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Measuring the Economic Flows of UK Human Capital

Sami Mubarak, Cliodhna Taylor, Gueorguie Vassilev, Richard Heys, Robbie Fisher, Ed Bailey, Sophie Peabody and Paul Dunstan

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DISCUSSION PAPER

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Contents

1. Introduction

It is well recognised that human capital estimates and statistics are an essential component of the broader suite of economic indicators beyond Gross Domestic Product (GDP). These estimates can help policymakers understand the drivers of economic progress and determine the sustainability of a country's long-term development trajectory. According to data from the Office for National Statistics (ONS) the UK's nominal human capital stock grew from £14.47 trillion in 2004 to £23.77 trillion in 2020, an increase of 64.3 percent. The human capital stock value is incredibly large so, given it's such an important component of sustainable economic progress, how can one incorporate the changes in the human capital stock into the broader national accounting framework (which underpins the measurement of GDP)? The causes of the change in the UK's nominal human capital stock, how to estimate these changes and how these changes could be incorporated into the national accounting framework are the focus of this research paper.

In his Nobel Memorial Lecture, Richard Stone (1984) discussed how accounting can be used to describe and understand society. More specifically, by organising data into a system of accounts, we can gain a clear picture of the stocks and flows of whatever phenomena (economic, socio-demographic or environmental) one is interested in and, therefore, analyse and understand the system they constitute. There are established methods and approaches to measuring the human capital stock (such as the Income-Based Approach and the Cost-Based Approach) which are detailed in United Nations Economic Commission for Europe's (UNECE) Guide on Measuring Human Capital (UNECE, 2016). However, there is less agreement and international guidance regarding the estimation of the economic flows of human capital. Economic flows, in this context, refers to the transactions that contribute to (or explain) the change in the stock of human capital from one accounting period to the next. This is analogous to the concept used in the System of National Accounts 2008 (SNA 2008) for physical capital e.g., the transactions contributing to the change in the aggregate stock of physical capital are known as economic flows.

This paper presents a method for estimating the economic flows (or transactions) associated with the UK's nominal human capital stock and uses data from ONS to estimate these flows. The paper is organised into eight sections with this introduction as the first section. Section 2 provides some background to how ONS measures the human capital stock using the Income-Based Approach. Section 3 describes the method used to decompose the change in the human capital stock from one year to the next to derive estimates for the economic flows of human capital for the years 2005 to 2020. These estimates are largely conceptually compatible with the National Accounts definitions.

Section 4 of this paper investigates how well the economic flows identified in this research are broadly analogous to those contained in the national accounting framework, namely: gross capital formation, capital consumption (depreciation), revaluations and other changes in volume. Similar discussions on this point have been documented in other work. For example, Jorgenson and Fraumeni (1989) devise a new system of national accounts for the United States to include fully comparable measures of investment in human capital and non-human capital to provide a more comprehensive perspective of the role of capital formation in U.S. economic growth[1]. UNECE (2016) describes the Satellite Account for Education and Training which provides the foundations for a human capital satellite account as a means for

[1] For a more recent version of the Jorgenson-Fraumeni accounting system and integrating it into the U.S. national accounts see Fraumeni, Christian and Samuels (2021, pp. 167–197).

integrating human capital into the national accounting framework. UNECE (2016) also provides an example of a human capital satellite account for Canada and how human capital could be integrated into the SNA 2008 structure.
Section 5 presents our estimates of the economic flows as contributions to the growth in the human capital stock from 2005 to 2020. Section 6 provides a discussion of the key strengths and limitations of this research and Section 7 details possible future developments to human capital flows estimation that this work may inspire.

2. Background to Human Capital Stocks Methodology

Human capital may be defined as “the knowledge, skills, competencies and attributes embodied within people that facilitate the creation of personal, social and economic well-being” (OECD, 2001, p.18). The stock of human capital for a country is the aggregated value of every individual’s human capital. There are three internationally recognised approaches to measuring the human capital stock: the Income-Based Approach, the Cost-Based Approach and the Indicator-Based Approach.

The Income-Based Approach involves calculating the Lifetime Labour Income (LLI) of individuals as implemented by Jorgenson and Fraumeni (1989). The LLI is the net present value of all future income streams that all individuals in the working-age population expect to earn throughout their lifetime. Office for National Statistics (ONS) publishes data[2] on the stock of UK human capital using the Income-Based Approach by calculating the projected Lifetime Earnings (LE) of people in the working-age population. This is slightly different to LLI in that ONS’s approach does not capture the income of the self-employed or the non-wages and salaries labour income for employees. Annual estimates of the UK’s human capital stock are derived using this method and data are currently available for the years 2004 to 2022.

2.1 Calculating Lifetime Earnings

This paper uses ONS’s human capital unpublished aggregated data, which is used to calculate estimates of the stock, to calculate the economic flows for human capital. These data contain information for the ‘average’ individual[3] in each age, sex and highest qualification level group for people aged between 16 and 65. The data are based on microdata from the Annual Population Survey[4] (APS), the Labour Force Survey[5] (LFS) and ONS Life Tables[6].
For each group, the unpublished aggregated dataset contains information including the average nominal projected Lifetime Earnings for individuals in that group, the number of individuals in the group, the probability that people in that group are economically active, the

[2] The latest estimates can be found in Office for National Statistics (2024).
[3] We use the term ‘average individual’ in this paper because the Lifetime Earnings values in ONS’s human capital unpublished aggregated data are exactly the same for each individual in a given sex, age and highest qualification level group by construction.
[4] The Annual Population Survey (APS) is a continuous household survey for the UK providing estimates between censuses of the main social and socio-economic variables at a local area level.
[5] The Labour Force Survey (LFS) is a quarterly household survey and the main source of labour market data in the UK. The LFS provides information on unemployment, economic inactivity, education and training, income from work and all aspects of people’s work.
[6] National Life Tables are produced annually by ONS and are based on population estimates, births and deaths. Among other uses, they provide a way of analysing age-specific death rates.

annual employee earnings for individuals in that group and mortality rates.

The calculation of nominal average projected LE for all individuals in a given sex (s), age (a) and highest qualification level (e) group can be summarised by equation 2.1 which can be found, along with further information, in Office for National Statistics (2013, p.12). It should be noted that this ONS methodology paper from 2013 states that the top category of qualification level used in the human capital methodology is 'Degree or equivalent'. ONS has since created a new top category for the human capital methodology which includes only Master's degrees and PhD degrees. For completeness, the highest qualification level categories used currently by ONS for human capital stock estimation, and this research, are:

1. 'Masters or PhD' includes only the higher degrees of Masters and PhDs
2. 'Degree or equivalent' includes degrees obtained at the end of undergraduate studies
3. 'Higher education' includes Diploma in Higher Education, Teaching Diplomas and National Vocation Qualification Level 4
4. 'A Levels or equivalent' includes A Levels[7], AS Levels and International Baccalaureates
5. 'GCSE grades A* to C (or 9 to 4) or equivalent' includes GCSE[8] grades A* to C (or 9 to 4) and BTEC first diploma
6. 'Other qualifications' includes GCSE grades below grade C (or below grade 4) and BTEC first certificate
7. 'No qualifications' includes individuals without formal qualifications

See ONS's 2019 human capital publication for further details on this point. For further information regarding the course of ONS's development of human capital estimates see the human capital workplan from 2018.

$$LE^{s,a,e} = EA^{s,a,e} \cdot ALI^{s,a,e} + \left\{ \left[\sum_{e}^{6} \left(LE^{s,a+1,e} \cdot PROB^{s,a,e} \right) \right] \cdot \left[\left(1 - MORT^{s,a} \right) \left(\frac{1+r}{1+\delta} \right) \right] \right\} \quad (2.1)$$

Where;

$LE^{s,a,e}$ = The average projected lifetime earnings for all individuals in a given sex, age and highest qualification level group

$EA^{s,a,e}$ = The proportion of people economically active for a given sex, age and highest qualification level group

[7] In the UK (mainly England, Wales and Northern Ireland), A Levels are subject-based qualifications which are most commonly listed as entry requirements by UK universities.

[8] In the UK (mainly England, Wales and Northern Ireland), the General Certificate of Secondary Education (GCSE) are qualifications that are generally required to progress to higher qualifications such as A Levels. Prior to 2020, GCSEs were graded according to letters with A* being the highest grade. Since 2020, a new grading system using numbers was introduced with 9 being the highest grade.

$ALI^{s,a,e}$ = The annual employee earnings for individuals in a given sex, age and highest qualification level group

$PROB^{s,a,e}$ = The probability that the individual in a given sex, age and highest qualification level will increase their highest qualification level in a single year's time[9]

$MORT^{s,a}$ = Mortality rate for an individual in a given sex and age group

r = Nominal wage growth rate[10]

δ = Discount rate[11]

The summation term on the right-hand side of equation 2.1 accounts for the probability that people may improve their highest qualification level. An example of what this summation term is doing will make this clearer. For a person aged 24, there are probabilities built into this model that account for the possibility that they could increase their highest qualification level in the next year. These probabilities are multiplied by the corresponding discounted lifetime earnings values for a person aged 25 and the results are then summed together to give the total amount of discounted earnings they could accrue in their remaining lifetime.

It's also worth noting that a key assumption of the LE model is that, at a point in time, an individual with a given sex, age, and highest qualification level – representing a certain stratum of the working-age population – will progress through their lifetime and receive the same earnings as people older than them with the same sex and highest qualification level.

2.2 Total Human Capital Stock

Equation 2.1 calculates LE for the 'average' individual in a given sex (s), age (a) and highest qualification level (e) group. To calculate the stock of human capital, LE is calculated for the 'average' individual in each age, sex and highest qualification level group. These LE (human capital) values per group are then multiplied by the corresponding population figures for each group to obtain a total human capital value for each group. These total human capital figures by group are then summed to calculate the UK's total human capital stock. This is shown mathematically in equation 2.2.

$$HC_t = \sum_s \sum_a \sum_e LE_t^{s,a,e} \cdot N_t^{s,a,e} \tag{2.2}$$

Where:

HC_t = Total UK human capital stock in year t

[9] An assumption is made that an individual cannot go down in educational attainment in the next year so all probabilities of a lower educational attainment are set to zero.

