AN OVERLAPPING GENERATIONS APPROACH TO SKILL-BIASED TECHNOLOGICAL CHANGE AND HUMAN CAPITAL INVESTMENT

BY

JENNIFER WILGUS

A DISSERTATION SUBMITTED TO
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DEDICATION

This dissertation is dedicated to my family and friends who have been with me throughout the good times and tribulations as I have made my way on this journey. Thanks for all the hand-holding and support.

Most of all, I dedicate this dissertation to my loving parents who have stood by me throughout all my endeavors. I love and cherish you both!

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ABSTRACT

This dissertation addresses the issue of the skill premium by developing a quantitative theory of the effects of skill-biased technological change (SBTC) on household investment in human capital over the life-cycle. A primary objective of this dissertation has been to develop a framework that incorporates SBTC, skill acquisition, and the skill premium in order to respond to a recent controversy within the literature. The approach is twofold — an empirical analysis of household higher education consumption patterns using Consumer Expenditure Survey data over the period 1980 to 1998 and a series of theoretical quantitative experiments of the impact of SBTC on skill acquisition and the skill premium employing an overlapping generations approach. Comparing the quantitative steady-state profiles to the empirical profiles tests the SBTC hypothesis. If the profiles are similar the SBTC hypothesis is supported.

Empirically, the life-cycle profiles have statistically changed between the 1980s and the 1990s implying that the position in the life-cycle determines the significance of the income and substitution effects apparently arising from the increasing skill premium. Theoretically, a combination of the three individual intensive SBTC parameters replicates the results found in the empirical data although not perfectly. The comparative statics produce a widening skill premium that narrows for the old and may be explained by an associated substitution effect for the young accompanied by an income effect that dominates for older workers. The results show that given a dominant income effect for the older age cohorts the wage gap does not change much over time. Indeed, the model demonstrates that one can have SBTC *and* wage gaps for the old that do not change much

over time. Thus, this research is able to provide an answer to one question posed by Card and DiNardo (2002) regarding the skill-biased technological change hypothesis. As such, one cannot reject the SBTC hypothesis as a result of wage gaps that do not change much for the older age cohorts.

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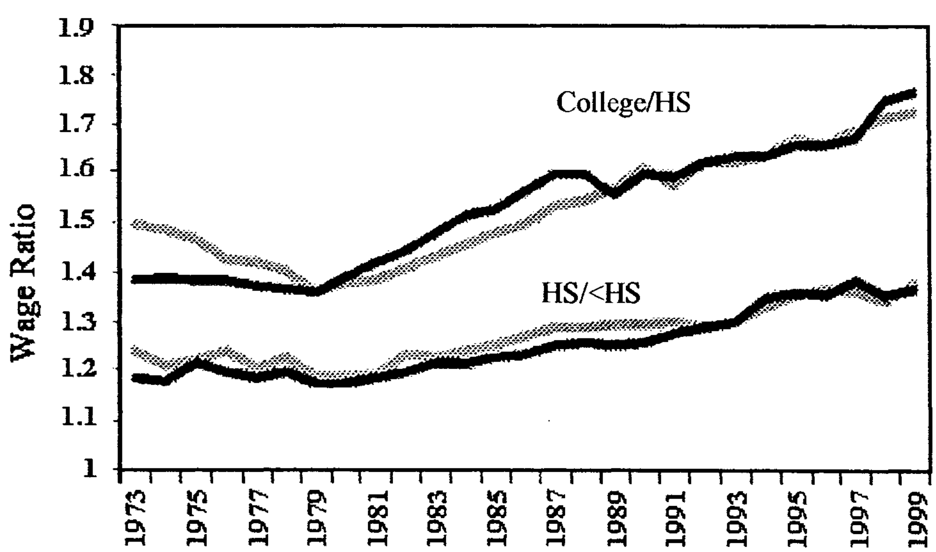
CHAPTER 1

THE WIDENING WAGE GAP BETWEEN SKILL LEVELS

Introduction

The past two decades have seen growth in the wage gap, also known as the skill premium, between skilled workers and unskilled workers. Specifically, the literature indicates that the skill premium has risen since late 1970 (Autor and Katz 1999, Bound and Johnson 1992, Card and DiNardo 2002, Hamermesh 1993, Heckman and Krueger 2003, Katz and Murphy 1992, Murphy and Welch 1992). Figure 1.1 illustrates the widening wage gap between skill levels. For the purposes of this research, *skilled workers* are defined as those who have at least a four-year college education while *unskilled workers* are defined as those with less than a four-year college education.



Note: Black line represents males and gray line represents females.
Source: Krueger (2003), page 5

Figure 1.1: College-High School Wage Ratio and High School-High School Dropout Wage Ratio, by Sex, 1973-1999

The literature is consistent in recognizing the widening wage gap; the causes of the gap however are not conclusive. This dissertation addresses the issue of the widening skill premium by developing a quantitative theory of the effects of skill-biased technological change (SBTC) on household skill acquisition over the life-cycle.[1] Although the literature defines SBTC in a variety of ways, for this analysis a general definition is utilized: *skill-biased technological change* (SBTC) reflects any technological change that increases the productivity of skilled labor to unskilled labor.

Bound and Johnson (1992) and Katz and Murphy (1992) identify skill-biased technological change as the most likely source of the widening skill premium. Recently, however, Card and DiNardo (2002) have questioned the unicausality of the skill-biased technological change hypothesis, as it currently stands, and its effect on the skill premium. They argue that with continuing advances in computer technology the wage gap should increase equally for every age. Yet in the data, the wage gap for the older age groups has not significantly changed over time.

By developing a quantitative theory in a model of skill acquisition, the validity of Bound and Johnson's (1992) theory can be tested through household higher education spending patterns. Furthermore, some answers to Card and DiNardo's (2002) questions concerning SBTC can be offered.

First, empirical analysis tests for structural change over time of household higher education consumption patterns. Second, this research considers whether the position in the life-cycle determines the relative importance of substitution and income effects

[1] The terms skill acquisition, human capital investment, and higher education expenditures are used interchangeably throughout this dissertation.

arising from the increasing skill premium. Finally, analysis of the comparative statics of the theoretical model reveals the type of skill-biased technological change required to replicate the consumption profiles implied by the data.

The *substitution effect* occurs when people, typically the young, substitute away from spending on other goods and services and towards higher education in order to acquire greater skills along with associated higher wages. The *income effect* occurs if those who are relatively human capital rich, typically the old, find additional human capital attainment unnecessary.[2]

This research builds on previous work in the literature in a variety of ways. First, it presents both an empirical and theoretical estimation of life-cycle profiles of higher education consumption, tying the "real world" data to an underlying theoretical economic model. The methodology provides a test of the impact of skill-biased technological change on higher education consumption. If the theoretical model produces profiles consistent with the empirical spending profiles, the hypothesis is supported. If not, the hypothesis is not supported. Next, this study is among the first to apply an overlapping generations model in order to derive household higher education consumption profiles for a twelve-period-lived individual. By employing a two-stage empirical methodology, the dissertation addresses issues of concern in the literature with respect to credit constraints as well as unobserved heterogeneity among agents. Finally, this research extends the SBTC literature by incorporating the skill acquisition sector and intensive skill-biased technological change.

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[2] For definitional purposes, *young* are those agents of working age in the model, 18-63, and *old* are those agents who are retired, age 64 to 78. The good news is that all who are reading this are still considered young in this model!

1.1 Empirical Analysis: The Heckit Model and Data

In order to generate higher education consumption profiles, the empirical analysis of the dissertation is centered on a two-step application of the data developed by Heckman (1976) known as the Heckit model. By utilizing a two-step approach, the endogeneity problems of omitted variable bias and sample-selection bias are eliminated. In the first stage a probit model of all consumers — those who spend on higher education and those who do not spend on higher education — is estimated to identify the probability of higher education participation. The second stage estimates an ordinary least squares (OLS) model utilizing a parameter estimate from stage one and other demographic and descriptive variables of those households who choose to participate in higher education. Consumption profiles are then generated from the OLS results. Complete details of the estimation technique are provided in Chapter 3.

To develop and estimate the Heckit model, a variety of data sources are employed. First, and foremost, U.S. Bureau of Labor Statistic's Consumer Expenditure Survey (CE) is utilized to gather spending and demographic data on households. The CE has the best available data on household consumption. Approximately 5,000 households are interviewed quarterly across the United States. Each household remains in the survey for four consecutive quarters after which they are rotated out and replaced by a new household. The dissertation uses Harris and Sabelhaus's (2000) reorganization of the CE, which sums the four quarterly records into an annual record for each household for the time period of 1980-1998. Next, U.S. Bureau of Labor Statistics (BLS) data for the period 1990-1998 are used to identify average U.S. unemployment rates to proxy business cycle effects. Finally, public higher education tuition and fees data are collected from various volumes of the *Digest of Education Statistics* published by the National Center for Education Statistics. All dollar denominated data are deflated by the Consumer Price Index – All Urban Consumers, 1982-1984 base year.

1.2 Theoretical Analysis: The Overlapping Generations Model

The theoretical analysis of the dissertation employs an overlapping generations (OLG) model with skill acquisition similar to Heckman et al. (1999) and Fowler and Young (2004). The OLG model allows for the replication of heterogeneity in households with respect to their age, implying the replication of the higher education expenditure profiles. Chapter 4 provides a discussion of the overlapping generations model.

Using model calibrations analogous to those in the literature (Heckman et al. 1999, Fowler and Young 2004, Krusell et al. 1997), life-cycle profiles are solved for different levels of skill-biased technology. The comparative statics allow exact quantification of the importance of skill-biased technological change in the skill premium.

To test the validity of the theoretical model, the comparative static profiles are contrasted to the empirical profiles. If the profiles are similar, then the theory of skill-biased technological change supports the empirics and Bound and Johnson's (1992) hypothesis that SBTC is the major cause of the skill premium. Additionally, given similar empirical and theoretical profiles the importance of the substitution and income effects hypothesis is supported which provides an answer to the puzzle that Card and DiNardo (2002) raise.

1.3 Major Findings

Empirically, the major findings are twofold. First, the life-cycle profiles have statistically changed between the 1980s and the 1990s implying that the position in the life-cycle appears to determine the relative importance of the income and substitution effects that presumably arise from the increasing skill premium. This result is important because it addresses one of the concerns set forth by Card and DiNardo (2002); in the data, the wage gap for the older age groups has not significantly changed over time. Given a relatively human capital rich older generation and a dominant income effect, one would not expect the older generation to continue to purchase higher education services in order to receive the associated higher wages. Thus, the wage gap for the older age groups is not expected to change significantly over time.

Second, higher education consumption expenditures display an increase in the midyears of the life-cycle, even after accounting for children and others of college age in the household, suggesting the possibility that those with a college degree may purchase more higher education services as a result of SBTC, also known as retooling. This finding is particularly interesting since it calls into question the traditional ideas of either diminishing returns to higher education or that preferences have only an intensive margin.[3] In other words, the participation decision (extensive margin) is just as important as the number of classes taken (intensive margin) and it is no longer solely a demand-side issue but choices made by the labor suppliers — those purchasing higher education

[3] In this study, *diminishing returns to higher education* means that as one ages each additional year of education produces progressively smaller benefits from the additional education. *Extensive margin* refers to the participation decision — to purchase higher education services or not. *Intensive margin* refers to how many classes to take: full-time or part-time.

services — are equally as important for our understanding of the effects of skill-biased technological change.

Theoretically, the following conclusions can be drawn from the quantitative experiments presented in Chapter 4. First, although pure substitution effects resulting from extensive SBTC are consistent with the widening skill premium over time they do not explain why the skill premium does not change much for the older age cohorts. Next, when intensive SBTC parameters are investigated separately, they lead to either pure substitution effects — A, pure income effects — H, a mixture of substitution and income effects — θ_1 and θ_2, or have little impact at all on skill acquisition while increasing the skill premium. Finally, a combination of the three individual intensive SBTC parameters is able to provide results similar to those found in Chapter 3, though not perfect: a substitution effect for the young accompanied by an income effect. This final result provides an explanation for one of the problems that Card and DiNardo (2002) cite regarding SBTC, namely, that a strong income effect leads to a skill premium that does not change much for the older age cohorts.

1.4 Organization of the Dissertation

The organization of the dissertation is as follows: Chapter 2 introduces some stylized facts about the skill premium and household spending on higher education along with their accompanying literature. Additionally, the chapter reviews the theoretical literature with respect to overlapping generations (OLG) models. Chapter 3 documents the empirical methodology, data sources, and creates a set of corresponding consumption profiles of household spending on higher education. Chapter 4 develops and tests the theoretical OLG model of skill acquisition and the skill premium relative to changes in skill-biased technology. Chapter 5 summarizes the results between the empirical and theoretical chapters and draws conclusions regarding the impact of skill-biased technological change on household higher education consumption profiles.

CHAPTER 2

THE SKILL PREMIUM AND SKILL-BIASED TECHNOLOGICAL CHANGE: RELEVANT LITERATURE

Introduction

The wage gap between skill levels has widened since late 1970, an extensive literature developed investigating the growth of the skill premium and its causes.[1] Until recently, the consensus revolved around skill-biased technological change and its impact on labor demand. Section 2.1 identifies and discusses a variety of studies investigating the cause of the skill premium and how it relates to skill-biased technological change. Interestingly, a recent debate over the unicausality of skill-biased technological change and its impact on the wage gap is one of the primary motivations for this dissertation.

To investigate the impact of skill-biased technological change on household higher education consumption over the life-cycle, a micro-level empirical analysis is undertaken. Section 2.2 introduces the literature that supports the dissertation's underlying empirical model and the creation of the household higher education consumption profiles.

An underlying theoretical approach to skill-biased technological change is needed to test the validity of the hypothesis. As such, a quantitative theory is set forth in a macroeconomic model of skill acquisition. Section 2.3 concludes the chapter by discussing the theoretical overlapping generations model and its use in the dynamic macroeconomic literature.

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[1] Autor and Katz (1999) provide a good synopsis of the existing literature.

2.1 The Widening Skill premium

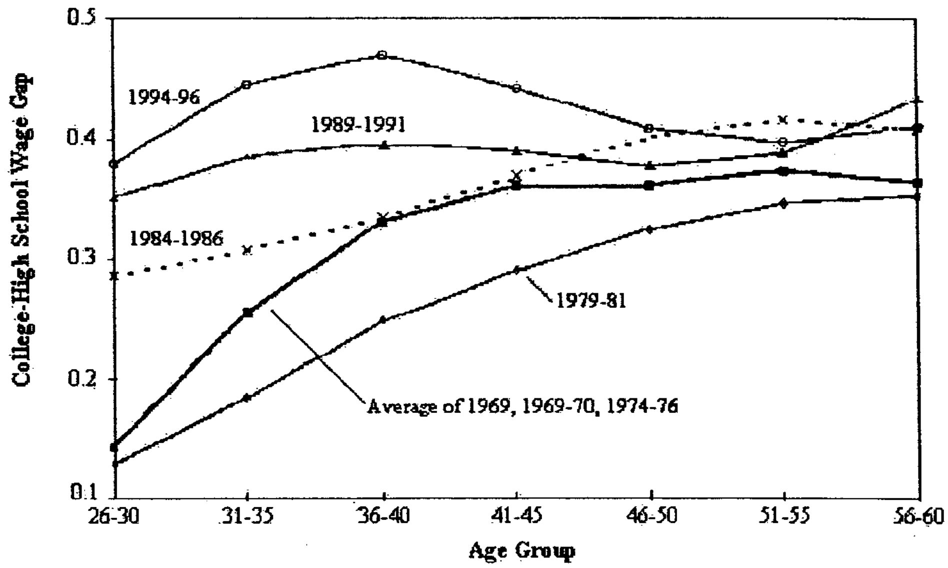
The majority of the empirical work investigating the structure of wages is based upon the Bureau of Labor Statistics data found in the Current Population Survey (CPS). The studies cited here are of no exception. Although a plethora of literature investigates the U.S. wage structure, Table 2.1 at the end of this section provides a break down of relevant literature based upon period of study, data sets employed, and major conclusions. Table 2.2 identifies other studies concerning the skill premium.

In an important paper, Bound and Johnson (1992), using CPS data, document the change in the wage structure for the decades of the 1970s and the 1980s. They identify three stylized facts about the wage structure: (1) the change in the average relative wage position of more-educated workers is higher than that for less-educated workers, (2) for those workers who do not have a college education, older workers' relative earnings rose compared to younger workers, especially for men, and (3) the relative wage profiles of women, although still less than men, grew at a faster rate than the men's wage profiles. The authors point out that based upon the increase in the labor supply, the relative wages of the demographic groups should be falling, ceteris paribus, rather than rising and conclude that a set of demand-shift factors powerful enough to overcome the supply-shift factors must exist in order to explain the wage structure developments. To investigate the demand-shift factors, they comprehensively evaluate four possible explanations for the increasing gap in the skill premium found separately in the literature: (1) intra-industry employment shifts toward better educated workers and female workers, (2) a downward shift in manufacturing employment and union power, (3) technological change, including skill-biased technology, and (4) a change in cohort effects with respect to the college-educated population. Using economic reasoning, they conclude that skill-biased technological change (SBTC) is the most likely explanation.

Concurrently, Katz and Murphy (1992) employ a supply and demand framework to analyze changes in the U.S. wage structure over 1963-1987 using CPS data. They find that all major relative wage differentials, excluding the male/female differential, increased over the period of their study. The authors identify stylized facts similar to those found in Bound and Johnson (1992): (1) the college skill premium rose from 1963 to 1971, fell throughout the 1970s, and rose sharply between 1979 and 1987, (2) experience differentials substantially expanded between 1963 and 1987, (3) growth in overall inequality accelerated in the 1980s, and (4) the male/female wage differential narrowed substantially between 1979 and 1987. They report that differential supply growth alone seems like an unlikely explanation of the observed relative wage changes and that demand growth is an important element over the period of study. They ascertain that rapid secular growth in the relative demand for "more skilled" workers in relatively skill-intensive industrial and occupations sectors is a key component of any consistent explanation for rising inequality and changes in the wage structure. Thus, like Bound and Johnson (1992) the authors conclude that the within-sector shifts are likely to reflect skill-biased technological change.

Autor, Katz, and Krueger (1998) take a longer-term approach to investigating the impact of skill-biased technological change on the U.S. wage structure. Using a variety of data sources and a supply and demand framework over a five-decade time span, 1940 to 1996, the authors study the relationship among observable technology indicators and skill upgrading to evaluate SBTC for recent increases in U.S. educational wage differentials. They argue that a sufficiently long time frame is vital to determine whether factors important to the 1980s, namely SBTC, were absent in other periods with different wage movements. Given the long time frame investigated, the authors indicate that their framework suggests that the relative demand for more-skilled workers grew more rapidly between 1970 and 1996 than during the previous three decades. Addressing the role of SBTC, the authors consistently find for both manufacturing and nonmanufacturing sectors that increased utilization of more-skilled workers is greater in the most computer-intensive industries. That result implies that skill-biased technological and organizational changes appear to have contributed to faster growth in relative skill demand within specific industries beginning in the 1970s. They also note, however, that it is not clear whether a causal interpretation of this relationship is appropriate.

As noted above, much of the existing literature is based upon the notion that SBTC is the driving factor in the skill premium. Recently, Card and DiNardo (2002) have questioned the unicausality of the skill-biased technological change hypothesis, as it currently stands, and its effect on the skill premium. They argue that, after controlling for cohort-specific supply, the relative demand for college-educated workers grew at a fairly even pace rather than continuing to increase with technology, calling into question the importance of skill-biased technological change. Figure 2.1 illustrates the changing age structure of the college-high school wage gap as posited by Card and DiNardo (2002).



Source: Card and DiNardo (2002), page 756.

Figure 2.1: Changing Age Structure of the College-High School Wage Gap

Their data indicate that the wage gap does not change much for the older age cohorts as seen in Figure 2.1, especially for the three lines illustrating 1984-1986, 1979-81, and the average of 1969, 1969-70, 1974-76. Though these facts weaken the SBTC hypothesis, the authors are unable to conclusively eliminate SBTC as a viable hypothesis. This dissertation addresses the wage gap issue set forth by Card and DiNardo (2002) by estimating a life-cycle profile to test the importance of substitution and income effects over time.

While the debate continues with respect to the primary cause of the diverging skill premium, Carneiro and Heckman (2003) and Krueger (2003) identify human capital development as the key to public policy addressing the issue of increasing income inequality. Their papers identify and evaluate various public policies aimed at reducing the wage gap. Carneiro and Heckman (2003) consider the importance of the life-cycle dynamics of learning and skill acquisition in policy formation — incorporating cognitive and noncognitive skills in addition to individual motivation. The authors argue that schools as well as families and firms have an impact on the creation of human capital. While the authors believe that polices toward choice, competition, and local incentives will promote productivity in the classroom, they find that policies that lessen credit constraints, such as the HOPE Scholarship program, tend to generate deadweight losses since the majority of the students receiving the scholarships will attend college anyway.

Krueger (2003), on the other hand, recommends public investment in education and training predominantly for the disadvantaged as a way to reduce income inequality since, "on the margin, the payoff from public human capital investment seems to be higher from investments in lower-income areas than from those in higher income areas" (page 60). The argument here is that as more disadvantaged children receive education the more likely they will continue with education and ultimately receive in return higher wages; thus reducing the wage gap. His "wish list" of such policies include, but are not limited to: full funding of Head Start, Early Head Start, and Job Corps, increasing the length of the school year, raising the compulsory schooling age to eighteen, reducing class size in low-income areas, and expanding funding for adult training programs.

The following two tables identify a portion of the literature regarding the wage gap. Table 2.1 identifies the relevant skill premium studies used in this research. Table 2.2 lists other studies that relate to skill-biased technological change and the skill premium.

Table 2.1: Relevant Skill Premium Studies

Author(s)	Description	Dataset	Conclusions
Bound and Johnson, 1992	Documents the change in wage structure over the decades of the 1970s and 1980s using a theoretical model that incorporates all of the major explanations.	CPS	The major cause in the changes to the wage structure was a shift in the skill structure of labor demand resulting from SBTC. skill-biased technological change.
Katz and Murphy, 1992	Analyzes the changes in the U.S. wage structure from 1963 to 1987 using a supply and demand framework.	CPS	Rapid secular growth in the demand for more educated, more skilled, and female workers appears to drive the observed changes in the wage structure.
Murphy and Welch, 1992	Examines the variation of male wage structure with regard to educational attainment and experience for the period of 1963 to 1989 using a supply and demand framework	CPS	The simple factor demand view of relative wages provides useful insights into the forces behind the dramatic changes in the wage structure. Report that changing demographics are important, while uncertain about SBTC.
Autor, Katz, and Krueger, 1998	Examines the effect of skill-biased technological change on the widening U.S. educational wage differentials, 1940-1996, using a supply and demand framework.	PUMS CPS MORG	Skill-biased technological and organizational changes accompanying the computer revolution appear to have contributed to faster growth in relative skill demand within detailed industries.
Card and DiNardo, 2002	Examines the SBTC hypothesis focusing on the implications of SBTC for overall wage inequality and for changes in wage differentials between groups during the 1980s and 1990s.	CPS OGR	SBTC hypothesis falls short as a unicausal explanation for the evolution of the U.S. wage structure in the 1980s and 1990s.

Table 2.1: Relevant Skill Premium Studies

Author(s)	Description	Dataset	Conclusions
Caneiro and Heckman, 2003	Examines human capital development as a key role for public policy to address the issue of increasing income inequality.	CPS	Policies aimed at choice, competition, and local incentives will promote productivity in the classroom.
Krueger, 2003	Examines human capital development and public policies relative to lower-income areas.	n.a.	Recommends public investment in education and training predominantly for the disadvantaged as a way to reduce income inequality.

Table 2.2: Other Skill-Biased Technology and Skill Premium Studies

Study	Description	Dataset	Conclusions
Autor and Katz, 1999	Presents an overview for understanding changes in the wage structure and overall earnings inequality – investigates the roles of SBTC, labor suppy and demand, unions, and minimum wage for the U.S and OECD nations.	CPS ORG PUMS OECD	Researchers should consider the roles of changes in labor market institutions, and competitive supply and demand factors in assessing changes in the wage structure; analysis can benefit from taking a longer-term historical perspective.
Allen, 2001	Presents evidence on how technological change is related to changes in wage gaps by schooling, experience, and gender.	CPS ORG	A strong correlation between R&D and capital-labor ratio acceleration and widening wage gaps by schooling.
Young, 2001	Studies the business cycle dynamics of the skill premium for skilled labor	CPS	Skill premium is countercyclical, but not strongly, and hours worked by skilled laborers are less volatile overall than unskilled laborers; introduction of capital-skill Complementarity has little impact on business cycle statistics.
Cuadras-Morato and Mateos-Planas, 2003	Investigates the interactions between changes in the labor market and in educational attainment employing a macro search-matching model.	CPS	Skill-biased shock accounts for part of the changes but the mismatch shock explains much of the changes, including the skill premium.
Light and Strayer, 2003	Investigate whether the wages of workers with identical college degrees vary with their college transfer patterns.	NLSY	Predicted wages for transfer students are at least as large as those for equivalent non-transfer students.

2.2 Household Consumption Profiles

An alternative way to test the relevance of skill-biased technological change on the wage structure is to model household higher education consumption over the life-cycle. If SBTC is important then one expects a shift in household spending on higher education services over time. This is known as structural change in the dynamic macroeconomic literature. A variety of life-cycle studies have examined consumption in general but none have specifically focused on higher education expenditures. This dissertation extends the literature by considering higher education acquisition. The study builds upon the work of Fernandez-Villarverde and Krueger (2002) and incorporates the notion of child equivalence as set forth by Browning and Ejrnæs (2002) using a two-stage empirical estimation technique developed by Heckman (1979). Table 2.3 at the end of this section presents a summary of the relevant literature. While labor economists have utilized Heckman's estimation technique often, a variety of other areas have been studied, examples include politics, firm profitability, education, health care, interracial contact, and family planning. Table 2.4 presents some of the literature employing Heckman's two-stage technique.

Fernandez-Villarverde and Krueger (2002) use a semi-nonparametric model and Consumer Expenditure Survey (CE) data to estimate life-cycle profiles of total, durable, and nondurable consumption, excluding higher education. Incorporating a household equivalence scale similar to Browning and Ejrnæs (2002), they find that household size accounts for approximately half of the hump-shaped paths over the life-cycle while the other half remains unaccounted for by the standard complete markets life-cycle model. The results imply that households do not smooth consumption over their lifetimes as posited by the standard life-cycle model. The authors identify liquidity constraints, prudence in light of uncertainty, and nonseparabilities in the utility function as potential explanations for their findings.

Browning and Ejrnæs (2002), using data from the U.K. Family Expenditure Survey FES), study the relationship between consumption and income over the life-cycle. By taking into account the number and ages of children within the household, the authors contest the literature that a precautionary saving motive is needed to reconcile data on lifetime patterns of consumption and income. The authors specify a model of intertemporal allocation in which households move resources from periods when they do not have children into periods when they do have children. They find that the data are not informative enough to convincingly distinguish between different explanations for the tracking of income by consumption, especially in the earlier stages of the life-cycle. This dissertation employs a child equivalence scale similar to Browning and Ejrnæs (2002).[2] See Chapter 3 Section 3.2 for a detailed explanation and estimation methodology.

Because this research considers the participatory actions of households with respect to higher education consumption, it is important to account for sample selection bias within the data. In a well-cited paper, Heckman (1979) develops a model for sample selection bias as a specification error. He points out that sample selection bias may arise for two reasons: (1) self selection by the individuals or data units being investigated and (2) sample selection decisions by analysts. Sample selection is found throughout the labor literature (e.g., wage models and labor participation models). The problem with sample selection is that the models do not, in general, estimate the population, resulting

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[2] See Chapter 3 Section 3.2 for a detailed explanation and estimation methodology.

in specification error. To correct for the bias, the author develops a simple consistent two-stage estimator that enables analysts to employ simple regression methods to estimate behavioral functions. For a full description of Heckman's (1979) estimation technique see Chapter 3 Section 3.3.

The following two tables identify a portion of the literature pertinent to consumption spending and applied estimation techniques. Table 2.3 presents the relevant literature used in this research. Table 2.4 identifies other studies utilizing the estimation technique employed in the empirical portion of this study.

Table 2.3: Relevant Consumption Studies

Study	Description	Dataset	Conclusions
Fernandez-Villaverde and Krueger, 2002	Estimates life-cycle profiles of consumption, controlling for demographics, cohort and time effects, employing household equivalence scales to a seminonparametric partial linear model.	CEX	Households do not smooth consumption over their lifetimes, especially with respect to consumer duarables.
Browning and Ejrnæs, 2002	Study the relationship of consumption and income over the lifecycle by taking in account the ages and number of children within the household.	FES	Able to contest the literature that a precautionary saving motive is needed to reconcile lifetime patterns of consumption and income.
Heckman, 1979	Develops a two stage estimator to account for sample selection bias that is utilized in simple regression methods to estimate behavioral functions.	n.a.	The simple estimator developed can be used in a variety of models for truncation, sample selection, limited dependent variables, and simultaneous equation models.

Table 2.4: Other Studies Employing the Heckman Sample Selection Model

Study	Issue Investigated	Description	Data Set
Weiss, 1988	Labor market — wages	Investigates reasons for discontinuous increases in wages associated with graduation from high school	PSID
Peoples, 1994	Labor market — wages	Investigates racial wage differentials for four market structure-union status groups.	CPS
Zabel, 1993	Labor market — wages	Analyzes the relationship between hours of work and labor force participation in four different types of models, including Heckman's model.	PSID
Blanton, 2000	Politics — human rights	Using a two-stage design, investigates U.S. arms exports in an effort to ascertain whether human rights, democracy and military aid are meaningful variables in arms transfer decisions.	DSAA
Poe, 1995	Politics — military aid	Investigate whether strategic, political, and economic interests as well as human rights and economic development are considered when making military aid decisions.	AID
Meernik, 2001	Politics — military force	Investigates the diversionary hypothesis that military force is used to distract the public from suffering economies and declining performance.	Variety of Sources
Mizruchi and Stearns, 2001	Firm Behavior	Examines the means by which relationship managers in a major commercial bank attempt to close transactions with their corporate customers.	Private interviews
Powers and Ellison, 1995	Sociology	Investigates the causes, processes, and consequences of interracial contact and black racial attitudes.	NSBA

2.3 Overlapping Generations Approach

The final section of this chapter relates to the theoretical model used in this dissertation. To investigate the impact of skill-biased technological change on human capital investment, the theoretical analysis employs an overlapping generations (OLG) model of skill acquisition drawing from Auerbach and Kotlikoff (1987), Heckman et al. (1999), Krusell et al. (1997), and Fowler and Young (2004). The OLG model allows for the replication of heterogeneity in households with respect to their age implying the replication of the higher education expenditure profiles. Table 2.5 at the end of this section identifies the most relevant studies and Table 2.6 incorporates other studies that have employed the numerical estimation technique used in this dissertation.

Auerbach and Kotlikoff (1987) are often cited as the authors of multi-period overlapping generations models. The authors point out that dynamic analysis is favored over static analysis when the study incorporates frequent change. To this end, dynamic analysis fits well within the topic considered in this dissertation. Since dynamic analysis considers both current and future generations, it allows one to distinguish policies that improve economic efficiency rather than merely redistribute resources across generations.[3] Additionally, the general equilibrium effects of choices on endogenous variables such as interest rates, wages, and saving are included. For this study, saving in the form of human capital acquisition is considered in a general equilibrium framework. For a detailed explanation of the multi-period OLG model, see Chapter 4 Section 4.1.

[3] Economic efficiency refers to the improvement of welfare in one segment of society without reducing the welfare of another segment of society.

Heckman et al. (1998) develop and estimate an OLG model of labor earnings, skill formation, and physical capital accumulation with heterogeneous human capital. They analyze schooling choices and post-school on-the-job investment in skills allowing for different skill sets based upon schooling levels. These authors incorporate new methods for estimating the demand for unobserved human capital as well as for determining the substitution relationships between skills and capital. The calibrated model is compared to results found in the literature. They find that a model of skill-biased technological change is consistent with the central feature of rising wage inequality as measured by the college-high school wage differential and the standard deviation of log earnings. Extending the model to incorporate the population effects of Baby Boomers, the authors' results are able to explain the wage inequality history as documented by Katz and Murphy (1992). This dissertation incorporates the human capital production function set forth by Heckman et al. (1998) and builds upon their conventional power utility specification of preferences by incorporating the effect of the disutility of hours spent working and going to school.

Krusell et al. (1997) address the issue of skill-capital complementarity and its effect on the skill premium over a three-decade time period employing CPS data from 1963 to 1992. The authors develop a theoretical framework that provides an understanding of the importance of skill-biased technological change in terms of observable variables such as wages, the capital equipment to skilled labor input ratio, and income shares of capital and labor. They use this framework to evaluate the fraction of historical variation in the skill premium that can be accounted for by changes in observed factor quantities. Krusell, et al. (1997) find that with capital-skill complementarity, changes in observed inputs can account for nearly all of the variation in the skill premium over the 30-year period of study. They report that increased wage inequality is a consequence of economic growth driven by the introduction of new, efficient technologies embodied in capital equipment.

This dissertation draws closely from Fowler and Young (2004) who investigate the cyclical behavior of the acquisition of skills over the life-cycle. Their model incorporates stochastic production, overlapping generations, and individual technologies for producing human capital. Business cycles are generated through variations in technology. Human capital production is also impacted by technology variations. They utilize a computational algorithm based on perturbation that is well suited for handling the large state space produced by OLG economies. Using the benchmark model, the authors find that the substitution effect dominates the wealth effect for all age groups, implying that schooling is countercyclical, contrary to the literature where procyclicality of schooling exists for the young. By making human capital acquisition shocks positively correlated to the total factor productivity shock, they are able to replicate the literature finding procyclicality of schooling for the young and counter cyclicality of schooling for the old.

