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An Intangible Infrastructure Approach Applied to the UK and the US.

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How does education contribute to productivity?
An intangible infrastructure approach applied to the UK and the US.

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Abstract

This paper treats spending on formal schooling as investment, i.e., as intangible social infrastructure. It adapts the Jorgenson-Fraumeni lifetime income framework to develop estimates of (a) education output as the increment to lifetime income due to this year's schooling and (b) the amount of knowledge held within the school system until students graduate (or dropout) and enter the labor force. This "schooling knowledge inventory" is an additional factor of production in the economy, and GDP is raised by the aggregate value of the return to these stocks.

New estimates of real education output, education TFP and total economy TFP are calculated using the UK as a case study for our framework. We find that (a) TFP growth for the education sector is higher, but that (b) total economy TFP growth is lower or little changed (because greater weight is given to a sector that still grows more slowly than other sectors in the economy). We also find that incorporating our new TFP measures for the UK education sector imply less of a slowdown in the country's TFP growth since 2007. We also discuss a preliminary application to US data.

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1 Introduction

Many studies consider how labor input may be better measured to improve estimates of productivity growth. This paper looks at the flip side of this issue, addressing how education may be consistently measured on the output and capital sides of the productivity equation. Education is viewed as intangible investment in (social) infrastructure, a treatment that we implement and find has significant implications for measuring education output and considering how its production affects GDP and productivity growth.

The social infrastructure approach used in this paper views education as a “public intangible" (e.g., as in **?**) and takes an outcome approach to measuring the value of education services, The paper first sets out how measuring education/schooling as social infrastructure can be incorporated into measures of GDP (final demand and factor payments) and productivity (real inputs and outputs). It then implements the framework for the United Kingdom and examines implications of the new empirics for measured productivity growth. Reflecting the notion that education involves the production of human capital, Jorgenson and Fraumeni’s lifetime income approach (Jorgenson and Fraumeni, 1989, 1992a,b) is used to build the outcome-based measures of education services used in this paper.

National accounts currently value education services based on input costs and typically use number of student enrollments or the number of graduates, disaggregated by education level or type of education program, for volume measures. In the intangible infrastructure approach, education services are rather defined as the acquisition of schooling-produced knowledge assets, assets that are expected to provide a return to society in a future period. The stocks of these assets are not used in current production (it takes many years to produce a graduate), but rather they are held in inventory, within the school system, until students graduate and enter the working age population. In a closed economy the output of the education sector would exactly match these intangible investments in knowledge, entering GDP as investment, not consumption. The change in the value of schooling knowledge stocks would appear in the gross operating surplus (GOS) of the education sector, and services from their volume an additional factor of production in productivity growth accounting. In an open economy some education outputs are services provided to foreign students who obtain their qualifications and then return to their native countries. This component would not be considered as social infrastructure in the domestic economy, as the education embodied in these students is typically not available for future production.

The plan of this paper is as follows. Section 2 sets out our education as social infrastructure framework. Section 3 summarizes the lifetime income model variant that underlies our calculations. Sections 4 and 5 discuss measurement issues and an application of the model and framework to the available data on education services in the UK. Section 6 presents our main results, i.e., our new measures for education output, education productivity, and their impact on total economy productivity. Here we also discuss the application to the US. A final section concludes.

2 Education as Social Infrastructure

This section sets out the aggregate relationships that govern production, factor payments, and accumulation of schooling knowledge assets in a social infrastructure framework. It assumes a closed economy to abstract from what are largely empirical complications arising from foreign students. The section also shows how schooling knowledge assets relate to conventional measures of human capital and total factor productivity, including the labor composition term used in those measures to capture changes in the skill and educational attainment characteristics of a national workforce.

2.1 Defining key terms

We assume that the goal of schools is to produce graduates. The gestation period for the production of graduates spans many years, however, and thus education output is the accumulated knowledge attributed to the school system in a given year. If each school year t starts with a “beginning" stock of knowledge in enrollees S_t^B and concludes with a “terminal’ stock of knowledge S_t^T, then the output of the school system is the production of new schooling knowledge, Q^S, is written as

$$Q_t^S = S_t^T - S_t^B \tag{1}$$

i.e., as the difference between the terminal and beginning stocks of schooling knowledge assets. Society’s investment in social infrastructure is then the value of student knowledge acquisition in a year, denoted as $P_t^E Q_t^S$.