[10] The nominal wage growth rate is assumed to be 2 percent each year.

[11] The discount rate is assumed to be 3.5 percent each year.

$LE_t^{s,a,e}$ = Average projected lifetime earnings in year t for all individuals in a given sex, age and highest qualification level group

$N_t^{s,a,e}$ = Population in year t for a given sex, age and highest education level group

3. Calculation of Flows

3.1 Method

This research uses ONS's human capital unpublished aggregated data, which includes the average projected Lifetime Earnings (LE) for individuals stratified by different categories of the population (age, sex, and highest qualification level), to decompose the change in the UK's human capital stock into various components. This work is similar to the research of Gu and Wong (2010) who demonstrate that the change in human capital stock between two periods can be decomposed into three components (investment, depreciation and revaluations) and provide estimates of these for Canada for the period 1971 to 2007.

The human capital stock can change for many reasons. For example, the stock could increase or decrease due to changes in the size of the working-age population, shifts in the composition of the population (according to people's ages, sex and levels of highest qualification attainment) and through fluctuations in people's earnings.
To decompose the changes in human capital stock, this research adopted a method of sequentially and cumulatively altering the variables in the unpublished aggregated human capital data, for a given year, so that the dataset's variables and characteristics represent the variables and characteristics of the following year's data. The basic principle underpinning this approach is that, after all the changes to year t's dataset are implemented, the resulting dataset would be a dataset identical to that of year $t + 1$.

A mathematical representation will make this more clear. Human capital stock is composed of two parts. The first part is the average projected LE for all individuals in a given sex, age, and education level group which is a function with all the variables in equation 2.1 as inputs into this function. This is shown in equation 3.1. As our research involves sequentially altering the inputs to this function, we include a '0' in the subscript notation of the LE dependent variable to indicate that this is the initial LE formula. When a change is made to an input, this notation increases by one. For example, when introducing the first change to the LE equation, we will have $LE_{t,1}^{s,a,e}$ and so on.

$$LE_{t,0}^{s,a,e} = f\left(EA_t^{s,a,e}, ALI_t^{s,a,e}, LE_t^{s,a+1,e}, PROB_t^{s,a,e}, MORT_t^{s,a}, r, \delta\right) \quad (3.1)$$

Where:

$LE_{t,0}^{s,a,e}$ = Average projected lifetime earnings in year t for all individuals in a given sex, age and highest qualification level group

$EA_t^{s,a,e}$ = Economic activity rate in year t for a given sex, age and highest qualification level group

$ALI_t^{s,a,e}$ = Annual employee earnings in year t for a given sex, age and highest qualification level group

$LE_t^{s,a+1,e}$ = Average projected lifetime earnings in year t of an individual one year older in the sex and highest education level category

$PROB_t^{s,a,e}$ = Probability in year t that an individual in a given sex, age and highest education level group will change to a different education level in a year's time

$MORT_t^{s,a}$ = Mortality rate in year t for a given sex and age group

r = Nominal wage growth rate

δ = Discount rate

The second part that forms human capital stock is the size and composition of the population for that sex, age, highest qualification level group which is a function of several inputs that can also be altered. In calculating total human capital stock, the population values act as a weight for the LE values. The total population can be calculated by summing across all sex, age and highest qualification level group populations. This is shown mathematically in equation 3.2. Like equation 3.1, we include a '0' in the subscript notation of the population variables (on the left-hand and right-hand-sides of the equation) to indicate that this is the initial population. Again, when a change is made to the population, this notation increases by one.

$$N_{t,0}^{Tot} = \sum_{s=1}^{2} \sum_{a=16}^{65} \sum_{e=1}^{7} N_{t,0}^{s,a,e}$$

3. 2

Where:

$N_{t,0}^{Tot}$ = Total UK working-age population in year t

$N_{t,0}^{s,a,e}$ = Population in year t for individuals in a given sex, age and highest education level group

Summing the product of these two functions for each sex, age and highest qualification level group gives the total human capital stock for the UK in year t as shown in equation 3.3.

$$HC_t = \sum_{s=1}^{2} \sum_{a=16}^{65} \sum_{e=1}^{7} LE_{t,0}^{s,a,e} \cdot N_{t,0}^{s,a,e}$$

3. 3

After a change to the human capital unpublished aggregated data is implemented, the economic flow is calculated as the difference between the new imputed total human capital stock value and the previous total human capital stock value before the change was implemented. This is summarised by equation 3.4:

$$EF_x = HC_2 - HC_1$$

3. 4

Where:

$EF_x =$ Economic flow for change x

$HC_1 =$ Human capital stock value before implementation of change x

$HC_2 =$ New imputed human capital stock value after implementation of change x

If the human capital stock increases after a change has been implemented, then the economic flow will have a positive value and will have a negative value if the stock decreases.

3.2 Changes to the Human Capital Stock

We identified multiple factors that could explain the change in human capital stock and grouped them into broader categories. The broader categories investigated as part of this research are: Population Composition Changes, Total Population Changes, Total Earnings Change and Earnings Distributions Changes. It is important to note, however, that there are other change categories that were identified but were deemed out of scope for this research. When applying these changes, the order of application needed to be considered. Our research decided on applying the changes in the following order:

1. Population Composition Changes
2. Total Population Changes
3. Total Earnings Change
4. Earnings Distributions Changes

The specific changes within these groups were applied sequentially in the order shown in Table 1 (starting with the Sex Composition Change and moving to the Age Composition Change and so on). The specific changes are discussed in sequence in the following sub-sections.

Table 1 also maps each change to its relevant economic flow category in national accounts as defined in System of National Accounts 2008 (SNA 2008). These national accounts economic flow categories are: Gross Capital Formation, Capital Consumption (Depreciation), Revaluations and Other Changes in Volume. Some of the changes we have identified as part of our research cannot be so easily allocated to one of these four high-level categories – a further discussion of the conceptual complexities around this is explored in Section 4.

Table 1: Summary of the changes made to the human capital stock

Change Group	Specific Change	Description	SNA 2008 Economic Flow Category
Population Composition Changes	Sex Composition Change	This captures the change in human capital stock resulting from shifts in the working-age population distribution between the two sexes.	Other Changes in Volume
	Age Composition Change	This captures the change in human capital stock due to shifts in the distribution of the working-age population between age groups.	Other Changes in Volume

	Highest Qualification Level Composition Change	This captures the effect on the human capital stock caused by shifts in the distribution of the working-age population between the highest qualification levels.	Gross Capital Formation
Total Population Changes	Retirement Effect	Removal of those aged 65 years old from the data.	Capital Consumption
	Death in the Population	Removal of those who have died between year t and year $t+1$ from the population data.	Capital Consumption
	Ageing Effect	The effect on human capital stock of individuals becoming a year older.	Capital Consumption
	New Sixteen-Year-Olds	The effect on human capital stock due to the inflow of new sixteen-year-olds joining the working-age population.	Gross Capital Formation
	Net Change in Economic Activity	The effect on human capital stock from the change in the proportion of people who are economically active among the working-age population.	Other Changes in Volume*
	Residual Population Change	This includes all the changes to the population that are not captured by the Population Composition Changes and Total Population Changes (such as net migration and any statistical discrepancies).	Other Changes in Volume
Total Earnings Change	Average Total Earnings Growth	Accounts for the effect on the stock from average total earnings growth for the whole population between year t and year $t+1$.	Revaluation
Earnings Distributions Changes	Average Earnings Growth Rate per Sex	Accounts for the effect on the stock from the distributional earnings growth by sex between year t and year $t+1$.	Revaluation
	Average Earnings Growth Rate per Age	Accounts for the effect on the stock from the distributional earnings growth by age between year t and year $t+1$.	Revaluation
	Average Earnings Growth Rate per Highest Qualification Level	Accounts for the effect on the stock from the distributional earnings growth by highest qualification level between year t and year $t+1$.	Revaluation*

* See Section 4 for further discussion

3.3 Population Composition Changes

The first group of flows encompass the **significant revisions to the nature of the existing working-age population**, which we refer to as Population Composition Changes. The composition of the working-age population can change over time which will affect the stock of human capital. For example, the sex composition of the working-age population – that is, the proportion of men relative to women – can change from one year to the next. Similarly, changes can occur to the age composition and the composition of the population according to levels of highest qualification. The logic underpinning the decision to include these changes follows from the idea that populations experiencing changes in their compositions towards those that have increasingly large lifetime earnings will experience increases in human capital stock.

