Human Capital Investment: Building an App for That

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This paper outlines the development of a prototype application to estimate the human capital investment of education-career selections. We explain the need to deliver the right information, to the right person, at the right time using a customizable, individualized, just-in-time format. We illustrate how a collaboration between academia and FinTech might leverage the power of distributed expertise to support human capital investment planning via robo-advising. With 112 research-based default parameters, the application can provide detailed financial estimates in seconds. The prototype includes an interface to customize 12 key parameters allowing for extensive exploration of career and education pathways. We illustrate technical elements, the complexity of comprehensive personal financial projections, psychological obstacles, the potential for agency conflict, and balancing academic rigor with user experience. We also offer some insight into challenges and opportunities of this pre-seed venture.

Keywords: career planning, consumer sovereignty, personal finance, robo-advice, technology, employment

INTRODUCTION

Why is there so much conflicting information about human capital investment? Is college the "right" decision with many students actually borrowing too little to finance their college path (Avery & Turner, 2012)? Or, as Caplan (2018) laments, is "there is way too much education" with "typical students burning through thousands of hours of material that neither raises their productivity nor enriches their lives" (pp. 2-3)? Extant research in this area is growing, yet tends to focus on population-level decision making and is of limited use to guide individuals (e.g., Abel & Deitz, 2014; Autor, 2014; Heckman & Letkiewicz, 2021; Lobo & Burke-Smalley, 2017). Given much population-level information, yet persistent confusion, we hypothesize that challenges stem from a lack of individualized information. Motivated by this concern, we outline a prototype human capital investment application developed by an academic-FinTech collaboration and challenges associated with a pre-emergence venture in this arena.

LITERATURE REVIEW AND MOTIVATION

Why the Reluctance to Address Human Capital Investment?

Studying and quantifying individual human capital investment is challenging. Unlike most other capital, a human capital investment is irreversible, collateralized with flesh, and generates returns via the generally opaque labor market. Indeed, the contingent nature of human capital does not lend itself to inclusion on a balance sheet (Washer & Nippani, 2004). Given these challenges, researchers may resort to a dichotomous approach to human capital (i.e., present or absent; see Siepel et al., 2017) or as perceived capability (i.e., entrepreneurial start-up self-efficacy, see Brush et al., 2017) rather than attempt to quantify the actual “value” of human capital. Even discussion of human capital – linking financial value to human value – can elicit strong emotions.

Perception of a robo-advising tool for human capital investment is also an important consideration. Some will view human capital investment robo-advising as a paternalistic device—a means of sorting the “haves” from the “have nots”—furthering inequality instead of decreasing it. Big data algorithms intended to aid human decision making are now criticized for creating disparities in health care (Obermeyer et al., 2019), access to credit (Natarajan & Nasiripour, 2019), data privacy (Hayes et al., 2020), and even parental rights (Eubanks, 2018). Given these considerations, a robo-advising platform providing information about human capital is likely to face criticism.

Much resistance may also arise from the very organizations most capable of guiding human capital investment – universities. Building human capital is a core function of these institutions, yet the financial rewards to human capital investment vary widely by discipline (Abel & Dietz, 2014; Webber, 2014). There exists substantial potential for agency conflict, both from administrators and faculty members, when institutions offer programs promising high variance of net present value (NPV). Both individuals and institutions may resist attempts to quantify the returns to human capital investment. Indeed, a grant reviewer for the current application bluntly stated, “Perhaps this will help some people not choose degrees that have no chance of paying back investment, but that will just kill the arts programs.” As such, faculty entrepreneurs in this area may adopt an “insurgent” mentality whereby the disclosure of the NPV of a chosen degree becomes an issue of social justice and social sustainability (Muñoz & Dimov, 2015).

Finally, university technology transfer may compound this potential agency conflict around user-focused human capital investment applications. Faculty work within a university ecosystem that must support entrepreneurial activities in order for research output to emerge into the marketplace (Thomas et al., 2020). Specifically, research outputs are owned, at least in part, by the originating university and must be developed with the support of the university technology transfer office. However, capabilities and styles of tech transfer offices vary widely (Weckowska, 2015). Even under the best of circumstances, there exists friction between the research-focused faculty, the commercialization-focused tech transfer office, and the enrollment-focused administrators within the university.

