in *next* period, $\widetilde{\epsilon}_{t+1}^l = (\widetilde{\epsilon}_{t+1}^{ls}, \widetilde{\epsilon}_{t+1}^{lw})$ and $\widetilde{\epsilon}_{t+1}^y = (\widetilde{\epsilon}_{t+1}^{ys}, \widetilde{\epsilon}_{t+1}^{yw})$. This alternative-specific value function assumes that future choices are optimally made for any given current decision.

[31] In the actual implementation, I use the quasi-terminal period, T^*, which is set to be 30 for all individuals, not T, to ease computational burden. Under this simplification, model individuals live up to age 49 (for those with $\underline{age} = 20$) to 54 (for those with $\underline{age} = 25$). As explained in Appedix B, the highest age observed in the data age is 39, so this simplification does not lose information from the empirical data.

[32] In the data, (h_t^s, h_t^w, l_{t-1}^s, l_{t-1}^w, a_t) is not always (across t's and the sample individuals) observed, and ($educ$, $\underline{age}$) is observed for all of the sample individuals. Note that $type$ is the variable to caputure unobserved hetertogeneity.

For $t = 1, ..., T$, let the part $E_t[V_{t+1}(s_{t+1})|d_t^j = 1, s_t]$ be denoted by $Emax_t$. Notice that this is a function that assigns each element of the predetermined state space *and* decisions (i.e, $\overline{s}_t \in \overline{S}_t$ and d_t^j) to some value.[33]

When the individual in the model (as well as the econometrician) wants to optimally choose a decision element in period t, he needs to know this function to compare $\{V_t^j(s_t)\}$ across j. He can do so in the following way. Consider the last period T. Then, for *each* $s_T \in S_T$, he has the following system of J equations:

$$\begin{cases} V_T^1(s_T) = u_T^1 + \beta V_{T+1}(d_T^1 = 1, s_T) \\ ... \\ V_T^J(s_T) = u_T^J + \beta V_{T+1}(d_T^J = 1, s_T), \end{cases}$$

where $V_{T+1}(d_T^j,\ s_T)$, or $Emax_T$, is the terminal value that he obtains by choosing $d_t^j = 1$ when the state is s_T.[34] So, if this terminal value is given for *all* d_T^j and *all* s_T, it is then possible to compute $Emax_{T-1}$ by taking expectations of $V_T(s_T) = \max[V_T^1(s_T), ..., V_T^J(s_T)]$, given the distribution of ϵ_T. He can then solve for $Emax_t$ for all t by recursively solving the simple static optimization problems of discrete choice that is a system of linear equations. Once $Emax_t$ functions are known, the optimal path of decisions, $\{(l_t)^*,\ (\Delta a_{t+1})^*\}_{t=1}^T$, can be determined as follows: conditional on the deterministic part of the state space S_t, the probability that an individual is observed to choose option j takes the form of an integral over the region of the space of the five errors such that j is the preferred option.

As the decision period approaches the final period, however, the dimension of the predetermined state space $\overline{S}_t$ becomes too huge for the econometrician to obtain the optimal decision path in a computationally reasonable manner (in terms of both memory allocation and running time), especially if there are many total number of decision periods as in this study.

To deal with this problem, I use an approximation method that was proposed by Keane and Wolpin (1994) and applied by the same researchers (1997, 2001) and many others, in which the $Emax_t$ functions are expressed polynomials of the state variables.[35] Specifically, starting with T, for each *type*, I randomly select many points, $\{h_T^s, \tau_T^s,\ h_T^w, l_{T-1}^w,\ a_T,\ educ,\ \underline{age}\}$,[36] and for each of these points, I calculate $V_T(s_T)$, given $Emax_T$.[37] I obtain estimates for the polynomial coefficients by regressing $\{V_T(s_T)\}$ on the polynomial, and then interpolate the $Emax_{T-1}$ polynomial by using these estimated coefficients. This interpolated $Emax_{T-1}$ is used to calculate the one in period $T-1$. After period $T-1$ and on, for each $t \in \{T-1, .., 2\}$, I use Monte Carlo integration over the distribution of the disturbance in period t ($\widetilde{\epsilon}_t^l = (\widetilde{\epsilon}_t^{ls}, \widetilde{\epsilon}_t^{lw})$ and $\widetilde{\epsilon}_t^y = (\widetilde{\epsilon}_t^{ys}, \widetilde{\epsilon}_t^{yw})$) for a randomly selected subset of S_t to obtain the approximated expected value of the maximum of the alternative-specific value functions at those state points,$Emax_{t-1}$.[38] This procedure continues to decision period 2, where the

[33] In determining the decision in period t, he observes initial shocks ϵ_t, and he uses this information. However, because of the independence between ϵ_t and ϵ_{t+1}, this information does not affect $Emax_t$.

[34] Note that there is no need to take expectations over the next period's shocks in the last period.

[35] I use the second degree polynomial, including all interactions between the state variables. The variables ϵ_t^{ls}, ϵ_t^{lw}, ϵ_t^{ys} and ϵ_t^{yw} do not have to be incorporated in Emax calculation because of their serial uncorrelation.

[36] Notice that age_t takes only one particular value given $\underline{age}$ and t, so it cannot be a component of the randomly chosen subset.

[37] This function has a parametric form and its parameters are the target of estimation. The actual parametric form is given in Appendix A.7.

[38] I use 1500 state points and 49 (22 if $t = 2$) variables for the approximations of the $Emax_t$ functions. The number of random draws for Monte Carlo integration is 30. The goodness of fit is assessed by the adjusted coefficients of determination: with the estimated parameter values they range from 99.84 to 99.98.

interpolated $Emax_1$ is calculated.

To computationally implement the above procedure, I need to specify parametric functional and model distributional assumptions. Appendix A shows the exact functional forms. I now turn attention to the data that is used for estimation.

5 Data

The data for estimation of the life-cycle model is constructed from the 1979-2000 waves of the 1979 youth cohort of the National Longitudinal Survey of Youth (NLSY79). Conducted every year for 1979 to 1993 and once two years for 1994-2004, the NLSY79 contains a nationally representative sample of 12,686 individuals (with 6,403 of them being males) who were 14-21 years old as of January 1, 1979. It contains a core random sample and oversamples of blacks, Hispanics, economically disadvantaged non-black/non-Hispanics, and members of the military. As of the 2000 interview round, all the individuals became 35-43 years old. In this study, I use the white male part in the core random sample.[39] This reduces the initial sample size 12,686 to 2,439. The further restriction on the dimension of individuals is explained in the following subsection.[40]

5.1 Data Construction

I first exclude individuals who have military experience (268 individuals) and then those who are judged to be professionals or farmers (102 individuals). Both professionals and farmers characterized by high rates of self-employment. Why I exclude these people is that the workings of labor markets for them may be quite different from those for nonprofessional, nonfarmers, and hence the decision to become a farm or professional self-employer may depend on different factors than the decision to become a nonfarm, nonprofessional self-employer. I then follow each white man of these 2,068 individuals after the (calender) year when he is considered to have finished schooling, no matter how long it takes for him to finish it. I drop, however, those who are judged to have started working too late (i.e. 26 years old or older) or too early (i.e. 14 years old). The total number of these people is 82. Also excluded are those who are judged to have temporally left for adult schooling in the midst of their work career (24 individuals). Some individuals have to be excluded if it is difficult to determine the first decision period, or if no survey years are covered when working (47 individuals). All money values in this paper are expressed in 2000 dollars. My final sample consists of 1,916 white males with a total of 32,166 person-year observations (which is an unbalanced panel).

Let the constructed data be denoted by $X = \{X_i\}_{i=1}^{N}$, where N is the number of individuals in the data and X_i is data for individual i. Using the notation in the dynamic model presented in Section 3, I can write the actual form of X_i as

$$X_i = \{(l_{i,t}^s, l_{i,t}^w),\ (y_{i,t}^s, w_{i,t}),\ a_{i,t+1}, age_{i,t})_{t=1}^{\widehat{T}_i},\ a_{i1},\ educ_i\},$$

where $\widehat{T}_i$ is the last period when individual i's information is available (note the difference between $\widehat{T}_i$ and T_i), $age_{i,1}$ is actually equal to $\underline{age_i}$ (so that both variables will be used inter-

[39] Future research would include studying issues of self-employment among non-whites (racial discrimination) and women (fertility and child rearing).

[40] Appedix B describes the details on the sample inclusion criteria and on how variables in my data are created.

changeably), and N is the number of individuals in the sample. Note also that consumption can be calculated up to period $\widehat{T}_i - 1$. So, essentially, I do not use data observations in period $\widehat{T}_i$. For the schooling variable $educ_i$, I consider only two categories, "High-school dropouts or graduates (H)" (called *non-college educated* hereafter), and "Some college degree or higher (C)" (called *college educated* hereafter), mainly because of the small numbers of the self-employment experienced. While $educ_i$ and $\underline{age_i}$ are observed for any i, the amount of initial asset $a_{i1}$is not necessarily observable for all $\overline{i\text{'s}}$.[41] The hourly wage, $w_{i,t}$, is observed constructed only when individual i worked as a paid worker. Similarly, $y^s_{i,t}$ is observed only when individual i worked as a self-employer in period t.[42]

The NLSY79 has detailed information on the self-employed themselves, but very limited information on the businesses they run.[43] This limited information on the financial side of self-employment, however, would not be too restrictive because modeling that part is kept to minimum in this study. We also no information on how many workers each self-employer employs in his firm. Remember, however, that I have assumed that production contribution by the self-employed is separable from that by his employees, so this data limitation is not restrictive to this study, either.

5.2 Descriptive Statistics

In this subsection, I explain key descriptive statistics of the constructed sample X.

5.2.1 Initial Conditions ($\underline{age_i}$, $educ_i$ and a_{i1}) and Information on Individual-Period Observations in the Pooled Data

Panel 1 in Table 3 shows the initial conditions of the sample individuals. First, remember that the earliest age for decisions is set to 20.[44] About 60 percent of the individuals start decisions at age 20, and 94 percent of them start decisions until age 23. Next, as for schooling attainment, 63 percent of the individuals are non-college educated and the remaining individuals are college educated. In the joint distribution of initial age and schooling (not shown), nearly 90 percent of the individuals in the non-college educated group start decisions at age 20, while about 50 percent of the college educated individuals start decisions at age 22

[41] Regarding the risk-free interest rate (r), I first computed for each year from 1979 to 2000 the difference between the nominal annual rate of federal funds and the next year's realized inflation rate (as a substitute for the expected inflation rate). I then impute the yearly average, 3.5%, to r ($r = 0.035$). I also use a constant rate of business capital depreciation (δ, and it is taken as a data input: as in Cagetti and De Nardi (2006), it is set to be 6.0% ($\delta = 0.060$).

[42] I carefully constructed "income from self-employment" in my data to capture the "returns to capital" as precisely as possible. In particular, I compared Income Information from the "Income Section" with from the "Employer Supplement Section" in the NLSY79. The downside of using the "Income Section" is that after 1995 income information is obtained once in every two years, which reduced the number of observed income. However, by comparing labor earnings calculated from the "Employer Supplement Section" with total income (the sum of wage/salary income and business income) calculated from the "Income Section", I found, for income from self-employment, the former appears to have downward bias especially for higher percentiles, while for income from paid-employment, both are surprisingly similar. So, I use the "Income Section" to calculate income from self-employment while the "Employer Supplement Section" is used to calculate income from paid-employment. See Appendix B for the details.

[43] Currently, at the US Census Bureau, effort are undertaken to integrate business and household data (the Longitudinal Employer-Household Dynamics (LEHD) program) and employer-employee data (the Integrated Lonitudinal Business Database (ILBD)). See Davis, Haltiwanger, Jarmin, Krizan, Miranda, Nucci, and Sandusky (2007) for details.

[44] Note also that the ealiest age when information on asset is available is age 20.

Table 3: Summary Statistics (NLSY79; White Males; Aged 20-39)

Variable	No.Obs.	Mean	Std.Dev.	Median	Max	Min
(Panel 1. Initial conditions)						
Age at the first decision period (%)						
20	1916	0.627	-	-	1	0
21	1916	0.114	-	-	1	0
22	1916	0.112	-	-	1	0
23	1916	0.083	-	-	1	0
24	1916	0.042	-	-	1	0
25	1916	0.022	-	-	1	0
Educational attainment (%)						
Non college-educated	1916	62.58	-	-	1	0
College-educated	1916	37.42	-	-	1	0
Net worth at the initial age of decisions	387	11940.8	39499.7	3952	576000	-38308
(Panel 2. Pooled)						
Age	32166	29.03	5.29	29	20	39
Labor supply (%)						
Self-employed	31494	0.069	-	-	1	0
Paid-employed, full-time	31494	0.705	-	-	1	0
Paid-employed, part-time	31494	0.099	-	-	1	0
Non-employed	31494	0.101	-	-	1	0
SE & full-time PE	31494	0.013	-	-	1	0
SE & part-time PE	31494	0.012	-	-	1	0
Experience of paid-employed work (years)	32166	6.27	4.65	6	19	0
Annual Income from self-employment	2079	51350.8	56971.4	36900	884801	64
Annual Income from paid-employment						
Full-time	22295	32932.4	23900.2	28560	990057	184
Part-time	3417	14256.8	10885.6	11900	228000	143
Net worth	17169	57312.4	118703.6	20008	2673988	-72600

Note 1: "Non college-educated" individuals are highschool dropouts and highschool graduates, and "College-educated" are individuals with some college education and more.
Note 2: "Years of paid-employed work experience" counts 1-year experience if an individual works as a full-time as a full-time wage worker, and 0.5-year experience if he works as a part-time wage worker.
Note 3: Monetary values are in terms of year 2000 dollars.

or 23. With respect to net worth that each individual owns at his first age of decisions, the considerable difference between the mean and the median suggest the skewness of the wealth distribution even in early 20s. As is expected, the joint distribution of initial net worth and schooling (not shown), both the mean (13,062 versus 9,505 dollars) and the median (5,495 versus 1840 dollars) are higher for the college educated.

Panel 2 in Table 3 displays information on individual-period observations in the pooled data. The average (and the median) age is 29. As is mentioned in Introduction, of all the observations on labor supply decisions, 7 percent are provided as self-employed work while 80 percent are as either full- or part-time paid-employed work. The average accumulated years of experience as a wage worker is 6.3 (excluding years as a self-employer). The mean income from self-employment (51,351 dollars) is considerably higher (56 percent higher) than that from full-time paid-employment (32,932 dollars). The median difference is much smaller: the median income from self-employment is 29 percent higher than that from full-

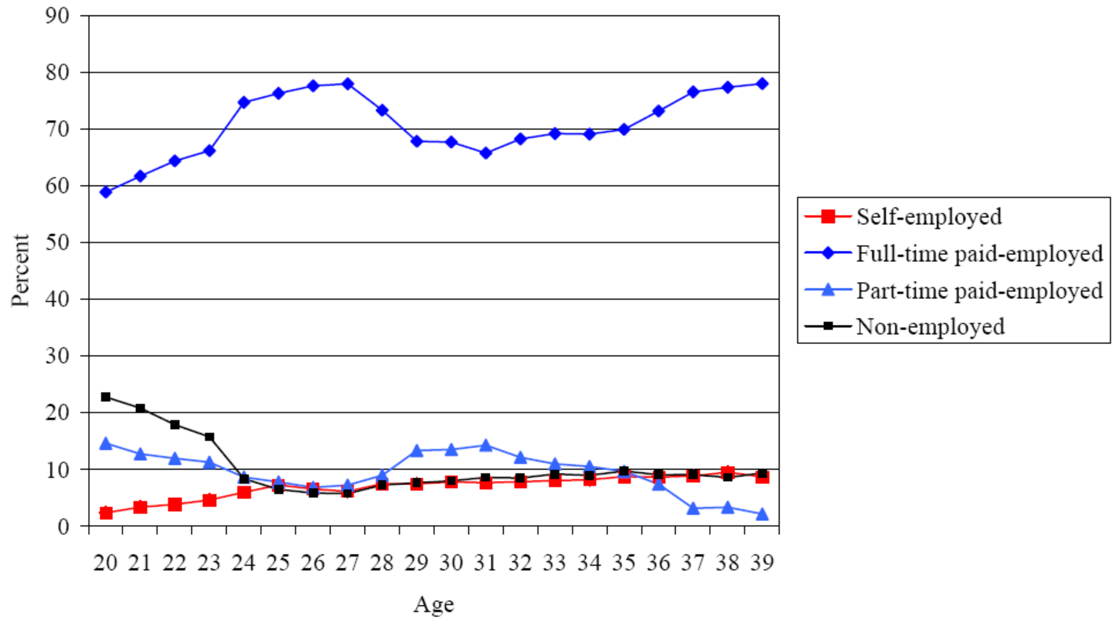

Figure 1: Distribution of Labor Supply Decisions by Age (White Males; NLSY79)

time paid-employment (36,900 versus 28,560 dollars). The mean income from part-time paid employment is 57 percent lower than that from full-time paid-employment. Lastly, the average net worth is 57,312 dollars while the median is 20,008 dollars.

5.2.2 Labor Supply Decisions: Age Profiles ($\{l^s_{i,t}, l^w_{i,t}\}$), Transitions, and Entry into and Exit from Self-Employment

Table 4 and Figure 1 show the marginal distribution of labor supply decisions by age. At age 20, only 2.4 percent of the white men are self-employed. Then, the rate increases rapidly until age 25 (7.3 percent). After that, it remains stable with a slight increase (9.5 percent at age 38). The rates of full-time paid employment are highest and stable over all the ages. Starting with 58.9 percent, the percentage grows to 77.9 percent at age 27. After that age, the number declines slightly (65.7 percent at age 31), and then it grows again. Corresponding to the slight decline in full-time paid employment, the rate of part-time paid-employment starts go up at age 27 after the decline since age 20, reaching 14.3 percent at age 31. Lastly, the percentage of the non-employed decreases rapidly in their early 20s: 22.8 percent at age 20 to 5.8 percent at age 27. Then, after age 28 the rates are stable with a slight increase (between 7.3 and 9.7).

Some key differences of self-employment by schooling have been already presented in Tables 1 and 2. In what follows, we look at details of life-cycle aspects of labor supply decisions. Table 5 shows the percentages of the individuals for the numbers of entries into self-employment. First, we find *self-employment experience is not rare*: 28.3 percent of individuals (543 out of 1916 individuals) have at least one year of self-employment experience. Second, we do not observe too many trials by the same young individual, however: 94.1 percent of them enters *only once or twice* in the data periods. As was already mentioned, the non-college educated is more likely to have self-employment experience than the college educated do.[45] Figure 2 shows an important difference in the timings of first entries into

[45]Remember that my data contains only nonprofessional white males in nonagricultural sectors. Excluded

Table 4: Marginal Distribution of Labor Supply Decisions by Age

Age (No.Obs.)	Self-employed	Paid-employed: Full-time	Paid-employed: Part-time	Non-employed	Dual-employed: SE & Full-time PE	Dual-employed: SE & Part-time PE
20 (1172)	2.4% 28	58.8% 689	14.6% 171	22.9% 268	0.9% 10	0.5% 6
21 (1393)	3.4% 47	61.7% 859	12.8% 178	20.8% 290	0.6% 9	0.7% 10
22 (1609)	3.9% 62	64.3% 1035	12.0% 193	17.9% 288	1.1% 18	0.8% 13
23 (1751)	4.6% 81	66.1% 1157	11.3% 197	15.9% 278	1.0% 18	1.1% 20
24 (1820)	6.0% 109	74.7% 1359	8.6% 157	8.4% 153	1.2% 22	1.1% 20
25 (1848)	7.3% 134	76.5% 1409	7.8% 144	6.5% 121	1.2% 23	0.9% 17
26 (1829)	6.6% 120	77.6% 1419	6.8% 125	5.9% 108	2.0% 37	1.1% 20
27 (1826)	6.1% 112	77.9% 1422	7.3% 133	5.8% 106	1.6% 30	1.3% 23
28 (1817)	7.5% 136	73.3% 1331	9.0% 164	7.3% 133	1.8% 32	1.2% 21
29 (1795)	7.5% 134	67.9% 1218	13.3% 239	7.7% 138	1.9% 35	1.7% 31
30 (1780)	7.8% 139	67.7% 1205	13.5% 240	8.0% 143	1.4% 25	1.6% 28
31 (1750)	7.7% 134	65.8% 1151	14.2% 249	8.6% 151	1.8% 31	1.9% 34
32 (1735)	7.8% 136	68.2% 1183	12.2% 211	8.5% 148	1.6% 28	1.7% 29
33 (1708)	8.0% 137	69.1% 1181	11.0% 188	9.3% 158	1.5% 25	1.1% 19
34 (1686)	8.2% 138	69.0% 1164	10.6% 178	9.0% 152	1.5% 25	1.7% 29
35 (1636)	8.7% 143	69.9% 1143	9.7% 159	9.8% 160	1.0% 16	0.9% 15
36 (1446)	8.6% 125	73.1% 1057	7.5% 108	9.1% 132	0.8% 11	0.9% 13
37 (1199)	8.8% 106	76.6% 918	3.2% 38	9.1% 109	1.1% 13	1.3% 15
38 (956)	9.6% 92	77.2% 738	3.5% 33	8.6% 82	0.6% 6	0.5% 5
39 (738)	8.8% 65	77.9% 575	2.2% 16	9.3% 69	0.8% 6	0.9% 7

Note: Percentages and number of observations.

Table 5: Distribution (percent) of the Number of Entries into Self-Employment

Number of entries into self-employment	All individuals	(Non-college)	(College)
0	69.8	68.2	72.5
1	19.5	20.8	17.4
2+	10.7	11.0	10.1
	100.0	100.0	100.0
(No.Obs.)	(1916)	(1199)	(717)

Note: Measured at the last periods observed in the data.

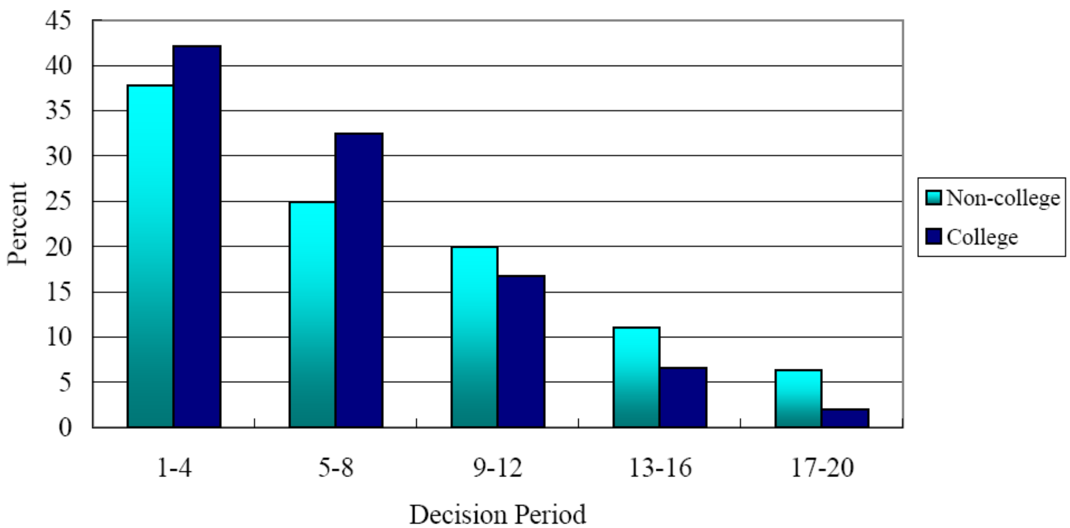

Figure 2: Distribution of Labor Supply Decisions by Age (White Males; NLSY79)

by schooling. Although the means and the medians of the first entries for both types of schooling are quite similar (8.2 (mean) and 7 (median) for the non-college educated, and 8.6 (mean) and 8 (median) for the college educated), the two distributions do not look similar: the highest percentage is attained at decision periods 5-8 for the college educated, while it is attained at decision periods 1-4 for the non-college educated.

