DIPLOMARBEIT

On the effects of the COVID-19 school-closures

ausgeführt am

Institute of Statistics and Mathematical Methods in Economics
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durch

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Kurzfassung

In dieser Masterarbeit wird eine Version des Modells präsentiert, welches in [FSKLP20] vorgestellt wird. Um die quantitativen Effekte der Schulschließungen in Bezug auf die Kinder, welche aus unterschiedlichen häuslichen Verhältnissen stammen, zu messen, wird ein Lebenszyklus Modell verwendet. Die Konsequenzen werden des Weiteren in unterschiedlichen Kategorien veranschaulicht. Unter anderem wird ein Blick auf das finale Humankapital der Kinder nach der Schulphase geworfen. Es werden auch der Kapitalwert des Einkommens bis zur Pensionierung, die summierten Vermögenswerte beziehungsweise die Konsumausgaben über ein gesamtes Leben berechnet und verglichen. Eine wichtige Erkenntnis aus dieser Analyse ist, dass die Corona-Krise den Kapitalwert des Einkommens und daraus resultierend, die summierten Vermögenswerte und den summierten Konsum der Kinder eindeutig verringert, abhängig davon, welche schulische Ausbildung ihre Eltern besitzen. Jedoch wird auch veranschaulicht, dass all diese Effekte fast vernachlässigbar sind, wenn zeitnah "distance learning" eingeführt wird. Außerdem wird gezeigt, dass das Alter des Kindes zu dem Zeitpunkt des Schocks eine wesentliche Rolle in der Schwere der Auswirkungen spielt. Die Kennzahlen der Eltern hingegen werden in diesem Modell durch die Corona-Krise, bis auf ein paar kleine Schwankungen während der Schulphase der Kinder, nicht beeinträchtigt. Jedoch korrelieren auch diese, wie bei den Kindern, positiv mit dem Bildungsniveau, was wiederum eine Bestätigung für eine gewisse Ungleichheit zwischen den Bildungsniveaus ist.

Abstract

In this master thesis, a version of the model presented in [FSKLP20] is modeled. A life cycle model is used to quantify the impact of school closures during the Corona crisis on children coming from households with different parental characteristics. The consequences of the Corona crisis are displayed in different aspects, hence for example the accumulated human capital of the children, the net present value of income or the total accumulated asset and consumption levels of children and parents. One major finding is that Corona decreases the net present value of income significantly and therefore also decreases the asset and consumption accumulation of the children, depending on the educational level of their parents. All the effects get drastically reduced or are almost neglectable if distance learning is introduced timely. Another finding of the thesis is that the age of the children at the time of the COVID-19 shock has a major influence on the severity of the effects. For the long-run effects of the parents, no findings except some small fluctuations in the consumption spending during the school years of their children are concluded. All values are positively correlated with the educational level of an individual which shows the inequality among different educational levels.

Danksagung

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Eidesstattliche Erklärung

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Name des Autors

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1 Introduction

The COVID-19 pandemic is not in the same heat as it was back in 2020 when the first cases occurred and governments worldwide reacted to it with school, university and childcare closures. The first closures happened back in March 2020 and lasted long into 2021. Even now these facilities face stricter regulations than other fields. The economic consequences of these closures and restrictions are quite measurable and appeared shortly after. The long-run effects on the children due to school and childcare closures are not that easy to measure. This master thesis deals with this question as the underlying paper of Nicola Fuchs-Schündeln, Dirk Krueger, Alexander Ludwig and Irina Popova named "The Long-Term Distributional and Welfare Effects" [FSKLP20] does.
In this thesis, the long-term asset situation and consumption spending of fictional US households is analyzed in a more restricted approach. This household consists of two parents which are treated as one unit and a fictional child unit. The underlying model is a life cycle model with heterogeneous agents who differ in qualities such as financial resources, education and human capital. The human capital for children is accumulated over time and its main inputs are a governmental investment, a private monetary investment from the parents and the educational level of the parents. When the life cycle of children starts, they live with their parents and only build up human capital with the input factors named above. After several years of school, they can decide if they want to continue to educate themselves or drop out of high school and start working. At this point, they leave the household of their parents and form a unit on their own, where they solve the same decision problem as their parents. This decision includes choosing future savings, consumption and eventually additional spendings for their children.

The experiments of interest in this thesis are the general effects of school closures if they last for one year on the one hand and whether or not a strategy such as distance learning is enough to compensate for the potential losses caused by COVID-19 on the other hand. Additionally, the focus of the analysis lies on the effects of the school closures but with a focus on the age of the children when the shock occurs.
In the underlying paper, [FSKLP20] they calibrated their quantitative parameters according to US survey data. On contrary, this thesis used their calibrated values and sometimes modified them slightly to match certain key values, such as the share of children in a certain education group. Once the baseline model is built and calibrated the COVID-19 shock is introduced and its influence on the human capital acquisition of the children, as well as the asset and consumption course of both children and parents is evaluated. As mentioned above these analyses are made also for a so-called distance learning model and the effect of the age of children when the shock occurs is analyzed.
The main results are partially equivalent to the conclusion in the paper, such as the observation of an overall welfare loss of the children. The net present value of the income (NPV) of the children is calculated for the different educational levels and reports a decrease among all levels. The NPV is positively correlated with the educational level of an individual but a major finding of the analysis is the fact that children with parents, who dropped out of high school get (relatively speaking) along better than children with parents who only own a high school diploma. This conclusion is also true for the asset and consumption levels of the children. The key metrics for parents are mostly unaffected by the COVID-19 shock and the resulting adjustments which are made to them. The asset and consumption levels are also higher for parents with a higher educational level. Values such as the monetary bequest value and additional spending on private tuition are also positively correlated with the educational level. The last fact the analysis is showing is that the later in the life of a child the COVID-19 shock occurs the more such values like the human capital, and therefore the NPV, assets and consumption, decrease. A remark for this thesis is that all functions are calibrated to perform within the model. To enhance this model one would have to use real data and calibrate certain functions and parameters to this data. In summary, this work confirms a certain gap between different education groups. This means that at several points the results show a difference between the educational levels.

These results are also represented within the literature dealing with the effects of COVID-19 and particularly with school closures. In [ADSZ22] the authors also focus on human capital accumulation and come to similar results as this thesis. Human capital decreases overall and the loss is positively correlated with the lower income of the family, which is equivalent to a lower education in the scope of this thesis. The authors of the paper [EFV21] focus on children in primary school in the Netherlands where the data sample is quite large (around $\approx 350,000$ children). In this paper, children have exams before and after the school closures that were caused by COVID-19, and the progress made is compared to the previous years. The findings are similar to the ones already mentioned. There are overall learning losses and these losses get worse the lower the educational level of the parents. Since the Netherlands are considerably advanced infrastructurally, the authors even suggest higher losses in countries that are less advanced or have longer school closures compared to the Netherlands, where they lasted roughly eight weeks.

This master thesis is structured as follows. Section 2 introduces the model which is a simpler version of the model introduced in [FSKLP20] and section 3 is dedicated to its calibration. The 4th section shows the numerical outcomes of the simulation and section 5 concludes.

2 The Model

The quantitative life cycle model used in this thesis is based on the model described in [FSKLP20]. At first, the structure of the model is explained, stating all variables necessary for the calculation of the long-run effects of school closures. Afterwards, a recursive formulation of the model is given.

2.1 Variables and Risk

The time in the model is discrete and noted by t. As mentioned above the base structure of our model is a life cycle model. The agents in the model are heterogeneous regarding the generation they belong to. Either they are *parents* or *children* noted by ch, pa respectively. They differ by their age $j \in \{1, ..., TT\}$ and their educational level $s \in \{do, hi, co\}$, where do stands for high school dropouts, hi for high school completion and co for college education. Parents and children also differ in their human capital. Parents own an initial human capital h and children have a lower initial human capital h_0, which builds up over time. The last thing they differ by is e, an idiosyncratic stochastic component that evolves according to

$$\ln e(t) = \rho \ln e(t-1) + \epsilon_t \quad \epsilon_t \overset{iid}{\sim} N(0, \sigma_\epsilon^2) \tag{2.1}$$

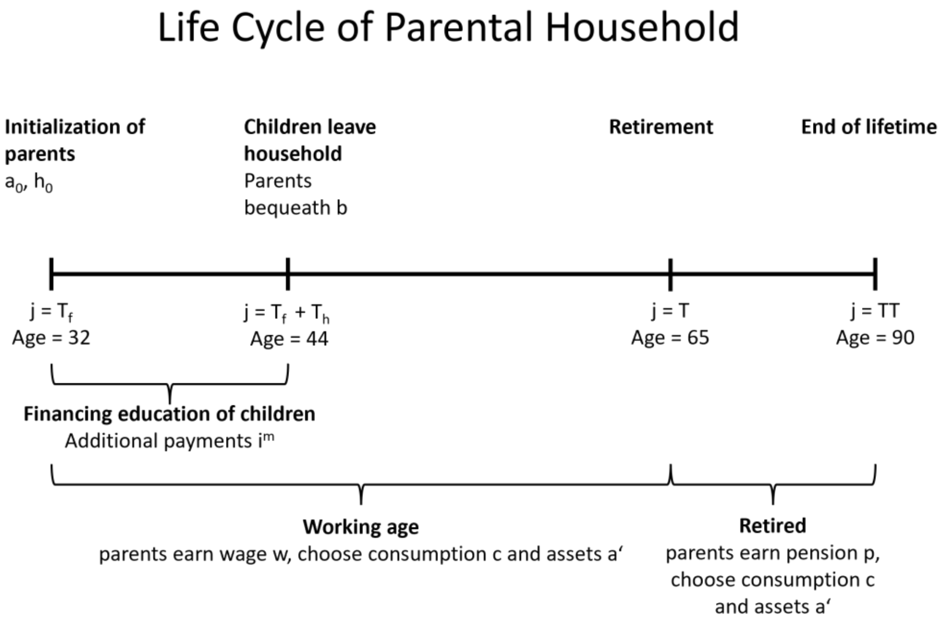
and $\rho \in [0, 1)$ which is a persistence parameter. The state variables are summarized in the following table 2.1.

State var.	Value	Interpretation
j	$j \ \in \{1, ..., TT\}$	Age
k	$k \ \in \{ch, pa\}$	Generation
a	$a \geq 0$	Assets
h	$h > 0$	Human capital
s	$s \ \in \{do, hi, co\}$	Educational level
e	$e(t)$	Income state

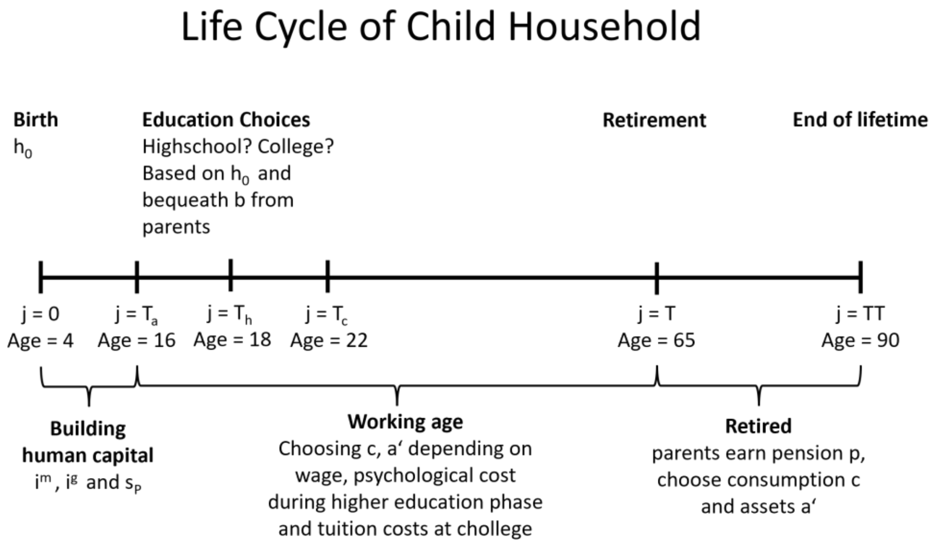
Table 2.1: State variables

2.2 Life Cycle of the Generations and Economic Decisions

This section describes the life cycle of the parents and generation of the children. In figure 2.1a the usual life of a parental household is described, respectively in figure 2.1b the life of children is displayed.