Research Goals

Our goal is a dynamic, applied model to address the most important financial decision facing young people. First, we search for a balance between simplistic user-friendly calculators with limited capacity, versus complex academic models that are designed for research rather than for users. The tool should be agnostic regarding education-career pathways in strictly providing financial projections. Meeting this goal would provide the *right information* to the user. Second, the model should allow users to employ editable default parameters as they consider their financial future. Research-based parameters are critical in providing users with appropriate benchmark values, while editability acknowledges the individual attributes of the *right person*. Lastly, the application should be consistently and easily accessible with just-in-time delivery to facilitate information at the *right time*. In the simplest form, we view the challenge as striking a balance in providing the *right information* to the *right person* at the *right time*.

Right Information

Individuals making human capital investment decisions are often confused about the direct costs of their investment (Velez & Horn, 2018) and legislative mandates to clarify college costs have been ineffective with many college websites still omitting critical information in their tuition calculators (Perna et al., 2021). Even if one can determine direct costs, other information is so difficult to coordinate that academic papers often omit key human capital investment variables (e.g., unemployment rates, taxes, Social Security). The sheer amount of information often results in over-weighting some aspects of the investment decision (i.e., college tuition) while under-weighing others (i.e., university graduation rates) (LaFave et al., 2018; Paulsen & St. John, 2002). Rather than attempting to distill a parsimonious model, we model in detail applying researched default parameters. This approach allows an individual to begin with average and then customize to their desire and ability. To capture the greatest value from this model, a user should be able to edit parameters based upon their own situation. Verified and accessible databases are available for a majority of the key parameters to establish credible default values. For example, median salary for particular jobs is available via application programming interface (API) from the Bureau of Labor Statistics. We contend that the primary utility and market potential of an applied model flows from the ability to customize at an individual-level. From a technology angle, a human capital investment planning tool could be stand-alone and useable without professionals. However, from a practical angle, robo-advising platforms are often difficult to navigate (Bartlett & McCarley, 2019). A personal finance professional, instructor, or a similarly trained individual following an established framework could be of great value in guiding the use of an application to estimate human capital investment options (Wright & Ross, 2021).

Right Person

While no shortage of research exists about the “average” college student, individuals often find it difficult to apply average information to their own circumstances (Savage, 2009). Yet some key variables in human capital calculations are critical to personalize. For example, whether or not college is a “good” investment depends largely on one’s individual discount rate and the expected number of periods after graduation. With issues so sensitive as putting a price on patience via the discount rate and confronting mortality via an estimate for remaining periods, one might imagine that some people would refuse to engage. Similarly, the earnings potential for a hopeful career path is a key individual variable, given substantial variation in compensation among various jobs. To this end, the application should allow sufficient customization options and suitable interface to be inclusive (Salampasis & Mention, 2018). While modeling these individual-level variables complicates an already complex problem, the benefits to informed investment decisions are potentially enormous.

Right Time

Financial literacy in young adults is decidedly poor with most high-school students reporting high confidence in finance yet scoring objectively low on financial literacy assessments (Lusardi et al., 2010). To further compound the issue, the adolescent brain is immature and biologically predisposed to favor “emotional” decisions over “rational” ones (Casey et al., 2008; Reyna & Farley, 2006). The higher-order cognitive skills needed for complex decisions, such as hypothetical thought are not fully developed until early adulthood (Giedd, 2008; Johnson et al., 2009). This maturation pattern requires that adolescents make consequential human capital investment decisions when they are underprepared, over confident, and developmentally distant from “homo economicus” (see Braun (2021) for a summary of this term).

While an application cannot speed development of the adolescent brain, it can offer information based on best-practices in the financial education field. Financial knowledge is particularly sensitive to time decay, so presenting appropriate information just-in-time is essential (Fernandes et al., 2014). However, just-in-time interventions are more effective when targeted at specific behaviors (Carlin & Robinson, 2012; Drever et al., 2015; Grinstead et al., 2011). Choi et al. (2016) assert a need for comprehensive financial coaching rather than tackling one interlinked issue after another. However, a just-in-time approach within a comprehensive framework requires trade-offs between theoretical purity and accessibility.