The present research builds on Fowler and Young (2004) by extending the production function to incorporate capital-skill complementarity as set forth by Krusell, et al. (1997) constant elasticity of substitution (CES) production technology and by separating effective labor into skilled and unskilled workers. In doing so is research investigates the impact of skill-biased technological change on human capital investment given skill-complementarity, CES production technology, and human capital production.

The last two tables present the literature relevant to the theoretical model utilized in this dissertation. Table 2.5 identifies the relevant overlapping generations studies applied in Chapter 4. Table 2.6 presents other studies employing the overlapping generations framework.

Table 2.5: Relevant OLG Studies

Study	Description	Dataset	Conclusions
Auerbach and Kotlikoff, 1987	Examines the effects of fiscal policy on the economy utilizing a dynamic OLG model.	Variety of Sources	Consumption taxation stimulates greater savings than income or wage taxation; officially reported government deficits can be misleading indicators of the "tightness" or "looseness" of fiscal policy; investment incentives can lead to declines in stock market values.
Heckman, Lochner, and Taber, 1998	Estimates an OLG model of labor earnings, skill formation, and physical capital accumulation with heterogeneous human capital	NLSY	A model of SBTC is consistent with the central feature of rising wage inequality measured by the college-high school wage differential and by the standard deviation of log earnings over the past 15 years.
Krusell, Ohanian, And Rios-Rull, 1997	Develops a framework for understanding SBTC in terms of observable variables; evaluates the fraction of variation in the skill premium that is accounted for by changes in observed factor quantities.	CPS	With skill-capital complementarity, changes in observed inputs alone can account for nearly all of the variation in the skill premium over the last three decades.
Fowler and Young, 2004	Investigate the cyclical behavior of skill acquisition over the life-cycle employing an OLG model that includes stochastic production and individual technologies for human capital production.	IFS IPEDS	The calibrated model predicts that schooling is countercyclical — at odds with the data. By making human capital acquisition shocks positively correlated with the TFP shock, procyclicality of schooling for the young and counter-. cyclicality for the old is replicated matching the data.

Table 2.6: Other Studies Employing the OLG Methodology

Study	Framework	Description
Heathcote, Storesletten and Violante, 2004	OLG	Examines the macroeconomic and welfare implications of the recent rise in wage inequality in the U.S. employing an OLG model with incomplete markets.
Browning, Hansen and Heckman, 1999	OLG	Explores the discordance between micro evidence and the macro use of it and suggests ways in which it can be eliminated.
Echevarria and Merlo, 1999	OLG	Explore gender differences in education in an OLG model where men and women bargain over consumption, number of children, and investment in education of their children.
Buiter and Kletzer, 1995	OLG	Investigates the effects of fiscal policy on economic growth in open and closed economies when liquidity constraints for human capital accumulation by the young are binding.

CHAPTER 3

LIFE-CYCLE PROFILES OF HIGHER EDUCATION CONSUMPTION

Introduction

This chapter estimates life-cycle profiles of higher education consumption in order to ascertain the presence of structural change. It is motivated by the debate in the literature regarding skill-biased technological change and its impact on wage inequality. As noted in the previous chapter, consensus in the literature tends to support Bound and Johnson (1992) who identify skill-biased technological change as the most likely cause of the increasing skill premium. On the other hand, Card and DiNardo (2002) have questioned the unicausality of the skill-biased technological change and its effect on the skill premium.

The facts set forth by Card and DiNardo (2002) that weaken the SBTC hypothesis — see Figure 2.1 and its related discussion in Chapter 2 — can be explained, however, by the presence of a dominant income effect for the older age groups. It is conceivable that the effects of rising skilled labor wages associated with SBTC can have differing effects on higher education demand over the life-cycle. For example: the old, who are relatively human capital rich and receive higher wages relative to the young, may choose a rate of human capital attainment that may actually fall (e.g., one college course instead of two) resulting in little change in the college-high school wage gap for that age group; this behavior reflects an income effect. Thus, estimation of empirical life-cycle consumption profiles allows for the testing of the importance of substitution and income effects over time. If the presence of income effects is found, then some answers regarding Card and DiNardo's (2002) questions can be offered.

Consumer Expenditure Survey (CE) data is used to estimate life-cycle profiles of higher education consumption. The study builds upon previous work and offers a variety of new developments. First, it builds upon Fernandez-Villaverde and Krueger's (2002) life-cycle model by investigating spending on higher education, a variable they chose to omit. Second, it addresses issues of concern with respect to credit constraints, unobserved heterogeneity, and endogeneity by employing a two-stage empirical methodology developed by Heckman (1976) known as the Heckit model.

The main findings are twofold. First and foremost, structural change is present; the life-cycle profiles have statistically changed between the 1980s and the 1990s — the young consume more higher education services while the old consume less in the 1990s with the turning point occurring near age 50. In terms of a theory, the position in the life-cycle appears to determine the relative importance of the income and substitution effects that presumably arise from the increasing college skill premium.

Second, higher education consumption expenditures display a peak in the midyears of the life-cycle, even after accounting for children and others of college age in the household. This suggests that the returns to tertiary education are positive in middle-years as well as early years. Indeed for ages between 20-28 and 35-59, the results indicate that the substitution effect dominates the income effect during the 1990s. Thus, one can infer that some type of retooling of skills to improve job prospects and wages may be taking place or that some households have delayed entering higher education markets until later in their lives. This finding is particularly interesting since it calls into question the traditional ideas of either diminishing returns to higher education or that preferences relate to only full-time or part-time attendance (intensive margin). Indeed, the decision to attend at all (extensive margin) is just as important as the number of classes to take.

This chapter proceeds as follows. Section 3.1 introduces some stylized facts regarding higher education expenditures and the skill premium. Section 3.2 identifies the data utilized in the empirical analysis. Section 3.3 discusses the empirical methodology set forth by Heckman (1976). Household higher education consumption profiles are developed and discussed in Section 3.4, and Section 3.5 concludes the chapter and introduces the theoretical overlapping generations model approach to comparative statics and its use in dynamic macroeconomic literature.

3.1 Stylized Facts of Household Spending on Higher Education: An Alternative Explanation of the Skill premium

Given the rising inequality in income and the notion that much of the wage gap is education driven due in part to skill-biased technological change, one would expect to see an increase in the demand for higher education.[1] In fact, data provided by the National Center for Education Statistics (NCES) typically show that tuition rates and the total enrollments (full-time and part-time) are rising. Table 3.1 documents the increase in the quantity of public higher education enrollments along with tuition and fee charges for the academic years 1980-81 through 1999-2000. Throughout the 20-year time span, full-time students make up between 56.3 and 59.4 percent of total enrollments with an average of 57.5 percent. Tuition and fees are deflated by the Consumer Price Index – All Urban Consumers, 1982-1984 base year. Following economic principles, the data

[1] The reason that higher education is identified here is that primary and secondary education in the United States is compulsory and provided by taxpayers. Higher education, on the other, relies more heavily on market prices in the form of tuition and fees.

support the notion that there exists an increase in the demand for tertiary education. Enrollments have increased by 1% per year even though real tuition and fees have grown by 4.9% per year.[2] This is consistent with an increase in the return to tertiary education.

Table 3.1: Public Higher Education Price and Enrollments

Academic Year	Enrollment	Percent Full-Time Enrolled	Tuition & Fees* (in thousands)
1980-1981	9,457,394	58.7	$6,760,199
1981-1982	9,647,032	58.0	$7,034,998
1982-1983	9,696,087	58.1	$7,560,496
1983-1984	9,682,734	58.3	$8,155,942
1984-1985	9,477,370	58.0	$8,323,038
1985-1986	9,479,273	57.8	$8,772,469
1986-1987	9,713,893	56.9	$9,305,322
1987-1988	9,973,254	56.6	$9,845,649
1988-1989	10,161,388	57.0	$10,512,057
1989-1990	10,577,963	56.6	$11,145,355
1990-1991	10,844,717	56.6	$11,674,081
1991-1992	11,309,563	56.5	$12,819,576
1992-1993	11,384,567	56.3	$13,891,818
1993-1994	11,189,088	56.8	$14,412,033
1994-1995	11,133,680	57.0	$14,782,796
1995-1996	11,092,374	57.0	$15,260,797
1996-1997	11,120,499	57.8	$15,698,611
1997-1998	11,196,119	58.2	$16,235,571
1998-1999	11,137,769	59.0	$16,826,984
1999-2000	11,309,399	59.4	$17,482,355

* Constant 1982-84 dollars

Source: Enrollment: *Digest of Education Statistics 2002*, Table 172
Tuition and Fees: *Digest of Education Statistics 2002*, Table 172

[2] Annual growth rates are calculated: $\left(\frac{year\,1999-2000\,data}{year\,1980-1981\,data}\right)^{1/20}$, where 20 represents the number of time periods.

Since the data support an increase in the demand for tertiary education[3], the next step is to evaluate the spending profiles of those households that purchase higher education services. If demand for higher education is increasing, then one expects a change in the associated household spending patterns. Indeed, there is evidence of a shift in the spending profile with respect to higher education. Using data from the Bureau of Labor Statistic's Consumer Expenditure Survey (CE) for the time periods of 1980 to 1998, Figure 3.1 illustrates the log of mean real higher education expenditures by age group in 1982-84 dollars.[4] The data are split into 12 age cohorts and meaned by decade. Table A.2 in the Data Appendix presents the data table used to depict Figure 3.1. The data verify that spending has consistently increased over the periods 1980-1989 to 1990-1998 for most, *but not all*, age cohorts. In fact, the old have appeared to decrease their spending.

Relative to the skill-biased technological change hypothesis, a suggestion is that the life-cycle motive for saving by human capital has been altered, either by the substitution effect or the income effect. Recall that the substitution effect suggests that the young, who are relatively human capital poor, substitute away from spending on other goods and services and towards tertiary education in order to acquire greater skills along with the associated higher wages. This is depicted as an increase in higher education consumption in the 1990s decade relative to the 1980s decade (i.e., the dotted line is above the solid line). On the other hand, the income effect suggests that for the old, who are relatively human capital rich, the rate of accumulation of human capital attainment may fall relative

[3] To further support the change in enrollments, Table A.1 in the Data Appendix breaks higher education enrollments by Age and Year.
[4] The data for Figure 3.1 includes only those households that spend on higher education.

to the previous decade. This is depicted as a decrease in higher education consumption in the 1990s decade relative to the 1980s decade (i.e., the dotted line is below the solid line).

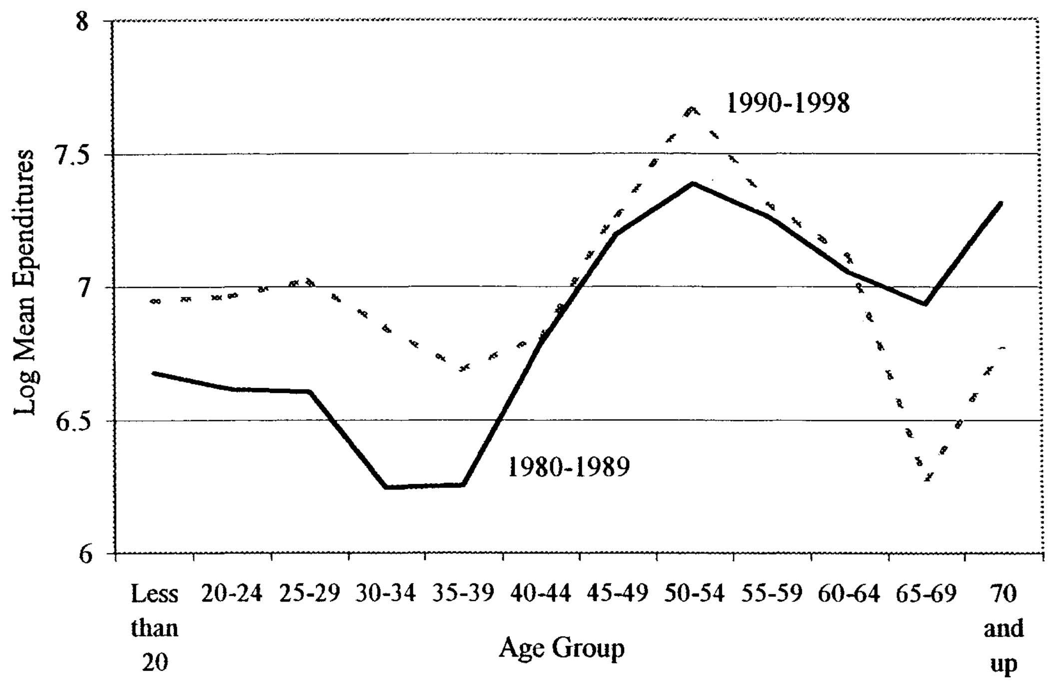

Figure 3.1: Log of Mean Higher Education Expenditures

In terms of its relationship to Card and DiNardo (2002), consider the following example. Let the wage of a skilled worker be given by equation (3.1):

$$w_{it} = w_t * h_{it} \tag{3.1}$$

where w_{it} is defined as the real wage of the i^{th} skilled worker at time t, w_t is the real wage common to *all skill levels* at time t, and h_{it} is the human capital attainment of the i^{th} person at time t. Suppose that an increase in the demand for skilled labor resulting from SBTC causes w_{it} to rise implying the i^{th} person's real wage increases. The worker is left with three choices: increase h_{it} by purchasing more higher education classes, decrease

h_{it} by taking less classes, or leave h_{it} unchanged. Assuming that a strong income effect dominates, then it is conceivable that the rate of skill attainment for the old actually falls; the old cut back the number of higher education hours. A strong income effect is most likely to occur for those who are relatively rich in human capital attainment. Reexamining Figure 2.1 on page 13 suggests that the old may be relatively rich in human capital. This economic reasoning could explain why the real wages of the old have not increased at the same rate as the skilled young, thus resolving a question posed by Card and DiNardo (2002) regarding SBTC.

For the young, represented by the 20-35 year old age groups in Figure 3.1, one can infer from the data that the substitution effect dominates their income effect since they are generally spending more on higher education during the 1990-98 period relative to the 1980-89 period. On the other hand, the income effect dominates the substitution effect for those age groups above 60 since they typically are spending less during the same time period. Additionally, the data also reveal increased spending by the middle-aged groups, 40s to late 50s. These changes may reflect such circumstances as household spending on children's higher education, a delay in childbearing with increased spending in later years, a substitution effect identified as retooling of skills, or a delay in entry into the higher education market.

In order to better explain the shape of the profiles, the next step is to estimate household higher education consumption profiles taking into consideration time, age, and other demographic effects. Section 3.2 introduces the data followed by Section 3.3 that discusses the empirical methodology used in the study to generate the spending profiles.

3.2 Data Utilized in the Empirical Model

To develop the empirical model, a variety of data sources are utilized. First, and foremost, the U.S. Bureau of Labor Statistic's Consumer Expenditure Survey (CE) is utilized to gather spending and demographic data on households. The CE has the best available data on household consumption. Approximately 5,000 households are interviewed quarterly across the United States. Each household remains in the survey for four consecutive quarters after which they are rotated out and replaced by a new household; this type of dataset is often referred to as a rotating panel. This research uses Harris and Sabelhaus' (2000) reorganization of the CE, which sums the four quarterly records into an annual record for each household for the time period of 1980-1998. Thus, if a household is first interviewed in 1980 Quarter 1, then all four quarters of 1980 data are contained in the record labeled 1980:1. If a household is first interviewed in 1980 Quarter 2, then 1980 Quarter 2 through Quarter 4 plus 1981 Quarter 1 data are included in the record labeled 1980:2. With the exception of 1985, 1995, and 1998, the process is continued through 1998:2. Due to changes in the survey process, 1985 and 1995 contain only the first two quarters and the reorganization was completed in the second quarter of 1998. The records representing Quarter 1 in each year 1980-1998 are considered in this study since they each represent the full year in which participation began and takes place. The number of observations for all consumers, those who spend on higher education and those who do not spend, is 28,952. Since the empirical model uses logs, any zero and missing values are omitted. Thus, the number of observations for all consumers used in the analysis is 13,400 and those households that spend on higher education numbers 1,999.

Next, U.S. Bureau of Labor Statistics (BLS) data for the period 1990-1998 are used to identify average regional U.S. unemployment rates to proxy business cycle effects. Since a household may reside in one region of the country and purchase higher education services in another, regional unemployment rates are used rather than national rates to pick up differing geographic business cycle effects. Finally, higher education tuition and fees data are collected from various volumes of the *Digest of Education Statistics* published by the National Center for Education Statistics. All wage, spending, and tuition data are deflated by the Consumer Price Index for All Urban Consumers (CPI-U), 1982-1984 base year. Table 3.2 on the following page identifies the variables utilized in this study.

Table 3.2: Descriptive and Summary Statistics of Data

Variable (1)	Description (2)	Mean: All Households (3) *	Mean: HHs that Spend on HE (4) *
Dependent Variables:			
hied	0/1: higher education participation	0.140	1.000
lhied	Log household spending on higher education		6.122
Independent Variables:			
age1	Age of head of household	40.282	37.062
agesq	Age squared of head of household	1,839.583	1,562.156
agecu	Age cubed of head of household	92,853.600	72,699.780
rinc	Real income of head of household	$16,523.660	$21,855.230
lrinc	Log real income of head of household	9.605	9.778
nohs	0/1: no high school diploma of head of household	0.215	0.094
hs	0/1: high school diploma of head of household	0.2974	0.165
coll	0/1: 4-yr college degree of head of household	0.1451	0.210
grad	0/1: graduate education of head of household	0.097	0.186
urb	0/1: urban residence	0.906	0.932
mwst	0/1: live in Mid-West	0.224	0.234
sth	0/1: live in South	0.272	0.248
west	0/1: live in West	0.237	0.299
blk	0/1: black head of household	0.112	0.066
asian	0/1: asian head of household	0.026	0.041
othrc	0/1: other race head of household	0.012	0.013
fem	0/1: female head of household	0.472	0.299
mar	0/1: married head of household	0.499	0.539
childeq	Number of equivalent children in household	0.461	0.288
childsq	Number of equivalent children squared in household	0.399	0.501
colage	Number of college-age people in household, excl. head	0.923	1.156
colagesq	Number of college-age people in household sq, excl. head	1.744	2.714
uer	Average regional unemployment rate	6.612	6.668
rtui	Real higher education tuition & fees	$5,139.879	$5,119.035
lrtui	Log of real higher education tuition & fees	8.519	8.515
dry2	0/1 indicator of time: 1990-1998	0.469	0.463
age90	Interaction: age of head of household and time	19.042	17.653
agesq90	Interaction: age square of head of household and time	869.179	755.612
agecu90	Interaction: age cubed of head of household and time	43,598.390	35,318.570
agechild	Interaction: age of head of household and number of equivalent children in household	15.338	18.634
agecol	Interaction: age of head of household and number of college-age people in household	41.199	52.733
imr	Inverse Mills ratio		1.335

* Number of observations: All households: 28,952 and Households that spend on higher education: 4,050.
Note: The omitted education variable is some college, *scoll.*

The third column of Table 3.2 represents the mean values of all households — those that spend and those that do not spend on higher education. The fourth column represents the means of only those households that choose to purchase higher education services. Some interesting points arise when comparing the two groups. For those who purchase higher education services: (1) the average age of the head of household is less: 37 vs. 40, (2) the average real income is higher: \$21,800 vs. \$16,500, (3) a greater percentage has a four-year college degree: 21% vs. 15% and are less likely to have dropped out of high school: 9% vs. 22%, (4) they are typically white: 88% vs. 85%, (5) the head of the household is predominantly male: 70% vs. 53%, (6) more than one-third have at least a four-year college degree, and (8) the number of people other than the head of household of college-age is higher: 1.15 vs. 0.92.

Multiple dependent variables are identified because a two-stage empirical model is to be employed. *Hied* is defined as a higher education participation indicator that is used in the first-stage of the estimation. *Lhied* is the log of real household spending on higher education that is used in the second-stage of the estimation.

A variety of independent variables are used to identify demographic, age, and time effects. The first set of independent variables capture the demographic nature of the data with respect to the head of household including age, income, race, education level, region of residence, gender, and marital status. Most of the omitted demographic variables are easily identifiable, except for education. The omitted education variable is some college. Next, four variables are included to describe the number of children — *childeq* and *childsq* — and the number of people in the household of college age other than the head of household — *collage* and *colagesq*. Business cycle effects are identified by *uer*, the regional unemployment rate as reported by the Bureau of Labor Statistics, 1980-1998. The price of higher education services is captured with two variables: real tuition and fees, *rtui,* and the log of real tuition and fees, *lrtui*. The price variables are based upon private and public institutions of higher education, thus the higher average price. To delineate between the two decades of study, the time variable *dyr90* and its interaction with respect to the age of the head of household — *age90*, *agesq90*, and *agecu90* — are considered. Additionally, the age of the head of household is interacted with the number of children and the number of people in the household who are of college age, *agechild* and *agecol*, respectively. Finally, the inverse Mills ratio, *imr,* is used to capture the impact of those households that choose not to participate in higher education and thus correct for endogeneity as well as credit constraint issues within the data.

Most variable descriptions are self-explanatory but *childeq* may need further explanation. In the CE survey each household can report up to 20 members. Thus, each household may have 20 different aged individuals. *Childeq* represents a scale of the number of children age 18 and under in each household (i.e., 1 child, 1.3 children, 3.1 children, etc). Employing a methodology similar to Fernandez-Villaverde and Krueger (2002) and Browning and Ejrnæs' (2002) household equivalence scale, *childeq,* is estimated as follows in equation (3.2):

$$n_{it} = \sum_{j=1}^{20}\left(\mu_0 + \mu_1\left(\frac{age_j}{18}\right) + \mu_2\left(\frac{age_j}{18}\right)^2 + \mu_3\left(\frac{age_j}{18}\right)^3\right) * \left(1 - d_j\right) \quad (3.2)$$

where n_{it} is the equivalent number of children, age_j is equal to the maximum of the individual's age or 18, $(\mu_0, \mu_1, \mu_2, \mu_3)$ are child response parameters used to approximate the age effects of children, and d_j is a zero-one dummy representing an adult when age_j is greater than 18. If the individual age is greater than 18 years old, then $d_j = 1$ and $n_{it} = 0$. On the other hand, if the individual is less than 18 years old, then $d_j = 0$ and $n_{it} > 0$. The restriction $\mu_3 = 1 - \mu_0 - \mu_1 - \mu_2$ is imposed so that the function is continuous. Employing estimates from Browning and Ejrnæs (2002), the child response parameters have the following values: $\mu_0 = -0.091$, $\mu_1 = 2.469$, and $\mu_2 = -5.73$. The data identified above are used to estimate the two-stage empirical model and determine household higher education consumption profiles as described in the next two sections.

3.3 Empirical Methodology

In order to generate higher education consumption profiles, a two-step application of the data is used. The estimation technique employed is a probit selection model set forth by Heckman (1976), sometimes referred to as the Heckit model. If everyone in the sample purchases higher education services, then a standard regression framework is applicable. A potential sample selection problem arises, however, because higher education consumption is observed only for those who participate in the market. The Heckit model is appropriate given that the data are sample selected according to higher education participation and then evaluated for only those who purchase higher education services. By utilizing a two-stage approach, the endogeneity problems of omitted variable bias, resulting from sample selection, and self-selection bias are eliminated. Additionally, the model allows for unobserved heterogeneity among households and takes into consideration those who may wish to purchase higher education services but are unable due to credit constraints.

In the first-stage, a probit model is estimated to identify the probability of spending on higher education. At this stage, all consumers are considered. It takes into consideration those who currently choose not to participate due to credit constraints or who have preferences for other goods and services.

Following Wooldridge (2002) and Heckman (1979), let c_{1i} be defined as real higher education consumption by households and c_{2i} be defined as a binary higher education participation indicator, the equations for individual i from a random draw of the population are given in (3.3a) and (3.3b):

$$c_{1i} = x_{1i}\beta_1 + u_{1i} \tag{3.3a}$$

$$c_{2i} = 1\,[x_{2i}\beta_2 + u_{2i} > 0] \qquad \text{for } i = 1,2,\ldots,N \tag{3.3b}$$

where x_{ji} is a $1 \times K_j$ vector of exogenous demographic and productivity regressors, including age, child, and time effects, β_j is a $K_j \times 1$ vector of parameters, and u_{ji} is a vector of error terms. The following assumptions are needed to apply the model: (a) (x_{ji}, c_{2i}) are always observed, c_{1i} is only observed when $c_{2i} = 1$. This first assumption identifies the sample selection nature of the problem; (b) (u_{ji}) is independent of x_{ji} with zero mean — the standard form of exogeneity of x_{ji}; (c) u_{2i} ~ normal $(0,1)$. Assumption (c) is needed for the derivation of the conditional expectation given sample selectivity, and (d) $\mathrm{E}(u_{1i} \mid u_{2i}) = \gamma_1 u_{2i}$. This assumption requires linearity in the population regression of u_{1i} on u_{2i}. Given the above assumptions, the equation for individual i becomes (3.4):

$$E(c_{1i} \mid x_{1i}, u_{2i}) = x_{1i}\beta_1 + E(u_{1i} \mid u_{2i}) = x_{1i}\beta_1 + \gamma_1 u_{2i} \tag{3.4}$$

If u_{1i} and u_{2i} are uncorrelated, then $\gamma_1 = 0$, there is no sample selection bias, and the parameter estimates, β_1, using OLS are consistent. If, however, $\gamma_1 \neq 0$, OLS parameters are not consistent and correction has to be made to deal with selection on unobservables. The inverse Mills ratio is employed to control for selection bias. Equation (3.4) is restated as (3.5):

$$E(c_{1i} \mid x_{ji}, c_{2i} = 1) = x_{1i}\beta_1 + \gamma_1 \lambda(x_i \delta_2) \quad \text{for } i = 1,2,\ldots,N \tag{3.5}$$

where $\lambda(x_i\delta_2)$ is the inverse Mills ratio and is estimated as the ratio of the probability density function (pdf) to the cumulative density function (cdf) or $\lambda(x_i\delta_2) = \varphi(x_i\delta_2)/\Phi(x_i\delta_2)$. Although δ_2 is unknown, a consistent estimator of δ_2 is available from the first-stage probit estimation of the selection equation. Using all consumer observations, the probit model (3.6) allows for the estimation of $\hat{\delta}_2$:

$$P(c_{2i} = 1 \mid x_i) = \Phi(x_i\delta_2) \tag{3.6}$$

The estimated inverse Mills ratio $\hat{\lambda}_{2i} \equiv \lambda(x_i\hat{\delta}_2)$ is then obtained and used in the second-stage of the Heckit model.

The second stage consists of obtaining estimates of $\hat{\beta}_1$ and $\hat{\gamma}_1$ from an OLS regression on the selected sample. The second-stage model is estimated using (3.7):

$$c_{1i} = x_{1i}\beta_1 + \hat{\lambda}_{2i}\gamma_1 \qquad \text{for } i = 1,2,\ldots N_1 \tag{3.7}$$

where $N_1 < N$ and the estimates of $\hat{\beta}_1$ and $\hat{\gamma}_1$ are consistent and are $\sqrt{N}$ -asymptotically normal.

With respect to higher education participation, stage-one or the probit stage of the empirical model, the following results are expected: Age is expected to have a nonlinear relationship to higher education participation. At relatively young ages the probability is expected to be positive. As one ages, however, the probability of purchasing higher education services is expected to fall. Real income is expected to positively impact the probability of participating in higher education. As real income rises, the likelihood of purchasing higher education services also rises. Due to higher education institution accessibility, the urban variable is expected to positively impact higher education participation. Initially, the number of children is expected to reduce the probability of participation due to resources being substituted toward other goods and services.[5] On the other hand, as the children age a positive effect is expected. The number of people other than the head of the household of college-age is expected to initially raise the probability of higher education participation; however, diminishing returns may exist. Finally, those heads of household with at least some college are expected to be more likely to purchase higher education services than those without a diploma or with only a high school diploma. Thus, the variable representing a four-year college degree, *coll,* and the variable representing more than a four-year college degree, *grad,* are each expected to positively impact the probability of higher education participation.

Dropping the independent variable, *rtui*, identifies the second-stage model. Although the tuition variable is important in the initial participation stage, one can argue

[5] Children are defined as someone less than 18 in this study.

that once the decision to participate in higher education is made tuition is no longer significant for two main reasons. First, while many people have the option of purchasing as few as one class per semester, financial aid in the form of lottery scholarships has become more commonplace. As such, students are required to take a minimum of a full-load in order to receive the scholarship. Other forms of financial aid such as assistantships and fellowships also require that students take at least a full load each semester. Each of these examples places a floor on the number of credit hours and cost of attendance – in many cases the dollar cost is zero. Additionally, due to time and course load constraints, students can take no more than a maximum of 18 to 24 credit hours per semester, thus placing a ceiling on the number of credit hours and cost of attendance. Given the existence of both a tuition floor and ceiling, the impact of tuition at the second stage — how much to actually spend — becomes less important.

After identifying the second-stage model, a variety of results are anticipated with respect to the log of real higher education consumption. Once again, age is expected to be significant and nonlinear. Similarly, the number of children and the number of people other than the head of household are expected to be nonlinear and significant. Due to the large number of higher education institutions in the northeast, the regional variables w*est, mwst, and sth* are expected to be negative and significant relative to the eastern region. To evaluate the impact of racial differences, the variable *blk* is expected to be negative and significant relative to *wht*. Finally, the amount of education held by the head of the household is expected to impact the log of real spending on education. Specifically, the low-education variables — no high school diploma and high school diploma — are expected to be negative and significant while the high-education variables — four-year college and graduate school — are expected to be positive and significant relative to head of household having some college education.

3.4 Results

The Heckit model results are summarized in Tables 3.3 and 3.5. These results are used to generate the consumption profiles depicted in Figures 3.3-3.6. Additionally, the estimation results in Table 3.4 are used to produce Figure 3.2 on page 49. The figure depicts the change in the probability of higher education participation over the life-cycle.

3.4.1 First Stage Results: The Probit Model

Table 3.3 presents the results of the first stage of the model. At this stage all consumers consider whether or not to participate in higher education, implying the importance of the extensive margin. Thus, the results represent the probability that participation takes place; $hied = 1$.

As expected the variables log of real income, four-year college degree, and some graduate school education are each positive and significant at the .05-level implying that an increase in these variables leads to an increase in the probability of spending on higher education. Similarly, the region variables west, mid-west, and south are positive and significant at the .05-level contrary to expectations suggesting that region of residence does not play a role in participation. The urban residence variable is positive and significant at the .10-level. The age variables and the interaction terms that include age are also significant at the .05-level. Given the nonlinear nature of age, however, the signs change throughout. As predicted, when the number of children increases in the household, the probability of spending on higher education falls presumably due to the need to substitute toward other goods and services such as food and clothing. Finally,

Table 3.3: Heckit Model Stage 1

Stage 1: Probit Model
Probability that hied = 1

hied	**Coefficient.**	**Std. Err.**	**z**	**P>|z|**
lrinc	0.0772	0.0148	5.23	0.000
age1	-0.1965	0.0513	-3.83	0.000
agesq	0.0047	0.0012	3.91	0.000
agecu	-0.0001	0.0000	-4.22	0.000
dyr2	1.8781	0.9956	1.89	0.059
age90	-0.1608	0.0734	-2.19	0.028
agesq90	0.0041	0.0017	2.38	0.017
agecu90	-0.0001	0.0000	-2.51	0.012
urb	0.2044	0.1199	1.71	0.088
mwst	0.1492	0.0441	3.38	0.001
sth	0.0924	0.0430	2.15	0.032
west	0.1394	0.0451	3.09	0.002
blk	-0.2347	0.0538	-4.36	0.000
asian	0.0677	0.0831	0.81	0.415
othrc	-0.1303	0.1242	-1.05	0.294
fem	0.0468	0.0384	1.22	0.223
nohs	-0.7044	0.0482	-14.61	0.000
hs	-0.4982	0.0404	-12.32	0.000
coll	0.1087	0.0443	2.46	0.014
grad	0.2908	0.0480	6.06	0.000
mar	-0.1496	0.0426	-3.51	0.000
uer	-0.0242	0.0141	-1.72	0.085
lrtui	-0.1031	0.1564	-0.66	0.510
childeq	-0.5124	0.1444	-3.55	0.000
childsq	0.0099	0.0222	0.44	0.657
agechild	0.0093	0.0031	3.01	0.003
Colage	0.5075	0.0757	6.71	0.000
colagesq	-0.0868	0.0091	-9.58	0.000
agecol	0.0060	0.0015	3.97	0.000
Intercept	1.2572	1.5198	0.83	0.408

Number of Observations: 13,400

as the number of people in the household who are of college age rises, the probability of spending on higher education rises, but at a diminishing rate as predicted.

An important consideration in this study is the effect of time on higher education participation. To this end, one may ask: has participation changed over time? As identified in the data section above, time is captured as an exogenous binary variable, *dyr2*; representing the decade of the 1990s. Furthermore, one can argue that household higher education expenditures change with age *and* over time. Thus, interaction terms are used to represent the nonlinear aspects of age with time: *age90*, *agesp90*, and *agecu90*.

Following Wooldridge (2002), if x_k denotes the time variables, then the partial effect from changing x_k from zero to one on the response probability, holding all other variables fixed, is given in (3.8):

$$G[\beta_1 + \beta_2 x_2 + \ldots + \beta_{k-1} x_{k-1} + \beta_k] - G[\beta_1 + \beta_2 x_2 + \ldots + \beta_{k-1} x_{k-1}] \tag{3.8}$$

where $G[\cdot]$ denotes a probit function. To create a graph of the change in probability of higher education participation, a series of steps is required. First, Table 3.4 identifies the stage-one probit variables and coefficients utilized. Next, log of consumption spending by age is estimated and the standard normal cumulative distribution (cdf) of the log of consumption spending is determined for each decade. The final step is to take the difference between the cdf of the 1990s and the cdf of the 1980s for each age. Figure 3.2 illustrates the change in the probability of higher education participation over the life-cycle. Table A.3 in the Appendix presents the complete data table used to depict Figure 3.2.