The left panel of 6 shows one-period transition rates of labor supply decisions for both schooling levels.[46] The first number in each cell is the percentage of transitions from origin to destination (row %) while the second is the percentage in a particular destination who started from each origin (column %). The table shows *persistence in self-employment and in full-time paid-employment*: 75.4 (73.6) percent of the non-college (college) educated self-employers in one year do self-employment the next year, and 85.4 (89.5) percent of the

are 40 lawers/accountants and 23 doctors. This seems the reason of a low self-employment rate among category "College or higher" because college degree is necessary to be a professional of these kinds. If these 63 individuals are added to the self-employment cell, then the rate of self-employment rate for the college educated will be 31.4% (=(182+63)/(717+63)).

[46] I define year of *entry* into self-employment t by $l^s_{i,t} = SE$ and $l^s_{i,t-1} = Zero$, and define year of *exit* from self-employment t by $l^s_{i,t} = SE$ and $l^s_{i,t+1} = Zero$. The duration of a SE spell is defined by the difference between the exit year and the entry year.

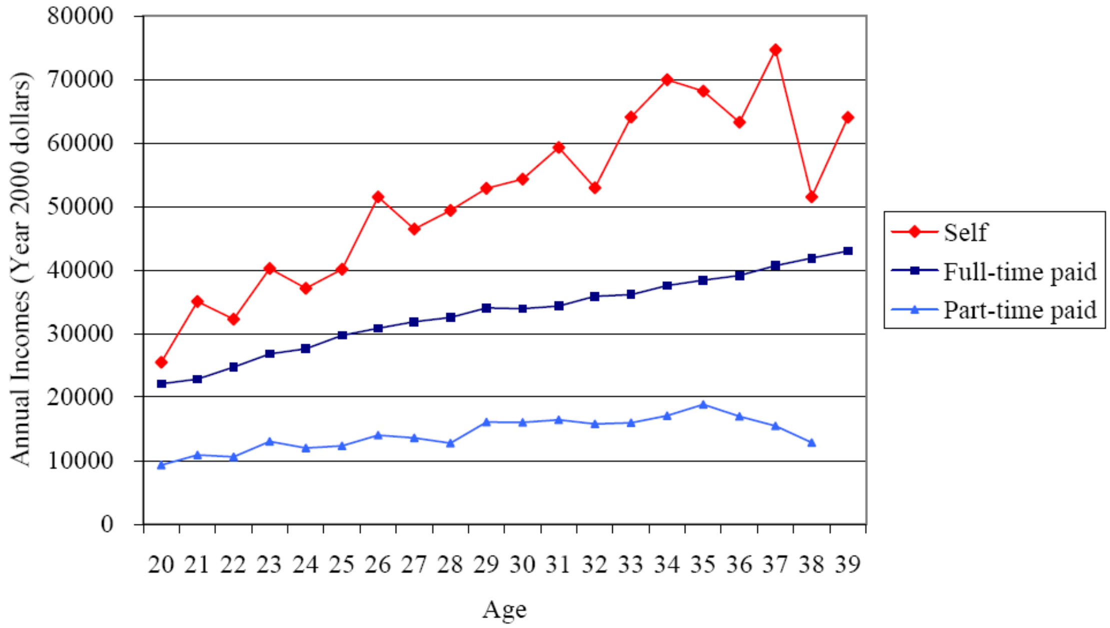

Figure 3: Age Profiles of Mean Annual Incomes

non-college (college) education who worked full-time as a wage worker in one year work as a full-time wage worker the next year. The age pattern of the self-employment and full-time paid employment is also worth attention. The left panel of 7 implies that self-employment in twenties is likely to end earlier than that in thirties: the transition rate of self-employment in twenties is 69 percent while that in thirties is 80 percent.

5.2.3 Age Profiles of Income ($\{y^s_{i,t}, y^w_{i,t}\}$) and of Net Worth ($\{a_{i,t}\}$)

As is already seen in Table 2, the self-employed earn more, on average, than the paid-employed do, and across the two groups of education levels, income from self-employment is higher than income from paid-employment (both for the mean and for the median). Table 8 and Figure 3 display age-specific mean real incomes from self-employment, from full-time and from part-time paid-employment. Real incomes rise with age in all the three modes of employment. The percentage difference between income and income from full-time paid-employment at early twenties is about 40 to 50 percent. It grows with age: at late thirties it becomes about 60 to 70 percent.

Table 9 and Figure 4 show the age profile of the mean and median net assets of all individuals. As is seen, the mean grows faster then the median does, and as a result, he mean net worth at late thirties is about 14 times larger than that at early twenties. The wealth distribution is thus more skewed in later ages.

6 Estimation Method

Using data X that is explained in the previous section, I estimate the parameters of the life-cycle model of employment mode decisions and wealth accumulation. Now, given the approximated values for $Emax_t$, it is possible to simulate individual behavior from the first decision period (one year after he finished schooling) to age 65, with an arbitrary pair of model parameters. I simulate individual choices (choice on labor and asset) and income

Table 6: Transition Matrices for Labor Supply Decisions (aged 20-39) by Schooling

Actual Non-college

Labor supply (t-1)		Labor supply (t) SE	PE Full-time	PE Part-time	NE
SE					
	Row %	75.4	7.2	2.6	6.2
	Column %	91.4	4.1	4.8	7.9
PE, Full-time					
	Row %	1.0	85.4	7.5	4.5
	Column %	1.2	49.2	14.1	5.7
PE, Part-time					
	Row %	1.7	51.1	28.0	18.4
	Column %	2.0	29.4	52.2	23.3
NE					
	Row %	4.4	29.9	15.5	49.7
	Column %	5.4	17.2	28.9	63.1

Predicted Non-college

Labor supply (t-1)		Labor supply (t) SE	PE Full-time	PE Part-time	NE
SE					
	Row %	83.0	10.3	0.9	5.8
	Column %	91.1	6.5	1.1	8.3
PE, Full-time					
	Row %	4.1	81.9	9.0	4.9
	Column %	4.5	52.3	11.0	7.1
PE, Part-time					
	Row %	2.2	49.0	43.3	5.5
	Column %	2.4	31.3	52.6	7.9
NE					
	Row %	1.8	15.5	29.0	53.7
	Column %	2.0	9.9	35.3	76.7

Actual College

Labor supply (t-1)		Labor supply (t) SE	PE Full-time	PE Part-time	NE
SE					
	Row %	73.6	8.4	3.3	4.2
	Column %	88.8	4.2	6.3	7.6
PE, Full-time					
	Row %	0.9	89.5	5.9	2.2
	Column %	1.1	45.5	11.3	4.0
PE, Part-time					
	Row %	2.9	56.0	27.8	12.5
	Column %	3.5	28.5	53.5	22.9
NE					
	Row %	5.5	42.7	15.0	35.7
	Column %	6.6	21.7	28.9	65.5

Predicted College

Labor supply (t-1)		Labor supply (t) SE	PE Full-time	PE Part-time	NE
SE					
	Row %	85.8	8.7	1.1	4.3
	Column %	89.7	4.3	3.2	6.5
PE, Full-time					
	Row %	4.3	91.6	2.8	1.2
	Column %	4.5	45.4	7.9	1.9
PE, Part-time					
	Row %	4.1	69.7	19.2	7.0
	Column %	4.3	34.5	54.0	10.5
NE					
	Row %	1.4	31.9	12.4	54.3
	Column %	1.5	15.8	34.9	81.1

Note 1: NE stands for non-employed, SE for self-employed, and PE for paid-employed.
Note 2: Rows labeled by "Row" contain the distribution of destinations (period t+1) conditional on origin (period t). Rows labeled by "Column" contain the distribution of origins conditional on destination. conditional on destination.
Note 3: "SE and full-time PE" and 'SE and part-time PS" are omitted, so the sums of the numbers across row or column are not 100.0.

Table 7: Transition Matrices for Labor Supply Decisions by Age Group

Actual
Aged 20-29

Labor supply (t-1)		Labor supply (t) SE	PE Full-time	PE Part-time	NE
SE					
	Row %	69.8	10.7	3.5	5.3
	Column %	89.8	5.8	6.3	7.8
PE, Full-time					
	Row %	1.3	85.5	7.1	4.5
	Column %	1.7	46.0	12.9	6.6
PE, Part-time					
	Row %	2.5	52.0	26.8	17.9
	Column %	3.2	27.9	48.9	26.5
NE					
	Row %	4.2	37.9	17.4	40.0
	Column %	5.4	20.4	31.8	59.1

Predicted
Aged 20-29

Labor supply (t-1)		Labor supply (t) SE	PE Full-time	PE Part-time	NE
SE					
	Row %	87.3	9.4	2.3	1.1
	Column %	94.3	6.0	2.6	1.6
PE, Full-time					
	Row %	2.5	77.4	13.4	6.7
	Column %	2.7	50.0	15.4	10.2
PE, Part-time					
	Row %	2.1	50.4	47.1	0.4
	Column %	2.3	32.6	54.1	0.6
NE					
	Row %	0.7	17.6	24.4	57.4
	Column %	0.7	11.4	28.0	87.6

Actual
Aged 30-39

Labor supply (t-1)		Labor supply (t) SE	PE Full-time	PE Part-time	NE
SE					
	Row %	79.4	4.7	2.2	5.8
	Column %	91.3	2.8	4.4	7.0
PE, Full-time					
	Row %	0.6	88.9	6.7	2.5
	Column %	0.6	52.2	13.4	3.1
PE, Part-time					
	Row %	1.6	53.4	29.3	14.9
	Column %	1.8	31.4	58.3	18.3
NE					
	Row %	5.4	23.4	12.0	58.5
	Column %	6.3	13.7	23.9	71.6

Predicted
Aged 30-39

Labor supply (t-1)		Labor supply (t) SE	PE Full-time	PE Part-time	NE
SE					
	Row %	83.8	9.7	0.1	6.4
	Column %	82.2	3.9	0.4	32.3
PE, Full-time					
	Row %	5.6	92.3	1.1	1.0
	Column %	5.5	36.7	4.2	4.9
PE, Part-time					
	Row %	6.4	75.6	16.6	1.5
	Column %	6.3	75.6	61.4	7.5
NE					
	Row %	6.2	73.8	9.2	10.9
	Column %	6.0	29.4	34.0	55.3

Table 8: Age Profiles of Mean Incomes by Labor Supply Decisions

Age	Self-employed	(std.dev.)	(no.obs.)	Paid-employed Full-time	(std.dev.)	(no.obs.)	Part-time	(std.dev.)	(no.obs.)
20	25479.4	3346.0	38	22086.9	336.1	694	9302.1	354.7	171
21	35048.4	5636.7	55	22819.5	316.8	863	10891.8	417.9	183
22	32257.9	3008.8	78	24716.4	325.3	1044	10601.5	366.4	200
23	40238.2	3843.4	105	26791.4	582.8	1164	13016.0	1313.4	215
24	37131.3	2607.6	129	27602.3	355.0	1363	11992.7	1043.6	176
25	40122.7	2776.5	153	29703.4	624.2	1415	12313.6	683.4	158
26	51498.5	7828.1	155	30816.8	683.0	1435	14001.5	875.2	142
27	46444.7	3553.9	140	31865.1	779.3	1433	13582.5	964.9	151
28	49377.0	4034.2	163	32530.4	578.2	1344	12751.8	465.4	182
29	52852.2	4196.9	166	34036.2	1015.2	1230	16071.5	704.7	266
30	54313.3	8016.5	142	33911.9	780.0	1206	16020.7	591.6	265
31	59283.8	6854.9	141	34311.0	584.3	1160	16416.3	795.8	275
32	52942.5	6308.6	134	35868.1	671.1	1183	15775.6	622.7	234
33	64065.8	6837.5	100	36102.0	584.0	1180	15953.5	846.3	202
34	69952.1	7038.6	113	37554.4	716.2	1161	17069.6	903.0	202
35	68146.2	11395.2	71	38395.4	694.1	1143	18845.6	879.1	165
36	63237.1	7187.5	69	39146.6	714.6	1060	16963.7	1038.1	119
37	74635.8	11327.1	52	40691.1	864.4	917	15458.6	2032.3	51
38	51499.3	5752.5	38	41868.1	987.1	730	12833.2	1144.4	38
39	64036.2	7761.4	37	42990.4	1315.7	570	-	-	-

Note 1: Numbers are in year 2000 dollars.
Note 2: Mean part-time income for age 39 is not shown
because the number of observations is small (22).

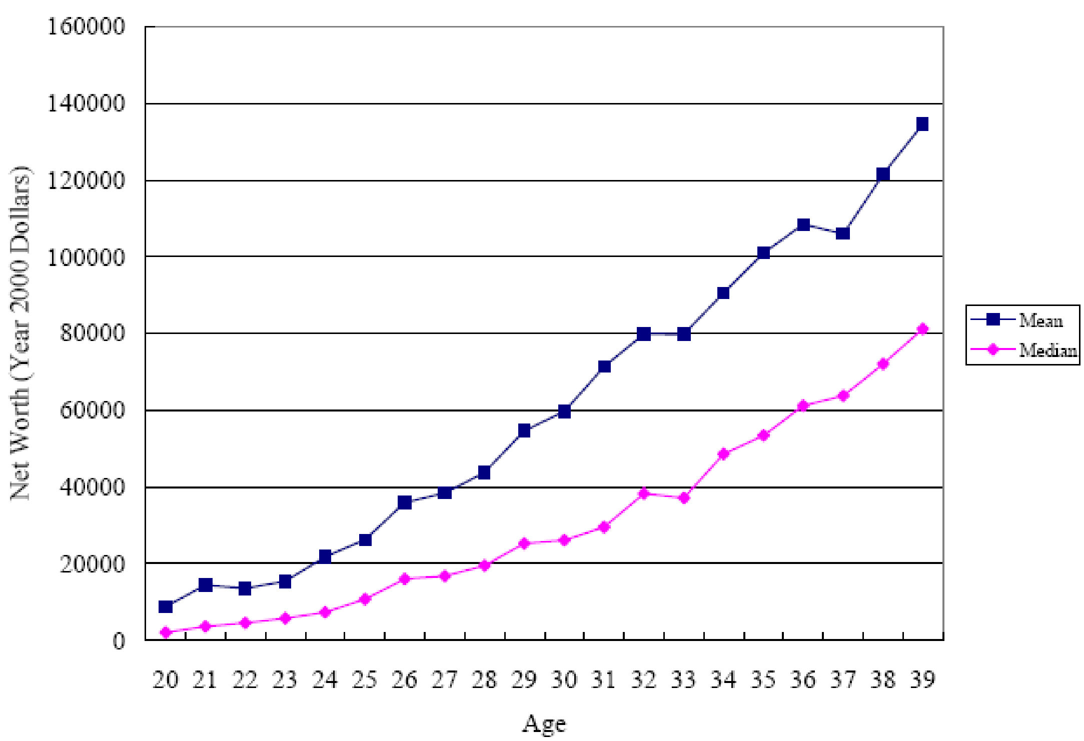

Figure 4: Actual Mean and Median of Net Worth

Table 9: Age Profile of Net Worth

Age (No.Obs.)	Mean	Median	25%	75%	Min	Max	Percent Negative
20 (138)	8829.1	2080	160	6840	-8480	184160	20.3
21 (311)	14437.0	3611	628	11200	-21038	576000	19.9
22 (588)	13556.3	4560	785	13860	-48165	769302	19.6
23 (834)	15453.4	5768	970	18240	-52560	364802	19.2
24 (1078)	21731.9	7300	1274	22338	-56836	814722	17.9
25 (1259)	26170.6	10640	2376	28576	-72336	679442	14.8
26 (1255)	35819.5	15985	3562	39672	-52820	742922	13.5
27 (1360)	38413.3	16800	3208	43916	-71438	912915	14.4
28 (1312)	43644.7	19382	4049	51778	-63510	1128144	13.0
29 (1327)	54481.7	25258	4620	61612	-60800	1905040	11.7
30 (1126)	59657.9	26101	5587	70702	-59796	1136710	12.1
31 (1123)	71103.3	29304	6838	73780	-59860	2594100	10.4
32 (953)	79519.8	38080	6991	87115	-56100	2231799	10.5
33 (925)	79702.4	37120	6100	93432	-59003	2579427	12.1
34 (836)	90289.1	48452	10681	111863	-69020	1217687	9.0
35 (842)	100622.3	52910	13807	118985	-63800	2023543	10.2
36 (651)	108198.7	60900	14160	141541	-49000	2673988	8.1
37 (516)	105425.2	62948	14329	143285	-56500	1421460	11.4
38 (436)	121347.6	71525	23723	160490	-55120	796098	6.7
39 (297)	134295.6	81000	20465	188400	-48760	816200	9.8

opportunities (including ones not chosen by the individual). The level of education and the initial amounts of net worth are taken as exogenous. At the initial decision period, any individual has no experience both for self-employment and for paid-employment.

Conditional on the deterministic part of the state space $\overline{S}_t$, the solution of the dynamic programming problem gives the conditional probability that an individual chooses option d, as the product of the type probabilities and a five-dimensional integral over the vector of shocks so that choice d is indeed optimal. If all variables in the state space were observed, then the conditional likelihood could be constructed as the the product, over time and individuals, of these probabilities.

However, a serious problem is that endogenous state variables in S_t are not always observed. In particular, as explained in Section 5, the NLSY79 started collecting information on asset in 1985, and since 1994 it has been collecting the asset information biannually.[47] Calculating the conditional choice probabilities would require one to integrate out all possible choices over the distribution of the unobserved elements. This would, however, be comutationally burdensome. I therefore adopt the method of *simulated maximum likelihood* developed by Keane and Wolpin (2001).[48] Notably, this method allows one to avoid computing the conditional probabilities, and only unconditional probabilities are used in estimation. The idea is that all observed outcomes are measured with error and model parameters are so chosen that the "distance" between simulated ("true") and observed outcomes is minimized.[49],[50]

Specifically, I first fix a trial vector of parameters $\theta \in \Theta$ and $type = 1, .., 4$. In each sim-th simulation (sim = 1,...,M), a period-by-period random shock ϵ_t^{sim} is generated for each decision period t. As a solution of the dynamic choice problem, starting with the initial level of asset $\widetilde{a}_1^{sim}$ (see below), for each permanent state (except $type$) ($educ, \underline{age}$), I generate outcome histories of (i) choice realizations $\{(\widetilde{l^s}_{e,t}^{sim}, \widetilde{l^w}_{e,t}^{sim}), \widetilde{\Delta a}_{e,t+1}^{sim}\}_{t=1}^T$, and (ii) the resulting realizations of income $(\widetilde{y^s}_{e,t}^{sim}, \widetilde{y^w}_{e,t}^{sim})$, and asset realizations for the next period $\widetilde{a}_{e,t+1}^{sim}$.[51] I denote the sim-th simulated data (outcome history) for individual i in case his type is $type$ by

$$\widetilde{X}_{i,type}^{sim} = (\{(\widetilde{l^s}_{i,type,t}^{sim}, \widetilde{l^w}_{type,t}^{sim}), (\widetilde{y^s}_{i,type,t}^{sim}, \widetilde{y^w}_{i,type,t}^{sim}), \widetilde{a}_{i,type,t+1}^{sim}, \widetilde{k}_{i,type,t}^{sim}, age_{i,type.t}^{sim}\}_{t=1}^T, \\ \widetilde{a}_{i,1}^{sim}, educ_i),$$

[47]In addition, other endogenous variables (labor choice and income) are sometimes missing.

[48]See Keane and Sauer (2007) for technical issues of this method. In particular, they argue that the method is not only computationally practical but has good small sample properties. For an application of the method, see e.g. Keane and Sauer (2009).

[49]A byproduct of this method is that one does not have to discretize all continuous outcome variables. In this study, I do not have to discretize values for income. This is because in the presense of (normally distributed) measurement error any observed outcome history is able to be generated by any simulated outcome history with a nonzero probability.

[50]In constructing the log liklihood function, Rendon (2006) focuses only on the path of state variables afer the year 1985 (when collection on asset information started). In particular, his log likelihood function is constructed conditional on the observation in the year 1985. After obtaining the behavioral parameters, Rendon (2006) goes on to recover the initial asset distribution by using the data from the initial decision period to the year 1985. The way he does so is to update the uniform prior on initial assets by conditional on subsequent behavior.

[51]Notice here that the model components that have no counterpart in the actual data, realized income *opportunities* for the current period $\{\widetilde{f}_{e,t}^m, \widetilde{w}_{e,t}^m\}_{t=1}^T$ and the level of human capital in the next period $\widetilde{\Psi}_{e,t+1}^m$, are also generated by simulation.

where $age^{sim}_{i,type,t}$ is actually independent of sim or $tupe$ (determined by $\underline{age}$ and t). I assume that $educ_i$ and $\underline{age_i}$ (and hence $age_{i,t}$) are observed without error for any individual i.

Now, let the probability of the observed history of individual i conditional on the simulated history be $\Pr(X_i|\widetilde{X}^{sim}_{i,type})$.[52] The novel feature of the estimation method used in the present study is that the calculation of $\Pr(X_i|\widetilde{X}^{sim}_{i,type})$ does not depend on the state variables at any decision period t. This property enables me to construct the (unconditional) likelihood from the distributions of the measurement and classification errors (and the assumption that each error is independently distributed over individuals and time).

Specifically, I first obtain, by simulating M outcome histories, the unbiased simulator of the probability of X_i

$$\widehat{\Pr}(X_i|\theta) = \frac{1}{2M} \sum_{type=1}^{2} \sum_{sim=1}^{M} \Pr(X_i|\widetilde{X}^{sim}_{i,type}) \frac{\Pr(type)}{M},$$

where $\Pr(type)/M$ is interpreted as the proportion of individuals with $type$ in all the simulated histories. The log likelihood is then given by

$$\log \mathcal{L}(\theta|\{X_i\}_{i=1}^{N}) = \sum_{i=1}^{N} \log(\widehat{\Pr}(X_i|\theta))$$

and the estimate for θ is so chosen that it maximizes the log likelihood.[53] Appendix C offers the actual functional form of $\log \mathcal{L}(\theta|\{X_i\}_{i=1}^{N})$. In the current implementation, I choose $M = 5N = 9580$. Standard errors are calculated using the outer product of numerical first derivatives.

7 Estimation Results

In this section, I discuss the fit of the estimated model to the key empirical moments as well as the interpretation of the estimated parameters.

7.1 Model Fit

To evaluate the fit of the estimated model, I artificially generated 9580 (5 times 1916) individual life-cycle paths to age 50 for each age of the first decision period (ages 20-26) using the estimated parameters.[54]

Table 10 compares the three key statistics about entry into and exit from self-employment in the actual data with those in the simulated data (the left part is a reproduction of Table 1). All the three characteristics are underpredicted both for the non-college and the college educated. In particular, entries into self-employment take place in later ages in the simulated

[52] With the notation here, what is explained in Footnote 46 is now stated that for an arbitrary $\widetilde{X}^m_e$, $\Pr(X_i|\widetilde{X}^m_e) > 0$ for any X_i thanks to (adequately modeled) classification and measurement errors.