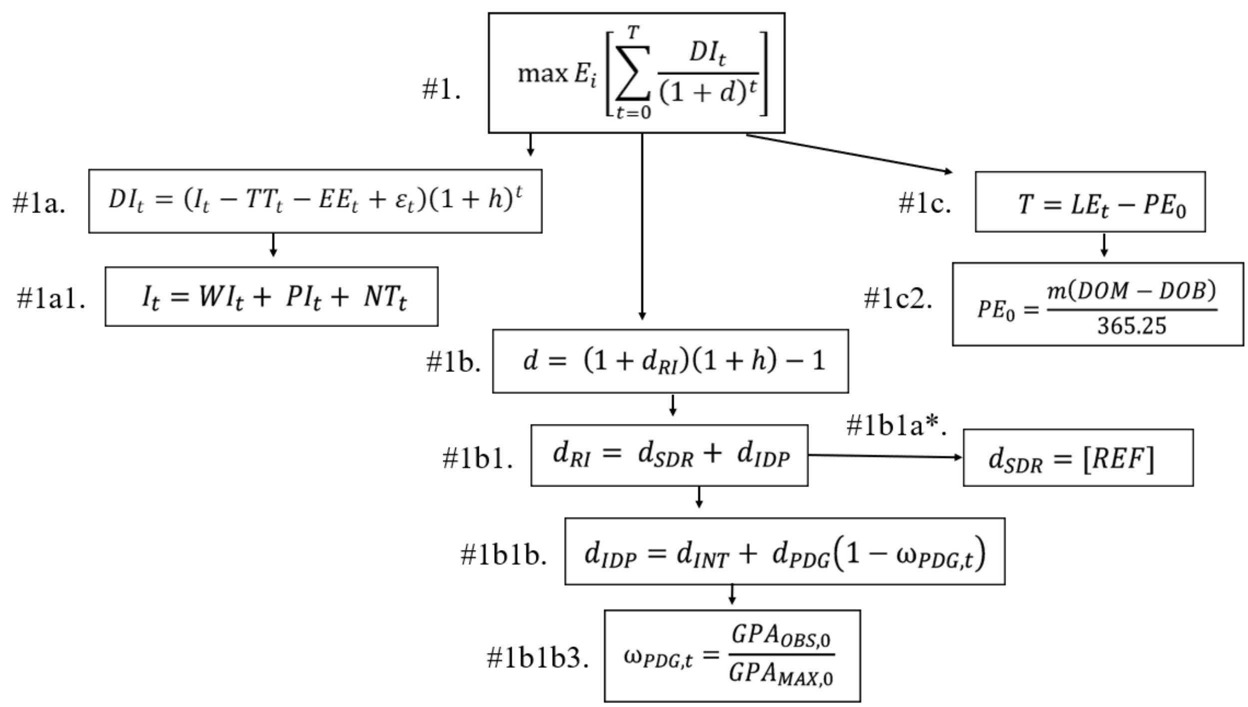
METHODS

A comprehensive education-career investment model must incorporate research-based parameters to facilitate estimation of a lifetime net present value (NPV). While others outline comprehensive lifetime models (Cunha et al., 2006, among others) we structure our model for individual-level application focusing on financial returns to an education-career investment, ceteris paribus, save for adjustments based on individual preferences. We begin with an adaptation of Becker's (1962) equation 5:

$$G = E_i\left[\sum_{t=0}^{T} \frac{DI_t}{(1+d)^t}\right] \quad (1)$$

where the net present value (NPV), G, is a function of individual expectations, $E_i[f(x)]$, using discretionary income, DI_t, from an education-career path applying discount rate, d, over T periods. Given the complexity and need for dynamic updates, we opt for a hierarchical alphanumeric nomenclature to identify both equations and variables rather than a traditional numeric equation identification (see Figure 1).

FIGURE 1
ILLUSTRATION OF THE INITIAL MODEL



Model Specification

Table I provides the default input parameters for the initial model which is outlined in Figure 1. Variables include government-determined parameters, education plans, career goals, personal timeline, and lifestyle selections, among others. The default parameters generally reflect national averages to the extent possible. The primary goal of model specification is to improve the model with better data (Table I) and greater expertise.