Some students graduate school with a secondary education degree while others remain in schools longer and obtain higher degrees. This implies that schooling knowledge investment reflects activity at a mix of education levels—akin to a mix of products in a tangible output-producing industry— implying that P_t^S and Q_t^S can be formulated as superlative price and volume index numbers that account for the product composition of the investment services produced by the education industry.

2.2 Production and factor payments

The production function for schooling-produced knowledge is given by

$$Q_t^E = A_t^E \, F^E (L_t^E \, , \, K_t^E , \; S_t^B). \tag{2a}$$

Equation (2a) states that the schooling-produced increment to human capital (the transformation of S_t^B to S_t^T) occurs via application of labor and capital services, L_t^E and K_t^E and the Hicksian shift term A_t^E. The shift term allows for changes in the productivity with which the inputs L_t^E, K_t^E, and S_t^B are transformed into new knowledge (i.e., output). Intermediate inputs are ignored for simplicity.

The factor payments equation corresponding to (2a) is written as

$$P_t^E Q_t^E = P_t^{L^E} L_t^E + P_t^{K^E} K_t^E + P_t^S S_t^B. \tag{2b}$$

As previously indicated, P_t^E is output price, which in our framework is also an investment (or asset) price. The price for labor services employed by education institutions $P_t^{L^E}$ is assumed to be competitive by underlying type (elementary teachers, high school principals, etc.) as determined in the broader economy.[1] The price of services from fixed capital (school buildings, computers, etc.) used in the sector is an ex ante capital rental price $P_t^{K^E}$. It is an ex ante price because the industry is largely nonmarket, i.e., it consists of public and/or nonprofit institutions serving households (NPISH), and the cost of the capital must be represented (imputed) by a public/household discount rate.[2]

The price of services from schooling-produced knowledge assets, P_t^S, is also a capital rental price. It reflects the marginal value product of the inventory capital (knowledge) held within the school system of a society, and $P_t^S S_t^B$ is the compensation attributed to this capital. The Jorgenson (1963) user cost relationship between this per period capital rental price and the price of producing an additional unit of the asset (P_t^E) is assumed to hold, i.e., $P_t^S = r_t^S P_t^E$, where r_t^S is the ex post return to society's expenditure on education ($P_t^{L^E} L_t^E + P_t^{K^E} K_t^E$). It is calculated as follows:

$$r_t^S = \frac{P_t^S S_t^B}{P_t^E S_t^B}, \tag{3}$$

where we assume S_t^B does not depreciate while students are enrolled in school.

2.3 Schooling knowledge and human capital

Here we set out the simple endogenous processes that relate (a) equation (2a) to the evolution of schooling knowledge stocks and (b) schooling graduates to total human capital.

The evolution of schooling knowledge stocks from the end of one school year to the beginning of the next—the relationship between S_t^T and S_{t+1}^B in (1)—involves accounting for exits from the school system (graduates, dropouts) and net migration of new school-age residents into the school system. New entrants at the lowest level of schooling are assumed to have zero knowledge stocks.

The effect of exits and net migration can be represented as time-varying proportionate adjustments to the terminal value of knowledge stocks from the preceding year, γ_t and η_t. Thus we write

$$S_t^B = (1 - \gamma_{t-1} + \eta_{t-1}) S_{t-1}^T, \tag{4a}$$

and substituting from (1) we have

$$S_t^T = \underbrace{Q_t^E + \eta_{t-1} S_{t-1}^T}_{\text{Knowledge Produced and/or Acquired via Migration}} + \underbrace{(1 - \gamma_{t-1}) S_{t-1}^T}_{\text{Knowledge Inventories from } t-1}. \tag{4b}$$

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[1] The price of labor services is super-scripted by E to indicate that the composition of labor by type is specific to the industry.

[2] In some societies, e.g., the United States, some education services are provided by for-profit organizations, the presence of which we ignore here.