[53] While some model parameters have their own structural relationships, thus are possible to be estimated independently from the other part of the model structure (e.g. the relationship between observed income and modeled income opportunities), the entire set pf model parameters enters the likelihood through the choice probabilities that are computed from the solution of the dynamic programming problem. Thus, I estimate all the parameters by maximixing the log likelihood function of probablities of outcome histories.

[54] In obtaining any information, simulated data for each invidual is used up to his last period that was covered.

Table 10: Three Characteristics on Entry into and Exit from Self-Employment: Actual and Predicted

	Actual		Predicted	
	Non-college educated	College educated	Non-college educated	College educated
Ever experience of self-employment (%)	31.78	27.48	26.76	24.43
First entry into self-employment occurs in less than or equal to first eight decision years (%)	62.72	74.62	59.34	69.20
Exit from self-employment in a year (%)	32.28	28.57	28.09	23.61

data than in the actual data. It, however, seems to well capture the differences by schooling on entry into and exit from self-employment.

Figures 5-8 compare simulated age profiles of labor supply decisions (self-employed, full-time paid-employed, part-time paid-employed and non-employed) with actual ones. The model does a good job in replicating the age pattern of self-employment: the rate of the self-employed increases until age 25 and then it becomes moderately stable in the remaining ages. As for the other modes of employment, the simulated profiles resemble the actual profiles reasonably well, except few ages around early thirties. In the right panel of Table 1, the predicted one-period transition matrix is presented. The diagonal four transition rates of staying in the same mode of employment are reasonably replicated, though the one for part-time paid employment for the non-college educated and the one for non-employment for the college educated seem relatively overpredicted. The observation that the percentage from full-time paid-employment to self-employment is lower than that from non-employment is not well captured by the model. The right panel of Table 7 display the two transition matrices that correspond to age group 20-29 and to age group. The predicted numbers well capture the stronger persistence of self-employment for ages 30-39, though they show that the estimated model is less successful in explaining the transitions around part-time paid employment and non-employment.

Figures 9-14 display age profiles of annual income for each mode of employment. The model does a good job in replicating the age patterns of income as well. Figure 15 shows the age profile of the mean net worth. The model well captures the growth of the mean by age, though it is under predicted for most of ages, and is also less successful in replicating the skewness of the wealth distribution.

Overall, the estimated model reasonably fits the main features of the actual data, though there are some discrepancies between the empirical observations and the model predictions. More improvement is expected in future work.

7.2 Parameter Estimates

A full list of the model's estimated parameters is given in Appendix D. Here I discuss main characteristics of the estimates.

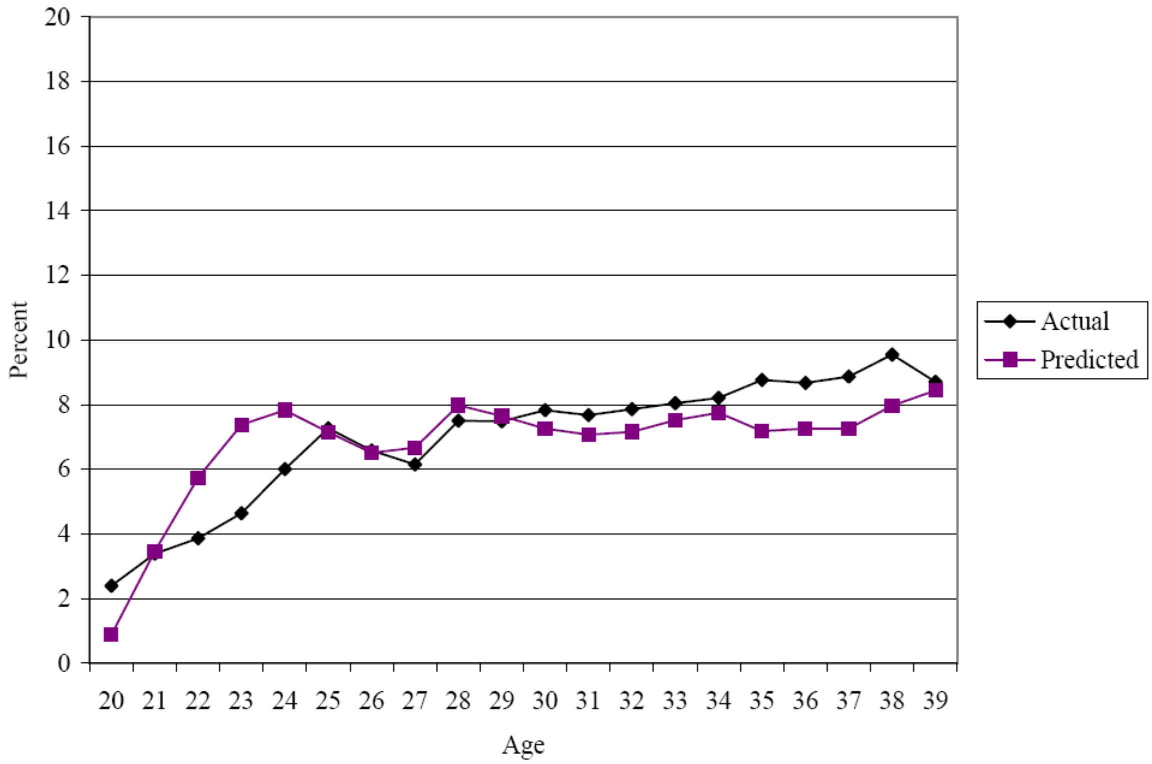

Figure 5: Age Profiles of the Self-Employed

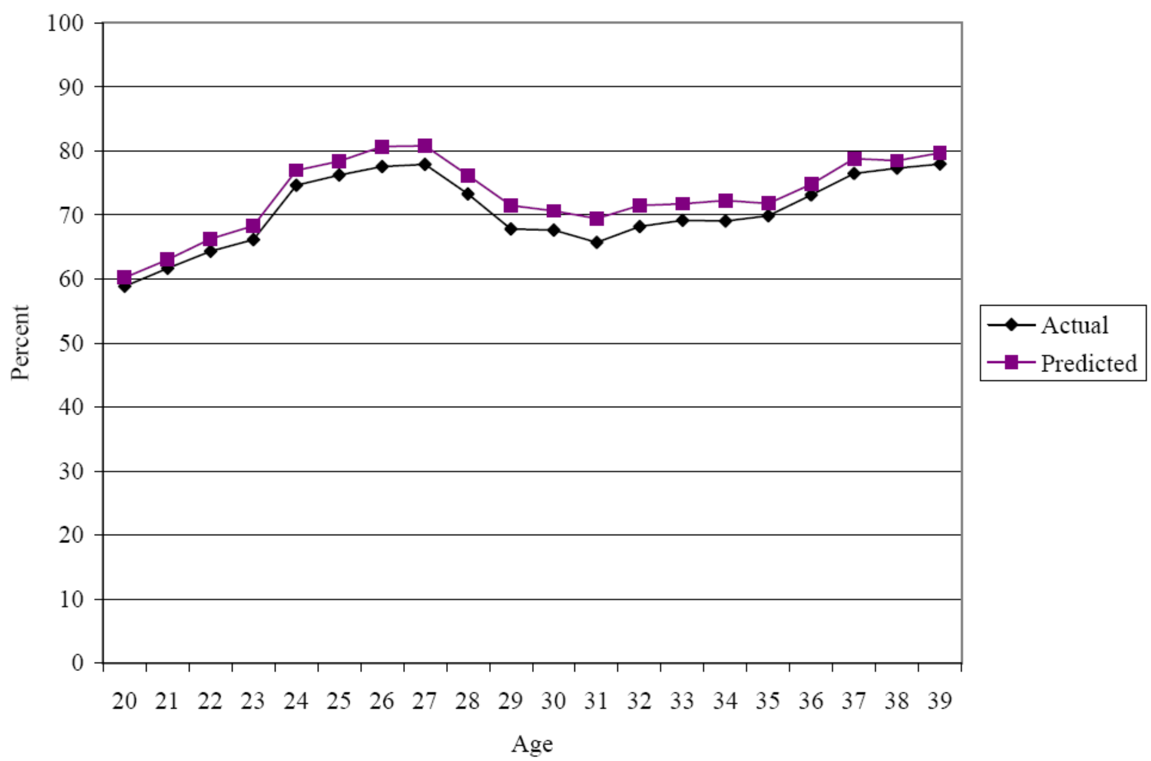

Figure 6: Age Profiles of the Full-Time Paid-Employed

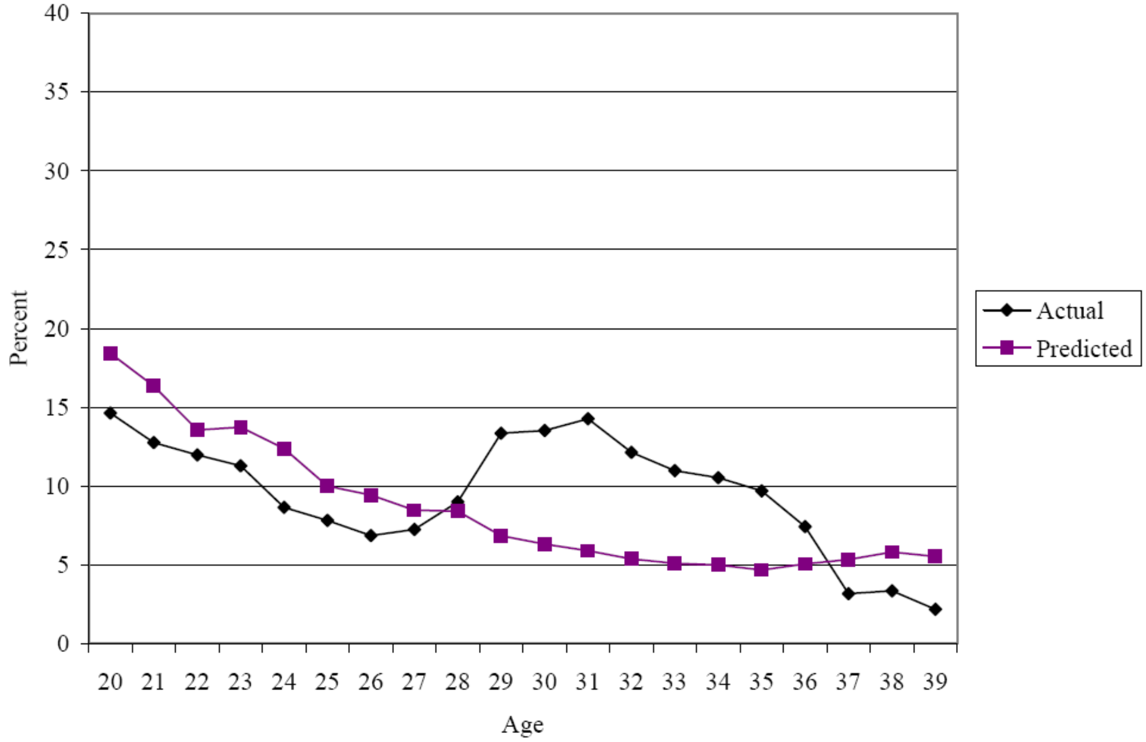

Figure 7: Age Profiles of the Full-Time Paid-Employed

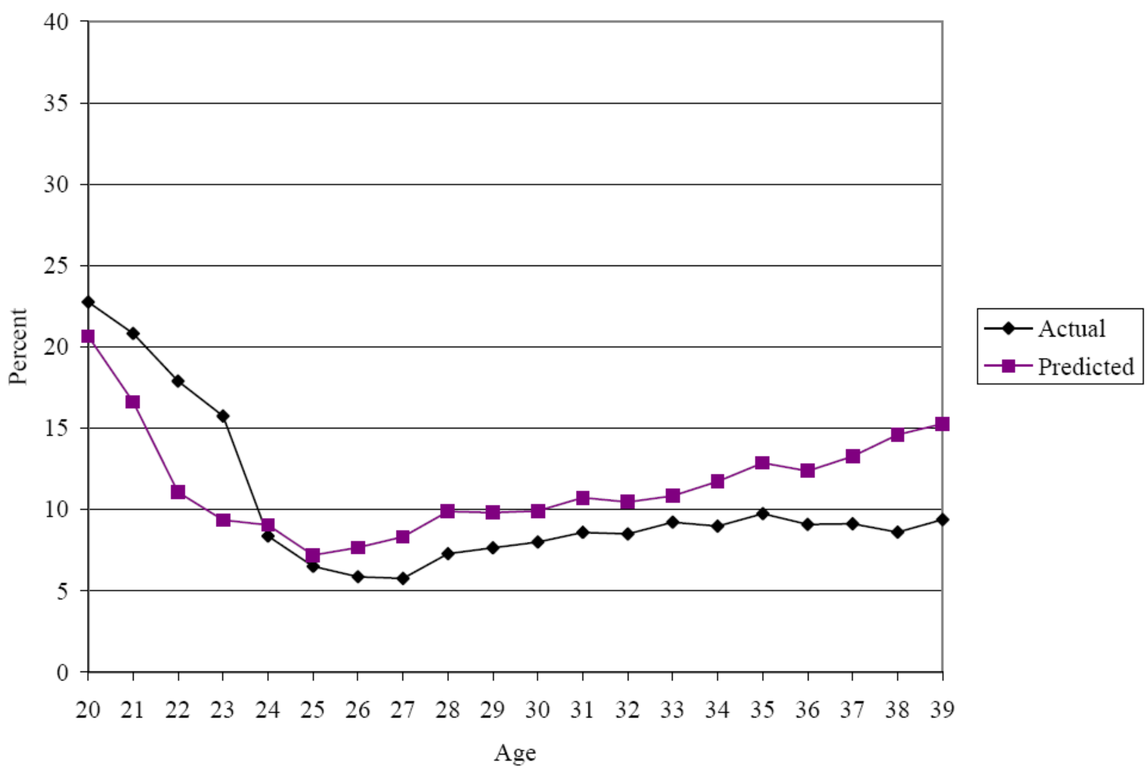

Figure 8: Age Profiles of the Non-Employed

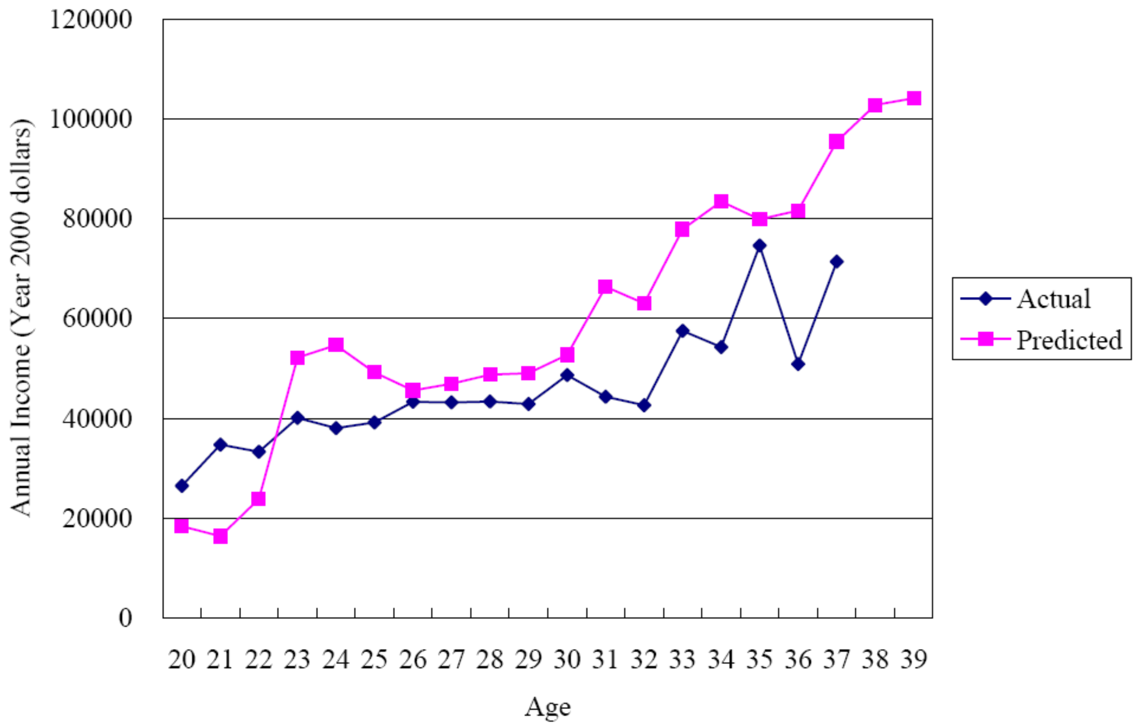

Figure 9: Age Profiles of the Mean Income from Self-Employment (Non-college)

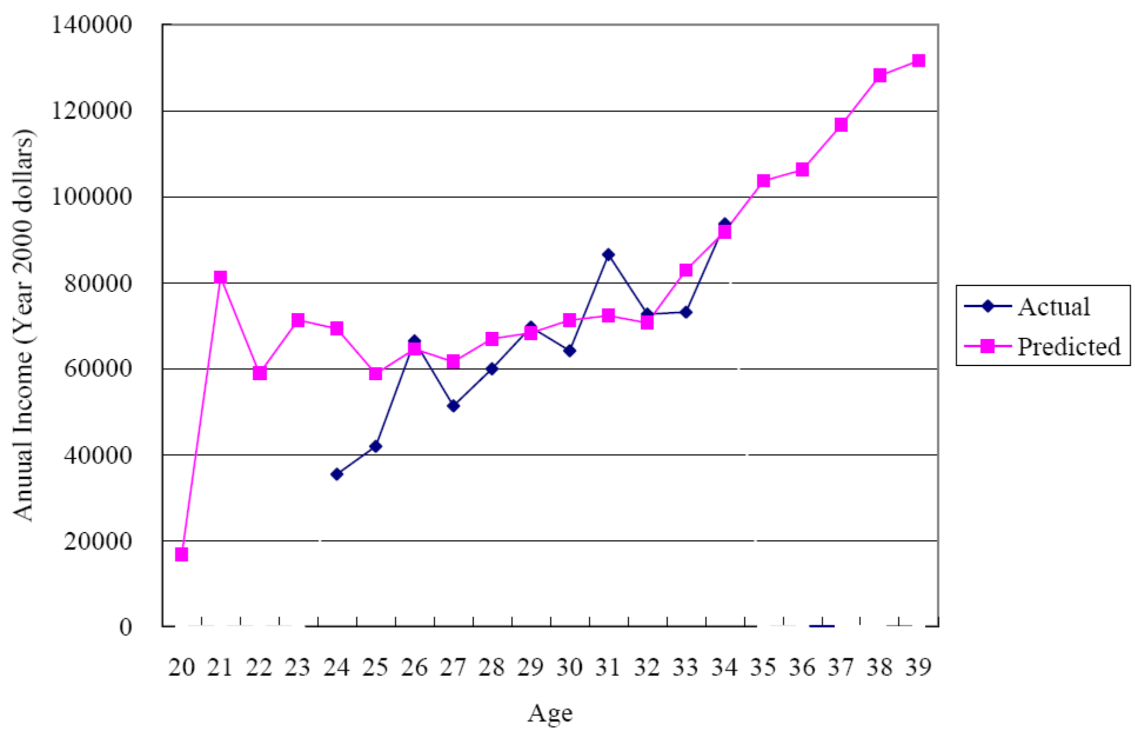

Figure 10: Age Profiles of the Mean Income from Self-Employment (College)

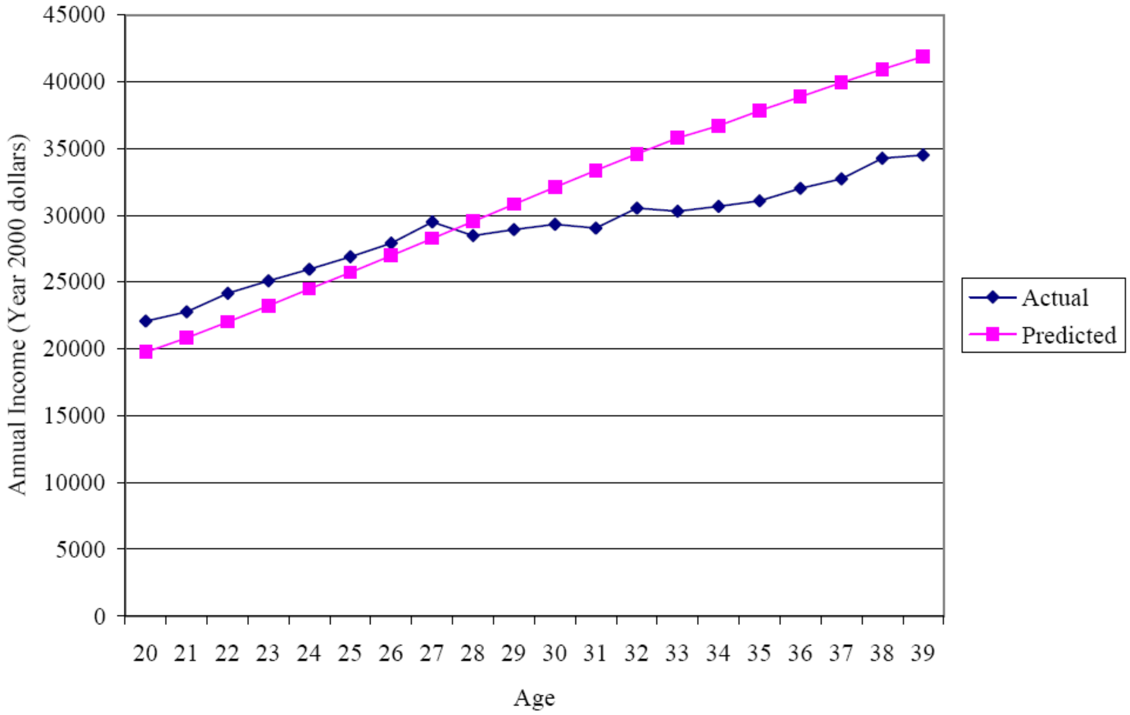

Figure 11: Age Profiles of the Mean Income from Full-time Paid-Employment (Non-college)

