Daddy Not Cool
Portfolio choice, human-capital investments & consumption

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Abstract This study, by developing a life-cycle model, numerically computes the optimal portfolio allocation of a parent with endogenous human-capital production of the offspring in an environment of correlated labour and stock market returns. The study explores the competing challenges of consumption, retirement savings and educational investments faced by an altruistic parent in a two-generation, multi-time period life-cycle setup. The problem is solved using dynamic programming where life-cycle profiles are generated using simulations. Consistent with empirical literature, results show shift towards bonds even in the early periods due to presence of an offspring. Portfolio allocation graph is double humped, reflecting the differential risk appetite of a parent with a dependent offspring as opposed to the same parent with an adult offspring. Presence of pension savings alters the profile to triple hump indicating higher risk appetite post retirement owing to pension annuities. Higher access to human-capital investment options is found to shift the portfolio allocation towards stock in the early periods, thus acting as a counter-weight to shift towards bonds. The study contributes by integrating the literatures on portfolio choice and human-capital.

Keywords Portfolio choice · Human capital
JEL classification: G11; N35

1 Introduction

Children play an important role in portfolio choice because of their higher consumption and educational needs. Besides, the presence of children introduces a new phase in an adult-worker's life-cycle apart from his/her regular working-life and retired phases. The focus of this study is to compute the finite-period portfolio allocation problem of a parent with a dependant offspring and explore the interaction between human-capital and stock market investments.

Portfolio theory began with the pioneering work of Samuelson (1969) and Merton (1969). Their work, assuming i.i.d. returns, CRRA utility and frictionless markets, proved that contrary to popular belief, portfolio allocation should remain constant over the lifetime irrespective of wealth or age. Bodie et al (1992) extended the model by including leisure and tradable labour supply and concluded that it is optimal for working agents to hold more stock than retired individuals. However, it is clearly established in the literature that a person is not allowed to borrow from ones future earnings due to asymmetric information and moral hazard problems. (Stiglitz and Weiss (1981)).

In a more realistic model, Cocco et al (2005) included non-tradable labour income, borrowing constraints and labour income risk into a finite-period life-cycle model. After solving the model through numerical simulations they concluded that, in contrast to Samuelson and Merton, the optimal fraction of risky asset in the portfolio actually goes down with age and wealth. They position their work as an extension of the consumption literature on buffer stock saving by Deaton (1989), Carroll and Samwick (1997) and Gourinchas and Parker (2002).

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Often a working individual will be a part of a household with offsprings. A parent can have a varied and wide set of interactions with his child ranging from pure altruism as in Becker (1974) where the utility of the child influences his own utility, to service minded altruism as in Cox (1987), to pure transfer motive where his investment in his child's human capital is a means of transferring resources inter-temporally (as in Cigno (1993)).

Recent studies like Love (2010) and Hubener et al (2016) include children in the parents' optimization problem to model the impact of demographic shocks like marital transition and children on portfolio choice. They find that children play an important role in portfolio choice because of higher consumption needs and college costs. Their study finds that for individuals with children, widowhood leads to a sharp reduction in stock investment as a fraction of total savings. This is consistent with empirical observations that young people, contrary to established literature (Cocco et al (2005)), have lesser stock holdings in their early life than expected.

This study therefore attempts to further explore the parental response to risk in the presence of children's consumption and human-capital requirements. The presence of children adds additional events in the parents' life-cycle dividing it into three broad phases: the joint-phase when the dependent offspring's consumption and human-capital needs are taken care of by the parent, the independent-phase when the grown-up offspring separates to start his own family and the parents' post retirement phase. The risk appetite of the parent is expected to be different in all the three phases, as also his assets and expenses.

The primary sources of risk are the labour market shocks and the stock market shocks. The presence of aggregate shocks to the economy makes the labour income process correlated with the dividend process. Baxter and Jermann (1995), Campbell (1993) and several other studies document the presence of strong correlation between labour market returns and stock market returns. Hence, in the event of high risk (strongly correlated labour and stock markets) the parents' portfolio allocation with dependent children is likely to be different from that of a single individual.

As opposed to Love (2010) and Hubener et al (2016) who model education costs as a lumpsum payment of permanent income, this study explicitly models a father's investments into his offspring's human capital considering downward altruism and parental valuing of human-capital as drivers of parental investment.

In doing so, this study considers a two-generation, finite time-period life-cycle portfolio choice problem of an altruistic parent facing the challenges of his own consumption, his childs consumption and education needs and his own retirement savings in the presence of borrowing constraints, bequests and pension funds.

The goal of this study is to distil out the variation in portfolio allocation of a parent in the different phases of his life-cycle as a response to increasing risk. The study analyses how portfolio choice changes for different parameters like correlation coefficient between stock and labour market shocks, higher access to educational investments, expected return of stock & bond, standard deviation of stock & wage shocks, risk aversion coefficient and introduction of taxes.

This study integrates into the existing literature on various aspects of portfolio choice like effect of taxes (Dammon et al (2001)), asset pricing implications (Constantinidies et al (1998) , Storesletten et al (2007)) and housing as an asset (Cocco (2005), Hu (2005) and Yao and Zhang (2005)).

Section 2 describes the environment in detail while sections 3 & 4 discuss the parameter values and simulation results of the benchmark cases. Section 5 presents the portfolio choice and consumption elasticities for various financial parameters like expected stock return, standard deviation of stock return, labour income risk and others. The mathematical solution and algorithm are presented in the online supplementary material.

2 The Environment

The model assumes a single parent single offspring set-up. The terms dad and son are used as proxies for parent and offspring[1]. There are 70 discrete time-periods in the model. Time starts at $t = 1$ when the offspring is an infant and the parent is 20 years older. There are two distinct phases in the model based on the offspring's stage of life : the first 20 time periods (referred to as the joint-phase) when the parent and the offspring are a single household and the adult-phase when the grown up offspring separates and starts his/her own household.

[1] the model is gender neutral and the focus is mainly on the transfer of resources from the older generation to the newer

In the first five time-periods (pre-school), the parent only incurs consumption expense on the offspring. Because, the child's health related expenses are not explicitly modelled, in the simulations the consumption expenses of the parent and child are assumed as equal.

From $6 \leq t \leq 20$ the parent can additionally either incur human-capital expenses of the child by sending him/her to school or in the extreme, augment family income by making the offspring work in the informal labour market.

From $t = 21$ onwards, the offspring separates from the parent and they have no economic interaction except for a last period planned bequest from the parent. At $t = 41$ the parent starts his/her retired life (age 61) and $t = 50$ is the last period of the parent's life (age 70). The parent leaves a constant fraction of his/her last period wealth as planned bequest. The offspring starts his/her adult life at $t = 21$ with zero assets, retires at $t = 60$ and $t = 70$ is the last time period in the model when the offspring dies. The model stays away from a dynastic framework by excluding further generations.

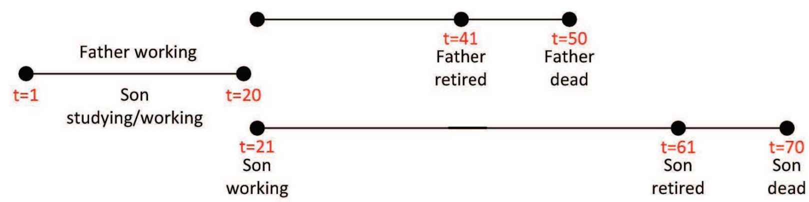


Fig. 1: Time-line : Two-generation, seventy discrete time-periods' life-cycle

Human-capital

From, $6 \leq t \leq 20$, the parent has an option of either educating the offspring or sending him/her to the informal labour market or a combination of both. The offspring is endowed with a unit amount of time in each period. The fraction of time devoted to education in time-period t is denoted as λ_t. The parent also decides the amount of books b_t to be invested in each period. The offspring's future income as an adult depends on the level of human capital accumulated in the education phase ($6 \leq t \leq 20$).

The household faces borrowing constraints every period as the parent cannot borrow against his/her offspring's future labour income due to moral hazard problems. The model also assumes that the parent has no borrowing options against his/her own future labour income due to labour-income risk.

The parent's human capital $H_{f,t}$[2] $= H_{dad}$ is assumed constant over time. The child's human capital at period $t+1$, in the education phase, is the function (Ben-Porath (1967)) of previous period's human capital $H_{s,t}$, ability level θ, time fraction spent studying λ_t, books invested b_t and the rate of depreciation δ.

$$\begin{aligned} H_{f,t+1} &= H_{f,t} = H_{dad} \\ H_{s,t+1} = f(\theta, \lambda_t, H_{s,t}, b_t) &= H_{s,t}(1-\delta) + \theta(\lambda_t)^{aa}(H_{s,t})^{bb}(b_t)^{cc} \end{aligned} \tag{1}$$

Since, the nutritional effect on human-capital is not modelled in the pre-school stage, human-capital is assumed to remain at the base level $\bar{H}$ upto age 6 after which its acquisition can start. Also, since the parent is solving the life-cycle model at $t = 1$ and assumes the offspring will be a separate household once he reaches age 21, the parent only takes into account formal education upto graduation[3]. Human-capital accumulation prospects of the independent offspring through On-the-Job Training (OJT) is not modelled.