(a)



(b)

Figure 2.1: Life Cycle of Child (b) and Parental Household (a)

2.2.1 Parents

The life cycle of the parental household is shown in figure 2.1a. Two equal individuals form the household, so there is no difference in any characteristics within a household. The initial age of the parents is noted by T_f and refers to an age of 32 years. The initial parameters drawn at random for the parents are the human capital h, the educational level s and the initial assets a. Each parental household has one child. In the first 12 years, parents have the option to support the education phase of the child with monetary transfers i^m. The time step $T_f + T_a$ marks the point where the child leaves the household of their parents, who then have to choose if they bequeath monetary transfer, which flows into their child's initial assets. At age 65 parents enter the retirement phase, which is marked by the time point T. This phase lasts 25 years until TT, which corresponds to an age of 90 years. At this point, the individuals pass away. Parents work during the educational phase of their child and until they reach retirement age. While they work they earn a wage w, choose consumption c, assets a' for their well-being and provide additional investments i^m for their child. The wage w they earn depends on their human capital h and education s. Additionally, they receive random shocks to their income level according to the equation 2.1. After they retire they receive a pension p depending on their educational level s, while choosing consumption c and assets a'. The model is designed in such a way that they will have consumed all their savings at the point they pass away.

2.2.2 Children

The birth of the child is marked with the time step $j = 0$ which corresponds to a real-life age of four years, similar to the starting age in [FSKLP20]. For the first $T_a - 1$ years the child does not make any economic choices, it lives with its parents, goes to school and builds up its human capital. The human capital is one of the most important factors in the model and is a function of the following structure

$$h' = g(j, h, s_p, i^m, i^g). \tag{2.2}$$

The parameter s_p describes the education of the parents and the variable i^g is the contribution of government schooling to the human capital. The last influencing factor is i^m which describes if parents additionally invest in their child.

The child attends school for 12 years, until it reaches the time step $j = T_a$, which means it is 16 years old. At this point, the child decides to continue to go to school, or drop out of high school and start working. This decision depends on its acquired human capital and monetary transfer b from the parents. The decision for higher education comes with benefits like higher wages in the future, but also puts some psychological cost p on the child. Nevertheless, all children at this time step leave the household of their parents and go to live independently. Dropouts immediately start working and earn wage w. Children that decide to continue to go to school also start working and earn a wage w, but only a fraction of the amount dropouts earn. One can think of that as a part-time job besides school/college. All of them are now responsible for their well-being, this means they choose consumption c and assets a'. After two years they graduate from high school and are again facing the decision to enter the labor market or to continue to study towards a college degree, which takes four more years to acquire. If they continue studying towards a college degree, they need to pay tuition fees $tuit$ and are facing higher psychological costs p. Students also work during this time to finance their life.

All higher educational choices are final so there is no quitting once the decision is made, and the college degree is a uniform bachelor's degree, with no specifications in this area. At the age of 22 or model time step $j = T_c$ all individuals enter the labor market at full rate, where the same structure as for the parents applies. For detailed information see section 2.2.1 above. Presumably most children are single after leaving their parent's household but for simplicity, we assume they are not. This doesn't mean that they are married but for example, they are always with a partner so that there are households of two all the time.

2.3 Decision Problem

In the following section, the decision problem for the child household and parental household are described respectively.

2.3.1 Children

As stated above, in the first 12 years children live with their parents so their first own meaningful decision in the model is made at an age of 16 years or time step $j = T_a$.

Educational decision

Children make a decision based on the following criteria: They receive a monetary transfer b from their parents which results in their starting assets a_0. The acquired human capital h during their schooling phase is important for future productivity $\gamma(s,h)$ and therefore also important for future wage levels $we_t\gamma(s,h)$. They can also choose to continue studying to obtain a higher educational level, but this is connected with tuition costs $tuit$ while in college and psychological costs $p(s,h)$ during both college and high school education. The psychological cost is decreasing in the human capital h. The variable e is explained in 2.1 and simulates a stochastic income shock which the individuals obtain. At the time point T_a the educational decision is made final, this means that children decide if they want to, finish or drop out of high school, or go to college. There is no further evaluation of their decision. As stated above the decisions are final, so there is no quitting. The human capital level is not affected by their educational decision, but their human capital does influence their future wages. The wage level sways in a certain range, this depends on the idiosyncratic stochastic component e. All this leads to the pre-educational decision value function which is given as

$$V(T_a, s, a_0 = b, h) = \max_{s\in\{do,hi,co\}} \{V(T_a, s = do, a_0 = b, h), V(T_a, s = hi, a_0 = b, h),$$
$$V(T_a, s = co, a_0 = b, h)\}.$$

Decisions during working age

We start with the children who decide to drop out of high school. These individuals enter the labor market and earn wages with their given productivity $\gamma(s = do, h)$ and corresponding income shocks e_t. The continuation value functions $V(j, s = do, e, a, h)$ are determined by a simple life cycle consumption-saving problem during working ages $j \in \{T_a + 1, ..., T\}$

$$V(j, do, e, a, h) = \max_{c,a'} \left\{ u(c) + \beta\xi(j) \sum_{e'} \pi(e'|e)V(j+1, do, e', a', h) \right\}$$

$$\text{s.t.} \quad c = y + (1+r)a - a'$$

$$y = \kappa(j) + we_t\gamma(do, h) - 1$$

$$a' \geq 0$$

Whereas $\kappa(j)$ is a deterministic age-specific component and $\xi(j)$ is an age-dependent survival factor, both described in more detail in section 3. The income function y is oriented on a form introduced in the lecture in Inequality in Macroeconomics [Sia1S]. At this point the idiosyncratic stochastic component e(t) already gets approximated by a discrete Markov chain, first it is an AR(1) process. The approximation by a discrete Markov chain is explained in detail in [Tau86]. For notation, purposes to highlight the difference e(t) will now be referred to as e_t.

Children who decide to attend high school for two more years are facing a certain psychological cost mentioned briefly above. The cost function $p(s, h)$ is described in 3. During the time children are attending high school they also work and earn a wage w and therefore acquire an income y. In this simplified model we do not model working hours in contrast to [FSKLP20]. To model reduced working time during high school and college, a variable $f(s)$ that reduces the earned wage is introduced. This variable depends on the educational level children try to achieve. The rest is similar to the individual dropping out of high school. For the time of $j \in \{T_a + 1, ...T_h\}$ the structure of the value functions looks like

$$
\begin{aligned}
V(j, hi, e, a, h) = \max_{c,a'} &\left\{ u(c) - p(hi, h) + \beta\xi(j) \sum_{e'} \pi(e'|e) V(j+1, hi, e', a', h) \right\} \\
\text{s.t.} \quad & c = y + (1+r)a - a' \\
& y = (\kappa(j) + w e_t \gamma(hi, h) - 1) f(hi) \\
& a' \geq 0
\end{aligned}
$$

Finally, the ones who decide to attend college and achieve a bachelor's degree are looked at. As a reminder, there is no distinguishment between higher forms of college education and all children, that decide to attend college or high school are completing it, so there is no quitting. This stage has the same structure as the one above (children attending high school) but lasts for four more years. The input states of the psychological cost function and working time variable $f(s)$ change after the time step T_h and for the next four years $j \in \{T_h + 1, ..., T\}$ the value functions and constraints in the life-cycle model read as

$$
\begin{aligned}
V(j, co, e, a, h) = \max_{c,a'} &\left\{ u(c) - p(co, h) + \beta\xi(j) \sum_{e'} \pi(e'|e) V(j+1, co, e', a', h) \right\} \\
\text{s.t.} \quad & c = y + (1+r)a - a' \\
& y = (\kappa(j) + w e_t \gamma(co, h) - 1) f(co) \\
& a' \geq 0
\end{aligned}
$$

After the time step T_h or respectively T_c all children, who choose a higher education degree, enter the labor market at full rate and the decision problem evolves to the same structure as for children who decide to drop out of high school.

Retirement phase

Individuals work for 49 years until time step $T = 49$ and then enter the retirement phase at an age of 65 years. This phase lasts for the rest of their lifes throughout $j \in \{T, ..., TT\}$ 25 years. At the time point $TT = 74$ or real-life age of 90 years, individuals die and the life cycle ends. The value function during this time reads as

$$
\begin{aligned}
V(j,s,a,h) = \max_{c,a'} &\{u(c) + \beta\xi(j)V(j+1,s,a',h)\} \\
\text{s.t.} \quad c &= y + (1+r)a - a' \\
y &= pen(s,h) \\
a' &\geq 0
\end{aligned}
$$

where $pen(s,h)$ is a fixed pension transfer without any shocks and displays the result of a fraction of their previous income y. The pension is dependent on the parameters s and h, since the educational level s and the productivity $\gamma(s,h)$ are used to calculate the income y.

2.3.2 Parents

As stated earlier there is no differentiation between different kinds of households, each household consists of two parents and one child. The parental household starts at a real lifetime of 32 years or model time T_f. As visible above, children only become economically active when they leave their parents' house. Parents get initialized with randomly drawn assets a, an initial given idiosyncratic productivity state $e(t=1)$ and human capital h. Their educational level is also drawn at random to match some overall distribution of education shares.

Children in the Household

For the first 12 years $j \in \{T_f, ..., T_f + T_a + 1\}$ children live with their parents. During this time the parents can choose if they want to additionally invest, noted by i^m, into their children's human capital. This could be for example private lessons. These investments have a positive effect on the human capital of their children. The value functions for these first 12 years are then of the following structure

$$
\begin{aligned}
V(j,s,e,a,h) = \max_{c,a',i^m} & \left\{ u(c) + \beta\xi(j) \sum_{e'} \pi(e'|e) V(j+1,s,e',a',h') \right\} \\
\text{s.t.} \quad & c = y + (1+r)a - a' - i^m \\
& y = \kappa(j) + w e_t \gamma(s,h) - 1 \\
& a' \geq 0 \\
& h' = g(j,h,s_p,i^m,i^g)
\end{aligned}
$$

Children leaving the Household and Working Phase

After 12 years of living with their parents the time step $T_j + T_a$ is reached and children make their educational decision as described above. Parents at this point also make an additional decision, they decide whether or not and if yes how much of their assets they bequeath to their children. This adds to the starting assets of the children. The value function at this point is of special form because it also consists of the value function of their children at the beginning of their life cycle. The parameter ν describes the altruistic behavior of the parents.

$$
\begin{aligned}
V(T_a+T_f,s,e,a,h) = \max_{c,a',b} & \left\{ u(c) + \beta\xi(j) \sum_{e'} \pi(e'|e) V(j+1,s,e',a',h) + \nu V(T_a,s,b,h) \right\} \\
\text{s.t.} \quad & c = y + (1+r)a - a' - b \\
& y = \kappa(j) + w e_t \gamma(s,h) - 1 \\
& a' \geq 0
\end{aligned}
$$

After this decision is made, children leave the household of their parents and the value function returns to a simple life cycle model.

$$V(j,s,e,a,h) = \max_{c,a'} \left\{ u(c) + \beta\xi(j) \sum_{e'} \pi(e'|e) V(j+1,s,e',a',h) \right\}$$
$$\text{s.t.} \quad c = y + (1+r)a - a'$$
$$y = \kappa(s) + w e_t \gamma(s,h) - 1$$
$$a' \geq 0$$

Retirement phase

Finally, parents at time step $j = T+1$ retire and for the remaining years $\{T, ..., TT\}$ the value function is of similar form as in section 2.3.1 and is stated below.

$$V(j,s,a,h) = \max_{c,a'} \{u(c) + \beta\xi(j) V(j+1,s,a',h)\}$$
$$\text{s.t.} \quad c = y + (1+r)a - a'$$
$$y = pen(s,h)$$
$$a' \geq 0$$

2.4 Government

The government provides the share i^g which refers to the public schooling system. We use the same value as in [FSKLP20] which is around 5000$ USD and based on UNESCO (1999-2005) as described in [Hol15].

