表8a 社会保険への非加入要因分析(公的年金) -推計結果(i)-

(公的年金への非加入に関する分析)		(1)			(2)			(3)			(4)			(5)		
被説明変数: 非加入;1, 加入;0		限界効果	標準誤差		限界効果	標準誤差		限界効果	標準誤差		限界効果	標準誤差		限界効果	標準誤差	
就業形態	非正規雇用(≒短時間被用者)	0.165	0.077	**	0.150	0.082	*	0.172	0.090	*	0.146	0.081	*	0.419	1.172	
(ベース;	その他無職	0.190	0.068	***	0.243	0.073	***				0.244	0.086	***	1.827	1.185	
自営業者)	その他無職(当期のみ)							0.325	0.102	***						
	その他無職(2期連続)							0.279	0.130	**						
	その他無職(3期連続)							0.381	0.099	***						
就業変化	正規雇用(t-1期)				-0.143	0.043	***	-0.156	0.050	***				-1.763	0.653	***
	正規雇用(t-1期)→その他無職(t期)										-0.120	0.061	**			
	その他無職(t-1期)→その他無職(t期)										0.010	0.065				
年齢	26-28歳	-0.036	0.057		0.034	0.117		0.468	0.136	***	0.043	0.119		0.514	1.299	
(ベース;	29-31歳	-0.083	0.060		-0.084	0.106		0.300	0.141	**	-0.072	0.109		0.061	1.390	
25歳以下)	32-34歳	-0.165	0.057	***	-0.182	0.090	**	0.170	0.133		-0.168	0.094	*	0.308	1.492	
	35-37歳	-0.179	0.064	***	-0.207	0.088	**	0.148	0.120		-0.197	0.092	**	0.253	1.569	
	38-40歳	-0.205	0.060	***	-0.229	0.075	***	0.067	0.109		-0.222	0.079	***	1.369	1.729	
	41-44歳	-0.227	0.062	***	-0.247	0.067	***				-0.243	0.070	***	2.020	1.960	
コーホート	61-63年生まれ	-0.030	0.085		-0.022	0.088		-0.096	0.080		-0.030	0.089				
(ベース;	64-66年生まれ	-0.155	0.079	*	-0.150	0.085	*	-0.167	0.081	**	-0.151	0.085	*			
60年以前	67-69年生まれ	-0.223	0.078	***	-0.253	0.083	***	-0.307	0.077	***	-0.255	0.083	***			
生まれ)	70-71年生まれ	-0.208	0.069	***	-0.239	0.064	***	-0.241	0.057	***	-0.241	0.064	***			
	72年以降生まれ	-0.249	0.080	***	-0.276	0.065	***	-0.305	0.058	***	-0.274	0.066	***			
最終学歴	高校卒	-0.162	0.047	***	-0.166	0.053	***	-0.182	0.058	***	-0.169	0.054	***	-2.743	1.204	**
(ベース;	短大・高専卒	-0.171	0.049	***	-0.139	0.059	**	-0.118	0.065	*	-0.144	0.059	**	-2.422	1.447	*
中学校卒)	大学卒以上	-0.162	0.051	***	-0.146	0.060	**	-0.082	0.071		-0.151	0.060	**	-3.313	1.507	**
資産	預貯金無し	0.161	0.037	***	0.162	0.045	***	0.133	0.049	***	0.164	0.044	***	1.094	0.607	*
	持ち家有り	-0.046	0.040		-0.045	0.047		-0.040	0.050		-0.045	0.046		-0.838	0.719	
時点効果		No			No			No			No			Yes		
サンプル数		846			660			549			660			660		
モデル等		Pooled Logit			Pooled Logit			Pooled Logit			Pooled Logit			Random-effect logit		