At any time period t, the maximum human-capital the child can enter the next time-period with, corresponds to $\lambda_t = \lambda_{max}$ and $b_t = b_{max}$ where $\lambda_{max} = 0$ when the child is in the pre-school stage and equal to 1 for other periods in the education phase.

$$H_{s,t+1}(\lambda_{max}, b_{max}) = f(\theta, \lambda_{max}, H_{s,t}, b_{max}) = H_{s,t}(1-\delta) + \theta(\lambda_{max})^{aa}(H_{s,t})^{bb}(b_{max})^{cc} \tag{2}$$

[2] subscript f stands for father, s stands for son

[3] refers to 15 years of education in developing countries like India. 12 years in school and 3 years in college. Similar to under-grad in US

b_{max} is the maximum investment possible in books at any time t and is zero at pre-school and then constant for a given income category. It varies for different income categories to reflect the inaccessibility of good schools/educational inputs for the poor households.

The dad has an explicit per-period utility from the educational inputs (education-time and books) he is able to afford for his child's human-capital production. The utility is assumed to have the following functional form:

$$u(\lambda_t, b_t) = pen.\Big(H_{s,t+1}(\lambda_t, b_t) - H_{s,t+1}(\lambda_{max}, b_{max})\Big) \tag{3}$$

where pen is a constant number (not function) signifying the amount of utility gain per-unit of additional human capital produced. pen is calibrated in the model such that a dad with matriculation level[4] of education, on average (10000 simulations), teaches his son upto matriculation or higher for 75% of the trials as is empirically reported by studies on Latin American and Indian data (Gaviria and Székely (2010) & Azam and Bhatt (2015)).

Thus $u(0,0) = -pen.H_{s,t+1}(max)$ and $u(\lambda_{max}, b_{max}) = 0$ and u is an increasing function of the inputs with an upper bound of zero.

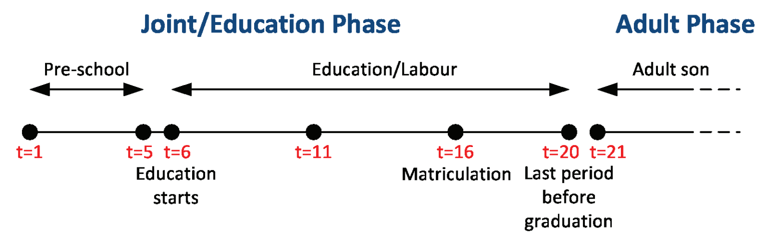


Fig. 2: Time-line: Important points in the son's education phase

Dad's wage

Wages are subjected to a per period wage shock e_t which can take two discrete values, $e_t = \{e_{low}, e_{high}\}$ such that $\mathbf{E}[e_t] = 1$. The actual wage of an adult with human-capital level H_{dad} at time t for given wage shock realization e_t

$$WAGE(H_{dad}, t, e_t) = \bar{G}^{t-1} H_{dad} e_t \tag{4}$$

where $\bar{G}$ is the exogenous growth in expected wage rate every year.

Therefore, the minimum expected adult wage corresponds to that of an adult with base level of human-capital ($\bar{H}$) and is equal to one[5] at $t = 1$ and grows exogenously at growth rate $\bar{G}$. In monetary terms one would be equivalent to \$2/day.

Financial assets

Financial assets consist of a risk-less one-period bond of gross real return R_0 and a risky one-period stock with gross real return R_{γ_t} where :

$$R_{\gamma_t} = R_0 + \mu + \gamma_t \tag{5}$$

γ_t is the time t shock to the stock return which can take two discrete values $\gamma_t = \{\gamma_{low}, \gamma_{high}\}$ such that $\mathbf{E}[\gamma_t] = 0$. μ is the excess return of stock over bond. Shocks to labour-wage e_t and stock returns γ_t can be correlated.

Child-labour wages

If the parent decides to send his/her offspring to work then the child-labour wages apply which according to a survey

[4] secondary level

[5] $\bar{H}$ is calibrated to be equal to 1.0

report on industries in Ghana, India, Phillipines and Uganda range from 20% to 66% of minimum adult-wage. At any given time t, for human-capital of son $H_{s,t}$, time-fraction λ_t spent in education, the child-labour wage earned is equal to :

$$CLWAGE(H_{s,t},t) = \bar{G}^{t-1}H_{relv}(1-\lambda_t) \tag{6}$$

where H_{relv} is the relevant, age dependent, child-labour wage rate defined in Table 1

Table 1: Child-labour wage rates

	$0 \leq age \leq 5$	$6 \leq age \leq 10$	$11 \leq age \leq 15$	$16 \leq age \leq 20$
H_{relv}	0	$0.33\bar{H}$	$0.5\bar{H}$	$H_{relv} = H_{matric}$ if $H_{s,t} > H_{matric}$ else $H_{relv} = \bar{H} = 1$

H_{matric} is the matriculation level[6] of human-capital and $\bar{H}$ is the base level of human-capital. From $16 \leq age \leq 20$ the wage rate is assumed as equal to the minimum adult wage rate if the human-capital level of the son is less than matriculation level of human-capital else the applicable wage-rate is the matriculation wage rate (which is 200% of the minimum adult wage rate). Child-labour wages are assumed as non-stochastic.

Expected Utility Maximization

Let $\Omega_t = (\gamma_t, e_t)$ denote the vector of the wage shock e_t and stock market shock γ_t at any time t. Both e_t and γ_t are individually uncorrelated over time. However, they can be cross-sectionally correlated. Let $\Omega^{(t)} = \Omega_1, \Omega_2, \Omega_3....\Omega_t$ denote the history of joint shocks[7] upto upto time t.

At time $t = 1$ and aggregate state Ω_1, for resources-in-hand $X_{f,1}$, human-capital of son $H_{s,1}$ and contributed-pension-fund deposit $PF_{f,1}$, the dad seeks to maximize the expected utility from his and his son's lifetime consumption accounting for per-period utility from educational inputs in the education phase. Hence, the dad's optimization problem subject to constraints is :

$$\max_{C_{f,t},C_{s,t},\lambda_t,\alpha_t,b_t} \Bigg(\Big(u(C_{f,1}) + \rho u(C_{s,1}) + u(\lambda_1, b_1) \Big) + \beta^{t-1}\mathbf{E}\Big[\sum_{t=2}^{20} u(\lambda_t(\Omega^{(t)}), b_t(\Omega^{(t)}))\Big] + \beta^{t-1}\mathbf{E}\Big[\sum_{t=2}^{50} u(C_{f,t}(\Omega^{(t)})) + \rho\Big(\sum_{t=2}^{70} u(C_{s,t}(\Omega^{(t)}))\Big)\Big]\Bigg)$$

subject to the following per-period constraints.

$$\begin{aligned} X_{f,t} + \bar{G}^{t-1}H_{relv}(1-\lambda_t) - s.b_t &= C_{f,t} + C_{s,t} + a'_t \\ X_{f,t+1}(\Omega_{t+1}) = a'_t R_{p,t+1} + \bar{G}^t e_{t+1} H_{dad}(1-\tau) \quad where \quad &\Big(R_{p,t+1} = R_0 + \alpha_t(R_{\gamma_{t+1}} - R_0)\Big) \\ H_{s,t+1} &= H_{s,t}(1-\delta) + \theta(\lambda_t)^{aa}(H_{s,t})^{bb}(b_t)^{cc} \\ PF_{f,t+1}(\Omega_{t+1}) &= PF_{f,t}R_0 + \bar{G}^t H_{dad} e_{t+1}\tau \\ a'_t \geq 0, \quad 0 \leq \alpha_t \leq 1, \quad 0 \leq \lambda_t &\leq 1, \quad b_t \leq b_{max} \end{aligned}$$

where $C_{f,t}, C_{s,t}$ are father and son's time t consumptions. $a'_t \quad and \quad \alpha_t$ are the net-savings and fraction of savings in stock at time t. Utility from consumption has been modelled as a standard CRRA utility, $u(C) = C^{1-\xi}/(1-\xi)$ and the father's utility from educational-inputs at time t for education time λ_t and books b_t is modelled as $u(\lambda_t, b_t) = pen.\Big(H_{s,t+1}(\lambda_t, b_t) - H_{s,t+1}(\lambda_{max}, b_{max})\Big)$.
s is a fraction of the invested books that the household has to bear. $1-s$ is the discount.
ρ is the downward altruism parameter and τ is the pension deduction rate. β is time-discounting parameter.

The LHS of the first constraint is the net-resources-in-hand post child-labour earnings and books' expenses while

[6] secondary level

[7] It must be noted that $\Omega^{(t)}$ is different from Ω_t (which denotes the realization of the joint shock at time t). An example of $\Omega^{(t)}$ for t=2 would be $\Omega^{(2)} = \Big((\gamma_{low}, e_{high}), (\gamma_{high}, e_{high})\Big)$

the RHS is the expenditures on consumptions and savings. The RHS of the second constraint is the $t+1$ time-period portfolio returns ($R_{p,t+1}$) from previous period's savings (a_t') added to pension-deducted dad's earnings at time $t+1$ which is equal to $t+1$ period state-contingent resources-in-hand. The third constraint is the next-period human-capital of the son as a function of time, books and current human-capital. The fourth constraint is the evolution of pension-savings (earning bond-returns R_0) over time. The others are inequality constraints related to savings, fraction of stock in savings portfolio, education-time and books. A detailed review of the constraints, solution methodology and algorithm is included in the additional supplementary material.