Table 3.4: Probit Estimation Coefficients

Variable	Coefficient
constant	1.257237
age1	-0.19650
agesq	0.00469
agecu	-0.00004
dry2	1.87808
age90	-0.16076
agesq90	0.00409
agecu90	-0.00003
urb	0.20444
lrinc	0.07721
uer	-0.02426
lrtui	-0.10316

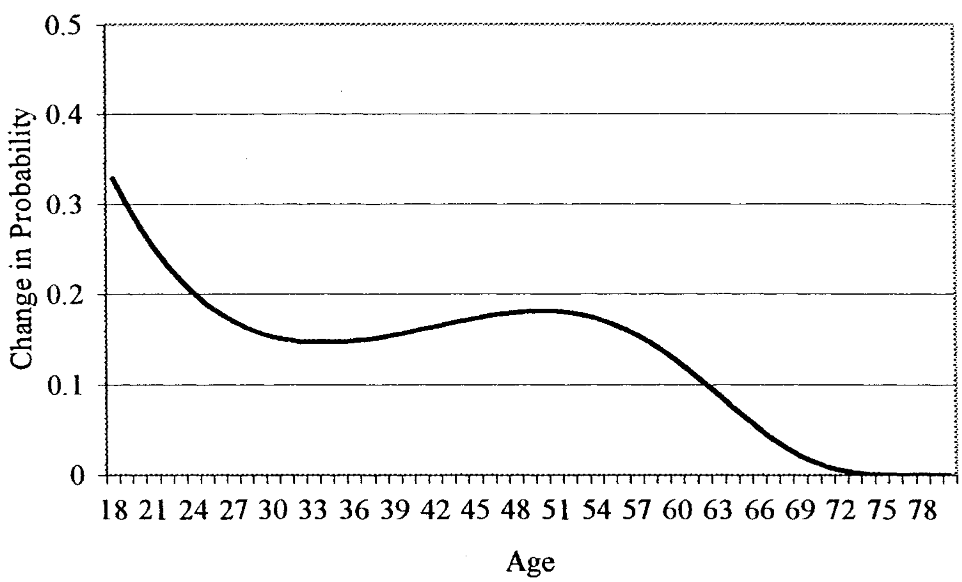

Figure 3.2: Change in the Probability of Participating in Higher Education Due to Age and Time

The results reveal that between the decades of 1980 and 1990 household participation in the higher education market has typically increased, ceteris paribus. Nonetheless, one cannot assume that because participation has increased for most ages over time skill acquisition has increased at the same rate for all ages. One explanation may be that the older age groups may take one course, thus treating higher education as a pure consumption good, while younger age groups take multiple courses and view higher education as an investment good.

3.4.2 Second Stage Results: Ordinary Least Squares Model

Table 3.5 presents the results for the second stage of the Heckit Model. At this stage only those households that purchase higher education services are considered. To capture the effects of all households — those who participate *and* those who do not — and to account for endogeneity and credit constraint issues, this stage incorporates the parameter estimate of the inverse Mills ratio, *imr*, found in the first stage.

The results indicate that, ceteris paribus, relative to those in the northeast survey participants in the south and west spent less on higher education. One explanation may be the concentration of higher education institutions in the northeast. As expected, the low-education coefficients — no high school diploma and high school diploma — are negative and significant relative to some college education and the high-education coefficients — four-year college degree and graduate school — are positive and significant, all at the .05 level. The race variable black is negative and significant at the .05-level implying that the log of real higher education consumption falls when the race is black relative to white. Once again the number of children in the household results in less higher education consumption, ceteris paribus, while the number of people of college age positively impacts spending at the .05-level. Finally, *imr*, the variable that captures non-spenders and eliminates selection bias, is significant and positive suggesting that including a measure of these households is important to the estimation of the log of real higher education consumption.

Table 3.5: Heckit Model Stage 2

Stage 2: OLS Model

Log of Real Spending on Higher Education

lhied	Coefficient.	Std. Err.	z	P>|z|
lrinc	0.1263	0.0820	1.54	0.123
age1	-0.7757	0.2383	-3.26	0.001
agesq	0.0186	0.0057	3.29	0.001
agecu	-0.0001	0.0000	-3.25	0.001
dyr2	5.9786	3.2670	1.83	0.067
age90	-0.4748	0.2529	-1.88	0.060
agesq90	0.0122	0.0061	2.01	0.045
agecu90	-0.0001	0.0000	-2.15	0.031
urb	0.4636	0.4021	1.15	0.249
mwst	-0.0866	0.1833	-0.47	0.637
sth	-0.3421	0.1490	-2.30	0.022
west	-0.7522	0.1779	-4.23	0.000
blk	-0.7374	0.2721	-2.71	0.007
asian	0.3206	0.2363	1.36	0.175
othrc	0.2058	0.3779	0.54	0.586
fem	0.2056	0.1185	1.74	0.083
nohs	-1.5984	0.6729	-2.38	0.018
hs	-1.1982	0.4742	-2.53	0.012
coll	0.4412	0.1572	2.81	0.005
grad	1.1001	0.2862	3.84	0.000
mar	-0.1394	0.1784	-0.78	0.434
uer	-0.0564	0.0353	-1.60	0.110
childeq	-1.7203	0.6548	-2.63	0.009
childsq	0.0559	0.0839	0.67	0.506
agechild	0.0294	0.0127	2.32	0.020
colage	1.3394	0.5130	2.61	0.009
colagesq	-0.2317	0.0844	-2.75	0.006
agecol	0.0158	0.0070	2.26	0.024
intercept	9.4978	2.1168	4.49	0.000
Mills:				
imr	2.5945	1.1926	2.18	0.030
Rho	0.9922			
Sigma	2.6149			
Number of Observations:		1,999		
	Null Hypothesis:	$H_0: \beta = 0$		
	Wald chi2 (56):	1,501.48		
	Prob > chi2:	0.0000		

Although the individual estimates for the time variables — *dyr2*, *age90* — in Table 3.5 are not significant, the joint test of the coefficients with respect to time is significant. The joint test comprises the four variables *dyr2*, *age90*, *agesq90*, and *agecu90* for each stage of the Heckit model and is found in Table 3.6.

Table 3.6: Joint Test of Coefficients

Null Hypothesis:	
H_0: $dyr2 = age90 = agesq90 = agecu90 = 0$	
Chi2 (8):	23.80
Prob > Chi2:	0.0025
Number of Observations:	
Censored:	11,401
Uncensored:	1,999

The joint test of the coefficients results in a chi-square (8) = 23.80 with a probability that the joint test is greater than chi-square equal to 0.0025. Specifically, one can reject the null hypothesis that the four time regressors have no impact on the probability of spending on higher education and on the log of real higher education consumption, ceteris paribus. Thus, the results indicate a shift in the log of real higher education consumption between the 1980s and the 1990s.

3.4.3 Household Higher Education Consumption Profiles

Parameter estimates from Table 3.5 and age are used to create the household higher education consumption profiles. First, for the decade of the 1980s, the variable representing the decade of the 1990s, *dyr2*, is omitted and each age coefficient, excluding the age-time interaction terms for the 1990s — *age90*, *agesq90*, and *agecu90* — is multiplied by age, 18 to 80, respectively. Next, the age variables are summed with the remaining coefficients identified as the "typical household". The resulting sum gives a consumption value by age. The final step is to graph consumption by age. The only difference for the decade of the 1990s is that all parameter coefficients are utilized. Household consumption profiles are generated for four different types of households: single with some college education, single with high school education, married with some college education, and married with high school education. The complete data tables from which the graphs are created are found in the Appendix labeled A.4-A.7 for each household type.

The typical household that generates the first profile is assumed to be: a single, white male who lives in the northeast, has some college education, and does not have any children. Table 3.7 provides the parameter estimates used to generate the profile. Figure 3.3 depicts the results.

Table 3.7: Parameter Coefficients for Single Household with Some College Education

Variable	Coefficient
constant	9.49781
age1	-0.77572
agesq	0.01863
agecu	-0.00014
dry2	5.97859
age90	-0.47477
agesq90	0.01220
agecu90	-0.00010
urb	0.46364
lrinc	0.12629
uer	-0.05638
imr	2.59448

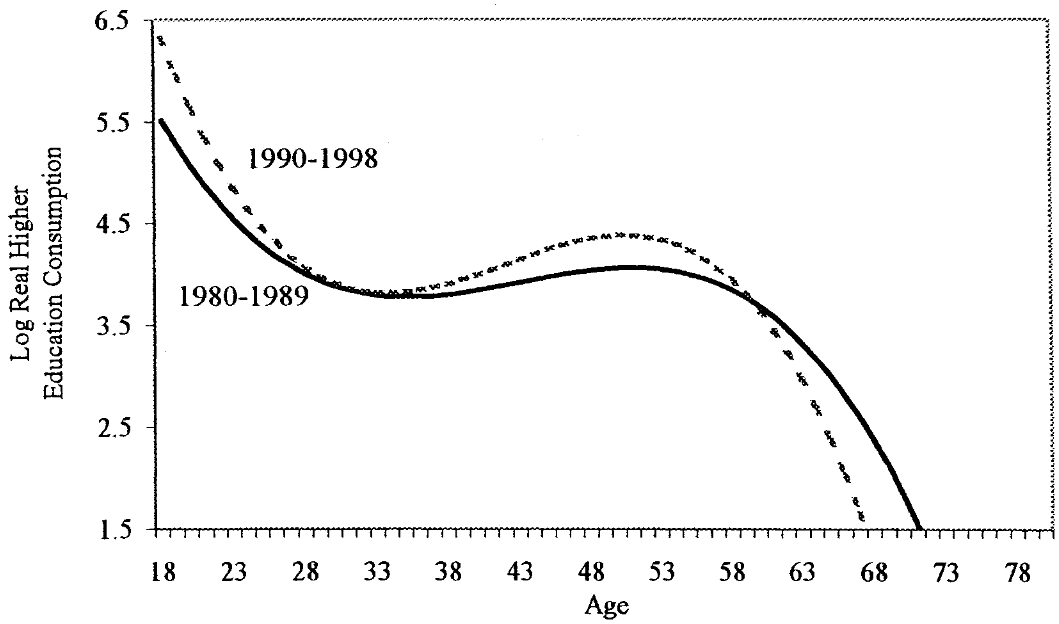

Figure 3.3: Log of Real Higher Education Consumption: Single with Some College Education

With the exception of the shape of the profiles for those 60 years old and above, Figure 3.3 is very similar to Figure 3.1, introduced in Section 3.1. As expected, the peak in Figure 3.3 smooths out in the mid-age groups due to the effects of children and others in the household of college age being held constant.

The second household has the following characteristics: single white male, who lives in the northeast, has only a high school education, and does not have any children. Table 3.8 provides the parameter estimates used to generate the profile. Figure 3.4 depicts the log of real higher education consumption profile.

Table 3.8: Parameter Coefficients for Single Household with High School Education

Variable	Coefficient
constant	9.497814
age1	-0.77572
agesq	0.01863
agecu	-0.00014
dry2	5.97859
age90	-0.47477
agesq90	0.01220
agecu90	-0.00010
urb	0.46364
lrinc	0.12629
uer	-0.05638
imr	2.59448
hs	-0.48082

Given that the typical household now only has a high school education, it is not surprising that the substitution effect is much stronger in the early and midyears of the life-cycle. As a result of the lower education level, the household must pursue education for a longer period of time to accumulate the skills necessary to take advantage of the skill premium. Thus, the 1990 profile in Figure 3.4 is much higher relative to the 1980 profile than in Figure 3.3. Additionally, given that the 1990s profile intersects the 1980s profile at age 63 rather than age 59, the income effect has shifted further to the right suggesting that the older worker must work for a longer period of time.

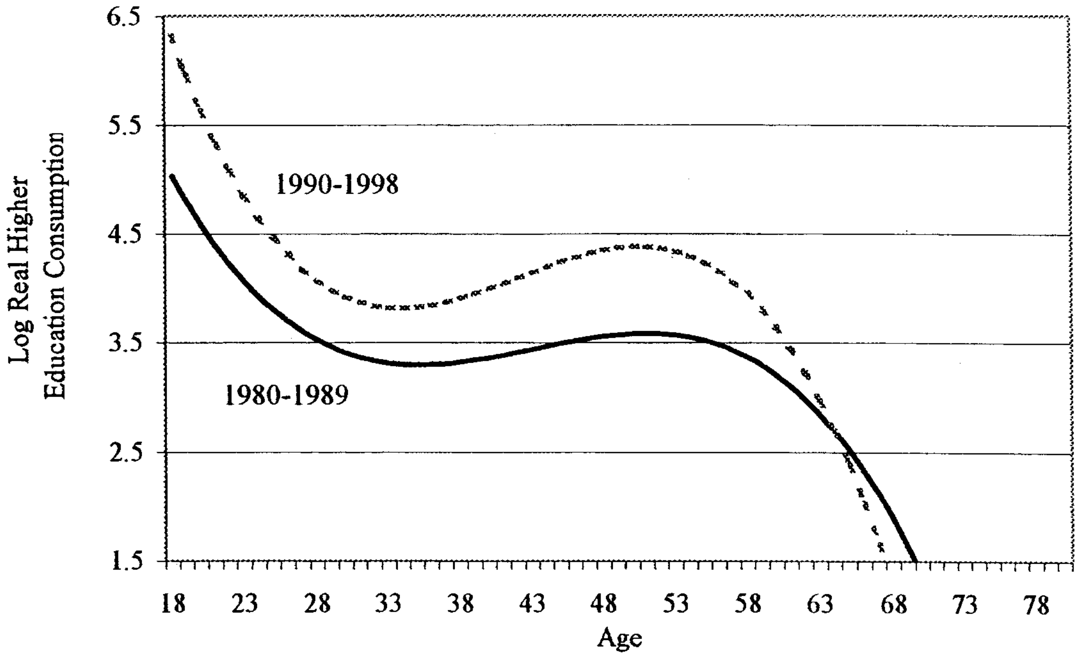

Figure 3.4: Log of Real Higher Education Consumption: Single with High School Education

The third household has the following characteristics: married white male, who lives in the northeast, has some college education, and does not have any children. Table 3.9 provides the parameter estimates used to generate the profile. Figure 3.5 depicts the consumption profile.

Table 3.9: Parameter Coefficients for Married Household with Some College Education

Variable	Coefficient
constant	9.497814
age1	-0.77572
agesq	0.01863
agecu	-0.00014
dry2	5.97859
age90	-0.47477
agesq90	0.01220
agecu90	-0.00010
urb	0.46364
lrinc	0.12629
uer	-0.05638
imr	2.59448
mar	-0.13945

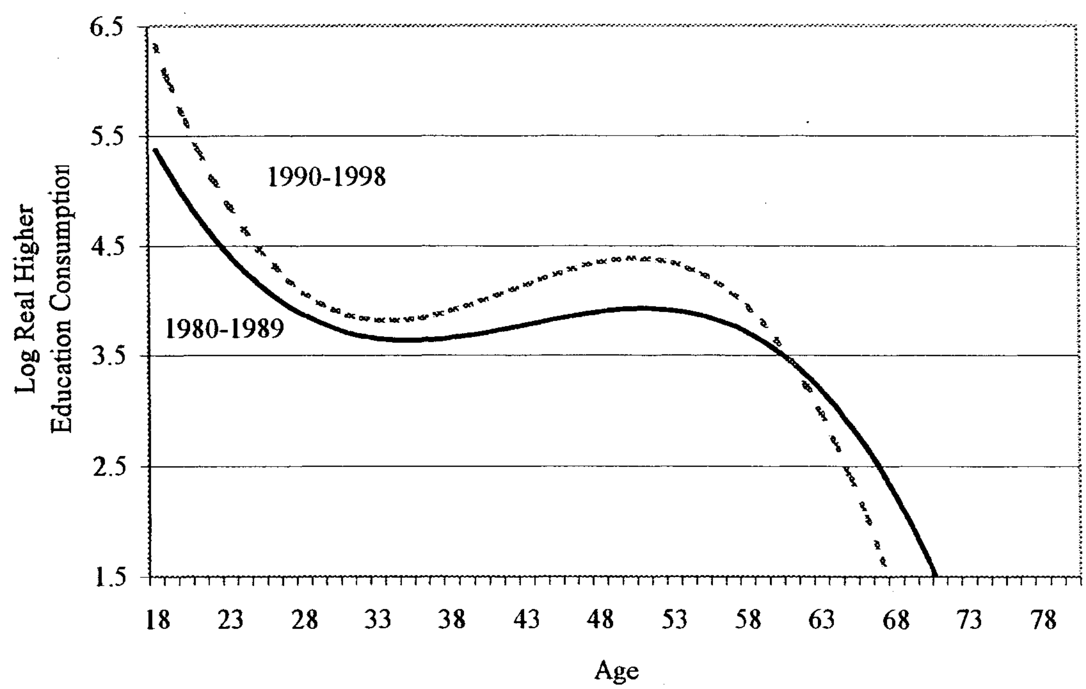

Figure 3.5: Log of Real Higher Education Consumption: Married with Some College Education

When compared to Figure 3.3, with the same level of education, this profile shifts up due to the increase in college-aged adults in the household. Thus, the substitution effect is larger when others of college age are introduced into the model. On the other hand, Figure 3.5's 1990s profile crosses the 1980s profile around the same age as in Figure 3.3. This suggests that both Figures 3.3 and 3.5 appear to have similar income effects.

The final profile is characterized as a married, white male that lives in the northeast, has only a high school education, and does not have any children. Table 3.10 provides the parameter estimates used to generate the profile. Figure 3.6 depicts the consumption profile.

This profile is the most exaggerated of the four since the household now has additional adults of college age and the head of the household has only a high school education. As a result, the profile shifts up much more than Figure 3.3 and the substitution effect is very prominent. Additionally, like Figure 3.4, the household must pursue education for a longer period of time to accumulate the skills necessary to take advantage of the skill premium. Thus, the income effect is virtually nonexistent except near retirement.

A similar set of profiles is generated with households having children. The consumption profiles, however, are very similar to the ones incorporating college-aged adults except having children results in profiles that are more exaggerated. Indeed the substitution effect dominates until close to retirement particularly when the head of household is married with children. For brevity and to omit redundancy, the profiles and associated data tables are available from the author upon request.

Table 3.10: Parameter Coefficients for Married Household with High School Education

Variable	Coefficient
constant	9.497814
age1	-0.77572
agesq	0.01863
agecu	-0.00014
dry2	5.97859
age90	-0.47477
agesq90	0.01220
agecu90	-0.00010
urb	0.46364
lrinc	0.12629
uer	-0.05638
imr	2.59448
mar	-0.13945
hs	-0.48082

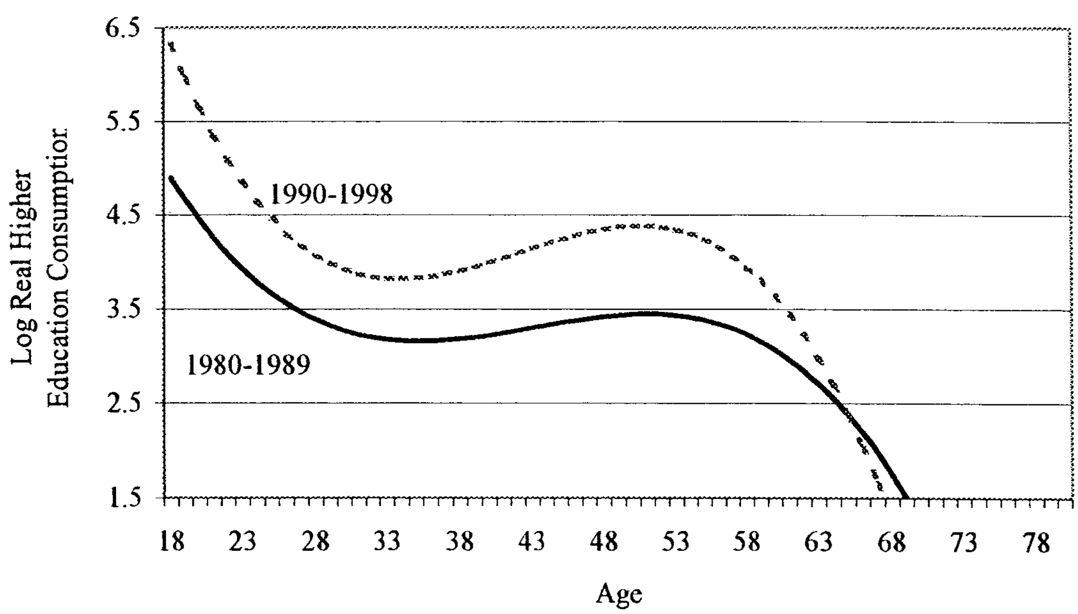

Figure 3.6: Log of Real Higher Education Consumption: Married with High School Education

Given the four profiles examined, the main findings are twofold. First and foremost, all life-cycle profiles display structural change. Each has statistically changed between the 1980s and the 1990s — the young consume more higher education services while the old consume less in the 1990s with the turning point occurring near age 50. In terms of a theory, the position in the life-cycle appears to determine the relative importance of the income and substitution effects that arise from the increasing college skill premium. Specifically, in the 1990s, the substitution effect dominates the income effect during the young- and middle-years of the life-cycle, even more so when the head of the household only has a high school education. On the other hand, the income effect dominates the substitution effect during the later-years of the life-cycle, ages 60-68.

Second, higher education consumption expenditures display a peak in the midyears of the life-cycle, even after accounting for children and after accounting for others of college age in the household. This suggests that the returns to tertiary education are positive in middle-years as well as early years; consistent with the findings of Table 3.1. Thus, one can infer that some type of retooling of skills may be taking place or that some households may be delaying entering higher education markets.

Because the substitution effect dominates in the early and midyears of the life-cycle and the income effect dominates in the later years, it is not surprising to find a fall in the demand for higher education as one reaches the later stages of the life-cycle; a puzzle as noted by Card and DiNardo (2002). Indeed, the results of this study correlate with Card and DiNardo's (2002) illustration.[6] In their illustration, the wage gap exhibits little change near age 60, a time when this study's profiles begin to exhibit the impact of the

[6] Card and DiNardo's (2002) illustration is the same as Figure 2.1 in Chapter 2.

income effect, implying that for the old, who are relatively human capital rich, the rate of accumulation of human capital attainment may fall resulting in little change in the college-high school wage gap.

These results illustrate the need to consider more carefully the effects of supply changes. It appears that the demand for skills (college spending) and hence the supply of skilled labor has significantly changed. Typically, the literature has focused on explaining the changing wage structure from changes in demand due to SBTC. These results force a reconsideration of the view that choices made by the labor suppliers are equally as important as demand changes for our understanding of the effects of skill-biased technological change. Additionally, the conclusions reveal that supply changes of skilled labor call into question the traditional ideas of either diminishing returns to higher education or that preferences for skill acquisition have only an intensive margin. Indeed, the decision to attend at all (extensive margin) is just as important as the number of classes to take (intensive margin).

The notion of skill-biased technological change and skill acquisition is the topic of Chapter 4 set forth to establish a theoretical foundation in a macroeconomic framework where labor supply choices are important. The purpose of this next step is to tie together an empirical and theoretical estimation of life-cycle profiles of higher education consumption. The simulated macroeconomic model results are to be compared to the empirical results found in this study in order to draw some conclusions regarding skill-biased technological change and its impact on human capital acquisition.

CHAPTER 4

THEORETICAL MODEL OF SKILL ACQUISITION

Introduction

In the previous chapter it is found that household consumption profiles exhibit significant structural change between the 1980s and the 1990s implying that the life-cycle motive for saving by human capital has been altered by the substitution and income effects. Conceivably the effects of rising wages for skilled labor associated with skill-biased technological change have differing effects on higher education demand over the life-cycle, thus inducing a labor supply response.

The goal of this chapter is to establish a theoretical foundation in a dynamic macroeconomic framework where labor supply choices are important. The next step will be to tie together the empirical estimation found in Chapter 3 with a quantitative theory of steady-state life-cycle profiles in order to test the importance of skill-biased technological change on skill acquisition expenditures. By altering the parameters associated with skill-biased technology, and hence the return to human capital, a series of experiments are conducted to evaluate the impact on the skill premium and skill acquisition expenditures. The main question addressed is whether the experiments that represent SBTC are consistent with the empirical profiles. In other words, can SBTC produce an income effect while increasing the skill premium?

The remainder of the chapter proceeds as follows: Section 4.1 outlines the theoretical model followed by the characterization of the dynamic equilibrium in Section 4.2. Calibration of the theoretical model takes place in Section 4.3 and the chapter concludes in Section 4.4 with five experiments and the associated results.

4.1 Theoretical Model

The theoretical analysis employs an overlapping generations (OLG) model of skill acquisition drawing from Auerbach and Kotlikoff (1987), Heckman et al. (1999), Krusell et al. (1997), and Fowler and Young (2004). The OLG model allows for the replication of heterogeneity in households with respect to their age implying the replication of the higher education expenditure profiles. The model is made up of three sectors: household, production, and skill acquisition. There are two types of agents that make economic decisions: households and firms. Households are of two types: unconstrained or skilled which implies that they are able to invest in both physical and human capital and credit constrained or unskilled which implies that they are unable to invest in physical and human capital. The model assumes that each unconstrained household operates its own skill-acquisition technology. Skill-biased technological change enters the model in both the skill acquisition sector and the production sector. As such, SBTC impacts the supply of labor through skill acquisition and the demand for labor through production.

4.1.1 The Household Sector

Following Auerbach and Kotlikoff (1987) and Fowler and Young (2004), at any given time the household sector comprises g overlapping generations of adults.[1] Each period, one generation dies and another takes its place. Agents from generation g live for I periods, retire after $I_R < I$ periods, and then die. At any point in time there is a set of agents indexed by $\tau \in I = \{0, 1, 2, \ldots, I-1\}$. For simplicity, no bequests or inheritances are considered in this model.

[1] For analysis purposes, adults are defined as those individuals of college age - 18 years of age and older.

Within each age cohort, individual tastes and initial capital stocks are assumed to be identical. Heterogeneity results from differences in tastes and capital stocks *among* age cohorts. Thus, the use of a representative agent for each generation enables one to describe the aggregate behavior of a generation by the behavior of a single member.

Agents in the model make lifetime decisions about consumption, saving, and leisure over their lives. Let $u(c_{t+\tau}^{g}, l_{t+\tau}^{g})$ be the flow of utility from consumption and leisure at time t and let lifetime utility be represented by $\sum_{t=0}^{I-1} \beta^{\tau} u\left(c_t^g, l_t^g\right)$ where β is a time preference discount factor such that $0 \leq \beta \leq 1$. Assume that $u(\cdot)$ is real valued, differentiable, strictly increasing, and strictly concave (Adda and Cooper 2003). Throughout the life-cycle, agents also decide whether or not to purchase higher education. The schooling option chosen provides the highest level of lifetime utility.

The time endowment is normalized such that $1 = n_{1,t+\tau}^{g} + n_{2,t+\tau}^{g} + l_{t+\tau}^{g}$ where n_1 is time devoted to labor, n_2 is time devoted to human capital accumulation or skill acquisition — time spent studying, and l is time devoted to leisure. Since there are no bequests and inheritances, agents invest in physical capital by consuming less in their working years than they earn in wages. Thus, the initial level of physical capital, k_0^g, is equal to zero. Each individual is born with an initial level of human capital or innate ability and chooses whether or not to add to the endowment, $h_{t+\tau}^{g} \geq 1$. Additionally, the old consume all goods and saving in their final period of life implying that $k_{t+\tau+1}^{g} = 0$.

There is no taxation and a measure of mortality is incorporated into the model. Since labor supply choices and schooling options are important in this framework, the time t problem of an agent born in period t is formally stated as (4.1):

$$\max_{\left\{c_{t+\tau}^{g}, n_{1,t+\tau}^{g}, n_{2,t+\tau}^{g}\right\}_{\tau=0}^{I-1}} E_t\left\{\sum_{\tau=0}^{I-1} \beta^{\tau} \psi_{\tau} u(c_{t+\tau}^{g}, n_{1,t+\tau}^{g}, n_{2,t+\tau}^{g})\right\} \tag{4.1}$$

where $\Psi_{\tau} = \prod_{i=0}^{\tau} \psi_{i}$ denotes the unconditional probability of surviving up to age τ with each ψ_{τ} representing the conditional probability of surviving from age $\tau - 1$ to τ. The budget constraints of a typical consumer born at time t at any time $t + \tau$ where $\tau \in I$ are given in (4.2a) and (4.2b):

$$c_{t+\tau}^{g} + k_{t+\tau+1}^{g} \leq (1 + r_{t+\tau} - \delta_k) k_{t+\tau}^{g} + w_{t+\tau}^{s} h_{t+\tau}^{g} n_{1,t+\tau}^{g} \tag{4.2a}$$

$$h_{t+\tau+1}^{g} \leq A\left(h_{t+\tau}^{g}\right)^{\theta_1} \left(n_{2,t+\tau}^{g}\right)^{\theta_2} + \left(1 - \delta_h\right) h_{t+\tau}^{g}, \tag{4.2b}$$

where k represents physical capital accumulation, r is the return to physical capital, δ_k and δ_h denote the depreciation rate associated with physical and human capital respectively, w^s is the real wage rate for skilled workers, θ_1 represents the private return on the existing stock of human capital, θ_2 measures the private return to study hours, h denotes existing human capital used in the production of future human capital, or the ability to "earn", and A is an ability to "learn" parameter and represents an exogenous shift in total efficiency of human capital formation for all g and $\tau \in I$. Note that θ_1, θ_2, A, and h all affect the returns to human capital production.

Equation (4.2a) satisfies the feasibility condition whereby consumption plus saving via physical capital is less than or equal to income. Equation (4.2b) states that tomorrow's human capital accumulation is less than or equal to human capital production plus today's level of human capital after depreciation.

Let $q_{t+\tau}^{g}$ be defined as a human capital production technology denoted by equation (4.3a):

$$q_{t+\tau}^{g} = A\left(h_{t+\tau}^{g}\right)^{\theta_1}\left(n_{2,t+\tau}^{g}\right)^{\theta_2} \tag{4.3a}$$

For simplicity, the input of physical capital into the production of human capital is ignored. Although this assumption seems restrictive, one can argue that it may not be a serious problem since human capital production is likely to be relatively labor-intensive (Heckman et al. 1998, Fowler and Young 2004). The marginal products with respect to existing human capital and skill acquisition hours are denoted in (4.3b) and (4.3c), respectively:

$$q_{h,t+\tau}^{g} = A\,\theta_1\left(h_{t+\tau}^{g}\right)^{\theta_1 - 1}\left(n_{2,t+\tau}^{g}\right)^{\theta_2} \tag{4.3b}$$

$$q_{n,t+\tau}^{g} = A\,\theta_2\left(h_{t+\tau}^{g}\right)^{\theta_1}\left(n_{2,t+\tau}^{g}\right)^{\theta_2 - 1} \tag{4.3c}$$

Equation (4.3b) represents the change in human capital production given a small change in existing human capital, ceteris paribus. Similarly, (4.3c) denotes the change in human capital production given a small change in skill acquisition hours, ceteris paribus.

For the agent who is credit constrained, all earned wages are consumed and no saving takes place. The general model of (4.1) and (4.2) is modified as indicated in (4.4) through (4.5b):

$$\max_{\left\{c_{t+\tau}^{g},\, n_{1,t+\tau}^{g}\right\}_{\tau=0}^{T-1}} E_t\left\{\sum_{\tau=0}^{I-1} \beta^{\tau}\psi_{\tau} u\left(c_{t+\tau}^{g}, n_{1,t+\tau}^{g}\right)\right\} \tag{4.4}$$

subject to:

$$c_{t+\tau}^{g} \leq w_t^u h_{t+\tau}^{g} n_{1,t+\tau}^{g} \tag{4.5a}$$

$$h_{t+\tau+1}^{g} = (1-\delta) h_{t+\tau}^{g} \tag{4.5b}$$

where w^u is the real labor wage rate for unskilled workers. Given the credit constraint, the individual has no ability to accumulate human capital beyond their initial endowment; thus, human capital merely depreciates over time as indicated in (4.5b).

4.1.2 The Firm

The representative firm is assumed to be infinitely lived, behaves competitively, and maximizes the current value of the firm by renting physical capital from the old and hiring labor hours — human capital — from the skilled and unskilled young. Additionally, technology enters into the firm's production function in two ways: general technology that is input neutral and skill-biased technology that impacts both labor supply and labor demand (Auerbach and Kotlikoff 1987, Fowler 2003).

At this point it is important to distinguish between skilled workers, those who accumulate human capital beyond the initial endowment, and unskilled workers. As defined in Chapter 3, skilled workers are assumed to be those agents with a four-year college education; denoted by $h_{t+\tau}^{g,s}$. On the other hand, unskilled workers have an education level of less than a four-year college degree and are denoted by $h_{t+\tau}^{g,u}$.

Physical capital is assumed homogeneous, while labor differs in its productive ability. Following Krusell et al. (1997), the firm utilizes capital and labor, both skilled and unskilled, subject to a constant elasticity of substitution (CES) production technology. The output in this economy is uncertain due to an aggregate random shock to total factor productivity — input neutral technology shock; denoted z_t. Specifically, the aggregate output from a firm is produced according to (4.6):

$$Y_t = \exp(z_t)\left[\alpha_t K_t^{\sigma_2} + (1-\alpha_t)\left(\lambda_t (SN_t)^{\sigma_1} + (1-\lambda_t)(UN_t)^{\sigma_1}\right)^{\frac{\sigma_2}{\sigma_1}}\right]^{\frac{1}{\sigma_2}} \tag{4.6}$$

where $K_t = \sum_{\tau=0}^{I-1} k_t^{g-\tau}$ represents aggregate physical capital, $SN_t = \sum_{\tau=0}^{I-1} h_t^{s,g-\tau} n_{1,t}^{g-\tau}$ is aggregate skilled labor, $UN_t = \sum_{\tau=0}^{I-1} h_t^{u,g-\tau} n_{1,t}^{g-\tau}$ is aggregate unskilled labor, α_t and λ_t are income share parameters with respect to physical capital and labor, respectively; λ_t also represents the level of skill-biased technology that impacts both skilled and unskilled labor. The parameters σ_1 and σ_2 govern the elasticity of substitution between physical capital, skilled labor and unskilled labor. Specifically, $1/(1-\sigma_1)$ is the elasticity of substitution between skilled and unskilled labor, $1/(1-\sigma_2)$ represents the elasticity of substitution between physical capital and labor — skilled and unskilled.