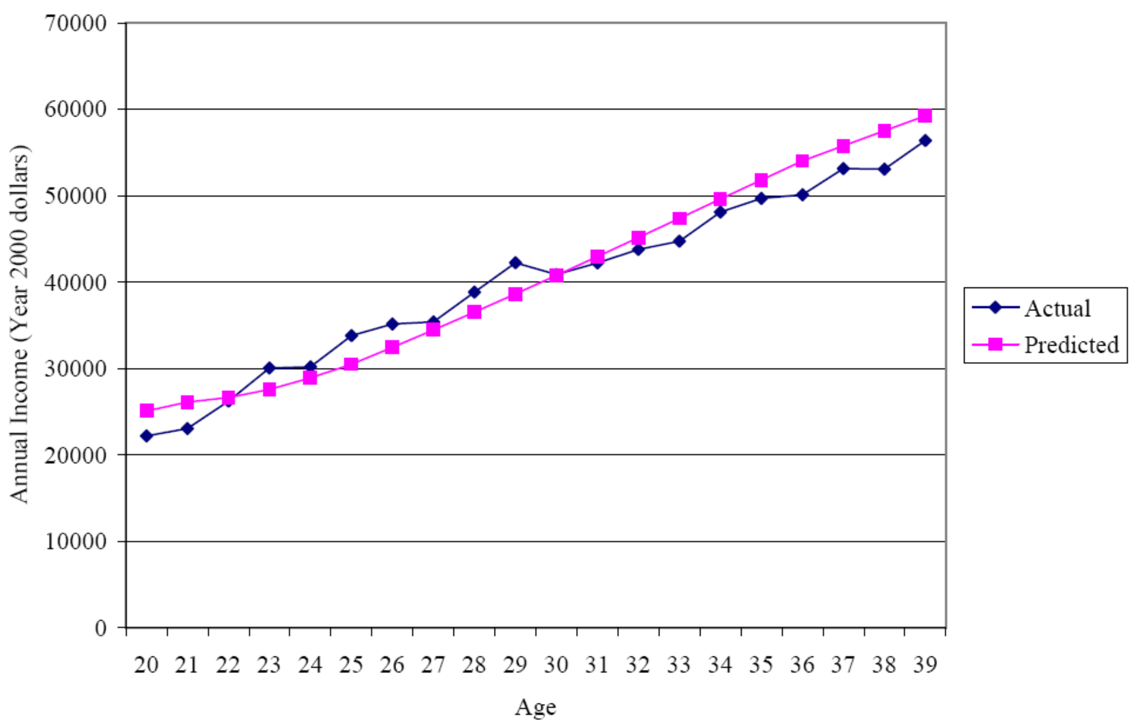

Figure 12: Age Profiles of the Mean Income from Full-time Paid-Employment (College)

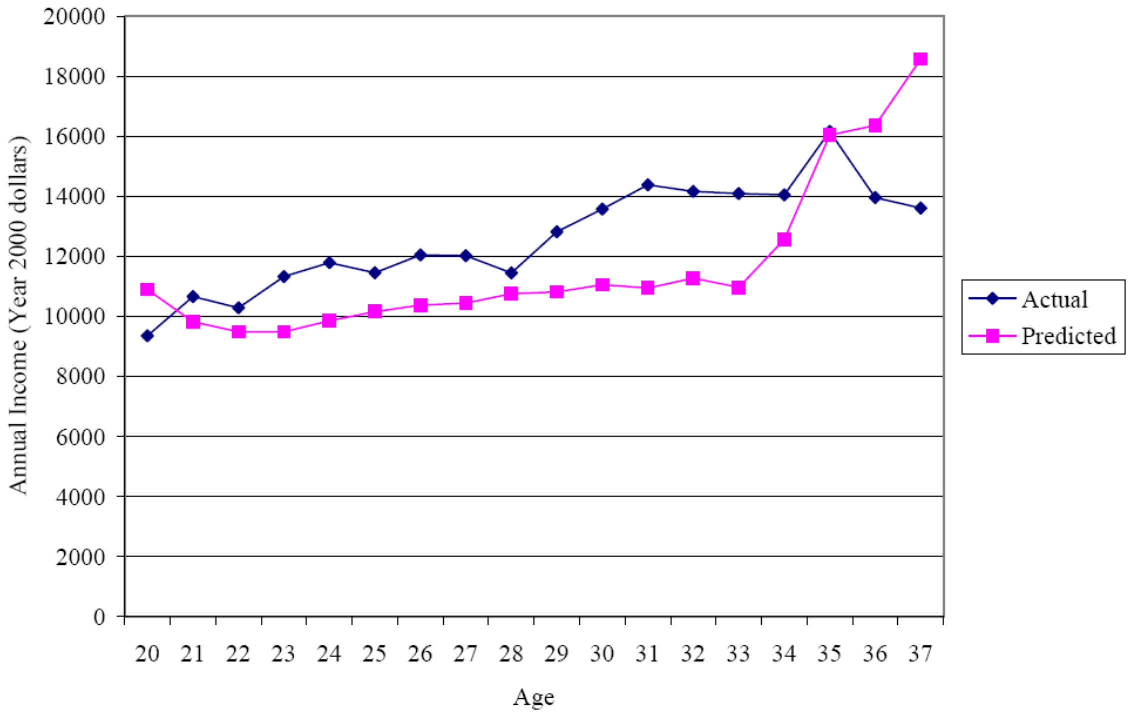

Figure 13: Age Profiles of the Mean Income from Part-time Paid-Employment (Non-college)

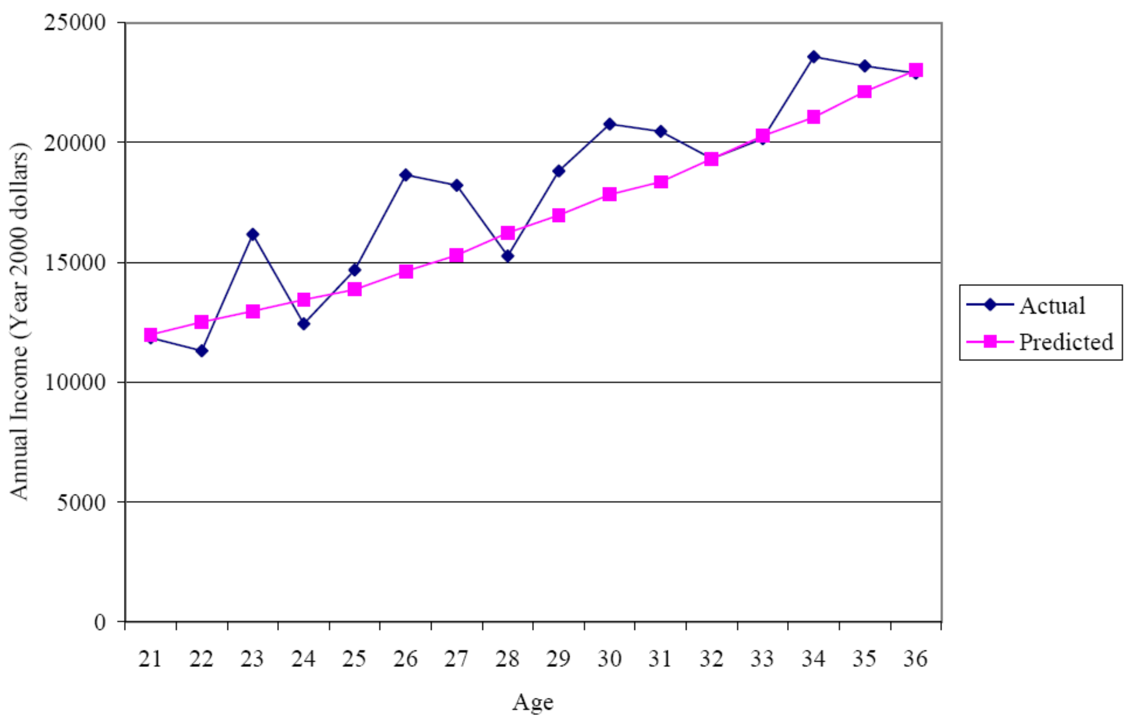

Figure 14: Age Profiles of the Mean Income from Part-time Paid-Employment (College)

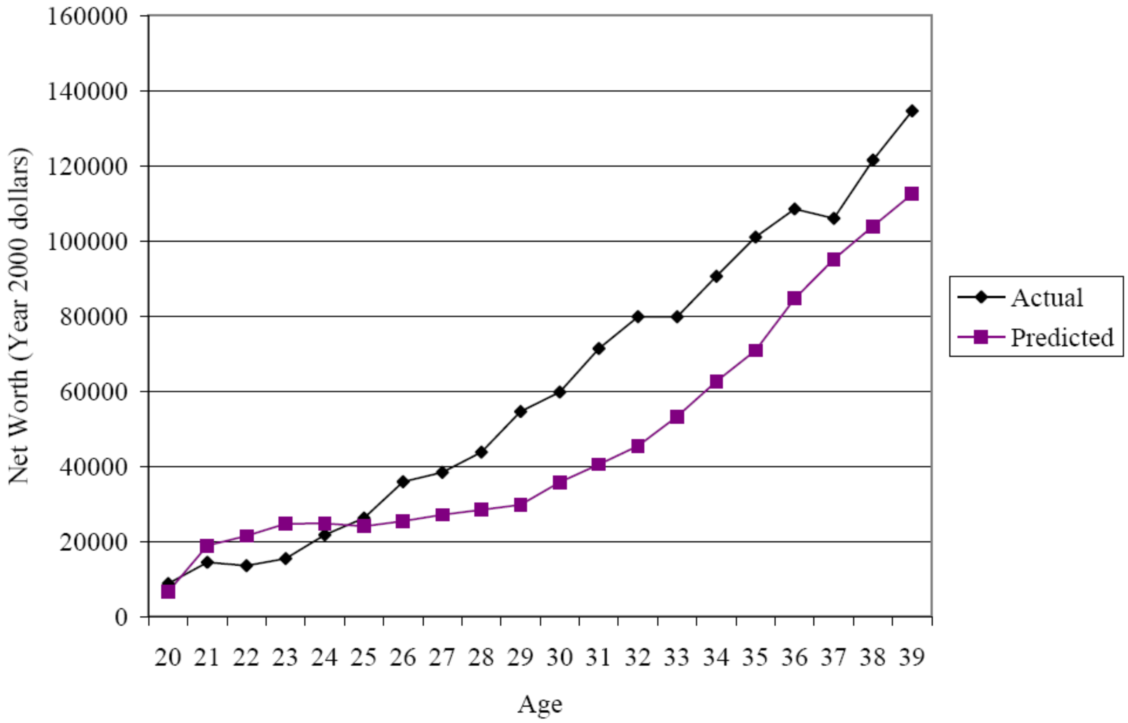

Figure 15: Age Profiles of the Mean Net Worth

7.2.1 Preference

The estimated rate with which all individuals discount utility values a year ahead is 97.56%. This means that the annual discount rate is 2.50%. Now, I turn attention to the CRRA coefficient.[55] With the CRRA form of utility, $u = c^{1-\mu_0}/(1-\mu_0)$, the coefficient of relative risk aversion is μ_0, the intertemporal elasticity of substitution in consumption is μ_0^{-1}. The typical estimated value for μ_0 in the literature is around -2. The estimated CRRA constants both for Type 1 and for Type 2 are much lower (0.483 and 0.472, respectively) than those in the macro literature, which is consistent with the recent studies that use micro data to estimate the parameter (e.g. Keane and Wolpin (2001), Gourinchas and Parker (2002), Keane and Imai (2004)). In these studies, the estimated values typically range between 0.5 and 2. Interestingly, this study's estimate for μ_0 is also close to Goeree, Holt, and Palfrey's (2002), who estimate the CRRA coefficient by laboratory experiments of generalized matching pennies games $\widehat{\mu}_0 = 0.440$. This low value for risk aversion also affects the individual's propensity to become a self-employer presumably because the estimated variance of income from self-employment is much higher than that from (full-time) paid-employment. If compared with the studies on entrepreneurship, my CRRA constant implies *less* risk averse individuals: In his estimation, Buera (2008a) does not estimate μ_0 (in his notation σ) and sets $\mu_0 = 1.50$ throughout.[56] Mondragon-Velez (2006) gives the estimate, $\widehat{\mu}_0 = 1.03$ (in his notation σ).[57]

My estimation results imply that *nonpecuniary* factors are important in explaining observed patterns of labor choice. The estimated value for disutility from self-employed work

[55] Evans and Jovanovic (1989) assume that individuals are risk neutral, while Buera (2008a,b) and Mondragon-Velez (2007) consider the CRRA utility. None of these papers takes into account labor disutility.

[56] In his study on effects of borrowing constraints on small manufacturing owner-firms in Ghana, Schündeln (2006) $\mu_1 = 0.50$.

[57] Mondragon-Velez (2007) does not consider heterogeneity in risk attitude.

in the first year of any spell (317.3 for Type 1 and 334.9 for Type 2) is twice as large as that from (full-time) paid work (164.9 for Type 1 and 179.9 for Type 2). Notice also that the estimated values for benefits from continuing self-employment are also high: they are as half as the values for labor disutility from self-employment. These large values are necessary to well replicate the observed persistence of self-employment. In the previous studies on self-employment, there were no estimates on nonpecuniary costs/benefits of entrepreneurship. Hamilton (2000) gives empirical findings that support the idea that self-employment offers significant nonpecuniary benefits. Specifically, in the data he uses (constructed from the 1984 panel of the Survey of Income and Program Participation (SIPP)), Hamilton (2000) finds that many self-employers experience lower earnings growth than wage workers do as well as lower earnings in initial periods of self-employment. He also finds little evidence that suggests that the earnings differential reflects the selection of low-ability individuals into self-employment. In the present study, I observe the higher mean and median incomes from self-employment than those from full-time paid-employment for each age in the age profiles of income. This finding is in contrast to Hamilton's (2000), though nonpecuniary benefits play important roles in replicating the age patterns of labor supply.[58] Mondragon-Velez 's (2006) unsatisfactory high estimates for entrepreneurial earnings may result from his exclusion of nonpecuniary factors. Without incorporating nonpecuniary costs/benefits of entrepreneurial work into a dynamic model, it may be very difficult to well capture dynamic aspects of self-employment in terms of both labor supply and income realization.

7.2.2 Entrepreneurial Production Function

My formulation allows for the coefficient of capital returns in the entrepreneurial production function to differ by schooling. The estimated value for the college educated is 0.16 $(= \widehat{\alpha}_0 + \widehat{\alpha}_1)$ while that for the non-college educated is 0.17 $(= \widehat{\alpha}_0)$. This finding is consistent with an observation is that college educated self-employers are more likely in the service industry while in non-college educated self-employers are more likely in the construction industry (Mondragon-Velez (2005)). The estimates for capital returns in the previous literature are much higher than those obtained here. This is presumably because I incorporate the component of human capital accumulation into the entrepreneurial production function. In contrast, Evans and Jovanovic (1989), Buera (2008a) and Mondragon-Velez (2006) estimate the following entrepreneurial production function:

$$y_t^s = A_t k_t^{\alpha}$$

where A_t is a compound component of nonstochastic and stochastic factors and human capital accumulation is not taken into account. The estimate of α by Evans and Jovanovic's (1989) is 0.22 (it is 0.23 in Xu's (1998) reestimation). As in the present study, Mondragon-Velez (2006) considers differences in capital returns by education (non-college and college). His estimates are: $\widehat{\alpha}(\text{non-college}) = 0.27$ and $\widehat{\alpha}(\text{college}) = 0.36$.

[58] This finding is also consistent with recent studies that show empirical evidence suggesting that self-employment may derive procedural utility (see e.g. Frey and Benz (2008) and Fuchs-Schündeln (2008)). The idea of procedural utility is that people may care not only about the outcomes but about the procedures that lead to them, and in this study's context, independent work in self-employment may give workers more satisfaction (the main difference of the two papers is that the latter allows for preference heterogeneity). Kawaguchi (2008), using job satisfactin scores in the NSLY79 and controlling for heterogeneity (in self-reporting one's own job satisfaction) at individual level, also finds evidence that self-employment gives workers more satisfaction than wage-employment does.

Table 11: Comparison with Evans and Leighton (1989, p.531)

	Evans and Leighton (1989)	**This study**
$\widehat{\gamma}_3^w$	0.0985	0.0868
$\widehat{\gamma}_4^w$	-0.2417	-0.2723
$\widehat{\gamma}_4^s$	0.1128	0.0967
$\widehat{\gamma}_5^s$	-0.4867	-0.1701
$\widehat{\gamma}_6^s + \widehat{\gamma}_7^s/50$	0.0212	0.0264

Note : In Evans and Leighton (1989), the composite of the coefficients, $\widehat{\gamma}_6^s + \widehat{\gamma}_7^s/50$, corresponds to the coefficient for the linear term for wage experience in the self-employment earnings equation.

7.2.3 Human Capital

Next, consider the estimated income opportunities. The contributions of college education and more to the human capital component are 25.2% for self-employed work ($= \widehat{\gamma}_1^s$) and 24.0% for wage work ($= \widehat{\gamma}_1^w$). These values lower estimates if compared with the literature on college premium in the Mincerian wage equation.[59] The difference between self-employment and paid-employment is small. The first one-year experience of full-time paid-employment increase the human capital component by 0.9 ($= \widehat{\gamma}_6^s - (\widehat{\gamma}_7^s/100)$) percent for self-employment and 8.4 ($= \widehat{\gamma}_6^w - (\widehat{\gamma}_7^w/100)$) percent for paid-employment. These two contrasting numbers are consistent with Kawaguchi's (2003) main finding that experience-earnings profiles were flatter in the human capital function for self-employment. Note, however, that Kawaguchi (2003) does not distinguish between experience of self-employment and that of wage employment. I distinguish these two, and the result is that in any spell, the first one-year of self-employment enhances the human capital component for self-employment by 7.5 ($= \widehat{\gamma}_4^s - \widehat{\gamma}_5^s/100$) percent. In contrast, ever experience of self-employment enhances the human capital component only by 0.8 ($= \widehat{\gamma}_3^s$) percent for self-employment and decreases the human capital component slightly for paid-employment (-0.3 ($= \widehat{\gamma}_5^w$) percent). Table 11 gives a comparison of the estimates of key parameters with Evans and Leighton's (1989,p.531). Except the estimate for the squared term of years in self-employment, the numbers seem close.

7.2.4 Lower Bound for Net Worth

Evans and Jovanovic (1989), Xu (1999), Buera (2008a) and Mondragon-Velez (2006) using the common notation in the literature $k_t \in [0, \lambda a_t]$ to express the borrowing constraints. The estimates of Evans and Jovanovic (1989), of Xu (1999) and of Buera (2008a) are $\widehat{\lambda} = 1.75$, $\widehat{\lambda} = 2.01$ and $\widehat{\lambda} = 1.01$, respectively. Mondragon-Velez (2006) does not estimate λ but compare various levels of λ ($\lambda = 1.0$, 1.25, 1.50, 1.75 and 2.0). In this study, λ is *not a*

[59] Evans and Leighton (1989) provide OLS estimates of log earnings equations for self-employers and wage workers. The variable for education is years of education. If we multiply these estimates by four, we obtain 41.1% for self-employment and 28.3% for paid-employment. For wage workers only, Heckman, Lochner and Todd (2008), for example, find, from the 1980 census, that the internal rate of returns for years 12-16 is 11%, so that the college premium is 44%.

constant, but a function of state variables. Specifically, the estimate for λ is given by

$$\begin{aligned}\widehat{\lambda} &= \widehat{\lambda}(a_t, h_t^s,\, h_t^w, age_t, educ, type; \widehat{\zeta}) \\ &\equiv 1 - \frac{\widehat{\underline{a}}_t}{a_t} \\ &= 1 - \frac{\underline{a}(h_t^s,\, h_t^w, age_t, educ, type; \widehat{\zeta})}{a_t}\end{aligned}$$

By incorporating the parameter estimates into the above equation, we have

$$\begin{aligned}&\widehat{\lambda}(a_t, h_t^s,\, h_t^w, age_t, educ, type; \widehat{\zeta}) \\ &= 1 + \frac{1}{a_t} \cdot (\exp[9.256 + 0.201 \cdot I(educ = college) + 0.355 \cdot I(h_t^s = 1) \\ &+0.063 \cdot h_t^w - 0.357 \cdot \frac{(h_t^w)^2}{100} - 0.028 \cdot (age_t - 20) + 0.207 \cdot \frac{(age_t - 20)^2}{100}]\Big) .\end{aligned}$$

As a example, this value becomes $\widehat{\lambda} = 1.62$ if I plug into the function $h_t^w = 6$ (the median for years of paid employed work; see Table 3), $age_t = 29$ (the median age) and $a_t = 20008$ (the median net worth) for the non-college educated who has never become a self-employer.

7.2.5 Type and the Propensity to Become a Self-Employer

It is interesting to notice that Type 1 individuals (comprising 28.0% of the simulated sample) and Type 2 individuals (comprising 72.0% of the simulated sample) are not much different in terms of risk attitude: the difference between the estimated values of Type 1's CRRA constant and of Type 2's is very small. Hence, as opposed to the

intuition behind the modeling by Kihlstrom and Laffont (1979) and by Kanbur (1979), heterogeneity in risk attitude may play a limited role in explaining the observed characteristics of the actual data.[60] The positive values of the estimated γ_2^w and γ_2^w suggest that Type 1 individuals are less productive both as a self-employer and as a wage worker. Type 2 individuals, who are more productive both in self-employment and in wage employment, are more likely to become a self-employer. Looking at Table 12 that shows the transition rates for Type 1 and for Type 2, we find that the transition rates from and to self-employment and from and to full-time paid employment are higher for Type 2 individuals. This may suggest that the decision to transit into self-employment may not be motivated by innate comparative advantage of one mode over another. The persistence of part-time paid employment, however, is higher while there is little difference as to the persistence of non-employment.

8 Counterfactual Experiments

One of the attractive features of using a dynamic structural model in empirical studies is that they can be used to predict the effects of (*ex ante*) counterfactual changes in exogenous variables. In this section, I conduct three counterfactual experiments to see their effects on the formation and continuation of self-employment. For each experiment, I first simulate behavior under the appropriately defined scenario, and then compare counterfactual behavior with the baseline behavior.

[60] Relatedly, Blanchflower and Oswald (1998, p.30) state that the classical writings such as Knight (1921), Schumpeter (1939) and Kirzner (1973) emphasized that "attitude to risk is not the central characteristic that determines who becomes an entrepreneur."

Table 12: Transition Matrices for Labor Supply Decisions by Type

Predicted

Overall

Labor supply (t-1)		Labor supply (t) SE	PE Full-time	PE Part-time	NE
SE					
	Row %	84.6	9.6	0.6	5.2
	Column %	91.7	5.7	0.8	8.1
PE, Full-time					
	Row %	4.2	85.6	6.6	3.5
	Column %	4.6	50.8	8.8	5.5
PE, Part-time					
	Row %	2.4	52.2	44.9	0.5
	Column %	2.6	31.0	59.4	0.7
NE					
	Row %	1.0	21.0	23.4	54.5
	Column %	1.1	12.5	31.0	85.6

Type 1

Labor supply (t-1)		Labor supply (t) SE	PE Full-time	PE Part-time	NE
SE					
	Row %	78.2	12.3	1.8	7.8
	Column %	90.7	8.6	1.8	10.7
PE, Full-time					
	Row %	4.3	72.7	11.4	11.7
	Column %	5.0	51.2	11.5	16.0
PE, Part-time					
	Row %	2.8	42.6	54.1	0.5
	Column %	3.3	30.0	54.6	0.6
NE					
	Row %	0.9	14.5	31.9	52.7
	Column %	1.0	10.2	32.2	72.6

Type 2

Labor supply (t-1)		Labor supply (t) SE	PE Full-time	PE Part-time	NE
SE					
	Row %	86.7	8.8	0.2	4.3
	Column %	92.4	4.7	0.3	7.1
PE, Full-time					
	Row %	4.2	90.2	5.0	0.7
	Column %	4.4	48.8	8.2	1.1
PE, Part-time					
	Row %	2.0	62.0	35.5	0.5
	Column %	2.1	33.6	58.5	0.8
NE					
	Row %	1.0	23.7	20.0	55.3
	Column %	1.1	12.8	33.0	91.0

Table 13: Changes in the Characteristics on Entry into and Exit from Self-Employment (Experiments 1-3)

	Baseline		Exp. 1		Exp. 2		Exp. 3	
	NC	C	NC	C	NC	C	NC	C
Ever experience of self-employment (%)	26.76	24.43	23.77	21.76	34.40	31.54	51.51	47.82
First entry into self-employment occurs in less than or equal to first eight decision years (%)	59.34	69.20	65.97	64.55	69.31	67.29	84.49	87.86
Exit from self-employment in a year (%)	28.09	23.61	19.60	21.51	45.98	38.81	42.22	32.25

Note: "NC" ("C") denotes "non-college educated"("college educated").