The adult son's future consumption and utility from consumption depends on his accumulated human capital level in the first twenty time-periods and the dad cares about it through the downward altruism parameter ρ. Beyond the utility from consumption that human-capital affords, the dad explicitly values the acquisition of human-capital which the model captures through the utility from educational inputs term $u(\lambda_t, b_t)$.

The dad solves the problem at $t = 1$ assuming that the income from endogenous human-capital he leaves the son with will be used to meet the consumption requirements of the adult son. The model stays away from a dynastic setup by excluding future generations.

3 Benchmark Parameter Values

3.1 The Benchmark Income Levels

The primary aim of this study is to compute the life-cycle portfolio allocation of an adult parent with graduation[8] level of human-capital and to monitor the influence of different financial parameters on portfolio choice.

This study assumes a linear relationship between expected income and human-capital level. The empirically reported ratios of incomes for different education levels have been used to calibrate human-capital levels. As per existing studies on developing countries, the average income level of an individual with secondary/matriculation level of education is roughly twice that of an illiterate person while a graduate individual's income is around 4.5 times that of an illiterate person (Agrawal (2012)). Therefore, human-capital levels of individuals with matriculation & graduation levels of education are assumed as twice and five times that of an illiterate person. To make the results generalizable the study conducts sensitivity analysis of results with respect to income.

In order to reduce one state variable for computational ease, this model only considers transitory income shocks for analysis. Including permanent shocks would improve the quality of results by capturing the additional impact of shock persistence over time. Since the focus is to distil out the difference in portfolio allocation (under high risk) of a parent with a dependant offspring vis-a-via a single adult, this study keeps the set-up simple by including only transitory shocks.

As proxies for the three levels of human-capital of the parent, the study considers three dads : The Graduate Dad, The Matric Dad and The Uneducated Dad. While the focus of this study is on the graduate dad's life-cycle portfolio allocation, the other two dad's are used for the calibration of the model parameter *pen*. The summary of the three dads is included in Table 2. Apart from income (and education), the three households are assumed heterogeneous with respect to their access to banks/financial markets and human-capital investment options.

Studies like Pal and Pal (2014), Rhine and Greene (2013), Djankov (2008) clearly highlight the limited financial access of low income/low education households in developing countries. In order to reflect the lack of access, the uneducated dad has been assumed to have no financial access while matric dad is a non-participant in the stock market. The uneducated dad's savings have negative real returns. Apart from financial access, access to educational resources is also a barrier for poor-uneducated households due to distance from school, discrimination and other supply bottlenecks. Shukla (2010) pegs the private educational and health related expenses of Indian households at around 12.5% of income. Since this study doesn't model health expenses explicitly, the upper-cap on total books' investment has been set at 25% of income (with 50% subsidy) for the uneducated and matric dads respectively. The graduate dad's b_{max} has been set at 20%. The results section includes sensitivity analysis of lifecycle variables with changing upper cap on books.

Calibration of *pen* : Several studies in literature have reported high correlations between the parent and the child's

[8] refers to 15 years of education in developing countries, 12 in school and 3 in college. Similar to under-grad level in US

educational attainment (Ermisch and Francesconi (2001), Woessmann (2004), Black et al (2003)). The parameter *pen*, which is a constant number capturing the per-period dad's utility from unit gain in son's human-capital, was calibrated to ensure that on average over 10,000 simulations a parent with matriculation level of human-capital ($H_{dad} = 2$) would teach his son upto the matriculation level or higher for 75% of the trials as reported by studies like Gaviria and Székely (2010) & Azam and Bhatt (2015) while a parent with zero years of formal education would not teach his/her offspring at all. After calibration it was set to $pen = 2.55$.

All households get a 50% discount on books. Contributed-pension-fund savings are ignored for now but will be considered later in the next section. In all the scenarios the son's value function has been computed with the assumption of bond market access to the son so as to keep it uniform.

Table 2: The three benchmark scenarios

	H_{dad}	Fin Access	Books-Discount	Book-Max	Pension-Fund
UnEduDad	1.0	None	50%	0.25	NA
MatricDad	2.0	Bond	50%	0.5	0
GraduateDad	5.0	Bond & Stock	50%	1.0	0

3.2 Consumption and Human Capital Parameters

Tables 3 & 4 present the human-capital and financial parameter values used in the study. Apart from parameter *pen* which the study explicitly calibrates, all other parameter values have been used from literature. The study presents the sensitivity analysis of the results with respect to some of the important parameters in the results section.

The study assumes a moderately risk averse individual with coefficient $\xi = 5$. Ability, θ and the other human-capital production coefficients, *aa*, *bb*, *cc* were used from Manuelli and Seshadri (2005) with minor modifications to give an average return of 11% when the child studies full-time with the maximum available books, $b_{max} = 1$. The dad's downward altruism coefficient ρ is assumed to be 1 in the joint phase ($1 \leq t \leq 20$) and 0.7 for the rest of the independent son's life-cycle. As discussed in the previous section, even though the dependent son would normally consume less than the dad, the study assumes dad-son consumption expenditures as equal ($\rho = 1$) in the joint phase since health and other expenses of the child are not modelled. The parameter *pen* after calibration was set to $pen = 2.55$.

Table 3: Benchmark : Consumption and human capital parameters

ξ	θ	aa(=bb)	cc	δ	ρ	discount	*pen*	$\bar{H}$	H_{matric}
5	0.16	0.75	0.2	1.8%	1/0.7	50%	2.55	1	2

3.3 Financial Parameters

The financial parameters are close to the values in Cocco et al (2005). A bond rate of $r_0 = 4\%$[9] is assumed and expected stock returns are assumed at $\mathbf{E}[r_s] = 9\%$[10]. The returns for the financially excluded uneducated dad household is assumed as $r_{nofin} = -5\%$. The variance of innovation to risky asset (stock shock) is taken as $var(\gamma_t) = 0.0246$ and the variance of logarithm of transitory wage shocks, $var(log(e_t))$, has been set at 0.085[11]. The correlation between income shocks and stock returns, has been assumed as $corr = 1$. We assume $corr = 1$ as the benchmark since the focus of this study is to elicit out the differences in portfolio allocation of a parent with a dependent offspring under increasing risk vis-a-vis a single working individual. Uncertainty in labour market and stock market is represented by two discrete states of respective shocks. Discount rate is set as $\beta = 0.98$. The dad leaves 15% of his last period's wealth as planned bequest to his son. Contributed-pension-fund deposits, if applicable, earn bond interest rates and are risk-free. However in the benchmark case the deduction rate τ is assumed zero. The exogenous growth rate of income is assumed at $\bar{G} = 1\%$.

[9] $R_0 = 1.04$
[10] $\mathbf{E}[R_s] = 1.09$
[11] where $E[log(e_t)] = 0$

Table 4: Benchmark : Financial parameters

r_0	$\mathbf{E}r_s$	r_{nofin}	var(γ_t)	var($log(e_t)$)	corr	β	τ	Bequest	$\bar{G}$
4%	9%	−5%	0.0246	0.085	1	0.98	0%	15%	1%

4 Calibration Results : Three Benchmark Scenarios

This section presents the simulation results for the graduate dad in comparison to the life-cycle profiles of the other two dads. The dad's affinity for human-capital parameter (pen) was calibrated such that on average the matric dad teaches his son upto matric or higher for 75% cases and the uneducated dad's offspring never goes to school. In order to generate average consumption and asset profiles, repeated simulation trials were done by drawing numerous realizations of the income and stock return shocks. The life-cycle profile values reported here are the cross-section means of 10,000 trials.

The per-capita consumption levels in the joint periods $C_{joint(1-20)}$[12], and independent dad's working and retired period consumptions, $\left(C_{dad(21-40)}\text{ and }C_{dad(41-50)}\right)$ as well as educational investments of the three households are presented in Table 5. H_{son} is the human-capital level of the adult offspring.