2.5 Thought Experiment

As mentioned in the introduction the goal of this thesis is to try to show the effects of the COVID-19 school closures in a simple life cycle model. To be more precise it is evaluated if a reduction in government schooling investments leads to overall lower human capital levels of children and if the age of the children when the shock occurs is important. This means the time point j when the shock happens will be varied. It will be observed if the shock leads to lower overall economic investments/decisions

from both, parents and children. The main focal point will be what happens to the human capital of the children, future asset and consumption levels, if parents are unaware of such a crisis and do not respond appropriately.
Further, the scenario that the governmental investments do not fully disappear is tested, but distance learning is introduced and so a certain amount of the i^g is kept. Since this measure was not established by governments at the beginning of the shock, the investments i^g slightly decreased to model this delay. The effectiveness of distance learning is the same as normal schooling since there could not be found any paper which deals with such research.

3 Calibration

3.1 Data

Most of the data which was not calibrated through the model comes from the paper [FSKLP20] and some other parameters are expertise values from the lecture [Sia1S]. The paper [FSKLP20] used three different sources in the first stage of the calibration which are the following: PSID, NLSY79 and PSID CDS. Regarding the scope of this thesis, the calibration phase of the model is omitted in the way that no statistical evaluation of the three sources or any regressions were made. If a certain parameter is used from [FSKLP20] it may have gotten adjusted to perform in this simplified model. Table 3.1 gives an overview of the values of the parameters and variables used in the model and their origin. If the source is [FSKLP20] the reference for where they got the value from is given. It is important to note that the observations of the data sets below are not used. It is only attempted to calibrate the model in a way to achieve values in the range the data suggests. All calibrations are made on a sample size of 1000 randomly and fictional created individuals.

PSID stands for Panel Study of Income Dynamics and is a longitudinal panel survey of American families, conducted by the Survey Research Center at the University of Michigan. The PSID measures economic, social, and health factors over the life course of families over multiple generations. Data has been collected from the same families and their descendants since 1968. In [FSKLP20] they used the four latest PSID waves: 2011, 2013, 2015 and 2017.

NLSY79 is a US national sample of women and men born between 1957 through 1964 and living in the United States when the survey began. Over the years they observed things like schooling, moving out of their parents' homes, decisions on continuing education and training, entering the labor market, serving in the military, marriage, starting families of their own, and thoughts about their retirement expectations.

PSID CDS the Child Development Supplement is a research component of the PSID. The CDS gives data on children and their extended families with which the dynamic process of early human and social capital formation can be studied. In [FSKLP20] they merged the respective waves of CDS and PSID.

Parameter	**Interpretation**	**Value**	**Source**
	Population		
$j = 0$	Age at economic birth (age 4)	0	
T_a	Age at educational decision (age 16)	12	
T_h	Age at finishing HS (age 18)	18	
T_c	Age at finishing CL (age 22)	22	
T_f	Fertility age (age 32)	12	[FSKLP20]
T	Retirement age (age 65)	61	
TT	End of life (age 90)	86	
	Preferences		
θ	Relative risk aversion parameter	1.50	[Sia1S]
β	Time discount rate	0.98	[FSKLP20]
ν	Altruism parameter	0.80	calibrated
	Labor Productivity		
$\gamma(s, h)$	Ability gradient of earnings	see main text	
$\rho_1(s)$	Productivity parameter	[0.351, 0.564, 0.793]	[FSKLP20]
ρ	Persistence parameter	0.92	[Sia1S]
σ_ϵ^2	Idiosyncratic variance	0.04	[Sia1S]
$f(s)$	Scaling parameter income	[0,2/7,1/7]	calibrated
	Endowments		
r	Interest rate	3.5	[FSKLP20]
$\underline{a}$	Borrowing limits for all individuals	0	
	Ability/Human Capital and Education		
ι	College tuition costs (annual, net of grans and subsidies)	13,213$	[BL20]
κ_i	Coeff. of human capital function	see main text	calibrated
ϕ	Psychological cost	see main text	
i^m	Average spending on private tuition per year	$\approx 15,000$$	calibrated
	Government		
i^g	Public early education spending by age	$\approx 5,000$$	UNESCO (1999-2005)

Table 3.1: Collection of parameters in the model, layout inspired by table 3 [FSKLP20]

3.2 Age Brackets and Survival function

The model starts at time step $j = 0$ and ranges up to $TT = 79$, every step refers to one year. The biological age of children at $j = 0$ is four years and parents are 32 years old at this point. Children are modeled from an age of four onward because in [FSKLP20] they say *"The reason for this initialization age is the calibration of the initial human capital endowment $h(j = 0)$, which is informed by data on test score measures at child biological ages three to five, as described below. Thus, children are irrelevant to the economic model for the first three years of their biological lives."* Children then make their higher education choice at age 16, which is model time $T_a = 12$, this also marks the point where they leave their parents' household. High school completion takes them two more years and for a college degree, they need to study four more years, reading in model time $T_h = 14$ and $T_c = 18$ respectively. Individuals enter the "fertility" age at model time $T_f = 32$, this refers to a biological age of 28 years. Retirement happens at time point $T = 49$ corresponding to a biological age of 65 and individuals live up to an age of 90 years or model time $TT = 74$.

An additional factor an individual faces is the survival function of the following form

$$\xi(s) = \begin{cases} 1 & \text{if } j = 0, ..., 40 \\ 1 - \left(\frac{TT-T}{TT-T}\right)^3 & \text{if } j = 41, ..., TT. \end{cases} \tag{3.1}$$

3.3 Wage, Productivity and Preferences

3.3.1 Wage

In section 2 it can be seen that the income function y reads as $y = \kappa(j) + we_t\gamma(s, h) - 1$. In [FSKLP20] they normalize wage w to 1, this approach is followed and the corresponding interest rate r is set to 3.5% which is common use and also applied in [FSKLP20]. The parameter κ is given by $\kappa(j) = \sqrt{j} - 0.11j$ and, as mentioned earlier, is an age-specific component which is a monotonous increasing and concave function in T.

3.3.2 Productivity

The productivity function γ is an important instrument in the model to calibrate the incomes of individuals. In [FSKLP20] they run regressions on the data set NLSY79 to get a function of the following form

$$\ln(\gamma(s,h)) = \rho_0(s) + \rho_1(s)\ln(\frac{h}{\bar{h}}).$$

The form used in this model is a simplified version of this one and reads as

$$\gamma(s,h) = \rho_1(s)\frac{h}{\bar{h}}.$$

which achieves the best results with the randomly generated data.

3.3.3 Preferences

An isoelastic utility function is used

$$u(c) = \frac{c^{1-\theta} - 1}{1-\theta} \tag{3.2}$$

and set to $\theta = 1.5$. This leads to the simplified version of $(-2/\sqrt{c}+2)$.
The psychological cost function for obtaining higher education is of the same form as in [FSKLP20], reading as

$$p(s,h) = \phi(1 + \zeta\mathbb{I}_{s=co}) + \frac{1}{h} \tag{3.3}$$

but parental education is not considered as an influence in different values of $p(s,h)$. It is monotonically decreasing and convex in the acquired human capital h. With the same value for $\phi = -0.05$ as in [FSKLP20] and a ζ value of $\{0.05, 0.92\}$ for high school respectively college students, satisfactory shares are achieved in the three education groups: High school dropouts 14.1%, high school education 58.1% and college education 27.8%. Figure 3.1 shows the values and table 3.2 summarizes them.

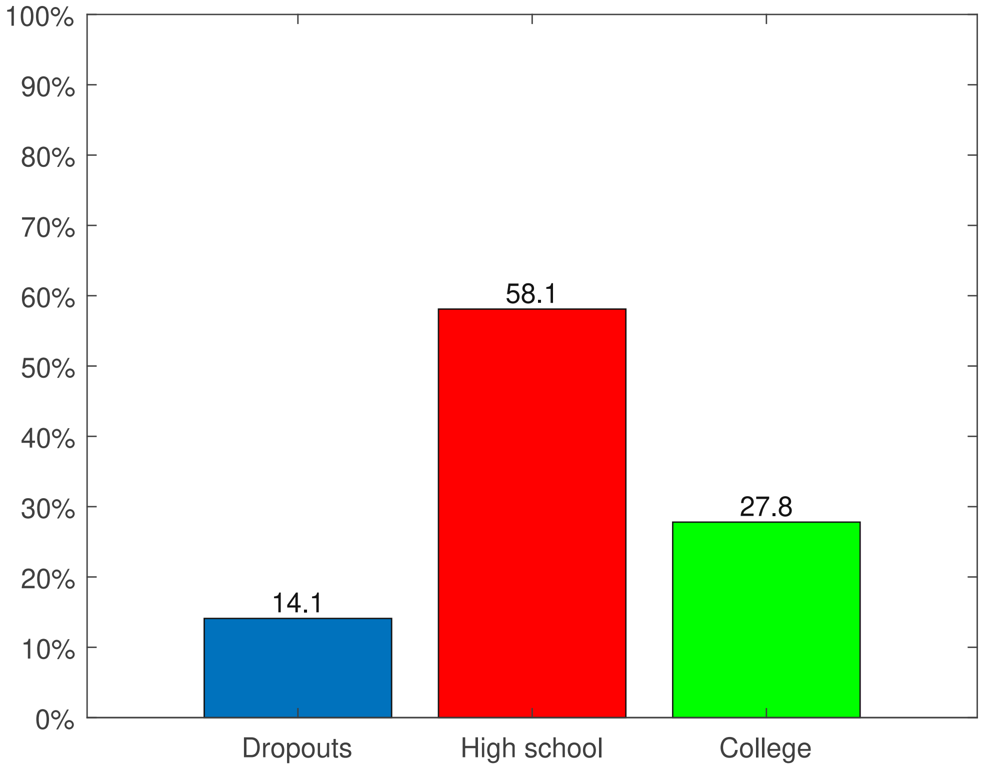


Figure 3.1: Barplot of shares of educational levels of children

Households discount utility rate β is set to 0.98 and thus matches the value in [FSKLP20]. Furthermore, the authors of [FSKLP20] calibrate the value to the PSID data according to [BL20].

3.4 Initial Distribution of Individuals

In this sections the model is calibrated to try to match the values in [FSKLP20]. They get their values from the PSID data after filtering for certain criteria.