8.1 Experiment 1: Relaxation of the Borrowing Constraints

The first experiment is to relax the estimated borrowing constraints to evaluate the extent to which they affect self-employment. Specifically, I make the asset floor $\underline{a}_t$ negatively very large to see the effects (1) on the percentage of those with experience of self-employment during the same periods that are covered by the NLSY79, (2) on the distribution of decision period when first entry into self-employment occurs, and (3) on the one-period transition rates. I consider the case of $\underline{a}_t = -\$30,000$ for any state (Experiment 1).[61]

Column "Exp.1" in Table 13 displays how the change affects the three key statistics in Table 1. Interestingly, relaxing the borrowing constraints weakens the propensity to enter into self-employment both for the non-college educated and for the college educated. This result presumably comes from the fact that there are two effects of relaxing the borrowing constraints: one is the direct effect that improves consumption smoothing over the life cycle, and the other is the indirect effect that makes individuals more likely to be non-employed. If we look at the age profiles of labor supply under the Baseline and under Experiment 1 in Table 13, we find that the rates of non-employment under Experiment 1 are likely to be higher before age 30 but are likely to be lower after age 30. Table 14 also compares the predicted age profile of self-employment with the one under the Baseline and under Experiment 1. The proportions of self-employers are now higher from the average 7 percent in the simulated sample to around 9 to 10 percent for the two experiments. The rates of increase are 30 to 40 percent, which is comparable to Evans and Jovanovic's (1989) results.

Turning back to Table 14, it is noteworthy that college-educated self-employers are now likely to enter into self-employment later than under the Baseline while non-college educated self-employers are likely to enter into self-employment earlier. The exit rates after the first year from self-employment improves more for the non-college educated while the effects on the college educated is weaker. These results together seem to suggest the differences of the effects of borrowing constraints by the level of schooling. Relaxation of borrowing constraints facilitates both the formation of and the continuation of self-employed businesses especially for the non-college educated. Lastly, Figures 16-19 show that there are no significant differences between incomes under the Baseline and those under Experiment 1.

[61] The estimated lower bound is between \$10,000 and \$18,000 for most of state variables.

Table 14: Changes in the Age Profiles of Labor Supply (Experiment 1)

	Self-Employment		Paid Employment		Non-Employment	
Age	**Baseline**	**Exp. 1**	**Baseline**	**Exp. 1**	**Baseline**	**Exp. 1**
20	0.9	1.1	78.6	78.9	20.7	20.0
21	3.5	2.2	79.4	78.4	16.6	19.4
22	5.7	5.8	79.8	72.4	11.1	21.8
23	7.4	6.2	82.1	76.6	9.4	17.2
24	7.8	7.3	89.3	81.4	9.1	11.4
25	7.2	6.9	88.4	83.6	7.2	9.5
26	6.5	6.4	90.1	84.8	7.7	8.7
27	6.7	6.5	89.3	84.2	8.3	9.3
28	8.0	8.2	84.6	81.3	9.9	10.5
29	7.7	8.0	78.4	81.6	9.8	10.4
30	7.3	7.8	77.0	81.8	9.9	10.4
31	7.1	7.8	75.4	81.5	10.7	10.7
32	7.2	7.9	76.9	83.7	10.5	8.4
33	7.5	8.2	76.9	84.5	10.8	7.4
34	7.8	8.8	77.3	83.9	11.7	7.4
35	7.2	9.5	76.5	84.3	12.9	6.2
36	7.3	10.6	79.9	83.6	12.4	5.8
37	7.3	11.5	84.2	83.4	13.3	5.1
38	8.0	11.9	84.3	83.0	14.6	5.1
39	8.4	12.6	85.3	82.2	15.3	5.2

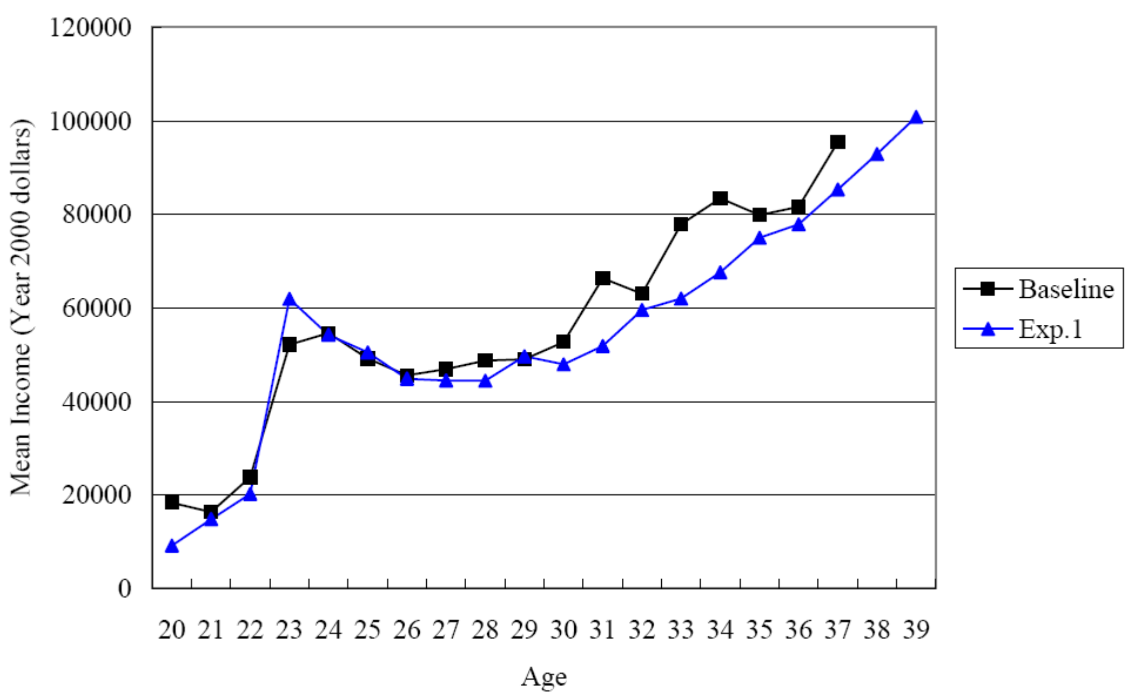

Figure 16: Changes in the Age Profiles of the Mean Income from Self-Employment (Non-college; Experiment 1)

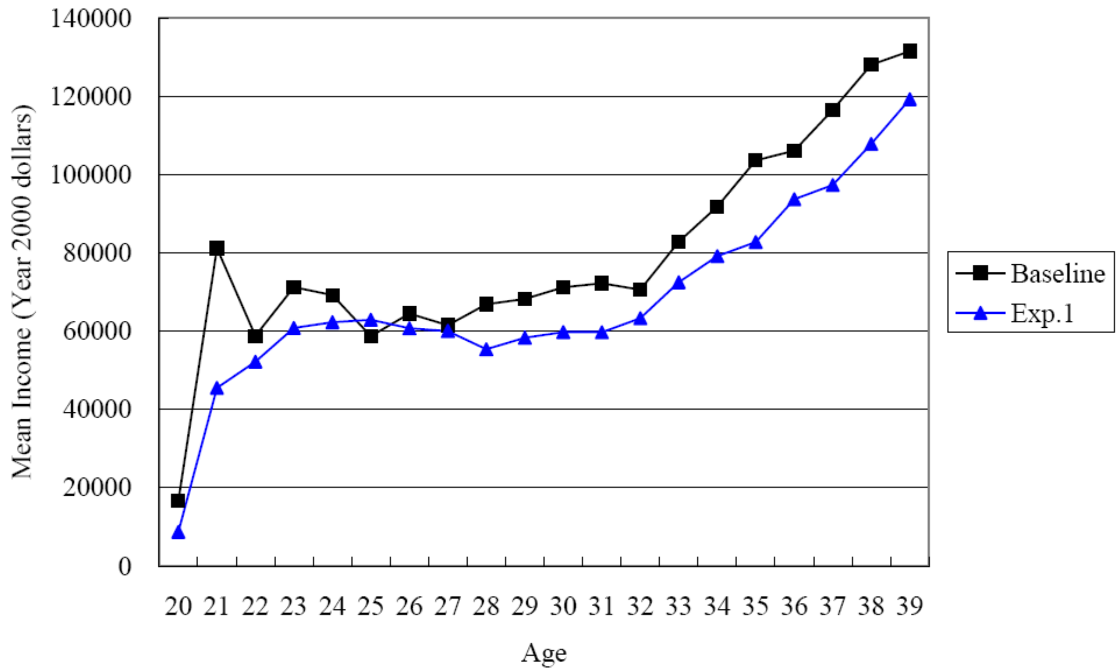

Figure 17: Changes in the Age Profiles of the Mean Income from Self-Employment (College; Experiment 1)

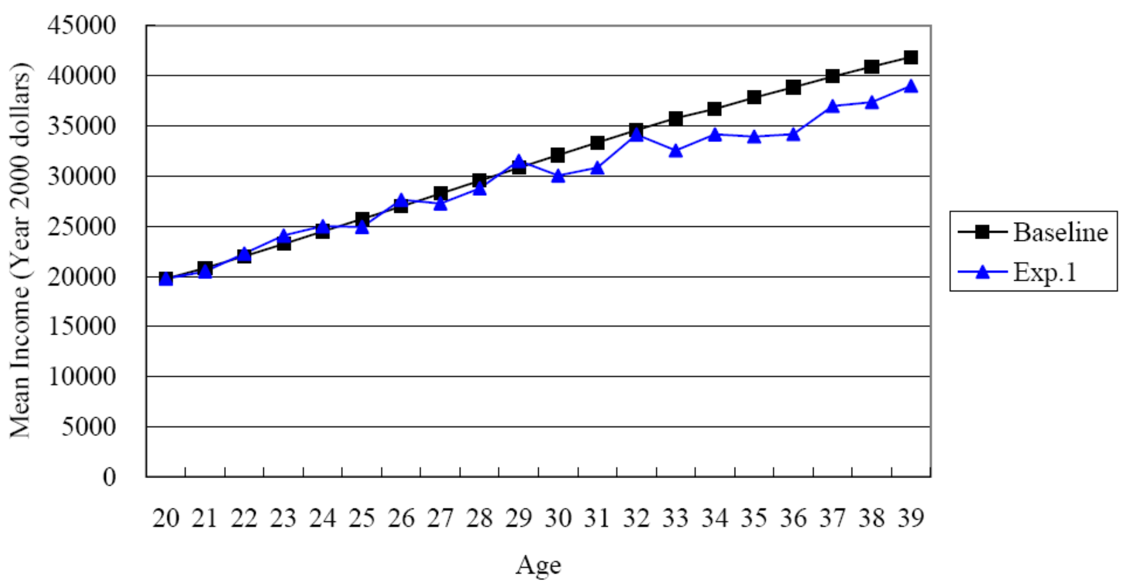

Figure 18: Changes in the Age Profiles of the Mean Income from Full-time Paid-Employment (Non-college; Experiment 1)

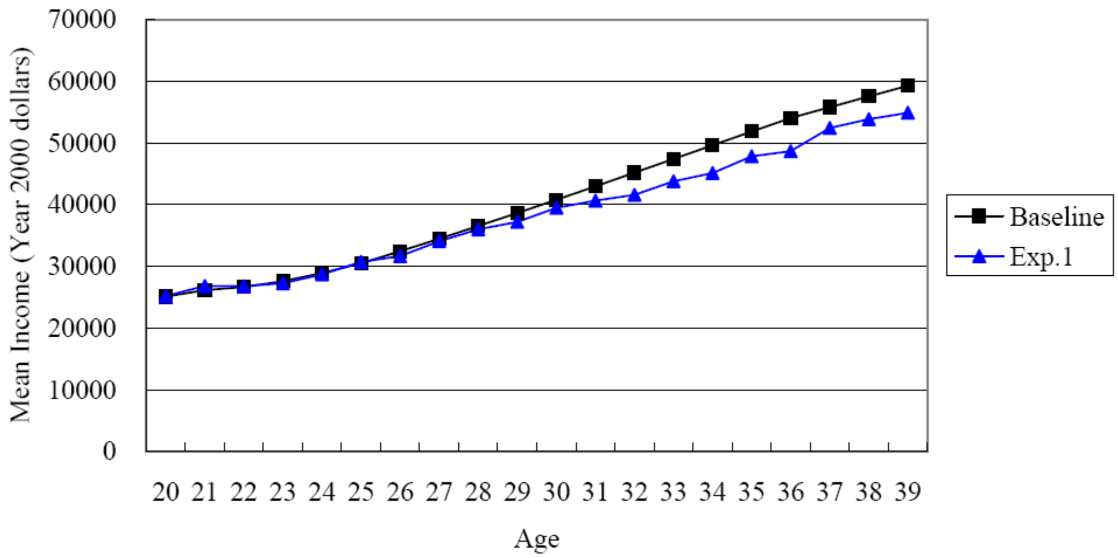

Figure 19: Changes in the Age Profiles of the Mean Income from Full-time Paid-Employment (College; Experiment 1)

8.2 Experiment 2: Injection to Business Capital

In this experiment, self-employers are subsidized through capital enhancement. Specifically, some amount of subsidy is given every year as long as individuals continue to be self-employed, and thus the amount of capital for self-employed is $(k_t^{\$} + subsidy)$ rather than $k_t^{\$}$ under the Baseline. I consider the case of $subsidy = \$30,000$.[62]

Column "Exp.2" in Table 13 displays how the subsidy scheme affects the three key statistics in Table 1. In comparison to the Baseline and Experiment 1, the ratios of those who ever experience self-employment for both schooling levels increase. While the college educated are now likely to enter into self-employment slightly later in their life, the non-college educated start self-employment earlier under the this subsidy scheme. The third item, however, shows that the subsidy scheme actually increases entries with shorter duration. In particular, nearly 50 percent of non-college educated self-employers exit in the first year.

Figures 20-23 show the changes in the age profiles of annual incomes of self-employment and of fullt-time paid employment. We find that increases of self-employment income are larger for the non-college educated. It is interesting to see that the mean incomes from full-time paid employment are now greater both for the non-college educated and for the college educated. This is presumably due to the decreases in the ratios of wage workers in the age profile of labor supply (Table 15).

8.3 Experiment 3: Injection to Self-Employment-Specific Human Capital

Most existing programs aims to assist unemployed workers to become self-employers through training. The next experiment is the one that gives indirect incentives for self-employment

[62] This and next experiments should be taken as thought experiments rather than as real policy experiments because the main program conducted today by the U.S. Small Business Administration (SBA) to support small businesses is by loan guarantees, and the SBA does not provide direct loans to start or expand a business.

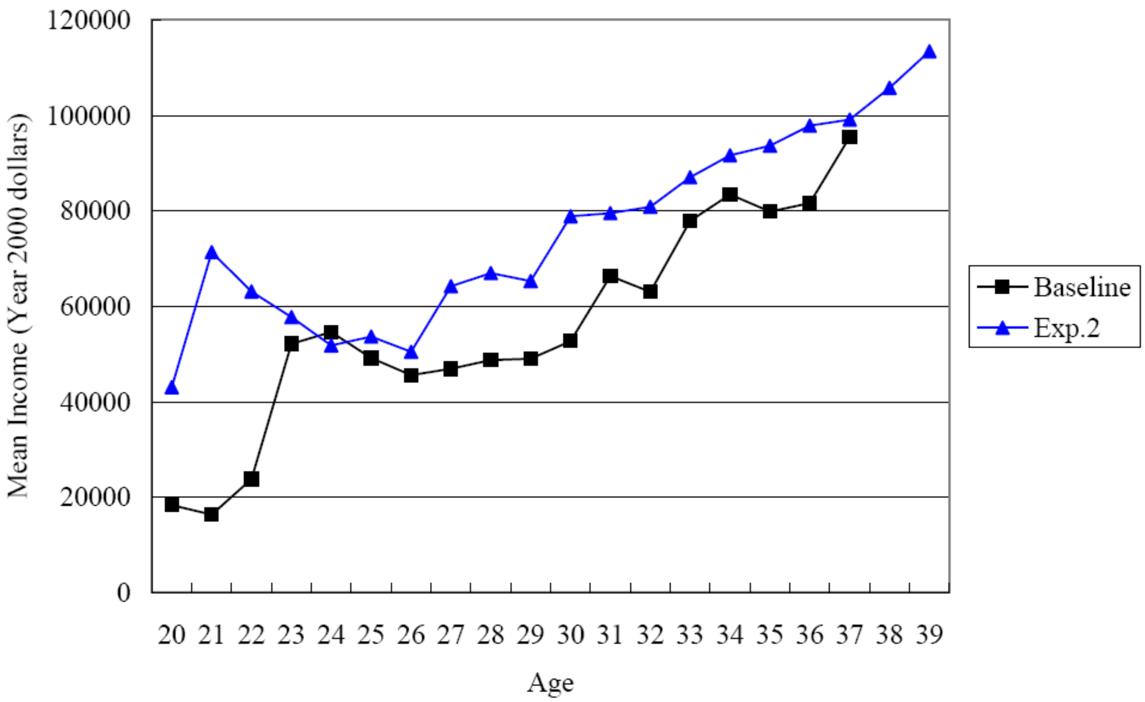

Figure 20: Changes in the Age Profiles of the Mean Income from Self-Employment (Non-college; Experiment 2)

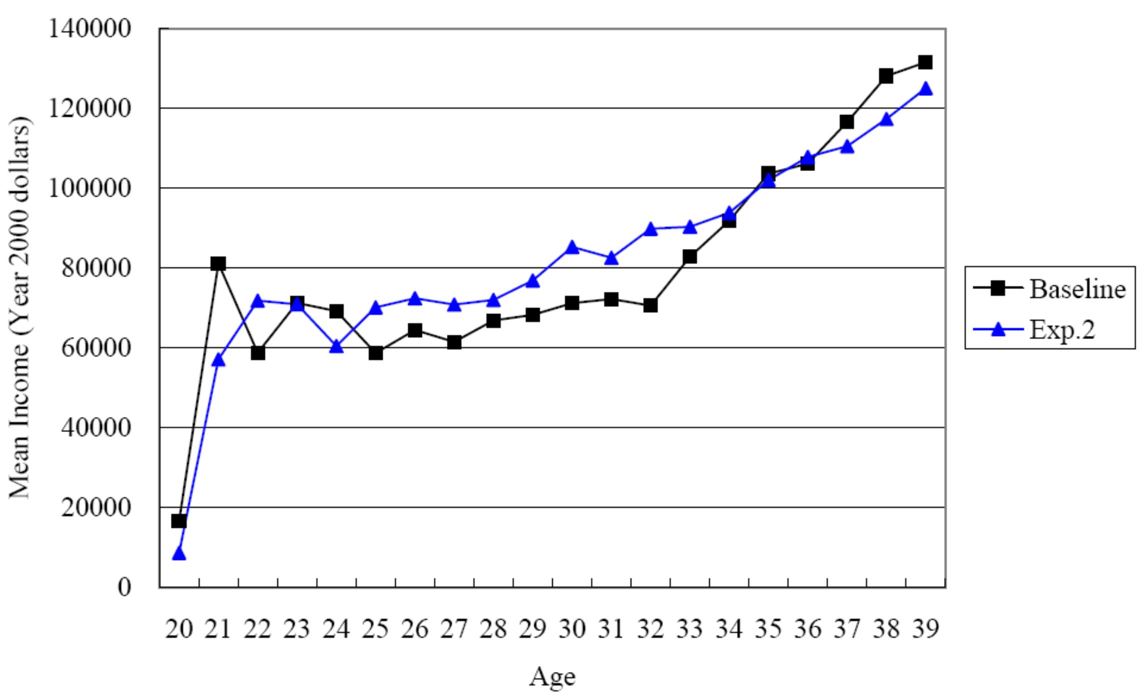

Figure 21: Changes in the Age Profiles of the Mean Income from Self-Employment (College; Experiment 2)

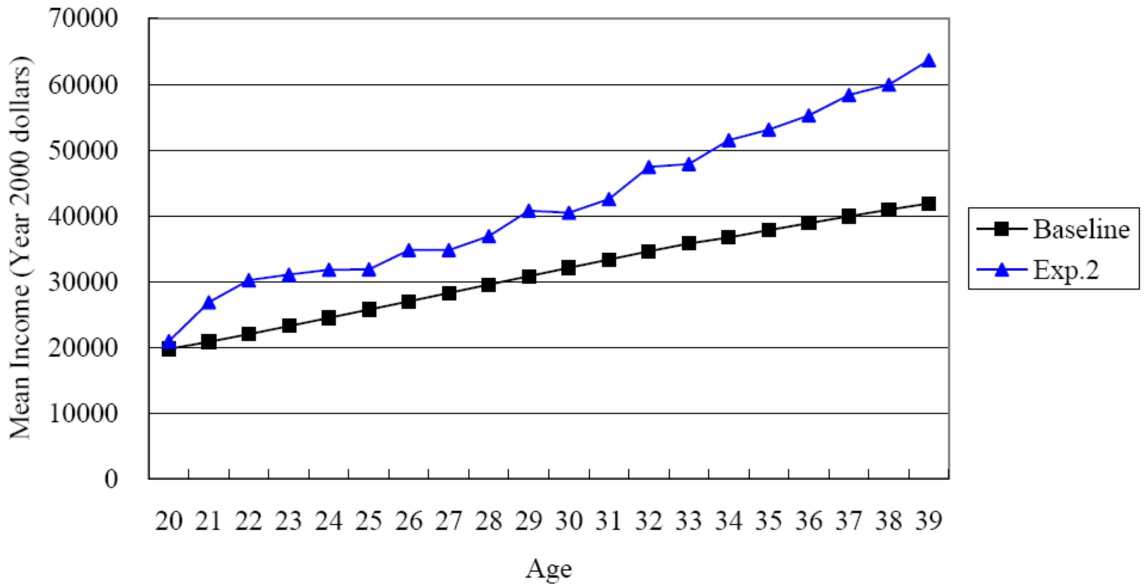

Figure 22: Changes in the Age Profiles of the Mean Income from Full-time Paid-Employment (Non-college; Experiment 2)