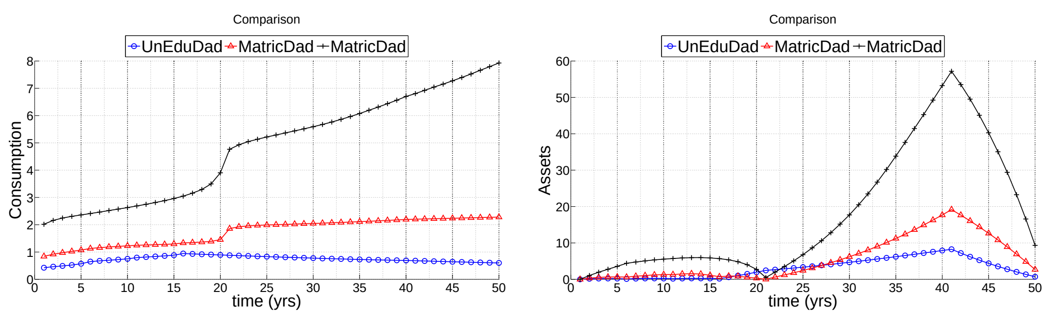
Table 5: Benchmark values of per-capita consumptions, bequest, net education-time, net books and human-capital level of the son

	$C_{jnt(1-20)}$	$C_{dad(21-40,41-50)}$	Beq	$Edu(yrs)$	$Books(Tot)$	H_{son}
UnEduDad	0.74	0.78, 0.64	0.11	0	0	1
MatricDad	1.16	2.05, 2.24	0.4	8.74	4.18	2.41
GradDad	2.70	5.55, 7.06	1.34	15	15	5

Per-capita consumption values mentioned. 1.0 is equivalent to $2/day.
Edu(years) & Books(Tot) refers to total investment in education-time and books over the fifteen years in education phase from ($6 \leq t \leq 20$).

The Graduate Dad ($H_{dad} = 5$) : Figure 3 plots the per-capita consumption and asset profiles of the graduate dad household in comparison with the other two households. The first 20 periods are the joint-periods and the next 30 time-periods are the independent dad's periods.

The son of a graduate dad gets full education in all periods with maximum permissible limit of $b_{max} = 1$ in every time period (Table 5). Only higher ability or higher access to educational inputs (higher b_{max}) can increase the human-capital level of the son any further. For this income category, consumption, savings and portfolio choice are the critical variables.



(a) Consumption (b) Assets

Fig. 3: Comparison of consumption and asset levels the of three households

Uneducated & Matrix Dad ($H_{dad} = 1$ **&** 2) : For the uneducated dad household, results show that child-labour is an optimal outcome of the life-cycle model. The son is never sent to school and the investment in books is zero (Table 5). The assets in the joint-periods are close to zero, revealing that the net income (including child-labour earnings) is entirely spent on consumption. Thereafter, the assets follow the usual humped shape peaking the year before the dad's retirement.

[12]refers to mean per-capita consumption for the time interval $1 \leq t \leq 20$ in the joint-phase

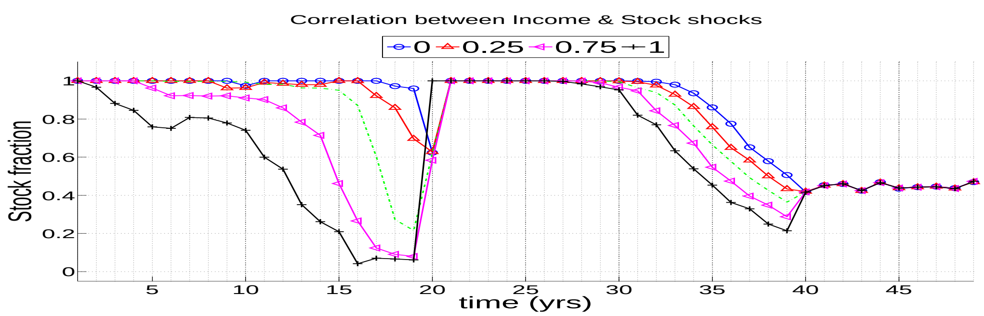
Overall, its a self-perpetuating inter-generational poverty trap where the child's future gets traded-off and the son, like dad, starts his adulthood with no education.

The same is not true for the matric dad household where the offspring gets partial education in all time periods and ends up with 20% higher human-capital than father. The average consumption level in the first 20 joint periods is 1.5 times the consumption level of the lowest income category.

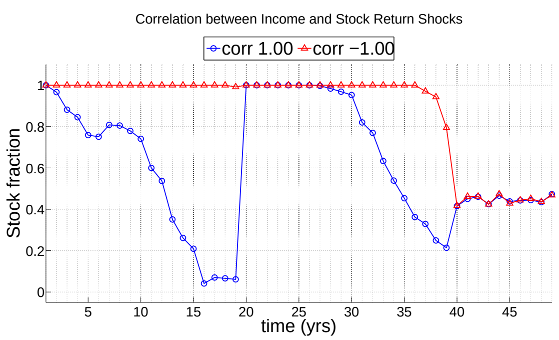
The asset profile of the three households reveals that unlike the uneducated dad, the matric and graduate dads start their independent phase with zero assets. The independent dad ideally would have borrowed resources from his independent phase to fund his higher consumption and human-capital expenses in the joint-phase. However, due to strict borrowing constraints the dad virtually runs two separate optimizations for the joint and independent phases as is reflected by the double humped asset profile of the matric and graduate dads. The asset levels of all the three dads peak the year before retirement in order to fund post-retirement consumption in the absence of pension funds. Introduction of contributed pension savings alters the asset profile interestingly and is discussed in section 5.3.

5 Sensitivity Analysis, Results and Discussion

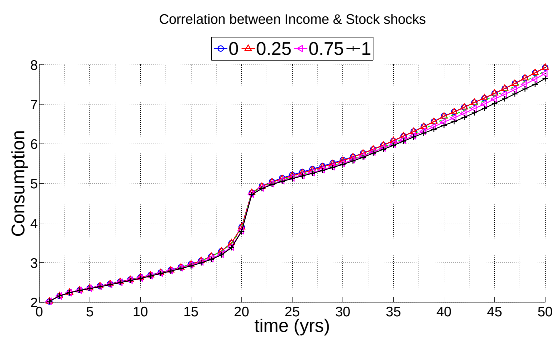
5.1 Correlation between income & stock return shocks



(a) Portfolio choice for a range of positive correlations



(b) Portfolio choice for correlations: +1 and -1



(c) Consumption

Fig. 4: Graduate dad's life-cycle portfolio choice & consumption for different correlations between labor & stock market shocks

This section explores the marginal impact of correlation between stock return shocks and income shocks on life-cycle variables. Figures 4(a) and (b) plot the life-cycle portfolio allocation of the father from $t = 1$ to 50 for different correlations of stock return and income shocks. Figure 4(c) plots his consumption profile for the 50 time-periods. Figures 14 (a) & (b) present the elasticities of portfolio choice[13] and consumption for different correlations of income and stock return shocks. The dad's life-cycle has been divided into 3 sub-periods: joint-phase, independent phase and retired phase. The

[13] for any time-period t, computed as the percentage shift in portfolio-choice towards stock for a 1% increase in correlation coefficient between labor & stock market shocks

consumptions in the above phases are represented by $C_{jnt(1-20)}$[14] , $C_{dad(21-40)}$ and $C_{dad(41-50)}$ respectively. In order to remove edge effects in computing portfolio elasticities, portfolio weights for last time-period of the joint-phase ($t = 20$) and the first time-period of independent dad's phase ($t = 21$) are ignored for elasticity computation.

Portfolio choice : A major contribution of this study is the finding that the life-cycle portfolio choice graph in an intergenerational set-up is significantly different from the portfolio choice of a single individual. The percentage of stocks in the savings portfolio of a parent, apart from varying with age and wealth, also varies with the stage of his intergenerational life-cycle. Figure 4(a) plots from $t = 1$ to 50 the life-cycle portfolio choice graph of the parent for various correlations of stock return and wage shocks.

For perfectly correlated shocks (corr =1), the portfolio choice curve forms a deep valley indicating shift to bonds in the first 20 time periods, unlike when the shocks are uncorrelated. However, after the adult son separates at $t = 21$, the now independent dad immediately shifts his investments back to stocks indicating higher risk appetite. Ceteris-paribus, the risk taking ability of a household with a single earning member with a dependant offspring is lower than that of a lone individual. In other words, the value function would have higher curvature for a two member household vis-a-vis a single member household. Since the weight-age of stocks in the portfolio is inversely related to curvature, the portfolio rule shifts monotonically towards bond in the joint-periods with increasing risk. The same is validated by the high negative elasticity (indicating migration to bonds) of portfolio weight of stock in joint-periods compared to other time-periods (Figure 14 (a)).

The portfolio rule follows the established pattern when shocks are uncorrelated as labour income then mimics a riskless asset. The ratio of present value of future labour income to wealth is an important variable in portfolio choice. In the initial years, the present value of future labour income is high and wealth is low due to binding constraints. Hence, portfolio choice is mostly stock. The wealth increases in mid-life as individuals are saving for retirement, and due to lower earning periods left, the present value of labour income is low. Hence, the portfolio rule starts shifting to bond a few years before retirement. The portfolio allocation, post-retirement, stays constant as depicted by zero elasticity of portfolio choice for $t = 41-50$ in Figure 14(a). Figure 4(b) depicts that negatively correlated stock returns (corr=-1) plays the role of an insurance, leading to portfolio choice consistently being loaded towards stock till a few year before retirement. Post retirement it stays constant due to absence of any further labour incomes.