Though this bears some similarity to the usual recursive capital accumulation equation, outflows from inventories ($\gamma_{t-1}S^{T}_{t-1}$) are not recurring losses of productive capital (as in capital consumption), but rather a recurring transfer of “finished" knowledge stocks (i.e., graduates) flowing into productive use elsewhere. Net migration of new resident students ($\eta_{t-1}S^{T}_{t-1}$, which note may be negative) also appears in (4b) and is distinct from production and accounted for separately for this reason.[3] (Inflows and outflows of nonresident foreign students are discussed below.)

Total human capital as set out by Becker (1975) and others includes the impact of investments in education, training, and health care. Total human capital is viewed this way in this paper, with the qualification that investments in formal education reflect production of knowledge via schooling activity only. The time that augments schooling knowledge production in the home is out of scope for both GDP and the model set out in this paper. The modeling of human capital acquisition via work experience versus investments in education is addressed in the measurement section of this paper. O'Mahony and Samek (2021) develop measures of health-adjusted human capital in related work, and employer-provided training services are capitalized in the Corrado, Hulten, and Sichel (2005, 2009) intangibles-expanded approach to business productivity analysis, which is complementary to this paper.

The usual approach to measuring the contribution of formal education on human capital looks at its impact over the working lifetime of an individual. In our framework the value of this capital would amount to cumulating each year's schooling-produced knowledge assets Q^{E}_{t}, after accounting for exits from the potential labor force due to death and ageing (recall again we ignore contributions from home production). What we measure in S^{B}_{t}, which nets out last year's graduates and dropouts, is then only a portion of the contribution of education to the total stock of human capital in a population.

The social infrastructure approach to measuring education output conforms to the larger human capital framework in which a distinction between students still in school accumulating knowledge versus graduates “launched" into the workforce gaining further knowledge through work experience and on-the-job training is made. In other words, If the value of the stock of *total* human capital in a population in period t is denoted by $P^{H}H_{t}$, and the stock potentially available for employment in t by $p^{\Phi}\Phi_{t}$, then have,

$$P^{HC}H_{t} = P^{WE}\Phi_{t} + P^{S}S_{t} \tag{5a}$$

where P^{HC} and P^{WE}, like $P^{E}S$, are investment (i.e., asset) prices and valuations are expressed at mid-period (implying per (4b) that the superscripts "B" and "T" can be dropped). Schooling knowledge stocks held by the existing workforce are of course embedded in Φ_{t}, and their returns are included in the usual productivity analysis as labor compensation. The usual productivity analysis, however, does not necessarily value the

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[3] Note further that per chapter 12 the System of National Accounts (SNA; European Commission et al., 2009), recurring losses from inventories due to graduation are to be recorded in the *capital account* whereas the “economic appearance" of an asset—akin to knowledge held by the net migration of school-age residents above the entry level—are to be recorded in the *other changes in the volume of assets account*. Like the capital account, the other changes in volume account feeds directly into the national balance sheet (and productive capital, which is why we account for both), but unlike increases in capital that arise from real net national investment, increases in capital that arise from the “economic appearance" of assets do not require a deferral of society's consumption.

production process that creates those stocks—the education system—on a consistent basis, i.e, it is not consistent with (5a).

Let Φ_t evolve to reflect a per period real return, ω_t^H, to work force experience, then after (a) accounting for exits from the work force due to death and aging (represented as a proportionate reduction, d_t, in real stocks) and (b) adding in entrants from schools (i.e., exits from schools, from (4a) above), we can write:

$$\Phi_t = (1+\omega_t^H)[(1- \ d_{t-1})\Phi_{t-1}] + \gamma_{t-1}S_{t-1} \tag{5b}$$

Note that as conventionally calculated, Φ_t is a measure of potential labor services, i.e., the stock of human capital available for the workforce. It thus differs from the usual labor services term, L_t in an aggregate production function, which measures actual services utilized in current production. The estimation of S_t^B, Φ_t, and H_t is discussed in sections **??** and **??** below, i.e., these quantities are not calculated via (4a), (5a), and (5b) but rather are built from microdata. The parameters γ and d are implicit in the underlying population and student enrollment data used to estimate the volume indexes for these stocks.