Implementation Requirements

At a high level, we establish a minimal set of requirements for implementation of the human capital investment application. The initial goal is not to build out the full application, but rather a Lean Startup

Approach (LSA) to enable engagement with prospective users (Ghezzi, 2019). Obtaining constructive feedback to steer productive FinTech development is critical, particularly when limited to a budget constrained by the resources accessible via a university technology transfer office. The following are implementation requirements of the prototype:

1. Intellectual property (IP) protection: The implementation must protect core IP leaks.
2. Familiar interface: The prototype must appear in a format that is familiar to users. This reduces the friction for onboarding new users allowing prototype deployments to focus on the capabilities of the tool rather than the interface.
3. Reasonable user experience (UX): While production-level quality UX is not required, it should nonetheless be understandable, easily readable, low latency, etc.
4. Scalable: Even at an early stage, one must factor in the ability of the approach to scale longer term. This could mean support for new features, a growing user base, or a variety of use cases.
5. Simple delivery: Delivery of the tool should minimize intervention from administrators, developers, or support staff.
6. Low cost: The system should require minimal maintenance expense to remain online and functional. Specifically, this includes keeping the software stack updated with regular operating system (OS) and tool updates so that it remains secure.

RESULTS AND DISCUSSION

The resulting prototype application at www.cashncareers.org suggests that a collaboration between academia and FinTech holds potential in developing a customizable, just-in-time human capital investment decision application. The model and default parameters with this prototype construction produce accessible and plausible human capital financial estimates.

Goal 1 Result: Right Information

We construct equations around research-based parameters and available data sources. In situations where theoretical purity conflicts with accessibility of quality data, we compromise to facilitate a functional system. While imperfect, the model uses verified data to yield projections such that the user may "off-load" many aspects of the calculation, including the tedious search for clear costs and coordination of relevant information. One key feature is the ability to account for opportunity costs, resulting in an agnostic tool that does not steer an individual toward any particular path but rather provides financial projections. We assert that while Table I includes many variables, still more variables could be reasonably included in an initial model. The volume and sourcing challenges of accessing quality parameters necessarily means that imperfect variables are included.

Given the six requirements outlined above, we implement the applied model using a cloud based serverless infrastructure. In this environment, the cloud provider professionally maintains machines, operating systems, patches, infrastructure software, etc., which are then rented out on an as-needed basis. This approach provides a high uptime, low maintenance, and highly scalable platform that can easily scale with the number of users and support more advanced features with very low up-front investment. When combined, the Table I data and application implementation offer users the ***right information.***

Goal 2 Result: Right Person

A prototype user can adjust financial information to apply scenario or sensitivity analysis appropriate to their individual circumstances. Specifically, the model should consider how individual qualities alter the financial projections. For example, the default high-school GPA of 2.59 must be editable to reflect academic variance. As a proxy for ability, GPA propagates through the model with an adjustment to the discount rate (equation 1b1b3*), the college completion probability (equation 1a1a1a3*), and earnings potential (equation 1a1a2a2*) with an end result of NPV variance given the same career selection. While this approach has much room for improvement, it does offer customizable financial and academic information—specific to the ***right person***.

Compared to gathering the information, allowing for customization of the information is relatively straightforward. The primary obstacle with customization is guiding users in how to make sensible adjustments. While the model incorporates the equations and default values, not all parameters are editable in the prototype. Our research team identified identify key variables to implement initially, however, we acknowledge that inclusion of additional customizable variables is a critical step going forward. Furthermore, implementation must be thoughtful to avoid UX overload.

Goal 3 Result: Right Time

In addition to the above architectural considerations (e.g., desktop and mobile access, high website uptime, etc.), we specifically optimize the system to achieve low latency response times. Our initial approach generated a variety of charts on the server side and then transmitted these to the client to display, in an attempt to minimize the amount of processing required by the client. In reality, between the processing required on the server side and the additional data transmission needed, we observed response times of about ten seconds, which is far too slow for a viable UX. The prototype implementation inverts this approach. Data for the charts is generated on the server side and semantically compressed, resulting in transmission of less than five kilobytes. The entire application programming interface (API) call takes about half a second to complete, including Secure Sockets Layer (SSL) session initiation and communication overhead. Displaying the resulting data takes less than 100 milliseconds as measured on a consumer grade laptop.

Development of a web-based tool to calculate one's NPV for their human capital investment is invaluable for the just-in-time approach to financial education and literacy. Research suggests young adults with unhealthy financial behaviors (e.g., low financial impulse control) are the most likely to consult online resources and social media for financial advice (Cao & Liu, 2017). Accordingly, accessible human capital investment information is likely to command a premium during adolescence. Targeting adolescents with a responsive web-based tool allows delivery at the ***right time*** to best leverage the resulting financial information.