***<1%, **<5%, *<10%. 標準誤差は, パネル推定を除いてRobust Standard Error.

表8b 社会保険への非加入要因分析(公的医療保険) -推計結果(ii)-

(公的医療保険への非加入に関する分析) 被説明変数: 非加入;1, 加入;0		(1)			(2)			(3)			(4)			(5)		
		限界効果	標準誤差		限界効果	標準誤差		限界効果	標準誤差		限界効果	標準誤差		限界効果	標準誤差	
就業形態	非正規雇用	0.017	0.050		-0.024	0.044		-0.018	0.048		-0.028	0.044		-0.824	1.361	
(ベース;	その他無職	0.084	0.046	*	0.065	0.043					0.082	0.052		1.510	1.316	
自営業者)	その他無職(当期のみ)							0.103	0.069							
	その他無職(2期連続)							0.025	0.075							
	その他無職(3期連続)							0.075	0.066							
就業変化	正規雇用(t-1期)				0.001	0.033		-0.015	0.034					0.016	0.683	
	正規雇用(t-1期)→その他無職(t期)										0.012	0.045				
	その他無職(t-1期)→その他無職(t期)										-0.043	0.028				
年齢	26-28歳	-0.032	0.040		0.030	0.111					0.031	0.106		-1.156	1.611	
(ベース;	29-31歳	0.018	0.049		0.069	0.125		0.018	0.045		0.075	0.121		-0.312	1.661	
25歳以下)	32-34歳	0.015	0.057		0.064	0.133		0.002	0.052		0.076	0.132		-1.460	1.792	
	35-37歳	0.029	0.071		0.086	0.155		0.031	0.075		0.091	0.152		-0.641	1.857	
	38-40歳	-0.015	0.060		0.035	0.133		-0.008	0.063		0.039	0.130		-1.615	2.054	
	41-44歳	0.054	0.099		0.141	0.208		0.065	0.108		0.161	0.212		-1.038	2.258	
コーホート	61-63年生まれ	0.045	0.062		0.058	0.060		0.034	0.057		0.075	0.064				
(ベース;	64-66年生まれ	0.010	0.062		0.040	0.065		0.048	0.068		0.039	0.064				
60年以前	67-69年生まれ	0.059	0.078		0.081	0.081		0.069	0.087		0.084	0.083				
生まれ)	70-71年生まれ	0.022	0.079		0.040	0.085		0.066	0.105		0.040	0.085				
	72年以降生まれ	0.055	0.081		0.068	0.097		0.048	0.099		0.074	0.099				
最終学歴	高校卒	-0.171	0.028	***	-0.195	0.031	***	-0.215	0.035	***	-0.199	0.032	***	-2.481	1.091	**
(ベース;	短大・高専卒	-0.108	0.021	***	-0.098	0.023	***	-0.101	0.024	***	-0.103	0.022	***	-1.845	1.329	
中学校卒)	大学卒以上	-0.092	0.023	***	-0.093	0.023	***	-0.089	0.025	***	-0.096	0.022	***	-3.333	1.595	**
資産	預貯金無し	0.067	0.025	***	0.090	0.030	***	0.112	0.033	***	0.093	0.029	***	1.480	0.649	**
	持ち家有り	-0.017	0.024		-0.015	0.027		-0.016	0.028		-0.017	0.027		0.012	0.752	
時点効果		No			No			No			No			Yes		
サンプル数		848			662			551			662			662		
モデル等		Pooled Logit			Pooled Logit			Pooled Logit			Pooled Logit			Random-effect logit		

***<1%, **<5%, *<10%. 標準誤差は，パネル推定を除いてRobust Standard Error.

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

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

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

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

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

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

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

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

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

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

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 × 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:

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

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

$$X_i = \{(l^s_{i,t}, l^w_{i,t}),\ (y^s_{i,t}, w_{i,t}),\ a_{i,t+1}, age_{i,t})_{t=1}^{\widehat{T}_i},\ a_{i1},\ educ_i\},$$

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 age_i are observed for any i, the amount of initial asset $a_{i1}$is not necessarily observable for all i'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 (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.