When either σ_1 or σ_2 equals zero, the model collapses to a Cobb-Douglas production technology. Thus, the general level of technology, z_t, and skill-biased technology, λ_t, impact the way the firm produces goods. For this analysis, the general level of technology is assumed to be constant, while skill-biased technology is allowed to change. The general level of technology evolves according to (4.7):

$$z_t = \phi z_{t-1} + \rho\varepsilon_t \tag{4.7}$$

and is to be calibrated in a subsequent section. The variable ε_t is white noise with unit variance and $\rho > 0$ scales up the variance of the innovations.

Profits of the firm are given by (4.8):

$$\Pi_t = \exp(z_t)F(K_t, SN_t, UN_t) - r_t K_t - w_t^s SN_t - w_t^u UN_t \tag{4.8}$$

where w_t^s is the real wage rate for skilled workers and w_t^u is the real wage rate for unskilled workers. Competitive behavior by the firms ensures that factors are paid their marginal productivities. The marginal productivity of a unit of physical capital equals its real rate of return in (4.9a):

$$\exp(z_t)F_1(K_t, SN_t, UN_t) = r_t \tag{4.9a}$$

where $F_1(\cdot) = \partial F(K_t, SN_t, UN_t) / \partial K_t$. The marginal productivity of an effective unit of skilled labor from the τ th person will equal its real wage in (4.9b):

$$\exp(z_t)F_2(K_t, SN_t, UN_t) = w_t^s \tag{4.9b}$$

where $F_2(\cdot) = \partial F(K_t, SN_t, UN_t) / \partial SN_t$. The marginal productivity of an effective unit of unskilled labor from the τ th person will equal its real wage in (4.9c):

$$\exp(z_t)F_3(K_t, SN_t, UN_t) = w_t^u \tag{4.9c}$$

where $F_3(\cdot) = \partial F(K_t, SN_t, UN_t) / \partial UN_t$. All households receive the same return on physical capital, but there is a nontrivial distribution of wages over the life-cycle due to differences in human capital acquisition.

4.2 Characterization of the Equilibrium

A generalized recursive competitive equilibrium brings together the firms and households in the model. The typical agent lives for I-periods and makes choices with respect to consumption, saving, and leisure over the life-cycle (Fowler and Young 2004).

The formal dynamic programming problem of a household born at time t at any time $t+\tau$ is given by the value function in (4.10) subject to (4.11a) and (4.11b):

$$v_\tau\left(s_{t+\tau}^g, S_{t+\tau}^g\right) = \max\left\{u\left(c_{t+\tau}^g, n_{1,t+\tau}^g, n_{2,t+\tau}^g\right) + \beta\frac{\psi_{\tau+1}}{\psi_\tau}E_{t+\tau}\left[v_{\tau+1}\left(s_{t+\tau}^g, S_{t+\tau+1}\right)\right]\right\} \quad (4.10)$$

where $s_{t+\tau}^g = \left(k_{t+\tau}^g, h_{t+\tau}^{s,g}, h_{t+\tau}^{u,g}, A\right)$, $S_{t+\tau} = \left(K_{t+\tau}, SN_{t+\tau}, UN_{t+\tau}, z_{t+\tau}\right)$ and subject to:

$$c_{t+\tau}^g + k_{t+\tau+1}^g \le \left(1 + r_{t+\tau} - \delta_k\right)k_{t+\tau}^g + w_{t+\tau}^s h_{t+\tau}^{s,g} n_{1,t+\tau}^g \quad (4.11a)$$

$$h_{t+\tau+1}^{s,g} \le A\left(h_{t+\tau}^g\right)^{\theta_1}\left(n_{2,t+\tau}^g\right)^{\theta_2} + \left(1-\delta_h\right)h_{t+\tau}^{s,g} \quad (4.11b)$$

Based on the behavior of the utility maximizing agents and the competitive behavior of the firm, the equilibrium is defined by the following:

Definition 1 (Recursive Competitive Equilibrium) *Given the stochastic process for Z and initial capital stocks, the competitive general equilibrium is a set of prices* $\left\{w_t^s, w_t^u, r_t\right\}_{t=0}^\infty$, *time allocations* $\left\{\left\{n_{1,t}^{g-\tau}, n_{2,t}^{g-\tau}\right\}_{\tau=0}^{I-1}\right\}_{t=0}^\infty$, *consumption allocations* $\left\{\left\{c_t^{g-\tau}\right\}_{\tau=0}^{I-1}\right\}_{t=0}^\infty$, *human capital investments* $\left\{\left\{q_{h,t+\tau}^{g-\tau}\right\}_{\tau=0}^{I-1}\right\}_{t=0}^\infty$, *capital allocations* $\left\{\left\{k_{t+1}^{g-\tau}, h_{t+1}^{g-\tau}\right\}_{\tau=1}^{I-1}\right\}_{t=1}^\infty$, *production plans for the firms* $\left\{K_t, SN_t, UN_t\right\}_{t=0}^\infty$, *and a set of value functions* $\left\{\left\{v_\tau(t)\right\}_{\tau=0}^{I-1}\right\}_{t=0}^\infty$ *such that, given period 0 capital stocks, the following conditions are satisfied for all t:*

4.2a The supply of factors equals the firm's demand:

$$K_t = \sum_{\tau=1}^{I-1} k_t^{g-\tau}, \quad SN_t = \sum_{\tau=0}^{I-1} h_t^{s,g-\tau} n_{1,t}^{g-\tau}, \quad UN_t = \sum_{\tau=0}^{I-1} h_t^{u,g-\tau} n_{1,t}^{g-\tau}.$$

4.2b The allocations are feasible:

$$C_t + K_{t+1} - (1-\delta_k)K_t = \exp(z_t)F(K_t, SN_t, UN_t)$$

where $C_t = \sum_{\tau=0}^{I-1} c_t^{g-\tau}$, $K_{t+1} = \sum_{\tau=0}^{I-1} k_t^g$, *and*

$$H_{t+1}^s - (1-\delta_h)H_t^s = \sum_{\tau=0}^{I-1} A\left(h_t^{s,g-\tau}\right)^{\theta_1}\left(n_{2,t}^{g-\tau}\right)^{\theta_2}$$

where $H_t^s = \sum_{\tau=0}^{I-1} h_t^{s,g-\tau}$.

4.2c Firms maximize profits each period and factor prices are competitive:

$$\pi_t = \max_{K_t, SN_t, UN_t} \left\{ \exp(z_t)F(K_t, SN_t, UN_t) - r_t K_t - w_t^s SN_t - w_t^u UN_t \right\}$$

Thus, the marginal productivity equations are satisfied:

(i) marginal productivity of physical capital: $\exp(z_t)F_1(K_t, SN_t, UN_t) = r_t$

(ii) marginal productivity of skilled labor: $\exp(z_t)F_2(K_t, SN_t, UN_t) = w_t^s$

(iii) marginal productivity of unskilled labor: $\exp(z_t)F_3(K_t, SN_t, UN_t) = w_t^u$.

4.2d Given the law of motion for the capital stocks, the price functions, initial conditions, and the transitions for the stochastic states, the value function is determined:

$$v_\tau(t+\tau) = \max\left\{ u\left(c_{t+\tau}^g, n_{1,t+\tau}^g, n_{2,t+\tau}^g\right) + \beta \frac{\psi_{\tau+1}}{\psi_\tau} E_{t+\tau}\left[v_{\tau+1}(t+\tau+1)\right] \right\}$$

subject to: (i) the terminal condition $v_I(t) = 0$ *for all t, (ii) the nonnegativity conditions* $c_t^g, k_{t+\tau}^g, h_{t+\tau}^{s,g}, h_{t+\tau}^{u,g} \geq 0$ *for all t and* τ*, (iii) the initial and ending conditions* $k_t^g = 0$ *and* $k_{t+I}^g = 0$ *for all t, and (iv) the budget constraints.*

Optimal behavior by the households ensures that the following Euler Equations and budget constraints hold for each agent g in each time period $t+\tau$. Each *skilled* agent will have three Euler equations: (1) investment in physical capital — a form of saving, (2) amount of skilled work — the negative of leisure, and (3) investment in human capital — the negative of leisure. The Euler equations are derived by comparing the marginal costs and marginal benefits associated with each type of consumption and saving activity.

The Euler equation for investment in physical capital is derived by considering the tradeoff between consumption and saving. Suppose the household from generation $g-\tau$ invests in a unit of time t physical capital. The marginal cost is the lost time t unit of consumption; in utility this is defined as the marginal utility of a unit of consumption: $u_1^{g-\tau} = \partial u(c_t^{g-\tau}, n_{1,t}^{g-\tau}, n_{2,t}^{g-\tau}) / \partial c_t^{g-\tau}$. In terms of marginal benefit, the agent receives the discounted gross return on capital $(1 + r_{t+\tau+1} - \delta_k)$; discounted by $\beta \frac{\psi_{\tau+1}}{\psi_\tau}$ and the marginal utility of one more unit of physical capital $u_1^{g+1-\tau} = \partial u(c_{t+1}^{g+1-\tau}, n_{1,t+1}^{g+1-\tau}, n_{2,t+1}^{g+1-\tau}) / \partial c_{t+1}^{g+1-\tau}$. Equating marginal benefits and costs gives Euler equation 1 in (4.12a):

$$u_1^{g-\tau} = \beta \frac{\psi_{\tau+1}}{\psi_\tau} E_{t+1}\{(u_1^{g+1-\tau})(1 + r_{t+\tau+1} - \delta_k)\} \tag{4.12a}$$

The Euler equation for a skilled worker is derived by considering the tradeoff between work and leisure. Suppose that the agent works one extra hour at time t. Then the marginal cost is the time t lost leisure; in utility this is defined as the marginal disutility of a unit of labor, $-u_2^{g-\tau} = \partial u(c_t^{g-\tau}, n_{1,t}^{g-\tau}, n_{2,t}^{g-\tau}) / \partial n_{1,t}^{g-\tau}$. In terms of marginal benefit, the agent receives an extra hour of wages for their human capital times the marginal utility associated with an extra unit of consumption, $w_{t+\tau}^{s} h_{t+\tau}^{s,g} \left(u_1^{g-\tau}\right)$. Equating the marginal benefits to the marginal costs gives Euler equation 2 in (4.12b):

$$-u_2^{g-\tau} = u_1^{g-\tau} w_{t+\tau}^{s} h_{t+\tau}^{s,g} \tag{4.12b}$$

The Euler equation for investment in human capital is derived by considering the tradeoff between obtaining an additional unit of human capital and leisure. Suppose that the agent invests in one unit of time t human capital. The marginal cost is the out-of-pocket and opportunity cost associated with purchasing one more unit of human capital and the time t lost leisure; in utility this is defined as the marginal utility of a unit of human capital, $\frac{-u_{3,t+\tau}}{q_{n,t+\tau}^{g}} = \partial u(c_t^{g-\tau}, n_{1,t}^{g-\tau}, n_{2,t}^{g-\tau}) / \partial n_{2,t}^{g-\tau}$.[2] In terms of marginal benefit, the agent receives the discounted gross return on human capital from work $w_{t+\tau+1}^{s} q_{n,t+\tau+1}^{g} n_{1,t+\tau+1}^{g}$; discounted by $\beta \frac{\psi_{\tau+1}}{\psi_{\tau}}$ and the marginal utility of one more unit of human capital. Additionally, given the investment in human capital, it is now easier for the household to obtain future human capital — implying learning begets learning or that skills acquired early facilitate later learning by increasing the marginal product of n_2. The benefit of learning begets learning is the marginal product of the human capital production function $q_{h,t+\tau+1}^{g}$. Equating the marginal benefits and costs gives (4.12c):

[2] See equation (B.5) of the technical note in Appendix B with respect to the computation of the skill acquisition price.

$$\frac{-u_{3,t+\tau}}{q_{n,t+\tau}^{t}}=\beta\frac{\psi_{\tau+1}}{\psi_{\tau}}E_{t+1}\left\{u_{1,t-\tau+1}w_{t+\tau+1}^{s}n_{1,t+\tau+1}^{g}+\left(\frac{-u_{3,t+\tau+1}}{q_{n,t+\tau+1}^{g}}\left[q_{h,t+\tau+1}^{g}+1-\delta_{h}\right]\right)\right\} \quad (4.12c)$$

Equations (4.12a)-(4.12c) must hold at any time t for each consumer born at time g-τ where $\tau \in I$. To generalize the model for all skilled agents, the stochastic Euler equations are given by equations (4.13a) through (4.13c). Note that the equations are functions of all states: current and future.

$$E_t\left\{SEE_1^{\tau}\left(s_t^{g-\tau}, s_{t+1}^{g-\tau}, S_t, S_{t+1}\right)\right\}_{\tau=0}^{I-1}=0 \quad (4.13a)$$

$$E_t\left\{SEE_2^{\tau}\left(s_t^{g-\tau}, s_{t+1}^{g-\tau}, S_t, S_{t+1}\right)\right\}_{\tau=0}^{I-1}=0 \quad (4.13b)$$

$$E_t\left\{SEE_3^{\tau}\left(s_t^{g-\tau}, s_{t+1}^{g-\tau}, S_t, S_{t+1}\right)\right\}_{\tau=0}^{I-1}=0 \quad (4.13c)$$

By the same logic, one could derive the Euler equation for the unskilled worker. Since that set of workers cannot invest in either human or physical capital, there will be only one Euler equation (4.14) and it is found by considering the tradeoff between work and leisure:

$$-u_2^{g-\tau}=u_1^{g-\tau}w_{t+\tau}^{u}h_{t+\tau}^{u,g} \quad (4.14)$$

Similarly, one can generalize for all unskilled agents in the model. The stochastic Euler equation is denoted by equation (4.15):

$$E_t\left\{SEE_2^{\tau}\left(s_t^{g-\tau}, s_{t+1}^{g-\tau}, S_t, S_{t+1}\right)\right\}_{\tau=0}^{I-1}=0 \quad (4.15)$$

The next step in the theoretical framework is to calibrate the model. Once the initial calibration is set, a series of numerical experiments are conducted and the results are discussed in section 4.4.

4.3 Calibration

To calibrate the model, the length of the life-cycle must be determined, a functional form of utility is needed, and a variety of parameters must be provided. The parameters form three groups: preferences, production, and skill acquisition. Table 4.2 at the end of this section provides a listing of the initial model parameters, descriptions, and values.

First, the length of the life-cycle, I, must be determined. In the OLG literature, agents typically make economic decisions over a 63-year period with retirement beginning at age 66. For this analysis, economic life starts at age 18, which implies that the terminal age is 80. To keep computation of the equilibria manageable, however, the life-cycle is condensed. Since data show that few people graduate from college in less than 5 years, each period in the model represents a 5-year time span. As such, the length of the life-cycle becomes $I = 12$ periods. For the skilled, retirement begins at age 64, or at the end of period 9. For the unskilled, there is no retirement. Each agent dies at age 77 or at the end of period 12.

Retirement represents the three periods where skilled labor hours are exogenously set to zero, $n_{1,t}^{10} = n_{1,t}^{11} = n_{1,t}^{12} = 0$. As a result of the exogenously set retirement age, skill acquisition hours stop after period eight since workers would not have enough time to be in the labor force to make skill acquisition worth while; thus, $n_{2,t}^{9} = n_{2,t}^{10} = n_{2,t}^{11} = n_{2,t}^{12} = 0$. The values for survival probabilities are presented in Table 4.1. The probabilities are estimated by converting the annual mortality probabilities from the U.S. Life Tables of the National Center for Health Statistics (1992) to the $I = 12$ life-cycle.

Table 4.1: Calibrations for Survival Probabilities

$\psi_0 = 1.00000$
$\psi_1 = 0.99731$
$\psi_2 = 0.99819$
$\psi_3 = 0.99717$
$\psi_4 = 0.99306$
$\psi_5 = 0.98510$
$\psi_6 = 0.97070$
$\psi_7 = 0.95365$
$\psi_8 = 0.92483$
$\psi_9 = 0.87436$
$\psi_{10} = 0.81549$
$\psi_{11} = 0.73835$
$\psi_{12} = 0.63981$

Next, equation (4.16) identifies preferences utilizing the conventional power utility specification (Fowler and Young 2004, Heathcote et al. 2004):

$$u(c, n_1, n_2) = \frac{c^{1-\gamma}}{1-\gamma} + \varphi \frac{(1 - n_1 - n_2)^{1-\mu}}{1-\mu} \tag{4.16}$$

The separable form of utility is chosen for two main reasons: (1) it permits one to separate the intertemporal elasticities of consumption and leisure, and (2) it is commonly used in the dynamic macroeconomic literature. The parameter γ represents the Arrow-Pratt coefficient of relative risk aversion. The parameter's value is restricted to the limiting case where $\gamma = 1$ giving our agents a reasonable amount of risk aversion.[3] Following Heckman et al. (1998), the parameter φ denotes the weight parameter on leisure and is set such that the average fraction of time devoted to work and study activities is roughly 0.4; this results in a value of $\varphi = 1.25$. The parameter μ determines

[3] As γ approaches 1, the consumption portion of the utility function collapses to the log of consumption. See Cooley and Prescott pp. 16-17 for a discussion of the limiting restriction.

the intertemporal labor supply elasticity; thus setting $\mu = 2$ falls within the range of existing estimates found in the micro and macro literature (Browning et al. 1999). Finally, a value is needed to discount preferences over time; $\beta = 1/(1.03)^5 = 0.8626$ is set at a value compatible with a yearly psychological rate of 3 percent (Fowler and Young 2004).

As indicated in equation (4.6) of section 4.1.2, the production function has four main parameters to calibrate, α, σ_1, σ_2, and λ

$$Y_t = \exp(z_t)\left[\alpha_t K_t^{\sigma_2} + (1-\alpha_t)\left(\lambda_t (SN_t)^{\sigma_1} + (1-\lambda_t)(UN_t)^{\sigma_1}\right)^{\frac{\sigma_2}{\sigma_1}}\right]^{\frac{1}{\sigma_2}} \tag{4.6}$$

The parameter σ_1 represents the demand elasticity of substitution between skilled and unskilled labor. This value is set at σ_1 = 0.3333 giving an elasticity of 1.5, consistent with estimates found in the literature — see Krusell et al. (1997) and Browning et al. (1999). Adapting Krusell et al. (1997) to incorporate total labor — not just skilled labor, the parameter governing the demand elasticity of substitution between capital and labor, σ_2, is set at –0.05, resulting in an elasticity of substitution of close to 1; not too different than the Cobb-Douglas specification where $\sigma_1 = \sigma_2 = 0$. The remaining parameters are set to match two observed facts from the data. First, the wage premium for the decade of the 1980's is approximately 1.4 (Card and DiNardo 2002). Second, investment's share of output is estimated to be 17% (Hendricks 2001). These facts imply a share of skilled labor in total labor of $\lambda_t = 0.51$ and capital's share of output of $\alpha_t = 0.34$. Additionally, the value for depreciation of physical capital is needed; $\delta_K = 1-(1-0.06)^5$ which implies a 6 percent annual depreciation rate, an average of the estimates most commonly found in the dynamic macroeconomic literature. Since z_t is an in input neutral technology shock, it is set to $z_t = 0$ and its evolution parameter, φ, is set following Fowler and Young, 2004; $\varphi = 0.5^5 = 0.03125$.

A final group of parameters are needed for skill acquisition, equation (4.3a) in Section 4.1.1 above:

$$q_{t+\tau}^{g} = A\left(h_{t+\tau}^{g}\right)^{\theta_1}\left(n_{2,t+\tau}^{g}\right)^{\theta_2} \tag{4.3a}$$

As stated previously, the parameter θ_1 represents the private return on the existing stock of human capital and is set at $\theta_1 = 0.52$. The parameter θ_2 measures the private returns to study hours. Like θ_1 it is set at $\theta_2 = 0.52$. It is not unusual to restrict the parameters to equality and they are within the wide range of estimates found in the literature — see Ben-Porath, 1967; Browning, et al., 1999; Fowler and Young, 2004; Heckman, 1976; and Rosen, 1976. The two parameters together imply increasing returns to scale in the human capital technology and the conditions $0 < \theta_1 < 1$ and $0 \leq \theta_2 \leq 1$ guarantee that the function is concave in the control variable. Additionally, estimates for A and δ_h are needed to complete the calibration of skill acquisition. First, A, the ability to "learn" parameter, is initially set to $A = 1$. Additionally, the level of human capital depreciation is initially set very close to zero, $\delta_h = 0.00005$ to allow for some loss in skill if human capital is not developed. Finally, the initial levels of skilled and unskilled human capital must be set. The skill levels are set according to those identified in the literature — see Fowler and Young, 2004 and Heckman, et al., 1998. Skilled human capital is set to $h_0^{s,g} = 11.35$ and unskilled human capital is set to $h_0^{u,g} = 9.53$.

Table 4.2 provides the initial model parameters, description, and values used to solve the benchmark model. The table has been broken down into three segments identifying the three sectors described in Sections 4.1.1 and 4.1.2 above.

Table 4.2: Initial Model Parameters, Descriptions, and Values

Preferences	**Description**
$\gamma = 1$	Arrow-Pratt measure of risk aversion
$\varphi = 1.25$	Weight parameter on leisure
$\mu = 2$	Determines the intertemporal labor supply elasticity
$\beta = 1.03^{-5} = 0.8626$	Discount factor for time preferences
Production	
$z = 0$	Exogenous input neutral technology shock
$\sigma_1 = 0.3333$	Determines demand elasticity of substitution between skilled and unskilled labor
$\sigma_2 = -0.05$	Determines demand elasticity of substitution between physical capital and labor
$\alpha = 0.34$	Share of physical capital to total labor
$\lambda = 0.51$	Share of skilled labor to total labor
$\delta_k = 1-(1-0.06)^5 = 0.266$	Depreciation rate of physical capital, 6% per year
$\varphi = 0.5^5 = 0.3125$	Evolution parameter of z
$k_0 = 0$	Initial level of physical capital
Skill Acquisition	
$\theta_1 = 0.52$	Private return on existing human capital stock
$\theta_2 = 0.52$	Private return on study hours
$A = 1$	Ability to "learn"
$\delta_h = 0.00005$	Depreciation rate of human capital
$h_0^s = 11.35$	Initial level of human capital of skilled
$h_0^u = 9.53$	Initial level human capital of unskilled

4.4 Quantitative Results

Given the initial parameter calibrations identified in the previous section, the model solves the steady-state profiles for preferences and human capital production such that the

Euler equations in Section 4.2 are satisfied. The model provides solutions to six main measures: steady-state skill hours, skill acquisition expenditures relative to consumption using average prices, the skill premium, the wage gap, human capital, and skilled consumption. As indicated in Section 4.1.1, skill hours represent the time spent studying and are estimated by dividing tomorrow's human capital net of depreciation by existing human capital times an exogenous efficiency shock. Skill acquisition expenditures are found by multiplying the skill acquisition price by the human capital production technology found in Section 4.1.1 equation (4.3a).[4] The skill premium is the ratio of mean of skilled labor income to mean of unskilled labor income and the wage gap is the log of the ratio of the skilled to unskilled labor income by age cohort, equations (4.17) and (4.18), respectively. Recall that the skilled only work for nine periods and then retire

$$Skill\,premium = \sum \frac{w_t^s h_t^{s,g} / 9}{w_t^u h_t^{u,g} / 12} \tag{4.17}$$

$$Wage\ gap^g = \log\left(\frac{w_t^s h_t^{s,g}}{w_t^u h_t^{u,g}}\right) \tag{4.18}$$

whereas unskilled work the entire 12 periods. Human capital investment is calculated by subtracting human capital depreciation from the human capital production technology, equation (4.3a) in Section 4.1.1. Steady-state skilled consumption is estimated by adding income earned from work and net saving by investment in physical capital. Skilled households earn wages for only nine of the 12 periods but are able to consume for 12 periods as a result of earnings from investment in physical capital.

[4] See equation (B.5) of the technical note in Appendix B with respect to the computation of the skill acquisition price.

In addition to the six main measures solved for in the models, means are also presented. Values such as mean skill acquisition price, mean skilled labor hours, and mean output provide valuable information when compared to changes in SBTC parameters.

The benchmark model represents the decade of the 1980s when the average skill premium is roughly 1.46, well within the wide range identified in the literature — Card and DiNardo, 2002; Heckman et al., 1997; and Krueger, 2003. Once the benchmark model is established, a series of numerical experiments are conducted to test the impact of skill biased technological change on the steady-state profiles. The results from the experiments represent the decade of the 1990s where the skill premium is rising. During the numerical experiments, the initial calibrations are adjusted such that the skill premium remains within the range found in the literature.

4.4.1 Benchmark Model

Using the initial calibrations identified in Table 4.2, the benchmark model is solved. Table 4.3 presents the mean results and Figure 4.1 illustrates the steady-state profiles of this model. The results will be compared relative to those obtained in the forthcoming experiments.

Table 4.3 reveals a few noteworthy facts. First, skilled workers do not have to work as many hours as unskilled workers since their human capital is more valuable and brings a higher wage rate. Given this fact, investment in human capital increases with age to 12.876 from the initial starting point of 11.35 presented in Table 4.2. Finally, given a skill acquisition price of 0.173, skill acquisition expenditures relative to consumption are about six percent, implying that human capital investment is beneficial.

Table 4.3: Means — Benchmark Model

Measure	Mean
Output	29.783
Skill Acquisition Price	0.173
Skilled Labor Hours	37.202
Unskilled Labor Hours	39.301
Skill Acquisition Expenditures	0.062
Skill Premium	1.461
Human Capital	12.876
Skilled Consumption	1.271

Comparative static steady-state profiles are illustrated in Figure 4.1. Although the skill acquisition expenditures graph, Figure 4.1(b), does not display the middle-age peak found in the empirical model of Chapter 3, the graphs appear to be consistent with economic logic and with those found throughout the literature. For example, as one ages there is less time to recoup the benefits of additional years of schooling. As such, it makes sense that spending on higher education services (i.e., skill acquisition expenditures) should fall. Stated differently, since one is expected to spend more time in school at younger ages, both skill hours and skill acquisition expenditures relative to consumption are higher in younger years and fall with age — panels (a) and (b), respectively.

Since this model does not incorporate factors that may lead to hump-shaped profiles such as taxation or social security, it is not surprising that skill acquisition expenditures fall smoothly with age. Given that the young are relatively poor in human capital, it is not surprising to see human capital — Figure 4.1(e) —rise with age as well as the skill premium and wage gap, panels (c) and (d), respectively. The wage gap, Figure 4.1(d) corresponds nicely to Card and DiNardo (2002), a result this research is attempting to

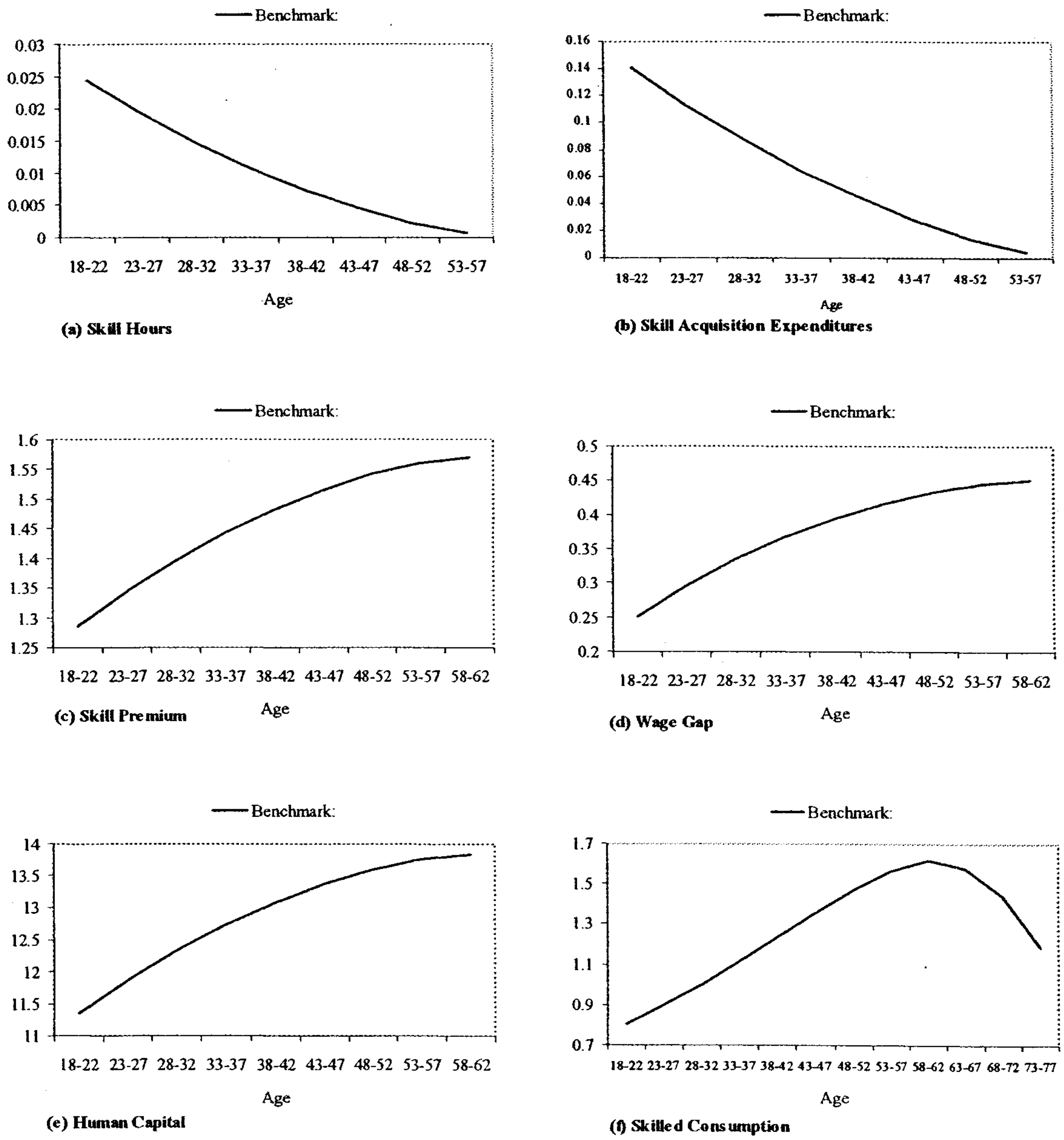

Figure 4.1: Steady-State Profiles — Benchmark Model

replicate.[5] Finally, consumption exhibits the typical "hump" shape consistently found in the life-cycle literature, implying that households do not necessarily smooth consumption by age.

The next step is to evaluate the effect of changes in skill-biased technological change; the following two sections accomplish this task. In order to investigate the impact of SBTC on the steady-state profiles, it is important to define the measure in terms of its affect on labor productivity. The literature identifies two main ways to define skill-biased technological change: extensive SBTC and intensive SBTC (Card and DiNardo 2002). *Extensive skill-biased technological change* takes place in the production sector and occurs when the marginal product of skilled workers increases while the marginal product of unskilled workers decreases. An example of this type of technological change may be the introduction of robotics in manufacturing (Johnson 1997). *Intensive skill-biased technological change* arises in the skill acquisition sector and occurs when the marginal product of skilled workers increases without necessarily decreasing the marginal product of unskilled workers. An example of this type of technological change may be the introduction of the Internet at campus libraries.

4.4.2 Extensive SBTC

In this dissertation, extensive SBTC is identified as an increase in the share of skilled labor to total labor, an increase in λ, in the production function equation (4.6). Thus, the first experiment adjusts the benchmark model by increasing λ from 0.51 to 0.53; similar to the experiment employed in Heckman et al, 1998. Although the increase

[5] Refer to Figure 2.1 in Chapter 2. The average wage gap for the 1980s falls somewhere between 0.2 and 0.4.

in λ is relatively small, approximately four percent, the impact on the wage premium is eight percent, increasing from 1.461 to 1.578 — numbers consistently within the range of skill premiums in the literature (Card and DiNardo 2002, Krueger 2003). Table 4.4 presents the means of the change in SBTC via λ compared to the benchmark model.

Table 4.4: Means — Extensive SBTC vs. Benchmark Model

Measure	Extensive SBTC Means	Benchmark Means	Percent Change
Output	29.961	29.783	0.6
Skill Acquisition Price	0.182	0.173	5.2
Skilled Labor Hours	37.483	37.202	0.8
Unskilled Labor Hours	39.301	39.301	n.c.
Skill Acquisition Expenditures	0.056	0.052	7.7
Skill Premium	1.578	1.461	8.0
Human Capital	12.901	12.876	0.2
Skilled Consumption	1.310	1.271	3.1

In all cases except unskilled labor hours, the increase in extensive SBTC results in higher means relative to the benchmark model. Recall that extensive SBTC occurs in the production function and increases the marginal product of skilled workers while at the same time lowers the marginal product of unskilled workers. As such, it is not surprising to find that skilled labor hours increase, although modestly, while unskilled labor hours remain unchanged.[6] The percentage change in both skill acquisition price and skill acquisition expenditures is positive and large relative to most of the other measures. This relationship may imply an increase in demand for skill acquisition expenditures similar to

[6] An interesting aside appears when comparing the percent change in output and skilled labor hours. While both are rising, skilled labor hours are rising faster. Thus, the notion of diminishing marginal product is confirmed when SBTC is of the extensive form.

the anecdotal evidence provided in Chapter 3. On the other hand, it may merely reflect the rising cost of higher education. Although steady-state human capital increases slightly, the skill premium rises by eight percent. Additionally, skill acquisition expenditures rise by more than seven percent. The combination of these results may infer that the slight gain in human capital investment results in higher relative wages making skill acquisition beneficial.