Yet, the accessibility and ease of use also presents challenges. Prototype testing indicates that while the majority of users understand the value of the tool to estimate a feasible financial future, not all users do so. Some appear to search for inputs that will increase the financial projections with little thought to the selections they are making. Upon finding a sufficiently high estimate, they appear sanguine with their financial future with seemingly no comprehension that despite disliking school their selected path requires a terminal degree. This result is concerning as the likelihood of a student with a history of academic underperformance achieving a terminal degree is quite low and, yet, consistent with the Dunning-Kruger effect where the individual lacks enough self-awareness to realize their incompetence (Kruger & Dunning, 1999). Again, proper use of any sufficiently complicated tool may require guidance from a professional.

CONCLUSION

Limitations and Future Directions

The limitations of this model and the overall approach are many. First, we acknowledge that financial costs and benefits of human capital investment are but one aspect of the decision-making process. Even though all areas of wellness are interconnected, dollars are relatively easy to operationalize while other dimensions of wellness are generally more difficult to define and measure (Swarbrick, 2006). Second, this model also does not address a number of hard-to-quantify aspects of human capital investment and career selection. Social considerations involving human capital may include positive externalities such as more effective citizenship, greater opportunities for mate selection, or simply having fun. Value based features such as career expenses, employment benefits, or other non-wage consideration are not explicitly included in this model. The model also fails to address a number of non-monetary individual considerations such as working conditions, perceived job usefulness (Wolfe & Patel, 2019), self-actualization or self-knowledge (Van Ewijk & Weber, 2021), and association with a particular institution.

Finally, this model does not explicitly address all aspects of a lifetime financial picture. Improving estimates without degrading the UX requires both the general intelligence of human experts and the specialized intelligence of smart machines, human-computer superminds (Malone, 2018). Machine learning presents a means to address, if not optimize, human interaction with a complex and dynamic model (Verbraeken et al., 2020). We also model human capital investment only in the United States as other nations have substantially different structures (see for example, Bönte & Filipiak, 2012; Hanafizadeh et al., 2014). Refining the prototype application requires careful analysis of the trade-offs between the rigor of estimates and the UX.

Implications

This work, and other digital resources to support human capital investment decisions such as Georgetown's College ROI tool (Carnevale et al., 2019) or Init2Winit (Chen et al., 2021), point the way toward the future of personal financial planning around education investments. Potential benefits include a more invested labor force, greater labor mobility, enhanced consumer sovereignty, and increased chances of entrepreneurial success (Millan et al., 2014). Higher education is often difficult to navigate for first-generation college students and those with limited economic means. As such, these same individuals may benefit the most from timely information regarding human capital investments. Research suggests that those with low levels of financial literacy are likely to rely on friends and family for financial advice (who may also have low financial literacy) and are less likely to engage in proactive investment behaviors (Van Rooij et al., 2011). Instead of a challenge, this behavior could be viewed as an opportunity; individuals who have been historically underserved by traditional financial institutions may be more likely to engage with FinTech, especially if accessible using a mobile device (Salampasis & Mention, 2018).

While the market is ripe for development of individual-level human capital investment tools (Julien & Ross, 2020), entrepreneurial perseverance in the area is a challenge. University faculty versed in research, modeling, and having close student interaction may be the most capable of developing such a tool, yet university resources and tech transfer funding exists in a complex milieu of administration, admission quotas, and transparency mandates. This pre-emergence venture is so closely tied to the university mission it requires a high degree of opportunity confidence (Dimov, 2010). Given the amplified potential for agency conflict, maintaining the emotional energy needed to persevere is critical (Walsh et al, 2020). Despite these substantial challenges, we assert that a human capital investment robo-advising platform holds great promise for those eager to explore a unique project—their own human capital investment.