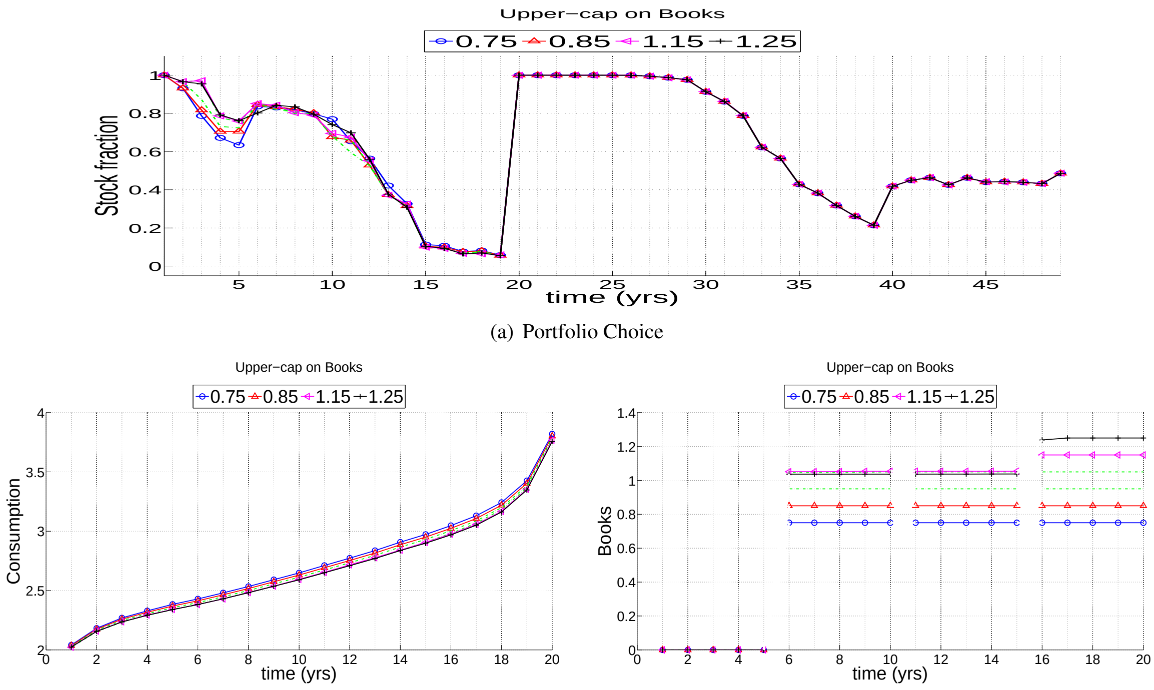
Consumption & Human-capital : The effect of correlation on the dad's life-cycle consumption is marginal (Figs 4(c) & 14 (b)). The maximum influence of high correlation is on the retired dad's consumption (elasticity touching -0.06) due to lower assets at retirement owing to portfolio shift to lower return yielding bonds with increasing risk. There is no impact of correlation on human-capital acquisition of the son over the entire range of correlations. Overall, correlation does seem to influence portfolio choice over the life-time significantly, particularly joint-period investments, but not life-cycle consumption and human-capital of the offspring.

5.2 Upper-cap on Books

The benchmark value of upper-cap on non-time human-capital inputs (books) was set at 1.0. This subsection explores the impact of relaxing that constraint on life-cycle portfolio choice and consumption. The range of b_{max} lies from 0.75 to 1.25. While the presence of children is seen to shift the portfolio-choice towards bond in the early periods, higher access to educational investment options acts as a counter-weight to it by tilting the dad's financial investments towards stock. Described below is the effect of higher educational access on life-cycle portfolio choice, consumption and human-capital.

Portfolio choice : Owing to higher availability of non-risky human-capital investment options, the dad's risk appetite for the risky asset grows and hence he shifts the early period (pre-school) portfolio savings towards stock (Figs 5 (a) & 14 (c)). The result is similar to Bodie et al (1992) where due to introduction of leisure in the utility function, the portfolio shifts towards stock owing to higer risk appetite of the agent. Higher books' investment option offers a diversification choice to the parent, thus affecting the portfolio graph towards stock in the early time periods. However, portfolio choice for the other time-periods remains more or less constant (Fig 5 (a)). Figure 14 (c) presents the elasticities of portfolio-choice for the joint-periods and clearly depicts the positive elasticity of portfolio weight in stock at the pre-school stage for b_{max} upto 1.05. The elasticities of pre-school portfolio choice are close to zero after that as portfolio weight of stock is bound between $[0,1]$.

[14] $1 \leq t \leq 20$



(a) Portfolio Choice

(b) Consumption (joint-periods)

(c) Books (joint-periods)

Fig. 5: Life-cycle plots for different upper-caps on books. $b_{max} \in [0.75, 1.25]$ with benchmark as 1.0

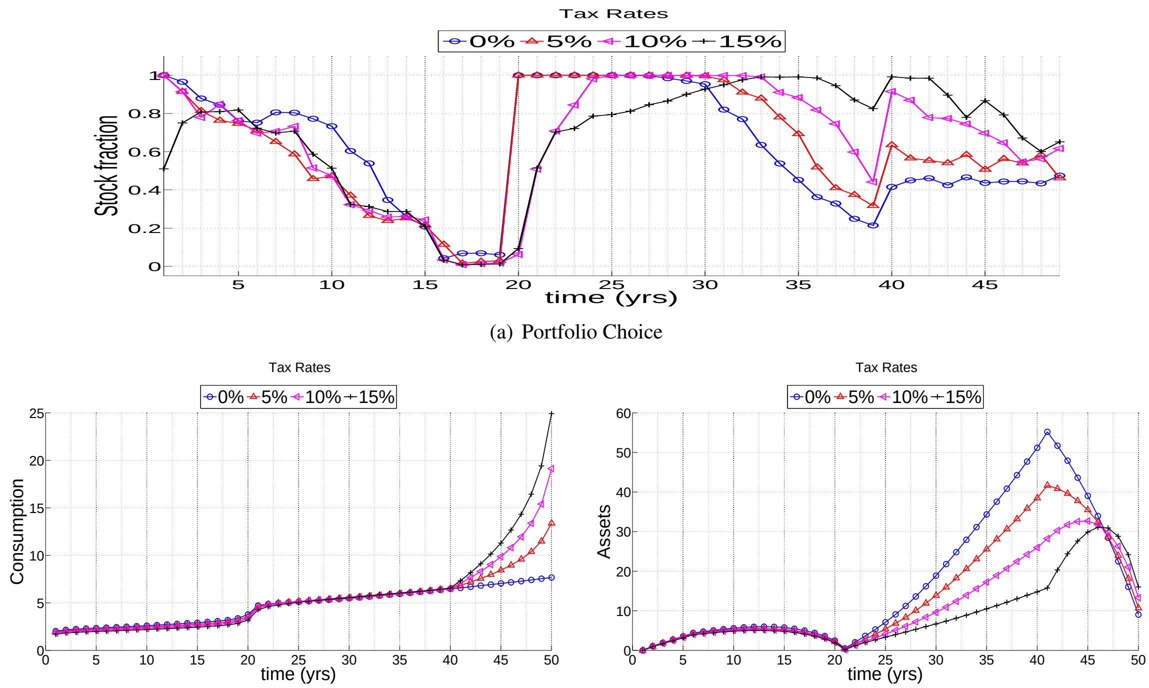
Consumption & Human-capital : Higher access to books' investment increases books' investment initially with unit elasticity and then with lower elasticity indicating higher appetite for educational investments (Figs 5 (c) & 14 (e)). Expectedly due to higher investments in human-capital the per-capita consumptions are lower and asset levels in the joint-periods are higher. Independent and retired dad's consumptions remain completely inelastic (Fig 14 (d)).

5.3 Contributed-Pension-Fund Savings

This subsection introduces mandatory contributed-pension-fund savings and examines its impact on life-cycle profiles. Unlike bond market savings, pension-fund savings are illiquid and the individual gets annuity payments from the accumulated pension funds post retirement. The independent son's value function has also been computed assuming a similar pension fund regime. Pension-deduction rates upto 25% have been considered with 0% being the benchmark level.

Portfolio choice : The most prominent observation is the switch to stocks in the retired dad's portfolio (Fig 6 (a)). In all the other scenarios without pension funds (discussed in subsequent sections), the retired dad's portfolio choice remains constant. However, in this case the retired dad's post retirement portfolio choice mimics that of the independent dad with stocks preferred initially and then an eventual switch to bonds in the later periods. This is supported by the positive elasticities of portfolio choice (Fig 14 (f)) for the retired dad (touching 3.23). Similarly, the working dad's pre-retirement period ($t = 32$ onwards) investments also start switching towards stock with increasing tax rates, as with large sums locked up in pension-deposits, the risk appetite of the dad is higher. The joint-periods' ($t = 1-19$) elasticity switches sign from negative to positive, but remains low in magnitude. The main driving force remains the shift towards stocks of the retired dad's investments, and early period trend adjusts accordingly.

Consumption & Human-capital : Due to locked-up pension-fund investments which are released only post-retirement, the retired dad's consumption ($C_{dad(41-50)}$) just goes over the top with elasticity between 4 to 5 (Figs 6 (b) & 14 (g)). Joint period consumption elasticities lie between -1.0 to -1.3 as more and more earnings get reserved in pension savings with increase in tax rates. The asset profile of the dad undergoes a very interesting change as depicted in Figure 6 (c). The asset profile is a normal hump-shape at lower tax rates, but with further increase in rates, disposable assets get reduced as his pension savings are enough for retirement thus, leading to a flat asset profile till upto retirement. Human-capital remains mostly inelastic. Education time has zero elasticity (Fig 14 (h)) and investment in books has a negative elasticity of around -0.15 with increase in deduction rates.