The rate of return to human capital in the workforce, ω_t^H in (5b), is also embedded in the microdata used to calculate human capital stocks, but ω_t^H is different from γ and d because ω_t^H is related to assumptions used in the calculation formulas for human capital, not the data per se. From the perspective of productivity analysis, ω_t^H is an ex post return to human capital that can be calculated and examined for consistency with the assumptions used to calculate the stocks. This paper's empirics does not close this circle because doing so does not have first order implications for the estimation of Q_t^E, as discussed in section **??**, but it is nonetheless a relevant subject for an extended analysis of the contribution of human capital to productivity growth.

2.4 Schooling knowledge and productivity growth

The social infrastructure treatment of education output implies that the knowledge held within schools, S_t, is a productive factor that appears in the production function and corresponding payments equation for the total economy. Thus, we have,

$$Q_t = A_t F(L_t, K_t, S_t) \tag{6a}$$

$$P_t^Q Q_t = P_t^L L_t + P_t^K K_t + P_t^S S_t. \tag{6b}$$

The expansion of the asset boundary to include knowledge assets held within schools involves a corresponding expansion of the production boundary of GDP (i.e., Q_t and $P_t^Q Q_t$ in (6a) and (6b) are redefined). To highlight this, let Q_t^m denote existing real GDP (aka "measured" GDP), in which case the economy's production and payments as currently measured is written,

$$Q_t^m = A_t^m F^{'}(L_t, K_t) \tag{7a}$$

$$P_t^{Q^m} Q_t^m = P_t^L L_t + P_t^K K_t. \tag{7b}$$

Comparing the two sets of equations, we see that, in addition to the inclusion of a new productive factor (S_t) aggregate total factor productivity, the aggregate GDP price index, and factor output elasticities (share weights) are potentially affected by the social infrastructure treatment of education services. Actual prices and quantities of fixed capital and labor inputs are unaffected by the move.

To analyze the impact on total factor productivity of capitalizing investment in education, we employ the Solow output/productivity growth decomposition using the following notation: We let dz denote the log change in Z_t, where Z_t is any variable in our model and $\bar{\sigma}_Q^Z$ a (Divisia) factor payment share for Z_t in Q (if Z_t is a factor); we then combine conventional inputs L_t and K_t into a weighted aggregate, X_t, i.e., $dx = \bar{\sigma}_{Q^m}^L dl + \bar{\sigma}_{Q^m}^K dk$. Finally, we let $\Delta\bar{v}_Q^E$ be the change in the (Divisia) share of education final output in GDP after it is revised to include education as social infrastructure.

Assuming cost minimization and that output elasticities are equal to factor shares, we log differentiate (6a) and express the result in terms of total factor productivity growth and factor shares from (6b); then we do the same with (7a) and (7b). This yields the following:

(8a) $$da = dq - \bar{\sigma}_Q^X dx - \bar{\sigma}_Q^S ds.$$

(8b) $$da^m = dq^m - dx.$$

Subtracting (8a) from (8b) we obtain

(9) $$\begin{aligned} da^m = da& \\ &- \Delta\bar{v}_Q^E(dq - dq^m) \\ &+ \bar{\sigma}_Q^S(ds - dx) \end{aligned}$$

which says that when schooling knowledge “inventory" is ignored, measured total factor productivity (TFP) growth da^m may (a) understate actual productivity growth da if education output is growing relative to the rest of the economy—the first term in (9)—but on the other hand da^m (b) may overstate actual TFP growth da when uncounted returns to the knowledge assets held within schools are growing faster than other factor inputs—the second term in (9). These terms are difficult to sign a priori without insight on demographic and migration trends in an economy, and the rates of growth of real education output and schooling knowledge assets relative to other economic activity and other productive factors is an empirical matter.

