How have health investments changed since COVID-19? An empirical Grossman model using UK panel data.

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Abstract
This paper uses the Grossman model to analyse the impact of the COVID-19 pandemic on health investments by using UK panel data from the Understanding Society database. It assesses the effect of the first and most significant lockdown on individuals' health investment in the UK; and how they changed their behaviour between the pre-pandemic and post-pandemic period. This paper finds a net lockdown effect of 17 minutes, which is statistically significant. This means lockdown caused individuals in the UK to invest more in their health. This paper also uses a differences-in-differences methodology to analyse if the lockdown affected different groups differently. It found that there was no statistically significant difference between high risk and low risk individuals. Both groups increased their health investments with no significant difference in minutes of investment between the groups.

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Introduction

The World Health Organisation (WHO) declared the outbreak of a Public Health Emergency of International Concern on 30th January 2020, and a pandemic on 11th March 2020[1]. On the 23rd of March 2020[2] the British Prime Minister Boris Johnson announced that individuals should "stay at home" as the United Kingdom would be going into lockdown. On the 26th of March the first lockdown measures legally came into force to "save lives", as a result of the outbreak of COVID-19 virus. This first lockdown led to UK Gross Domestic Product becoming 25% lower in April 2020 than it had been only two months earlier in February[3].

From personal experience, I noticed that the pandemic increased the amount of time I exercised as the university closed and my options for socialising became scarce and illegal. Put in economic terms; these new constraints in how limited resources (i.e. time) could be distributed resulted in my utility function adjusting to become more weighted to producing future health stock, by making health investments today. I became a healthaholic! This economic phenomenon is what motivates this research question. This paper will explore how this first lockdown, i.e. the most restrictive, changed individuals' health investments as a result of the outbreak of the COVID-19 pandemic.

This research is important because understanding how individuals' health investments change, as a result of an exogenous shock of a pandemic, can help public policy makers in deciding who to distribute resources to. By knowing who is worse affected by the pandemic, they can decide where funding and support needs to be directed; in order to improve individual health outcomes. Obesity is a huge problem for the NHS. The NHS spent an

[1] https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020
[2] https://www.instituteforgovernment.org.uk/sites/default/files/timeline-lockdown-web.pdf
[3] https://commonslibrary.parliament.uk/research-briefings/cbp-8866/#:~:text=GDP%20declined%20by%209.7%25%20in,two%20months%20earlier%20in%20February.

estimated £6.1 billion on tacking obesity-related illnesses in 2014/15 alone[4]. Obesity also has serious negative implications for economic development and costs UK society £27 billion a year. Understanding how a pandemic affects health investments can have huge cost saving benefits for the government as well as help them increase individuals' welfare via possible intervention in the market. This is why this research is important.

This research question will be explored by extending upon Grossman's (1972) demand for health model. First previous literature will be studied by exploring how others, in the health economics field, have used the Grossman model to conduct empirical research in order to get an understanding of what others have done before. Next Grossman's model will be explored, in detail, via the theoretical framework whereby predictions will be made about how the pandemic may have affected health investments by using comparative statics. Moving forward, the methodology will be outlined whereby a differences-in-difference analytical framework will be discussed. This will help in exploring whether the lockdown effect caused differences in health investments between high risk (treatment) and low risk (control) groups of individuals. Then the empirical model will be outlined, and the dataset explained; whereby the variables chosen in the model will be justified. Finally, the empirical results from the static and dynamic regressions will be discussed, where it will be found that the first lockdown caused net health investments to increase by 17 minutes. The differences-in-differences results will show that there are no significant differences between the control and treatment group in how their health investments changed as a result of the lockdown. After the results have been discussed, they will be put into the context of the wider literature. This will help in concluding what this research tells us, as health economists, about human behaviour, and what it adds to the wider empirical Grossman model literature.

[4] https://www.gov.uk/government/publications/health-matters-obesity-and-the-food-environment/health-matters-obesity-and-the-food-environment--2

Literature Review

Others have used Grossman's demand for health model to conduct empirical research into economic questions of health investments. Bolin and Lindgren (2002) researched the significance of chronic health conditions, such as asthma and allergies, in predicting individuals' health behaviour. They used Swedish panel data. They found that people with asthma were less healthy than the general population while people with allergies were indifferent in their level of health stock. However, they found that asthmatics and individuals with allergies invested more in their health than those without chronic conditions. This question of how chronic conditions affect health relates to this research since it will explore the differences in health behaviour between individuals at high-risk to COVID to those who are not. This paper used a similar self-assessed EXERCISE variable as its proxy for health investments, which takes value 1-5, where 1 indicates the respondent doesn't exercise at all and 5 indicates they exercise at least twice a week. This research differs from this approach by breaking down different types of exercising, into vigorous, moderate and light (walking) intensities to see the change in each specific health investment before and after COVID. This paper also builds upon Bolin and Lindgren by looking at the health investments in terms of a continuous time variable, in terms of minutes exercised rather than a more general limited dependent variable measure of exercise. Building upon Bolin and Lindgren's results this paper may find that high-risk individuals have a lower level of health but may make more health investments due to them being less efficient producers of health whereby they produce smaller amounts: given the same inputs of time and health care. This is due to individuals with chronic illness having higher rates of depreciation in health. However, this paper may find that high risk individuals will demand less health due to them having a higher net cost of health capital, whereas they don't get as much benefit of a health investment as an low risk individual i.e. high-risk individuals have a higher opportunity cost of making a health investment.

Bolin, Jacobson and Lindgren (2002) also try to empirically test the Grossman model using the same Swedish dataset. They measure both the demand for health, using self-assessed health as an indicator for health as well as measuring health investments using exercise as an indicator. The latter is similar to this research paper. Different to this study, they use a probit model to estimate both these equations. They find that age and having children decreases health investments while education, wealth and being male increase health investments. In terms of interpretation within the probit model; this means that individuals who have more education, more wealth or that are male have a higher probability of being part of the highest health investment group i.e. they more likely to exercise regularly. While those with children or who are older are less likely to belong to the high health investment group i.e. they are less likely to exercise regularly. Bolin et al also found some evidence that the experience of divorce lowered health investments, but this was not fully supported in the data. It was also found that the marginal effect on health investments from a change in the wage rate was not significant. These results from Bolin et al can give this paper some indication of what it should expect from the data in measuring the relationship between health investments and several independent variables in the empirical model.

Hunter et al (2018) researched the association between time preference, present-bias and physical activity and its implication for designing behaviour change interventions. Although this research is not concerned with measuring different discount rates and time inconsistency discounting; it is relevant to the wider literature and helps identify how governments can best target health interventions. They find that discount rates and present-biasedness have significant impact on physical activity levels (aka health investments). Hunter et al results show that individuals who are present-biased and who had a higher discount rate undertook significantly less physical activity than their patient and non-present-biased counterparts. In numerical terms they associated a 3% lowering of the discount rate and a 1.14 unit reduction in the present-bias parameter with a 30 minute increase of weekly physical activity. The methodology behind this research was in a field experiment where 406 office-based employees were given a loyalty card to monitor their physical activity during office hours. These employees were randomly allocated into an incentive and no incentive group. They then gave these individuals various options for potential payoffs which ranged from smaller amounts paid soon compared to larger amounts given after a long delay. This indicated individuals time preference. Similar questions were asked to control for participants risk preference to avoid upward-biases in time preference estimates. This study by Hunter et al helps understand individuals time preferences which can inform how policy makers can best intervene to address health behaviours. This is important because an individual's decision to initiate or maintain a healthy habit (i.e. investing in their health) has a trade-off between short term costs (time and effort) and a long-term health benefit (increase in health stock). This research is important as it can help understand how health interventions can be most effective as failing to identify present-biased, procrastination and self-control problems will lead to unsuccessful public health interventions. This gives a behavioural economics component to analysing health investments and is therefore important in understanding how individuals change their behaviour over time in relation to producing health stock.