(a) Portfolio Choice

(b) Consumption

(c) Assets

Fig. 6: Life-cycle plots for different tax rates. $\tau \in [0\%, 25\%]$ with benchmark as 0%

5.4 Expected Stock Return

This subsection explores the impact of increase in expected stock returns on life-cycle portfolio choice and consumption. Expected stock returns lie in the range from 6.75 % to 11.25 % with 9 % being the benchmark. Pension-fund deduction rates remain at 0% as in the benchmark scenario.

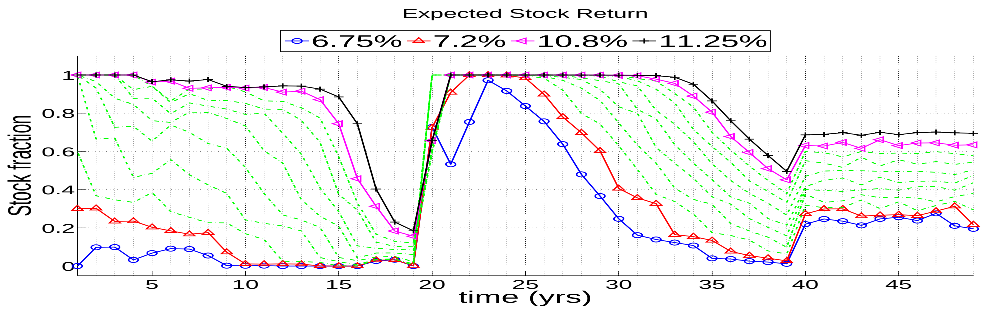
Portfolio choice : Due to higher expected stock return, there will be the twin effect of portfolio shift towards stock and also a general increase in assets due to higher returns (Figures 7(a) & (c)). The elasticities of portfolio shift (touching 33) are highest in the joint-periods where the risk appetite of the household is lowest (Figure 14 (i)). The portfolio shift to stocks with increasing stock returns is monotonic and high for all time periods with the lowest elasticity being 5.92.

Consumption & Human-capital : The elasticities of consumption are highest for the later periods where assets are higher with retired dad's consumption elasticity touching 13 (Figs 7(b) & 14 (j)). Human-capital outcomes remain completely inelastic to fall in expected stock returns.

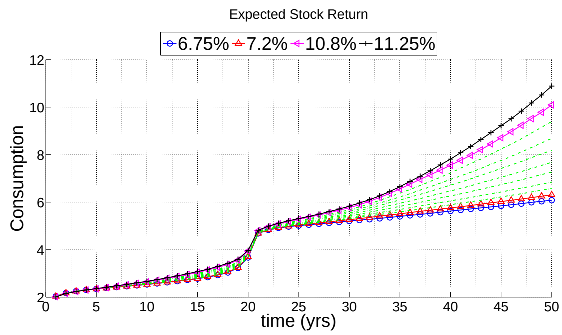
5.5 Standard Deviation of Stock Return

This subsection explores the impact of standard deviation of stock returns on life-cycle portfolio-choice and consumption. Standard deviations are in the range of 0.68 % to 40.68 % with 15.68 % being the benchmark. Pension deductions remain at 0% as in the benchmark case.

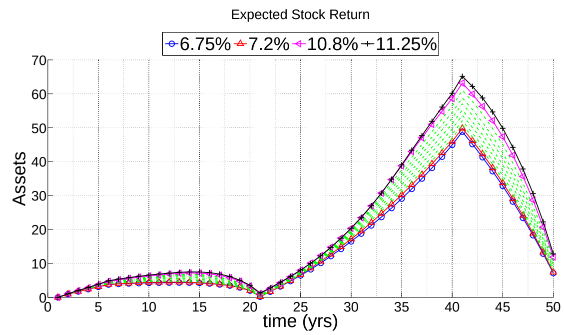
Portfolio choice : With increasing standard deviation of stock returns, due to higher risk associated with stock, the portfolio switches uniformly to bonds for all time-periods with elasticities touching -7.3 (Figures 8(a) & 14(k)). The initial values of portfolio-choice elasticities are low as the switch from stock to bond starts only after the standard deviation levels cross a certain threshold. The port-matric periods of joint-phase ($t = 16 - 20$) are the most sensitive and are the first to respond to increasing stock return uncertainty.



(a) Portfolio Choice



(b) Consumption



(c) Assets

Fig. 7: Life-cycle plots for different expected stock returns. $E[r_\gamma] \in [6.75\%, 11.25\%]$ with benchmark as 9%

Consumption & Human-capital : Joint-periods' consumption elasticity is negative but small in magnitude due to low asset levels in the joint-periods (Figs 8(b) & 14(l)). The fall in joint-period consumption with increasing standard deviation of stock is primarily due to portfolio shift to low return bonds as a result of higher risk associated with stocks. Retired dad's consumption first rises at low standard deviation levels due to higher early period precautionary savings. Upon further increase of standard deviation, due to significant portfolio shift to bonds, retired-dad's consumption starts to fall. Independent dad's consumption falls monotonically with elasticity around -0.2. Human-capital levels remain unaffected.

5.6 Standard Deviation of Income Shocks

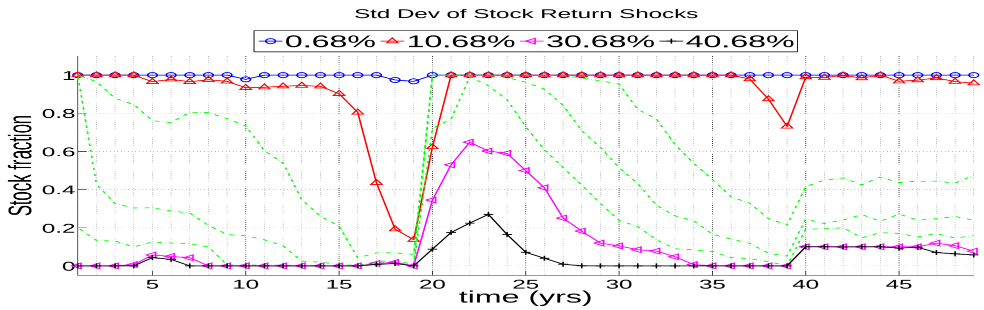
This subsection explores the marginal impact of change in the standard deviation of income shocks on portfolio-choice and consumption. Standard deviations from 0% to 54.15% have been considered with the benchmark value being 29.15%.

Portfolio choice : Along expected lines, to mitigate labour income risk, portfolio choice switches towards bonds in all time periods (Figures 9(a) and 14(m)). The joint-periods when the risk appetite is lowest are the most sensitive with elasticity of portfolio choice touching -2.9. The elasticity of portfolio choice for the independent dad is also negative but not as high as joint-periods as his risk appetite is higher. The retired dad is immune from this due to non-existence of labour income.

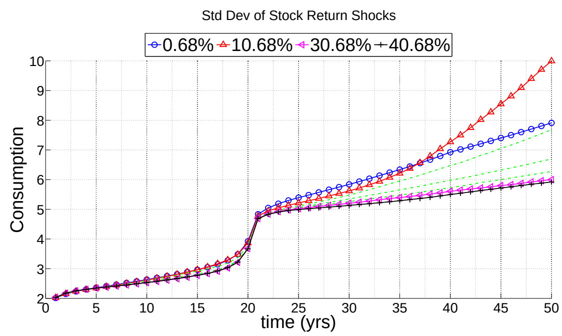
Consumption & Human-capital : Expectedly, higher wage risk leads to higher precautionary savings in the two separate optimization zones for the father (joint-phase and independent-phase). Figure 9(b) shows that consumptions in the early parts of joint and independent phases ($t = 1 - 10$ & $t = 21 - 30$) fall and assets grow with increase in wage risk due to precautionary savings motives. Therefore, joint-periods' consumption elasticities are negative and retired dad's consumption elasticities are positive (Fig 14(n)). Overall the impact of wage risk on independent and retired dad's consumption is marginal as indicated by the low magnitude of consumption elasticities. There is no impact of higher wage risk on human-capital investments.

5.7 Bond Returns

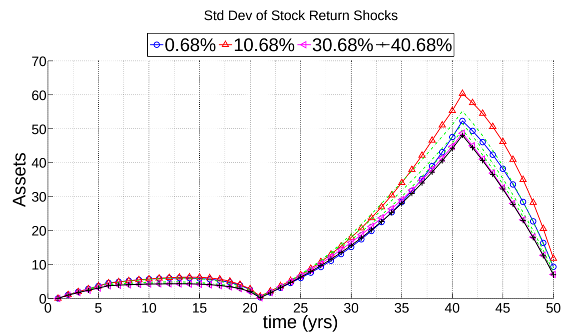
This subsection explores the impact of bond returns on life-cycle variables. Bond returns from 1 % to 8 % have been considered with the benchmark case as 4%.