Graphically, it is apparent that the extensive SBTC parameter has the greatest impact on the skill premium and its associated wage gap — see Figure 4.2(c) and (d). The graphs confirm the conclusions drawn from Table 4.4 above that a slight increase in human capital investment leads to higher relative wages and greater skill acquisition expenditures. In terms of the SBTC hypothesis, Figure 4.2(b) may be interpreted as a pure substitution effect into higher education — the model exhibiting an increase in extensive SBTC lies above the benchmark model. Both the skill premium and the wage gap appear to widen as one ages, contradictory to the results found in Card and DiNardo (2002) — see Figure 2.1 in Chapter 2. Hence an increase in extensive SBTC does not provide an answer to one of Card and DiNardo's (2002) critiques of the SBTC hypothesis, namely that the wage gap changes very little in older age groups. Additionally, extensive SBTC fails to reflect an income effect in skill acquisition expenditures.

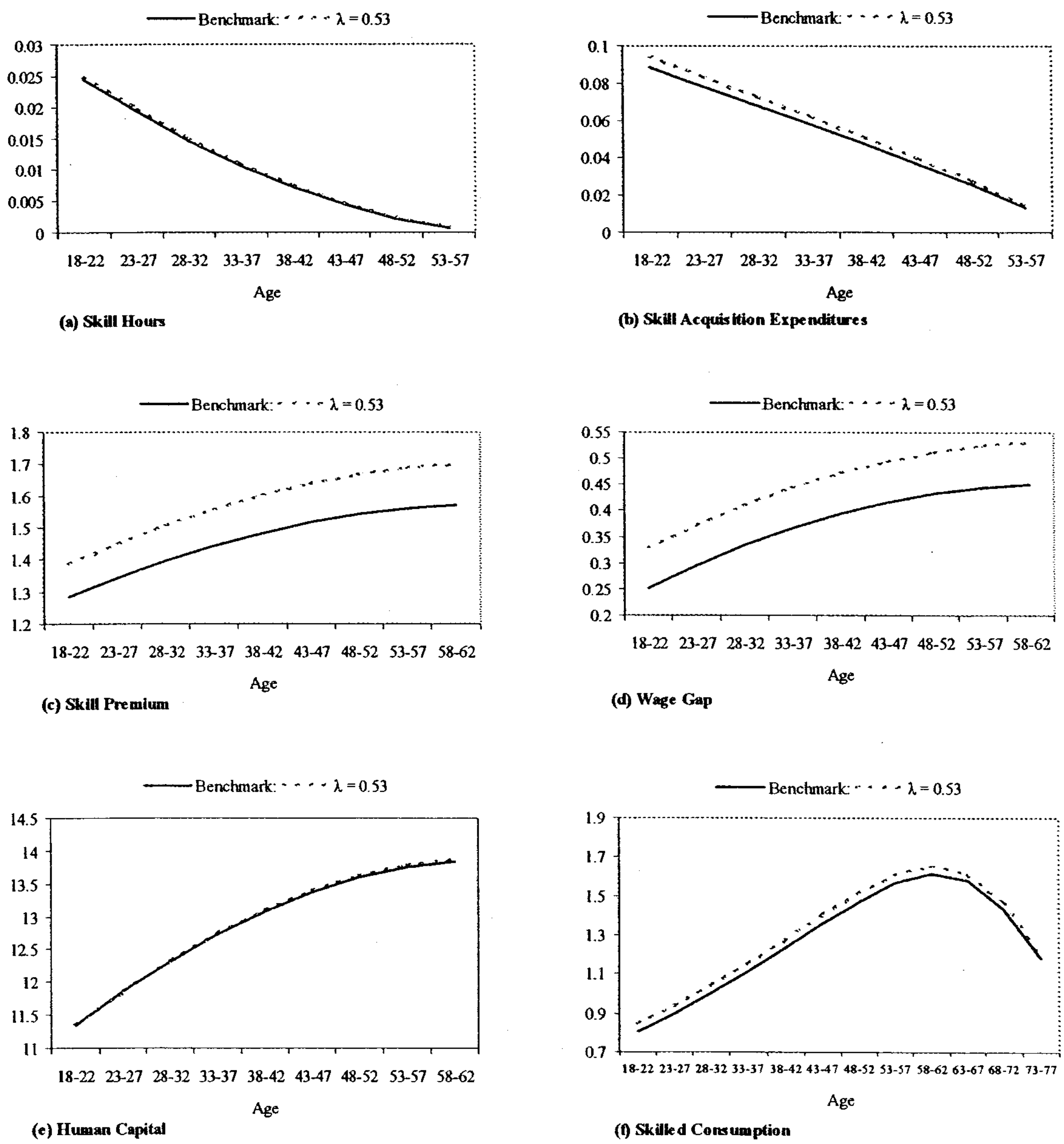

Figure 4.2: Steady-State Profiles — Increase in Extensive SBTC Parameter

4.4.3 Intensive SBTC

Recall that intensive SBTC occurs in the skill acquisition sector. Hence the parameters impacting human capital technology are investigated — A, h_0, θ_1 and θ_2; increases in any of these parameters increases the return to human capital. The quantitative experiments first solve for the impact of the parameters separately and then solve a model employing a combination of the parameters.

a. Increase in A:

The first numerical experiment increases A, the ability to "learn" parameter, from 1 to 1.3, a change of 30 percent. An example of this type of change in technology may be the introduction of computers; both existing human capital and the amount of time spent studying become more valuable. Table 4.5 provides the mean results of this exercise. At first glance, this SBTC parameter impacts skill acquisition expenditures significantly with a percentage increase of about 58 percent relative to the benchmark model. As the ability to learn rises, agents substitute into higher education. Because skill acquisition expenditures rise, human capital investment also rises increasing the skill premium. An interesting impact is the rise in skilled labor hours relative to the benchmark model. This effect is somewhat representative of many students who concurrently choose to work and pursue a college education. It is not surprising to see a fall in unskilled labor hours since an increase in A encourages skill acquisition which may induce some unskilled agents to substitute out of the labor market into higher education. At first glance, the fall in the skill acquisition price seems problematic. When considering how skill prices are computed, however, it becomes clear; the marginal product of skill hours is rising faster

Table 4.5: Means — Intensive SBTC: *A* vs. Benchmark Model

Measure	Intensive SBTC: *A* Means	Benchmark Means	Percent Change
Output	30.591	29.783	2.7
Skill Acquisition Price	0.165	0.173	-4.6
Skilled Labor Hours	40.335	37.202	8.4
Unskilled Labor Hours	30.591	39.301	-22.2
Skill Acquisition Expenditures	0.082	0.052	57.7
Skill Premium	1.502	1.461	2.8
Human Capital	13.975	12.876	8.5
Skilled Consumption	1.329	1.271	4.6

than the disutility of increasing skill hours rises relative to that of the benchmark model.[7] As such the price is lower than the benchmark model, resulting in a negative percentage change. Given the rise in the skill premium, both consumption and output rise.

Graphically, the effects of increasing A become more apparent. Figure 4.3 depicts the results. Changes in skill hours occur as a direct result of an increase in skill acquisition expenditures. As more higher education services are purchased — panel (b), the amount of time spent studying — panel (a) — also rises. The skill premium and the wage gap exhibit an interesting shape; at young ages the skill premium and wage gap are actually lower relative to the benchmark model. Recall that skill-specific wages are given by equation (3.1) $w_{it} = w_t * h_{it}$. One explanation for the shape of the skill premium and wage gap graphs may be that as the supply of human capital, h_{it}, increases, the wage common to all skills, w_t, falls. Thus, the skill premium and wage gap are initially below the benchmark model due to lower wages and relatively lower levels of human capital.

[7] See equation (B.5) of the technical note in Appendix B with respect to the computation of the skill acquisition price.

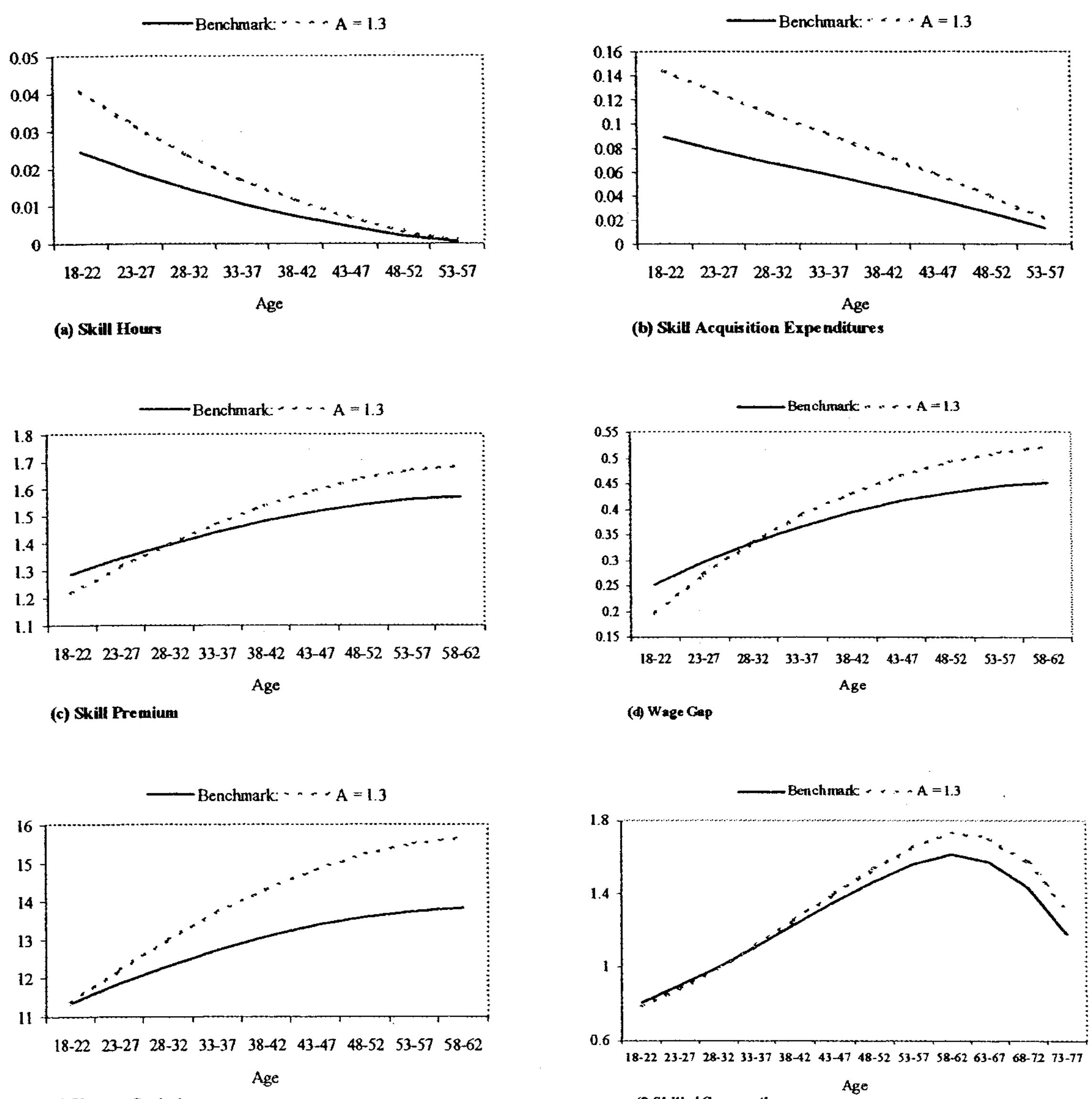

Figure 4.3: Steady-State Profiles — Increase in Intensive SBTC Parameter A

As h_{it} for the skilled increases relative to the unskilled, the skill premium and wage gap both rise even with a lower common wage. Consumption follows a similar pattern of starting just below the benchmark model and rising with age as human capital investment rises. This result makes sense given that consumption increases as relative skilled wages increase.

The impact of increasing the intensive SBTC parameter A has the same overall effect on skill acquisition expenditures as an increase in extensive SBTC. Skill acquisition expenditures remain above the benchmark model for all ages, representing a pure substitution effect in terms of the SBTC hypothesis. While A helps to explain a widening skill premium and wage gap, it does not provide an explanation for an income effect in the older age groups and does not answer Card and DiNardo's (2002) question regarding SBTC.

b. Increase in H:

Next, the intensive SBTC parameter representing initial level of skilled human capital (or the ability to "earn"), H, is allowed to increase nearly 15 percent from 11.35 to 13. An example of this type of change may be a result of an improved K-12 educational system or innate endowed ability. Table 4.6 presents the mean results relative to the benchmark model. Not surprising, when one starts out with more initial human capital they do not need to purchase as much throughout their lives. Consequently, skill acquisition expenditures fall relative to the benchmark model. At the same time, the skilled spend more of their time in the labor force rather than studying resulting in an increase in skilled labor hours. The skill acquisition price falls by about three percent.

Table 4.6: Means — Intensive SBTC: *H* vs. Benchmark Model

Measure	Intensive SBTC: *H* Means	Benchmark Means	Percent Change
Output	31.894	29.783	7.1
Skill Acquisition Price	0.168	0.173	-2.9
Skilled Labor Hours	42.162	37.202	13.3
Unskilled Labor Hours	39.301	39.301	n.c.
Skill Acquisition Expenditures	0.051	0.052	-1.9
Skill Premium	1.517	1.461	3.8
Human Capital	14.541	12.876	12.9
Skilled Consumption	1.376	1.271	8.3

One explanation for the falling skill price is that skill acquisition expenditures have fallen and thus the demand for higher education has fallen for a given supply resulting in lower prices. The skill premium rises relative to the benchmark but not by the same proportion as initial human capital increased — 3.8% vs. 15%; a direct result of less skill acquisition. Under this experiment, both consumption and output increase. Intuitively this makes sense. When one has a higher initial level of human capital, then the skilled wage is also higher relative to the unskilled. With higher relative wages, the skilled can consume more ultimately leading to higher output.

The results are also depicted graphically in Figure 4.4. Panel (a) illustrates a fall in skill acquisition hours; they lie under the benchmark model. This graph goes hand-in-hand with Figure 4.4(b) a fall in skill acquisition expenditures. As expenditures fall, the amount of time spent studying also falls. This result illustrates a pure income effect. The initial high level of human capital helps to increase the skill premium and wage gap, though not proportionately. With higher relative wages, consumption also rises.

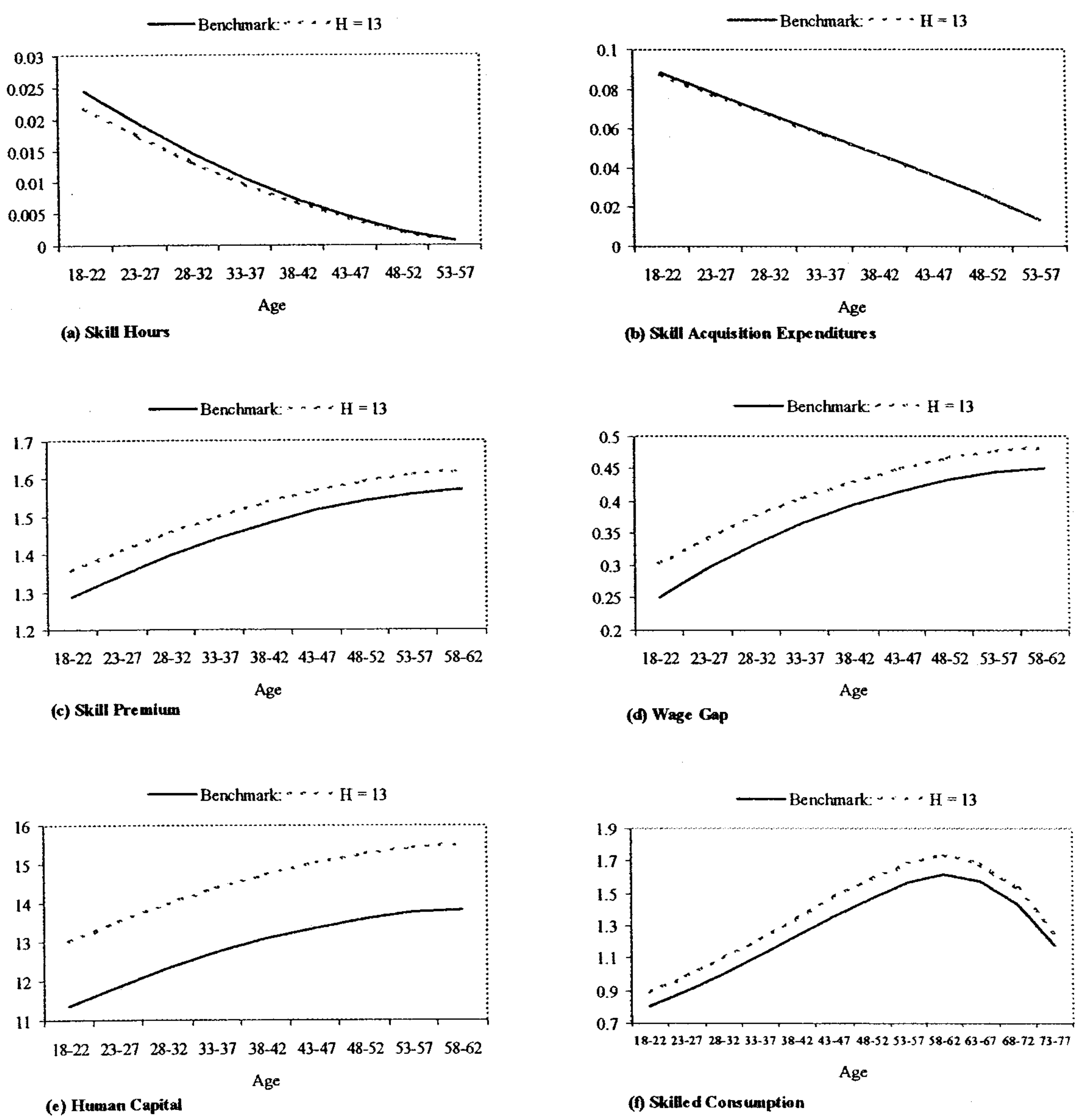

Figure 4.4: Steady-State Profiles — Increase in Intensive SBTC Parameter *H*

Although panels (c) and (d) do not flatten out as one ages, the impact of an increase in the intensive SBTC parameter H helps to explain a rising skill premium and wage gap. While panels (a) and (b) illustrate a pure income effect, they do nothing to explain a substitution effect in terms of the SBTC hypothesis.

c. ***Increase in θ_1 and θ_2:***

The next experiment involves increasing the return to human capital parameters, θ_1 and θ_2. The parameter θ_1 represents the private rate of return to existing human capital and is increased 25 percent from 0.52 to 0.65. An example of this type of parameter increase may be the use of capstone courses at universities whereby the student is called upon to use all existing human capital gained in the pervious courses. The parameter θ_2 denotes the private rate of return to studying and is increased 15 percent from 0.52 to 0.60. An example of this type of parameter increase may be the introduction of the Internet in college libraries.

Table 4.7 presents the mean results relative to the benchmark model. As in the case of increasing SBTC parameter A, skill acquisition price falls when skill acquisition expenditures rises significantly relative to the benchmark model. Like an increase in the intensive SBTC parameter A, the large increase in expenditures implies that the number of hours spent studying also rises, resulting is rising disutility from studying and a lower skill price. Although human capital investment rises by 2.5 percent, the skill premium only increases by about one percent. As such, the return to human capital parameters appear to have a much greater impact on skill acquisition expenditures than on the skill premium. Given the small rise in the skill premium, consumption and output also exhibit small increases.

Table 4.7: Means — Intensive SBTC: θ_1 and θ_2 vs. Benchmark Model

Measure	Intensive SBTC: θ_1 and θ_2 Means	Benchmark Mean	Percent Change
Output	29.979	29.783	0.7
Skill Acquisition Price	0.171	0.173	-1.2
Skilled Labor Hours	38.028	37.202	2.2
Unskilled Labor Hours	39.301	39.301	n.c.
Skill Acquisition Expenditures	0.058	0.052	11.5
Skill Premium	1.475	1.461	0.9
Human Capital	13.196	12.876	2.5
Skilled Consumption	1.286	1.271	1.2

Figure 4.5 illustrates the results. As noted above, human capital investment rises with age. Like the results of the SBTC parameter A, the skill premium, wage gap, and consumption each start off below the benchmark model and rise above it with age. A similar argument can be posited that skill acquisition expenditures lead to increases in human capital that change the relative wage of skilled labor ultimately leading to growth in the wage premium and the wage gap. As relative wages increase, consumption follows.

The most interesting results, however, are Figures 4.5(a) and (b), skill hours and skill acquisition expenditures, respectively. In both cases, the increase in the return to human capital, via increases in θ_1 and θ_2, starts off above the benchmark model and crosses below it. Though not perfect, in terms of the SBTC hypothesis Figure 4.5(b) illustrates the substitution and income effects similar to those found in the empirical data of Figure 3.3 of Chapter 3.

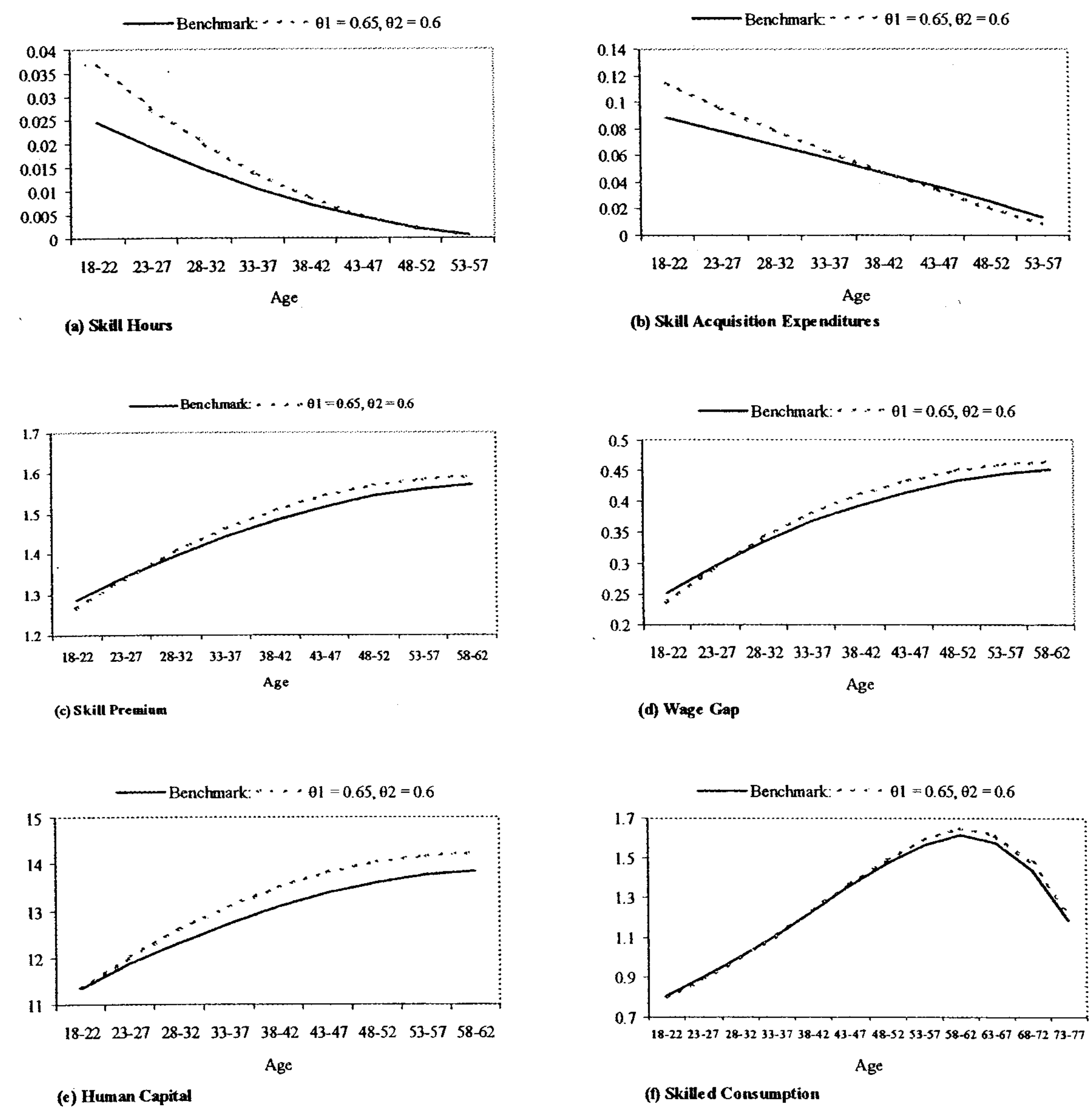

Figure 4.5: Steady-State Profiles — Increase in SBTC Parameters θ_1 and θ_2

Though this experiment accomplishes the task of identifying an income and substitution effect with respect to skill acquisition expenditures, it does little to address changes in the skill premium and wage gap.

d. Increase in A, H, θ_1 and θ_2:

The final experiment combines increases in all of the intensive SBTC parameters to test whether both results can be accomplished. Since increasing all four parameters by their individual experiment amounts would increase the skill premium above that in the literature, the parameters are increased within the range defined by their initial benchmark amounts and their individual experiment amounts. The ability to "learn" parameter A is increased 10 percent from 1 to 1.1, the ability to "earn" parameter H is increased about six percent from 11.35 to 12, and the return to human capital parameters θ_1 and θ_2 are restricted to remain equal and increased 25 percent from 0.52 to 0.65. The mean results are presented in Table 4.8. The skill premium rose to 1.491 well within the range presented in the literature. This combination results in a direct increase in human capital driven by the parameter H. Additionally, both skill acquisition expenditures and skill acquisition price fall relative to the benchmark model, again driven primarily by the ability to "earn" parameter H. As the initial level of human capital rises, there is less incentive to purchase more higher education resulting in a decline in skill acquisition expenditures and a decline in skill acquisition price resulting from less demand for higher education services. The higher skill premium resulting from both an increase in the ability to "learn" parameter A and the ability to "earn" parameter H, enables greater consumption that ultimately leads to greater output in the economy.

Table 4.8: Means — Intensive SBTC: Combination vs. Benchmark Model

Measure	Intensive SBTC: Combo Means	Benchmark Means	Percent Change
Output	30.651	29.783	2.9
Skill Acquisition Price	0.170	0.173	-1.7
Skilled Labor Hours	39.345	37.202	5.8
Unskilled Labor Hours	39.301	39.301	n.c.
Skill Acquisition Expenditures	0.050	0.052	-3.8
Skill Premium	1.491	1.461	2.1
Human Capital	13.567	12.876	5.4
Skilled Consumption	1.316	1.271	3.5

Graphically, the results tell a bit of a different story. While panels (c) through (f) of Figure 4.6 present similar results of increases relative to the benchmark model, panels (a) and (b) depict changes with respect to age. For example, Table 4.8 indicates that mean skill acquisition expenditures fall, but for the young age groups Figure 4.6(b) depicts an increase in expenditures relative to the benchmark model. In terms of the SBTC hypothesis, this represents a substitution effect. As agents age, however, the combined comparative static falls below the benchmark model, representing an income effect. Since mean skill acquisition expenditures fall, this implies that the income effect dominates for this combination of intensive SBTC parameters. Skill hours logically follow the same pattern. These results are driven primarily by the return to human capital parameters θ_1 and θ_2. Another interesting result is illustrated in panel (c). The skill premium remains above the benchmark model and widens but then begins to flatten out as the agent ages. One result the individual experiments are unable to accomplish. Since the wage gap is the log of the skill premium, it follows the same pattern as the skill

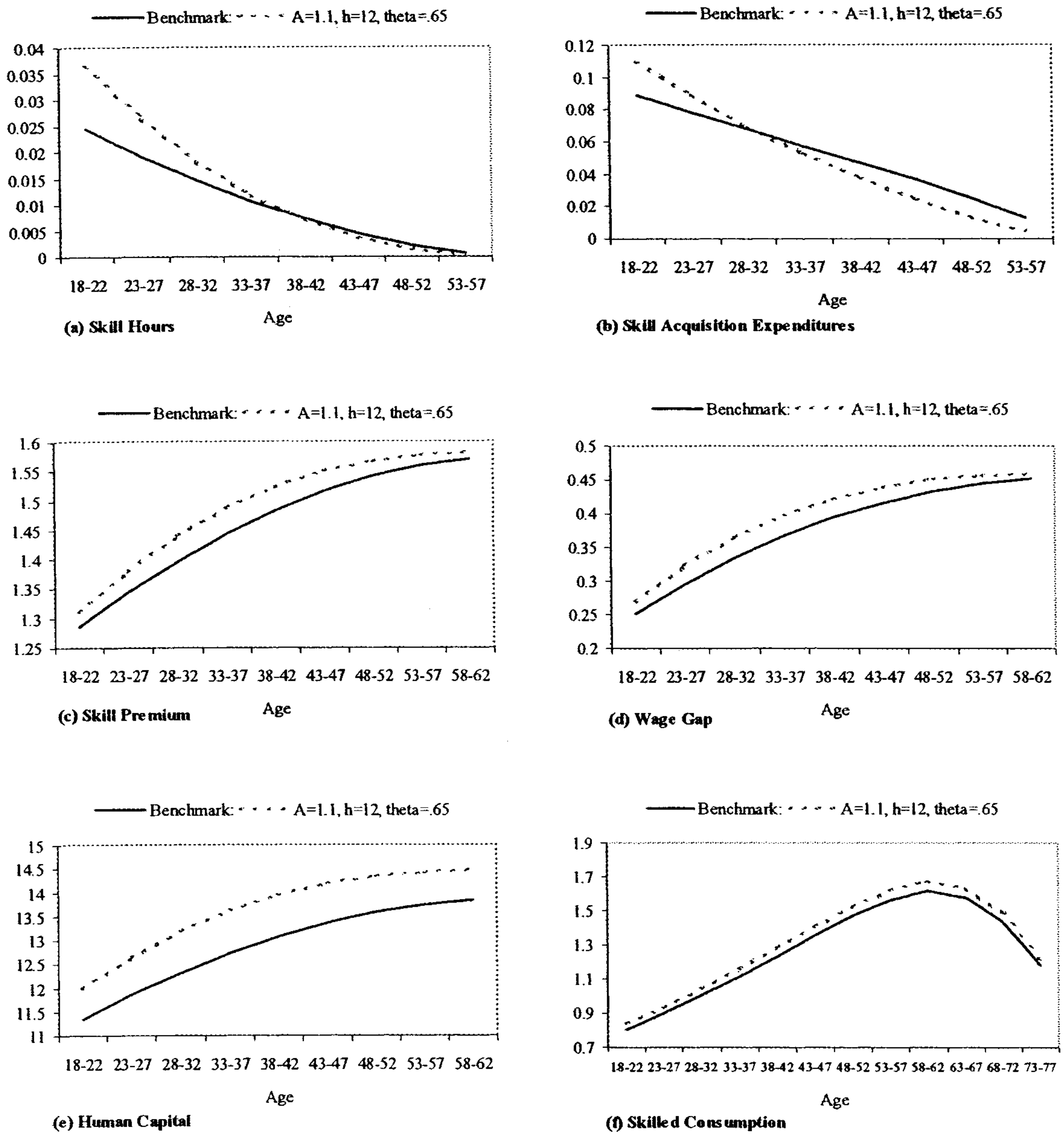

Figure 4.6: Steady-State Profiles — Increase in Combination of SBTC Parameters

premium. Finally, given that the skill premium rises, it is not surprising that consumption also rises relative to the benchmark model.

This final experiment appears to reproduce the facts set forth in chapter 3 in terms of the SBTC hypothesis, namely the existence of a substitution effect and an income effect in skill acquisition expenditures. Additionally, the model illustrates that for the older age groups, the skill premium and wage gap change very little; a fact pointed out by Card and DiNardo (2002) that they could not explain using the SBTC hypothesis. Figure 4.7 depicts the change in the wage gap verifying that the gap approaches zero suggesting that for the older age groups the wage gap does not change much relative to the benchmark level. Initially, the wage gap increases but as the worker ages the wage gap falls suggesting that a dominant income effect lowers the amount of human capital acquisition and results in both a falling skill premium and wage gap.

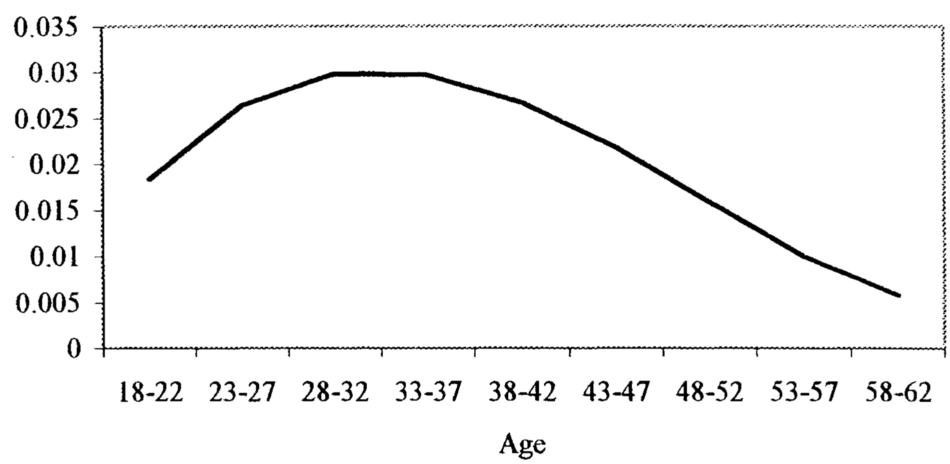

Figure 4.7: Change in the Wage Gap by Age

4.5 Summary

The following conclusions can be drawn from the numerical experiments presented in this chapter. First, although pure substitution effects resulting from extensive SBTC are consistent with the widening skill premium over time they do not explain why the skill premium has leveled off over time for the older age groups. When intensive SBTC parameters are investigated separately, they lead to either pure substitution effects — A, a mixture of substitution and income effects — θ_1 and θ_2, or have little impact at all on skill acquisition expenditures while increasing the skill premium. A combination of the three individual intensive SBTC parameters produces the results found in the empirical data although not perfectly. The comparative statics produce a widening skill premium that flattens out for the old and may be explained by an associated substitution effect for the young accompanied by an income effect that dominates for older workers. The final result provides an explanation for one of the problems that Card and DiNardo (2002) cite regarding SBTC, namely, that a strong income effect results in little change in the skill premium and thus the wage gap of the older age groups.