Hakkinen et al (2006) measured the health production function and health input functions for four lifestyle variables (smoking, alcohol consumption, exercise and unhealthy diet) for young adults in Finland. They used the 15D index which is a single index score that measures fifteen health related quality of life dimensions based on answers to a questionnaire. They also estimated the effects of education and the lifestyle variables on the dimensions of 15D. They collected data on individuals in Northern Finland's 1966 Birth Cohort study and collected data at 1 years, 14 years and 31 years. Their results found that for males, important factors impacting health were education, all four lifestyle factors, as well as some exogenous variables at 31 years and variables describing parents' background, and health and behaviour at 14 years. While among females they found that education doesn't impact health. These results are interesting but not super relevant for this study. What's more interesting is that Hakkinen et al measured how exercise (along with education) effected the dimension of the 15D index. For males they found that exercise has positive and significant effects in increasing health through improving the index score in breathing, elimination, mental functioning, discomfort and symptoms, depression, distress, and vitality. While for females they found that exercise improves the score only for mental functioning and vitality. However, Hakkinen argues that since these effects (even for males) are modest, that it may not be cost-effective to invest in more education since Finland already has internationally high educational status. This study isn't that informative for exploring health investment but does give more insight into the mechanism of how health investments increase health outcomes through exploring the 15D index.

Theoretical Framework

The theoretical framework for this research paper is based on Grossman's model of demand-for-health and health investments (Grossman, 1972) introduced over 50 years ago. It is a major theory in health economics and has been a major contribution to economics as a whole. It provides a clear theoretical model which allows economists to undertake economic analysis of individual health behaviour. This framework will start by building up Grossman's theoretical model step by step to show how health investments are made and how health is produced. Then it will theorise and complete comparative statics analysis to explore how the exogenous shock of the pandemic is expected to affect such health investments and hence the production of health. First the framework will discuss different groups of health producers, since it is expected that the pandemic will not cause an equal effect to all. Through this analysis, this part of the paper hopes to hypothesise conclusions based on the economic theory from the Grossman model. This will be done via comparative statics which will be tested empirically in later sections of this research project.

Health is a variable which changes throughout an individual's life cycle, and which can be controlled via health investments. Health is a form of human capital, and it is a valuable asset that pays dividends throughout the lifecycle but depreciates with age. This is why managing health is an economic problem, since individuals optimise based on their preferences for health and their budget constraint. The Grossman model provides a detailed framework which shows the trade-offs in health management and treats health as something which individuals choose. In the model, health is treated as a consumption good, a capital good and an input into gaining utility from consuming other goods.

An individual allocates resources between two variables: H_t and Z_t. This individual derives utility from their health, H_t, and other goods Z_t. This is the basic decision which underlines the model. In order to increase these variables and hence utility, individuals must invest in time and market inputs. Health is a stock; meaning that investments made yesterday determine the level of health an individual has today. This will be the starting point of any given individual, however in order to increase this health stock into the following period a person must invest time into increasing their health. An example of this can be going to the gym or doing a morning run. The use of market goods which improve health are also an important input in the health equation: this can include a gym membership or a pair of running shoes. It is a combination of these inputs which produce health in any given period. From the model so far, it can be concluded that an individual's starting health point, their leisure time available to invest in health and their income are key determinates of their health stock. Moving forward, individuals face a trade-off where they can purchase market non-health goods, J_t, with their income like football tickets or a new video game instead of buying health goods ,M_t . In order to derive utility from these goods, time must be given to such activities. Therefore, there is a fundamental trade-off between time and income spent producing H_t or producing Z_t

$$H_t = (H_{t-1}, T_t^H, M_t) \qquad (1)$$

$$Z_t = (T_t^Z, J_t) \qquad (2)$$

H_{t-1}= Health stock yesterday

T_t^H=Time investing in Health

M_t=Health goods

T_t^Z=Time spent "Playing"

J_t=Non-Health goods

Time has already been discussed in determining an individual's investment decisions but there is also unproductive time i.e. time being spent stick, T^S, as well as time spent working, T^W. The income from working indirectly enhances H and Z through the amount of goods the individual can buy, M_t and J_t. The time constraint an individual faces is also joined by a budget constraint in which she cannot spend more than she earns. Therefore, not all individuals can look like a Hollywood movie star, because they don't have the time or the money to make the health investments. Below is our time constraint and budget constraint.

$$T^{TOTAL} = T^W + T^Z + T^H + T^S \quad (3)$$

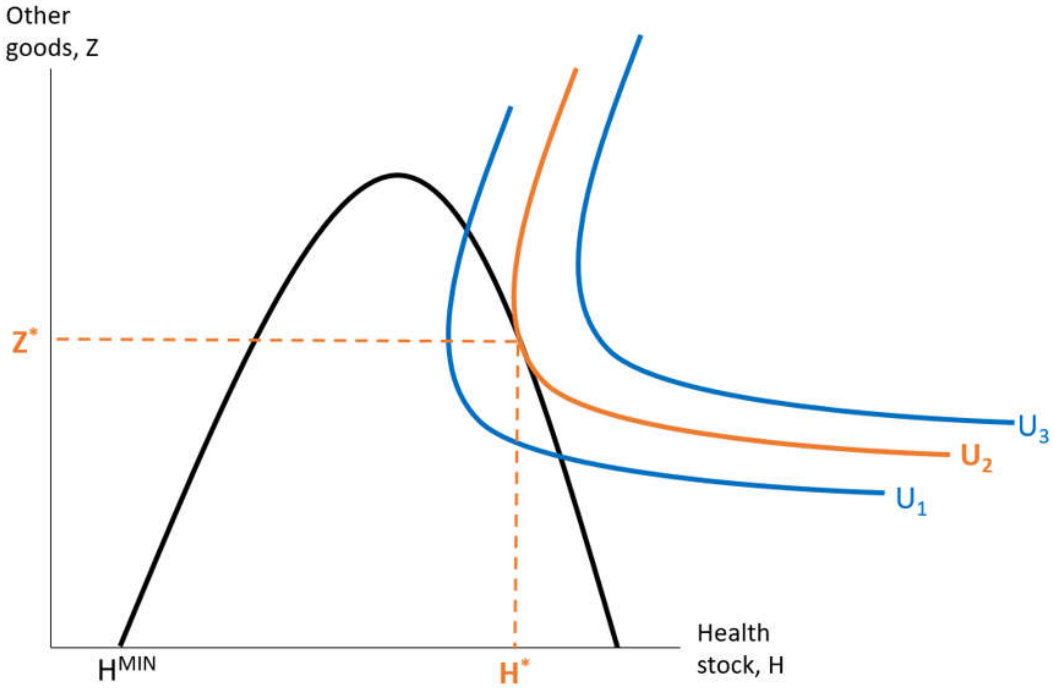
$$Y_t = wT_t^W \quad (4)$$

$$p_M M_t + p_J J_t = wT_t^W = Y_t \quad (5)$$

Where w is the wage and p_M is the price of health goods and p_J is the price of non-health goods.

Now that it has been defined how utility is accumulated and the constraints individuals face; it can modelled how such individuals optimise their choice between health stock and consumption of other goods in a one period model, subject to their time and budget constraint. It is important to note that health can't be equal to zero, since there is a baseline health level a person needs to be alive; so, it is impossible for an individual to choose to produce no health whatsoever.