As an illustrative example, the sex composition of the working-age population (e.g. the proportion of men to women in the working-age population) can change from year t to year $t+1$. To capture this effect on the human capital stock, the sex composition of the total working-age population for year $t+1$ is determined and is then applied equally across the population in year t by each age and highest qualification group (these other two demographic compositions are held constant). In other words, the proportion of men (or women) from year $t+1$ is applied equally to the population figure of each age by highest qualification level group in year t.
The sex composition change is achieved by calculating equation 3.5 for each sex by age by highest qualification level group. Equation 3.5 is the general form to calculate the new population figure for a given sex by age by highest qualification level group with year $t+1$'s sex composition.

$$N_{t,1}^{s,a,e} = \sum_{s=1}^{2} N_{t,0}^{s,a,e} * \left(\frac{\sum_{a=16}^{65} \sum_{e=1}^{7} N_{t+1}^{s,a,e}}{N_{t+1}^{Tot}} \right) \tag{3.5}$$

Where:

$N_{t,1}^{s,a,e}$ = New imputed population value for a given sex, age and highest qualification level group with year $t+1$'s sex composition applied

$N_{t,0}^{s,a,e}$ = Population value for a given sex, age and highest qualification level group with year t's sex composition

$N_{t+1}^{s,a,e}$ = Population value for a given sex, age and highest qualification level group from year $t+1$

N_{t+1}^{Tot} = Total population value for year $t+1$

The first term on the right-hand side of equation 3.5 gives the total population in a given age by highest qualification level group in year t. The second term gives the proportion of men (or women) in year $t+1$. The total working-age population is then calculated in the way outlined in equation 3.2 but now the population values that are aggregated are those calculated using equation 3.5. Mathematically, equation 3.2 becomes:

$$N_{t,1}^{Tot}(= N_{t,0}^{Tot}) = \sum_{s=1}^{2}\sum_{a=16}^{65}\sum_{e=1}^{7} N_{t,1}^{s,a,e}$$

3.6

Where:
$N_{t,1}^{Tot}$ = Total population value for year t with year $t+1$'s sex composition applied

$N_{t,1}^{s,a,e}$ = New imputed population value for a given sex, age and highest qualification level group with year $t+1$'s sex composition applied

Note that the new total population value in equation 3.6, which incorporates year $t+1$'s sex composition, is equal to the previous total population value ($N_{t,0}^{Tot}$) with year t's sex composition. The new population data given by equation 3.5 is then aggregated with the LE data according to equation 3.3 to give the new imputed total human capital stock value for year t as shown in equation 3.7.

$$HC_t = \sum_{s=1}^{2}\sum_{a=16}^{65}\sum_{e=1}^{7} LE_{t,0}^{s,a,e} \cdot N_{t,1}^{s,a,e}$$

3.7

The change in the value of the human capital stock – that is, the economic flow – from the change in the sex composition is calculated as the newly-imputed human capital stock value in year t minus the original human capital stock value in year t. This effectively captures what the change in the value of the human capital stock would be between year t and $t+1$ purely from changing the sex composition of the working-age population.

A similar process was then applied to this new working-age population (as described by equation 3.6) to transform the age composition and highest qualification level composition so that they reflect those of year $t+1$. The application of the population composition changes is done in a cumulative way so that the newly-imputed population values from the sex composition change are used in the age composition change and so on.
For the age composition change, the proportion of men (or women) by age in year $t+1$ is applied equally to each highest qualification level group's population value – using the previously derived population data, $N_{t,1}^{s,a,e}$, containing year $t+1$'s sex composition – for year t to derive population values with year $t+1$'s sex and age composition. This is shown in Equation 3.8. The highest qualification level composition is held constant for this change.

$$N_{t,2}^{s,a,e} = \sum_{s=1}^{2}\sum_{a=16}^{65} N_{t,1}^{s,a,e} * \left(\frac{\sum_{e=1}^{7} N_{t+1}^{s,a,e}}{N_{t+1}^{Tot}}\right)$$

3.8

Where:

$N_{t,2}^{s,a,e}$ = New imputed population value for a given sex, age and highest qualification level group in year t with year $t+1$'s sex and age compositions applied

$N_{t,1}^{s,a,e}$ = Imputed population value for a given sex, age and highest qualification level group in year t with year $t+1$'s sex composition applied

$N_{t+1}^{s,a,e}$ = Population value for a given sex, age and highest qualification level group from year $t+1$

N_{t+1}^{Tot} = Total population value for year $t+1$

For a given sex by age by highest qualification level group, the first term on the right-hand side of equation 3.8 is the population for that highest qualification level group from year t. The second term is the proportion of a given sex and age group in year $t+1$. This process is repeated for each group to derive a new working-age population for year t with year $t+1$'s sex and age composition applied. The total working-age population is then given by equation 3.9. The process described previously to calculate the economic flow is then repeated to estimate the effect on the human capital stock from the change in the age composition from year t to year $t+1$.

$$N_{t,2}^{Tot}(= N_{t,0}^{Tot}) = \sum_{s=1}^{2}\sum_{a=16}^{65}\sum_{e=1}^{7} N_{t,2}^{s,a,e}$$

3. 9

Where:

$N_{t,2}^{Tot}$ = Total population value for year t with the sex and age compositions of year $t+1$ applied

For the highest qualification level composition change, for a given sex by age by highest qualification level group, the imputed population value is derived by applying the proportion of men (or women) per age and highest qualification group in year $t+1$ to the total working-age population figure of year t. This is shown in equation 3.10.

$$N_{t,3}^{s,a,e} = \sum_{s=1}^{2}\sum_{a=16}^{65}\sum_{e=1}^{7} N_{t,2}^{s,a,e} * \left(\frac{N_{t+1}^{s,a,e}}{N_{t+1}^{Tot}}\right)$$

3. 10

Where:

$N_{t,3}^{s,a,e}$ = New imputed population value for a given sex, age and highest qualification level group in year t with year $t+1$'s sex, age and highest qualification level compositions applied

$N_{t,2}^{s,a,e}$ = Imputed population value for a given sex, age and highest qualification level group with year $t+1$'s sex and age compositions applied

$N_{t+1}^{s,a,e}$ = Population value for a given sex, age and highest qualification level group from year $t+1$

N_{t+1}^{Tot} = Total population value for year $t+1$

As done previously, the process is repeated for all groups to obtain year t's working-age population with year $t+1$'s sex, age and highest qualification level compositions applied. The resulting working-age population figures, represented by $N_{t,3}^{s,a,e}$, contain year $t+1$'s sex, age and highest qualification level compositions but the total population value for year t remains constant as shown in equation 3.11.

$$N_{t,3}^{Tot}(= N_{t,0}^{Tot}) = \sum_{s=1}^{2}\sum_{a=16}^{65}\sum_{e=1}^{7} N_{t,3}^{s,a,e}$$

3. 11

Where:

$N_{t,3}^{Tot}$ = Total population value for year t with the sex, age and highest qualification level compositions of year $t+1$ applied

Again, the process described previously is repeated to estimate the effect on the human capital stock from the change in the highest qualification level composition from year t to year $t+1$. It should be stated for clarity that during the Population Composition Changes, all other variables were held constant. That is, individuals retiring and dying were not removed, the ageing effect was not applied and the sixteen-year-olds from year t were not brought in from year $t+1$'s dataset.

3.4 Total Population Changes

The second group of flows encompass the **significant inflows and outflows that affect the aggregate size of the total working-age population** such as: people "retiring", death, ageing, newly turned sixteen-year-olds joining the working-age population and the change in the proportion of individuals who are economically active. The estimation of these effects will now be described.

For the purposes of the human capital stock methodology, the working-age population is considered to be those aged 16 to 65 – so that, for simplicity, we can refer to people "retiring" once they turn 66 for the purposes of human capital measurement. This effect was estimated by removing all individuals aged 65 from the dataset. This is shown mathematically by equation 3.12 with those who "retire" in year t removed from the working-age population.

$$N_{t,4}^{Tot} = \sum_{s=1}^{2}\sum_{a=16}^{64}\sum_{e=1}^{7} N_{t,4}^{s,a,e} \left(= N_{t,3}^{Tot} - \sum_{s=1}^{2}\sum_{e=1}^{7} N_{t,3}^{s,a=65,e}\right)$$

3. 12

where

$$N_{t,4}^{s,a,e} = N_{t,3}^{s,a,e}$$

Similarly, the death of individuals would also cause the loss of their lifetime earnings from the working-age population and decrease the stock of human capital. This effect was estimated by applying the mortality rates to the population to determine the number of individuals who died between year t and year $t + 1$ and then calculating the new human capital stock. Equations 3.13 and 3.14 illustrate this change.

$$N_{t,5}^{Tot} = \sum_{s=1}^{2} \sum_{a=16}^{64} \sum_{e=1}^{7} N_{t,5}^{s,a,e}$$

3. 13

where

$$N_{t,5}^{s,a,e} = N_{t,4}^{s,a,e} * (1 - MORT_{t+1}^{s,a})$$

3. 14

As mentioned in Section 2, a key assumption of the Lifetime Earnings method is that, at a point in time, an individual with a given sex, age, and highest qualification level – representing a certain stratum of the working-age population – will progress through their lifetime and receive the same lifetime earnings as people older than them with the same sex, and highest qualification level. So if, say, the average 25-year-old with a certain set of characteristics earns £30,000 a year in 2023, while the average 26-year-old with the same characteristics earns £35,000 a year, then the starting assumption is that the stratum of 25-year-olds will go on to earn £35,000 in 2024 once they have turned 26. The one caveat to this is that there is an assumption of 2 percent nominal wage growth, so in 2024 the stratum of 26-year-olds would be assumed to earn £35,000 * 1.02 = £35,700 a year.