(a) Portfolio Choice



(b) Consumption



(c) Assets

Fig. 8: Life-cycle plots for different standard deviations of stock return shocks. $var(r_\gamma) \in [0.68\%, 40.68\%]$ with benchmark as 15.68%

Portfolio choice : With increase in risk-free bond returns, the portfolio shifts towards bonds leading to negative elasticities (touching -2.9) of portfolio choice for all time periods (Figs 13(a) & 14 (o)). The joint-phase, being more sensitive, has higher magnitudes of elasticities initially. The latter joint-period elasticities taper off as portfolio weight is bound between [0-1] so once a corner is reached there can't be any further increase/decrease beyond that point.

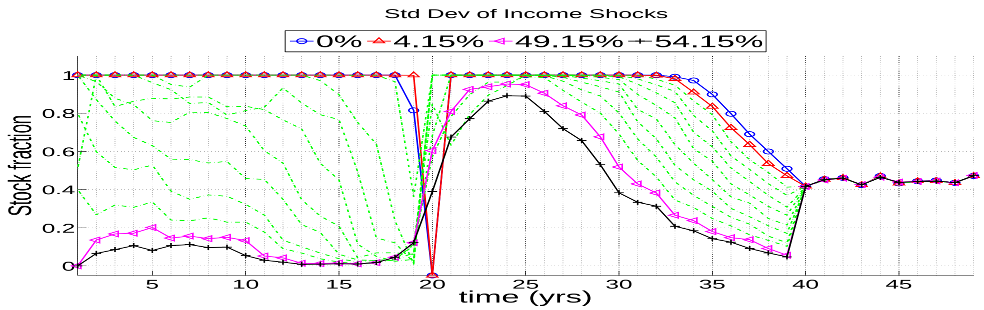
Consumption & Human-capital : The effect of increase in bond returns on life-cycle consumption is ambiguous. Due to shift in portfolio choice from higher return yielding stock to bond, there will be a tendency for assets to fall. However, the increase in rate of return of bonds adds a counterweight to it. As a consequence, the elasticities of all consumptions are negative at low bond return rates, but turn positive after touching 6% returns (Figs 13(b) & 14 (p)). The elasticities of the retired dad's consumption, with greater assets, are higher in magnitude compared to independent and joint-phase dad. Human-capital remains completely inelastic to fall in bond returns.

5.8 Risk Aversion Coefficient

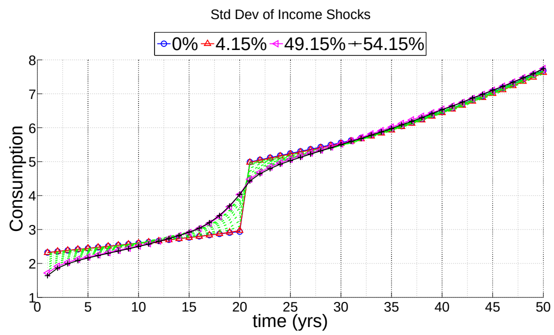
This subsection explores the impact of risk aversion coefficient on life-cycle variables. The range of the values considered are from 3.75 to 6.25 with 5.0 being the benchmark.

Portfolio choice : Figures 12(a) & 14 (q) depict that with increasing risk aversion, to minimize risk, the portfolio shifts away from stock for all time periods. The joint-phase elasticity is the maximum touching -1.36. The independent dad and the retired dad's portfolio elasticities are also negative but lower in magnitude.

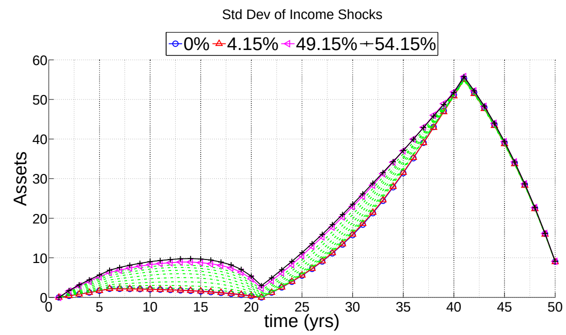
Consumption & Human-capital : The retired dad is the most affected with his consumption elasticity touching -0.3 (Figs 12(b) & 14 (r)) owing to lower assets due to portfolio shift to bonds in the earlier time-periods. The joint-period and independent dad's consumption elasticities are also negative for the same reason but smaller in magnitude. Educational investments remain completely inelastic.



(a) Portfolio Choice



(b) Consumption



(c) Assets

Fig. 9: Life-cycle plots for different standard deviations of income shocks. $var(log(e_t)) \in [0\%, 54.15\%]$ with benchmark as 29.15%

5.9 Other parameters (ρ, *pen* & Dad's Income)

Parameters like downward altruism coefficient ρ, which is the weight given by the parent to utility from consumption of the adult son, and parameter *pen* which captures the parent's affinity from human-capital play no role in altering life-cycle portfolio allocation of the father. Since human-capital investments of the graduate dad remains inelastic to the levels of these parameters (for 25% deviations), these parameter values do not alter the curvature of the value function. Therefore, both consumption and portfolio choice remain unaffected. Expectedly, portfolio choice remains completely inelastic to income level of the father even though life-cycle consumption changes in response to higher income.

6 Conclusion

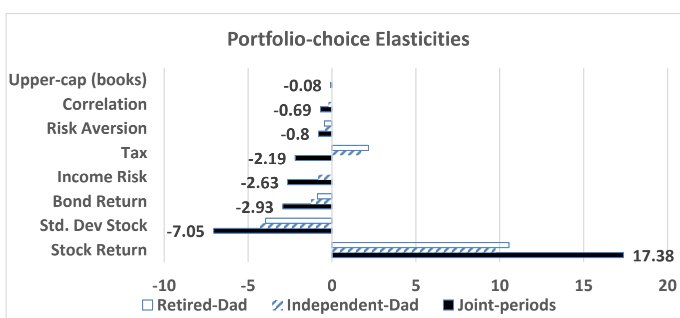


Fig. 10: Comparison of elasticities of portfolio choice

The attempt of this paper is to verify if under high risk scenarios the life-cycle portfolio allocation of an individual undergoes any alterations if he is a parent as opposed to a single individual. Consistent with empirical findings and at variance with established literature (Cocco et al (2005)), due to higher consumption & human-capital expenses on children, results show a shift towards bonds even in the early periods with increasing correlation between labour and stock market shocks. Upon exit of the adult offspring to start a new household, the (still working) parent shifts back portfolio allocation to stocks, thus forming a double-humped life-cycle portfolio choice graph.

Introduction of pension-annuities alters the portfolio graph to a triple hump as now even the retired dad, due to pension annuities, has higher risk appetite leading him to shift his portfolio savings towards stock in the early post retirement time periods. As a consequence, contributed pension fund savings has opposite effect on joint-period and independent dad's portfolio elasticities. All other parameters have been found to have similar effects on joint-phase and independent-phase portfolio elasticities of the dad, though with different magnitudes. An interesting finding of the study is that greater access to educational inputs (books) influences pre-school portfolio allocation towards stock as access to risk-free human-capital investment options increases the dad's risk appetite for the risky stock.

Figure 10 plots, in increasing magnitude of joint-periods' elasticities[15], the impact of various parameters on portfolio choice. It is evident from Figure 10 that the elasticities of portfolio choice of the parent with a dependent child are different from that of the parent after the offspring has separated as indicated by different lengths of bar graphs for joint-periods' elasticities and independent & retired-dad's elasticities, thus revealing different risk appetite for the risky stock at different stages of life-cycle. Expected stock return has the highest impact on portfolio weight of stock where a 1% increase in expected return on stock leads to a 17.3% shift in portfolio weight of stock in the joint-periods. Except for correlation coefficient, risk aversion & upper-cap on books, all other parameters have joint-period elasticities of portfolio choice greater than 1.0 (in magnitude).

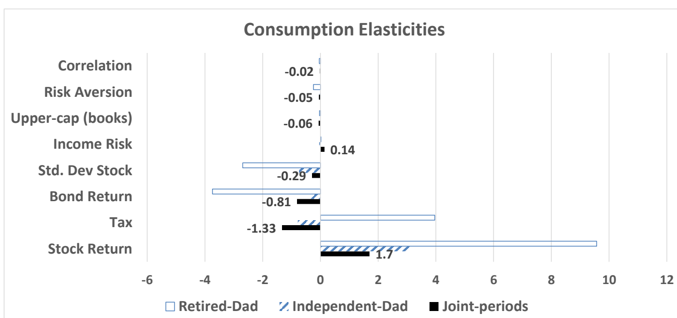


Fig. 11: Comparison of elasticities of consumption

Figure 11 plots the consumption elasticities in order of increasing magnitude of joint-periods' consumption elasticities for the different model parameters. Compared to portfolio choice, the elasticities of joint-period consumption are much lower in magnitude with expected stock return and contributed-pension-funds-rate being the only parameters with elasticities greater than 1.0 (in magnitude). In most of the cases, the most affected is the retired dad with much higher asset levels.