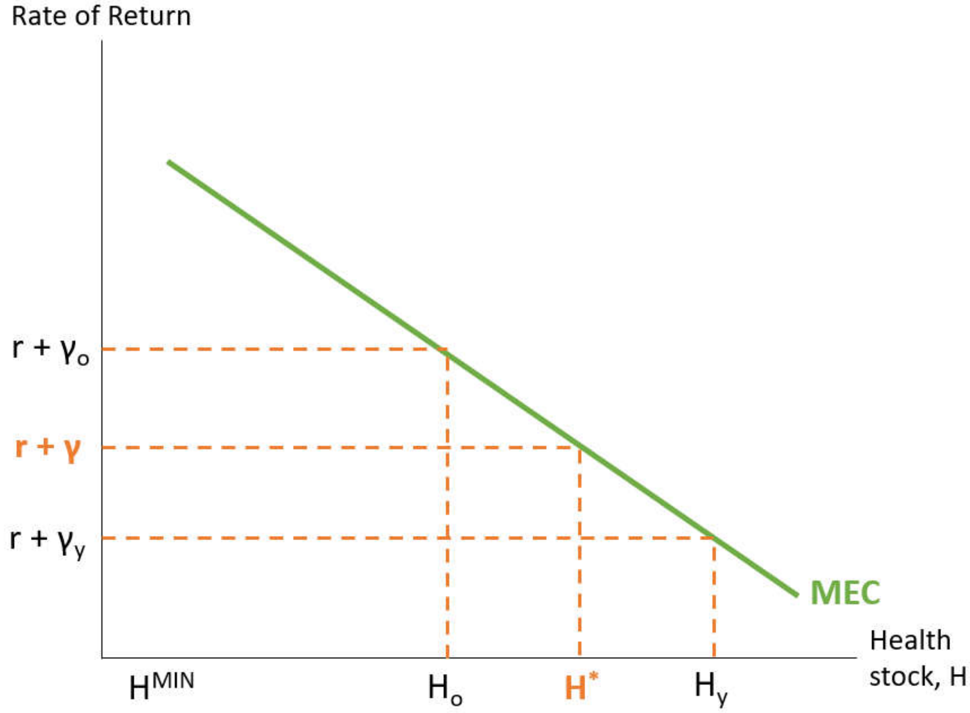
Figure 1: Single-Period Optimisation



The PPF represents the trade-off between health production and production of other goods. The constraints an individual faces are built into the PPF, and individuals optimise where their utility function is tangent to the PPF and choose their desired Z and H in a single period.

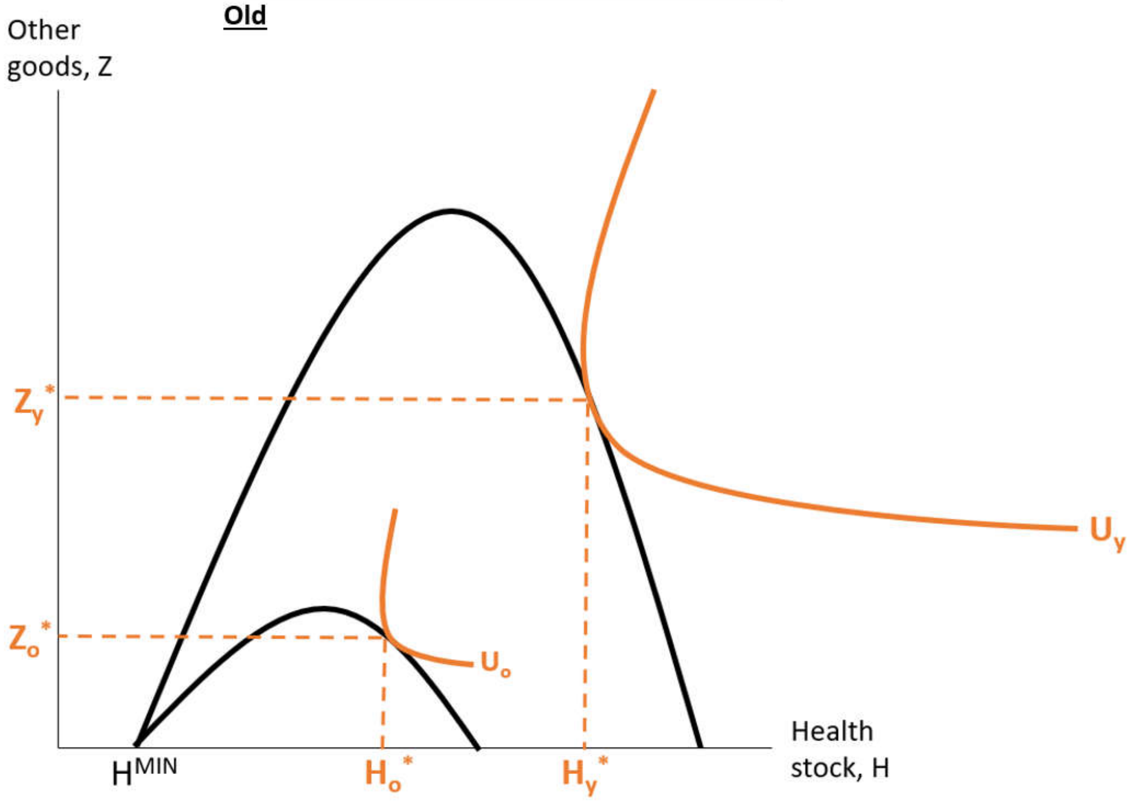
The theoretical framework so far has built up a basic one-period framework, but it is important to note that not all individuals are equally efficient at producing health. The marginal efficiency of health capital curve (MEC) shows the lifetime return from a marginal investment in health at an exogenous level of health stock. The curve is downward sloping to reflect the diminishing returns to health investments. For example, if a person is very unhealthy, a small investment will have a greater return than a premier league footballer going on an extra run. There is an opportunity cost to investing in health which is represented by r. This represents alternative market investments that pay an interest r. Aging also effects the efficiency of health investments and causes depreciation in health investments which is represented by γ. This means that the return from investments becomes smaller and smaller as a person gets older. Or put alternatively older individuals must invest more in health in order to remain at the same level of health stock. This acts as a second cost of investing in H. These costs mean that investing in health must pay at least r+γ for an individual to want to invest. If the return is less, then depreciation γ lowers the effective return to health below r, making other opportunities more desirable. Therefore, the market return of other investments plus depreciation (r+γ) is the price of health capital. A high value for r+γ lowers an individual's optimal health stock, which older people tend to have due to a higher depreciation rate.

Figure 2: Marginal Efficiency of Health Capital Curve



Due to older individuals being less efficient producers of health they also have less productive time, due to being ill more often. This results in them having a lower time-constraint as well as a lower budget constraint as income diminishes as an individual reaches the end of the life cycle. This results in less production of health and less consumption of non-health goods due to being on a lower PPF. To complete our single-period model, the outcomes between young and old will be compared below.