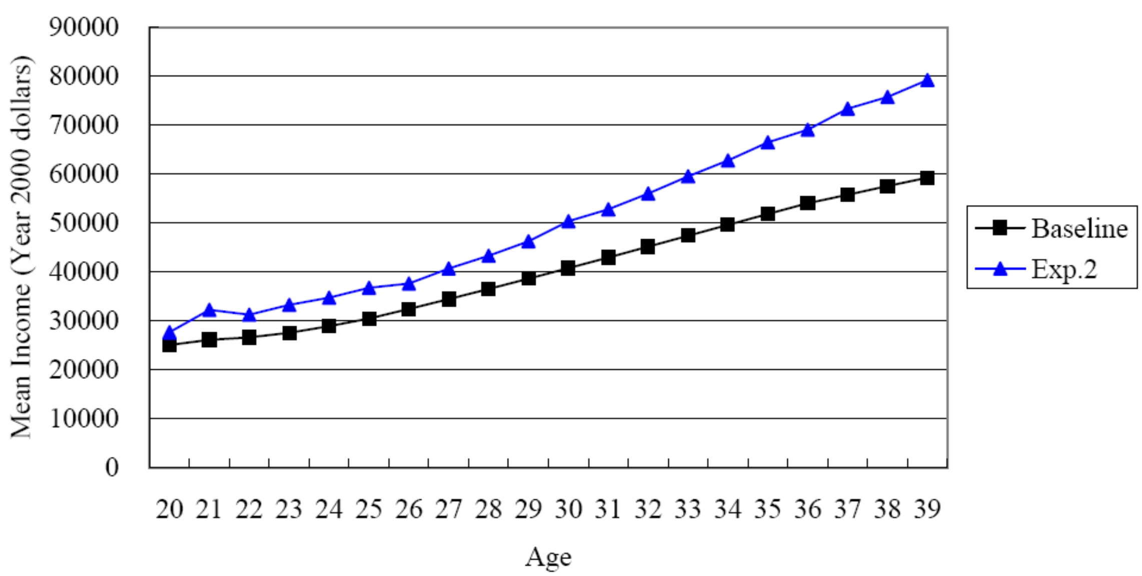

Figure 23: Changes in the Age Profiles of the Mean Income from Full-time Paid-Employment (College; Experiment 2)

Table 15: Changes in the Age Profiles of Labor Supply (Experiment 2)

	Self-Employment		Paid Employment		Non-Employment	
Age	**Baseline**	**Exp. 2**	**Baseline**	**Exp. 2**	**Baseline**	**Exp. 2**
20	0.9	1.3	78.6	78.8	20.7	19.9
21	3.5	4.4	79.4	72.9	16.6	22.7
22	5.7	6.4	79.8	79.5	11.1	14.1
23	7.4	8.3	82.1	77.3	9.4	14.4
24	7.8	9.0	89.3	77.7	9.1	13.3
25	7.2	9.9	88.4	76.0	7.2	14.1
26	6.5	8.9	90.1	80.6	7.7	10.5
27	6.7	8.2	89.3	80.6	8.3	11.2
28	8.0	8.0	84.6	78.7	9.9	13.3
29	7.7	7.6	78.4	77.8	9.8	14.6
30	7.3	6.7	77.0	78.5	9.9	14.8
31	7.1	6.9	75.4	80.7	10.7	12.5
32	7.2	6.4	76.9	80.3	10.5	13.3
33	7.5	6.2	76.9	78.2	10.8	15.6
34	7.8	6.7	77.3	75.3	11.7	18.0
35	7.2	7.0	76.5	71.0	12.9	22.0
36	7.3	7.6	79.9	71.1	12.4	21.3
37	7.3	8.1	84.2	70.0	13.3	21.9
38	8.0	8.7	84.3	70.6	14.6	20.8
39	8.4	9.5	85.3	62.4	15.3	28.1

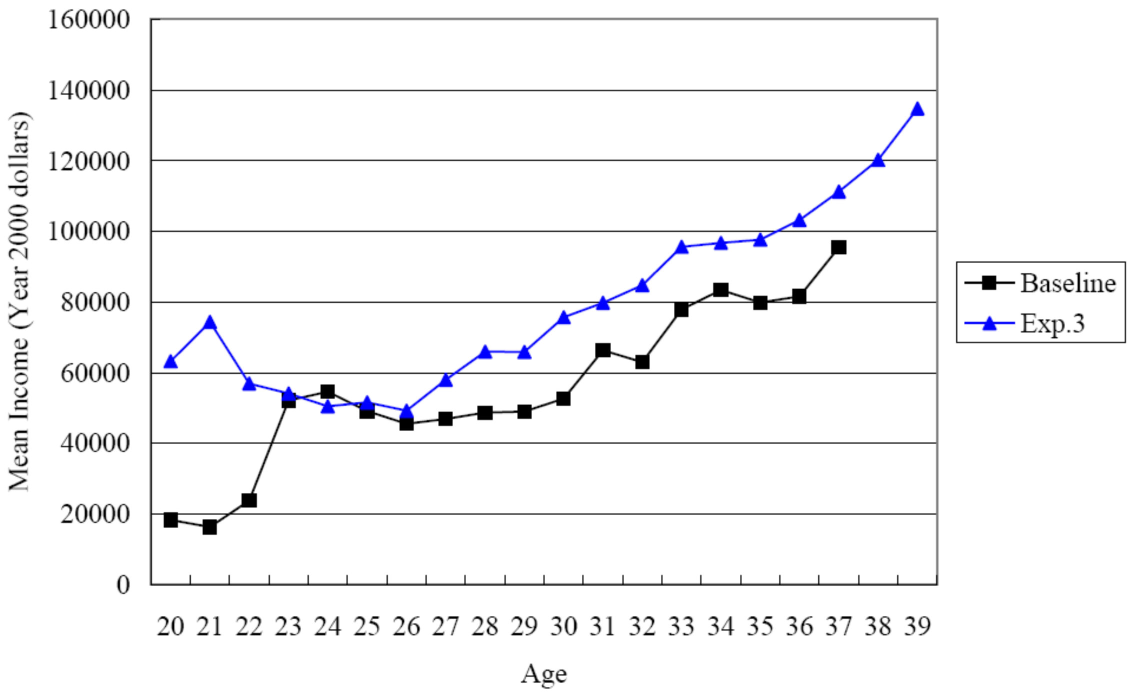

Figure 24: Changes in the Age Profiles of the Mean Income from Self-Employment (Non-college; Experiment 3)

before entering the labor force. Specifically, it sees the effects of enhanced entrepreneurial skill (by, for example, training offered to improve skills that are useful for self-employed work). Conceptually, it corresponds to changing $\widehat{\gamma}_0^s = 1.839$ to a higher value. I set it equal to the constant part for the wage-sector specific human capital, $\widehat{\gamma}_0^w = 2.322$ (Experiment 3).

Column "Exp.3" in Table 13 displays how the counterfactual stuation affects the three key statistics in Table 1. The directions in the changes are similar to those by Experiment 2: it induces more individuals to enter into self-employment earlier in their life-cycle, but they are likely to exit from self-employment sooner. Figures 24-27 show that the directions in the changes in the mean incomes are also similar with Experiment 2. The changes in the age profile of labor supply are also similar (not shown) with slightly higher ratios of the self-employed.

9 Concluding Remarks

In this paper, I have proposed and estimated a life-cycle model of entrepreneurial choice and wealth accumulation. The data for estimation are taken from the cohort of young white males from the NLSY79. Inclusion of the nonpecuniary benefits of self-employment in the model is important to accurately replicate the age patterns of labor supply. The estimated model is used to conduct counterfactual experiments. My results suggest that both a reasonable subsidy and an enhancement of human capital specific to self-employment would have a small impact on self-employment in the labor supply cohort up to age 39 in terms of either the age profile of self-employment or whether individuals have ever experienced self-employment. In contrast, a moderate relaxation of the borrowing constraints encourages entries into self-employment, and the average duration of self-employment is longer. Although the counterfactual experiments in this study are conducted with the use of US

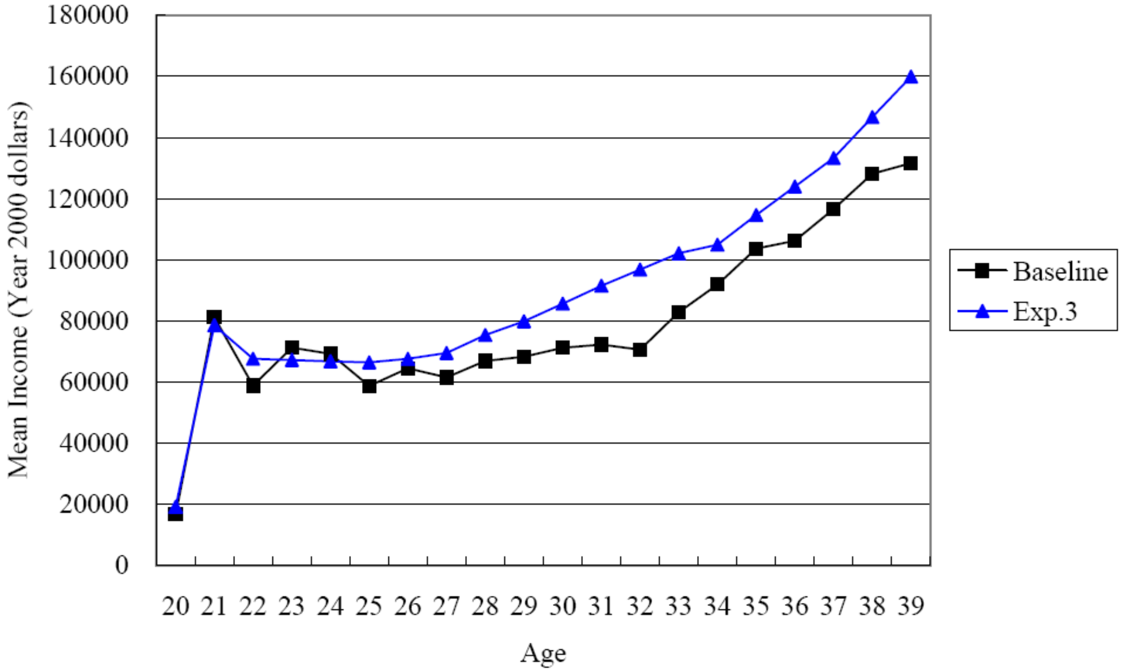

Figure 25: Changes in the Age Profiles of the Mean Income from Self-Employment (College; Experiment 3)

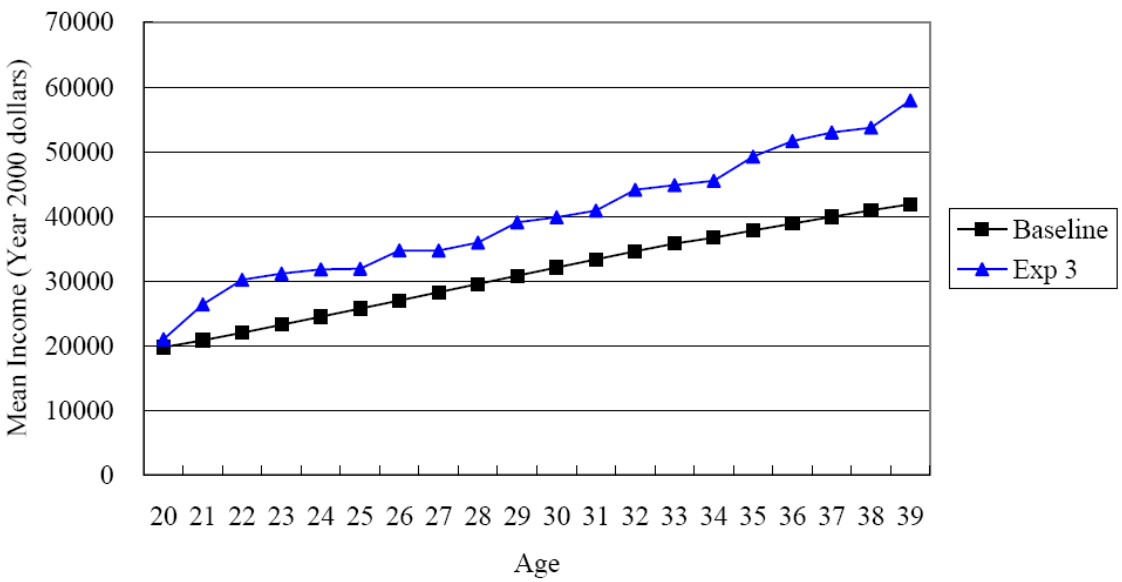

Figure 26: Changes in the Age Profiles of the Mean Income from Full-time Paid-Employment (Non-college; Experiment 3)

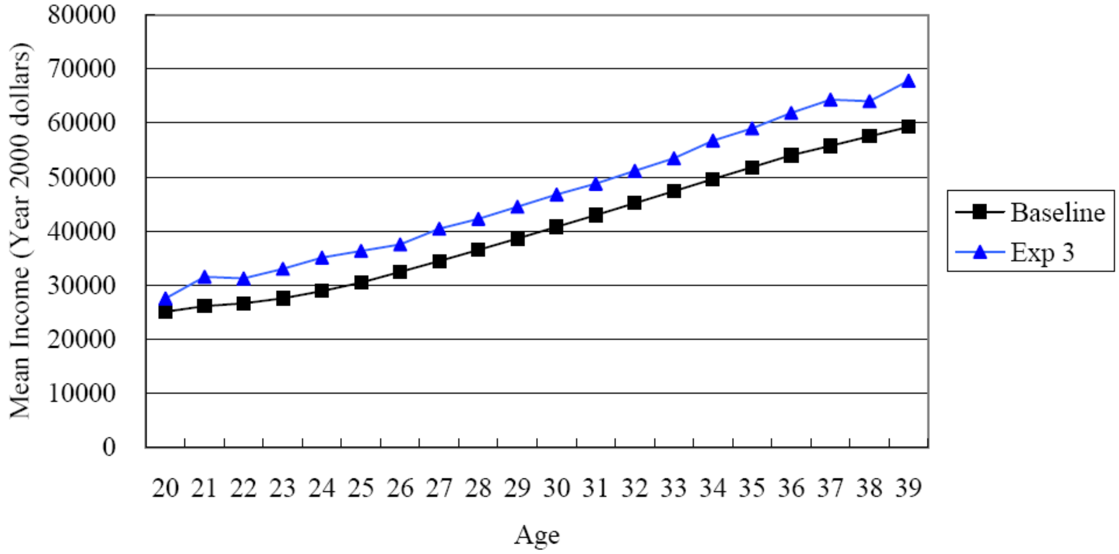

Figure 27: Changes in the Age Profiles of the Mean Income from Full-time Paid-Employment (College; Experiment 3)

data, insights from the experiments would be useful in considering what determines the dynamic characteristics of self-employment. However, as with any empirical work, the present study should not be taken as definitive, and further research remains to be undertaken, in particular, to determine how different setups and specifications would alter the conclusions.

The sample I use for this study consists of white males. To members of minority groups who are seeking self-employment opportunities, public assistance programs for self-employment would be relevant, as such individuals may face more severe borrowing constraints than white males. Self-employment assistance programs sometimes target specific groups; for example, structurally unemployed or displaced workers and social assistance recipients. The framework in the present study can be extended to study nonwhite self-employment.

The present study has considered the model of a single agent. It would be interesting and important to study various self-employment issues by extending Blau's (1987) two-sector (entrepreneurial and corporate) general equilibrium model to a dynamic model.[63] A more fundamental question is what entrepreneurial skills are.[64] Family background would also play an important role.[65] These and other interesting questions about self-employment are

[63] Blau's (1987) time series regression analysis found that six effects could explain most of the increase in the proportion of male workers that were self-employed from 1973 to 1982. In order of importance, the six effects were: an increase in a self-employment factor productivity index; a decrease in the marginal tax rate at a real income of $7000; an increase in the social security benefit level; a decrease in the real minimum wage; and a decrease in the age of the male labor force.

[64] Using data from a list of MBA alumni at a business school, Lazear (2005) found that, on average, those alumni with experience of self-employment (in an incorporated business) took courses from a broader area of specialties. The difference between the number of courses taken in the student's specialty and the average number of courses taken in other fields. A study by White, Thornhill and Hampson (2006) used data collected from 31 MBA students with significant prior involvement in new venture creation and from 79 other students with no new venture startup experience, and found that a *testosterone* (an endocrine hormone) effect upon behavior (new venture creation) is partially mediated by the psychological (risk propensity).

[65] For example, Hundley (2006) found evidence that whereas both parental self-employment and family income significantly increased a man's propensity to become a self-employer, the former effect is amplified by the latter.

left for future research.

Appendix A Exact Functional Forms Used to Simulate the Model

In this appendix, I show the exact forms of functions as they are used in *simulating* the life-cycle model. Essentially, when trying to match the model predictions to the empirical patterns in many dimensions, I am concerned about disentangling as precisely as possible unobserved heterogeneity from such effects as the life-cycle and the hysteresis effects on labor choice and saving decisions. Age variables and lagged choice variables in the utility function and the human capital functions are thus added to prevent the overstatement of the unobserved heterogeneity.

To *estimate* the model (by the simulated unconditional maximum likelihood method), I need parameterization for classification and measurement to connect simulated data and the observed data. I also need to determine the rule on how to fill in missing initial asset observations. The exact specification for these parts is given in Appendix C. The total number of the parameters in the current specification that are necessary for simulation (given an initial condition) is 64. In what follows, $I(\cdot)$ is an indicator function that assigns one if the term inside the parenthesis is true and zero otherwise.

A.1 Preference: Time Discount Factor, β, and the Utility Function, $u(\cdot;\epsilon_t^{ls},\epsilon_t^{lw};\mu)$ (16 Parameters)

I assume that β is a common constant for all individuals. The utility function is given as the following CRRA form augmented by τ_t^s, l_{t-1}^w and age_t:

$$
\begin{aligned}
u_t &= u(c_t, l_t^s, l_t^w, \tau_t^s, l_{t-1}^w, age_t,\, type; \epsilon_t^{ls}, \epsilon_t^{lw}; \mu) \\
&= \frac{c_t^{1-\mu_0(type)}}{1-\mu_0(type)} \\
&\quad - \underbrace{[\mu_{1,s}(type,\tau_t^s) + \epsilon_t^{ls}]\cdot I(l_t^s > 0)}_{\text{disutility from self-employment}} \\
&\quad - \underbrace{[\mu_{1,w}(type) + \epsilon_t^{lw}]\cdot [I(l_t^w \text{ is } \textit{full-time}) + \mu_{1,w,part}\cdot I(l_t^w \text{ is } \textit{part-time})]}_{\text{disutility from paid-employment}} \\
&\quad - \underbrace{\mu_{2,full}(type)\cdot I(l_t^s > 0\ \&\ l_t^w \text{ is } \textit{full-time}) - \mu_{2,part}(type)\cdot I(l_t^s > 0\ \&\ l_t^w \text{ is } \textit{part-time})}_{\text{disutility from dual job holding}} \\
&\quad + \underbrace{\mu_{3,s\to s}(type,\tau_t^s)\cdot I(l_t^s > 0\ \&\ \tau_t^s \geq 1)}_{\text{utility benefit from staying in SE}},
\end{aligned}
$$

where

$$\mu_0(type) = \mu_{00} + \mu_{01}\cdot I(type = 2)$$

is the parameter for relative risk aversion parameter ("prudence"),

$$
\begin{cases}
\mu_{1,s}(type,\tau_t^s) = \mu_{10,s} + \mu_{11,s}\cdot I(type=2) + \mu_{12,s}\cdot \tau_t^s \\
\mu_{1,w}(type) = \mu_{10,w} + \mu_{11,w}\cdot I(type=2)
\end{cases}
$$

are parameters for labor disutility and

$$\begin{cases} \mu_{2,full}(type) = \mu_{20,full} + \mu_{21,full} \cdot I(type = 2) \\ \mu_{2,part}(type) = \mu_{20,part} + \mu_{21,part} \cdot I(type = 2) \end{cases}$$

are additional disutility if he works as a self-employer and as a wage worker in the same period. Parameter $\mu_{3,\cdot\cdot}$, interpreted as utility benefits from staying in self-employment when he has been a for τ_t^s years is

$$\mu_{3,s\to s}(type, \tau_t^s) = \mu_{40,s\to s} + \mu_{41,s\to s} \cdot I(type = 2) + \mu_{42,s\to s} \cdot \tau_t^s$$

A.2 Constraints: Lower Bound for Financial Net Worth, $\underline{a}(\cdot;\zeta)$, and the Consumption Floor, $c_{\min}$ (8 Parameters)

The borrowing constraint requires that net financial assets not fall below some nonpositive lower bound. I allow the constraint to evolve as a function of the individual's level of education, work experience and (unobserved) type as well as age:

$$\begin{aligned} \underline{a}_t &= \underline{a}(h_t^s, h_t^w, age_t, educ; \zeta) \\ &= -\exp[\zeta_0 + \zeta_1 \cdot I(educ = college) + \varsigma_2 \cdot I(h_t^s = 1) \\ &+ \zeta_3 \cdot h_t^w + \zeta_4 \cdot \frac{(h_t^w)^2}{100} + \zeta_5 \cdot (age_t - 20) + \zeta_6 \cdot \frac{(age_t - 20)^2}{100}] \end{aligned}$$

for $t = 2, ..., T$.[66] The interpretation is that education, work experience and type serve (through human capital) to forecast future earnings potential. The dependence of the lower bound on age is in expectation of getting a better fit. Together with $c_{\min}$, which I assume is a common constraint for all individual, the lower bound gives the upper and lower bounds for c_t and for a_{t+1}:

$$\begin{cases} c_{\min} \le c_t \le y_t + (1-\delta)k_t + (1+r)a_t - \underline{a}_{t+1} \\ \underline{a}_{t+1} \le a_{t+1} \le y_t + (1-\delta)k_t + (1+r)a_t - c_{\min} \end{cases}$$

where c_t and a_{t+1} are related through the budget constraint:

$$c_t + a_{t+1} = y_t + (1-\delta)k_t + (1+r)a_t.$$

[66] Remember that the initial financial net worth a_1 must also satisfy $a_1 \ge \underline{a}_1$; otherwise, the upper bound for k_1, $a_1 - \underline{a}_1$, could be negative. In this study, I simply look at the minimum of financial net worth in the first decision period for each cell in the following table.

age 20	-15840.0 (obs.no. = 138)
ages 21-23	-38308.0 (obs.no. = 177)
ages 24-25	-21864.0 (obs.no. = 72)

Why I do not collapse the table by education is that the numbers of observations with college for age 20 and of those with noncollege for ages 24-25 are very small. I simply assume that the lower bound, $\underline{a}_1$, for each age level is 1.20 × minimum (negative for all of the three case) of observations (-19008.0 for age 20, -45969.6 for ages 21 to 23 and -26236.8 for ages 24 and 25).