With this model in mind, the effect of ageing may be estimated by replacing the LE of a given stratum, in year t, with the LE for the same stratum that are one year older in year t . So, the individual aged 45 of a given sex and highest qualification level now would have their LE in period t replaced by the LE of an individual aged 46 with the same sex and highest qualification level. That is, when going from year t to year $t + 1$, we assume that an individual aged 45 in year t will have the LE of an individual aged 46 in year t. We assume there is no other change in LE other than this pure ageing effect. The total human capital stock was then re-calculated and the economic flow determined in the usual way described previously. The mathematics of how we derived the ageing effect is shown in equations 3.15 and 3.16 (note the change in the starting value of the age summation term as we have one less age group – the sixteen-year-olds – in the total human capital stock summation calculation as a result of the ageing effect).

$$N_{t,6}^{Tot} = \sum_{s=1}^{2} \sum_{a=17}^{65} \sum_{e=1}^{7} N_{t,6}^{s,a,e}$$

3. 15

where

$$N_{t,6}^{s,a,e} = N_{t,5}^{s,a+1,e}$$

3. 16

The working-age population also has an influx of new sixteen-year-olds each year. This change was implemented by bringing the population figures of sixteen-year-olds from year $t+1$ into year t's dataset and re-calculating the stock and then the flow. Following on from Equation 3.15, equation 3.17 shows this change mathematically:

$$N_{t,7}^{Tot} = \sum_{s=1}^{2}\sum_{a=16}^{65}\sum_{e=1}^{7} N_{t,7}^{s,a,e} \left(= N_{t,6}^{Tot} + \sum_{s=1}^{2}\sum_{e=1}^{7} N_{t+1}^{s,a=16,e}\right)$$

3. 17

Where:

$N_{t,7}^{s,a,e} = N_{t,6}^{s,a,e}$ for ages, a, between 17 and 65

$N_{t,7}^{s,a=16,e} = N_{t+1}^{s,a=16,e}$ for ages, a, equal to 16

The proportion of people who are economically active in the working-age population is a key factor in the calculation of LE, as it defines who is and who is not included in the human capital stock. Therefore, fluctuations in the number of individuals classified as economically active will affect the growth in human capital stock. To capture this phenomenon, the variable for the proportion of economically active people from year $t+1$ was applied to the data for year t. LE was then re-calculated (see equation 3.1) using this new variable. Total human capital stock was also re-calculated and the economic flow (change in the stock) determined in the usual way.
In terms of a mathematical expression, equation 3.1 can be rewritten to show that LE in year t is now calculated using the proportion of economically active people from year $t+1$ while keeping all other variables constant. This is the first effect that affects the calculation of LE. Equations 3.17 and 3.18 are then used to re-calculate the stock of human capital and the economic flow from this change.

$$LE_{t,1}^{s,a,e} = f\left(EA_{t+1}^{s,a,e}, ALI_{t}^{s,a,e}, LE_{t}^{s,a+1,e}, PROB_{t}^{s,a,e}, MORT_{t}^{s,a}, r, \delta\right)$$

3. 18

3.5 Residual Population Change

The Population Composition Changes and the Total Population Changes both transform the working-age population of year t to reflect the working-age population of year $t+1$. These have effectively assumed that the human capital stock is a cohort whose characteristics may change over time, but the people in that cohort only change due to new 16-years-olds, people retiring, or people dying. However, there are **other factors that affect the overall size and composition of the working-age population that we have not been able to either estimate or identify due to data and modelling limitations (such as immigration, emigration and any statistical discrepancies**). Therefore, a separate flow was created to capture the 'residual', or 'remaining', effects causing the working-age population to change from year t to year $t+1$.

The Residual Population Change is treated as a composite value capturing all these other effects that impact the population. This composite value was determined by replacing the population variable from year t with the corresponding population variable from year $t+1$

and then recalculating the stock by multiplying this population variable by the new LE figures created in the previous Net Change in Economic Activity step.

Some accompanying algebra will help clarify the approach taken to calculate the Residual Population Change. From the previous step, the Net Change in Economic Activity, the human capital stock, $HC_{t,1}$, is given in equation 3.19 using the population variable from equation 3.17 and equation 3.18 as the LE variable.

$$HC_{t,1} = \sum_{s=1}^{2} \sum_{a=16}^{65} \sum_{e=1}^{7} LE_{t,1}^{s,a,e} \cdot N_{t,7}^{s,a,e}$$

3.19

The next step is to then re-calculate the human capital stock, shown in equation 3.20, with year $t+1$'s working-age population which is the population that the Population Composition Changes and Total Population Changes have been endeavouring to reach. The LE variable used in calculating this human capital stock is also given by equation 3.18.

$$HC_{t,2} = \sum_{s=1}^{2} \sum_{a=16}^{65} \sum_{e=1}^{7} LE_{t,1}^{s,a,e} \cdot N_{t+1}^{s,a,e}$$

3.20

The difference between these two human capital stock values gives an estimate of the remaining population effects that are not captured explicitly by this research. The Residual Population Change is expressed mathematically in equation 3.21.

$$Residual\ Population\ Change_t = HC_{t,2} - HC_{t,1}$$

3.21

It should be made clear that this research is not able to separately identify the effect of net migration (the difference between the number of immigrants to the UK and the number of emigrants from the UK) on the human capital stock, due to data being unavailable within ONS's unpublished aggregated human capital data. The effect, therefore, of net migration on the human capital stock is implicitly captured within the Residual Population Change, and *a priori* may be assumed to be the lion's share of this value.

3.6 Average Total Earnings Change

The previous changes have all affected the size and composition of the working-age population. The stock of human capital may also change due to annual employee earnings growth. To capture this effect the average total earnings growth was estimated between year t and year $t+1$. For this change (and the three subsequent earnings changes described in the next section) the working-age population from year $t+1$ was used to calculate the human capital stock to capture the pure earnings effect without any population effects distorting the estimates.

A weighted average of total annual employee earnings was calculated for year t and year $t+1$. The growth rate between these weighted averages was determined and applied to the original annual employee earnings, $ALI_t^{s,a,e}$, to impute a new annual employee earnings variable, $\widehat{ALI_t^{s,a,e}}$.
A weight was calculated for each age, sex and highest qualification level group using the group's population as a proportion of the total working-age population (as shown in equation 3.22).

$$W_t^{s,a,e} = \frac{n_{t+1}^{s,a,e}}{N_{t+1}}$$

3. 22

Where:
$W_t^{s,a,e}$ = Population weight for an individual of a given sex, age and highest qualification level in year t

$n_{t+1}^{s,a,e}$ = Population size for an individual of a given sex, age with a given highest qualification level in year $t+1$

N_{t+1} = Total population in year $t+1$

The newly derived annual employee earnings variable was then used to recalculate Lifetime Earnings. This calculation of LE is shown in Equation 3.23:

$$LE_{t,2}^{s,a,e} = f\left(EA_{t+1}^{s,a,e}, \widehat{ALI_t^{s,a,e}}, LE_t^{s,a+1,e}, PROB_t^{s,a,e}, MORT_t^{s,a}, r, \delta\right)$$

3. 23

A newly-imputed human capital stock value was calculated by multiplying the LE as calculated in equation 3.23 by the population variable from year $t+1$. This is expressed mathematically in equation 3.24. The flow was then calculated in the usual way.

$$HC_t = \sum_{s=1}^{2}\sum_{a=16}^{65}\sum_{e=1}^{7} LE_{t,2}^{s,a,e} \cdot N_{t+1}^{s,a,e}$$

3. 24

3.7 Earnings Distribution Changes

The rate of earnings growth may differ among subsets of the population (e.g. by sex, age and highest qualification level). For this reason, estimates of the differential in earnings growth for each subset of the population were calculated to determine their effect on the growth of the human capital stock. For the Earnings by Sex and Earnings by Age changes, a similar approach was taken to the Average Total Earnings Change in that a weighted average was calculated and the growth in this weighted average between the two years was determined. The difference between the methods, however, is in how the weights are calculated.

3.7.1 Earnings by Sex

For the Earnings by Sex change, two total population values were calculated: one for men and one for women. Weights for male sub-populations are calculated as a proportion of the total number of males (the same applies for females). As an example, equation 3.25 shows how the weight for a male of a given age and highest qualification level was calculated.

$$W_t^{Male,a,e} = \frac{n_{t+1}^{Male,a,e}}{N_{t+1}^{Male}} \tag{3.25}$$

Where:
$W_t^{Male,a,e}$ = Population weight for a male, of a given age and highest qualification level in year t

$n_{t+1}^{Male,a,e}$ = Population size for a male, of a given age and highest qualification level in year $t+1$

N_{t+1}^{Male} = Total population of males in year $t+1$

The growth in weighted average earnings was then calculated for each sex and applied to the original annual employee earnings variable to impute a new earnings variable that was then used to re-calculate LE and, in turn, the human capital stock and flow.

3.7.2 Earnings by Age

For the Earnings by Age change, a total population figure was calculated for each age by sex group by summing the population across highest qualification levels in that age and sex combination. An example of the weight calculation for a 65-year-old male with a given highest qualification level is shown mathematically in equation 3.26.

$$W_t^{Male,65,e} = \frac{n_{t+1}^{Male,65,e}}{N_{t+1}^{Male,65}} \tag{3.26}$$

Where:
$W_t^{Male,65,e}$ = Population weight for a male, aged 65 with a given highest qualification level in year t

$n_{t+1}^{Male,65,e}$ = Population size for a male, aged 65 with a given highest qualification level in year $t+1$

$N_{t+1}^{Male,65}$ = Total population of males aged 65 regardless of highest qualification level in year $t+1$

The growth in the weighted average earnings was derived for each sex and age group and then each growth rate was applied to the original annual employee earnings variable to impute a new earnings variable. LE was then re-calculated with this newly-imputed earnings variable in order to calculate the flow from this effect.

3.7.3 Earnings by Highest Qualification Level

The last earnings change is the earnings growth by highest qualification level. As the effects of the growth in earnings by sex and age have already been accounted for, this was calculated indirectly as a 'residual flow' by re-calculating LE with year $t + 1$'s annual employee earnings variable, $ALI_{t+1}^{s,a,e}$. The resulting LE variable can then be expressed by equation 3.27.

$$LE_{t,3}^{s,a,e} = f\left(EA_{t+1}^{s,a,e}, ALI_{t+1}^{s,a,e}, LE_{t}^{s,a+1,e}, PROB_{t}^{s,a,e}, MORT_{t}^{s,a}, r, \delta\right) \quad 3.27$$

A newly-imputed human capital stock value was then calculated using the LE in equation 3.27 and the flow for this effect was determined by taking the difference between the result from equation 3.28 and the human capital stock from the Earnings by Age Change.

$$HC_t = \sum_{s=1}^{2} \sum_{a=16}^{65} \sum_{e=1}^{7} LE_{t,3}^{s,a,e} \cdot N_{t+1}^{s,a,e} \quad 3.28$$

4. Accounting Categorisation

4.1 Approach

Ideally, calculation of human capital flows for the purpose of economic accounting should begin from the first principles of the particular conceptual components which would be required throughout the accounts to fully incorporate human capital across the accounts, such as in Dunn (2022). With those conceptual components defined, it would then be the role of the economic accountant to research data sources and methodologies to measure each component. In this research we invert this process, drawing on research such as Dunn (2022) to instead examine the extent to which the decomposition of human capital flows discussed can be mapped onto a high-level categorisation of these flows into human capital gross capital formation, capital consumption, revaluations, and other changes in volume. These four high level categories mirror those for decomposing capital stock changes in the SNA 2008.