Figure 3: Single Period Optimisation Young vs Old



Comparative Statics

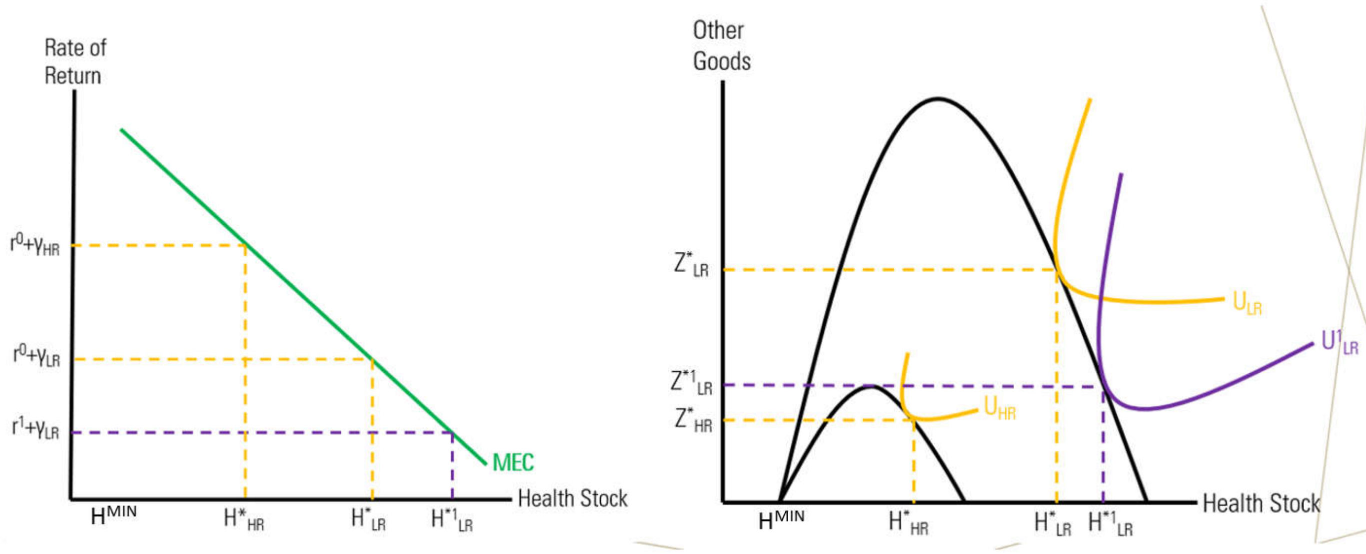
Now that the theoretical model has been completed it is now time to analyse how the exogenous shock of the COVID-19 pandemic will affect the demand for health and health investments. The starting point will be by looking at the health function. During the pandemic, many workers were told to work from home to prevent the spend of the virus. From a theoretical perspective, this will mean many workers may have seen a decrease in T^W as a result of not having to commute to work, meaning workers will reallocate their productive time. This could show up as an increase in T^H and hence an increase in H. On the other hand, some group of workers may have lost income due to being on furlough, a government scheme in which the government provided grants to employers so they can pay staff up to 80% of their wage[5], assuming not all firms paid the remaining 20%. Access to health goods like the gym was also lost due to lockdown restrictions. This means that less health goods, M, could be purchases and hence a decrease in H. However furloughed workers may also benefit from the possible increase in T^H. 11.7 million employees had been furloughed as of 14th October 2021 while 36.5% of workers had ever worked at home at some point in 2020, up from 26.7% in 2019[6]. As many as 46.6% of employees reported that they had worked from home in April 2020 at some point during the first lockdown. The effect on health is ambiguous due to the opposite nature of these effects however it would be thought that due to the economic impact of the pandemic, that the opportunity cost of alternative market investments will decrease, hence making investments in health more desirable. So, the model predicts overall, that the pandemic will increase the demand for health investments, at least for young people due to their risks of death from the virus being relatively low. This can change the shape of their utility function as their preferences shift towards health rather than other goods. Older individuals (or individuals with health problems) may find it more difficult to increase their health, due to increased pressure on the NHS leading to appointment delays or having to shield which decreases their physical activity. These are issues which disproportionately will affect older individuals as well as people who are considered high risk

[5] Francis-Devine, B., Powell, A., Clark H.(2021). Coronavirus Job Retention Scheme: statistics. House of Commons Library.

[6] https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/datasets/homeworkingintheuklabourmarket

to COVID-19 due to having pre-existing chronic health conditions. Figure 4 presents how the model predicts the shock would have affected low risk individuals and high-risk individuals. Overall, the Grossman model of health has been formulated and discussed in detail about how individuals make health investments. It has been discussed how health is produced and the trade-off between H and Z as well as discussing both the time and budget constraints that

Figure 4: Multi-Period Optimisation Young vs Old when facing COVID-19 Pandemic Shock



individuals face. Next, it was discussed how individuals optimise their health using optimisation theory. It has also been discussed how the diminishing returns to health investments work as well as how the alternative market return and aging affects the optimisation of health. Then it was explored how the exogenous shock of the COVID-19 pandemic may affect different aspects of the model and such model provided a prediction of how the shock will affect health investment in low risk individuals via the possible increase in time investing in health as well as the reduction in rate of return of alternative investments. This provides a strong starting point to being the empirical analysis.

Methodology

Like Bolin, Jacobson and Lingren (2002) this research would like to empirically test Grossman's model of health investment using panel data. This paper will also measure exercise as a proxy for an individual's health investment, however it will measure the actual time they spent exercising (in minutes) rather than a qualitative self-reported measure between 1 to 5. Differently from Bolin et al, this paper will measure different components of health investments to measure the difference in effects of different intensities of exercise. This will be split into light (walking) exercise, moderate exercise and vigorous exercise.

In terms of measuring the COVID-19 effect (or the lockdown effect) on health investments, this paper will conduct a differences-in-differences model to see how the COVID-19 effect varies between different groups of individuals. A differences-in-differences methodology is very useful for economic analysis when we are interested in how a sudden change in the economic environment affects the behaviour of different groups of individuals. A difference-in-difference model is justified in this analysis since the theoretical framework suspects that during the lockdown; certain individuals invested more in their health than in normal times (i.e. the period before). In other words, the framework suspects there is a structural break in the data; where one group's (i.e. low risk individuals) behaviour changes while another group's (i.e. high risk individuals) behaviour may have remained the same or changed to a different extent. A difference-in-differences model allows us to measure this behaviour change and clearly see the difference in outcome of the two groups of individuals: in a panel data setting. This model will help make conclusions about how the pandemic affected different groups of individuals by analysing the data. In this research the COVID-19 pandemic creates a natural experiment where COVID-19 is treated as an exogenous shock to the Grossman model; and the methodology seeks to analyse how this shock to health investments affects different groups of individuals; via the popular differences-in-differences model. This offers empirical results for a dynamic Grossman model; where it is explored how health investments change over time following an exogenous shock of a pandemic.

In setting up the differences-in-differences model a high-risk group, which will be the treatment group, will be identified; while all others who don't meet the criteria of being high-risk individuals will be considered the control group. The high-risk group will consist of individuals who have health conditions which make them potentially have a higher risk of mortality if contracting the disease. Consistent with the research[7], the treatment group included individuals with health conditions which makes them potentially high risk as well as individuals over 75, as older individuals have a lower health stock and therefore are less healthy than the mean age. These health conditions included individuals with asthma, congestive heart failure, coronary heart disease, cancer, diabetes, high blood pressure, chronic kidney disease and individuals with a body mass index >40. It may be questioned why high risk individuals are the treatment group when it is their behaviour which is predicted to stay constant over time and low risk individuals whose will change. This has been done because the theoretical framework predicts that in the general population; that health investments should increase when the options for allocation of resources (i.e. individuals' choices about how to spend their time) change. Therefore, high risk individuals are being chosen as the treatment group because the economic framework predicts that it is their behaviour which will be different to the norm in the UK population. Equation (6) shows the theoretical regression model for each health investment.

$$H_{it} = \beta_0 + \delta_0 Post + \beta_1 HighRisk + \delta_1 Post * HighRisk + \mu X_{it} + u \quad (6)$$