The specific adjustments to expenditure side GDP have not been set out in this section, but note from (6b) and (7b) that $\Delta\bar{v}_Q^E$, the increase in the (Divisia) share of education final output in GDP after it is revised to include education as social infrastructure, must necessarily equal $\bar{\sigma}_Q^S$, the GDP share of the value of this year's education production that is compensation for beginning-of-period knowledge stocks. This implies that the terms in (9) may be rearranged as follows:

(10) $$da = (1 + \bar{\sigma}_Q^S)\, da^m + \bar{\sigma}_Q^S(ds - dq^E)$$

The first term on the right-hand side of equation (10) says that, because a new productive factor has been "added" to the economy, the resulting productivity of the economy should be proportionately greater by the payment made to the new factor. The second term says that, beyond the expected boost to productivity via the first term, productivity may be further boosted when beginning-of-period student knowledge stocks grow faster than the growth in knowledge added via education. This describes many possible situations, including one in which successive cohorts of the population enter higher levels of schooling at higher rates, or there is significant net migration into higher levels of schooling. This suggests that the relationship between ds^B and dq^E has many complexities when there are multiple levels of education in the analysis, and that productivity analysis is informed by tracking investments, enrollment churn, and net returns to education at each level. School systems can influence their own performance by improving graduation and retention rates, but they have no control over demographic trends, which may strongly affect school performance measured in terms of graduates.

3 Knowledge capital measurement: Approach

3.1 Lifetime income

We begin by abstracting from employment outcomes and labor force dropouts and simply assume that any student enrolled in school will, in the following year, if they leave education, earn the market wage corresponding to that level of education.

The Jorgenson-Fraumeni (JF) framework calculates the value of human capital stocks based on lifetime incomes by gender (s), age (a) and education level (e). Their original papers calculate this for all persons in the population. A more common approach is to calculate the stock only for the working population, e.g. Gu and Wong (2010) as well as Wei (2004). In this paper we begin with the active population, removing those age groups where school is compulsory, aged < 16, and those where all persons have retired permanently from the workforce, which we take as aged > 80.

Let:

y = current labor market income
li = lifetime income
δ = discount rate
g = average income growth
sr = survival rate
pop = population

The JF framework calculates lifetime income by sex, age and education recursively. The simplest assumption is to say that lifetime income is 0 beyond some age, say 80. For an individual aged 80, lifetime income (li) in year t is just current labor income (y).

(11) $$li_{s,a=80,e,t} = y_{s,a=80,e,t}$$

For an individual aged 79 lifetime income is current labor market income plus discounted future income of someone aged 80 with the same education and gender, conditional on survival:

$$li_{s,a=79,e,t} = y_{s,a=79,e,t} + sr_{s,a=80,e,t}\frac{1+g}{1+\delta}li_{s,a=80,e,t} \tag{12}$$

In general, the lifetime income of those aged a and education level e is given by:

$$li_{s,a,e,t} = y_{s,a,e,t} + sr_{s,a+1,e,t}\frac{1+g}{1+\delta}li_{s,a+1,e,t} \tag{13}$$

This valuation for each individual at time t is the value of current income plus the income of those one year older of the same sex and educational attainment times growth in income discounted to the present, plus the income of those two years older and so on up to age 80. It therefore assumes that the best estimate of a person's income next year is that earned this year by a similar person (same gender, education) who is one year older. This assumption is contentious and is discussed further in the concluding section. Note the standard JF model includes the probability of moving to higher education levels for younger individuals, but for this exercise we just consider lifetime earnings for final education levels.

3.2 Value of human capital

The total value of the human capital stock of a population in year t can be calculated by summing the lifetime earnings, li, by s, a, and e:

$$P_t^H H_t = \sum_s\sum_a\sum_e pop_{s,a,e,t}li_{s,a,e,t} \tag{14}$$

In measuring the nominal value of education as social infrastructure we concentrate on the portion of the population enrolled in education. Following Christian (2010, 2014), we estimate "net investment from education of persons enrolled in school" as:

$$P_t^E Q_t^E = \sum_s\sum_a\sum_e enr_{s,a,e,t}(li_{s,a+1,e+1,t} - li_{s,a,e,t}) \tag{15}$$

Enrollments (enr) are multiplied by the amount by which lifetime earnings at that age, sex and education change with the addition of one extra year of education and the one extra year of age required to achieve that additional education. In the estimation of lifetime incomes, we set g=2 percent and δ=3.5 percent; these are assumptions currently employed in human capital stock calculations by ONS (Jones and Fender, 2011). Note that in equation (15) we are taking the difference between two lifetime earnings which depend on common values for g and δ. In practice, however, we use qualifications rather than the years of schooling shown in equation (15), and the increments to earnings need to take account of the length of time it takes to achieve particular qualifications, in which case g and r feature.