Not all components of our decomposition can be neatly allocated to one of the four high level categories. Where this is the case, we discuss which category we believe to be most relevant and why, while discussing where the component has conceptual overlap with other categories. This process also highlights where there are difficulties marrying the guidance for human capital in UNECE (2016) with the economic accounting principles of SNA 2008.

4.2 Gross Capital Formation

We propose the categorisation of "New 16-Year-Olds" into gross capital formation, although this isn't without contention, and it is important to highlight the (reasonable) assumptions this categorisation necessitates. The appearance of a new 16-year-old within the human capital stock represents a new addition to the stock of human capital so, at first glance, it naturally appears to fit as gross capital formation. The first point of possible contention with this categorisation arises from the discrepancy in timing this would cause between the timing of the production of the human capital – e.g. the timing of the education received, some portion of which could have been received, say, at age 5 – and the timing of when the gross capital formation is actualised, which by definition is recorded when someone turns 16.

Discrepancies in timing between production and gross capital formation are not unusual in economic accounting. They are often captured as 'work in progress'. The agreed method to record gross capital formation as having taken place, in line with SNA 2008, is when economic ownership is transferred to the unit intending to use the product as an asset (SNA, 2008, para. 10.53). Products with a long production time covering several periods can have their initial production accounted as work in progress for the unit producing the product, and then recorded as gross capital formation when the product is transferred.

The question then becomes "when is ownership of a person's human capital transferred to the person themselves?". While the correct answer to this would require further discussion and research, the answer required to justify categorisation of "New 16-Year-Olds" as gross capital formation is "at the age of 16". This does not seem an unreasonable assumption. Prior to the age of 16, people in the UK are not able to fully utilise their "human capital" by working due to labour laws and are likely to have minimal independent discretion about the acquisition of education. In this case, we could imagine education and other human capital related products as being acquired by a household while a child is age 0 to 15, and the "human capital" created by the household being categorised as work in progress. At the age of 16, the person becomes their own independent institutional unit (an economically active individual) within the household institutional sector, and there is a transfer of the work in progress to this new institutional unit, at which point it is counted as gross capital formation.

We also propose the inclusion of the "Highest Qualification" component as gross capital formation, although this draws out a more fundamental potential discrepancy between the UNECE 2016 and SNA 2008 in measurement of capital stocks. According to SNA 2008, the value of gross capital formation should be fully reflected in an equal change in the value of a capital stock and should be recorded when economic ownership of the product is transferred to the unit intending to use the product as capital. This can be seen through looking at the decomposition of changes in a capital stock given in SNA (2008, para. 13.8):

> The value of the stock of a specific type of asset in the opening balance sheet;
>
> *plus* the total value of the same type of asset acquired, less the total value of the same type of asset disposed of, in transactions that take place within the accounting period: transactions in non-financial assets are recorded in the capital account (including consumption of fixed capital) and transactions in financial assets are recorded in the financial account;
>
> plus the value of other positive or negative changes in the volume of these assets held, for example, as a result of the discovery of a subsoil asset or the destruction of an asset (as a result of war or a natural disaster): these changes are recorded in the other changes in the volume of assets account;
>
> plus the value of the positive or negative nominal holding gains accruing during the period resulting from a change in the price of the asset: these changes are shown in the revaluation account;

equals the value of the stock of the asset in the closing balance sheet.

So, other things being equal, then Gross Capital Formation (GCF) in the form of increased qualifications should result in the stock of human capital increasing by an amount equal to that GCF between the relevant balance sheet opening and closing period.

This logically demands that gross capital formation must take place at the time of, or after, production. In the case of educational level, as measured by highest qualifications, their value can be measured as the expected additional future discounted earnings which they confer on the person who received them. According to the logic of SNA 2008, this "investment" in higher qualifications should be recorded either when the education is received, or at a later date – whenever the capital is acquired (see the discussion of the "New 16-year-olds" component for more on this distinction).

However, UNECE (2016) seems to contradict this logic, as it values human capital stocks based on *expected* future highest qualifications levels. To exemplify this point, let us imagine a person "a" who gains education and a new highest qualification in period t. For simplicity, let's assume that this is the only qualification available – so people either have this qualification or no qualification. Let's say that prior to their acquisition of the education and qualification that, based on previous experience, someone like "a" would have a 50 percent probability of acquiring this higher qualification. According to the logic of UNECE, in period $t-1$ their human capital stock would be equal to 50 percent * their expected lifetime earnings *without* the new qualification, plus 50 percent * their expected lifetime earnings *with* the new qualification. In period $t+1$, following a's acquisition of the education and qualification, their human capital would be equal to their expected lifetime earnings *with* the new qualification. The difference in human capital stocks between period $t-1$ and period $t+1$, where (by assumption) the only thing which has changed is the acquisition of this education and associated qualification, is equal to 0.5 * their expected lifetime earnings with the qualification minus 0.5 * their expected lifetime earnings without the qualification. Another way of putting this is that the difference in human capital is equal to 0.5 * the future earnings differential associated with the qualification.

This outcome is peculiar, as the value of the new human capital acquired through the education – the value of the GCF – should, according to paragraph 13.8 of the SNA quoted earlier, be equal to the difference in the stock values. In line with SNA, the value of an asset is equal to the flow of benefits it accrues to the owner (SNA, 2008, para. 10.8) – and so GCF should be equal to the differential in the flow of benefits which the GCF confers. In human capital terms, this should mean GCF in human capital is equal to the future earnings differential associated with it. But in this case, the difference in the stock values is only half that amount. This is a result of UNECE (2016) specifying that the stock value in $t-1$ should include the (probability weighted) value of education which had not yet been received.

More generally, UNECE (2016) implies that the value of *future* increases in education/qualifications is included in capital stocks *now*. This implies either that the value of future education is being included as human capital gross capital formation *before* the education has been produced, or that education/qualifications are not directly connected to human capital gross capital formation. Both of these implications seem at odds with SNA and generally with economic accounting principles.

The reconciliation of these issues is a worthy area of future research, potentially leading to two approaches to tackling this issue. The first would follow the current UNECE (2016) based approach and is likely more useful for users who want to take certain levels of educational achievement as a given for the purposes of examining *changes* in educational achievement (which may be of particular use in some educational policy contexts). The second would be the development of more national accounts consistent measures which only include the value of higher qualifications once those have been received.

Within this paper, due to constraints of the data we have available as well as our aim to maintain consistency with the currently produced human capital stocks data, there is no component for the total value of newly acquired highest qualifications. However, there is a component for the difference between *expected* increases in highest qualifications and *actual* increases in highest qualifications. Increased educational attainment would appear a clear case of human capital gross capital formation, and as a sub-component of increased educational attainment this should also be categorised into gross capital formation. It is worth highlighting that this is a net figure – as the difference between expected and actual increases in highest qualification, it can be positive (where actually achieved outcomes exceed expected outcomes) or negative (where actually achieved outcomes are lower than expected outcomes).

4.3 Capital Consumption

The "ageing effect" is a fairly clear-cut example, at least within the current human capital stocks guidance, of capital consumption – reflecting the decrease in the value of a capital stock due to ageing. It's worth highlighting though that, for the purposes of valuing human capital stocks, a person's earnings are forecast based on the differentials in earnings for people in their stratum (i.e. with the same sex and qualifications) as age increases. To the extent that earnings differentials for age (when other things are held equal) reflect differences in work experience, this means that a person's work experience as they age is forecast to grow (or decline) in line with the average growth in work experience for their stratum. As such, expected growth in work experience associated with ageing is implicitly assumed to not be gross capital formation, as it already factors into stock calculations. In line with this, the "ageing effect" is perhaps smaller than some might expect, as it already implicitly assumes that someone's work experience will grow as they age. So while, for example, the human capital of women aged 30 with a degree will fall when they're aged up to 31 (by an amount equal to their earnings at age 30), this will likely be offset to some extent by the assumption – based on the input data – that earnings will be higher at age 31. The "ageing effect" is a fairly clear-cut example of capital consumption, reflecting the decrease in the value of a capital stock due to ageing.

The "Retirement" effect could be considered an extension of the "ageing effect", reflecting specifically the ageing of human capital between the ages of 65 and 66 – and as such is also clearly a case of capital consumption. However, this does highlight an issue with the human capital stocks methodology when it comes to its integration with economic accounting; national accounts include production undertaken by all labour, regardless of the age at which it is undertaken, to be accounted for as an output of human capital.

The final effect we would classify to capital consumption is "Death in population", although not without reservations. In an economic accounting setting, in line with the spirit of SNA 2008, capital consumption should include standard, expected wear and tear – which need not be uniform across the capital stock. So, where there is an expected probability that a piece of machinery, say, will permanently break down in two years' time, if this does come to pass then the value of this would be categorised to capital consumption. However, unexpected and exceptional causes of capital destruction, such as destruction due to a natural disaster, would be categorised as other changes in volume.

Applying this logic to “Death in population”, only deaths occurring due to expected causes should be included – although, to be clear, this should also cover causes with low probabilities. However, deaths due to events comparable to natural disasters should be excluded. While in previous years this may have been a relatively small portion of deaths, arguably deaths due to the COVID-19 pandemic should be considered as being due to an unexpected and exceptional cause and therefore treated as other changes in volume rather than as capital consumption. However, as it is not possible in the current human capital methodology to distinguish between causes of death, for this study all deaths are treated as capital consumption.