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APPENDIX

TABLE 1
DEFAULT PARAMETERS FOR THE CLASS OF 2020

Equation	Variable	Parameter description	Default (t=0)	Units	Source
1a1a(1a&2a1(b&c) / 1b1b3b	$GPA_{OBS,0}$	High school grade point average (GPA)	2.59	#	French, Homer, Popovici, & Robins (2015)
1a1a1a	$GPA_{OBS,1}$	Stage 1 grade point average (GPA)	2.85	#	assume 10% higher than prior stage
1a1a1a	$GPA_{OBS,2}$	Stage 2 grade point average (GPA)	3.13	#	assume 10% higher than prior stage
1a1a1a	$GPA_{OBS,3}$	Stage 3 grade point average (GPA)	3.44	#	assume 10% higher than prior stage
1c2a / 1a3b2b / 1a3c2	m	Periods per year	12	months	assume monthly
1a1a1a1	$GPA_{I,\mu,1}$	Mean incoming GPA of cohort: stage 1	2.59	#	French et al. (2015)
1a1a1a1	$GPA_{I,\mu,2}$	Mean incoming GPA of cohort: stage 2	2.85	#	assume 10% higher than prior stage
1a1a1a1	$GPA_{I,\mu,3}$	Mean incoming GPA of cohort: stage 3	3.13	#	assume 10% higher than prior stage
1a1a1a1	$GPA_{I,\mu,4}$	Mean incoming GPA of cohort: stage 4	3.44	#	assume 10% higher than prior stage
1a1a1a2	$\omega_{IAC,1}$	Probability of completion: stage 1	80.62	%	assume an exponential function
1a1a1a2	$\omega_{IAC,2}$	Probability of completion: stage 2	65.00	%	Chatterjee & Ionescu (2012)
1a1a1a2	$\omega_{IAC,3}$	Probability of completion: stage 3	52.40	%	assume an exponential function
1a1a1a2	$\omega_{IAC,4}$	Probability of completion: stage 4	42.25	%	assume an exponential function
1a1a2a1a	γ_{GPA}	Earnings premium and GPA	12.81	%	French et al. (2015)
1a1a2b	$W_{IC,\mu,0}$	Median bachelor degree wages	57180	$/year	US Census Bureau (2018)
1a1a2c	$\epsilon_{1,IC,t}$	Earned wages, successful investment	1 or 0	Dummy	assigned if applicable
1a1a2c X / 1a1a3c X	UED	Unemployment duration	5	months	US Bureau of Labor Statistics (2019c)
1a1a2d	$\epsilon_{2,IC,t}$	Collected unemployment, successful investment	1 or 0	Dummy	assigned if applicable
1a1a2d X	$\omega_{UE,IC}$	Unemployment rate college graduate	3.41	%/year	US Bureau of Labor Statistics (2019a)
1a1a2e1 / 1a1a3e1	UE_{MAX}	Maximum unemployment insurance	362	$/week	Bonn (2019)

1a1a3 X	$Y_{retirement}$	Expected retirement age	66	years	Newport (2019)
1a1a3b / 1a1a3e	$W_{IF,\mu,0}$	Median high school diploma wages	34298	$/year	US Census Bureau (2018)
1a1a3c	$\epsilon_{3,IF,t}$	Earned wages, failed investment	1 or 0	Dummy	assigned if applicable
1a1a3c X	m_{child}	Time out of work per child	3	months	US Department of Labor (2012)
1a1a3d	$\epsilon_{4,IF,t}$	Collected unemployment, failed investment	1 or 0	Dummy	assigned if applicable
1a1a3d X	$\omega_{UE,IF}$	Unemployment rate high school graduate	7.18	%/year	US Bureau of Labor Statistics (2019b)
1a1b1	$\epsilon_{5,t}$	Collecting social security payments	1 or 0	Dummy	assigned based on SS age
1a1b1 X	$Y_{early\ SS}$	Stop work age for partial benefits	62	years	Social Security Administration (2019b)
1a1b1 X	$Y_{full\ SS}$	Full retirement age	67	years	Social Security Administration (2019b)
1a1b21	ω_{SS}	Social security percent of working wages	40.00	%	Social Security Administration (2019a)
1a1b3	$\epsilon_{6,t}$	Collecting retirement payments	1 or 0	Dummy	assigned based on retirement age
1a1b5 / 1a1b5c	r_{IR}	Investment returns	6.08	%/year	assumed equal to unsubsidized graduate rate
1a1c1	C_0	Income from charity and government	0	$/year	assume no assistance
1a1c2	G_0	Gifts	9130	$/year	Wightman, Schoeni, & Robinson (2012)
1a1c3 / 1a3b1	$\epsilon_{7,i,t}$	Investment in stage i human capital	1 or 0	Dummy	assume investment through stage 2
1a1c4a	$AS_{i=1,0}$	Scholarships & student grants: stage 1	9519	$/year	Baum, Ma, Pender, & Libassi (2018)
1a1c4a	$AS_{i=2,0}$	Scholarships & student grants: stage 2	9519	$/year	Baum, Ma, Pender, & Libassi (2018)
1a1c4a	$AS_{i=3,0}$	Scholarships & student grants: stage 3	10389	$/year	Baum, Ma, Pender, & Libassi (2018)
1a1c4a	$AS_{i=4,0}$	Scholarships & student grants: stage 4	12055	$/year	Baum, Ma, Pender, & Libassi (2018)
1a1c4b1 / 1a3b3(a)	m_C	Academic terms per year	3	semesters	Bostwick, Fischer, & Lang (2022)
1a1c4b3 / 1a3b3(c)	m_I	Investment terms per year	2	semesters	assume no summer courses
1a2a / 1a2a1	$\omega_{ST,t}$	State income tax rate	4.25	%/year	Loughead & Wei (2019)
1a2a / 1a2a1	$\omega_{LT,t}$	Local income tax rate	0.00	%/year	Moreno (2018)
1a2a1	TD_0	Standard deduction	12200	$/year	El-Sibaie (2018)
1a2a1	TE_0	Standard exemption	0.00	$/year	El-Sibaie (2018)
1a2a1	$\omega_{SST,t}$	Social security rate	6.20	%/year	Internal Revenue Service (2019)
1a2a1	$TC_{SST,0}$	Social security cap	132900	$/year	Internal Revenue Service (2019)