[7] https://www.nhs.uk/conditions/coronavirus-covid-19/people-at-higher-risk/who-is-at-high-risk-from-coronavirus/

Table 1 Illustration of the Differences-in-Differences Estimator

	Pre-COVID	Post-COVID	Post – Pre
Low Risk	β_0	$\beta_0 + \delta_0$	δ_0
High Risk	$\beta_0 + \beta_1$	$\beta_0 + \delta_0 + \beta_1 + \delta_1$	$\delta_0 + \delta_1$
High Risk – Low Risk	β_1	$\beta_1 + \delta_1$	$\boldsymbol{\delta_1}$

[1] *Bold indicates the differences-in-differences estimator*

In order to see the lockdown effect for the model, two periods will be used. Panel data from 2019 will be used as the pre-pandemic period as this will represent individuals' health investment behaviour in 'normal' times. This will be compared to data from April 2020 since this is immediately after the UK went into lockdown on 26th March; and hence this is where it is expected that the lockdown effect will be its peak. An extension to this research could be to measure health investments in different stages of the pandemic from all the different lockdowns and their various rules; but this is beyond the scope of this research paper.

Empirical Model

The analytical starting point of the model is to focus on how health investments are determined during the lockdown period and seeing how they differentiate from previous research done in 'normal' health investment times. This will be done using a static model of health investments where it will include similar variables to ones used prior in other empirical Grossman models as well as some specific COVID-19 variables. These include variables such as whether the individual is on furlough or is a key worker, to see how these variables affected health investments during the lockdown in April 2020. Unlike Hakkinen et al (2006) all these variables will be treated exogenously since the focus is on the outcome variables of minutes of health investments rather than complex analysis of the relationship between health investments and some other explanatory variables. Below are the static models of vigorous health investments; moderate health investments and light health investments (i.e. walking) during April 2020 (i.e. peak lockdown in the UK).

$$Timevig_i = \beta_0 + \beta_1 HighRisk + \beta_2 Age + \beta_3 Age^2 + \beta_4 Female + \beta_5 WorkFromHome + \beta_6 HoursWorked + \beta_7 HoursWorked^2 + \beta_8 Furlough + \beta_9 KeyWorker + \beta_{10} Income + u \quad (7)$$

$$Timemod_i = \beta_0 + \beta_1 HighRisk + \beta_2 Age + \beta_3 Age^2 + \beta_4 Female + \beta_5 WorkFromHome + \beta_6 HoursWorked + \beta_7 HoursWorked^2 + \beta_8 Furlough + \beta_9 KeyWorker + \beta_{10} Income + u \quad (8)$$

$$Timewalk_i = \beta_0 + \beta_1 HighRisk + \beta_2 Age + \beta_3 Age^2 + \beta_4 Female + \beta_5 WorkFromHome + \beta_6 HoursWorked + \beta_7 HoursWorked^2 + \beta_8 Furlough + \beta_9 KeyWorker + \beta_{10} Income + u \quad (9)$$

The justification for the explanatory variables has come from the literature as well as adding some COVID-19 specific variables to understand more about how the pandemic affected individuals' health investments.

When compared to Bolin & Lindgren's model; these models vary based on their findings as well as from this paper's research question being different in nature. For example, they decided to only include age and not age squared in their regression. This may be a mistake because over the life cycle individuals choose to invest different amounts in their health investments, which is unlikely to be a linear relationship. Individuals time constraints change with age and their preferences for producing health also change. For example, a young person at university may find they have excess time to invest in their health but when they enter the labour market, they may find less non-work hours to invest in their health. However, when this same person retires, they may use this excess time to invest in their health; even though they are less efficient producers of health compared to when they were younger. From this reasoning it is clearly wrong to expect age to have a linear effect with an individual's health investments. Therefore the age squared term has been included in the empirical models.

Again, different from Bolin & Lindgren; these empirical models have included an hours worked and hours worked squared term in the regression. The reasoning for this is quite simple. Since these models focus on time spent (in minutes) making health investments, there is a direct trade-off between spending time working and spending time exercising. Differently Bolin & Lindgren used work absenteeism as their indicator of health investment and used a Poisson model. Again, these models included a squared term since it is expected that hours worked has a non-linear relationship with health investments. For example, working 20 hours a week may encourage health investment as it gets the individual out the house while an individual working an 80 hour week unlikely has the time and energy to make health investments.

From Bolin & Lindgren findings, some variables have been omitted when comparing the models above to theirs, such as having children or being married. This is because their results suggest that these variables have little influence on how much health investments individuals make. Unfortunately, education couldn't be included in the empirical model, even though it plays an important role in Grossman's model, due to the limitations of the dataset.

Similarly, to Bolin & Lindgren, a variable for income has been included. It was decided that annual income of individuals will be included while they included wage rate and wealth in their analysis. This model decided not to omit income, even though Bolin & Lindgren found no statistical significance in the wage coefficient, since it plays a key role in Grossman's theory. However, it is important to note that income can affect health through the channel of the amount of health goods an individual can buy. This model is measuring the minutes spent investing in health rather than health itself; meaning much of this income effect may not show in the data. That is because individuals who earn more may be able to pay personal trainers, for example, to help them exercising meaning that their health investments may be more efficient to increasing health stock than an investment of a poorer individual going on a run. A higher wage rate also increases the availability of productive time, hence strengthening the incentives for being healthy. In contrast, a higher wage rate can also lead to less health investments since it makes investing in one's health more expensive relative to working for a high wage. Therefore, the effect of income on health investments is ambiguous and merits being measured in the regression models.

A female dummy variable has also been included to measure the gendered difference in health investments, like many other empirical health economists have done.

In terms of the dynamic model a differences-in difference model will be used as discussed in the methodology above and in equation (6) where μX_{it} represents all the controls from the static equations. Three differences-in-differences regressions will be conducted:

$$Timevig_{it} = \beta_0 + \delta_0 Post + \beta_1 HighRisk + \delta_1 Post * HighRisk + \mu X_{it} + u \quad (10)$$

$$Timemod_{it} = \beta_0 + \delta_0 Post + \beta_1 HighRisk + \delta_1 Post * HighRisk + \mu X_{it} + u \quad (11)$$

$$Timewalk_{it} = \beta_0 + \delta_0 Post + \beta_1 HighRisk + \delta_1 Post * HighRisk + \mu X_{it} + u \quad (12)$$

These regressions will allow the total net effect of the pandemic on health investment to be calculated by aggregating the δ_0 coefficients from the vigorous, moderate and light (walking) health investments. While the aggregation of the δ_1 coefficients will measure the total net differences-in-differences between the low risk individuals and the high risk individuals, in terms of their health investments. This is a unique approach to an empirical Grossman model investigation since neither Bolin et al; Hunter et al or Hakkinen et al separated health investments into different components based on intensity. This methodology and empirical model can have implications for understanding the types of health investments people make and how different independent variables interact with different intensities of health investments. It can also help understand how the exogenous shock of a pandemic (or a lockdown effect); affects the different intensities of health investments (or exercise).

Data

In order to undertake the empirical analysis on health investments of individuals in the United Kingdom and how the COVID-19 pandemic affected such investments; the Understanding Society panel data will be used. Understanding Society is the UK Household Longitudinal Study and is based at the Institute for Social and Economic Research at the University of Essex. The panel nature of the dataset means it tracks participants over time in order to understand long-term behaviour of individuals in the UK. It helps researchers and policy makers explore how the UK is changing over many years and has been running since 2009; where it has interviewed 40,000 households.