Implementation of (15) also requires some assumptions on increments to lifetime earnings for those in compulsory education, e.g., children aged 4-15 in the UK system. Gu and Wong (2015) estimate this by discounting backwards the lifetime earnings of those who reach the age at which compulsory education ends, e.g., aged 16.

(16) $$li_{s,a,e,t} = sr_{s,16,e,t} \frac{1+g^{16-a}}{1+\delta^{16-a}} li_{s,16,e,t},$$

for 4<a<16 and e=1 and then calculate the increments for each year. Lifetime earnings for initial schooling are not being compared to any other level, effectively implying that a person who has no education would have zero earnings. An alternative would be to compare lifetime earnings at this first education level with assumed earnings for a person with no education. Below we experiment with assuming someone with no education would earn the minimum wage throughout their lifetime.

The value of the stock of human capital of students enrolled in schools at the beginning of the school year, $P_t^S S_t^B$, is implicit in (14) and (15). It is given by

(17) $$P_t^{S^B} S_t^B = \sum_s \sum_a \sum_e enr_{s,a,e,t} li_{s,a,e,t}$$

In contrast with calculations derived using (15), the values for stocks calculated via equation (14) or (17) are sensitive to assumptions used for the parameters g and δ, an issue that has been discussed in human capital literature, e.g., Abraham (2010); Jones and Fender (2011).

3.3 Volume and price indexes

The nominal values from (15) and (17) can be divided into volume and price components. The volume indexes for both education output and schooling assets inventory are based on a Tornqvist aggregation of education enrollments, using weights based on the estimates of lifetime income. The index for real education output uses the increment in lifetime labor incomes due to education, cross-classified by age, sex, and education level, as weights. The index for real schooling knowledge inventory stocks uses lifetime labor income (cross-classified similarly) at the beginning of the school year, i.e., we have

(18a) $$\Delta lnQ_t^E = \sum_{s,a,e} \overline{\varphi^Q}_{s,a,r,t} \left[ln(enr_{s,a,e,t}) - ln(enr_{s,a,e,t-1})\right]$$

(18b) $$\Delta lnS_t^B = \sum_{s,a,e} \overline{\varphi^S}_{s,a,r,t} \left[ln(enr_{s,a,e,t}) - ln(enr_{s,a,e,t-1})\right]$$

where $\overline{\varphi}^Q_{s,a,e,t}$ is the share of individuals with s, e, a in the total value of investment in education, averaged over year $t-1$ and t (i.e., a Divisia share) and $\bar{\varphi}^S_{s,a,e,t}$ is a similarly defined Divisia share in the total value of schooling assets inventory.

The price indexes for education output (P_t^E) and beginning-of-period schooling assets ($P_t^{S^B}$) are obtained by dividing the relevant nominal values by the relevant volume index from (18). Noting that the nominal value of human capital not held within the school system can be generated by subtracting equation (17) from equation (14), a volume and price index for this component of total human capital, Φ_t can be calculated in a similar fashion.

4 Measuring net investment in education: Conceptual issues

There are a number of issues to resolve in order to value equations (15) and (17), the net investment in human capital for persons enrolled in education and the value of the stock of human capital of students enrolled in schools at the beginning of the school year. The most important include the attribution of lifetime earnings to education and the utilisation of human capital through employment propensities and reductions due to dropouts. In what follows we also discuss the nature of the education progression of students, and volume measure and corresponding deflators. The discussion here refers, as examples, to specific issues that arise for the UK education data as the results in section 6 are only presented for that country. However, similar issues arise for the United States work-in-progress.