This study suffers from a number of limitations. Since the focus of the study is a single adult-worker as opposed to a population of workers, apart from calibrating model parameter *pen*, the study picks the other parameter values from established literature. Since the study doesn't consider a distribution of workers and hence can't match moments to data to calibrate parameters, the study performs sensitivity analysis of the results to verify the parameter assumptions. In order to reduce one state variable for faster computation, the study only considers temporary shocks for analysis. Including permanent shocks would improve the quality of results by incorporating effect of shock persistence over time. The study also abstracts from other motives of parental investments in children or two-sided altruism models which may lead to more complex outcomes. Endogenous fertility with exchange motives of the parent may be interesting extensions that the study currently doesn't explore.

Conflict of Interest : The authors declare that they have no conflict of interest.

[15] computed for 5% deviations from benchmark values except bond-returns and correlation which were computed for 25% deviations

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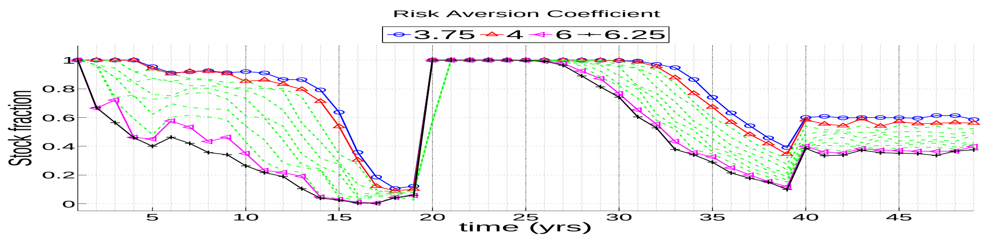
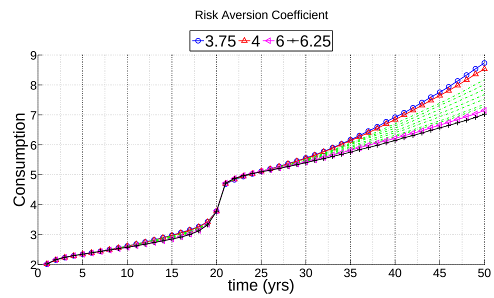
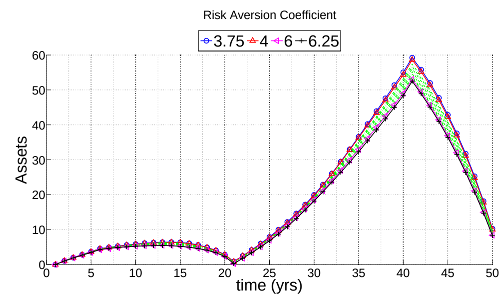
Appendices



(a) Portfolio Choice

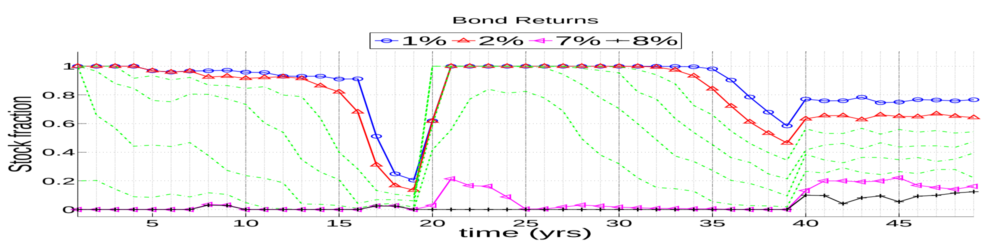


(b) Consumption

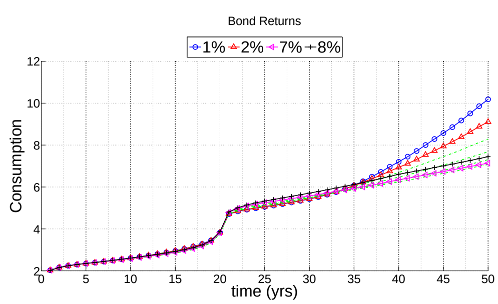


(c) Assets

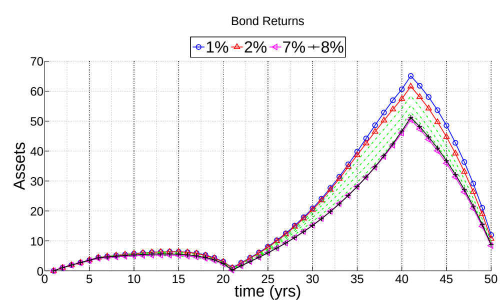
Fig. 12: Life-cycle plots for different values of risk aversion coefficient. $\xi \in [3.75, 6.25]$ with benchmark as 5.0



(a) Portfolio Choice

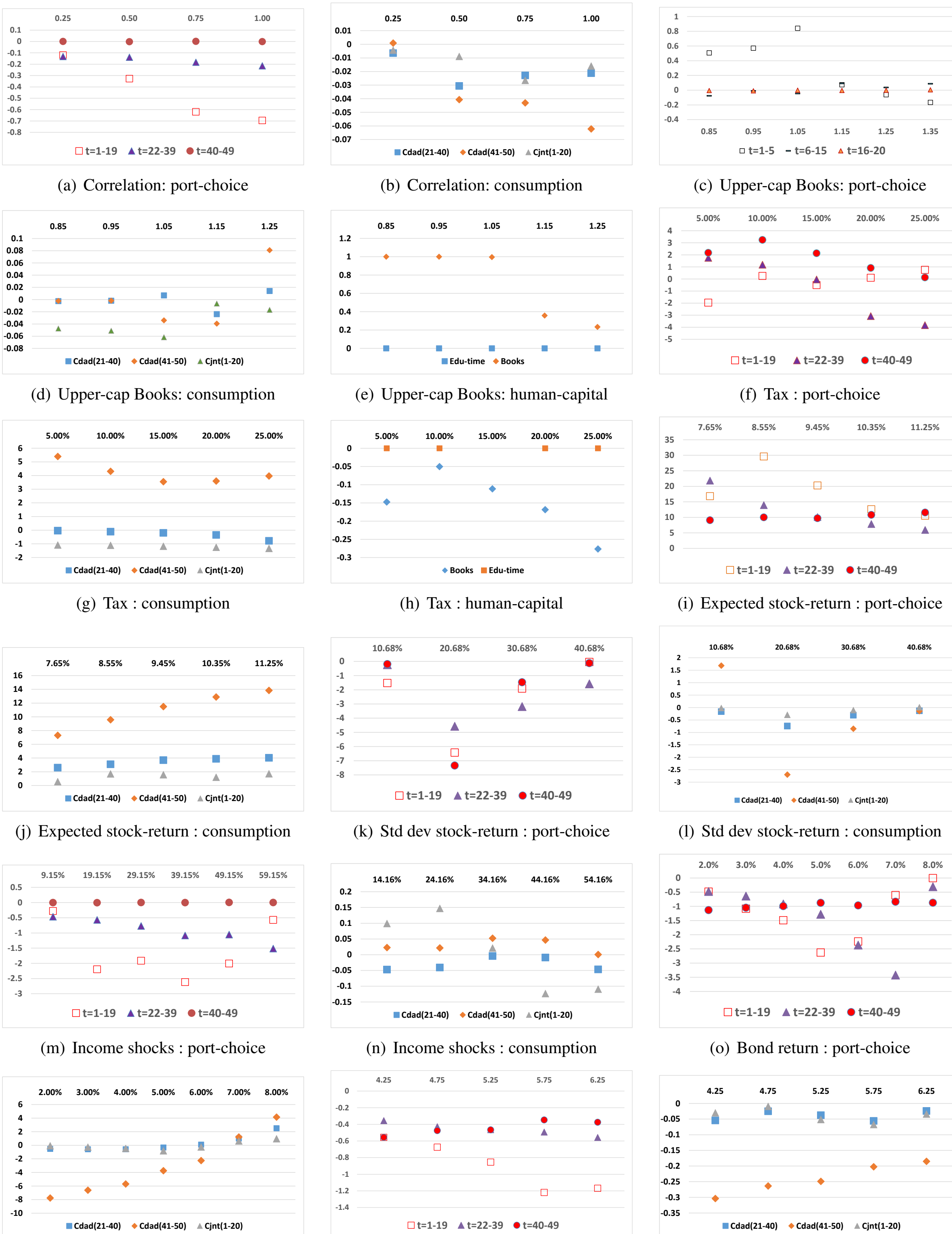


(b) Consumption



(c) Assets

Fig. 13: Life-cycle plots for different bond return rates. $r_b \in [1\%, 8\%]$ with benchmark as 4%



(a) Correlation: port-choice
(b) Correlation: consumption
(c) Upper-cap Books: port-choice
(d) Upper-cap Books: consumption
(e) Upper-cap Books: human-capital
(f) Tax : port-choice
(g) Tax : consumption
(h) Tax : human-capital
(i) Expected stock-return : port-choice
(j) Expected stock-return : consumption
(k) Std dev stock-return : port-choice
(l) Std dev stock-return : consumption
(m) Income shocks : port-choice
(n) Income shocks : consumption
(o) Bond return : port-choice
(p) Bond return : consumption
(q) Risk aversion : port-choice
(r) Risk aversion : consumption

Fig. 14: Elasticities of portfolio choice, consumption, investments in edu-time, books & human-capital for different parameters