This large database allows me to paint an accurate picture of what determines health investments in the UK. The database covers all ages of population (15-114) and all four countries of the UK (England, Scotland, Wales, Northern Ireland) allowing this research to get insights into the whole population from a random sample of households spread between all ages and regions of the country. The richness of the database and the random elements will ensure that the results of this paper carry economic significance and will help tell the story of how the pandemic has affected health investments by comparing the pre-pandemic and post-pandemic data.

Particularly the specific COVID-19 part of the database will be made use of where participants from the main Understand Society sample were asked questions about the changing impact of the pandemic on UK individuals and families. This COVID-19 specific survey was conducted between April 2020 and September 2021, but this research will only study the April 2020 survey since that is where the peak 'lockdown effect' will have the greatest impact on health investments. This COVID-19 part of the survey has allowed this research paper to use pandemic specific variables; such as someone being considered a key worker; or if they were part of the UK government's furlough scheme; or whether an individual was told by the NHS to shield. These COVID-19 specific data points have helped vastly in answering questions such as: how has being on furlough affected health investment? Or is the net health investment effect the same among key workers as compared to the general population? The COVID-19 variables have also helped distinguish which individuals should be in the control and treatment groups.

In carrying out this project, the data points from the April 2020 survey (post-pandemic) with data points recorded in 2019 (pre-pandemic) were merged, in order to find how the pandemic immediately affected the time individuals chose to allocate towards producing health.

Table 2. Description of variables and their summary statistics

	Mean	*Standard Deviation*	*Min*	*Max*	*Observations*
Vigorous Activity (mins)	75.986	206.913	0	6720	28,250
Moderate Activity (mins)	84.298	224.876	0	5880	28,644
Light Activity (mins)	150.942	282.998	0	6720	32,698
High Risk	0.411	0.492	0	1	34,437
Age	50.873	16.973	15	114	34,437
Age^2	2876.119	1710.900	225	12996	34,437
Female	0.581	0.493	0	1	34,407
Working at Home	0.532	0.499	0	1	19,870
Hours worked	23.221	18.695	0	168	19,802
Hours $worked^2$	888.715	1075.682	0	28224	19,802
Furlough	0.197	0.397	0	1	17,433
Key worker	0.447	0.497	0	1	19,866
Annual Income (£s)	2386.429	6797.030	0	203000	18,146

Table 1 is a description of the variables used in the regression analysis. It shows three indicator variables of possible health investments an individual could make at any given point of time. These have been transferred into minutes based on individuals' responses to survey questions about their exercise habits. The three variables have been cleaned from variables available in Understanding Society's exercise module.

In terms of vigorous activity individuals were asked how many days per week they spent doing vigorous physical activity like heavy lifting, digging, aerobics, or fast bicycling then asked how long they spend doing these activities in minutes and hours. These variables were transferred into minutes and then times by the number of days spent doing such activities.

The same was done for both moderate activity, which includes activities such as carry light loads, bicycling at a regular pace or doubles tennis, and light activity. Light activities were measured simply as minutes spent walking per week. Over both the pre-COVID and post-COVID period these activities gave a means of 75.986 minutes; 84.298 minutes and 150.942 minutes. The large sample and the variety of exercise intensities gives the research a strong basic for determining how individuals made health investments both before and after the pandemic.

In terms of the control group and treatment groups; Table 1 shows that the mean of the high risk variable is 0.411 meaning that roughly 41% of the sample is considered high risk individuals and hence there is a large number of observations for both the treatment group (high risk individuals) and the control group (low risk individuals). As mentioned in the methodology; the treatment group is derived from individuals who were either over 75 at the time of data collection or who had one of the chronic conditions which puts individuals at higher risk of getting seriously ill from COVID-19.

It can also be seen that the average age of the sample is 50.8 years. This is around 10 years older than the median age of the UK population, which is around 40.5, according to Statista[8]. This means our sample is slightly skewed towards the older population, but this is

[8] https://www.statista.com/statistics/275394/median-age-of-the-population-in-the-united-kingdom/

justified since our sample only includes individuals over the age of 15. Individuals under this age are unlikely to think about health as an investment so it therefore not interesting to study how much health investments children make as they don't have full autonomy over their inputs for producing health.

The sample is also slightly skewed towards females with 58% being women. The mean hours of work is 23.2 hours which is less than the average weekly hours of full-time workers in the UK, which is 36.5 according to Statista[9]. This lower mean is as a result of 28.84% of the sample working 0 hours a week at the time of data collection. The average current earnings amount was around £2,386 per annum which is way below the UK median weekly earnings of £633[10]. However, income will still be included in the statistical analysis since it plays an important role in the Grossman model even though the data is not the richest, this is the best available in the Understanding Society panel.

Moving forward to the COVID specific variables; 53% of the sample worked at home at least at some point while just under 20% were part of the governments furlough scheme. Around 45% of the sample also considered themselves key workers at the time of the questionnaire.

[9] https://www.statista.com/statistics/280763/average-working-hours-uk/#:~:text=Average%20weekly%20hours%20of%20work,in%20the%20UK%201992%2D2022&text=As%20of%20February%202022%2C%20the,the%20same%20period%20of%202021.

[10] https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/earningsandworkinghours/bulletins/annualsurveyofhoursandearnings/2021#:~:text=the%20data%20section.-,Median%20weekly%20pay%20for%20full%2Dtime%20employees%20was%20%C2%A3611,and%20%C2%A3585%20in%202019.

Results

The first stage of the analysis was to understand what factors have the greatest impact on determining health investments of individuals in the United Kingdom. Table 3 summarises the general marginal effects of the independent variables on the different types of health investments: vigorous, moderate and light activity. The only independent variable that is significant in determining all three different types of health investments was working from home; where it was found that working from home has a significant negative effect on health investments. Simply put working from home had a negative impact on the time individuals invested in their health stock. This is interesting as these findings empirically go directly against the theoretical framework outlined above in this paper. This paper discusses how the COVID-19 pandemic made more individuals work from home; and hence decrease their time working, T^W, since workers no longer have to commute to the office. The predictions expected this to cause an increase in time investing in health investments, T^H, as individuals look for an alternative use for this time. Therefore it would be thought that this coefficient may be positive; as many individuals had to switch to working from home, as the United Kingdom locked down on the 26th March 2020, and hence would use their extra leisure time to invest in their health. This appears not to have been the case from the data as working from home has a strong negative coefficient. Table 3 also suggests that initially as individuals age they invest less in their health (as shown by this statistically significant negative age coefficient); while as they get older they decide to invest more in their health (as shown by the statistically significant positive age^2 coefficient). This may be consistent with the theoretical Grossman framework because as individuals age, they become less efficient producers of health; and hence have to invest more in their health to maintain the same level of health stock. This may be one explanation for the non-linear relationship between age and health investments. Another explanation may be that investing in one's health when an individual is young is less important to individuals as they are already at a high level of health in their life cycle. This means young people prefer to invest their leisure time into other activities like their hobbies or going out with friends or staying extra hours at work to try to earn a promotion. In other words, a young person utility function is more weighted towards producing Z_t i.e. deriving utility from time spent investing in non-health activities. On the other hand, an older individual may be less concerned with going out with their friends, or they may not want to do extra hours at work as they are already at their maximum earnings potential in their career. Older people may have their utility function shift towards investing time in their health as they try to fight back against illness which comes with age. For example, their doctor may tell them they need to lower their blood pressure or tell them they must lose weight in order to prevent further ill health down the road. Older people will also work less as they retire or reduce their working hours allowing their time available to invest in their health to dramatically increase. These factors may explain the statistically significant non-linear relationship between age and health investments that can be seen in both the vigorous and light activity health investment regression models. Differently, time invested in moderate activity sees no statically significant effect of age; as both age and age^2 are not significantly different from 0 at any significance level. All other independent variables see no statically significant relationships with health investments; other than women appearing to invest more time in light activity than men.