4.1 Attribution

What is the income of a person one year older with the same education level capturing? In Mincer's canonical wage equation, in which individual j's wage is a return to human capital, there are two key terms: one is a return to schooling (ED) and the other one a return to work experience (LX). This suggests that $HC_j = ED_j + LX_j$ where HC_j is individual j's total human capital and LX_j is the portion acquired through work, i.e. labor market, experience. From the point of view of the schooling system, this suggests schooling-produced knowledge assets can be defined as the present discounted value of expected wages of graduates upon entry to the labor market, i.e. when the return to experience is virtually nil. Then the income stream arising from education services should be constant at the graduation earnings through time. In that case the lifetime income stream only depends on how long the person is in the workforce after graduation.

The other extreme is to assume that all future labor income is attributable to the level of educational attainment of the individual. This amounts to using the full JF calculation. However, in our context it is difficult to justify this assumption. A practical solution might be to derive the wages on graduation as a $T-year$ average from the point of graduation. This could be justified by assuming some degree of asymmetric information whereby firms do not pay the full marginal product immediately in case the worker turns out to be a lemon.

Another approach is to use Mincer regressions, controlling for other influences, such as experience, which was the method used by O'Mahony and Stevens (2009) and O'Mahony, Pastor, Peng, Serrano, and Hernàndez (2012). While this method allows for direct modelling of the probability of employment, it leads to difficult econometric issues, mostly relating to identifying the difference between age and experience. We pursue this approach by modelling the following Mincer regression by sex and four age bands (age 16-19, 20-24, 25-29 and 30-80):

$$lnpay_{it} = \beta_1 exp_{it} + \beta_2 training_{it} + \beta_3 PT_{it} + \gamma' edu_{it} + \delta_t \tag{19}$$

where $lnpay$ is the logarithm of the individual i's gross weekly pay of the first and the second job (should the respondent have one) at time t multiplied by 52 weeks, exp represents the individual's years of work experience, training is a dummy variable to control for any job-related education/training programs respondants carried out in the last 4 weeks and PT reflects if the individual is part-time employed. The experience variable is constructed by taking the average graduation age at each qualification level and deducting that from the current age at time t. We control for education attainment using a vector of covariates (edu) representing the highest qualification obtained and employ individual year dummies for 1996 to 2018. From this model we obtain predicted average wages for full-time work at each of the formal qualification levels by sex and age band, net of a person's work experience. This is the approach used below.

4.2 Education progression, absence and drop outs

Education systems are typically organised around qualification rather than years of schooling. In the UK, for example, these are divided into four groups: GCSE or equivalent (the typical exam qualification attained usually at the age of 16), A-level or equivalent (the typical exam qualification for those who stay on at school, usually attained at age 18), further education (FE), which is post-secondary but below tertiary, typically vocational qualification that can either be a follow on from GCSE (or sometimes from A-level) and higher education (HE), tertiary education leading to a degree or equivalent. In the US, we divide qualifications into the following groups: high school diploma or equivalent such as GED (the typical exam qualification attained usually at the age of 17 or 18), some college but no degree (where an individual has attended college but did not receive any degree), 2 year associate degrees (which can be occupational/vocational or academic programs), 4 year degrees such as Bachelor's degrees and postgraduate degrees, which include Master's, professional school and doctorate degrees.

This means that assumptions need to be made to implement equations (15) and (17) in regard to progression across different types of qualifications. In both countries, we compare lifetime earnings of individuals with the lowest qualification, i.e. GCSE in the UK and high school diploma in the US, with someone with the same qualification but who is one year younger. In the UK, lifetime income of students with A-levels are compared with lifetime incomes of those with GCSE two years younger as the usual duration to attain that qualification is two years. FE are also compared with GCSE assuming a duration of two years while HE is compared to A-levels as most students go to University following A-levels rather than progression via FE qualifications. Here it is assumed it takes three years to attain the degree. This comparison is carried out for all students aged between 16 and 35 in the UK.

Progression is much more complicated in the US, where students can go directly to a 4 year college degree from high school or indirectly from a two year or even a community college degree. In our preliminary calculations for US, lifetime income of individuals with some college but no degree is compared with lifetime incomes of those with a high school diploma who is one year younger. Both, 2 year and 4 year degrees are compared with high school diploma assuming a duration of two and 4 years, respectively. Finally, lifetime income of postgraduates are compared with lifetime incomes of those with a 4 year degree who are three years younger. This comparison is carried out for all students aged between 16 and 45 in the US due to some enrolments even at older ages. We are currently experimenting with some alternatives so this is one reason why, in this version of the paper, we do not present numbers for the US education outputs.