In the final chapter, conclusions are drawn with respect to the results of Chapters 3 and 4. If the theoretical and empirical profiles are similar, then Bound and Johnson's (1992) hypothesis that skill-biased technological change as a cause of the skill premium is supported. Additionally, given similar profiles, the importance of a dominant income effect in the older age groups provides an answer to a question relating to SBTC posed by Card and DiNardo (2002) — namely that SBTC and a wage gap that does not change much could coexist.

CHAPTER 5

SUMMARY AND CONCLUSIONS

The purpose of this dissertation has been to address the issue of the skill premium by developing a quantitative theory of the effects of skill-biased technological change (SBTC) on household investment in human capital over the life-cycle. The primary motivation for this research stems from the recent controversy regarding the causal effect of SBTC on the skill premium originally posited in the literature. Until recently, consensus within the literature regarding the widening skill premium is based upon the work of Bound and Johnson (1992) and Katz and Murphy (1992) who identify skill-biased technological change as the most likely source. Recently, however, Card and DiNardo (2002) have questioned the unicausality of the skill-biased technological change hypothesis and its effect on the wage premium. One argument is directed at the shape of the skill premium profile over time. With continuing advances in computer technology the wage gap should increase equally for every age, yet within the data, the wage gap for the older age groups has not significantly changed over time. A primary objective of this dissertation has been to develop a quantitative framework that incorporates SBTC, skill acquisition, and the skill premium in order to respond to the controversy within the literature. The approach is twofold — an empirical analysis of household higher education consumption patterns (i.e., skill acquisition profiles) and a series of theoretical numerical experiments of the impact of SBTC on skill acquisition and the skill premium.

First, empirical analysis of household higher education consumption patterns using data from the U.S. Bureau of Labor Statistic's Consumer Expenditure Survey (CE) tests for the presence of structural change over time and ascertains whether the position in the life-cycle appears to determine the relative importance of substitution and income effects that presumably arise from the increasing wage premium. To generate the consumption profiles, the empirical analysis of the dissertation is centered on a two-step analysis of the data. By utilizing a two-step approach, the endogeneity problems of omitted variable bias and sample-selection bias are eliminated. In the first stage a probit model of all consumers — those who spend on higher education and those who do not spend on higher education — is estimated to identify the probability of higher education participation. The second stage estimates an ordinary least squares (OLS) model utilizing a parameter estimate from stage one, known as the inverse Mills ratio, and other demographic and descriptive variables of those households who choose to participate in higher education. Consumption profiles are then generated from the OLS results.

Empirically, the major findings are twofold. First, the life-cycle profiles have statistically changed between the 1980s and the 1990s implying that the position in the life-cycle determines the significance of the income and substitution effects apparently arising from the increasing skill premium. This result is important because it addresses one of the concerns set forth by Card and DiNardo (2002). In the data, the wage gap for the older age groups has not significantly changed over time. Given a relatively human capital rich older generation and a dominant income effect, one would not expect the older generation to continue to purchase higher education services in order to receive the associated higher wages. Thus, the wage gap for the older age groups is not expected to change significantly over time. Second, higher education consumption expenditures display an increase in the midyears of the life-cycle, even after accounting for children and others of college age in the household. One explanation may be the existence of retooling before retirement due to perverse incentives resulting from social security or other types of retirement plans. This finding is particularly interesting since it calls into question the traditional ideas of either diminishing returns to higher education or that preferences have only an intensive margin. Consequently, it is no longer solely a demand-side issue but choices made by the labor suppliers — those purchasing higher education services — are equally as important for our understanding of the effects of skill-biased technological change.

The theoretical analysis employs an overlapping generations (OLG) model of skill acquisition given skill-biased technological change. The OLG model allows for the replication of heterogeneity in households with respect to their age, implying the replication of the higher education expenditure profiles. Thus, one is able to evaluate the comparative statics resulting from the numerical experiments of Chapter 4 to the empirical results of Chapter 3. Using model calibrations analogous to those in the literature, life-cycle profiles are solved for different levels of skill-biased technology. Analysis of the comparative statics will test the type of skill-biased technological change, extensive or intensive, required to replicate the spending profiles implied by the data.

The following conclusions can be drawn from the quantitative experiments presented in Chapter 4. First, although pure substitution effects resulting from extensive SBTC are consistent with the widening skill premium over time they do not explain why the skill premium has not changed much for the older age cohorts. Next, when intensive SBTC parameters are investigated separately, they lead to either pure substitution effects — A, pure income effects — H, a mixture of substitution and income effects — θ_1 and θ_2, or have little impact at all on skill acquisition while increasing the skill premium. Finally, a combination of the three individual intensive SBTC parameters replicates the results found in the empirical data although not perfectly. The comparative statics produce a widening skill premium that narrows for the old and may be explained by an associated substitution effect for the young accompanied by an income effect that dominates for older workers. The numerical experiment finds that given a dominant income effect for the older age groups the wage gap for that group does not change much over time. Indeed, the model demonstrates that one can have SBTC *and* wage gaps for the old that do not change much over time. Thus, this dissertation is able to provide an answer to one question posed by Card and DiNardo (2002) regarding the skill-biased technological change hypothesis. As such, one cannot reject the SBTC hypothesis as a result of wage gaps that do not change much for the older age groups.

The theoretical experiments, however, do not generate a peak in the midyears of the life-cycle as the empirical model does. One explanation may be that the numerical experiment is unable to capture such things as a change in incentives resulting from social security prior to retirement that may be driving the peak in the empirical model. Additionally, the increase in the mid-years of the life-cycle as presented in the empirical model may merely represent some change not reflected in skilled-biased technology such as delayed entry into higher education resulting from preferences or credit constraints when young. As such, the quantitative theory of SBTC partially supports the empirical results and Bound and Johnson's (1992) hypothesis that SBTC is the major cause of the widening skill premium cannot be rejected.

The next phase of this research aims to incorporate measures to better reflect the increase in skill acquisition in the mid-years of the life-cycle as well as using alternative human capital production technology specifications. While more complicated, incorporating social security into the OLG model is one way to try to refine the quantitative theory. Additionally, incorporating a measure of credit constraints for the young into the OLG framework may work as an alternative method for generating an increase in skill acquisition in the mid-years of the life-cycle.

Another opportunity for future research on SBTC would develop the human capital production technology such that the intensive SBTC parameter A, ability to "learn", is skill hour augmenting. In that case, the parameter enters the function with skill hours and is impacted by the private return to skill hours. Thus, increasing the return to skill hours by such means as Internet technology on campuses will have an affect on skill hours as well as the SBTC parameter ability to "learn". An alternate method would make the parameter human capital augmenting so that it enters the human capital production technology through the existing level of human capital.

While this research has built upon the literature regarding both extensive and intensive SBTC, it is only a beginning. There are multiple factors that can potentially impact the growth of SBTC and its relationship to human capital production and the acquisition of skills; such factors may include, but are not limited to, government policy toward human capital investment such as lottery scholarships and extending financial aid, K-12 policy such as No Child Left Behind with resulting spill-over effects into higher education, the general public's perception of the importance of higher education, and research and development programs designed to continually improve technological infrastructure within universities, firms, and communities alike.

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APPENDIXES

Appendix A
Data Appendix

Table A.1: Total Higher Education Enrollment by Age & Year, in thousands

	1987	1991	1993	1995	1997	1999
All Students	12,767	14,359	14,305	14,262	14,502	14,791
Less than 18	207	214	246	285	353	384
18-19	2,697	2,594	2,722	2,796	2,969	3,182
20-21	2,392	2,753	2,607	2,617	2,727	2,873
22-24	2,026	2,151	2,492	2,357	2,305	2,338
25-29	1,840	1,898	2,026	2,114	2,126	2,033
30-34	1,242	1,270	1,338	1,295	1,208	1,157
35-39	883	966	1,020	980	936	888
40-49	872	1,054	1,181	1,235	1,229	1,191
50-64	292	282	339	356	407	442
65 and up	103	64	78	81	79	77
Age Unknown	214	1,115	255	145	162	228

Source: Various issues of *Digest of Education Statistics*, 2002: Table 175, 2000: Table 176, 1998: Table 175, 1996 and 1994: Table 172, and 1992: Table 163.

Table A.2: Log of Mean Higher Education Expenditures

Age Cohort	N	1980s	1990s
Less than 20	104	6.678295	6.946313
20-24	317	6.616596	6.963771
25-29	224	6.607106	7.026152
30-34	153	6.245165	6.846984
35-39	162	6.254638	6.686361
40-44	215	6.786233	6.817324
45-49	269	7.194984	7.27047
50-54	227	7.387009	7.661752
55-59	104	7.261333	7.314901
60-64	63	7.055314	7.111998
65-69	24	6.936522	6.281946
70 and up	15	7.312224	6.760234

Table A.3: Change in the Probability of Higher Education Participation Over the Life-Cycle

1980s/ Age	normsdist	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*urb*	*lrinc*	*uer*	*lrtui*
18	0.142	-1.073	1.257	-3.537	1.520	-0.220	0.204	0.742	-0.161	-0.879
19	0.128	-1.134	1.257	-3.734	1.694	-0.259	0.204	0.742	-0.161	-0.879
20	0.117	-1.191	1.257	-3.930	1.877	-0.302	0.204	0.742	-0.161	-0.879
21	0.107	-1.243	1.257	-4.127	2.069	-0.349	0.204	0.742	-0.161	-0.879
22	0.099	-1.290	1.257	-4.323	2.271	-0.401	0.204	0.742	-0.161	-0.879
23	0.091	-1.332	1.257	-4.520	2.482	-0.459	0.204	0.742	-0.161	-0.879
24	0.085	-1.371	1.257	-4.716	2.703	-0.521	0.204	0.742	-0.161	-0.879
25	0.080	-1.405	1.257	-4.913	2.933	-0.589	0.204	0.742	-0.161	-0.879
26	0.076	-1.436	1.257	-5.109	3.172	-0.663	0.204	0.742	-0.161	-0.879
27	0.072	-1.463	1.257	-5.306	3.421	-0.742	0.204	0.742	-0.161	-0.879
28	0.068	-1.487	1.257	-5.502	3.679	-0.828	0.204	0.742	-0.161	-0.879
29	0.066	-1.508	1.257	-5.699	3.946	-0.919	0.204	0.742	-0.161	-0.879
30	0.063	-1.526	1.257	-5.895	4.223	-1.018	0.204	0.742	-0.161	-0.879
31	0.062	-1.542	1.257	-6.092	4.509	-1.123	0.204	0.742	-0.161	-0.879
32	0.060	-1.555	1.257	-6.288	4.805	-1.235	0.204	0.742	-0.161	-0.879
33	0.059	-1.566	1.257	-6.485	5.110	-1.355	0.204	0.742	-0.161	-0.879
34	0.058	-1.575	1.257	-6.681	5.424	-1.482	0.204	0.742	-0.161	-0.879
35	0.057	-1.582	1.257	-6.878	5.748	-1.616	0.204	0.742	-0.161	-0.879
36	0.056	-1.588	1.257	-7.074	6.081	-1.759	0.204	0.742	-0.161	-0.879
37	0.056	-1.593	1.257	-7.271	6.424	-1.910	0.204	0.742	-0.161	-0.879
38	0.055	-1.596	1.257	-7.467	6.776	-2.069	0.204	0.742	-0.161	-0.879
39	0.055	-1.599	1.257	-7.664	7.137	-2.236	0.204	0.742	-0.161	-0.879
40	0.055	-1.602	1.257	-7.860	7.508	-2.413	0.204	0.742	-0.161	-0.879
41	0.054	-1.604	1.257	-8.057	7.888	-2.598	0.204	0.742	-0.161	-0.879
42	0.054	-1.605	1.257	-8.253	8.277	-2.793	0.204	0.742	-0.161	-0.879

Table A.3: Change in the Probability of Higher Education Participation Over the Life-Cycle

1980s/ Age	normsdist	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*urb*	*lrinc*	*uer*	*lrtui*
43	0.054	-1.607	1.257	-8.450	8.676	-2.997	0.204	0.742	-0.161	-0.879
44	0.054	-1.610	1.257	-8.646	9.084	-3.211	0.204	0.742	-0.161	-0.879
45	0.053	-1.613	1.257	-8.843	9.502	-3.435	0.204	0.742	-0.161	-0.879
46	0.053	-1.616	1.257	-9.039	9.929	-3.670	0.204	0.742	-0.161	-0.879
47	0.053	-1.621	1.257	-9.236	10.365	-3.914	0.204	0.742	-0.161	-0.879
48	0.052	-1.627	1.257	-9.432	10.811	-4.169	0.204	0.742	-0.161	-0.879
49	0.051	-1.634	1.257	-9.629	11.266	-4.435	0.204	0.742	-0.161	-0.879
50	0.050	-1.643	1.257	-9.825	11.731	-4.713	0.204	0.742	-0.161	-0.879
51	0.049	-1.654	1.257	-10.022	12.204	-5.001	0.204	0.742	-0.161	-0.879
52	0.048	-1.668	1.257	-10.218	12.688	-5.301	0.204	0.742	-0.161	-0.879
53	0.046	-1.683	1.257	-10.415	13.180	-5.613	0.204	0.742	-0.161	-0.879
54	0.044	-1.701	1.257	-10.611	13.682	-5.936	0.204	0.742	-0.161	-0.879
55	0.043	-1.722	1.257	-10.808	14.194	-6.272	0.204	0.742	-0.161	-0.879
56	0.040	-1.746	1.257	-11.004	14.715	-6.621	0.204	0.742	-0.161	-0.879
57	0.038	-1.774	1.257	-11.201	15.245	-6.982	0.204	0.742	-0.161	-0.879
58	0.036	-1.805	1.257	-11.397	15.785	-7.356	0.204	0.742	-0.161	-0.879
59	0.033	-1.839	1.257	-11.594	16.334	-7.743	0.204	0.742	-0.161	-0.879
60	0.030	-1.878	1.257	-11.790	16.892	-8.143	0.204	0.742	-0.161	-0.879
61	0.027	-1.920	1.257	-11.987	17.460	-8.557	0.204	0.742	-0.161	-0.879
62	0.025	-1.968	1.257	-12.183	18.037	-8.985	0.204	0.742	-0.161	-0.879
63	0.022	-2.019	1.257	-12.380	18.623	-9.427	0.204	0.742	-0.161	-0.879
64	0.019	-2.076	1.257	-12.576	19.219	-9.883	0.204	0.742	-0.161	-0.879
65	0.016	-2.138	1.257	-12.773	19.825	-10.353	0.204	0.742	-0.161	-0.879
66	0.014	-2.205	1.257	-12.969	20.439	-10.839	0.204	0.742	-0.161	-0.879
67	0.011	-2.277	1.257	-13.166	21.063	-11.339	0.204	0.742	-0.161	-0.879

Table A.3: Change in the Probability of Higher Education Participation Over the Life-Cycle

1980s/ Age	normsdist	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*urb*	*lrinc*	*uer*	*lrtui*
68	0.009	-2.356	1.257	-13.362	21.697	-11.854	0.204	0.742	-0.161	-0.879
69	0.007	-2.440	1.257	-13.559	22.340	-12.385	0.204	0.742	-0.161	-0.879
70	0.006	-2.531	1.257	-13.755	22.992	-12.931	0.204	0.742	-0.161	-0.879
71	0.004	-2.628	1.257	-13.952	23.653	-13.493	0.204	0.742	-0.161	-0.879
72	0.003	-2.731	1.257	-14.148	24.324	-14.071	0.204	0.742	-0.161	-0.879
73	0.002	-2.842	1.257	-14.345	25.005	-14.666	0.204	0.742	-0.161	-0.879
74	0.002	-2.960	1.257	-14.541	25.694	-15.277	0.204	0.742	-0.161	-0.879
75	0.001	-3.085	1.257	-14.738	26.394	-15.905	0.204	0.742	-0.161	-0.879
76	0.001	-3.218	1.257	-14.934	27.102	-16.549	0.204	0.742	-0.161	-0.879
77	0.000	-3.358	1.257	-15.131	27.820	-17.211	0.204	0.742	-0.161	-0.879
78	0.000	-3.507	1.257	-15.327	28.547	-17.891	0.204	0.742	-0.161	-0.879
79	0.000	-3.663	1.257	-15.524	29.284	-18.588	0.204	0.742	-0.161	-0.879
80	0.000	-3.829	1.257	-15.720	30.030	-19.302	0.204	0.742	-0.161	-0.879

1990s/ Age	normsdist	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*lrinc*	*uer*	*lrtui*
18	0.471	-0.073	1.257	-3.537	1.520	-0.220	1.878	-2.894	1.324	-0.188	0.204	0.742	-0.161	-0.910
19	0.429	-0.178	1.257	-3.734	1.694	-0.259	1.878	-3.055	1.475	-0.221	0.204	0.742	-0.161	-0.910
20	0.393	-0.272	1.257	-3.930	1.877	-0.302	1.878	-3.215	1.635	-0.258	0.204	0.742	-0.161	-0.910
21	0.360	-0.358	1.257	-4.127	2.069	-0.349	1.878	-3.376	1.802	-0.298	0.204	0.742	-0.161	-0.910
22	0.332	-0.435	1.257	-4.323	2.271	-0.401	1.878	-3.537	1.978	-0.343	0.204	0.742	-0.161	-0.910
23	0.307	-0.503	1.257	-4.520	2.482	-0.459	1.878	-3.698	2.162	-0.392	0.204	0.742	-0.161	-0.910
24	0.287	-0.564	1.257	-4.716	2.703	-0.521	1.878	-3.858	2.354	-0.445	0.204	0.742	-0.161	-0.910
25	0.269	-0.617	1.257	-4.913	2.933	-0.589	1.878	-4.019	2.554	-0.503	0.204	0.742	-0.161	-0.910

Table A.3: Change in the Probability of Higher Education Participation Over the Life-Cycle

1990s/ Age	normsdist	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*lrinc*	*uer*	*lrtui*
26	0.254	-0.662	1.257	-5.109	3.172	-0.663	1.878	-4.180	2.762	-0.566	0.204	0.742	-0.161	-0.910
27	0.241	-0.702	1.257	-5.306	3.421	-0.742	1.878	-4.341	2.979	-0.634	0.204	0.742	-0.161	-0.910
28	0.231	-0.735	1.257	-5.502	3.679	-0.828	1.878	-4.501	3.204	-0.707	0.204	0.742	-0.161	-0.910
29	0.223	-0.762	1.257	-5.699	3.946	-0.919	1.878	-4.662	3.437	-0.785	0.204	0.742	-0.161	-0.910
30	0.217	-0.784	1.257	-5.895	4.223	-1.018	1.878	-4.823	3.678	-0.869	0.204	0.742	-0.161	-0.910
31	0.212	-0.801	1.257	-6.092	4.509	-1.123	1.878	-4.984	3.927	-0.959	0.204	0.742	-0.161	-0.910
32	0.208	-0.813	1.257	-6.288	4.805	-1.235	1.878	-5.144	4.184	-1.055	0.204	0.742	-0.161	-0.910
33	0.206	-0.821	1.257	-6.485	5.110	-1.355	1.878	-5.305	4.450	-1.157	0.204	0.742	-0.161	-0.910
34	0.204	-0.826	1.257	-6.681	5.424	-1.482	1.878	-5.466	4.724	-1.266	0.204	0.742	-0.161	-0.910
35	0.204	-0.827	1.257	-6.878	5.748	-1.616	1.878	-5.627	5.006	-1.381	0.204	0.742	-0.161	-0.910
36	0.205	-0.825	1.257	-7.074	6.081	-1.759	1.878	-5.788	5.296	-1.502	0.204	0.742	-0.161	-0.910
37	0.206	-0.821	1.257	-7.271	6.424	-1.910	1.878	-5.948	5.594	-1.631	0.204	0.742	-0.161	-0.910
38	0.208	-0.815	1.257	-7.467	6.776	-2.069	1.878	-6.109	5.901	-1.767	0.204	0.742	-0.161	-0.910
39	0.210	-0.807	1.257	-7.664	7.137	-2.236	1.878	-6.270	6.215	-1.910	0.204	0.742	-0.161	-0.910
40	0.212	-0.798	1.257	-7.860	7.508	-2.413	1.878	-6.431	6.538	-2.061	0.204	0.742	-0.161	-0.910
41	0.215	-0.788	1.257	-8.057	7.888	-2.598	1.878	-6.591	6.869	-2.219	0.204	0.742	-0.161	-0.910
42	0.218	-0.778	1.257	-8.253	8.277	-2.793	1.878	-6.752	7.208	-2.386	0.204	0.742	-0.161	-0.910
43	0.221	-0.768	1.257	-8.450	8.676	-2.997	1.878	-6.913	7.556	-2.560	0.204	0.742	-0.161	-0.910
44	0.224	-0.758	1.257	-8.646	9.084	-3.211	1.878	-7.074	7.911	-2.743	0.204	0.742	-0.161	-0.910
45	0.227	-0.749	1.257	-8.843	9.502	-3.435	1.878	-7.234	8.275	-2.934	0.204	0.742	-0.161	-0.910
46	0.229	-0.742	1.257	-9.039	9.929	-3.670	1.878	-7.395	8.647	-3.134	0.204	0.742	-0.161	-0.910
47	0.231	-0.736	1.257	-9.236	10.365	-3.914	1.878	-7.556	9.027	-3.343	0.204	0.742	-0.161	-0.910
48	0.232	-0.733	1.257	-9.432	10.811	-4.169	1.878	-7.717	9.415	-3.561	0.204	0.742	-0.161	-0.910
49	0.232	-0.732	1.257	-9.629	11.266	-4.435	1.878	-7.877	9.811	-3.788	0.204	0.742	-0.161	-0.910
50	0.232	-0.734	1.257	-9.825	11.731	-4.713	1.878	-8.038	10.216	-4.025	0.204	0.742	-0.161	-0.910

Table A.3: Change in the Probability of Higher Education Participation Over the Life-Cycle

1990s/ Age	normsdist	Log High Ed Cons.	*constant*	*agel*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*lrinc*	*uer*	*lrtui*
51	0.230	-0.739	1.257	-10.022	12.204	-5.001	1.878	-8.199	10.628	-4.271	0.204	0.742	-0.161	-0.910
52	0.227	-0.749	1.257	-10.218	12.688	-5.301	1.878	-8.360	11.049	-4.528	0.204	0.742	-0.161	-0.910
53	0.223	-0.762	1.257	-10.415	13.180	-5.613	1.878	-8.520	11.478	-4.794	0.204	0.742	-0.161	-0.910
54	0.218	-0.780	1.257	-10.611	13.682	-5.936	1.878	-8.681	11.916	-5.070	0.204	0.742	-0.161	-0.910
55	0.211	-0.804	1.257	-10.808	14.194	-6.272	1.878	-8.842	12.361	-5.357	0.204	0.742	-0.161	-0.910
56	0.203	-0.832	1.257	-11.004	14.715	-6.621	1.878	-9.003	12.815	-5.655	0.204	0.742	-0.161	-0.910
57	0.193	-0.867	1.257	-11.201	15.245	-6.982	1.878	-9.164	13.276	-5.963	0.204	0.742	-0.161	-0.910
58	0.182	-0.908	1.257	-11.397	15.785	-7.356	1.878	-9.324	13.746	-6.283	0.204	0.742	-0.161	-0.910
59	0.170	-0.956	1.257	-11.594	16.334	-7.743	1.878	-9.485	14.224	-6.613	0.204	0.742	-0.161	-0.910
60	0.156	-1.011	1.257	-11.790	16.892	-8.143	1.878	-9.646	14.711	-6.955	0.204	0.742	-0.161	-0.910
61	0.141	-1.074	1.257	-11.987	17.460	-8.557	1.878	-9.807	15.205	-7.309	0.204	0.742	-0.161	-0.910
62	0.126	-1.144	1.257	-12.183	18.037	-8.985	1.878	-9.967	15.708	-7.674	0.204	0.742	-0.161	-0.910
63	0.111	-1.223	1.257	-12.380	18.623	-9.427	1.878	-10.128	16.219	-8.052	0.204	0.742	-0.161	-0.910
64	0.095	-1.311	1.257	-12.576	19.219	-9.883	1.878	-10.289	16.737	-8.441	0.204	0.742	-0.161	-0.910
65	0.079	-1.409	1.257	-12.773	19.825	-10.353	1.878	-10.450	17.265	-8.843	0.204	0.742	-0.161	-0.910
66	0.065	-1.516	1.257	-12.969	20.439	-10.839	1.878	-10.610	17.800	-9.257	0.204	0.742	-0.161	-0.910
67	0.051	-1.633	1.257	-13.166	21.063	-11.339	1.878	-10.771	18.343	-9.685	0.204	0.742	-0.161	-0.910
68	0.039	-1.760	1.257	-13.362	21.697	-11.854	1.878	-10.932	18.895	-10.125	0.204	0.742	-0.161	-0.910
69	0.029	-1.899	1.257	-13.559	22.340	-12.385	1.878	-11.093	19.455	-10.578	0.204	0.742	-0.161	-0.910
70	0.020	-2.049	1.257	-13.755	22.992	-12.931	1.878	-11.253	20.023	-11.045	0.204	0.742	-0.161	-0.910
71	0.014	-2.211	1.257	-13.952	23.653	-13.493	1.878	-11.414	20.599	-11.525	0.204	0.742	-0.161	-0.910
72	0.009	-2.385	1.257	-14.148	24.324	-14.071	1.878	-11.575	21.183	-12.019	0.204	0.742	-0.161	-0.910
73	0.005	-2.571	1.257	-14.345	25.005	-14.666	1.878	-11.736	21.776	-12.526	0.204	0.742	-0.161	-0.910
74	0.003	-2.771	1.257	-14.541	25.694	-15.277	1.878	-11.897	22.377	-13.048	0.204	0.742	-0.161	-0.910
75	0.001	-2.984	1.257	-14.738	26.394	-15.905	1.878	-12.057	22.985	-13.584	0.204	0.742	-0.161	-0.910

Table A.3: Change in the Probability of Higher Education Participation Over the Life-Cycle

1990s/ Age	normsdist	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*lrinc*	*uer*	*lrtui*
76	0.001	-3.211	1.257	-14.934	27.102	-16.549	1.878	-12.218	23.602	-14.135	0.204	0.742	-0.161	-0.910
77	0.000	-3.453	1.257	-15.131	27.820	-17.211	1.878	-12.379	24.228	-14.700	0.204	0.742	-0.161	-0.910
78	0.000	-3.709	1.257	-15.327	28.547	-17.891	1.878	-12.540	24.861	-15.281	0.204	0.742	-0.161	-0.910
79	0.000	-3.980	1.257	-15.524	29.284	-18.588	1.878	-12.700	25.503	-15.876	0.204	0.742	-0.161	-0.910
80	0.000	-4.267	1.257	-15.720	30.030	-19.302	1.878	-12.861	26.152	-16.486	0.204	0.742	-0.161	-0.910

Table A.4: Log of Higher Education Consumption: Single Household with Some College Education

1980s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*urb*	*rinc*	*uer*	*imr*
18	5.517	9.498	-13.963	6.036	-0.840	0.464	1.235	-0.376	3.464
19	5.283	9.498	-14.739	6.726	-0.988	0.464	1.235	-0.376	3.464
20	5.069	9.498	-15.514	7.452	-1.153	0.464	1.235	-0.376	3.464
21	4.876	9.498	-16.290	8.216	-1.335	0.464	1.235	-0.376	3.464
22	4.701	9.498	-17.066	9.017	-1.534	0.464	1.235	-0.376	3.464
23	4.545	9.498	-17.841	9.856	-1.753	0.464	1.235	-0.376	3.464
24	4.406	9.498	-18.617	10.731	-1.992	0.464	1.235	-0.376	3.464
25	4.284	9.498	-19.393	11.644	-2.252	0.464	1.235	-0.376	3.464
26	4.177	9.498	-20.169	12.594	-2.533	0.464	1.235	-0.376	3.464
27	4.085	9.498	-20.944	13.582	-2.836	0.464	1.235	-0.376	3.464
28	4.007	9.498	-21.720	14.606	-3.163	0.464	1.235	-0.376	3.464
29	3.942	9.498	-22.496	15.668	-3.514	0.464	1.235	-0.376	3.464
30	3.890	9.498	-23.271	16.768	-3.891	0.464	1.235	-0.376	3.464
31	3.848	9.498	-24.047	17.904	-4.293	0.464	1.235	-0.376	3.464
32	3.817	9.498	-24.823	19.078	-4.722	0.464	1.235	-0.376	3.464
33	3.796	9.498	-25.599	20.289	-5.179	0.464	1.235	-0.376	3.464
34	3.783	9.498	-26.374	21.537	-5.664	0.464	1.235	-0.376	3.464
35	3.778	9.498	-27.150	22.822	-6.178	0.464	1.235	-0.376	3.464
36	3.781	9.498	-27.926	24.145	-6.723	0.464	1.235	-0.376	3.464
37	3.789	9.498	-28.701	25.505	-7.299	0.464	1.235	-0.376	3.464
38	3.802	9.498	-29.477	26.903	-7.907	0.464	1.235	-0.376	3.464
39	3.821	9.498	-30.253	28.337	-8.548	0.464	1.235	-0.376	3.464

Table A.4: Log of Higher Education Consumption: Single Household with Some College Education

1980s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*urb*	*rinc*	*uer*	*imr*
40	3.842	9.498	-31.029	29.809	-9.222	0.464	1.235	-0.376	3.464
41	3.866	9.498	-31.804	31.318	-9.932	0.464	1.235	-0.376	3.464
42	3.892	9.498	-32.580	32.864	-10.676	0.464	1.235	-0.376	3.464
43	3.919	9.498	-33.356	34.448	-11.457	0.464	1.235	-0.376	3.464
44	3.946	9.498	-34.131	36.069	-12.275	0.464	1.235	-0.376	3.464
45	3.973	9.498	-34.907	37.727	-13.131	0.464	1.235	-0.376	3.464
46	3.997	9.498	-35.683	39.422	-14.026	0.464	1.235	-0.376	3.464
47	4.020	9.498	-36.459	41.155	-14.961	0.464	1.235	-0.376	3.464
48	4.038	9.498	-37.234	42.925	-15.936	0.464	1.235	-0.376	3.464
49	4.053	9.498	-38.010	44.732	-16.953	0.464	1.235	-0.376	3.464
50	4.062	9.498	-38.786	46.577	-18.013	0.464	1.235	-0.376	3.464
51	4.066	9.498	-39.562	48.458	-19.115	0.464	1.235	-0.376	3.464
52	4.062	9.498	-40.337	50.377	-20.262	0.464	1.235	-0.376	3.464
53	4.051	9.498	-41.113	52.333	-21.453	0.464	1.235	-0.376	3.464
54	4.032	9.498	-41.889	54.327	-22.691	0.464	1.235	-0.376	3.464
55	4.003	9.498	-42.664	56.358	-23.975	0.464	1.235	-0.376	3.464
56	3.963	9.498	-43.440	58.426	-25.306	0.464	1.235	-0.376	3.464
57	3.913	9.498	-44.216	60.531	-26.686	0.464	1.235	-0.376	3.464
58	3.850	9.498	-44.992	62.673	-28.116	0.464	1.235	-0.376	3.464
59	3.775	9.498	-45.767	64.853	-29.595	0.464	1.235	-0.376	3.464
60	3.686	9.498	-46.543	67.070	-31.126	0.464	1.235	-0.376	3.464
61	3.582	9.498	-47.319	69.324	-32.708	0.464	1.235	-0.376	3.464
62	3.463	9.498	-48.094	71.616	-34.343	0.464	1.235	-0.376	3.464
63	3.327	9.498	-48.870	73.945	-36.032	0.464	1.235	-0.376	3.464
64	3.174	9.498	-49.646	76.311	-37.775	0.464	1.235	-0.376	3.464

Table A.4: Log of Higher Education Consumption: Single Household with Some College Education

1980s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*urb*	*rinc*	*uer*	*imr*
65	3.003	9.498	-50.422	78.714	-39.573	0.464	1.235	-0.376	3.464
66	2.814	9.498	-51.197	81.155	-41.428	0.464	1.235	-0.376	3.464
67	2.604	9.498	-51.973	83.633	-43.340	0.464	1.235	-0.376	3.464
68	2.374	9.498	-52.749	86.148	-45.310	0.464	1.235	-0.376	3.464
69	2.122	9.498	-53.524	88.700	-47.338	0.464	1.235	-0.376	3.464
70	1.848	9.498	-54.300	91.290	-49.426	0.464	1.235	-0.376	3.464
71	1.550	9.498	-55.076	93.917	-51.575	0.464	1.235	-0.376	3.464
72	1.229	9.498	-55.852	96.581	-53.785	0.464	1.235	-0.376	3.464
73	0.882	9.498	-56.627	99.282	-56.057	0.464	1.235	-0.376	3.464
74	0.510	9.498	-57.403	102.021	-58.393	0.464	1.235	-0.376	3.464
75	0.110	9.498	-58.179	104.797	-60.792	0.464	1.235	-0.376	3.464
76	-0.316	9.498	-58.954	107.610	-63.256	0.464	1.235	-0.376	3.464
77	-0.772	9.498	-59.730	110.461	-65.786	0.464	1.235	-0.376	3.464
78	-1.256	9.498	-60.506	113.349	-68.383	0.464	1.235	-0.376	3.464
79	-1.771	9.498	-61.282	116.274	-71.047	0.464	1.235	-0.376	3.464
80	-2.316	9.498	-62.057	119.236	-73.779	0.464	1.235	-0.376	3.464