3.4.1 Parents

In [FSKLP20] they have different states of parental relationships, there could be single or married households. This model, as stated earlier, looks only at households of two people.

Educational Shares

The population shares in the three categories $s \in \{do, hi, co\}$ are summarized in table 3.2 which includes the values from table 5 in [FSKLP20] for married couples.

Education	Target share %	Cal. share %
do	16.21	14.10
hi	55.77	58.10
co	28.02	27.80

Table 3.2: Population fractions by education (married households only)

One way to implement these shares into the model is to draw human capital for parents randomly and obtain thresholds so that the distribution is equal to the levels in table 3.2. The human capital h is in the interval $[0.01, 2.5]$, further explained in section 3.5.

Assets and Income

In contrast to [FSKLP20] this model has a no-borrowing policy. So an external source for mean assets, which has the same classification as our model, is used. The article [Mag20] includes all the information needed and is consistent with other articles. The values are summarized in table 3.3.

Education	Value # [$]
do	14,000
hi	24,000
co	66,000

Table 3.3: Median assets for a certain education (expressed in 2020 dollars)

The median income used to calibrate the model is from [NCfES22] and the corresponding values for different levels of education are summarized in table 3.4. Note that the values in both tables are per couple.

The value for high school education is set as the benchmark and the other two are calibrated to match the values approximately. To achieve these values the idiosyncratic stochastic component e_t is adjusted for the three levels of education. This

Education	**Value # [$]**	**Model value target #**	**Model value actual #**	**Diff. %**
do	60,000	1.325	1.347	1.66
hi	75,000	1.656	1.669	0.79
co	120,000	2.649	2.620	-1.09

Table 3.4: Median income for a certain education (expressed in 2020 dollars)

approach does not alter the distribution, it's just a scaling. After the calculation the values are $e_{t,h} = [0.85 \cdot e_t, e_t, 1.70 \cdot e_t]$.

3.5 Human Capital Production Function

The approach used in [FSKLP20] is too complicated for the scope of this thesis. Children draw their initial human capital h_0 within a certain range. The distribution is uniformal across the range of $[0.001, 0.5]$, which is a smaller range than the general human capital covers $[0.01, 2.5]$. The function 2.2 shows the structure of the human capital function.

$$h' = \kappa_0 h + \kappa_1 i^m + \kappa_2 i^g + \kappa_3 s^p. \tag{3.4}$$

In the equation 3.4 the coefficients κ got calibrated to perform within the model and to achieve similar values as in [FSKLP20]. In table 3.5 the calibrated values of the κ-values are displayed.

Coefficient	**Value #**
κ_0	0.80
κ_1	0.10
κ_2	0.30
κ_3	0.06

Table 3.5: Values of the κ coefficients

The values of h in 3.4 lie within the boundaries that are set for the human capital in the model, which are $h \in [0.01, 2.5]$. The second term i^m is not a specific value, rather it's an indicator $\{0, 1\}$ to show if parents choose to additionally invest into their children's human capital allocation during period j or not. The cost of the private tuition is mentioned in table 3.1 and calculated roughly as $15,900\$ = 53 \cdot 2 \cdot 37.5\$$, which breaks down to 37.5$ per session for two times within a week, for the whole year with $i^m = 1$. The third input is the monetary investments from the government. The assigned value of 5000$ is the same as in [FSKLP20]. The last term in 3.4 refers to the educational level of the children's parents.

3.6 Tuition Costs and Borrowing Constraint

For the tuition costs during college, the values from [FSKLP20] are adopted. They calibrate their tuition costs and borrowing constraints according to [KL16]. According to them, the net cost of one year of college education (tuition, fees, room and board net of grants and education subsidies) amounts to 13,213$.

For the simplicity of the model, contrary to [FSKLP20], there is no borrowing constraint, so individuals are always forced to keep their assets greater or equal to zero.

4 Results

In this chapter, the effects of the thought experiments stated in section 2.5 are discussed. The observations are split into different sections in which the focus lies on different aspects of interest. As stated in the corresponding section, the COVID-19 shock lasts for one year and therefore also for one period in the model.

The simulations in this thesis, in comparison to [FSKLP20], are not based on real data. Individuals are fictional and not drawn from real data observations in contrary to the corresponding paper. For this thesis, it is not considered a limiting factor since certain key factors are calibrated to match the values in [FSKLP20]. The main task is to replicate the model with extra restrictions and to see if its outcomes are still feasible and realistic. [1] As stated in section 2.5, the main thought experiment would be the introduction of distance learning and how it could help to reduce the effects of the COVID-19 school closures. Since the model has certain assumptions and the school closures are modeled by reducing the governmental investments i^g to zero, it has been decided to model the distance learning factor as a compensating factor for this reduction. This means the value for i^g is not decreased all the way to zero but only decreased by 30%. This value is based on the assumption that during the one year of school closures 70% of that time the government already established distance learning, and that the effectiveness of distance learning is the same as that of normal schooling. The model is compared with the distance learning effect to the baseline model and the COVID-19 model. With the COVID-19 model the same model as the baseline model is meant, but the government investments i^g are set to zero during one period, in particular $j = 5$. For notation purposes, it is referred to the baseline model as "BLM", the COVID-19 model as COVID-19 and the distance learning model as "DLM". The second part of the result section shows the outcomes of the model if the shock occurs at the different ages of the children.

[1]The model was coded and simulated in MATLAB.

4.1 Comparison of the baseline, COVID-19 model and distance learning model

The following legend is applied in most of the plots, if a different legend is used the explanation is by the corresponding figure.

—— (blue)	Individuals who dropped out of HS $s = do$
—— (red)	Individuals with HS education $s = hi$
—— (green)	Individuals with CL education $s = co$
- - - - (blue)	Individuals who dropped out of HS, with COVID-19 shock $s = do$
- - - - (red)	Individuals with HS education, with COVID-19 shock $s = hi$
- - - - (green)	Individuals with CL education, with COVID-19 shock $s = co$
········ (blue)	Individuals who dropped out of HS, in DLM $s = do$
········ (red)	Individuals with HS education, in DLM $s = hi$
········ (green)	Individuals with CL education, in DLM $s = co$

4.1.1 Monetary investments of parents

This section takes a closer look at the two monetary investments parents can make. One is the one-time transfer at the start of the life cycle of the children called heredity. The other one is the investment into private tuition.

Bequeath of parents

In figure 4.1 the average bequeath of the parents to their children is shown. This is grouped into three categories depending on the educational level of the parents. The pattern is quite clear, the higher the educational level gets, the more the parents transfer to their children to ease their entry into the economic cycle. This behavior is valid for all three models, visible by the three different pillars in the plot. The pattern is very reasonable from an economical point of view, since on average parents with a higher educational level have higher assets to draw from (see also 3.4). Another interesting observation is that between the BLM and C19 model the transfers slightly increase. For detailed insight refer to tables 4.1 to 4.3 in which the numerical values are stated.

Tables 4.1 to 4.3 show the differences in increase between the three different models. In general, the economical results one would expect after a COVID-19 crisis can be observed. The most striking observation is the increase in transfers among the high school dropout education group. This increase could be driven by the need to compensate for the loss caused by the COVID-19 shock. The other education groups only experience small increments in transfer levels, while parents with a high school diploma on average even transfer less in the DLM model. This is best displayed by tables 4.2 to 4.3 where the **Diff. tot. %** shows minimal differences for the college education group and more severe differences for the dropout and high school education groups.

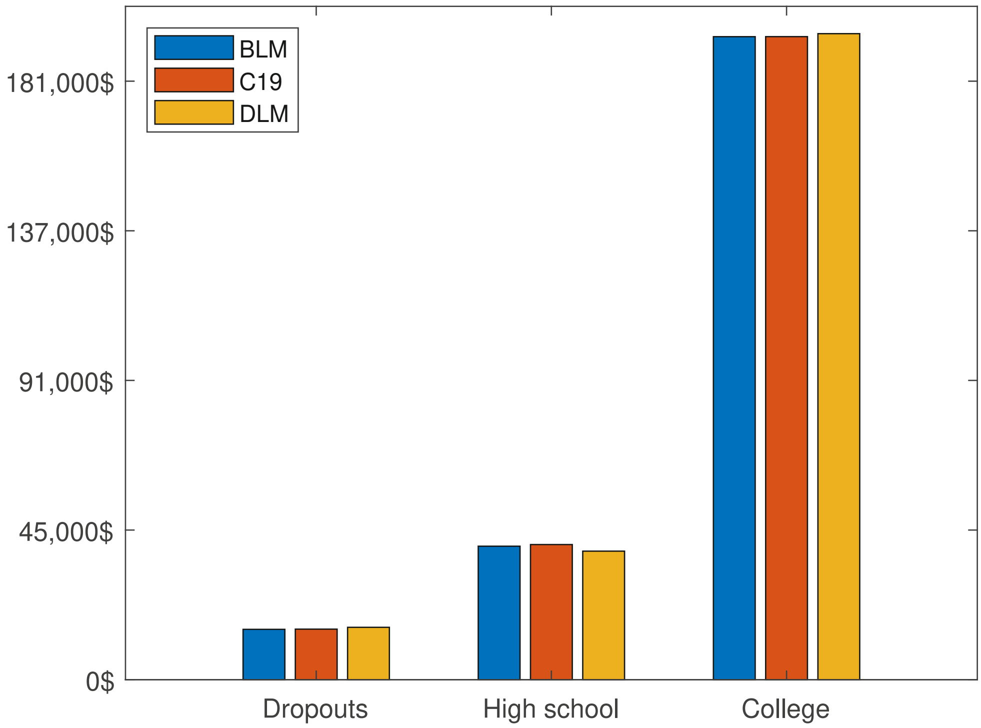


Figure 4.1: Average bequeath of parents across different educational levels, before and after

Education	BL # [$]	Diff. %	COVID-19 # [$]	Diff. %	Diff. tot. %
do	15.237	-	15.302	-	0.43
hi	40.407	165.19	40.909	167.34	1.24
co	194.662	1177.55	194.677	1172.21	0.01

Table 4.1: Overview of average bequeath of parents, BL and COVID-19

Education	BL # [$]	Diff. %	DLM # [$]	Diff. %	Diff. tot. %
do	15.237	-	15.851	-	4.03
hi	40.407	165.19	38.915	145.50	-3.69
co	194.662	1177.55	195.575	1133.82	0.47

Table 4.2: Overview of average bequeath of parents, BL and DLM

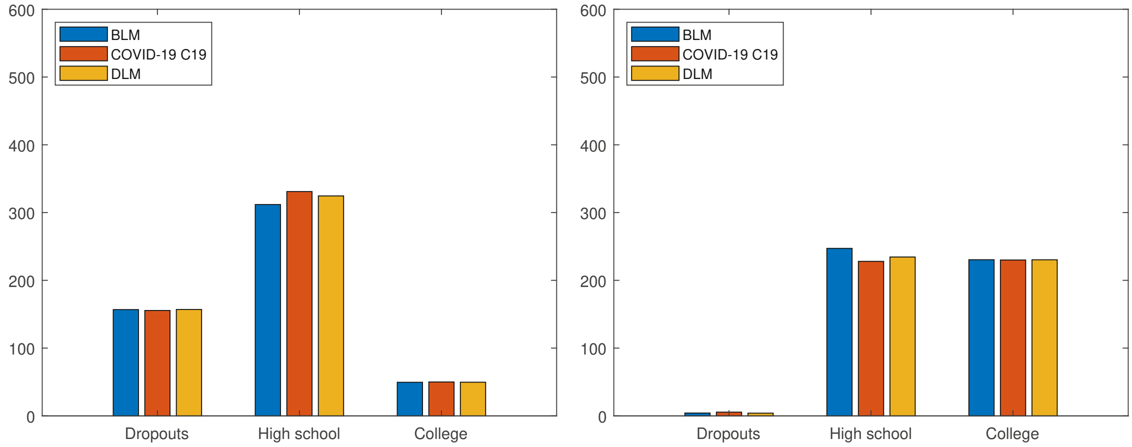
Education	C19 # [$]	Diff. %	DLM # [$]	Diff. %	Diff. tot. %
do	15.302	-	15.851	-	3.59
hi	40.909	167.34	38.915	145.50	-4.87
co	194.677	1172.21	195.575	1133.82	0.46

Table 4.3: Overview of average bequeath of parents, BL and DLM

Additional investments on private tuition

In this section, the observed results were grouped into three categories. The categories are again the three educational levels. In figure 4.2 a barplot of the total number of individuals who choose whether or not to invest in additional private tuition. Since this decision is made by the parents for every period during the first twelve years, the result is aggregated by the mean to conclude one final result. Figure 4.2a shows the number of parents who choose not to invest in private tuition and figure 4.2b shows the complementary side. This means by adding for example the count of all the blue pillars one receives all 1000 individuals in the model as a result. Tables 4.4 to 4.6 give again an overview and also state the differences among the groups in percent.