4.4 Revaluations

The most substantial component which can be mapped as a revaluation is the “average total earnings growth” component – which, while holding population weights equal, increases earnings in each stratum by the rate of growth for average earnings for the working-age population. As this represents an increase in the capital stock which does not derive from any change in the composition of the stock, and so does not reflect a change in the volume of human capital, it can be seen to be a revaluation. In essence, this captures earnings “inflation”, as well as the impact on earnings of labour-augmenting technological changes which would increase (or decrease) labour productivity.

All changes in the “Earnings Distributions Changes” group – which includes the differential in earnings growth by sex, age, and highest qualification – can be reasonably categorised to revaluations. These components can be interpreted as the effects of unexpected relative price movements in the value of different kinds of human capital. As such they do not reflect the addition or consumption of human capital and, as a result, must be revaluations.

It is important to note, however, that the result that these components only reflect *unexpected* price movements in the valuation of different kinds of human capital is a consequence of assumptions in the human capital stocks model around how expected future earnings increases are calculated. By assumption, expected earnings growth across different characteristics is assumed to be equal. This means, for example, that there are no expectations for the proportional earnings differential between different qualifications to change over time. As a result, any actual change in the earnings between qualification levels will be caught in this “Earnings Distributions Changes” component, as the model assumes that this is unexpected.

The earnings by highest qualification level change is more difficult to classify, however. This relates to the fact that the Income-Based approach to measuring human capital stock assumes that there is a certain probability that individuals will increase their education level in the future and earn a premium associated with this increase in qualification level. These premia that are associated with increases in a person’s highest qualification level may change over time due to changes in supply and demand conditions. For example, during the global COVID-19 pandemic, it is possible that the demand for those holding PhDs in epidemiology increased, in turn leading to an increase in the earnings of specialist epidemiologists. The key point is that the quality of the PhDs of epidemiologists have not changed but they are now more in demand. The increase in earnings by highest qualification associated with this phenomenon would be classified as a revaluation in the national accounts.

However, it’s worth noting that some portion of this effect could be better aligned to gross capital formation. This is the case for qualifications not yet received, but which factor into the current human capital stocks based on the probability those qualifications will be gained and their expected contribution to future earnings. Between the period where the qualification is not gained, and the period in which the qualification is gained, the quality of that qualification could change – say, perhaps, due to an increase in the quality of further education. In this case, related changes in the premium associated with this qualification don't reflect a change in supply and demand conditions, but instead reflect a change in the real volume of human capital associated with the qualification – and, as a result, the amount of gross capital formation (GCF) associated with gaining that qualification. As such, this subset of the effect of changes in the highest qualification could be argued to be better aligned with GCF. Although this has not been done as part of this paper, it would be a fruitful area for future research.

4.5 Other Changes in Volume

Two of the population composition effects ("age composition", "sex composition") and the "residual population change" can be thought of as Other Changes in Volume. "Age composition" is likely to reflect a particular impact of net migration on the UK workforce. Theoretically, in the absence of immigration and emigration, changes in the age composition of the human capital stock should be completely enumerated through the appearance of new 16-year-olds, retirement, ageing, and death. Practically, even in the absence of immigration and emigration, there would still be some amount of statistical discrepancy. However, there is also a real volume effect through immigration and emigration – although we can't single these populations out within the ONS human capital system, we can observe part of its impact (albeit only a net impact) on the human capital stock through its unexplained change in the age composition. As migration is best thought of as an Other Changes in Volume (as it affects the volume of UK human capital without a transaction taking place to create/use this new human capital), then this specific subset of the effect of net migration on human capital should be categorised as an Other Changes in Volume.
The "sex composition" effect is analogous to the "age composition" effect in that it will partially capture the effect of net migration. However, the sex composition effect will also capture the net effect on the human capital stock of people who change their sex over time, which can be thought of as an Other Changes in Volume.

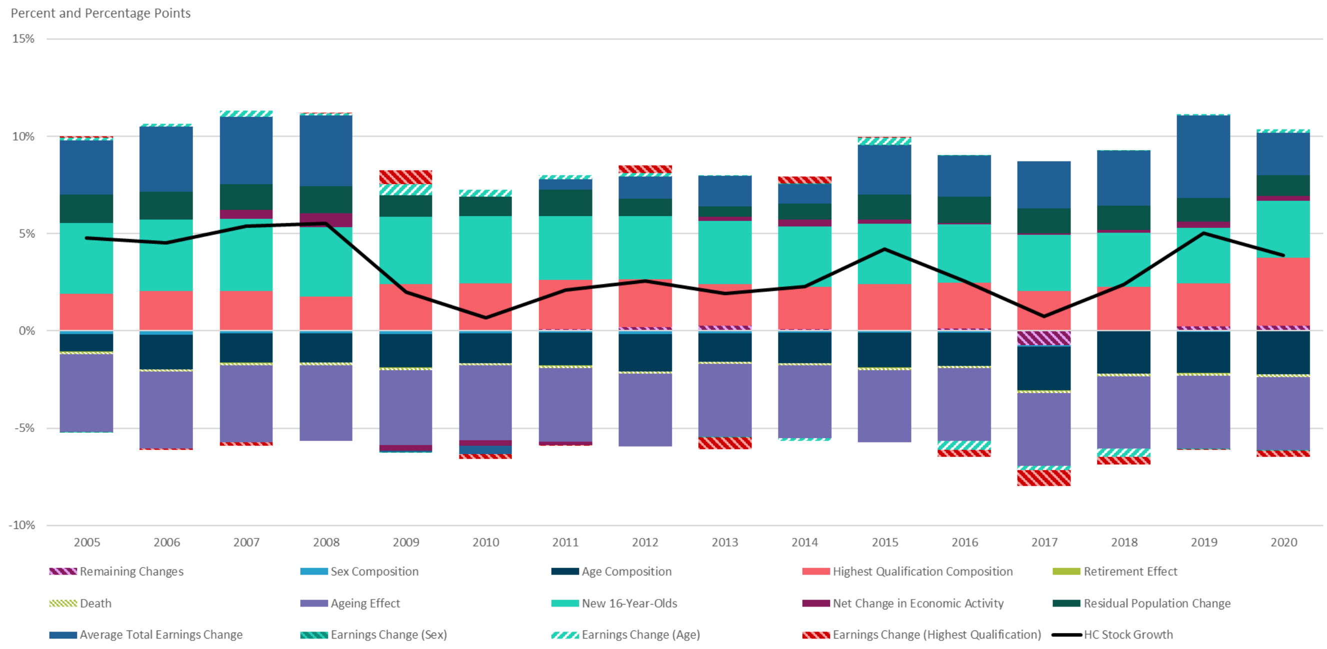
The net change in economic activity is more difficult to classify. An argument could be made to classify this as gross capital formation as an "investment" could be made by an organisation (e.g. government) to enable people to move from inactivity to economic activity (e.g. through work training schemes). However, many movements between activity and inactivity are unrelated to these investment-like decisions, and instead reflect the personal decisions of individuals – for example, the decision to step away from the labour market to raise a family. This results in the human capital abruptly moving in and out of the balance sheet, in much the same way as economic appearances and disappearances of produced capital – and as such, is best aligned to Other Changes in Volume. Ideally, future research would untangle these two separate reasons for moves between inactivity and activity, but in the absence of that research we have taken the decision to allocate this as a whole to Other Changes in Volume.

5. Results

The results of this research are summarised in Figure 1 which shows the growth of the UK's annual nominal human capital stock and the contributions[12] to this growth from the economic flows derived as part of this research.

[12] The 'contribution' to human capital stock growth from each flow was calculated as the proportion of the flow to the total stock value in the previous year. For example, the contribution for the sex composition

Figure 1: Contributions to the growth in UK nominal human capital stock
Percent and percentage points, 2005 to 2020, UK



Source: Office for National Statistics

Note: The economic activity rate variable used in ONS's unpublished aggregated human capital data is calculated as a three-year average using the current year's value and the two preceding years' values. For this reason, the first three years of data used in our analysis (2004 to 2006) have the same economic activity rate variable. This explains why the first two years' contributions are zero for the Net Change in Economic Activity.

The flows that were consistently the largest positive contributors to the growth in the UK's stock of human capital were the inflows of new sixteen-year-olds and the change in the working-age population's highest qualification composition. The growth in average total earnings was also a large contributor in the years to 2008 before becoming a negative contributor in 2009 and 2010 and then contributing positively again in the years thereafter. The flows that were consistently the largest negative contributors to the growth of the UK's human capital stock were the ageing effect and the change in the working-age population's age composition.

The flows that had a less significant impact on the growth of human capital were the changes in the distribution of earnings (between sex, age and highest qualification), the net change in economic activity, people retiring and death in the population.
There is also a 'Remaining Changes' category shown in Figure 1 which accounts for the total value of the flows that are not explained by our research. Specifically, it is the difference between the total human capital stock in year t (plus the economic flows identified in this research) and the value of year $t + 1$'s total human capital stock.

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change for 2006 was calculated by dividing the nominal flow value for 2006 by the nominal total stock value for 2005. The sum of all these proportions for a given year is equal to the rate of growth in the stock between the two relevant years. The same method was used to construct Figure 2.

There are several periods throughout the time series where noticeable changes in the growth of human capital stock occur. The first occurs between 2008 and 2009 in which growth fell from 5.5 percent to 2.0 percent. The main cause of this was the fall in the average total earnings change which had consistently been one of the largest positive contributors to the growth in the stock. The net change in economic activity also became negative for the first time in 2009 contributing further to this change in the growth. The growth rate from 2009 to 2010 fell further due to the contribution from total average earnings change becoming more negative and the contribution from the change in earnings by highest qualification becoming negative.