A.3 Human Capital, $\overline{\Psi}^m(\cdot;\gamma^m)$, $m = w, s$, and the Rental Price for Part-time Paid-Employment, R^p (17 Parameters)

In the present study, I consider mode-specific human capital, that is, I distinguish human capital that is used for paid-employment ($\overline{\Psi}_t^m$) and that for self-employment ($\overline{\Psi}_t^s$). For paid-employment, the market value of human capital is given by

$$\begin{aligned} R^j \cdot \overline{\Psi}_t^w &= R^j \cdot \overline{\Psi}_t^w(h_t^w,\, h_t^s,\, age_t,\, educ,\, type;\gamma^w) \\ &= R^j \cdot \exp[\underbrace{\gamma_0^w}_{\text{constant}} + \underbrace{\gamma_1^w \cdot I(educ = college)}_{\text{schooling}} + \underbrace{\gamma_2^w \cdot I(type = 2)}_{\text{type}} \\ &+ \underbrace{\gamma_3^w \cdot h_t^w + \gamma_4^w \cdot \frac{(h_t^w)^2}{100}}_{\text{accumulated "own" experience}} + \underbrace{\gamma_5^w \cdot I(h_t^s = 1)}_{\text{ever experience in SE}} \\ &+ \underbrace{\gamma_6^w \cdot (age_t - 20)}_{\text{age effect}}] \end{aligned}$$

where R^j is the *rental price* for j-time paid employment. Since the relative price matters, I normalize $R^f = 1$. For self-employment, the value of human capital is given by

$$\begin{aligned} \overline{\Psi}_t^s &= \overline{\Psi}_t^s(h_t^s,\, \tau_t^s,\, h_t^w,\, age_t,\, educ, type;\gamma^s) \\ &= \exp[\underbrace{\gamma_0^s}_{\text{constant}} + \underbrace{\gamma_1^s \cdot I(educ = college)}_{\text{schooling}} + \underbrace{\gamma_2^s \cdot I(type = 2)}_{\text{type}} \\ &+ \underbrace{\gamma_3^s \cdot I(h_t^s = 1)}_{\text{ever "own" experience}} + \underbrace{\gamma_4^s \cdot \tau_t^s + \gamma_5^s \cdot \frac{(\tau_t^s)^2}{100}}_{\text{accumulated "own" experience \textit{in a row}}} + \underbrace{\gamma_6^s \cdot h_t^w + \gamma_7^s \cdot \frac{(h_t^w)^2}{100}}_{\text{accumulated experience in PE}} \\ &+ \underbrace{\gamma_8^s \cdot (age_t - 20)}_{\text{age effect}}]. \end{aligned}$$

As in the standard literature on human capital formation, the productivity of human capital for mode $m = s, w$ in period t depends on his attained education (γ_1^m) and the quadratic form of his past experience in mode m ($\gamma_{2,m'}^m$ and $\gamma_{3,m'}^m$). Notice that the specification above assumes that unobserved heterogeneity with respect to entrepreneurial skills/talents is used only in self-employment ($\gamma_{1,type}^s$). Additional terms are to capture an effect of work experience in the other mode (γ_4^m), an age effect (γ_5^m), a benefit from staying (γ_6^m), and a first-year experience effect (γ_7^m).

A.4 Entrepreneurial Production Function, $f([\overline{\Psi}_t^s l_t^s], k_t, \epsilon_t^{ys};\alpha)$ (2 Parameters)

As explained in the main text, the parametric form for f is

$$\begin{aligned} & f([\overline{\Psi}_t^s l_t^s], k_t, \epsilon_t^{ys};\alpha) \\ &= [\overline{\Psi}_t^s l_t^s]^{1-\alpha} {k_t}^{\alpha} \exp(\epsilon_t^{ys}), \end{aligned}$$

where I consider the dependence of schooling on capital returns, α:

$$\alpha = \alpha_0 + \alpha_1 \cdot I(educ = 1).$$

A.5 Type Proportions, $\Pr(type, initial\ conditions; \eta)$ (4 Parameters)

In the current specification, I assume that there are two unobserved types, $type = 1{,}2$. The type probabilities are logistic functions of the initial conditions. Specifically, they are written by

$$\Pr(type = 2;\ initial\ conditions,\ \eta) = \frac{\exp\left(\begin{array}{c}\eta_{0,2} + \eta_{1,2} \cdot I(educ = college) \\ +\eta_{2,2} \cdot \dfrac{a_1}{10000} + \eta_{3,2} \cdot I(\underline{age} \geq 23)\end{array}\right)}{1 + \exp\left(\begin{array}{c}\eta_{0,2} + \eta_{1,2} \cdot I(educ = college) \\ +\eta_{2,2} \cdot \dfrac{a_1}{10000} + \eta_{3,2} \cdot I(\underline{age} \geq 23)\end{array}\right)}$$

and $\Pr(type = 1;\ initial\ conditions,\ \eta) = 1 - \Pr(type = 2;\ initial\ conditions,\ \eta)$.[67]

A.6 Variances and the Covariances of the Period-by-Period Disturbance, $\sigma^2_{\epsilon,\cdot}$ (6 Parameters)

The period-by-period disturbances to labor disutility, $\epsilon^l_t = (\epsilon^{ls}_t, \epsilon^{lw}_t)$ and $\epsilon^y_t = (\epsilon^{ys}_t, \epsilon^{yw}_t)$, and to the borrowing constraint, ϵ^a_t, are observed in the beginning of each period. I assume that ϵ^l_t, ϵ^y_t and ϵ^a_t are independently and identically distributed. For ϵ^l_t and ϵ^y_t, I assume serial independence across t, and I allow correlation between ϵ^{ls}_t and ϵ^{lw}_t. Specifically, I assume $\epsilon^l_t \sim N(0, \Sigma^l)$, where the variance-covariance matrix, Σ^l, is given by

$$\Sigma^l = \begin{pmatrix} \sigma^2_{\epsilon,ls} & \cdot \\ \sigma_{\epsilon,(ls,lw)} & \sigma^2_{\epsilon,lw} \end{pmatrix}.$$

Similarly, I assume $\epsilon^{ys}_t \sim N(0, \Sigma^y)$ where

$$\Sigma^y = \begin{pmatrix} \sigma^2_{\epsilon,ys} & \cdot \\ \sigma_{\epsilon,(ys,yw)} & \sigma^2_{\epsilon,yw} \end{pmatrix}.$$

A.7 Quasi-Terminal $Emax$ Function, $Emax_{T^*}(\cdot; \kappa_{T^*})$ (5 Parameters)

To ease computational burden, the terminal period is set to be $T^* < T$.[68] I assume the following specification:

$$\begin{aligned} Emax_{T^*} &= Emax_{T^*}(a_{T^*+1}, educ, h^s_{T^*+1}, h^w_{T^*+1}; \kappa_{T^*}) \\ &= \kappa_{T^*,1} \cdot a_{T^*+1} + \kappa_{T^*,2} \cdot \frac{(a_{T^*+1})^2}{10000} \\ &\quad + \kappa_{T^*,3} \cdot I(educ{=}college) \\ &\quad + \kappa_{T^*,4} \cdot h^s_{T^*+1} + \kappa_{T^*,5} \cdot h^w_{T^*+1} \end{aligned}$$

Remember that this form of specification is one of many other alternatives. Future work should elaborate more on this issue.

[67] Variables related to family background and psychological characteristics could be included. In the present study I do not use them because I want to keep the numbers of individuals in the sample as large as possible so that the number of the self-employed does not become smaller in each age. For example, I need to drop 90 out of the current 1,916 individuals.

[68] Specifically, I set $T^* = 30$ for all individuals.

Appendix B Details on the Construction of the Data

The aim of this appendix is to show how the data for estimation,

$$\begin{aligned} X &= \{X_i\}_{i=1}^N \\ &= \{((l_{i,t}^s, l_{i,t}^w),\ (y_{i,t}^s, w_{i,t}),\ a_{i,t+1},\ k_{i,t},\ age_{i,t})_{t=1}^{\widehat{T}_i},\ a_{i1},\ educ_i\}_{i=1}^N, \end{aligned}$$

is constructed from the original 1979 cohort of the National Longitudinal Survey of Youth (NLSY79).[69] The first and last calender years for which information from data is utilized are 1979 and 2000.[70]

Remember that the decision period in my life-cycle model is a *calender year* (job durations, for example, are measured in terms of years), while various information is available on a weekly or monthly basis. So, the original data must be arranged to match the length of the decision period in the model. Other modifications are necessary to accommodate the data to the life-cycle model.

After showing the construction of the age variable in B.1, I show my rules on how to determine the first decision period for each individual in B.2. B.3 explains the restriction on the person dimension. I then give details on the construction of the main variables in B.4. For the sake of presentations, these processes are explained in order, but the actual process of data construction was not implemented in this order because, for example, the restriction on the person dimension needs some information on variables constructed in B.4.

B.1 Constructing Age Variable, $age_{i,t}$

Respondent's data of birth was asked twice: in survey years 1979 and 1981. Although it is suspicious that there are some misreportings of birth year,[71] I simply use the 1979 information. First, I calculate an individual's age in months at each interview date by

interview date (month/year) - DOB (month/year) in the 1979 survey.

Then, I compute his age in months as of January of the interview year simply by

age at interview date (in months) - (interview month -1) (in months).

B.2 Determining Age in the First Decision Period

Remember that schooling decision is not modelled in the life-cycle model. The individual in the model starts decisions one year after when he completed schooling. His year of schooling is taken as an exogenous variable in the dynamic model, and it does not change over time. To follow each individual in the data from his first decision period, I need to determine when he is considered to have finished schooling. Again, note that the decision period of my choice

[69] All the original data was retrieved online at the "NLS Investigator" (http://www.nlsinfo.org/web-investigator/).

[70] While I use the survey rounds up to 2002, I do not take 2002 as the final year because the year 2002 survey did not collect information on assets. The reason why I also use the year 2002 survey is that it covers weekly labor status information after the interview date in 2000.

[71] I found 14 observations (out of the core while male sample; 2,439 observations) are suspected to have misreported his birth year. The number is small, so this problem should be minor. Also note that all original 2439 respondents answered the question in 1979. For details, see the documation attched to the data (will be available in due course).

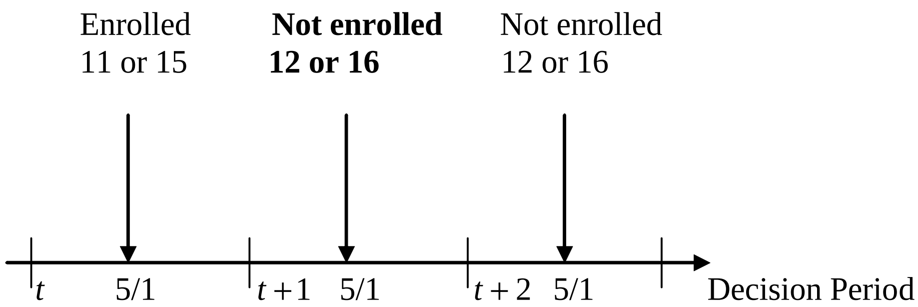

Figure 28: Typical Pattern of Transition from Schooling to Work/Non-Work

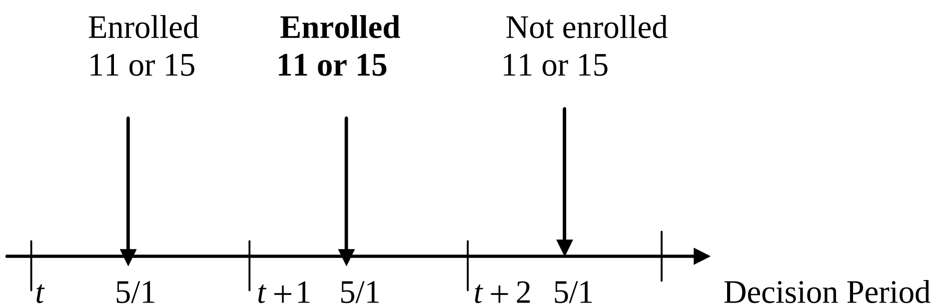

Figure 29: An Ambiguous Case of Transition

is a *calender* year. I must therefore be careful about the differences between calender years and *school* years, because it matters to the transition from schooling to work/non-work.

At each survey round, each respondent's school enrollment status as of May 1 of each year is available. I collapse the four categories in the original data into two as follows:

$$\begin{cases} \text{Enrolled} \leftarrow \text{“Enrolled in high school” or “Enrolled in college”} \\ \text{Not Enrolled} \leftarrow \text{“Not enrolled, completed less than 12th grade”} \\ \qquad\qquad\qquad\qquad \text{or “Not enrolled, high school graduate.”} \end{cases}$$

Using this information on "school enrollment status as of May 1st" (denoted by "$enrollment_{i,t}$"), however, alone may not be precise. This problem is depicted as follows.

In most cases, we expect to observe patterns as shown in Figure 28. The horizontal arrow shows the timeline, and each partition corresponds to one period (t, $t+1$ and $t+2$). For each period, the status of school enrollment (the first row) and the accumulated year of schooling (the second row) are observed. The story that would be the most plausible to the information in this figure is the following. The individual graduated from school at some point after May 1st of period t, obtaining one more year of schooling. This is found by the information in period $t+1$: he is not enrolled in school and his year of schooling increased from the one in the previous year If that is the case, it is natural to assume that year $t+1$ is the first decision period.

Now, suppose that we observe a pattern as in Figure 29. In this case, it would be natural to assume that he stopped schooling in year t, even though he was reportedly enrolled in school year $t+1$ because he did not obtain one more year of schooling.

To avoid this type of ambiguity, I need to look at *changes* in his "Highest Degree Completed as of May 1st" (denoted by variable "$completed_{i,t}$") to determine the first decision period. Essentially, I want to find when his $completed_{i,t}$ stopped to increase. The first decision period should be one year after the year when his $completed_{i,t}$ firstly stopped to increase.

When I see an individual's $completed_{i,t}$ go up again after years of constant $completed_{i,t}$, I judge whether or not he is considered to have temporary left for additional schooling (see Restriction PD-4 in B.3). More formally, I adopt the following rules to determine when the first decision period is.

Rule 1. If individual i is not enrolled in school as of May 1st of year t ($enrollment_{i,t} = 0$), then I say he is not enrolled in school in year t ($in\_school_{i,t} = 0$).

Rule 2. If individual i is enrolled in school as of May 1st of year t ($enrollment_{i,t} = 1$), then I say he is enrolled in school in year t ($in\_school_{i,t} = 1$) if

$$completed_{i,t+1} > completed_{i,t},$$

and he is not enrolled in school year t ($in\_school_{i,t} = 0$) if

$$completed_{i,t+1} \leq completed_{i,t}.$$

In this way, for each individual, any calender year is categorized into "1" (attended school) or "0" (did not attend school), as long as "school enrollment status as of May 1" and "highest grade completed as of May 1" are available for that year. For most of individuals, "1"s appear in a row when young and "0"s in subsequent years. This case has no difficulty in determining the first decision period. For other individuals, I decided whether or not he is judged to have temporary left for additional schooling by looking at the computed hours worked and the monthly information on school enrollment.[72]

B.3 Restriction on the Person Dimension, N

I employ the following steps to restrict on the person dimension (PD) for the data used for this study.

- Restriction PD-1. I extract the *white male* part in the *core random* sample.[73] This reduces the initial sample size 12,686 to 2,439.

- Restriction PD-2. Next, to drop individuals who have served in the *military*, I look at the "Weekly Labor Force Status" Section (from Week 0 in 1978 to Week 52 in 2000).[74] If an individual's labor force status is "military" in any week since January 1, 1978, then he is excluded from the sample. I find 268 observations have ever been in the military (10.99%). This reduces the sample size 2,439 to 2,171.

- Restriction PD-3. Using the defined occupation for individual i in year t (see B.4.1. below), I exclude *professionals* and *farmers*. First, I exclude individuals who experienced any of the following occupations in any year t: "Accountants and auditors," "Lawyers and judges," "Health diagnosing occupations," and "Farming, forestry & fishing occupations." I then find, among the nonmilitary experienced, 361 observations have ever experienced professional or farmer.[75] I put 259 of them back to the sample if they were

[72] Monthly attendance record is available after January, 1980.

[73] One can retrive all necessary data online by filitering "R0173600 $\leq$ 2" ("R0173600" is the sample identification code).

[74] The 1979 year survey covers weekly labor status in 1978 as well.

[75] Among those already excluded in Restriction CS-2, 26 observations have ever experienced professional or farmer.

a professional or a farmer before the first decision period, if they are judged to have temporally worked for such jobs, or if they were in such occupations as pharmacist and registered nurse. The number of excluded individuals is now 102 (4.70%). This process reduces the sample size 2,171 to 2,069.

- Restriction PD-4. I drop individuals who are judged to have temporary left for adult schooling (24 individuals),[76] to have started working late (26 years old or older; 80 individuals) as well as 2 individuals whose first decision period is judged 14 years old. I also exclude individuals if it is difficult to determine the first decision period (6), or if no survey years are covered when working (41). The number of excluded individuals is 153 (7.39%), and this process reduces the sample size 2,069 to 1,916.

My final sample consists of 1,916 white males with a total of 32,166 person-year observations.

B.4 Construction of the Main Variables

Here I show how the main variables are constructed from the NLSY79. First, I utilize the weekly information is available whether or not someone was self-employed.

B.4.1 Defining Self-Employment and Wage-Employment

To obtain information on whether an individual is a self-employer or a wage worker in a year, I look at the "Class of Worker" Section (up to 2002 survey year). For each "job"[77] (up to five jobs for each survey year) a respondent reports whether he[78]

(1) worked/works for a private company or individual for wages, salary, or commission,
(2) was/is a government employee,
(3) was/is *self-employed* in his/her own business, professional practice or farm, or
(4) was/is working without pay in a family business or farm,

for that job. In the NLSY79, the respondent is classified (by his/her answers to the job classification questions) as *self-employed* if[79]

> "he or she owned at least 50 percent of the business,
> was the chief executive officer or principal managing partner of the business, or
> was supposed to file a form SE for Federal income taxes"

or he or she identifies himself or herself as

> "an independent contractor, independent consultant, or free-lancer."

Using this information, I associate each job with information on whether the respondent worked as a self-employer or as a paid-worker for that job. Specifically, a job is attached

[76] I made judgment by looking at calculated hours worked, changes in the highest degree completed, and the monthly school enrollment information.

[77] All references to a "job" should be understood as references to an employer.

[78] Category (1) includes individuals working for pay for settlement houses, churches, unions, and other private nonprofit organizations until 1994 when these begun to be independently coded.

[79] See ftp://www.nlsinfo.org/pub/usersvc/NLSY79/NLSY79%202004%20User%20Guide/79text/cow.htm.

to *self-employment* if it is categorized as (3), and is attached to *paid-employment* if it is categorized as (1) or (2). Category (4) will not be considered as "worked/works."

Not all the jobs listed in the NLSY79 can be identified either as self-employed or as paid-employed. This is because the "Class of Worker" information is collected only for the current (the CPS item) jobs[80] and ones for which the respondent worked for more than 10 (after 1988) or 20 (prior to 1988) hours a week and for more than 9 weeks since the last interview. This limited form of information should be innocuous for this study, however, because in the actual estimation these "temporary" jobs will not be counted as worked due to the discretization of the variable "hours worked." in B.4.2.[81]

For each job, we also have information (if provided) on labor market opportunities (the weekly average of hours worked[82] and the weekly average of hourly rate of pay). These items are used in the following calculation of the actual hours worked and the diecretization.

One caveat is that owners of incorporated businesses may or may be excluded if they draw a salary from their businesses and interpret this behavior as the one of a wage worker. Thus, the above definition of self-employers refers essentially to sole proprietors and partners of unincorporated businesses.

B.4.2 Mode of Employment and Work Intensity, $(l_{i,t}^s, l_{i,t}^w)$

I look at the "Weekly Labor Force Status" Section and the "Dual Jobs" Section (1979-2000)[83] and the job characteristics information obtained above. For each individual, information on weekly labor force status is available up to the date that the last interview that he responded covers. So, the last year when the information is available is the one right before the year when "0" ("no info reported for week") appears in an array.

For each individual $i \in \{1, ..., N\}$, I know (if information is provided) whether job j ($j = 101$, ..., 105, 201, ..., 1905, 2001, ..., 2005)[84] is attached to self-employment or to paid-employment. I compute i's total hours worked for job j in calender year t, $total\_hours\_worked_{i,t}^j$, by

$$total\_hours\_worked_{i,t}^j, = weekly\_hours\_worked_i^j \times weeks_{i,t}^j,$$

where $weekly\_hours\_worked_i^j$ is individual i's weekly average of hours worked and $weeks_{i,t}^j$ is the number of weeks he worked for job j in year t. Both of them are available in the NLSY79.

I then aggregate jobs according to whether they are attached to self- or to paid-employment. I calculate total hours worked for m-mode employment ($m \in \{self, paid\}$) in year t,

[80] In 1994, the occupation, industry and class of worker information for 353 CPS employers were not collected. This error would be innocuous for my study because these CPS employers were either less than 9 weeks in duration since the last interview, or were employers for whom the respondent worked less than 10 hours per week. For more information on this editing error, see http://www.nlsinfo.org/nlsy79/nlsy79_errata.php3.

[81] Note that week-by-week information on hours worked and hourly rate of pay is collected for almost all jobs appearing in the data. So, if we do not care about the class of worker, we can well grasp total hours worked and wage earnings in any week.

[82] In the 1988 survey round, the NLSY79 started asking hours worked at home separately for each job. By hours worked, I mean the sum of hours worked at workplace home and those at home.

[83] "Weekly Labor Force Status" information is available (since January 1, 1978) on whether a respondent was (a) working, (b) associated with an employer, (c) unemployed, (d) out of the labor force, (e) not working, or (f) in active military duty.

[84] Remember each calender year covers up to 5 jobs and we have 20 calender years; the first one or two digits correspond to survey years and the last digit to the job number.

$total\_hours\_worked^{l}_{i,t}$, by

$$total\_hours\_worked^{m}_{i,t} = \sum_{j \in m} total\_hours\_worked^{j}_{i,t}.$$

Remember that I assume that the individual in the model chooses descretized hours worked. Specifically, I employ the following descretization that allows natural interpretation: in year t, individual i

$$\begin{cases} \text{did } \textit{not} \text{ work as a self-employer if } 0 \leq total\_hours\_worked^{self}_{i,t} < 700 \ (= 20 \text{ hours} \times 35 \text{ weeks}), \\ \textit{worked} \text{ as a self-employer if } total\_hours\_worked^{self}_{i,t} \geq 700. \end{cases}$$

and he

$$\begin{cases} \text{did } \textit{not} \text{ work as a wage earner if } 0 \leq total\_hours\_worked^{paid}_{i,t} < 700, \\ \text{worked as a } \textit{part-time} \text{ wage earner if } 700 \leq total\_hours\_worked^{paid}_{i,t} < 1400 \\ \qquad\qquad\qquad\qquad\qquad\qquad (= 40 \text{ hours} \times 35 \text{ weeks}), \text{ and} \\ \text{worked as a } \textit{full-time} \text{ wage earner if } total\_hours\_worked^{self}_{i,t} \geq 1400. \end{cases}$$

I do not consider the possibility that an individual decides on how many hours he works, and assume that if he works in self-employment or in full-time paid-employment, his hours worked is 2000, and if he works as a part-time wage worker they are 1000.[85]

The reason why I do not distinguish between full-time and part-time self-employment is that the number of individuals who choose part-time self-employment is very small for each age that is covered in the data. I say that he was *non-employed* in year t if he did work in both modes of employment. Note that as Table 4 in the main text shows, "dual-employment" (worked as a self-employer and as a wage earner in the same year) is observed with small fractions. One reason why one is self-employed and is a wage worker in the same year would be that he works for an employer during the day and runs his own business in the evenings. Another possible reason is that he worked as a wage worker early in the year and worked as self-employer late in the year.

B.4.3 Net Worth, $a_{i,t}$

Collecting information on assets began in survey year 1985,[86] with exceptions of survey years 1991 and 2002. Assets are measured at interview dates. To calculate financial net worth, I follow Keane and Wolpin (2001), Imai and Keane (2004) and many others who use asset information in the NLSY79: I first add up the following variables to construct total positive assets:[87],[88]

$$\begin{cases} \text{(1) "Market value of residential property the respondent or his spouse (R/S) owns"} \\ \text{(2) "Total market value of vehicles including automobiles R/S owns"} \\ \text{(3) "Total amount of money assets like savings accounts of R/S"} \\ \text{(4) "Total market value of all other assets each worth more than \$500" and} \\ \text{(5) "Total market value of farm/business/other property the R/S owns".} \end{cases}$$

[85] Under this categoralization, the mean hours worked for self-employment, for full-time paid-employment, and for part-time paid-employment over the ages covered in the data (20-39) are, 2056.2, 2315.5, and 1061.4, respectively. The hours worked for and for full-time paid-employment increase moderately over age, and the ones for part-time paid-employment are stable. This assumption thus seems innocuous.