Overall there is a decline in private tuition investments for children. Only parents with no high school degree try to level out some negative effects of the COVID-19 shock by investing into their children (last column of table 4.4). This behavior is not present for parents with a higher educational level and therefore quite special, since parents who drop out of high school are also the ones who bequeath more to their children with the COVID-19 shock being present. Whether or not this strategy has a noticeable influence on the human capital levels of the children is answered in section 4.1.2.



(a) No investment, $i^m = 0$

(b) Additional investment, $i^m = 1$

Figure 4.2: Count of parents across different educational levels who invest in private tuition

Education	**BL #**		**Diff. %**		**COVID-19 #**		**Diff. %**		**Diff. tot. %**	
	$i^m = 0$	$i^m = 1$	$i^m = 0$	$i^m = 1$	$i^m = 0$	$i^m = 1$	$i^m = 0$	$i^m = 1$	$i^m = 0$	$i^m = 1$
do	157	4	-	-	156	6	-	-	-0.85	32.00
hi	312	247	49.71	98.31	331	228	53.02	97.59	6.15	-7.75
co	50	230	-216.30	98.19	50	230	-211.00	97.61	0.84	-0.18

Table 4.4: Overview of additional investments on private tuition, BL - COVID-19

Education	**BL #**		**Diff. %**		**DLM #**		**Diff. %**		**Diff. tot. %**	
	$i^m = 0$	$i^m = 1$	$i^m = 0$	$i^m = 1$	$i^m = 0$	$i^m = 1$	$i^m = 0$	$i^m = 1$	$i^m = 0$	$i^m = 1$
do	157	4	-	-	157	4	-	-	0.11	-4.00
hi	312	247	49.71	98.31	325	234	51.63	98.29	4.09	-5.16
co	50	230	-216.30	98.19	50	230	-216.11	98.26	0.17	-0.04

Table 4.5: Overview of additional investments on private tuition, BL - DLM

Education	**COVID-19 #**		**Diff. %**		**DLM #**		**Diff. %**		**Diff. tot. %**	
	$i^m = 0$	$i^m = 1$	$i^m = 0$	$i^m = 1$	$i^m = 0$	$i^m = 1$	$i^m = 0$	$i^m = 1$	$i^m = 0$	$i^m = 1$
do	56	6	-	-	157	4	-	-	0.96	-27.27
hi	31	228	53.02	97.59	325	234	51.63	98.29	-1.94	2.81
co	0	230	-211.00	97.61	50	230	-216.11	98.26	-0.67	0.14

Table 4.6: Overview of additional investments on private tuition, COVID-19 - DLM

4.1.2 Human capital

First, a closer look is taken at the average human capital accumulation in figure 4.3. At time point $j = 5$ the COVID-19 shock occurs and therefore all human capital levels drop (dashed and dotted lines). There is also a similar trend observable as in the previous section, which is that children of parents with higher educational levels get along better. This means that the human capital levels are more stable if parents have a higher education, which is probably because the educational level of the parents influences the human capital level of the children in a positive way. Nevertheless, the human capital levels of children in all three categories came out lower than in the baseline model, which is reasonable since during COVID-19 the investments of the government into the human capital of the children equaled zero. Tables 4.7 to 4.9 summarize the results again in a similar manner as in the previous sections/tables.

Although COVID-19 has a bad influence on the human capital levels of the children, table 4.7 for example shows, especially in the "Diff. tot. %" column, that the impact of the crisis is not as drastic as in the first period after the shock. Here the drop in the values ranges from 14-27% and later the difference only ranges from 2-4%. This means that if parents and children have time to compensate for the losses caused by COVID-19, the difference between the human capital levels is not that severe. The effects of the still-present differences are explained in the next section. The DLM performs as expected and decreases the impact of the shock to a certain level. Overall all education groups get along better, which is exactly what one would expect and hope for if a strategy such as distance learning is implemented. The last thing worth mentioning are the differences in the human capital levels of children whose parents have a high school diploma, compared to parents who dropped out of high school. Within this category parents who dropped out of high school do relatively better than ("Diff. tot %" column in table 4.7 to 4.9) parents with a high school diploma. Figuratively speaking the drop in human capital levels is smaller for the first category of parents. This might be because parents who dropped out of high school spend more money on private tuition for their children.

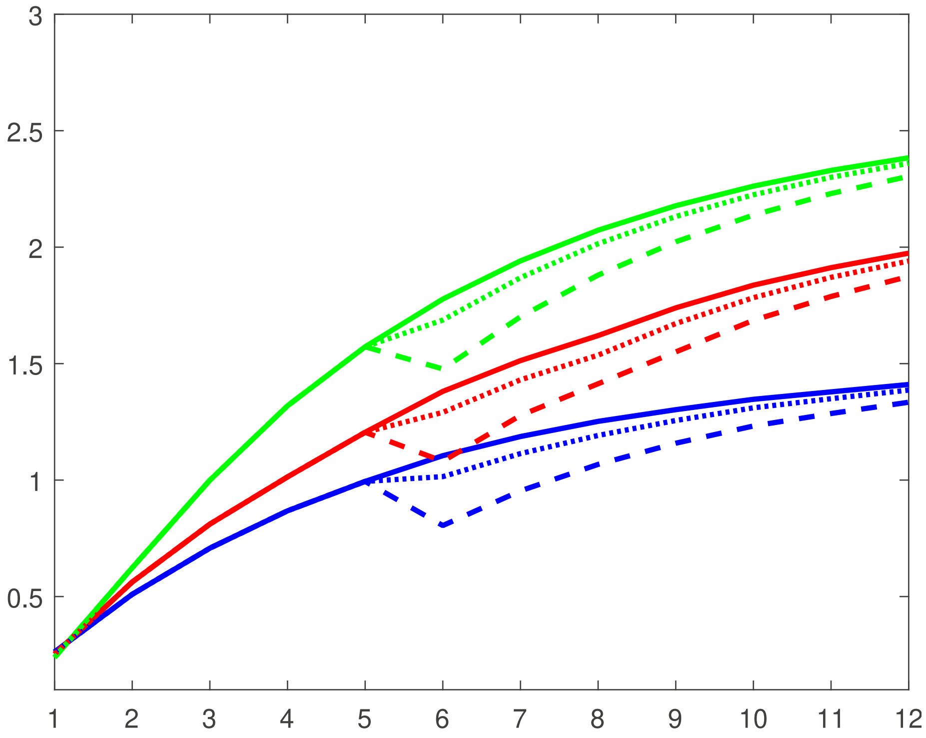


Figure 4.3: Average human capital of children, before and after

Education	Baseline #		Diff. %		COVID-19 #		Diff. %		Diff. tot. %	
	$j=6$	$j=12$	$j=6$	$j=12$	$j=6$	$j=12$	$j=6$	$j=12$	$j=6$	$j=12$
do	1.105	1.410	-	-	0.805	1.334	-	-	-27.15	-5.40
hi	1.381	1.974	24.97	39.97	1.081	1.874	34.28	40.47	-21.73	-5.06
co	1.777	2.384	60.85	69.01	1.477	2.304	83.53	72.70	-16.88	-3.34

Table 4.7: Overview of human capital levels for two periods, $j = 6$ one period after shock, $j = 12$ end of education phase of children, BL - COVID-19

Education	Baseline #		Diff. %		DLM #		Diff. %		Diff. tot. %	
	$j=6$	$j=12$	$j=6$	$j=12$	$j=6$	$j=12$	$j=6$	$j=12$	$j=6$	$j=12$
do	1.105	1.410	-	-	1.015	1.386	-	-	-8.15	-1.70
hi	1.381	1.974	24.97	39.97	1.291	1.941	27.18	39.97	-6.52	-1.70
co	1.777	2.384	60.85	69.01	1.687	2.360	66.24	70.22	-5.06	-1.00

Table 4.8: Overview of human capital levels for two periods, $j = 6$ one period after shock, $j = 12$ end of education phase of children, BL - DLM

Education	COVID-19 #		Diff. %		DLM #		Diff. %		Diff. tot. %	
	$j = 6$	$j = 12$	$j = 6$	$j = 12$	$j = 6$	$j = 12$	$j = 6$	$j = 12$	$j = 6$	$j = 12$
do	0.805	1.334	-	-	1.015	1.386	-	-	26.09	3.91
hi	1.081	1.874	34.28	40.47	1.291	1.941	27.18	39.97	19.43	3.54
co	1.477	2.304	83.53	72.70	1.687	2.360	66.24	70.22	14.22	2.42

Table 4.9: Overview of human capital levels for two periods, $j = 6$ one period after shock, $j = 12$ end of education phase of children, COVID-19 - DLM

4.1.3 Average Effects on asset accumulation and consumption

Finally, the focus is laid on the asset accumulation and consumption spending of both, parents and children. The question to be answered is: Is there an influence at all in this model and if yes, is it conclusive and why does it occur?

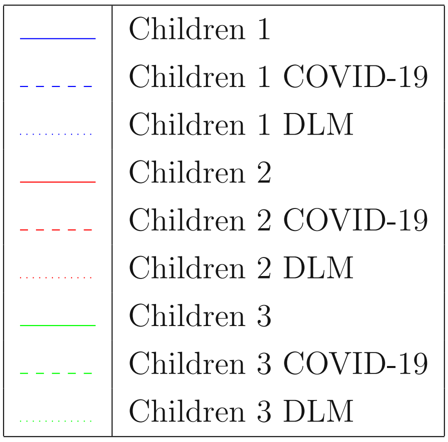
Children

Firstly the focus is put on the children in the model. Since the only influential factors on future asset accumulation and consumption spending are the human capital levels and the starting assets, the results from the previous sections are needed. For the simulation run of the parents also 1000 fictional children are created who accumulate human capital over time and receive one-time monetary transfers which result in their starting assets. These 1000 children are then used to run another simulation to obtain the final results of the three models on the children. The children once again obtain different Markov states and are aggregated by the mean of the educational level of their parents to compress the results. The mean values for starting assets and human capital can be seen in table 4.10.