Growth in the stock recovered slightly between 2010 and 2011 due to the total average earnings change contributing positively again and an increase in the positive contribution of the residual population change. Growth remained broadly stable until 2015 when a large increase in the positive contribution from the change in average total earnings caused a noticeable increase in stock growth for that year.

A decline in growth was then seen between 2015 and 2016 primarily due to the decrease in the positive contribution of the average total earnings change and negative contributions from changes in earnings by age and highest qualification. A further large fall in stock growth occurred between 2016 and 2017 as the negative contributions from the age composition and change in earnings by highest qualification increased. Also, the contribution from the Remaining Changes component turned negative for the first time in the period under study and the decline in the positive contribution from the highest qualification composition component both contributed to this decline in growth.

Growth in the stock recovered between 2017 and 2018 as the Remaining Changes component went from having a negative contribution to having virtually no effect on growth. This was coupled with an increased positive contribution from the change in average total earnings and a decreased negative contribution from the change in earnings by highest qualification.

Growth increased again between 2018 and 2019 due primarily to the increased positive contribution from the average total earnings growth component and, to a lesser extent, the contributions from the earnings changes by age and highest qualification becoming positive and less negative, respectively.

The following sub-sections look at some of the components more closely.

5.1 New Sixteen-Year-Olds

The addition of new cohorts of sixteen-year-olds each year had a significant positive contribution to human capital stock growth for all years. The large contribution from this component can be explained by 16-year-olds having the highest value of lifetime earnings of any age group in the working-age population as they have the largest number of years remaining in their working lives.

5.2 Highest Qualification Level Composition

The change in the UK's working-age population's highest qualification level composition contributed positively and significantly for all years of the analysis. Broadly speaking, a positive value for this component can be thought of as representing a workforce which is more qualified, while a negative value represents a workforce which has become less qualified. As this component is positive throughout the period, this demonstrates that a long-term shift towards a more educated working-age population is a key source of gross capital formation in UK human capital.

In 2020, the contribution of the Highest Qualification Level Composition component saw a very large increase relative to preceding years. In fact, 2020 saw the largest contribution from this component to the growth in human capital stock by a large margin. More accurately, in 2020 this component contributed 3.49 percentage points to stock growth, 0.94 percentage points higher than its second largest contribution to growth in 2011 (which equalled 2.55 percentage points). This phenomenon coincided with a significant increase in the proportion of individuals in the working-age population obtaining bachelor's degrees and post-graduate degrees. This can be seen in ONS's National Human Capital population estimates in the UK: 2004 to 2020.

5.3 Average Total Earnings Growth

For most years, the change in average total earnings was a positive and significant contributor to growth in the stock of human capital. In 2009, however, the contribution from average total earnings growth became negative. It's contribution to overall growth in human capital declined sharply from 3.64 percentage points in 2008 to negative 0.08 percentage points in 2009, accounting for most of the fall in the value of the human capital stock over this period. The contribution of average total earnings growth began to recover from 2011, contributing positively to the growth in the stock for succeeding years.

Given that the LE method uses individuals' earnings as the basis for valuing human capital stock, it is to be expected that changes in average total earnings will have a large effect on the growth in human capital stock.

5.4 Age Composition of the Working-Age Population

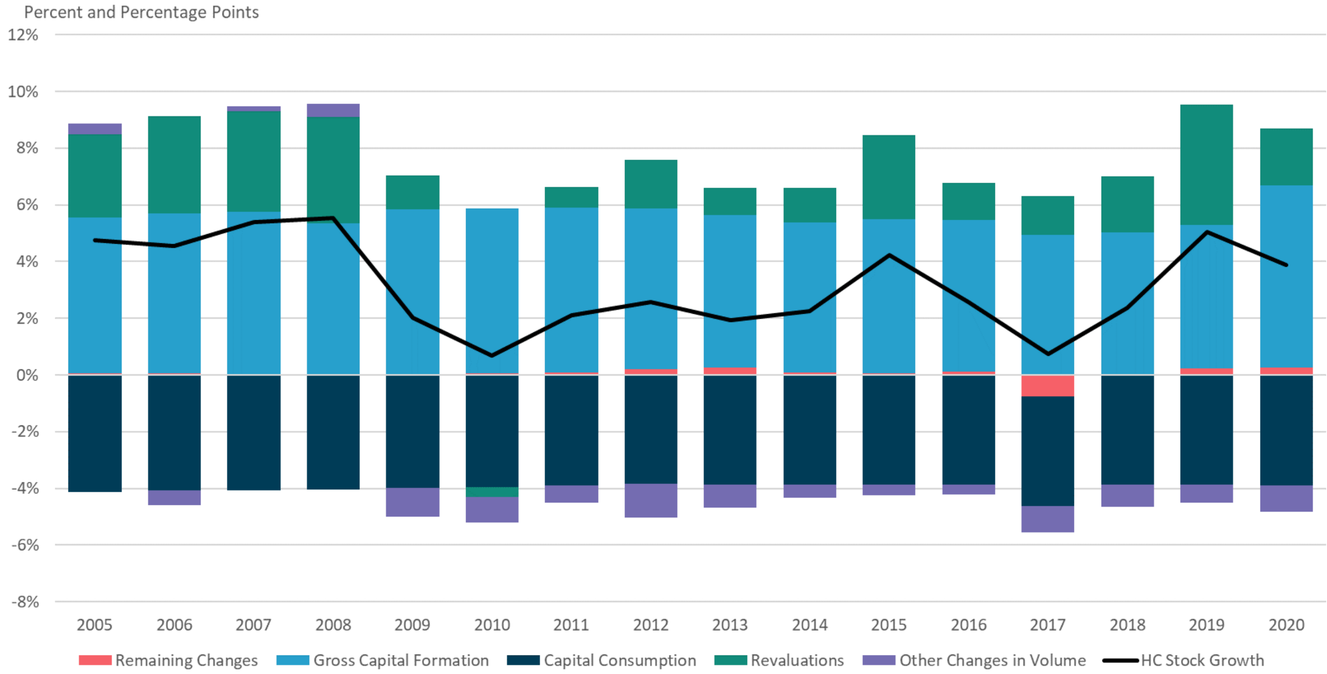
For all years, the change in the age composition of the working-age population was a large negative contributor to the human capital stock, with the scale of this negative contribution tending to grow over time. For example, while the average contribution for 2005 to 2007 was negative 1.39 percent, this had grown to negative 2.16 percent by 2018 to 2020.

5.5 National Accounts Economic Flows

It is also useful to group the flows we have estimated into the higher-level economic flow categories associated with the System of National Accounts 2008 (SNA 2008). Figure 2 presents the contributions of the flows to the UK's human capital stock growth but this time the flows are grouped into their corresponding higher-level SNA 2008 economic flow categories as mapped in Table 1.

Figure 2: Contributions to the growth in UK nominal human capital stock with flows grouped into SNA 2008 flow categories

Percent and percentage points, 2005 to 2020, UK



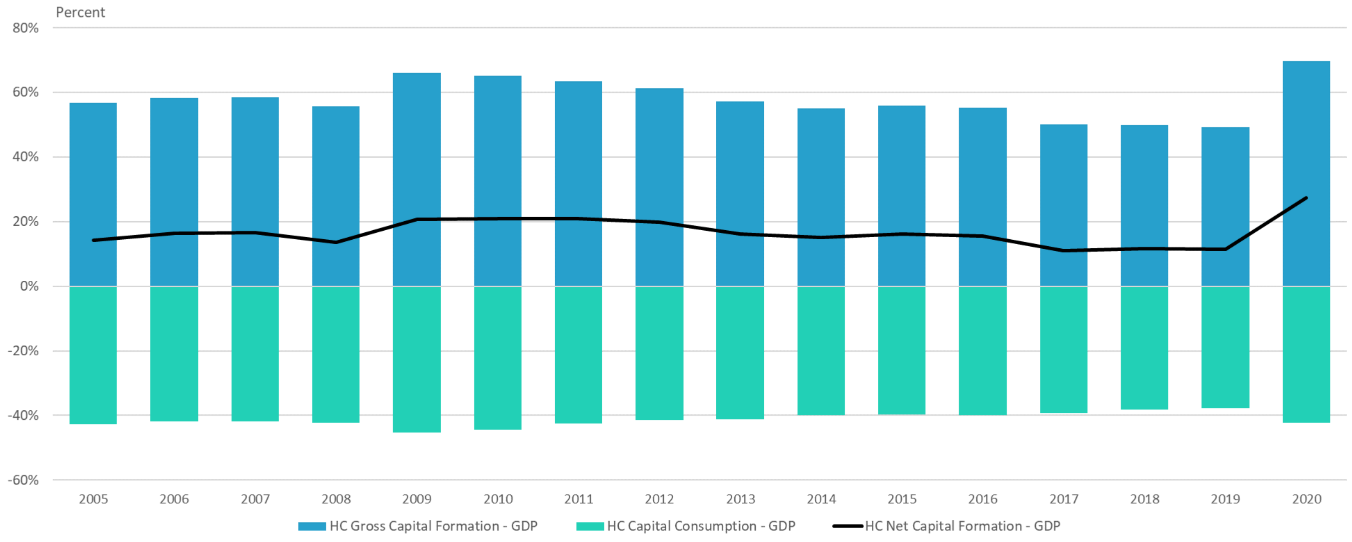
Source: Office for National Statistics

Throughout the period, the Gross Capital Formation and Capital Consumption components remained broadly consistent between 2005 and 2020. Gross Capital Formation and Capital Consumption had the largest effects on the growth of the human capital stock with Gross Capital Formation contributing positively and Capital Consumption contributing negatively. The Revaluations component, however, experienced the most variation of all the SNA 2008 economic flow categories. The Revaluations component contains the earnings changes, including the Average Total Earnings Growth change, which exhibited relatively more variation compared to the other flows throughout the period. For most years, Revaluations contributed positively to the growth in the UK's human capital stock except for 2010 when Revaluations contributed negatively to human capital stock growth.