1a2a1	$\omega_{MT,t}$	Medicare tax	1.45	%/year	Internal Revenue Service (2019)
1a2a1	$TC_{MT,0}$	Medicare cap	200000	$/year	Internal Revenue Service (2019)
1a2a1	$\omega_{AMT,t}$	Additional medicare tax	0.90	%/year	Internal Revenue Service (2019)
1a2a1	ω_{FT1}	Federal income 10% tax rate	9700	$	El-Sibaie (2018)
1a2a1	ω_{FT2}	Federal income 12% tax rate	39475	$	El-Sibaie (2018)
1a2a1	ω_{FT3}	Federal income 22% tax rate	84200	$	El-Sibaie (2018)
1a2a1	ω_{FT4}	Federal income 22% tax rate	160725	$	El-Sibaie (2018)
1a2a1	ω_{FT5}	Federal income 32% tax rate	204100	$	El-Sibaie (2018)
1a2a1	ω_{FT6}	Federal income 35% tax rate	510300	$	El-Sibaie (2018)
1a2a1	ω_{FT7}	Federal income 37% tax rate	no cap	$	El-Sibaie (2018)
1a3a6a	K	Number of children	2	#	Roser (2019)
1a3a6b	KC_1	Cost per child #1 per month	954.17	$/month	Lino et al. (2017)
1a3a6b	KC_2	Cost per child #2 per month	646.67	$/month	Lino et al. (2017)
1a3a6b	KC_{3+}	Cost per child #3 and more per month	278.33	$/month	Lino et al. (2017)
1a3a6b X	Y_{child}	Age at first child	26	years	Bui & Miller (2018)
1a3a6b X	$Y_{next\ child}$	Time between children	2.5	years	Kraft (2012)
1a3a6b X	$Y_{child\ out}$	Age out of parent's care	22	years	OECD (2007)
1a3a7a	$\epsilon_{8,t}$	Living with partner	1 or 0	Dummy	assume living status aligns with marriage
1a3a7a X	$Y_{marriage}$	Age at first marriage	28.65	years	Population Reference Bureau (2019)
1a3a7b	$\epsilon_{9,t}$	Partner is employed	1 or 0	Dummy	assume partner employment
1a3a7c	$\omega_{LE,t}$	Living expense % by partner when employed	0.00	%	assume contribution is independent
1a3a7d	$\omega_{LB,t}$	Living expense % by partner, baseline	50.00	%	assume an even split
1a3b2	$AT_{i=1,0}$	Annual tuition: stage 1 (Lower division)	3943	$/year	Ma, Baum, Pender, & Libassi (2018)
1a3b2	$AT_{i=2,0}$	Annual tuition: stage 2 (Upper division)	10723	$/year	Ma, Baum, Pender, & Libassi (2018)
1a3b2	$AT_{i=3,0}$	Annual tuition: stage 3 (Graduate)	18765	$/year	assume 75% increase from prior stage
1a3b2	$AT_{i=4,0}$	Annual tuition: stage 4 (Terminal)	32838	$/year	assume 75% increase from prior stage
1a3b4	h_{CT}	Expected tuition inflation	3.80	%/year	College Board (2019)