Table 3 Estimated effects on health investments from changes in independent variables for adult individuals in the United Kingdom

Variable	Health Investments		
	Vigorous Activity (mins)	Moderate Activity (mins)	Light Activity (mins)
High Risk	n.s.	n.s.	n.s.
Age	-	n.s.	-
Age^2	+	n.s.	+
Female	n.s.	n.s.	+
Working at Home	-	-	-
Hours Worked	n.s.	n.s.	n.s.
$Hours\ Worked^2$	n.s.	n.s.	n.s.
Furlough	n.s.	n.s.	n.s.
Key Worker	n.s.	n.s.	n.s.
Annual Income (£s)	n.s.	n.s.	n.s.

Table 4, 5 and 6 show a detailed breakdown of the static health investment regressions taken during the first and most prohibited UK COVID lockdown. They show the marginal effects of each independent variable on the given health investment. It can be seen that working from home was undoubtedly the most consistent factor which determined the amount of time individuals invested in their health. As can be seen from Table 4, 5 and 6 working from home, on average, led to a 25 minute decrease in vigorous activity; a 26.5 minute decrease in moderate activity and a 41 minute decrease in light activity (walking) per week. Since in Table 4 and Table 6 age is statistically significant and negative; and age^2 is statically significant and positive; this means that initially as individuals age, they invest less in their health up until the minimum of the function; when they start investing more in their health as they age. If age is truly a quadratic function with a U-shape; this means, there are increasing marginal returns. That means for say vigorous activity that the minimum of the function will be equal to (-(-4.096)/2(0.064)) = 32. So, individuals invest less in their health until they reach 32 and then they start investing more in their health. However, it is unlikely that age has exactly a quadratic relationship with health investments so this cannot be completely confirmed in the paper's conclusions. For light activity the minimum of the age function is approximately 28 years. In Table 6 it shows that women invest approximately 16 more minutes into light activity than men.

Table 4 Marginal effects for the health investment equation. Vigorous Activity as the indicator for health investments.

	Change in minutes of vigorous activity	
Variable	Marginal effect	P-value
Constant	**161.443**	0.000
High Risk	-0.526	0.943
Age	**-4.096**	0.012
Age^2	**0.064**	0.001
Female	-1.013	0.878
Working at Home	**-25.178**	0.001
Hours Worked	-0.312	0.563
$Hours\ Worked^2$	0.014	0.129
Furlough	0.842	0.936
Key Worker	4.526	0.529
Annual Income (£s)	-0.0005	0.529

[1]Bold indicates that the estimated coefficient is significant at the 10% level.

Table 5 Marginal effects for the health investment equation. Moderate Activity as the indicator for health investments.

	Change in minutes of moderate activity	
Variable	Marginal effect	P-value
Constant	**102.120**	0.008
High Risk	3.426	0.669
Age	-1.601	0.377
Age^2	**0.035**	0.090
Female	1.003	0.891
Working at Home	**-26.541**	0.001
Hours Worked	-0.219	0.705
$Hours\ Worked^2$	0.0139	0.167
Furlough	1.596	0.889
Key Worker	7.997	0.313
Annual Income (£s)	-0.0006	0.276

[1]Bold indicates that the estimated coefficient is significant at the 10% level.

Table 6 Marginal effects for the health investment equation. Light Activity as the indicator for health investments.

	Change in minutes of light activity (walking)	
Variable	Marginal effect	P-value
Constant	**140.234**	0.000
High Risk	7.565	0.272
Age	**-3.278**	0.033
Age^2	**0.058**	0.001
Female	**16.274**	0.011
Working at Home	**-40.957**	0.000
Hours Worked	1.009	0.055
$Hours\ Worked^2$	-0.004	0.687
Furlough	-0.518	0.959
Key Worker	9.915	0.151
Annual Income (£s)	-0.0003	0.492

[1]*Bold indicates that the estimated coefficient is significant at the 10% level.*

Table 7, 8 and 9 shows the results for the differences-in-differences model where the model tries to explore if there is a statically significant difference between the change in health investments post-COVID between high risk and low risk groups of individuals. The results find that investments in vigorous activity and moderate activity increased (at a statistically significant level) for both the control group (low risk individuals) and the treatment group (high risk individuals); as shown by Table 7 and 8. However; as seen in Table 9; investment in light activity (walking) decreased for both groups of individuals, at a statically significant level. Surprisingly, to the contrary of the predictions by our theoretical Grossman model, all three differences-in-differences estimate produced a coefficient which isn’t significantly different than zero. This means that there was no noticeable difference between the health investments of low risk and high risk individuals. It can be seen that high risk individuals across the sample actually invested more in health for both time invested in vigorous and light activity, albeit not at a statistically significant level, at 4.9 minutes and 6.9 minutes respectively. The empirical results imply that high risk individuals don’t invest less in their health investments; compared to low risk individuals; when an exogenous shock of a pandemic effects the Grossman model. High risk individuals actually behave the same as the theoretical model expected low risk individuals to behave. As a result of the pandemic (or what Table 10 calls the lockdown effect) both high risk and low risk individuals increased investment in their health.

Table 7 Differences-In-Differences estimator for vigorous activity

	Pre-COVID	Post-COVID	Post – Pre
Low Risk	65.150	$65.150 + 32.191$ $= 97.341$	32.191*** P-value = 0.000
High Risk	$65.150 + 0$ $= 65.150$	$65.150 + 32.191$ $+ 0 + 4.938$ $= 102.279$	$32.191 + 4.938$ $= 37.129$
High Risk – Low Risk	0	$0 + 4.938 = 4.938$	$\mathbf{4.938}$ P-value = 0.657

[1]*Bold indicates the differences-in-differences estimator*
[2]**** indicates estimated coefficient significant at 1% level.*

$$Timevig_{it} = \beta_0 + \delta_0 Post + \beta_1 HighRisk + \delta_1 Post * HighRisk + \mu X_{it} + u \quad (10)$$

$$Timevig_{it} = 65.150 + 32.191 Post + 4.938 Post * HighRisk + u \quad (13)$$

Table 8 Differences-In-Differences estimator for moderate activity

	Pre-COVID	Post-COVID	Post – Pre

Low Risk	72.574	$72.574 + 24.495$ $= 97.069$	24.495*** P-value = 0.000
High Risk	$72.574 + 0$ $= 72.574$	$72.574 + 24.495$ $+ 0 - 2.073$ $= 94.996$	$24.495 - 2.073$ $= 22.422$
High Risk – Low Risk	0	$0 - 2.073 =$ -2.073	**−2.073** P-value = 0.854

[1]Bold indicates the differences-in-differences estimator
*[2]*** indicates estimated coefficient significant at 1% level.*

$$Timemod_{it} = \beta_0 + \delta_0 Post + \beta_1 HighRisk + \delta_1 Post * HighRisk + \mu X_{it} + u \quad (11)$$
$$Timemod_{it} = 72.574 + 24.495Post - 2.073Post * HighRisk + u \quad (14)$$

Table 9 Differences-In-Differences estimator for light activity (walking)

	Pre-COVID	Post-COVID	Post – Pre
Low Risk	169.062	$169.062 - 39.845$ $= 129.217$	−39.845*** P-value = 0.000
High Risk	$169.062 + 0$ $= 169.062$	$169.062 - 39.845$ $+ 0 + 6.884$ $= 136.101$	$-39.845 + 6.884$ $= -32.961$

High Risk – Low Risk	0	$0 + 6.884 = 6.884$	$\mathbf{6.884}$ P-value = 0.854

[1]Bold indicates the differences-in-differences estimator
*[2]*** indicates estimated coefficient significant at 1% level.*

$$Timewalk_{it} = \beta_0 + \delta_0 Post + \beta_1 HighRisk + \delta_1 Post * HighRisk + \mu X_{it} + u \quad (12)$$

$$Timewalk_{it} = 169.062 - 39.845Post + 6.884Post * HighRisk + u \quad (15)$$

Table 10 shows the net lockdown effect i.e. the effect of the exogenous shock of a global pandemic to the Grossman model. It shows that when the increase in vigorous and moderate activity is aggregated with the decrease in light activity; it results in a net lockdown effect of almost an additional 17 minutes in health investments from individuals.