	Model	Assets a_0	Human capital h_0
Children 1	Base	15,237	1.410
	COVID-19	15,302	1.334
	DLM	15,851	1.386
Children 2	Base	40,407	1.974
	COVID-19	40,909	1.874
	DLM	38,915	1.941
Children 3	Base	194,662	2.384
	COVID-19	194,677	2.304
	DLM	195,575	2.360

Table 4.10: Overview of mean starting values of assets and human capital of the three children groups

The results from this approach are displayed in figure 4.4 and table 4.11 respectively. The legend of figure 4.4 is a bit different and reads as follows:



It can be observed from the plots that there are differences between the baseline model and the COVID-19 model for all three educational levels. [2] For children who have parents that own a high school diploma the difference is also visible between the distance learning and baseline model. This is plausible since in earlier sections it is visible that this group of children gets away the worst within the three education groups. Intuitively one would expect that this should be the group of children with parents who dropped out of high school, but since this group experienced some

[2] In these plots the colors do not refer to the educational choices of the children, they refer to the educational level of their parents. The education choice of the children for this simulation is summarized in section 4.2.3.

contribution from their parents the effects in this group are closer to children from parents with a college degree. This means that the extra spending made by the parents indeed pays off.

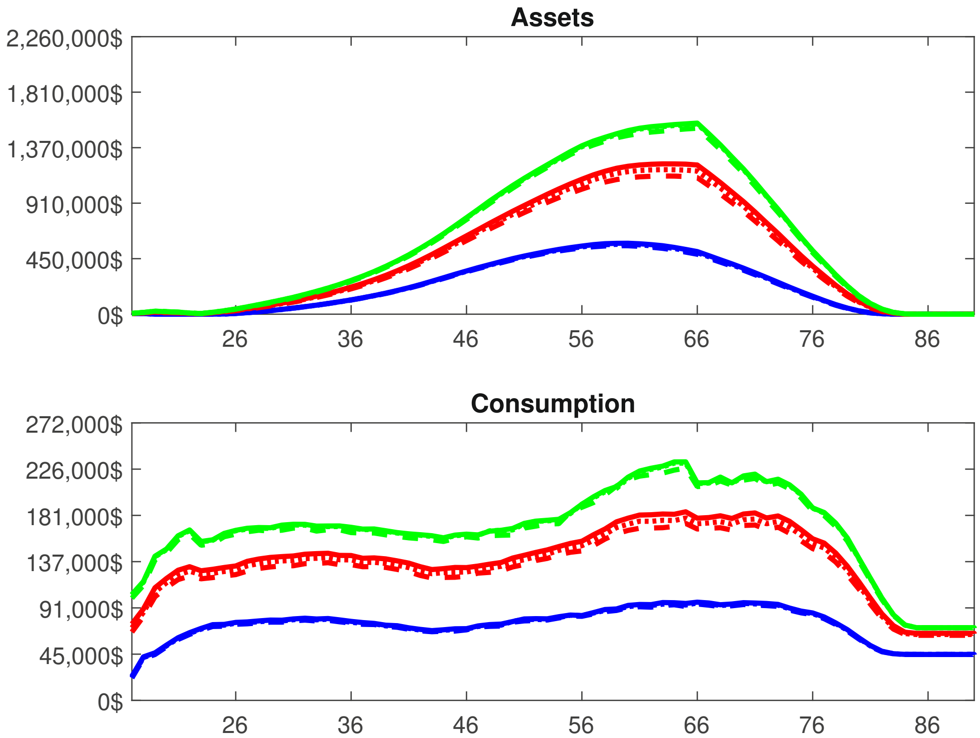


Figure 4.4: Asset and consumption levels of children across the three models

	BL # [$]	**COVID-19 # [$]**	**DLM # [$]**	**Diff. tot. %** (BL - COVID-19)	**Diff. tot. %** (BL - DLM)	**Diff. tot. %** (C19 - DLM)
			Assets			
Children 1	16.763	16.238	16.547	-3.13	-1.29	1.90
Children 2	35.479	32.743	34.192	-7.71	-3.63	4.42
Children 3	44.752	43.649	44.538	-2.47	-0.48	2.04
			Assets			
Children 1	5.489	5.378	5.443	-2.01	-0.83	1.20
Children 2	10.156	9.522	9.845	-6.25	-3.07	3.39
Children 3	12.338	12.087	12.298	-2.03	-0.33	1.74

Table 4.11: Total sum of accumulated assets and consumption for the six children over the life cycle in million US dollars

Lastly the net present value (NPV) at the end of the working age T is calculated and displayed in table 4.12. The NPV is a useful metric that discounts (with the interest rate) future income and values present income more. The table shows the same pattern already described above. Children of parents with a high school diploma are better in absolute terms than children of parents who dropped out of high school, but relatively they get along worse than then children with parents who dropped out of high school.

	BL # [$]	COVID-19 # [$]	DLM # [$]	Diff. tot. % (BL - COVID-19)	Diff. tot. % (BL - DLM)	Diff. tot. % (C19 - DLM)
Children 1	1.742	1.699	1.724	-2.47	-1.03	1.47
Children 2	3.333	3.107	3.225	-6.78	-3.24	3.80
Children 3	4.124	4.026	4.109	-2.38	-0.36	2.06

Table 4.12: NPV for the three children groups in million US dollars

Parents

For the parents, the same approach as in the sections before was conducted. Figure 4.5 displays the behavior for the different educational levels.

Overall there is no difference observable, which might be because the shock only lasted for one period and the adjustments of the parents were not that severe. One feature that is quite noticeable is the drop in the green line around age 45, which refers to the assets of parents with a college degree. This is probably because this group of parents bequeaths significantly more money to their children than the rest of the parents.

Table 4.13 shows the total accumulated assets over time and supports the result seen in the figure. The table highlights small differences among the consumption models. These differences are quite small and probably the result of the adjustments parents make during the education phase of their children.

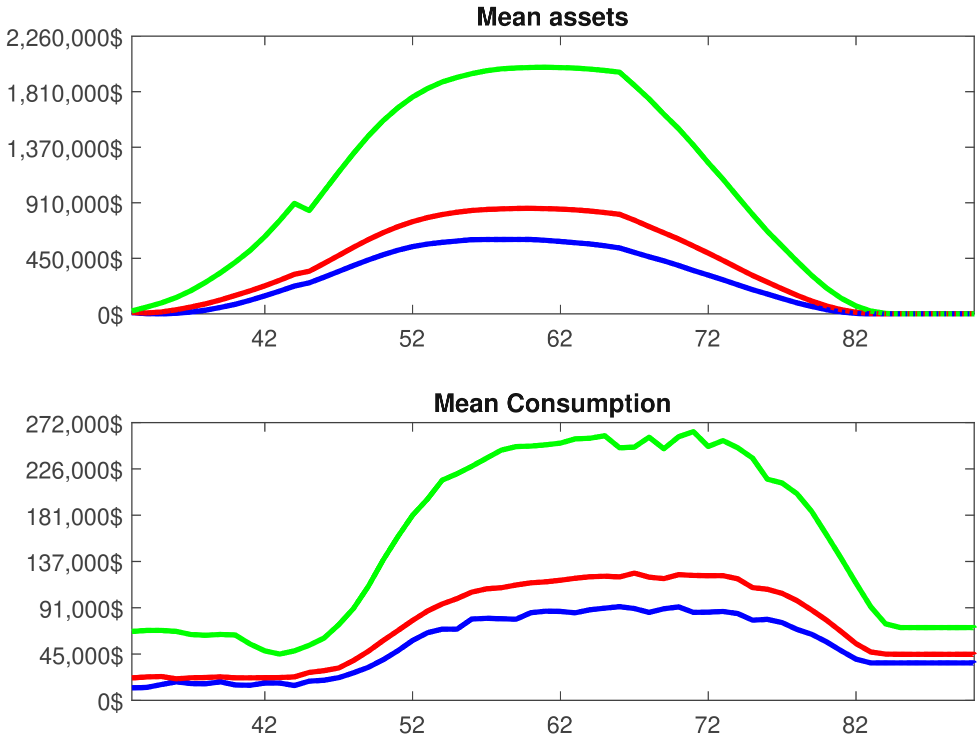


Figure 4.5: Asset and consumption levels of parents across the three models

Educ.	BL # [$]	COVID-19 # [$]	DLM # [$]	Diff. tot. % (BL - COVID-19)	Diff. tot. % (BL - DLM)	Diff. tot. % (C19 - DLM)
			Assets			
do	16.021	16.021	16.015	0.00	-0.04	-0.04
hi	23.478	23.478	23.567	0.00	0.38	0.38
co	57.317	57.317	57.317	0.00	0.00	0.00
			Consumption			
do	3.103	3.100	3.103	-0.09	0.00	0.09
hi	4.244	4.254	4.251	0.23	0.16	-0.07
co	9.042	9.043	9.042	0.01	0.00	-0.01

Table 4.13: Total sum of accumulated assets and consumption for parents over the life cycle in million US dollars

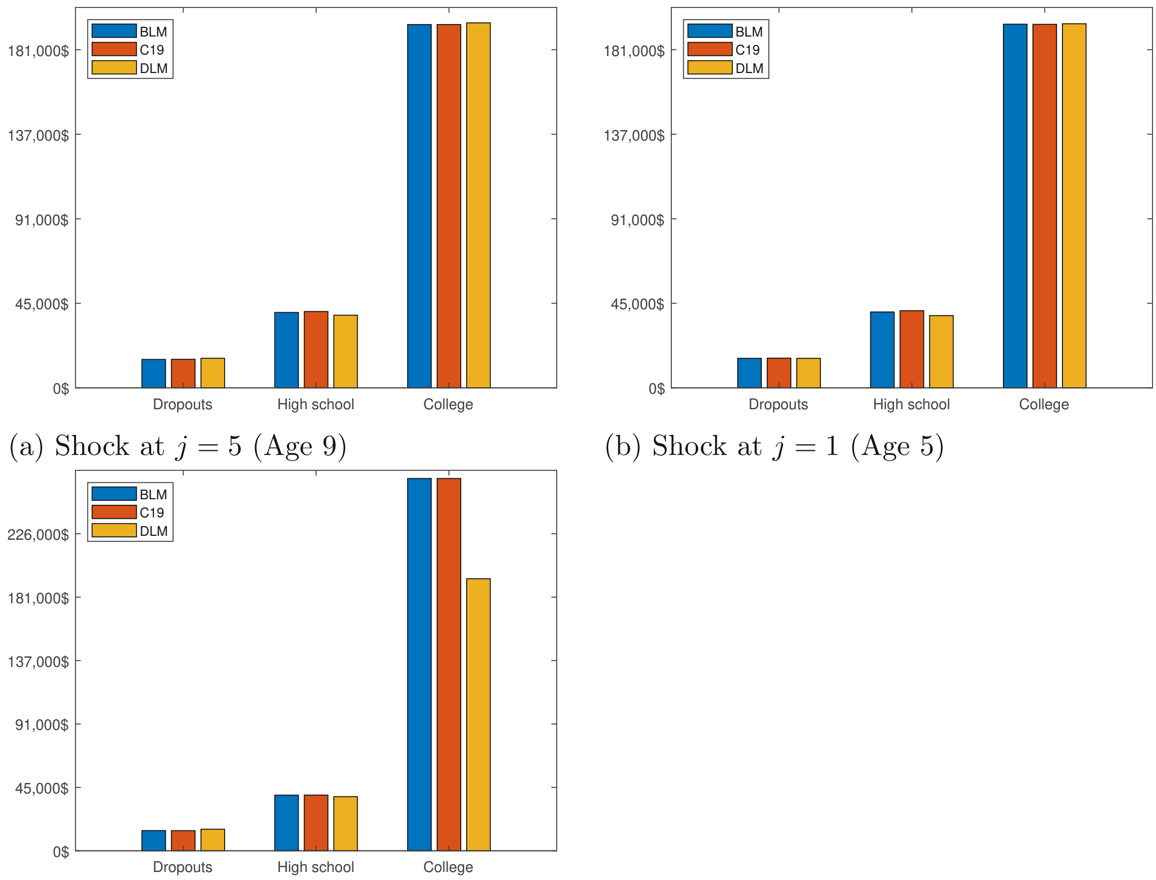
4.2 Children at different ages

In this section, the focus lies on the impact of the COVID-19 shock on the human capital level and certain key values (already seen above) if the age of the children is modified. In the previous analysis, the COVID-19 shock occurred in the fifth period corresponding to a biological age of nine years. So the effects were most likely noticed after this period. Now the model is re-run but the first time the shock occurs at the beginning of the model, in period one (biological age of five), and the second time it occurs almost in the last period, more explicitly in period ten (biological age of 14). The reason why period twelve is not a good choice is due to the fact how the model is constructed, the effects would not be seen.