1a3c1	$\epsilon_{10,t}$	Student loan repayment phase	1 or 0	Dummy	assigned if applicable
1a3c2a	C_1	Periods from stage 0 to stage 1	24	months	assume two years
1a3c2a	C_2	Periods from stage 1 to stage 2	28	months	Cataldi et al. (2011)
1a3c2a	C_3	Periods from stage 2 to stage 3	24	months	assume two years
1a3c2a	C_4	Periods from stage 3 to stage 4	24	months	assume two years
1a3c2a2	$\epsilon_{11,t}$	Investment phase dummy	1 or 0	Dummy	assigned if applicable
1a3c2a3	$\epsilon_{12,t}$	Discretionary income < 0	1 or 0	Dummy	assigned if applicable
1a3c2a4	$\epsilon_{13,t}$	Annual student loans < maximum loans	1 or 0	Dummy	assigned if applicable
1a3c2b4	ML_1	First-year undergraduate annual limit	9500	$	US Department of Education (2019b)
1a3c2b4	ML_1	Second-year undergraduate annual limit	10500	$	US Department of Education (2019b)
1a3c2b4	ML_2	Third-year and more undergraduate annual limit	12500	$	US Department of Education (2019b)
1a3c2b4		Undergraduate aggregate loan limit	57500	$	US Department of Education (2019b)
1a3c2b4	ML_3	Graduate and professional annual limit	20500	$	US Department of Education (2019b)
1a3c2b4		Graduate and professional aggregate loan limit	138500	$	US Department of Education (2019b)
1a3c2c2	r_1	Unsubsidized loan rate: stage 1 (Undergraduate)	4.53	%/year	US Department of Education (2019b)
1a3c2c2	r_2	Unsubsidized loan rate: stage 2 (Undergraduate)	4.53	%/year	US Department of Education (2019b)
1a3c2c2	r_3	Unsubsidized loan rate: stage 3 (Graduate)	6.08	%/year	US Department of Education (2019b)
1a3c2c2	r_4	Unsubsidized loan rate: stage 4 (Graduate)	6.08	%/year	US Department of Education (2019b)
1a3c6	P_1	Repayment plan 1 (10 years)	7500	$	US Department of Education (2019a)
1a3c6	P_2	Repayment plan 2 (12 years)	10000	$	US Department of Education (2019a)
1a3c6	P_3	Repayment plan 3 (15 years)	20000	$	US Department of Education (2019a)
1a3c6	P_4	Repayment plan 4 (20 years)	40000	$	US Department of Education (2019a)
1a3c6	P_5	Repayment plan 5 (25 years)	60000	$	US Department of Education (2019a)
1a3c6	P_6	Repayment plan 6 (30 years)	no cap	$	US Department of Education (2019a)
1a3d1	$\epsilon_{14,t}$	Line of credit balance > 0	1 or 0	Dummy	defined
1a3d14	r_Q	Borrowing rate	6.08	%/year	assumed equal to unsubsidized graduate rate
1a3d2	$\epsilon_{15,t}$	Discretionary income + student loan draw > 0	1 or 0	Dummy	defined

1a3d2	$\epsilon_{16,t}$	DI + student loan draw - Q > 0	1 or 0	Dummy	defined
1a3d3	$\omega_{Q,t}$	Target debt paydown	75.00	%	assumed
1a3e	$\omega_{RR,t}$	Target retirement savings	40.00	%	50-30-20 rule (20/(30+20))
1a5	h	Expected inflation	2.00	%/year	Federal Reserve (2019)
1b1a	d_{SDR}	Social discount rate	3.50	%/year	Moore et al. (2004)
1b1b1	d_{INT}	Individual discount adjuster	0.00	%/year	assumed
1b1b2	d_{PDG}	Individual delayed gratification	18.00	%/year	Warner and Pleeter (2001)
1b1b3b	$GPA_{MAX,0}$	Maximum GPA in high school	4.00	#	assumed
1c1	Y_{life}	Life expectancy at birth	78.70	years	Arias, Xu, and Kochanek (2019)
1c2b	DOM	Date of model	5/30/ 2020	date	Add 17 years & round up to May 30th
1c2c	DOB	Date of birth	7/4/ 2002	date	Default reference selected as July 4th