Table 10 Net Lockdown Effect on Health Investments

	Lockdown Effect
Change in Vigorous Activity	32.191 mins
Change in Moderate Activity	24.495 mins
Change in Light Activity (Walking)	-39.845 mins
Net Lockdown Effect	**16.841 mins**

[1]Bold indicates the net lockdown effect on health investments.

Conclusions and Discussion

In this empirical research paper, the effect of the exogenous shock of the COVID-19 pandemic on health investments have been analysed using a version of the empirical Grossman model. According to the results, the shock resulted in an increase in net health investment of approximately 17 minutes across the sample of UK individuals. It has also been seen that this shock causes a homogenous effect as found by the insignificance of all three differences-in-differences coefficients; where high risk and low risk individuals experience the same lockdown effect on the minutes they invest in their health.

In making conclusions about the results above, the findings will be compared with Bolin & Lindgren's papers on the empirical Grossman model on Swedish panel data as discussed in the literature review. This makes an appropriate comparison as both this research paper and theirs use a similar framework and empirical Grossman model to make conclusions about how individuals invest in their health and what factors influence health investments. By comparing the similarities and differences, it will create a bigger picture and put this research into the context of the literature which came before it.

The empirical findings are similar to Bolin & Lindgren's as they both find no significant relationship between income and health investments. Bolin & Lindgren use wage rate as their variable for income while this paper used annual earnings. However, Bolin & Lindgren did find that wealth was positively correlated with health investments; which was a variable which wasn't explored in this version of the Grossman model. Differently from Bolin & Lindgren's model; the above model decided to model age as a non-linear function which found that individuals initially invest less in their health as they age then after reaching the minimum; they increase their health investments. This is vastly different from Bolin & Lindgren's finding which model age as a linear function and find a negative relationship between age and health investments i.e. as an individual ages they invest less in their health.

Again, different from Bolin & Lindgren this paper only found a statistically significant coefficient for gender for light health investments, where woman invested more than men. Moreover Bolin & Lindgren found that the probability of maintaining a high exercise level increased; if the respondent was a man indicating that men invest more in health than women do. However, in another of Bolin & Lindgren papers referenced in the literature review section; they found that women with chronic conditions, like asthma and allergies, invested more in their health than men with the same conditions.

Unique to the health economics field; this paper adds to the existing literature by analysing the effect of an exogenous shock of a global pandemic to the Grossman model. It uses an empirical Grossman model and UK panel data to analyse the effect of this shock on individuals' health investments. Differently to other literature, who use work-absenteeism and limited dependent variables of exercise as the dependent variables; this paper uses a continuous dependent variable for three different types of health investments: vigorous, moderate and light activity. This allows the lockdown effect to be decomposed into three different parts and then aggregated into a net lockdown effect. It also uses a differences-in-differences model to measure how this shock to the Grossman model effects different groups of individuals.

Overall, the results go against the comparative statics predicted in the theoretical framework section of this research paper. It predicted that high risk individuals won't change their health investment behaviour while low risk individuals would change their utility function in favour of investing in producing health, H, rather than producing utility from investing in other goods which derive utility, Z.

Figure 5: Multi-Period Optimisation when facing COVID-19 Pandemic Shock

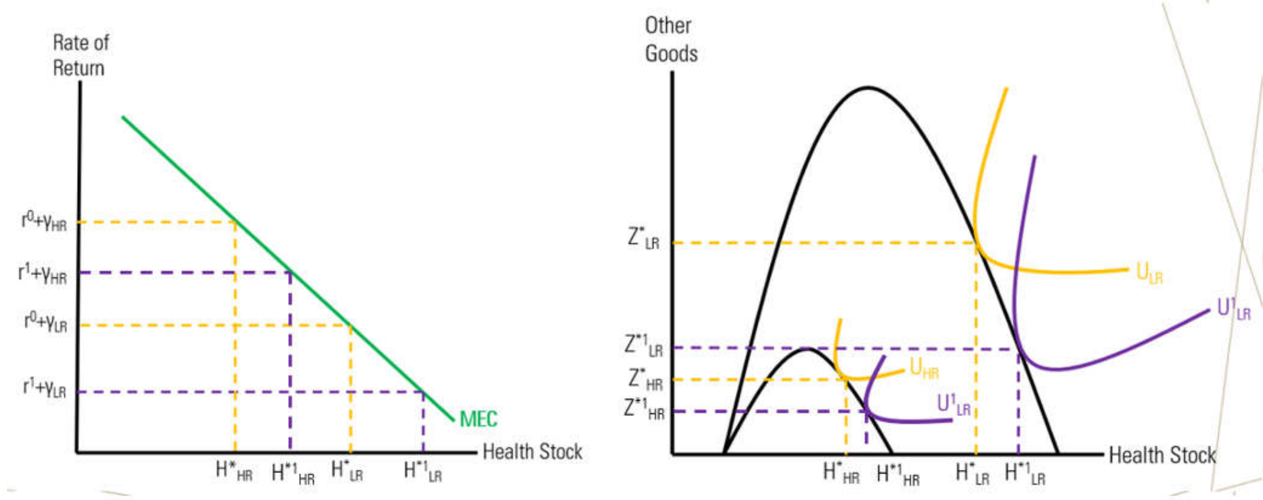


Figure 5 is an adjustment from the comparative statics which were explored in the theoretical framework. It now takes into account the homogenous effects a pandemic has on health investments i.e. the lockdown effect. It is known from the insignificant differences-in-differences coefficients that the effect of the pandemic was no different between high risk and low risk individuals. That means; differently from the prediction; that both high risk and low risk groups of people take advantage of this lower opportunity cost of alternative investment, r^1. This means that both groups change their utility function away from utility derived by non-health activities; which have become limited due to the UK lockdown; to gaining more utility from investing in one's health. Figure 5 is backed up empirically by the increasing in health investments by 17 minutes as a result of the net lockdown effect.

The empirical results have implications for public health policy as it helps policy makers understand the dynamics in play when the Grossman model is faced with a global pandemic as a shock. From my results it can encourage the government to invest in schemes to encourage individuals who work from home to exercise more; as they are the ones who seem to be investing less in their health and hence they may be at risk of their health stock reducing. If working from home is to become more normal in a 'post-pandemic' world; than issues of lack of exercise by people working from home could cost the NHS a considerable sum in tackling obesity related illnesses like diabetes and high blood pressure. These results also have implications for improving upon Grossman's model. Since there was no significant different between the group's health investments; this may mean that the push of a lower opportunity cost is greater than the pull of the risk to health from contracting a dangerous disease (i.e. COVID-19) even within high risk groups. This has implications for how health economists understand human behaviour.

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