4.2.1 Monetary investments of parents

Bequeath of parents

First, the focus lies again on the one-time monetary transfer of the parents which results in starting assets of their children. In 4.6 the results are shown.
The most significant difference occurs when the age of the children is equal to 14. Parents with a college degree in the BLM and C19 bequeath a lot more to their children in comparison to the DLM where the levels did not change concerning the other two age categories.



(a) Shock at $j = 5$ (Age 9)

(b) Shock at $j = 1$ (Age 5)

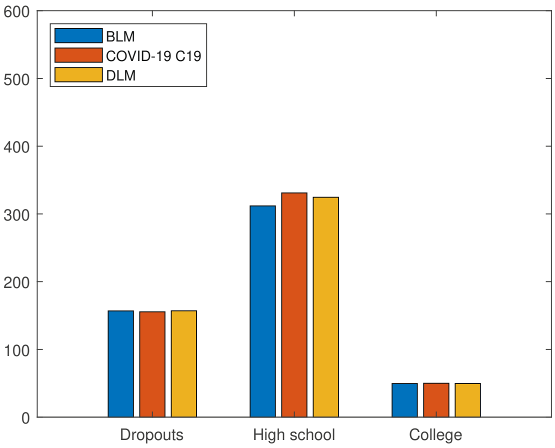
(c) Shock at $j = 10$ (Age 14)

Figure 4.6: Comparison of bequeath levels, if COVID-19 happens during different ages

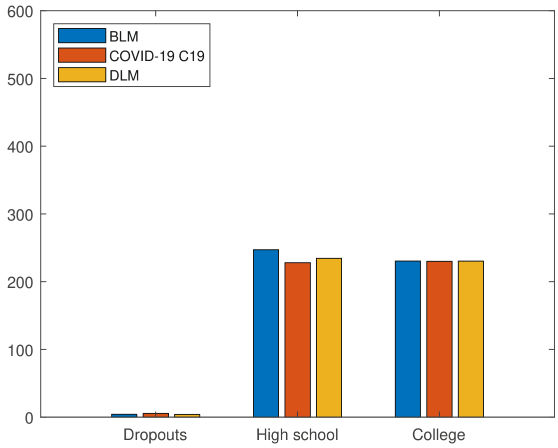
Additional investments on private tuition

In a similar manner to the one above, this section shows the difference between the additional investments into private tuition if the shock occurs at different ages. In 4.7 the results of the simulation are shown.

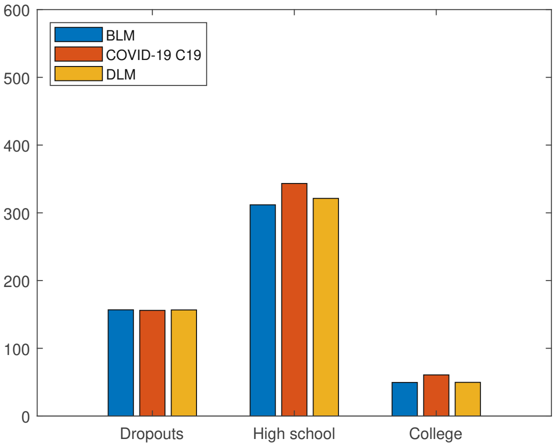
The figures show a lot of differences between the models and the age categories. The significant difference in the previous subsection may get explained by looking at the last row in figure 4.7. There are no severe changes between the three models observable, parents assumably try to compensate for the loss caused by COVID-19 with the increase in the monetary transfer. In the second row, their children are at the start of the education phase and have a lot of time to equalize the effects of the shock. The major finding, looking at the plots in the middle, is that parents invest less into their children. This is probably because two components (the educational level of the parents and governmental investments) of the human capital function work over time and can compensate more of the loss.



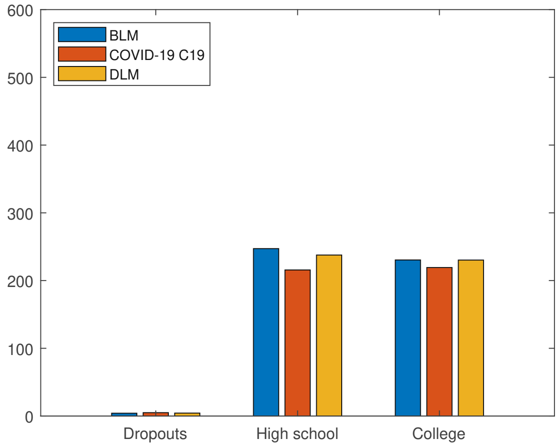
(a) No investment, $i^m = 0$ (Age 9)



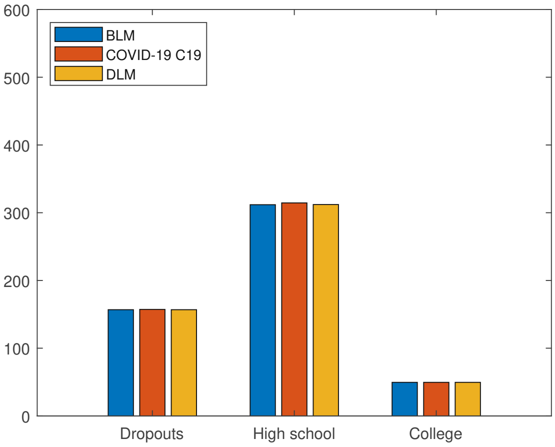
(b) Additional investment, $i^m = 1$ (Age 9)



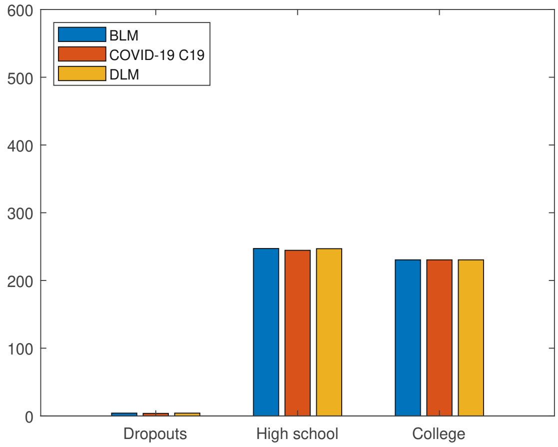
(c) No investment, $i^m = 0$ (Age 5)



(d) Additional investment, $i^m = 0$ (Age 5)



(e) No investment, $i^m = 0$ (Age 14)



(f) Additional investment, $i^m = 0$ (Age 14)

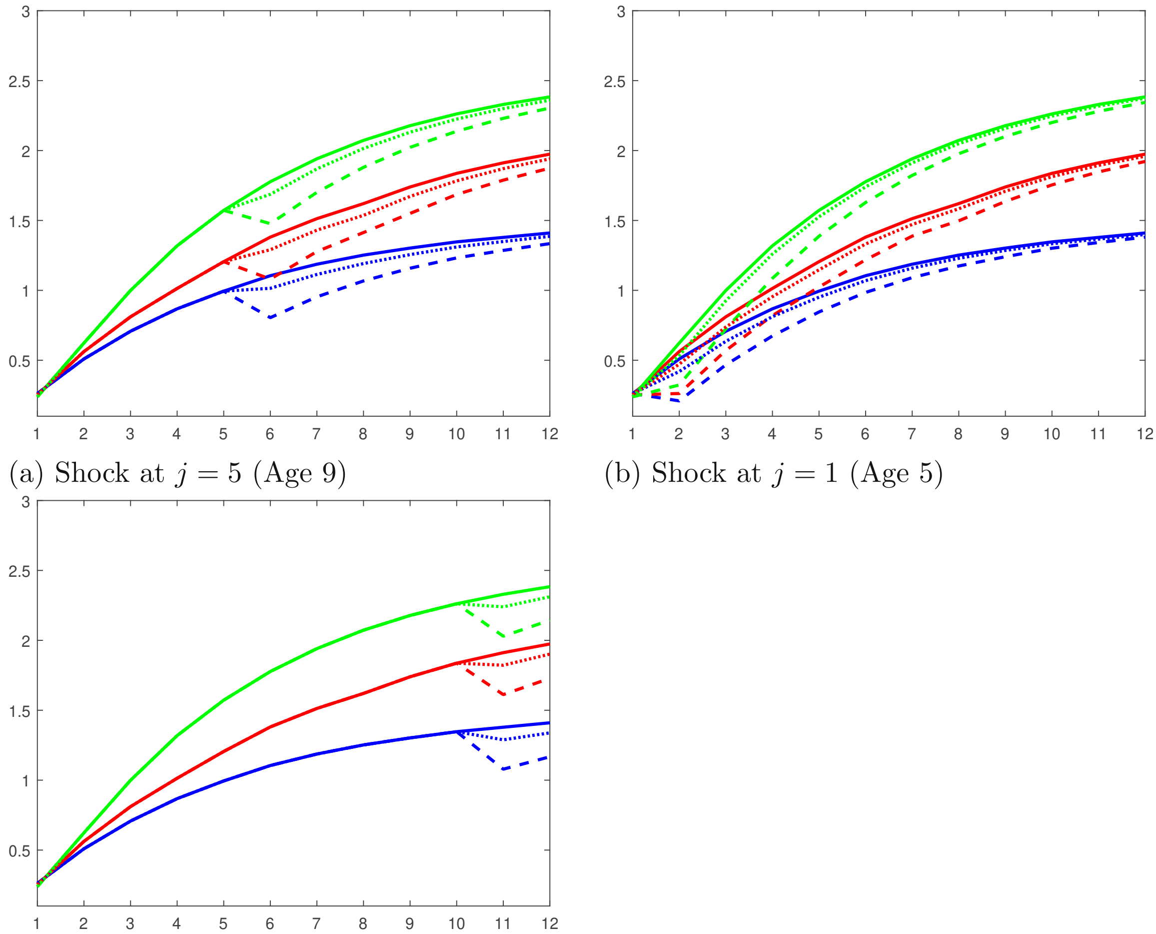
Figure 4.7: Count of parents across different educational levels who invest into private tuition for different ages

4.2.2 Human capital

In this section, the point of interest lies in the acquired human capital over the education period. The main objective is to identify differences in the human capital levels at the end of the phase when the COVID-19 shock happens at a different age. In figure 4.8 one can look at the human capital accumulation over time between the three observed scenarios which were already described in the sections above. The following plot displays the educational level in a known manner but doesn't refer to the educational level of the children but to one of their parents.
The observed pattern is consistent with the conclusions above. Human capital levels are higher if parents have a higher educational level and the distance learning strategy decreases the impact of the COVID-19 shock. The difference between figure 4.8b and figure 4.8c is the time at which the shock occurs, this is equivalent to the age of the children. So the conclusion which can be made by looking at this plot is that the later the shock occurs in the life of children and within the education phase, the worse it is for their human capital allocation. This is logical since all years during the education phase are weighted equally within the model. This means if the shock happens earlier in life, children and especially parents have more time to compensate for potential losses caused by COVID-19. This is observable in figure 4.8. For detailed information one can have a look at table 4.14, supporting the results described above.