1990s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*rinc*	*uer*	*imr*
18	6.323	9.498	-13.963	6.036	-0.840	5.979	-8.546	3.952	-0.579	0.464	1.235	-0.376	3.464
19	5.963	9.498	-14.739	6.726	-0.988	5.979	-9.021	4.403	-0.681	0.464	1.235	-0.376	3.464
20	5.637	9.498	-15.514	7.452	-1.153	5.979	-9.495	4.879	-0.794	0.464	1.235	-0.376	3.464
21	5.343	9.498	-16.290	8.216	-1.335	5.979	-9.970	5.379	-0.920	0.464	1.235	-0.376	3.464
22	5.081	9.498	-17.066	9.017	-1.534	5.979	-10.445	5.903	-1.057	0.464	1.235	-0.376	3.464

Table A.4: Log of Higher Education Consumption: Single Household with Some College Education

1990s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*rinc*	*uer*	*imr*
23	4.848	9.498	-17.841	9.856	-1.753	5.979	-10.920	6.452	-1.208	0.464	1.235	-0.376	3.464
24	4.643	9.498	-18.617	10.731	-1.992	5.979	-11.394	7.025	-1.373	0.464	1.235	-0.376	3.464
25	4.465	9.498	-19.393	11.644	-2.252	5.979	-11.869	7.623	-1.552	0.464	1.235	-0.376	3.464
26	4.311	9.498	-20.169	12.594	-2.533	5.979	-12.344	8.245	-1.745	0.464	1.235	-0.376	3.464
27	4.182	9.498	-20.944	13.582	-2.836	5.979	-12.819	8.891	-1.955	0.464	1.235	-0.376	3.464
28	4.075	9.498	-21.720	14.606	-3.163	5.979	-13.294	9.562	-2.180	0.464	1.235	-0.376	3.464
29	3.988	9.498	-22.496	15.668	-3.514	5.979	-13.768	10.257	-2.422	0.464	1.235	-0.376	3.464
30	3.921	9.498	-23.271	16.768	-3.891	5.979	-14.243	10.977	-2.681	0.464	1.235	-0.376	3.464
31	3.872	9.498	-24.047	17.904	-4.293	5.979	-14.718	11.721	-2.958	0.464	1.235	-0.376	3.464
32	3.839	9.498	-24.823	19.078	-4.722	5.979	-15.193	12.489	-3.254	0.464	1.235	-0.376	3.464
33	3.821	9.498	-25.599	20.289	-5.179	5.979	-15.667	13.282	-3.569	0.464	1.235	-0.376	3.464
34	3.816	9.498	-26.374	21.537	-5.664	5.979	-16.142	14.099	-3.903	0.464	1.235	-0.376	3.464
35	3.823	9.498	-27.150	22.822	-6.178	5.979	-16.617	14.941	-4.257	0.464	1.235	-0.376	3.464
36	3.841	9.498	-27.926	24.145	-6.723	5.979	-17.092	15.807	-4.633	0.464	1.235	-0.376	3.464
37	3.868	9.498	-28.701	25.505	-7.299	5.979	-17.566	16.697	-5.030	0.464	1.235	-0.376	3.464
38	3.903	9.498	-29.477	26.903	-7.907	5.979	-18.041	17.612	-5.449	0.464	1.235	-0.376	3.464
39	3.944	9.498	-30.253	28.337	-8.548	5.979	-18.516	18.551	-5.890	0.464	1.235	-0.376	3.464
40	3.989	9.498	-31.029	29.809	-9.222	5.979	-18.991	19.515	-6.355	0.464	1.235	-0.376	3.464
41	4.038	9.498	-31.804	31.318	-9.932	5.979	-19.466	20.503	-6.844	0.464	1.235	-0.376	3.464
42	4.089	9.498	-32.580	32.864	-10.676	5.979	-19.940	21.515	-7.357	0.464	1.235	-0.376	3.464
43	4.140	9.498	-33.356	34.448	-11.457	5.979	-20.415	22.552	-7.895	0.464	1.235	-0.376	3.464
44	4.189	9.498	-34.131	36.069	-12.275	5.979	-20.890	23.613	-8.459	0.464	1.235	-0.376	3.464
45	4.236	9.498	-34.907	37.727	-13.131	5.979	-21.365	24.698	-9.049	0.464	1.235	-0.376	3.464
46	4.279	9.498	-35.683	39.422	-14.026	5.979	-21.839	25.808	-9.665	0.464	1.235	-0.376	3.464
47	4.317	9.498	-36.459	41.155	-14.961	5.979	-22.314	26.943	-10.310	0.464	1.235	-0.376	3.464

Table A.4: Log of Higher Education Consumption: Single Household with Some College Education

1990s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*rinc*	*uer*	*imr*
48	4.347	9.498	-37.234	42.925	-15.936	5.979	-22.789	28.101	-10.982	0.464	1.235	-0.376	3.464
49	4.370	9.498	-38.010	44.732	-16.953	5.979	-23.264	29.284	-11.683	0.464	1.235	-0.376	3.464
50	4.382	9.498	-38.786	46.577	-18.013	5.979	-23.738	30.492	-12.413	0.464	1.235	-0.376	3.464
51	4.383	9.498	-39.562	48.458	-19.115	5.979	-24.213	31.724	-13.172	0.464	1.235	-0.376	3.464
52	4.371	9.498	-40.337	50.377	-20.262	5.979	-24.688	32.980	-13.962	0.464	1.235	-0.376	3.464
53	4.344	9.498	-41.113	52.333	-21.453	5.979	-25.163	34.261	-14.783	0.464	1.235	-0.376	3.464
54	4.302	9.498	-41.889	54.327	-22.691	5.979	-25.638	35.566	-15.636	0.464	1.235	-0.376	3.464
55	4.243	9.498	-42.664	56.358	-23.975	5.979	-26.112	36.895	-16.521	0.464	1.235	-0.376	3.464
56	4.165	9.498	-43.440	58.426	-25.306	5.979	-26.587	38.249	-17.439	0.464	1.235	-0.376	3.464
57	4.067	9.498	-44.216	60.531	-26.686	5.979	-27.062	39.627	-18.390	0.464	1.235	-0.376	3.464
58	3.947	9.498	-44.992	62.673	-28.116	5.979	-27.537	41.030	-19.375	0.464	1.235	-0.376	3.464
59	3.805	9.498	-45.767	64.853	-29.595	5.979	-28.011	42.457	-20.394	0.464	1.235	-0.376	3.464
60	3.638	9.498	-46.543	67.070	-31.126	5.979	-28.486	43.908	-21.449	0.464	1.235	-0.376	3.464
61	3.444	9.498	-47.319	69.324	-32.708	5.979	-28.961	45.384	-22.539	0.464	1.235	-0.376	3.464
62	3.224	9.498	-48.094	71.616	-34.343	5.979	-29.436	46.884	-23.666	0.464	1.235	-0.376	3.464
63	2.974	9.498	-48.870	73.945	-36.032	5.979	-29.910	48.409	-24.830	0.464	1.235	-0.376	3.464
64	2.694	9.498	-49.646	76.311	-37.775	5.979	-30.385	49.958	-26.031	0.464	1.235	-0.376	3.464
65	2.383	9.498	-50.422	78.714	-39.573	5.979	-30.860	51.531	-27.270	0.464	1.235	-0.376	3.464
66	2.038	9.498	-51.197	81.155	-41.428	5.979	-31.335	53.129	-28.548	0.464	1.235	-0.376	3.464
67	1.658	9.498	-51.973	83.633	-43.340	5.979	-31.810	54.751	-29.866	0.464	1.235	-0.376	3.464
68	1.242	9.498	-52.749	86.148	-45.310	5.979	-32.284	56.398	-31.223	0.464	1.235	-0.376	3.464
69	0.789	9.498	-53.524	88.700	-47.338	5.979	-32.759	58.068	-32.621	0.464	1.235	-0.376	3.464
70	0.296	9.498	-54.300	91.290	-49.426	5.979	-33.234	59.764	-34.060	0.464	1.235	-0.376	3.464
71	-0.237	9.498	-55.076	93.917	-51.575	5.979	-33.709	61.484	-35.541	0.464	1.235	-0.376	3.464
72	-0.812	9.498	-55.852	96.581	-53.785	5.979	-34.183	63.228	-37.064	0.464	1.235	-0.376	3.464

Table A.4: Log of Higher Education Consumption: Single Household with Some College Education

1990s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*rinc*	*uer*	*imr*
73	-1.431	9.498	-56.627	99.282	-56.057	5.979	-34.658	64.996	-38.629	0.464	1.235	-0.376	3.464
74	-2.094	9.498	-57.403	102.021	-58.393	5.979	-35.133	66.789	-40.239	0.464	1.235	-0.376	3.464
75	-2.804	9.498	-58.179	104.797	-60.792	5.979	-35.608	68.606	-41.892	0.464	1.235	-0.376	3.464
76	-3.562	9.498	-58.954	107.610	-63.256	5.979	-36.082	70.448	-43.590	0.464	1.235	-0.376	3.464
77	-4.370	9.498	-59.730	110.461	-65.786	5.979	-36.557	72.314	-45.334	0.464	1.235	-0.376	3.464
78	-5.228	9.498	-60.506	113.349	-68.383	5.979	-37.032	74.205	-47.123	0.464	1.235	-0.376	3.464
79	-6.138	9.498	-61.282	116.274	-71.047	5.979	-37.507	76.120	-48.959	0.464	1.235	-0.376	3.464
80	-7.102	9.498	-62.057	119.236	-73.779	5.979	-37.982	78.059	-50.842	0.464	1.235	-0.376	3.464

Table A.5: Log of Higher Education Consumption: Single Household with High School Education

1980s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*urb*	*rinc*	*uer*	*imr*	*hs*
18	5.036	9.498	-13.963	6.036	-0.840	0.464	1.235	-0.376	3.464	-0.481
19	4.802	9.498	-14.739	6.726	-0.988	0.464	1.235	-0.376	3.464	-0.481
20	4.588	9.498	-15.514	7.452	-1.153	0.464	1.235	-0.376	3.464	-0.481
21	4.395	9.498	-16.290	8.216	-1.335	0.464	1.235	-0.376	3.464	-0.481
22	4.220	9.498	-17.066	9.017	-1.534	0.464	1.235	-0.376	3.464	-0.481
23	4.064	9.498	-17.841	9.856	-1.753	0.464	1.235	-0.376	3.464	-0.481
24	3.925	9.498	-18.617	10.731	-1.992	0.464	1.235	-0.376	3.464	-0.481
25	3.803	9.498	-19.393	11.644	-2.252	0.464	1.235	-0.376	3.464	-0.481
26	3.696	9.498	-20.169	12.594	-2.533	0.464	1.235	-0.376	3.464	-0.481
27	3.604	9.498	-20.944	13.582	-2.836	0.464	1.235	-0.376	3.464	-0.481
28	3.526	9.498	-21.720	14.606	-3.163	0.464	1.235	-0.376	3.464	-0.481
29	3.461	9.498	-22.496	15.668	-3.514	0.464	1.235	-0.376	3.464	-0.481
30	3.409	9.498	-23.271	16.768	-3.891	0.464	1.235	-0.376	3.464	-0.481
31	3.367	9.498	-24.047	17.904	-4.293	0.464	1.235	-0.376	3.464	-0.481
32	3.336	9.498	-24.823	19.078	-4.722	0.464	1.235	-0.376	3.464	-0.481
33	3.315	9.498	-25.599	20.289	-5.179	0.464	1.235	-0.376	3.464	-0.481
34	3.302	9.498	-26.374	21.537	-5.664	0.464	1.235	-0.376	3.464	-0.481
35	3.297	9.498	-27.150	22.822	-6.178	0.464	1.235	-0.376	3.464	-0.481
36	3.300	9.498	-27.926	24.145	-6.723	0.464	1.235	-0.376	3.464	-0.481
37	3.308	9.498	-28.701	25.505	-7.299	0.464	1.235	-0.376	3.464	-0.481
38	3.322	9.498	-29.477	26.903	-7.907	0.464	1.235	-0.376	3.464	-0.481
39	3.340	9.498	-30.253	28.337	-8.548	0.464	1.235	-0.376	3.464	-0.481
40	3.361	9.498	-31.029	29.809	-9.222	0.464	1.235	-0.376	3.464	-0.481
41	3.386	9.498	-31.804	31.318	-9.932	0.464	1.235	-0.376	3.464	-0.481
42	3.412	9.498	-32.580	32.864	-10.676	0.464	1.235	-0.376	3.464	-0.481

Table A.5: Log of Higher Education Consumption: Single Household with High School Education

1980s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*urb*	*rinc*	*uer*	*imr*	*hs*
43	3.439	9.498	-33.356	34.448	-11.457	0.464	1.235	-0.376	3.464	-0.481
44	3.466	9.498	-34.131	36.069	-12.275	0.464	1.235	-0.376	3.464	-0.481
45	3.492	9.498	-34.907	37.727	-13.131	0.464	1.235	-0.376	3.464	-0.481
46	3.517	9.498	-35.683	39.422	-14.026	0.464	1.235	-0.376	3.464	-0.481
47	3.539	9.498	-36.459	41.155	-14.961	0.464	1.235	-0.376	3.464	-0.481
48	3.558	9.498	-37.234	42.925	-15.936	0.464	1.235	-0.376	3.464	-0.481
49	3.572	9.498	-38.010	44.732	-16.953	0.464	1.235	-0.376	3.464	-0.481
50	3.582	9.498	-38.786	46.577	-18.013	0.464	1.235	-0.376	3.464	-0.481
51	3.585	9.498	-39.562	48.458	-19.115	0.464	1.235	-0.376	3.464	-0.481
52	3.582	9.498	-40.337	50.377	-20.262	0.464	1.235	-0.376	3.464	-0.481
53	3.571	9.498	-41.113	52.333	-21.453	0.464	1.235	-0.376	3.464	-0.481
54	3.551	9.498	-41.889	54.327	-22.691	0.464	1.235	-0.376	3.464	-0.481
55	3.522	9.498	-42.664	56.358	-23.975	0.464	1.235	-0.376	3.464	-0.481
56	3.483	9.498	-43.440	58.426	-25.306	0.464	1.235	-0.376	3.464	-0.481
57	3.432	9.498	-44.216	60.531	-26.686	0.464	1.235	-0.376	3.464	-0.481
58	3.370	9.498	-44.992	62.673	-28.116	0.464	1.235	-0.376	3.464	-0.481
59	3.294	9.498	-45.767	64.853	-29.595	0.464	1.235	-0.376	3.464	-0.481
60	3.205	9.498	-46.543	67.070	-31.126	0.464	1.235	-0.376	3.464	-0.481
61	3.101	9.498	-47.319	69.324	-32.708	0.464	1.235	-0.376	3.464	-0.481
62	2.982	9.498	-48.094	71.616	-34.343	0.464	1.235	-0.376	3.464	-0.481
63	2.846	9.498	-48.870	73.945	-36.032	0.464	1.235	-0.376	3.464	-0.481
64	2.694	9.498	-49.646	76.311	-37.775	0.464	1.235	-0.376	3.464	-0.481
65	2.523	9.498	-50.422	78.714	-39.573	0.464	1.235	-0.376	3.464	-0.481
66	2.333	9.498	-51.197	81.155	-41.428	0.464	1.235	-0.376	3.464	-0.481
67	2.123	9.498	-51.973	83.633	-43.340	0.464	1.235	-0.376	3.464	-0.481

Table A.5: Log of Higher Education Consumption: Single Household with High School Education

1980s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*urb*	*rinc*	*uer*	*imr*	*hs*
68	1.893	9.498	-52.749	86.148	-45.310	0.464	1.235	-0.376	3.464	-0.481
69	1.641	9.498	-53.524	88.700	-47.338	0.464	1.235	-0.376	3.464	-0.481
70	1.367	9.498	-54.300	91.290	-49.426	0.464	1.235	-0.376	3.464	-0.481
71	1.069	9.498	-55.076	93.917	-51.575	0.464	1.235	-0.376	3.464	-0.481
72	0.748	9.498	-55.852	96.581	-53.785	0.464	1.235	-0.376	3.464	-0.481
73	0.401	9.498	-56.627	99.282	-56.057	0.464	1.235	-0.376	3.464	-0.481
74	0.029	9.498	-57.403	102.021	-58.393	0.464	1.235	-0.376	3.464	-0.481
75	-0.370	9.498	-58.179	104.797	-60.792	0.464	1.235	-0.376	3.464	-0.481
76	-0.797	9.498	-58.954	107.610	-63.256	0.464	1.235	-0.376	3.464	-0.481
77	-1.252	9.498	-59.730	110.461	-65.786	0.464	1.235	-0.376	3.464	-0.481
78	-1.737	9.498	-60.506	113.349	-68.383	0.464	1.235	-0.376	3.464	-0.481
79	-2.252	9.498	-61.282	116.274	-71.047	0.464	1.235	-0.376	3.464	-0.481
80	-2.797	9.498	-62.057	119.236	-73.779	0.464	1.235	-0.376	3.464	-0.481

1990s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*rinc*	*uer*	*imr*	*hs*
18	6.323	9.498	-13.963	6.036	-0.840	5.979	-8.546	3.952	-0.579	0.464	1.235	-0.376	3.464	-0.481
19	5.963	9.498	-14.739	6.726	-0.988	5.979	-9.021	4.403	-0.681	0.464	1.235	-0.376	3.464	-0.481
20	5.637	9.498	-15.514	7.452	-1.153	5.979	-9.495	4.879	-0.794	0.464	1.235	-0.376	3.464	-0.481
21	5.343	9.498	-16.290	8.216	-1.335	5.979	-9.970	5.379	-0.920	0.464	1.235	-0.376	3.464	-0.481
22	5.081	9.498	-17.066	9.017	-1.534	5.979	-10.445	5.903	-1.057	0.464	1.235	-0.376	3.464	-0.481
23	4.848	9.498	-17.841	9.856	-1.753	5.979	-10.920	6.452	-1.208	0.464	1.235	-0.376	3.464	-0.481
24	4.643	9.498	-18.617	10.731	-1.992	5.979	-11.394	7.025	-1.373	0.464	1.235	-0.376	3.464	-0.481
25	4.465	9.498	-19.393	11.644	-2.252	5.979	-11.869	7.623	-1.552	0.464	1.235	-0.376	3.464	-0.481

Table A.5: Log of Higher Education Consumption: Single Household with High School Education

1990s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*rinc*	*uer*	*imr*	*hs*
26	4.311	9.498	-20.169	12.594	-2.533	5.979	-12.344	8.245	-1.745	0.464	1.235	-0.376	3.464	-0.481
27	4.182	9.498	-20.944	13.582	-2.836	5.979	-12.819	8.891	-1.955	0.464	1.235	-0.376	3.464	-0.481
28	4.075	9.498	-21.720	14.606	-3.163	5.979	-13.294	9.562	-2.180	0.464	1.235	-0.376	3.464	-0.481
29	3.988	9.498	-22.496	15.668	-3.514	5.979	-13.768	10.257	-2.422	0.464	1.235	-0.376	3.464	-0.481
30	3.921	9.498	-23.271	16.768	-3.891	5.979	-14.243	10.977	-2.681	0.464	1.235	-0.376	3.464	-0.481
31	3.872	9.498	-24.047	17.904	-4.293	5.979	-14.718	11.721	-2.958	0.464	1.235	-0.376	3.464	-0.481
32	3.839	9.498	-24.823	19.078	-4.722	5.979	-15.193	12.489	-3.254	0.464	1.235	-0.376	3.464	-0.481
33	3.821	9.498	-25.599	20.289	-5.179	5.979	-15.667	13.282	-3.569	0.464	1.235	-0.376	3.464	-0.481
34	3.816	9.498	-26.374	21.537	-5.664	5.979	-16.142	14.099	-3.903	0.464	1.235	-0.376	3.464	-0.481
35	3.823	9.498	-27.150	22.822	-6.178	5.979	-16.617	14.941	-4.257	0.464	1.235	-0.376	3.464	-0.481
36	3.841	9.498	-27.926	24.145	-6.723	5.979	-17.092	15.807	-4.633	0.464	1.235	-0.376	3.464	-0.481
37	3.868	9.498	-28.701	25.505	-7.299	5.979	-17.566	16.697	-5.030	0.464	1.235	-0.376	3.464	-0.481
38	3.903	9.498	-29.477	26.903	-7.907	5.979	-18.041	17.612	-5.449	0.464	1.235	-0.376	3.464	-0.481
39	3.944	9.498	-30.253	28.337	-8.548	5.979	-18.516	18.551	-5.890	0.464	1.235	-0.376	3.464	-0.481
40	3.989	9.498	-31.029	29.809	-9.222	5.979	-18.991	19.515	-6.355	0.464	1.235	-0.376	3.464	-0.481
41	4.038	9.498	-31.804	31.318	-9.932	5.979	-19.466	20.503	-6.844	0.464	1.235	-0.376	3.464	-0.481
42	4.089	9.498	-32.580	32.864	-10.676	5.979	-19.940	21.515	-7.357	0.464	1.235	-0.376	3.464	-0.481
43	4.140	9.498	-33.356	34.448	-11.457	5.979	-20.415	22.552	-7.895	0.464	1.235	-0.376	3.464	-0.481
44	4.189	9.498	-34.131	36.069	-12.275	5.979	-20.890	23.613	-8.459	0.464	1.235	-0.376	3.464	-0.481
45	4.236	9.498	-34.907	37.727	-13.131	5.979	-21.365	24.698	-9.049	0.464	1.235	-0.376	3.464	-0.481
46	4.279	9.498	-35.683	39.422	-14.026	5.979	-21.839	25.808	-9.665	0.464	1.235	-0.376	3.464	-0.481
47	4.317	9.498	-36.459	41.155	-14.961	5.979	-22.314	26.943	-10.310	0.464	1.235	-0.376	3.464	-0.481
48	4.347	9.498	-37.234	42.925	-15.936	5.979	-22.789	28.101	-10.982	0.464	1.235	-0.376	3.464	-0.481
49	4.370	9.498	-38.010	44.732	-16.953	5.979	-23.264	29.284	-11.683	0.464	1.235	-0.376	3.464	-0.481
50	4.382	9.498	-38.786	46.577	-18.013	5.979	-23.738	30.492	-12.413	0.464	1.235	-0.376	3.464	-0.481

Table A.5: Log of Higher Education Consumption: Single Household with High School Education

1990s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*rinc*	*uer*	*imr*	*hs*
51	4.383	9.498	-39.562	48.458	-19.115	5.979	-24.213	31.724	-13.172	0.464	1.235	-0.376	3.464	-0.481
52	4.371	9.498	-40.337	50.377	-20.262	5.979	-24.688	32.980	-13.962	0.464	1.235	-0.376	3.464	-0.481
53	4.344	9.498	-41.113	52.333	-21.453	5.979	-25.163	34.261	-14.783	0.464	1.235	-0.376	3.464	-0.481
54	4.302	9.498	-41.889	54.327	-22.691	5.979	-25.638	35.566	-15.636	0.464	1.235	-0.376	3.464	-0.481
55	4.243	9.498	-42.664	56.358	-23.975	5.979	-26.112	36.895	-16.521	0.464	1.235	-0.376	3.464	-0.481
56	4.165	9.498	-43.440	58.426	-25.306	5.979	-26.587	38.249	-17.439	0.464	1.235	-0.376	3.464	-0.481
57	4.067	9.498	-44.216	60.531	-26.686	5.979	-27.062	39.627	-18.390	0.464	1.235	-0.376	3.464	-0.481
58	3.947	9.498	-44.992	62.673	-28.116	5.979	-27.537	41.030	-19.375	0.464	1.235	-0.376	3.464	-0.481
59	3.805	9.498	-45.767	64.853	-29.595	5.979	-28.011	42.457	-20.394	0.464	1.235	-0.376	3.464	-0.481
60	3.638	9.498	-46.543	67.070	-31.126	5.979	-28.486	43.908	-21.449	0.464	1.235	-0.376	3.464	-0.481
61	3.444	9.498	-47.319	69.324	-32.708	5.979	-28.961	45.384	-22.539	0.464	1.235	-0.376	3.464	-0.481
62	3.224	9.498	-48.094	71.616	-34.343	5.979	-29.436	46.884	-23.666	0.464	1.235	-0.376	3.464	-0.481
63	2.974	9.498	-48.870	73.945	-36.032	5.979	-29.910	48.409	-24.830	0.464	1.235	-0.376	3.464	-0.481
64	2.694	9.498	-49.646	76.311	-37.775	5.979	-30.385	49.958	-26.031	0.464	1.235	-0.376	3.464	-0.481
65	2.383	9.498	-50.422	78.714	-39.573	5.979	-30.860	51.531	-27.270	0.464	1.235	-0.376	3.464	-0.481
66	2.038	9.498	-51.197	81.155	-41.428	5.979	-31.335	53.129	-28.548	0.464	1.235	-0.376	3.464	-0.481
67	1.658	9.498	-51.973	83.633	-43.340	5.979	-31.810	54.751	-29.866	0.464	1.235	-0.376	3.464	-0.481
68	1.242	9.498	-52.749	86.148	-45.310	5.979	-32.284	56.398	-31.223	0.464	1.235	-0.376	3.464	-0.481
69	0.789	9.498	-53.524	88.700	-47.338	5.979	-32.759	58.068	-32.621	0.464	1.235	-0.376	3.464	-0.481
70	0.296	9.498	-54.300	91.290	-49.426	5.979	-33.234	59.764	-34.060	0.464	1.235	-0.376	3.464	-0.481
71	-0.237	9.498	-55.076	93.917	-51.575	5.979	-33.709	61.484	-35.541	0.464	1.235	-0.376	3.464	-0.481
72	-0.812	9.498	-55.852	96.581	-53.785	5.979	-34.183	63.228	-37.064	0.464	1.235	-0.376	3.464	-0.481
73	-1.431	9.498	-56.627	99.282	-56.057	5.979	-34.658	64.996	-38.629	0.464	1.235	-0.376	3.464	-0.481
74	-2.094	9.498	-57.403	102.021	-58.393	5.979	-35.133	66.789	-40.239	0.464	1.235	-0.376	3.464	-0.481
75	-2.804	9.498	-58.179	104.797	-60.792	5.979	-35.608	68.606	-41.892	0.464	1.235	-0.376	3.464	-0.481

Table A.5: Log of Higher Education Consumption: Single Household with High School Education

1990s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*rinc*	*uer*	*imr*	*hs*
76	-3.562	9.498	-58.954	107.610	-63.256	5.979	-36.082	70.448	-43.590	0.464	1.235	-0.376	3.464	-0.481
77	-4.370	9.498	-59.730	110.461	-65.786	5.979	-36.557	72.314	-45.334	0.464	1.235	-0.376	3.464	-0.481
78	-5.228	9.498	-60.506	113.349	-68.383	5.979	-37.032	74.205	-47.123	0.464	1.235	-0.376	3.464	-0.481
79	-6.138	9.498	-61.282	116.274	-71.047	5.979	-37.507	76.120	-48.959	0.464	1.235	-0.376	3.464	-0.481
80	-7.102	9.498	-62.057	119.236	-73.779	5.979	-37.982	78.059	-50.842	0.464	1.235	-0.376	3.464	-0.481

Table A.6: Log of Higher Education Consumption: Married Household with Some College Education

1980s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*urb*	*rinc*	*uer*	*imr*	*mar*
18	5.378	9.498	-13.963	6.036	-0.840	0.464	1.235	-0.376	3.464	-0.139
19	5.143	9.498	-14.739	6.726	-0.988	0.464	1.235	-0.376	3.464	-0.139
20	4.930	9.498	-15.514	7.452	-1.153	0.464	1.235	-0.376	3.464	-0.139
21	4.736	9.498	-16.290	8.216	-1.335	0.464	1.235	-0.376	3.464	-0.139
22	4.562	9.498	-17.066	9.017	-1.534	0.464	1.235	-0.376	3.464	-0.139
23	4.406	9.498	-17.841	9.856	-1.753	0.464	1.235	-0.376	3.464	-0.139
24	4.267	9.498	-18.617	10.731	-1.992	0.464	1.235	-0.376	3.464	-0.139
25	4.144	9.498	-19.393	11.644	-2.252	0.464	1.235	-0.376	3.464	-0.139
26	4.038	9.498	-20.169	12.594	-2.533	0.464	1.235	-0.376	3.464	-0.139
27	3.946	9.498	-20.944	13.582	-2.836	0.464	1.235	-0.376	3.464	-0.139
28	3.868	9.498	-21.720	14.606	-3.163	0.464	1.235	-0.376	3.464	-0.139
29	3.803	9.498	-22.496	15.668	-3.514	0.464	1.235	-0.376	3.464	-0.139
30	3.750	9.498	-23.271	16.768	-3.891	0.464	1.235	-0.376	3.464	-0.139
31	3.709	9.498	-24.047	17.904	-4.293	0.464	1.235	-0.376	3.464	-0.139
32	3.678	9.498	-24.823	19.078	-4.722	0.464	1.235	-0.376	3.464	-0.139
33	3.656	9.498	-25.599	20.289	-5.179	0.464	1.235	-0.376	3.464	-0.139
34	3.644	9.498	-26.374	21.537	-5.664	0.464	1.235	-0.376	3.464	-0.139
35	3.639	9.498	-27.150	22.822	-6.178	0.464	1.235	-0.376	3.464	-0.139
36	3.641	9.498	-27.926	24.145	-6.723	0.464	1.235	-0.376	3.464	-0.139
37	3.649	9.498	-28.701	25.505	-7.299	0.464	1.235	-0.376	3.464	-0.139
38	3.663	9.498	-29.477	26.903	-7.907	0.464	1.235	-0.376	3.464	-0.139
39	3.681	9.498	-30.253	28.337	-8.548	0.464	1.235	-0.376	3.464	-0.139
40	3.703	9.498	-31.029	29.809	-9.222	0.464	1.235	-0.376	3.464	-0.139
41	3.727	9.498	-31.804	31.318	-9.932	0.464	1.235	-0.376	3.464	-0.139

Table A.6: Log of Higher Education Consumption: Married Household with Some College Education

1980s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*urb*	*rinc*	*uer*	*imr*	*mar*
42	3.753	9.498	-32.580	32.864	-10.676	0.464	1.235	-0.376	3.464	-0.139
43	3.780	9.498	-33.356	34.448	-11.457	0.464	1.235	-0.376	3.464	-0.139
44	3.807	9.498	-34.131	36.069	-12.275	0.464	1.235	-0.376	3.464	-0.139
45	3.833	9.498	-34.907	37.727	-13.131	0.464	1.235	-0.376	3.464	-0.139
46	3.858	9.498	-35.683	39.422	-14.026	0.464	1.235	-0.376	3.464	-0.139
47	3.880	9.498	-36.459	41.155	-14.961	0.464	1.235	-0.376	3.464	-0.139
48	3.899	9.498	-37.234	42.925	-15.936	0.464	1.235	-0.376	3.464	-0.139
49	3.913	9.498	-38.010	44.732	-16.953	0.464	1.235	-0.376	3.464	-0.139
50	3.923	9.498	-38.786	46.577	-18.013	0.464	1.235	-0.376	3.464	-0.139
51	3.926	9.498	-39.562	48.458	-19.115	0.464	1.235	-0.376	3.464	-0.139
52	3.923	9.498	-40.337	50.377	-20.262	0.464	1.235	-0.376	3.464	-0.139
53	3.912	9.498	-41.113	52.333	-21.453	0.464	1.235	-0.376	3.464	-0.139
54	3.892	9.498	-41.889	54.327	-22.691	0.464	1.235	-0.376	3.464	-0.139
55	3.863	9.498	-42.664	56.358	-23.975	0.464	1.235	-0.376	3.464	-0.139
56	3.824	9.498	-43.440	58.426	-25.306	0.464	1.235	-0.376	3.464	-0.139
57	3.773	9.498	-44.216	60.531	-26.686	0.464	1.235	-0.376	3.464	-0.139
58	3.711	9.498	-44.992	62.673	-28.116	0.464	1.235	-0.376	3.464	-0.139
59	3.635	9.498	-45.767	64.853	-29.595	0.464	1.235	-0.376	3.464	-0.139
60	3.546	9.498	-46.543	67.070	-31.126	0.464	1.235	-0.376	3.464	-0.139
61	3.443	9.498	-47.319	69.324	-32.708	0.464	1.235	-0.376	3.464	-0.139
62	3.323	9.498	-48.094	71.616	-34.343	0.464	1.235	-0.376	3.464	-0.139
63	3.188	9.498	-48.870	73.945	-36.032	0.464	1.235	-0.376	3.464	-0.139
64	3.035	9.498	-49.646	76.311	-37.775	0.464	1.235	-0.376	3.464	-0.139
65	2.864	9.498	-50.422	78.714	-39.573	0.464	1.235	-0.376	3.464	-0.139

Table A.6: Log of Higher Education Consumption: Married Household with Some College Education