[86] Remember that this implies that the earliest age at which I have information on assets is essentially 20.

[87] For Item (3), the total market value of stocks/bonds/mutual funds became distinguishable in 1988, and the total amount of money holdings like IRA/Keogh, 401k/403b and CDs became distinguishable in 1994.

[88] If the respondent does not report at least one of the items, I set the assets variable to "missing." I do the same to the debts items.

Then, to construct total debts, I add up the following items:

$$\begin{cases} \text{(1) “Amount of mortgages \& back taxes R/S owes on residential property”} \\ \text{(2) “Amount of other debts R/S owes on residential property”} \\ \text{(3) “Total amount of money R/S owes on vehicles including automobiles”} \\ \text{(4) “Total amount of other debts over \$500 R/S owes” and} \\ \text{(5) “Total amount of debts on farm/business/other property R/S owes”.} \end{cases}$$

I subtract the total debts from the total assets and call it *net worth*. I exclude top and bottom 1% of financial net worth (greater than $653,755.7 and less than -72,600, respectively). The numbers of excluded observations are 181 and 180, respectively.

B.4.4 Income in Self-Employment and Wage in Paid-Employment, $(y^s_{i,t}, w_{i,t})$

Difficulties in measuring and interpreting income from self-employment are well known. If an individual i works for self-employment ($l^s_{i,t} > 0$) with a positive amount of business capital ($k_{i,t} > 0$), then his income both from his entrepreneurial production function should be a combination of income from labor and from capital. The issue is whether or not the self-reported income from self-employment includes the returns to business capital, $k_{t,t}$. In the following, I explain the problem and how I mitigate it.

First, there are two sources of information on income in the NSLY79:

> (1) Information on “wage/salary” is obtained from the event history (in the Employer Supplement Section) on reported jobs. For each reported job, the respondent is asked wage and the time unit of the wage.
>
> (2) In addition, the NLSY79 has global questions on the amounts of various types of “annual income” in the previous year. These are summarized in the Income Section. In particular, the Income Section asks separately about “wage/salary income” and “business or farm income (after expense).”

At first, it would seem that information source (2) works better than source (1) because the distinction between “wage/salary income” and “business or farm” is explicit in (2) while it is obscure in (1). So, suppose that I use information source (2). It is unclear, however, what corresponds to $y^s_{i,t}$. It seems safe to assume neither “wage/salary income” nor “business or farm” contains the depreciated capital, $(1-\delta)k_t$. The reason is shown in Table B-3 for my final person-year observations: “(Business income)/k_t” does not seem constant over changes in percentiles.

Some respondents are still likely to mix the returns to labor and the returns to capital, even though the Income Section asks about both income sources separately. As Fairlie (2005, pp.43-44) points out, and as is verified with my final sample, about half of the self-employed with positive earnings report wage/salary income, but do not report business income. Fairlie (2005) ascribes this problem to the ordering of questions. In the NLSY79, respondents are asked, (1) “How much money did you get from the military?”; (2) “Excluding military pay, how much money did you get from wages, salary, commissions, or tips?”; and (3) “Excluding anything you already mentioned, did you receive any business income?” Some of the self-employed thus may have reported their income in the second question and did not correct their mistake.[89]

[89] Another issue is on the accuracy or the reliability of the question. The exact sentence of the question is: “How much did you receive *after expences* from your farm or business in the past calender year?” One odd thing is that we have no observations with negative business income.

To overcome this issue, I decided to use *the sum of "salary/wage income" and "business income" in the Income Section as income from self-employment,* $y^s_{i,t}$. I trim outliers of the income observations to remove their effects on the results. Note here that I do not drop entire persons with outliers from the sample, but in estimation I treat outliers as missing values. Specifically, if the sum of wage/salary and business incomes from the Income Section exceeds \$1,000,000, I treat *both* wage/salary and business incomes as missing. The number of such observations is 16.

For wage from paid-employment, $w_{i,t}$, I use information source (1).

B.4.5 Education ($educ_i$)

Each respondent's highest grade completed as of May 1 of each year is also available.[90] I keep an individual's year of education constant through his decision periods.[91] After imputation, I collapse "Highest Grade Completed" into:

$$\begin{cases} \text{High-school Dropout } (HD)\text{: education } < 12 \\ \text{High-school Graduate } (HG)\text{: education } = 12 \\ \text{Some College } (SC)\text{: } 13 \leq \text{ education } \leq 15 \\ \text{College Graduate } (CG)\text{: education } \geq 16. \end{cases}$$

In the actual implementation, I consider two levels of schooling: schooling H (HD or HG) and schooling C (SC or CG). I define the education dummy by

$$educ_i = \begin{cases} 0 & \text{if } i \text{ is a high-school dropout or graduate} \\ 1 & \text{otherwise.} \end{cases}$$

Appendix C Details on the Construction of the Log Likelihood

C.1 Classification Error for Hours Worked, E^s and E^w (2 Parameters)

The classification error for self-employment is characterized by parameter E^s in the following way:

$$\begin{aligned} \Pr((l^s_{i,t})^{obs} = 1 | \widetilde{l^s}^{sim}_{i,type,t} = 1) &= E^s + (1 + E^s)\widehat{\Pr}((l^s_{i,t})^{obs} = 1) \\ \Pr((l^s_{i,t})^{obs} = 1 | \widetilde{l^s}^{sim}_{i,type,t} \neq 1) &= (1 - E^s)\widehat{\Pr}((l^s_{i,t})^{obs} = 1) \end{aligned}$$

where

$$E^s = \frac{\exp(E^s_0)}{1 + \exp(E^s_0)}$$

[90] I do not use AFQT in this study because among the 1916 individuals in the Restriction CS-4, scores of 154 individuals are missing.

[91] It is known that there are issues of inconsistencies on information on the highest grade completed in the NLSY79. For example, we sometimes observe an individual's "Highest Grade Completed" suddenly jumps even if his "School Enrollment Status"s are zero around that year. See the NLSY79 User's Guide (p.143) for details. I used my own judgment to determine one's highest grade completed when I saw inconsistensies.

and

$$\widehat{\Pr}((l^s_{i,t})^{obs} = 1) = \frac{1}{N}\sum_{i=1}^{N} I((l^s_{i,t})^{obs} = 1).$$

Note here that

$$\begin{aligned}&\Pr((l^s_{i,t})^{obs} = 1)\\&\quad = \Pr((l^s_{i,t})^{obs} = 1|\widetilde{l^s}^{sim}_{i,type,t} = 1)\widehat{\Pr}((l^s_{i,t})^{obs} = 1) + \Pr((l^s_{i,t})^{obs} = 1|\widetilde{l^s}^{sim}_{i,type,t} \neq 1)[1 - \widehat{\Pr}((l^s_{i,t})^{obs} = 1)],\end{aligned}$$

which is equal to $\widehat{\Pr}((l^s_{i,t})^{obs} = 1)$. The classification error for full-, part- and zero-time paid employment, E^w, is constructed similarly. That is,

$$E^w = \frac{\exp(E^w_0)}{1 + \exp(E^w_0)}.$$

C.2 Measurement Error for the Continuous Variables, $\sigma^2_{\xi,\cdot}$ (4 Parameters)

First, the measurement error in *financial net worth* is modeled as

$$(a_{i,t})^{obs} = \widetilde{a}^{sim}_{i,type,t} + \xi^a_t$$

where $\xi^a_t \sim N(0, \sigma^2_{\xi,a})$ and $\sigma_{\xi,a} = \sigma_{\xi,a,0} + \sigma_{\xi,a,1}|(a_{i,t})^{obs}|$. Similarly, the measurement error in *income* from self-employment is modeled in

$$\exp(\xi^{y^s}_t) = |(y^s_{i,t})^{obs} - \widetilde{y^s}^{sim}_{i,type,t}|$$

where $\xi^{y^s}_t \sim N(0, \sigma^2_{\xi,y^s})$, and the the one from j-time paid-employment is modeled in

$$\exp(\xi^{y^w}_t) = |(y^w_{i,t})^{obs} - \widetilde{y^w}^{sim}_{i,type,t}|$$

where $\xi^{y^w}_t \sim N(0, \sigma^2_{\xi,y^w})$.

C.3 Parametric Form of the Likelihood Contribution

With the given specification of classification/measurement errors, the actual expression for the likelihood contribution for individual i in mth simulation is given by

$$
\begin{aligned}
&\Pr(X_i|\widetilde{X}_{i,type}^{sim},\theta) \\
&= \left[\frac{1}{\sqrt{2\pi\sigma_{\xi,a}^2}}\exp\left[-\frac{[(a_{i,t})^{obs}-\widetilde{a}_{i,type,1}^{sim}]^2}{2\sigma_{\xi,a}^2}\right]\right] I(a_{i,1}\ \textit{is observed}) \\
&\times \prod_{t|l_{i,t}^s=1 \text{ is observed}} \Pr((l_t^s)^{obs}\ \textit{is self-employment}) \\
&\times \prod_{t|l_{i,t}^s=0 \text{ is observed}} \Pr((l_t^s)^{obs}\ \textit{is zero self-employment}) \\
&\times \prod_{t|\text{``}l_{i,t}^s=\text{full-time'' is observed}} \Pr((l_t^s)^{obs}\ \textit{is full-time paid-employment}) \\
&\times \prod_{t|\text{``}l_{i,t}^s=\text{ part-time'' is observed}} \Pr((l_t^s)^{obs}\ \textit{is part-time paid-employment}) \\
&\times \prod_{t|\text{``}l_{i,t}^s=0\text{'' is observed}} \Pr((l_t^s)^{obs}\ \textit{is zero paid-employment}) \\
&\times \prod_{t|y_{i,t}^s \text{ is observed}} \left[\frac{1}{|(y_{i,t}^s)^{obs}-\widetilde{y^s}_{i,type,t}^{sim}|\sqrt{2\pi\sigma_{\xi,y^s}^2}}\exp\left[-\frac{[\log((y_{i,t}^s)^{obs})-\log(\widetilde{y^s}_{i,type,t}^{sim})]^2}{2\sigma_{\xi,y^s}^2}\right]\right] \\
&\times \prod_{t|y_{i,t}^w \text{ is observed}} \left[\frac{1}{|(y_{i,t}^w)^{obs}-\widetilde{y^w}_{i,type,t}^{sim}|\sqrt{2\pi\sigma_{\xi,y^w}^2}}\exp\left[-\frac{[\log((y_{i,t}^w)^{obs})-\log(\widetilde{y^w}_{i,type,t}^{sim})]^2}{2\sigma_{\xi,y^w}^2}\right]\right] \\
&\times \prod_{t|a_{i,t+1} \text{ is observed}} \left[\frac{1}{\sqrt{2\pi\sigma_{\xi,a}^2}}\exp\left[-\frac{[(a_{i,t+1})^{obs}-\widetilde{a}_{i,type,t+1}^{sim}]^2}{2\sigma_{\xi,a}^2}\right]\right].
\end{aligned}
$$

Appendix D Parameter Estimates

All the parameter estimates are presented below. The number of estimated parameters is 64. Numerical values in parentheses are standard errors.[92] The maximized value for the log likelihood is -4886.575.

D.1 Preference: Time Discount Factor, β, and the Utility Function, $u(\cdot;\mu)$ (16 Parameters)

D.1.1 Time Discount Factor (β)

- (Parameter #1) $\beta = \underset{(0.0061353226)}{0.9755769}$

[92] Standard errors of the parameters that are transformed from the estimated parameters are calculated by the delta method.

D.1.2 CRRA Constant (μ_0)

- (#2) $\mu_{00} = \underset{(0.0002139242)}{0.4826716}$

- (#3) $\mu_{01} = \underset{(0.0038772353)}{-0.0125118}$ (dummy for Type 2)

$$\rightarrow \text{(CRRA constant)}\begin{cases} \mu_0(type = 1) = \mu_{00} = 0.4826716 \\ \mu_0(type = 2) = \mu_{00} + \mu_{01} = 0.4701598 \end{cases}$$

D.1.3 Labor Disutility (μ_1 and μ_2)

- (#4) $\mu_{10,s} = \underset{(0.0000680669)}{317.2780}$

- (#5) $\mu_{11,s} = \underset{(0.0002151270)}{17.59601}$

- (#6) $\mu_{12,s} = \underset{(0.8354703000)}{-3.305609}$

$$\rightarrow \begin{cases} \mu_{1,s}(type = 1, \tau_t^s) = \mu_{10,s} + \mu_{12,s} \cdot \tau_t^s = 317.2780 - 3.305609 \cdot \tau_t^s \\ \mu_{1,s}(type = 2, \tau_t^s) = \mu_{10,s} + \mu_{11,s} + \mu_{12,s} \cdot \tau_t^s = 334.87401 - 3.305609 \cdot \tau_t^s \end{cases}$$

- (#7) $\mu_{10,w} = \underset{(0.0024144244)}{164.8727}$

- (#8) $\mu_{11,w} = \underset{(0.0003711260)}{14.99203}$

$$\rightarrow \begin{cases} \mu_{1,w}(type = 1) = \mu_{10,w} = 164.8727 \\ \mu_{1,w}(type = 2) = \mu_{10,w} + \mu_{11,w} = 179.86473 \end{cases}$$

- (#9) $\mu_{10,w,part} = \underset{(0.0000569326)}{0.5377413}$

$$\rightarrow \begin{cases} [\mu_{1,w}(type) + \epsilon_t^{lw}] \cdot [I(l_t^w \text{ is } \textit{full-time}) + \mu_{1,w,part} \cdot I(l_t^w \text{ is } \textit{part-time})] \\ = 0.5377413 \cdot [\mu_{1,w}(type) + \epsilon_t^{lw}] \end{cases}$$

- (#10) $\mu_{20,full} = \underset{(0.0001590083)}{1822.401}$

- (#11) $\mu_{21,full} = \underset{(0.0018489889)}{220.5993}$

$$\rightarrow \begin{cases} \mu_{2,full}(type = 1) = \mu_{20,full} = 1822.401 \\ \mu_{2,full}(type = 2) = \mu_{20,full} + \mu_{21,full} = 2043.0003 \end{cases}$$

- (#12) $\mu_{20,part} = \underset{(0.0494701270)}{1424.098}$

- (#13) $\mu_{21,part} = \underset{(0.0009061550)}{197.5852}$

$$\rightarrow \begin{cases} \mu_{2,part}(type = 1) = \mu_{20,part} = 1424.098 \\ \mu_{2,part}(type = 2) = \mu_{20,part} + \mu_{21,part} = 1621.6832 \end{cases}$$

D.1.4 Benefits from Staying in the Same Mode of Employment (μ_3)

- (#14) $\mu_{40,s\to s} = \underset{(0.0003087667)}{159.9276}$
- (#15) $\mu_{41,s\to s} = \underset{(0.0025971585)}{23.56863}$
- (#16) $\mu_{42,s\to s} = \underset{(0.0098452289)}{9.834752}$

$$\to \begin{cases} \mu_{4,s\to s}(type=1,\tau_t^s) = \mu_{40,s\to s} + \mu_{42,s\to s}\cdot\tau_t^s = 159.9276 - 9.834752\cdot\tau_t^s \\ \mu_{4,s\to s}(type=2,\tau_t^s) = \mu_{40,s\to s} + \mu_{41,s\to s} + \mu_{42,s\to s}\cdot\tau_t^s = 183.49623 - 9.834752\cdot\tau_t^s \end{cases}$$

D.2 Lower Bound for Net Worth, $\underline{a}(\cdot;\zeta)$, and the Consumption Floor, $c_{\min}$ (8 Parameters)

D.2.1 Lower Bound for Net Worth ($\underline{a}(\cdot;\zeta)$)

- (#17) $\zeta_0 = \underset{(0.0008765895)}{9.256721}$ (constant term)
- (#18) $\zeta_1 = \underset{(0.0002339659)}{-0.001713}$ (dummy for the college-educated)
- (#19) $\zeta_2 = \underset{(0.0002433008)}{0.353281}$ (dummy for experience of self-employment)
- (#20) $\varsigma_3 = \underset{(0.0006186087)}{0.060926}$ (accumulated years of paid-employment)
- (#21) $\zeta_4 = \underset{(0.0000981532)}{-0.358549}$ (accumulated years of paid-employment squared, divided by 100)
- (#22) $\zeta_5 = \underset{(0.0009014859)}{-0.029473}$ (age)
- (#23) $\zeta_6 = \underset{(0.0003437550)}{0.205846}$ (age squared, divided by 100)

D.2.2 Consumption Floor ($c_{\min}$)

- (#24) $c_{\min} = \underset{(0.0003918820)}{129.3269}$

D.3 Human Capital, $\overline{\Psi}^m(\cdot;\gamma^m)$, $m = w, s$, and the Rental Price for Part-time Paid-Employment, R^p (17 Parameters)

D.3.1 Paid-Employment ($\overline{\Psi}^w(\cdot;\gamma^w)$)

- (#25) $\gamma_0^w = \underset{(0.0000893260)}{2.311925}$ (constant term)
- (#26) $\gamma_1^w = \underset{(0.0004235156)}{0.240281}$ (dummy for the college-educated)
- (#27) $\gamma_2^w = \underset{(0.0001987118)}{0.006273}$ (dummy for Type 2)

- (#28) $\gamma_3^w = \underset{(0.0005028620)}{0.086725}$ (accumulated years of paid-employment)

- (#29) $\gamma_4^w = \underset{(0.0010253931)}{-0.272293}$ (accumulated years of paid-employment squared, divided by 100)

- (#30) $\gamma_5^w = \underset{(0.0000324085)}{-0.003291}$ (dummy for experience of self-employment))

- (#31) $\gamma_6^w = \underset{(0.0013710919)}{0.007934}$ (age)

D.3.2 Rental Price for Part-time Paid-Employment (R^p)

- (#32) $R^p = \underset{(0.0002607080)}{1.1647760}$

D.3.3 Self-Employment ($\overline{\Psi}^s(\cdot;\gamma^s)$)

- (#33) $\gamma_0^s = \underset{(0.0021833163)}{2.444152}$ (constant term)

- (#34) $\gamma_1^s = \underset{(0.0004054129)}{0.280044}$ (dummy for the college-educated)

- (#35) $\gamma_2^s = \underset{(0.0000675430)}{0.008961}$ (dummy for Type 2)

- (#36) $\gamma_3^s = \underset{(0.0001483043)}{0.008406}$ (dummy for experience of self-employment)

- (#37) $\gamma_4^s = \underset{(0.0017562581)}{0.096725}$ (accumulated years of self-employment in a row)

- (#38) $\gamma_5^s = \underset{(0.0012691955)}{-0.170103}$ (accumulated years of self-employment in a row squared, divided by 100)

- (#39) $\gamma_6^s = \underset{(0.0291003160)}{0.028571}$ (accumulated years of paid-employment)

- (#40) $\gamma_7^s = \underset{(0.0040131691)}{-0.110880}$ (accumulated years of paid-employment squared, divided by 100)

- (#41) $\gamma_8^s = \underset{(0.0000230824)}{0.0655306}$ (age)

D.4 Entrepreneurial Production Function, $f(\cdot;\alpha)$ (2 Parameters)

- (#42) $\alpha_0 = \underset{(0.0007083222)}{0.1744350}$ (capital returns)

- (#43) $\alpha_1 = \underset{(0.0000490642)}{-0.0123996}$ (dummy for the college-educated)

$$\rightarrow \text{(capital returns)} \begin{cases} \alpha(educ = \textit{non-college}) = \widehat{\alpha_0} = 0.1744350 \\ \alpha(educ = \textit{college}) = \widehat{\alpha_0} + \widehat{\alpha_1} = 0.1620354 \end{cases}$$

D.5 Type Proportions, $\Pr(\cdot;\eta)$ (4 Parameters)

- (#44) $\eta_{0,2} = \underset{(0.0022314987)}{-0.8543712}$ (constant term)
- (#45) $\eta_{1,2} = \underset{(0.0000527258)}{0.4519807}$ (dummy for the college-educated)
- (#46) $\eta_{2,2} = \underset{(0.0443405550)}{0.0000025}$ (net worth)
- (#47) $\eta_{3,2} = \underset{(0.0000398636)}{0.6448548}$ (dummy for age when started working being greater than or equal to 23)

$$\rightarrow \begin{cases} \Pr(type = 1) = 0.3658664 \\ \Pr(type = 2) = 0.6341336 \end{cases}$$

D.6 Variances and the Covariances of the Period-by-Period Disturbance, $\sigma^2_{\epsilon,\cdot}$ (6 Parameters)

- (#48) $\sigma_{\epsilon,ls} = \underset{(0.0002412930)}{136.69850}$ (disutility from self-employed work)
- (#49) $\sigma_{\epsilon,lw} = \underset{(0.0128387660)}{47.039350}$ (disutility from paid-employed work)
- (#50) $\sigma_{\epsilon,(ls,lw)} = \underset{(0.3296192000)}{2.6065150}$ (disutility correlation between self- and paid-employed)
- (#51) $\sigma_{\epsilon,ys} = \underset{(0.0000738572)}{0.6260160}$ (income from self-employed work)
- (#52) $\sigma_{\epsilon,yw} = \underset{(0.0001690397)}{0.2127060}$ (income from paid-employed work)
- (#53) $\sigma_{\epsilon,(ys,yw)} = \underset{(0.0013701618)}{0.0823533}$ (income correlation between self- and paid-employed)

D.7 Quasi-Terminal $Emax$ Function, $Emax_{T^*}(\cdot;\kappa_{T^*})$ (5 Parameters)

- (#54) $\kappa_{T^*,1} = \underset{(0.0920327680)}{0.0218159}$ (net worth)
- (#55) $\kappa_{T^*,2} = \underset{(0.0000859060)}{-0.0004184}$ (net worth squared, divided by 10000)
- (#56) $\kappa_{T^*,3} = \underset{(0.0001891246)}{13662.890}$ (dummy for college-educated)
- (#57) $\kappa_{T^*,4} = \underset{(0.0021382151)}{4946.5890}$ (dummy for experience of self-employment)
- (#58) $\kappa_{T^*,5} = \underset{(0.0000701953)}{306.77500}$ (accumulated years of paid-employment)

D.8 Measurement Error (6 Parameters)

- (#59) $E_0^s = \underset{(0.0003832295)}{2.0010930}$ (whether self-employed or not)
- (#60) $E_0^w = \underset{(0.0003898737)}{2.8493010}$ (whether paid-employed or not)
- (#61) $\sigma_{\xi,a,0} = \underset{(0.0015494599)}{0.9165500}$ (net worth)
- (#62) $\sigma_{\xi,a,1} = \underset{(0.0011238761)}{0.8819036}$ (coefficient for the absolute value of net worth)
- (#63) $\sigma_{\xi,y^s} = \underset{(0.0063716951)}{28.736100}$ (income from self-employment)
- (#64) $\sigma_{\xi,y^w} = \underset{(0.0077598407)}{26.189700}$ (income from paid-employment)

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