For most years, Other Changes in Volume caused the human capital stock to decline and had the smallest impact on the stock compared to the other three SNA 2008 flow categories except for the year 2010 in which Revaluations was the smallest contributor of the four SNA 2008 categories. The Remaining Changes component – that is, the change in the stock that is not explained by this research – had a very small, positive effect on the human capital stock for nearly all years except for a more noticeable negative contribution in 2017 of negative 0.75 percentage points. Further research would be needed to understand the cause of this negative value.

It is also useful to see the ratio of human capital gross capital formation and capital consumption to Gross Domestic Product (GDP). Figure 3 shows the ratio of human capital gross capital formation, capital consumption and net capital formation to GDP. GDP at current prices and non-seasonally adjusted is used to calculate these ratios.

Figure 3: Nominal human capital gross capital formation and capital consumption as ratios to nominal GDP
Percent, 2005 to 2020, not seasonally adjusted, UK



Source: Office for National Statistics

Human capital net capital formation was calculated by subtracting capital consumption of human capital from gross capital formation of human capital. There was a noticeable increase in the ratio of human capital net capital formation to GDP from 11.4 percent in 2019 to 27.4 percent in 2020. This was caused by two phenomena. Firstly, the lower value of nominal GDP for 2020 associated with the COVID-19 pandemic relative to the two preceding years and, secondly, the much larger value for human capital gross capital formation resulting from a large increase in the positive contribution of the highest qualification composition change in 2020 as discussed in Section 5.2.

6. Strengths and Limitations of the Research

Currently, there is little in the way of internationally agreed guidance regarding estimating the economic flows of human capital. There are aspects of the methods in this research that could be discussed further and debated.

As mentioned in Section 3, we could have applied the changes in a completely different order. The selection of when certain changes should be applied is an important one. For example, if we had implemented the Net Change in Economic Activity – which affects the calculation of Lifetime Earnings (LE) – before applying any of the population changes we would have obtained different LE values per sex, age and highest qualification level group. Sensitivity analysis would be needed to determine how altering the order in which these changes are applied affects the overall results.

There are other potential changes that we have not been able to estimate explicitly. Perhaps the most significant of these is the effect of net migration (the difference between the number of immigrants and the number of emigrants) on the human capital stock. There may also be other factors that affect the human capital stock that we have not been able to identify explicitly in this analysis.

A more fundamental limitation of the research relates to the difference between the Income-Based Approach and the definition of human capital from the OECD which is an all-encompassing definition. The Income-Based Approach to measuring the human capital stock does not explicitly identify the effects of other phenomena such as individuals' innate abilities, physical/mental health and motivation levels on human capital. A more holistic measure of human capital may need to be developed to explicitly identify and estimate these broader phenomena associated with human capital.
We should also recognise that the approach taken for this paper is not the only potential method of calculating human capital flows. This research has estimated the flows indirectly by decomposing the change in the stock. It may be possible to take the opposite approach and calculate human capital flows directly and then use the flows to construct the human capital stock estimates.

One feature that has not been explored in this research is the change in the efficiency of human capital. For example, a decline in the efficiency of individuals' human capital would be associated with the depreciation (capital consumption) of the stock of human capital. Estimation of this phenomenon is beyond the scope of this paper. For more on this topic, see Inklaar and Papakonstantinou (2020) and Fraumeni (2022) who estimate and analyse vintage effects associated with human capital.

7. Potential Future Developments

A key area of future research would be to investigate and resolve the conceptual and measurement issues outlined in Section 4. While some of these are constraints of the data set and the human capital stocks model used in this analysis – the inability, for example, for us to be able to isolate the effect of net migration – some are issues core to reconciling human capital accounting with national accounting.

One prominent example of this is the use, for the purpose of constructing Lifetime Earnings, of forecasting future increases in qualifications and the inclusion of the future gains from those qualifications in the valuation of current capital stocks. This does not appear consistent with national accounting principles and prohibits the measurement of much of education as gross capital formation in human capital (see Section 4.2 for more discussion on this point). Work towards incorporation of human capital in a national accounting framework would benefit from conceptual research into how human capital can be measured more in line with national accounting principles, as well as empirical estimates of human capital stocks and flows according to these different conceptualisations.

8. Summary

This paper has presented a method for estimating the economic flows of human capital for the UK between 2005 and 2020. A broad range of factors (or changes) were identified that could affect the UK's stock of human capital from one year to the next. These changes were then mapped to broader categories of economic flows as defined in the System of National Accounts 2008 (Gross Capital Formation, Capital Consumption, Revaluations and Other Changes in Volume). The paper then discussed our rationale for the allocation of the changes we identified into the SNA economic flow categories and the specific cases where this allocation is more difficult.

Our research used ONS's unpublished aggregated human capital data to provide estimates for the economic flows. Our results show that the largest positive contributions to growth in the UK's human capital stock were the inflows of new sixteen-year-olds joining the working-age population each year, the change in the highest qualification composition of the working-age population and the change in average total earnings. The largest negative contributions to the UK's human capital stock growth came from the ageing effect and changes in the working-age population's age composition.
Further research is needed to estimate the effects of net migration on the stock of human capital more explicitly as information on net migration is currently not available in ONS's unpublished aggregated human capital data.

We hope this paper inspires others to investigate this area of research which is crucial for incorporating human capital into the national accounting framework and developing measures of sustainable economic progress.

Appendix: Full Results and Data

Table A.1: UK human capital flows for each change
£millions, current prices, UK

Change	2005	2006	2007	2008	2009	2010	2011	2012
Sex Composition	-25,834	-27,356	-22,678	-23,198	-27,767	-20,953	-15,960	-28,710
Age Composition	-129,047	-270,355	-237,091	-248,231	-304,073	-274,723	-305,727	-355,909
Highest Qualification Composition	265,719	304,936	316,373	288,193	413,870	432,768	460,811	455,263
Retirement Effect	-1,535	-1,654	-1,870	-2,031	-4,032	-3,095	-2,709	-3,974
Death	-17,636	-17,980	-18,586	-19,499	-20,710	-20,701	-19,985	-19,693
Ageing Effect	-576,883	-597,803	-625,230	-651,442	-678,275	-689,322	-683,517	-687,817
New 16-Year-Olds	529,369	552,413	587,518	600,480	610,099	615,994	594,519	596,893
Net Change in Economic Activity	0	0	73,628	115,046	-47,130	-52,398	-32,499	4,113
Residual Population Change	209,720	220,398	210,537	233,851	198,635	184,910	243,191	161,776
Average Total Earnings Change	400,896	503,616	550,331	608,533	-13,711	-77,397	96,796	209,241
Earnings Change (Sex)	-6,329	3,606	190	817	-6,463	710	1,820	5,636
Earnings Change (Age)	24,162	21,006	46,556	14,521	101,995	62,339	36,365	32,734
Earnings Change (Highest Qualification)	7,836	-10,788	-30,936	3,727	124,932	-45,322	-7,377	68,911

Source: Office for National Statistics

Notes:

- These figures have been rounded which may explain any difference between the results in this paper and any attempted reconstruction of our results.
- The values for the Net Change in Economic Activity in 2005 and 2006 are zero. This is because the economic activity rate variable used in ONS's unpublished aggregated human capital data was the same for 2004, 2005 and 2006 so there was no change in economic activity for 2005 and 2006 causing the economic flow to be zero in 2005 and 2006.

Table A.1 (continued): UK human capital flows for each change
£millions, current prices, UK

Change	2013	2014	2015	2016	2017	2018	2019	2020
Sex Composition	-20,607	-19,026	-16,057	-19,744	-13,245	-5,041	-12,193	-1,367
Age Composition	-277,127	-300,833	-356,465	-348,949	-474,043	-460,744	-460,958	-506,792
Highest Qualification Composition	409,069	419,669	460,085	488,886	434,576	478,108	481,937	797,812
Retirement Effect	-4,232	-3,826	-4,084	-4,138	-4,471	-4,559	-4,535	-5,177
Death	-19,889	-20,190	-20,844	-22,339	-22,877	-23,550	-24,246	-26,747
Ageing Effect	-709,809	-720,416	-736,510	-767,596	-788,916	-791,786	-815,654	-859,123
New 16-Year-Olds	611,871	605,387	611,440	613,296	610,783	593,662	618,060	669,580
Net Change in Economic Activity	43,651	65,974	47,794	13,665	15,449	28,975	70,932	60,253
Residual Population Change	103,198	159,728	250,041	283,436	272,065	268,016	265,654	237,340
Average Total Earnings Change	294,389	193,224	503,335	431,151	508,791	597,842	922,425	505,168
Earnings Change (Sex)	-4,607	2,130	6,185	2,845	-4,256	42	-9,795	-10,320
Earnings Change (Age)	6,977	-29,653	67,953	-94,799	-46,180	-93,108	14,373	34,685
Earnings Change (Highest Qualification)	-115,252	71,417	8,066	-73,143	-172,181	-82,501	-425	-72,612

Source: Office for National Statistics

Note: These figures have been rounded which may explain any difference between the results in this paper and any attempted reconstruction of our results.

Table A.2: Total UK human capital stock

£billions, current prices, UK

Year	Human Capital Stock Value
2004	14,471
2005	15,160
2006	15,848
2007	16,704
2008	17,628
2009	17,983
2010	18,105
2011	18,486
2012	18,960
2013	19,325
2014	19,763
2015	20,598
2016	21,126
2017	21,283
2018	21,789
2019	22,885
2020	23,771

Source: Office for National Statistics

Note: These figures have been rounded which may explain any difference between the results in this paper and any attempted reconstruction of our results.

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