1980s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*urb*	*rinc*	*uer*	*imr*	*mar*
66	2.674	9.498	-51.197	81.155	-41.428	0.464	1.235	-0.376	3.464	-0.139
67	2.465	9.498	-51.973	83.633	-43.340	0.464	1.235	-0.376	3.464	-0.139
68	2.234	9.498	-52.749	86.148	-45.310	0.464	1.235	-0.376	3.464	-0.139
69	1.982	9.498	-53.524	88.700	-47.338	0.464	1.235	-0.376	3.464	-0.139
70	1.708	9.498	-54.300	91.290	-49.426	0.464	1.235	-0.376	3.464	-0.139
71	1.411	9.498	-55.076	93.917	-51.575	0.464	1.235	-0.376	3.464	-0.139
72	1.089	9.498	-55.852	96.581	-53.785	0.464	1.235	-0.376	3.464	-0.139
73	0.743	9.498	-56.627	99.282	-56.057	0.464	1.235	-0.376	3.464	-0.139
74	0.370	9.498	-57.403	102.021	-58.393	0.464	1.235	-0.376	3.464	-0.139
75	-0.029	9.498	-58.179	104.797	-60.792	0.464	1.235	-0.376	3.464	-0.139
76	-0.456	9.498	-58.954	107.610	-63.256	0.464	1.235	-0.376	3.464	-0.139
77	-0.911	9.498	-59.730	110.461	-65.786	0.464	1.235	-0.376	3.464	-0.139
78	-1.395	9.498	-60.506	113.349	-68.383	0.464	1.235	-0.376	3.464	-0.139
79	-1.910	9.498	-61.282	116.274	-71.047	0.464	1.235	-0.376	3.464	-0.139
80	-2.456	9.498	-62.057	119.236	-73.779	0.464	1.235	-0.376	3.464	-0.139

1990s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*rinc*	*uer*	*imr*	*mar*
18	6.323	9.498	-13.963	6.036	-0.840	5.979	-8.546	3.952	-0.579	0.464	1.235	-0.376	3.464	-0.139
19	5.963	9.498	-14.739	6.726	-0.988	5.979	-9.021	4.403	-0.681	0.464	1.235	-0.376	3.464	-0.139
20	5.637	9.498	-15.514	7.452	-1.153	5.979	-9.495	4.879	-0.794	0.464	1.235	-0.376	3.464	-0.139
21	5.343	9.498	-16.290	8.216	-1.335	5.979	-9.970	5.379	-0.920	0.464	1.235	-0.376	3.464	-0.139

Table A.6: Log of Higher Education Consumption: Married Household with Some College Education

1990s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*rinc*	*uer*	*imr*	*mar*
22	5.081	9.498	-17.066	9.017	-1.534	5.979	-10.445	5.903	-1.057	0.464	1.235	-0.376	3.464	-0.139
23	4.848	9.498	-17.841	9.856	-1.753	5.979	-10.920	6.452	-1.208	0.464	1.235	-0.376	3.464	-0.139
24	4.643	9.498	-18.617	10.731	-1.992	5.979	-11.394	7.025	-1.373	0.464	1.235	-0.376	3.464	-0.139
25	4.465	9.498	-19.393	11.644	-2.252	5.979	-11.869	7.623	-1.552	0.464	1.235	-0.376	3.464	-0.139
26	4.311	9.498	-20.169	12.594	-2.533	5.979	-12.344	8.245	-1.745	0.464	1.235	-0.376	3.464	-0.139
27	4.182	9.498	-20.944	13.582	-2.836	5.979	-12.819	8.891	-1.955	0.464	1.235	-0.376	3.464	-0.139
28	4.075	9.498	-21.720	14.606	-3.163	5.979	-13.294	9.562	-2.180	0.464	1.235	-0.376	3.464	-0.139
29	3.988	9.498	-22.496	15.668	-3.514	5.979	-13.768	10.257	-2.422	0.464	1.235	-0.376	3.464	-0.139
30	3.921	9.498	-23.271	16.768	-3.891	5.979	-14.243	10.977	-2.681	0.464	1.235	-0.376	3.464	-0.139
31	3.872	9.498	-24.047	17.904	-4.293	5.979	-14.718	11.721	-2.958	0.464	1.235	-0.376	3.464	-0.139
32	3.839	9.498	-24.823	19.078	-4.722	5.979	-15.193	12.489	-3.254	0.464	1.235	-0.376	3.464	-0.139
33	3.821	9.498	-25.599	20.289	-5.179	5.979	-15.667	13.282	-3.569	0.464	1.235	-0.376	3.464	-0.139
34	3.816	9.498	-26.374	21.537	-5.664	5.979	-16.142	14.099	-3.903	0.464	1.235	-0.376	3.464	-0.139
35	3.823	9.498	-27.150	22.822	-6.178	5.979	-16.617	14.941	-4.257	0.464	1.235	-0.376	3.464	-0.139
36	3.841	9.498	-27.926	24.145	-6.723	5.979	-17.092	15.807	-4.633	0.464	1.235	-0.376	3.464	-0.139
37	3.868	9.498	-28.701	25.505	-7.299	5.979	-17.566	16.697	-5.030	0.464	1.235	-0.376	3.464	-0.139
38	3.903	9.498	-29.477	26.903	-7.907	5.979	-18.041	17.612	-5.449	0.464	1.235	-0.376	3.464	-0.139
39	3.944	9.498	-30.253	28.337	-8.548	5.979	-18.516	18.551	-5.890	0.464	1.235	-0.376	3.464	-0.139
40	3.989	9.498	-31.029	29.809	-9.222	5.979	-18.991	19.515	-6.355	0.464	1.235	-0.376	3.464	-0.139
41	4.038	9.498	-31.804	31.318	-9.932	5.979	-19.466	20.503	-6.844	0.464	1.235	-0.376	3.464	-0.139
42	4.089	9.498	-32.580	32.864	-10.676	5.979	-19.940	21.515	-7.357	0.464	1.235	-0.376	3.464	-0.139
43	4.140	9.498	-33.356	34.448	-11.457	5.979	-20.415	22.552	-7.895	0.464	1.235	-0.376	3.464	-0.139

Table A.6: Log of Higher Education Consumption: Married Household with Some College Education

1990s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*rinc*	*uer*	*imr*	*mar*
44	4.189	9.498	-34.131	36.069	-12.275	5.979	-20.890	23.613	-8.459	0.464	1.235	-0.376	3.464	-0.139
45	4.236	9.498	-34.907	37.727	-13.131	5.979	-21.365	24.698	-9.049	0.464	1.235	-0.376	3.464	-0.139
46	4.279	9.498	-35.683	39.422	-14.026	5.979	-21.839	25.808	-9.665	0.464	1.235	-0.376	3.464	-0.139
47	4.317	9.498	-36.459	41.155	-14.961	5.979	-22.314	26.943	-10.310	0.464	1.235	-0.376	3.464	-0.139
48	4.347	9.498	-37.234	42.925	-15.936	5.979	-22.789	28.101	-10.982	0.464	1.235	-0.376	3.464	-0.139
49	4.370	9.498	-38.010	44.732	-16.953	5.979	-23.264	29.284	-11.683	0.464	1.235	-0.376	3.464	-0.139
50	4.382	9.498	-38.786	46.577	-18.013	5.979	-23.738	30.492	-12.413	0.464	1.235	-0.376	3.464	-0.139
51	4.383	9.498	-39.562	48.458	-19.115	5.979	-24.213	31.724	-13.172	0.464	1.235	-0.376	3.464	-0.139
52	4.371	9.498	-40.337	50.377	-20.262	5.979	-24.688	32.980	-13.962	0.464	1.235	-0.376	3.464	-0.139
53	4.344	9.498	-41.113	52.333	-21.453	5.979	-25.163	34.261	-14.783	0.464	1.235	-0.376	3.464	-0.139
54	4.302	9.498	-41.889	54.327	-22.691	5.979	-25.638	35.566	-15.636	0.464	1.235	-0.376	3.464	-0.139
55	4.243	9.498	-42.664	56.358	-23.975	5.979	-26.112	36.895	-16.521	0.464	1.235	-0.376	3.464	-0.139
56	4.165	9.498	-43.440	58.426	-25.306	5.979	-26.587	38.249	-17.439	0.464	1.235	-0.376	3.464	-0.139
57	4.067	9.498	-44.216	60.531	-26.686	5.979	-27.062	39.627	-18.390	0.464	1.235	-0.376	3.464	-0.139
58	3.947	9.498	-44.992	62.673	-28.116	5.979	-27.537	41.030	-19.375	0.464	1.235	-0.376	3.464	-0.139
59	3.805	9.498	-45.767	64.853	-29.595	5.979	-28.011	42.457	-20.394	0.464	1.235	-0.376	3.464	-0.139
60	3.638	9.498	-46.543	67.070	-31.126	5.979	-28.486	43.908	-21.449	0.464	1.235	-0.376	3.464	-0.139
61	3.444	9.498	-47.319	69.324	-32.708	5.979	-28.961	45.384	-22.539	0.464	1.235	-0.376	3.464	-0.139
62	3.224	9.498	-48.094	71.616	-34.343	5.979	-29.436	46.884	-23.666	0.464	1.235	-0.376	3.464	-0.139
63	2.974	9.498	-48.870	73.945	-36.032	5.979	-29.910	48.409	-24.830	0.464	1.235	-0.376	3.464	-0.139
64	2.694	9.498	-49.646	76.311	-37.775	5.979	-30.385	49.958	-26.031	0.464	1.235	-0.376	3.464	-0.139
65	2.383	9.498	-50.422	78.714	-39.573	5.979	-30.860	51.531	-27.270	0.464	1.235	-0.376	3.464	-0.139

Table A.6: Log of Higher Education Consumption: Married Household with Some College Education

1990s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*rinc*	*uer*	*imr*	*mar*
66	2.038	9.498	-51.197	81.155	-41.428	5.979	-31.335	53.129	-28.548	0.464	1.235	-0.376	3.464	-0.139
67	1.658	9.498	-51.973	83.633	-43.340	5.979	-31.810	54.751	-29.866	0.464	1.235	-0.376	3.464	-0.139
68	1.242	9.498	-52.749	86.148	-45.310	5.979	-32.284	56.398	-31.223	0.464	1.235	-0.376	3.464	-0.139
69	0.789	9.498	-53.524	88.700	-47.338	5.979	-32.759	58.068	-32.621	0.464	1.235	-0.376	3.464	-0.139
70	0.296	9.498	-54.300	91.290	-49.426	5.979	-33.234	59.764	-34.060	0.464	1.235	-0.376	3.464	-0.139
71	-0.237	9.498	-55.076	93.917	-51.575	5.979	-33.709	61.484	-35.541	0.464	1.235	-0.376	3.464	-0.139
72	-0.812	9.498	-55.852	96.581	-53.785	5.979	-34.183	63.228	-37.064	0.464	1.235	-0.376	3.464	-0.139
73	-1.431	9.498	-56.627	99.282	-56.057	5.979	-34.658	64.996	-38.629	0.464	1.235	-0.376	3.464	-0.139
74	-2.094	9.498	-57.403	102.021	-58.393	5.979	-35.133	66.789	-40.239	0.464	1.235	-0.376	3.464	-0.139
75	-2.804	9.498	-58.179	104.797	-60.792	5.979	-35.608	68.606	-41.892	0.464	1.235	-0.376	3.464	-0.139
76	-3.562	9.498	-58.954	107.610	-63.256	5.979	-36.082	70.448	-43.590	0.464	1.235	-0.376	3.464	-0.139
77	-4.370	9.498	-59.730	110.461	-65.786	5.979	-36.557	72.314	-45.334	0.464	1.235	-0.376	3.464	-0.139
78	-5.228	9.498	-60.506	113.349	-68.383	5.979	-37.032	74.205	-47.123	0.464	1.235	-0.376	3.464	-0.139
79	-6.138	9.498	-61.282	116.274	-71.047	5.979	-37.507	76.120	-48.959	0.464	1.235	-0.376	3.464	-0.139
80	-7.102	9.498	-62.057	119.236	-73.779	5.979	-37.982	78.059	-50.842	0.464	1.235	-0.376	3.464	-0.139

Table A.7: Log of Higher Education Consumption: Married Household with High School Education

1980s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*urb*	*rinc*	*uer*	*imr*	*mar*	*hs*
18	4.897	9.498	-13.963	6.036	-0.840	0.464	1.235	-0.376	3.464	-0.139	-0.481
19	4.663	9.498	-14.739	6.726	-0.988	0.464	1.235	-0.376	3.464	-0.139	-0.481
20	4.449	9.498	-15.514	7.452	-1.153	0.464	1.235	-0.376	3.464	-0.139	-0.481
21	4.255	9.498	-16.290	8.216	-1.335	0.464	1.235	-0.376	3.464	-0.139	-0.481
22	4.081	9.498	-17.066	9.017	-1.534	0.464	1.235	-0.376	3.464	-0.139	-0.481
23	3.925	9.498	-17.841	9.856	-1.753	0.464	1.235	-0.376	3.464	-0.139	-0.481
24	3.786	9.498	-18.617	10.731	-1.992	0.464	1.235	-0.376	3.464	-0.139	-0.481
25	3.664	9.498	-19.393	11.644	-2.252	0.464	1.235	-0.376	3.464	-0.139	-0.481
26	3.557	9.498	-20.169	12.594	-2.533	0.464	1.235	-0.376	3.464	-0.139	-0.481
27	3.465	9.498	-20.944	13.582	-2.836	0.464	1.235	-0.376	3.464	-0.139	-0.481
28	3.387	9.498	-21.720	14.606	-3.163	0.464	1.235	-0.376	3.464	-0.139	-0.481
29	3.322	9.498	-22.496	15.668	-3.514	0.464	1.235	-0.376	3.464	-0.139	-0.481
30	3.269	9.498	-23.271	16.768	-3.891	0.464	1.235	-0.376	3.464	-0.139	-0.481
31	3.228	9.498	-24.047	17.904	-4.293	0.464	1.235	-0.376	3.464	-0.139	-0.481
32	3.197	9.498	-24.823	19.078	-4.722	0.464	1.235	-0.376	3.464	-0.139	-0.481
33	3.175	9.498	-25.599	20.289	-5.179	0.464	1.235	-0.376	3.464	-0.139	-0.481
34	3.163	9.498	-26.374	21.537	-5.664	0.464	1.235	-0.376	3.464	-0.139	-0.481
35	3.158	9.498	-27.150	22.822	-6.178	0.464	1.235	-0.376	3.464	-0.139	-0.481
36	3.160	9.498	-27.926	24.145	-6.723	0.464	1.235	-0.376	3.464	-0.139	-0.481
37	3.169	9.498	-28.701	25.505	-7.299	0.464	1.235	-0.376	3.464	-0.139	-0.481
38	3.182	9.498	-29.477	26.903	-7.907	0.464	1.235	-0.376	3.464	-0.139	-0.481
39	3.200	9.498	-30.253	28.337	-8.548	0.464	1.235	-0.376	3.464	-0.139	-0.481
40	3.222	9.498	-31.029	29.809	-9.222	0.464	1.235	-0.376	3.464	-0.139	-0.481
41	3.246	9.498	-31.804	31.318	-9.932	0.464	1.235	-0.376	3.464	-0.139	-0.481
42	3.272	9.498	-32.580	32.864	-10.676	0.464	1.235	-0.376	3.464	-0.139	-0.481
43	3.299	9.498	-33.356	34.448	-11.457	0.464	1.235	-0.376	3.464	-0.139	-0.481
44	3.326	9.498	-34.131	36.069	-12.275	0.464	1.235	-0.376	3.464	-0.139	-0.481

Table A.7: Log of Higher Education Consumption: Married Household with High School Education

1980s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*urb*	*rinc*	*uer*	*imr*	*mar*	*hs*
45	3.353	9.498	-34.907	37.727	-13.131	0.464	1.235	-0.376	3.464	-0.139	-0.481
46	3.377	9.498	-35.683	39.422	-14.026	0.464	1.235	-0.376	3.464	-0.139	-0.481
47	3.399	9.498	-36.459	41.155	-14.961	0.464	1.235	-0.376	3.464	-0.139	-0.481
48	3.418	9.498	-37.234	42.925	-15.936	0.464	1.235	-0.376	3.464	-0.139	-0.481
49	3.433	9.498	-38.010	44.732	-16.953	0.464	1.235	-0.376	3.464	-0.139	-0.481
50	3.442	9.498	-38.786	46.577	-18.013	0.464	1.235	-0.376	3.464	-0.139	-0.481
51	3.446	9.498	-39.562	48.458	-19.115	0.464	1.235	-0.376	3.464	-0.139	-0.481
52	3.442	9.498	-40.337	50.377	-20.262	0.464	1.235	-0.376	3.464	-0.139	-0.481
53	3.431	9.498	-41.113	52.333	-21.453	0.464	1.235	-0.376	3.464	-0.139	-0.481
54	3.412	9.498	-41.889	54.327	-22.691	0.464	1.235	-0.376	3.464	-0.139	-0.481
55	3.382	9.498	-42.664	56.358	-23.975	0.464	1.235	-0.376	3.464	-0.139	-0.481
56	3.343	9.498	-43.440	58.426	-25.306	0.464	1.235	-0.376	3.464	-0.139	-0.481
57	3.293	9.498	-44.216	60.531	-26.686	0.464	1.235	-0.376	3.464	-0.139	-0.481
58	3.230	9.498	-44.992	62.673	-28.116	0.464	1.235	-0.376	3.464	-0.139	-0.481
59	3.155	9.498	-45.767	64.853	-29.595	0.464	1.235	-0.376	3.464	-0.139	-0.481
60	3.066	9.498	-46.543	67.070	-31.126	0.464	1.235	-0.376	3.464	-0.139	-0.481
61	2.962	9.498	-47.319	69.324	-32.708	0.464	1.235	-0.376	3.464	-0.139	-0.481
62	2.842	9.498	-48.094	71.616	-34.343	0.464	1.235	-0.376	3.464	-0.139	-0.481
63	2.707	9.498	-48.870	73.945	-36.032	0.464	1.235	-0.376	3.464	-0.139	-0.481
64	2.554	9.498	-49.646	76.311	-37.775	0.464	1.235	-0.376	3.464	-0.139	-0.481
65	2.383	9.498	-50.422	78.714	-39.573	0.464	1.235	-0.376	3.464	-0.139	-0.481
66	2.193	9.498	-51.197	81.155	-41.428	0.464	1.235	-0.376	3.464	-0.139	-0.481
67	1.984	9.498	-51.973	83.633	-43.340	0.464	1.235	-0.376	3.464	-0.139	-0.481
68	1.753	9.498	-52.749	86.148	-45.310	0.464	1.235	-0.376	3.464	-0.139	-0.481
69	1.502	9.498	-53.524	88.700	-47.338	0.464	1.235	-0.376	3.464	-0.139	-0.481
70	1.227	9.498	-54.300	91.290	-49.426	0.464	1.235	-0.376	3.464	-0.139	-0.481
71	0.930	9.498	-55.076	93.917	-51.575	0.464	1.235	-0.376	3.464	-0.139	-0.481

Table A.7: Log of Higher Education Consumption: Married Household with High School Education

1980s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*urb*	*rinc*	*uer*	*imr*	*mar*	*hs*
72	0.608	9.498	-55.852	96.581	-53.785	0.464	1.235	-0.376	3.464	-0.139	-0.481
73	0.262	9.498	-56.627	99.282	-56.057	0.464	1.235	-0.376	3.464	-0.139	-0.481
74	-0.111	9.498	-57.403	102.021	-58.393	0.464	1.235	-0.376	3.464	-0.139	-0.481
75	-0.510	9.498	-58.179	104.797	-60.792	0.464	1.235	-0.376	3.464	-0.139	-0.481
76	-0.937	9.498	-58.954	107.610	-63.256	0.464	1.235	-0.376	3.464	-0.139	-0.481
77	-1.392	9.498	-59.730	110.461	-65.786	0.464	1.235	-0.376	3.464	-0.139	-0.481
78	-1.876	9.498	-60.506	113.349	-68.383	0.464	1.235	-0.376	3.464	-0.139	-0.481
79	-2.391	9.498	-61.282	116.274	-71.047	0.464	1.235	-0.376	3.464	-0.139	-0.481
80	-2.937	9.498	-62.057	119.236	-73.779	0.464	1.235	-0.376	3.464	-0.139	-0.481

1990s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*rinc*	*uer*	*imr*	*mar*	*hs*
18	6.323	9.498	-13.963	6.036	-0.840	5.979	-8.546	3.952	-0.579	0.464	1.235	-0.376	3.464	-0.139	-0.481
19	5.963	9.498	-14.739	6.726	-0.988	5.979	-9.021	4.403	-0.681	0.464	1.235	-0.376	3.464	-0.139	-0.481
20	5.637	9.498	-15.514	7.452	-1.153	5.979	-9.495	4.879	-0.794	0.464	1.235	-0.376	3.464	-0.139	-0.481
21	5.343	9.498	-16.290	8.216	-1.335	5.979	-9.970	5.379	-0.920	0.464	1.235	-0.376	3.464	-0.139	-0.481
22	5.081	9.498	-17.066	9.017	-1.534	5.979	-10.445	5.903	-1.057	0.464	1.235	-0.376	3.464	-0.139	-0.481
23	4.848	9.498	-17.841	9.856	-1.753	5.979	-10.920	6.452	-1.208	0.464	1.235	-0.376	3.464	-0.139	-0.481
24	4.643	9.498	-18.617	10.731	-1.992	5.979	-11.394	7.025	-1.373	0.464	1.235	-0.376	3.464	-0.139	-0.481
25	4.465	9.498	-19.393	11.644	-2.252	5.979	-11.869	7.623	-1.552	0.464	1.235	-0.376	3.464	-0.139	-0.481
26	4.311	9.498	-20.169	12.594	-2.533	5.979	-12.344	8.245	-1.745	0.464	1.235	-0.376	3.464	-0.139	-0.481
27	4.182	9.498	-20.944	13.582	-2.836	5.979	-12.819	8.891	-1.955	0.464	1.235	-0.376	3.464	-0.139	-0.481
28	4.075	9.498	-21.720	14.606	-3.163	5.979	-13.294	9.562	-2.180	0.464	1.235	-0.376	3.464	-0.139	-0.481
29	3.988	9.498	-22.496	15.668	-3.514	5.979	-13.768	10.257	-2.422	0.464	1.235	-0.376	3.464	-0.139	-0.481

Table A.7: Log of Higher Education Consumption: Married Household with High School Education

1990s/ Age	Log High Ed Cons.	*constant*	*age1*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*rinc*	*uer*	*imr*	*mar*	*hs*
30	3.921	9.498	-23.271	16.768	-3.891	5.979	-14.243	10.977	-2.681	0.464	1.235	-0.376	3.464	-0.139	-0.481
31	3.872	9.498	-24.047	17.904	-4.293	5.979	-14.718	11.721	-2.958	0.464	1.235	-0.376	3.464	-0.139	-0.481
32	3.839	9.498	-24.823	19.078	-4.722	5.979	-15.193	12.489	-3.254	0.464	1.235	-0.376	3.464	-0.139	-0.481
33	3.821	9.498	-25.599	20.289	-5.179	5.979	-15.667	13.282	-3.569	0.464	1.235	-0.376	3.464	-0.139	-0.481
34	3.816	9.498	-26.374	21.537	-5.664	5.979	-16.142	14.099	-3.903	0.464	1.235	-0.376	3.464	-0.139	-0.481
35	3.823	9.498	-27.150	22.822	-6.178	5.979	-16.617	14.941	-4.257	0.464	1.235	-0.376	3.464	-0.139	-0.481
36	3.841	9.498	-27.926	24.145	-6.723	5.979	-17.092	15.807	-4.633	0.464	1.235	-0.376	3.464	-0.139	-0.481
37	3.868	9.498	-28.701	25.505	-7.299	5.979	-17.566	16.697	-5.030	0.464	1.235	-0.376	3.464	-0.139	-0.481
38	3.903	9.498	-29.477	26.903	-7.907	5.979	-18.041	17.612	-5.449	0.464	1.235	-0.376	3.464	-0.139	-0.481
39	3.944	9.498	-30.253	28.337	-8.548	5.979	-18.516	18.551	-5.890	0.464	1.235	-0.376	3.464	-0.139	-0.481
40	3.989	9.498	-31.029	29.809	-9.222	5.979	-18.991	19.515	-6.355	0.464	1.235	-0.376	3.464	-0.139	-0.481
41	4.038	9.498	-31.804	31.318	-9.932	5.979	-19.466	20.503	-6.844	0.464	1.235	-0.376	3.464	-0.139	-0.481
42	4.089	9.498	-32.580	32.864	-10.676	5.979	-19.940	21.515	-7.357	0.464	1.235	-0.376	3.464	-0.139	-0.481
43	4.140	9.498	-33.356	34.448	-11.457	5.979	-20.415	22.552	-7.895	0.464	1.235	-0.376	3.464	-0.139	-0.481
44	4.189	9.498	-34.131	36.069	-12.275	5.979	-20.890	23.613	-8.459	0.464	1.235	-0.376	3.464	-0.139	-0.481
45	4.236	9.498	-34.907	37.727	-13.131	5.979	-21.365	24.698	-9.049	0.464	1.235	-0.376	3.464	-0.139	-0.481
46	4.279	9.498	-35.683	39.422	-14.026	5.979	-21.839	25.808	-9.665	0.464	1.235	-0.376	3.464	-0.139	-0.481
47	4.317	9.498	-36.459	41.155	-14.961	5.979	-22.314	26.943	-10.310	0.464	1.235	-0.376	3.464	-0.139	-0.481
48	4.347	9.498	-37.234	42.925	-15.936	5.979	-22.789	28.101	-10.982	0.464	1.235	-0.376	3.464	-0.139	-0.481
49	4.370	9.498	-38.010	44.732	-16.953	5.979	-23.264	29.284	-11.683	0.464	1.235	-0.376	3.464	-0.139	-0.481
50	4.382	9.498	-38.786	46.577	-18.013	5.979	-23.738	30.492	-12.413	0.464	1.235	-0.376	3.464	-0.139	-0.481
51	4.383	9.498	-39.562	48.458	-19.115	5.979	-24.213	31.724	-13.172	0.464	1.235	-0.376	3.464	-0.139	-0.481
52	4.371	9.498	-40.337	50.377	-20.262	5.979	-24.688	32.980	-13.962	0.464	1.235	-0.376	3.464	-0.139	-0.481
53	4.344	9.498	-41.113	52.333	-21.453	5.979	-25.163	34.261	-14.783	0.464	1.235	-0.376	3.464	-0.139	-0.481
54	4.302	9.498	-41.889	54.327	-22.691	5.979	-25.638	35.566	-15.636	0.464	1.235	-0.376	3.464	-0.139	-0.481

Table A.7: Log of Higher Education Consumption: Married Household with High School Education

Age	Log 1990s/ High Ed Cons.	*constant*	*agel*	*agesq*	*agecu*	*dyr2*	*age90*	*agesq90*	*agecu90*	*urb*	*rinc*	*uer*	*imr*	*mar*	*hs*
55	4.243	9.498	-42.664	56.358	-23.975	5.979	-26.112	36.895	-16.521	0.464	1.235	-0.376	3.464	-0.139	-0.481
56	4.165	9.498	-43.440	58.426	-25.306	5.979	-26.587	38.249	-17.439	0.464	1.235	-0.376	3.464	-0.139	-0.481
57	4.067	9.498	-44.216	60.531	-26.686	5.979	-27.062	39.627	-18.390	0.464	1.235	-0.376	3.464	-0.139	-0.481
58	3.947	9.498	-44.992	62.673	-28.116	5.979	-27.537	41.030	-19.375	0.464	1.235	-0.376	3.464	-0.139	-0.481
59	3.805	9.498	-45.767	64.853	-29.595	5.979	-28.011	42.457	-20.394	0.464	1.235	-0.376	3.464	-0.139	-0.481
60	3.638	9.498	-46.543	67.070	-31.126	5.979	-28.486	43.908	-21.449	0.464	1.235	-0.376	3.464	-0.139	-0.481
61	3.444	9.498	-47.319	69.324	-32.708	5.979	-28.961	45.384	-22.539	0.464	1.235	-0.376	3.464	-0.139	-0.481
62	3.224	9.498	-48.094	71.616	-34.343	5.979	-29.436	46.884	-23.666	0.464	1.235	-0.376	3.464	-0.139	-0.481
63	2.974	9.498	-48.870	73.945	-36.032	5.979	-29.910	48.409	-24.830	0.464	1.235	-0.376	3.464	-0.139	-0.481
64	2.694	9.498	-49.646	76.311	-37.775	5.979	-30.385	49.958	-26.031	0.464	1.235	-0.376	3.464	-0.139	-0.481
65	2.383	9.498	-50.422	78.714	-39.573	5.979	-30.860	51.531	-27.270	0.464	1.235	-0.376	3.464	-0.139	-0.481
66	2.038	9.498	-51.197	81.155	-41.428	5.979	-31.335	53.129	-28.548	0.464	1.235	-0.376	3.464	-0.139	-0.481
67	1.658	9.498	-51.973	83.633	-43.340	5.979	-31.810	54.751	-29.866	0.464	1.235	-0.376	3.464	-0.139	-0.481
68	1.242	9.498	-52.749	86.148	-45.310	5.979	-32.284	56.398	-31.223	0.464	1.235	-0.376	3.464	-0.139	-0.481
69	0.789	9.498	-53.524	88.700	-47.338	5.979	-32.759	58.068	-32.621	0.464	1.235	-0.376	3.464	-0.139	-0.481
70	0.296	9.498	-54.300	91.290	-49.426	5.979	-33.234	59.764	-34.060	0.464	1.235	-0.376	3.464	-0.139	-0.481
71	-0.237	9.498	-55.076	93.917	-51.575	5.979	-33.709	61.484	-35.541	0.464	1.235	-0.376	3.464	-0.139	-0.481
72	-0.812	9.498	-55.852	96.581	-53.785	5.979	-34.183	63.228	-37.064	0.464	1.235	-0.376	3.464	-0.139	-0.481
73	-1.431	9.498	-56.627	99.282	-56.057	5.979	-34.658	64.996	-38.629	0.464	1.235	-0.376	3.464	-0.139	-0.481
74	-2.094	9.498	-57.403	102.021	-58.393	5.979	-35.133	66.789	-40.239	0.464	1.235	-0.376	3.464	-0.139	-0.481
75	-2.804	9.498	-58.179	104.797	-60.792	5.979	-35.608	68.606	-41.892	0.464	1.235	-0.376	3.464	-0.139	-0.481
76	-3.562	9.498	-58.954	107.610	-63.256	5.979	-36.082	70.448	-43.590	0.464	1.235	-0.376	3.464	-0.139	-0.481
77	-4.370	9.498	-59.730	110.461	-65.786	5.979	-36.557	72.314	-45.334	0.464	1.235	-0.376	3.464	-0.139	-0.481
78	-5.228	9.498	-60.506	113.349	-68.383	5.979	-37.032	74.205	-47.123	0.464	1.235	-0.376	3.464	-0.139	-0.481
79	-6.138	9.498	-61.282	116.274	-71.047	5.979	-37.507	76.120	-48.959	0.464	1.235	-0.376	3.464	-0.139	-0.481
80	-7.102	9.498	-62.057	119.236	-73.779	5.979	-37.982	78.059	-50.842	0.464	1.235	-0.376	3.464	-0.139	-0.481

Appendix B
Technical Note Regarding the Computation of Average Skill Acquisition Price

Given a time endowment normalized such that $1 = n^g_{1,t+\tau} + n^g_{2,t+\tau} + l^g_{t+\tau}$, the time t problem of an agent born in period t is formally stated as:

$$\max_{\left\{c^g_{t+\tau}, n^g_{1,t+\tau}, n^g_{2,t+\tau}\right\}_{\tau=0}^{I-1}} E_t\left\{\sum_{\tau=0}^{I-1} \beta^\tau \psi_\tau u(c^g_{t+\tau}, n^g_{1,t+\tau}, n^g_{2,t+\tau})\right\} \tag{B.1}$$

subject to the budget constraints:

$$c^g_{t+\tau} + k^g_{t+\tau+1} \le (1 + r_{t+\tau} - \delta_k)k^g_{t+\tau} + w^s_{t+\tau}h^g_{t+\tau}n^g_{1,t+\tau} \tag{B.2a}$$

$$h^g_{t+\tau+1} \le A\left(h^g_{t+\tau}\right)^{\theta_1}\left(n^g_{2,t+\tau}\right)^{\theta_2} + (1-\delta_h)h^g_{t+\tau}, \tag{B.2b}$$

The Lagrangian becomes:

$$\begin{aligned} L = \sum_{\tau=0}^{I-1} \beta^\tau \psi_\tau u(c^g_{t+\tau}, n^g_{1,t+\tau}, n^g_{2,t+\tau}) + \lambda_1\left((1 + r_{t+\tau} - \delta_k)k^g_{t+\tau} + w^s_{t+\tau}h^g_{t+\tau}n^g_{1,t+\tau} - c^g_{t+\tau} - k^g_{t+\tau+1}\right) + \\ \lambda_2\left(A\left(h^g_{t+\tau}\right)^{\theta_1}\left(n^g_{2,t+\tau}\right)^{\theta_2} + (1-\delta_h)h^g_{t+\tau} - h^g_{t+\tau+1}\right) \end{aligned} \tag{B.3}$$

where λ_1 represents the shadow price of consumption and λ_2 represents the shadow price of skill acquisition. Taking the first order condition with respect to skill hours allows one to solve for λ_2.

F.O.C.

$$\frac{\partial u(c^g_{t+\tau}, n^g_{1,t+\tau}, n^g_{2,t+\tau})}{\partial n^g_{2,t+\tau}} + \lambda_2\theta_2 A {h^g_{t+\tau}}^{\theta_1} {n^g_{2,t+\tau}}^{\theta_2-1} = 0 \tag{B.4}$$

After algebraic manipulation, the average price of skill acquisition is found:

$$\lambda_2 = -\sum_{\tau=1}^{I} \frac{\left(\partial u(c^g_{t+\tau}, n^g_{1,t+\tau}, n^g_{2,t+\tau}) / \partial n^g_{2,t+\tau}\right) \Big/ \theta_2 A {h^g_{t+\tau}}^{\theta_1} {n^g_{2,t+\tau}}^{\theta_2-1}}{I} \tag{B.5}$$