Model	**Education**		
	do	*hi*	*co*
Baseline	1.410	1.974	2.384
COVID-19	-5.40%	-5.06%	-3.34%
C19 younger age	-2.11%	-2.65%	-1.65%
C19 older age	-17.24%	-12.45%	-10.07%
DLM	-1.70%	-1.70%	-1.00%
DLM younger age	-0.77%	-0.74%	-0.41%
DLM older age	-5.10%	-3.67%	-3.02%

Table 4.14: Overview of human capital differences for three different ages of children



(a) Shock at $j = 5$ (Age 9)

(b) Shock at $j = 1$ (Age 5)

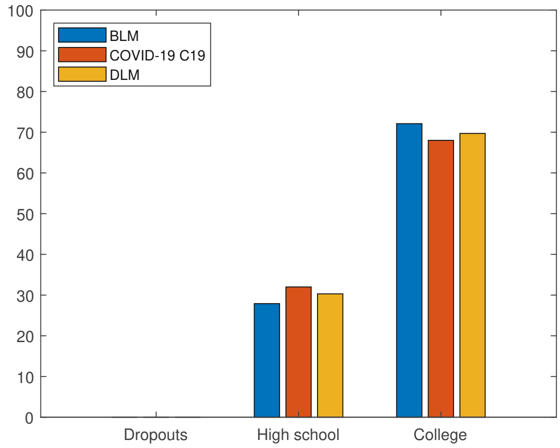
(c) Shock at $j = 10$ (Age 14)

Figure 4.8: Comparison of the human capital levels, if COVID-19 happens during different ages

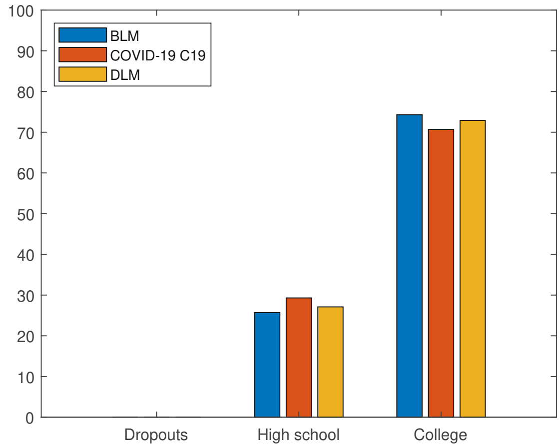
4.2.3 Education decision

This section shows one limiting factor of the constructed model. In the section 3.4 the shares of each education group are stated. The calibration of the model happens on a more general level than the process in 4.1.3 describes. To be more specific, in the first stage the model gets calibrated so that the education shares match the stated values in [FSKLP20] (can be seen in table 3.2). Then the parents are simulated and with them their fictional children who accumulate human capital. The acquired human capital on average is way higher than the human capital used to calibrate the model which achieves the shares in 3.2. The final education shares of the children

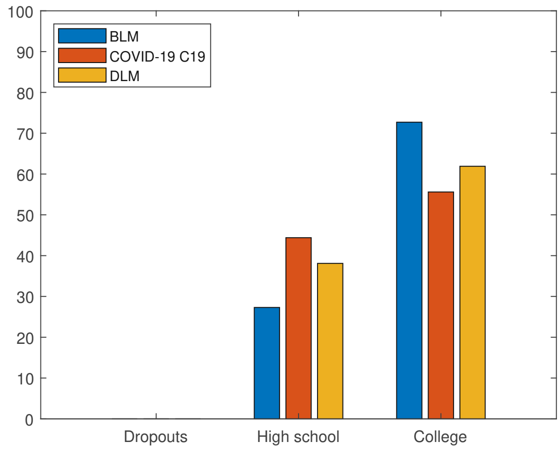
used in 4.1.3 and the next section are shown in figure 4.9.
One can see that not one child chooses to drop out of high school and most children choose to go to college. This might seem unrealistic in comparison to the levels displayed in 3.2 but they are not that unlikely in comparison to current data as [Han21] shows.



(a) Shock at $j = 5$ (Age 9)



(b) Shock at $j = 1$ (Age 5)



(c) Shock at $j = 10$ (Age 14)

Figure 4.9: Comparison of education shares, if COVID-19 happens during different ages

4.2.4 Average Effects on asset accumulation and consumption

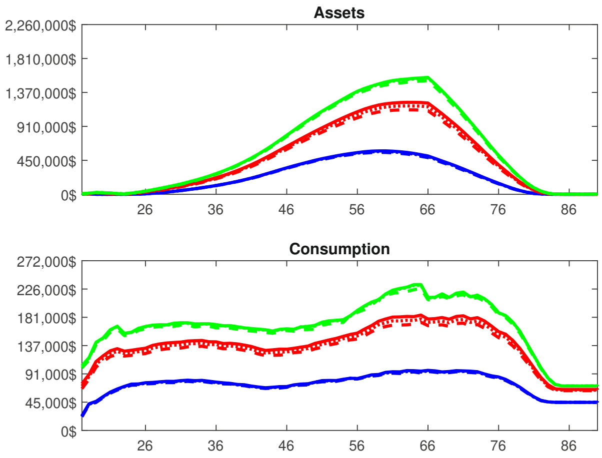
In comparison to the upper section, the focus in this chapter only lies on the children. Again the three metrics (assets, consumption and net present value of income) will be evaluated and a conclusion will be made. To give a first overview of the experiment look at figure 4.10 which is showing the asset and consumption levels. The legend of the figures follows the same logic as in 4.2.2

The trend of the previous sections is present as well. The later the COVID-19 shock occurs the more impact it has on the future asset and consumption levels of the children. This influence is quite severe in 4.10c for the red lines which refer to children of parents with a high school degree. This is briefly explained in the previous sections, but summarizing one can say that parents with a high school diploma do the least to compensate for the losses caused by COVID-19 within the three education categories. Another possible explanation is given below.

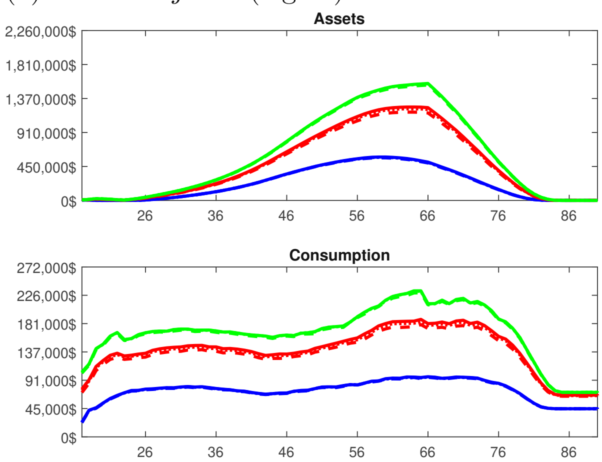
In table 4.15 the net present value of income is calculated again between the different models and compared to the values of the baseline model. This table shows the significant difference between the high school educational level and the other two if the shock occurs late in the life of a child. Since the other key factors such as bequeath of parents, additional investment into private tuition and human capital do not explain such a clear difference among the educational levels, this could be related to more drastic changes displayed in 4.9. In this figure, the share of children who choose a high school education changes more drastically than in the other two education groups, which leads to a larger pool of children in this category and therefore might change the values of assets, consumption and NPV in an observed manner.

Model	**Education**		
	do	*hi*	*co*
Baseline	1.742	3.333	4.124
COVID-19	-2.47%	-6.78%	-2.38%
C19 younger age	-1.26%	-4.84%	-1.16%
C19 older age	-7.35%	-20.61%	-7.57%
DLM	-1.03%	-3.24%	-0.36%
DLM younger age	-0.46%	-1.68%	-0.15%
DLM older age	-2.24%	-10.99%	-2.24%

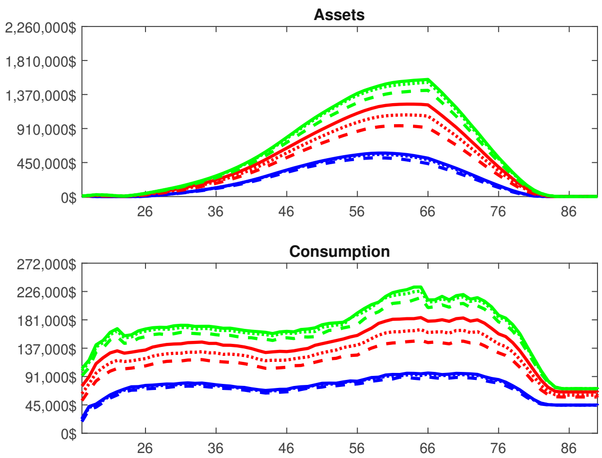
Table 4.15: Net present value of income (in million US dollars) for different time points of shock occurrence (children of different age)



(a) Shock at $j = 5$ (Age 9)



(b) Shock at $j = 1$ (Age 5)



(c) Shock at $j = 10$ (Age 14)

Figure 4.10: Comparison of the asset and consumption levels of children, if the shock occurs at a different age

5 Conclusion

This thesis focused on the effects of school closures during the early years of the COVID-19 pandemic. Therefore a look at the model in [FSKLP20] is taken and a version of this model is implemented. Similar to the paper, only the effects of the school closure are investigated hence the reduction of governmental investments. Furthermore this model compares a distance learning model where the reduction of investments was smaller. The shock in the model happened unexpectedly and parents could adapt their decision to compensate for potential losses.

The main results are that COVID-19 has the influence one would expect when parents are not aware of such a shock happening. The human capital levels in all three groups are lower than in the baseline model. The highest difference in relative terms is in the group of parents who have a high school diploma. The difference between the baseline model and the COVID-19 model is higher than the effects in the model in which distance learning is present. Another fact that could be identified is that the time point has a major influence if parents do not compensate for the losses that happen during the crisis. The older the children are, who therefore are closer to the end of the education phase, the more they could be influenced by the losses in the human capital. As seen later on, the reduction of the human capital has a major influence on the NPV, the total accumulated assets of the children and also their consumption. This could be even worse when the shock occurs near the end of the education phase.

The conclusions are limited by the structure of the model, respectively the approach used in the scope of this thesis. Possible improvements are the implementation of an income recession similarly caused by COVID-19 as in [FSKLP20]. This could result in visible effects on the parents. The final education shares could be better. To improve this, one would need a different human capital function or even real data to calibrate the shares and functions.

The main takeaway from this thesis is that one year of total school closures has a noticeable impact on the future welfare of the children if strategies such as distance learning are not implemented. Another way to solve this problem would be to invest more in private tuition but not every household can afford such extra spendings. This problem describes the gap between different educational levels which is also present in this model.

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