Further complications arise when students are absent from school or drop out all together as these reductions in knowledge assets also have to be taken into account. If individuals enrolled in education do not complete their studies, or only partially attend a school year, their future earnings will be affected. For example, in England about 4 percent of sessions in primary and secondary schools are missed due to absence, although only 1 percent are unauthorized (Department for Education, 2018). Absences, however, tend to be concentrated on specific individuals so that in recent years around 10 percent of pupils aged 15 or younger are defined as “persistent" absentees, missing more than 10 percent of sessions. Although for older pupils the rate is slightly higher at around 13 percent, the trend has been declining for both age groups from 14 percent for the younger and from 23 percent for the older pupils in the 1990s. At the higher education level, the UK Higher Education Statistics Authority (HESA) statistics show that about 7 percent of young and 12 percent of mature full-time students enrolled in their first degree drop out within one year of starting that degree. The share of both, young and mature students dropping out of a higher degree program is around 16 percent. Absenteeism and drop out rates in the US are measured slightly differently. Data on drop out rates capture individuals enrolled in high school rather than higher education. More precisely, it captures the proportion of 15 to 24 year olds in grades 10 through 12 who leave high school between two grades without earning a high school diploma or a GED. It is around 4 percent for males and 4 percent for females. Pupils absent from school grades 4, 8 and 12 for 10 days or more account for around 3 percent of all male and 2 percent of all female pupils.

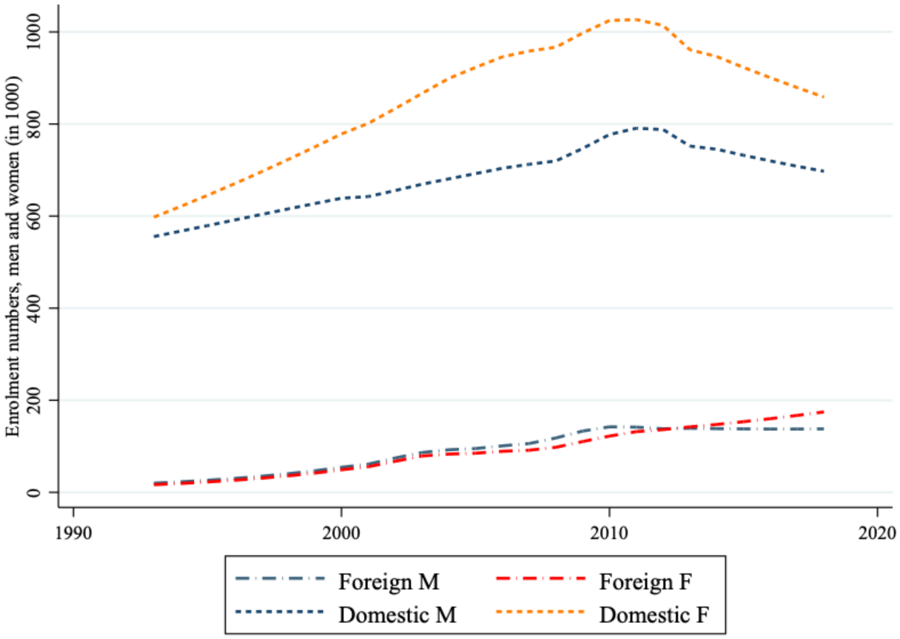
4.3 Foreign students

In viewing education as an intangible asset to be added to the national accounts, a complication arises when the people being educated come from abroad. The knowledge assets of graduates exiting the country needs to be excluded in the calculation of education services as national investment in social infrastructure, and we need to assume that the probabilistic full resource cost of the annual education of foreign students is charged to them (i.e. their charges reflect the costs of their education discounted by the probability they enter the domestic labor force). In this way P^E retains its interpretation as the price of schooling-produced domestic knowledge assets because the cost incurred in producing a foreign graduate is fully offset in revenues.

Trends in the foreign student share of UK education enrollments suggest the treatment of foreign students will have an impact outcome-based measures of education services. Figure 1 displays growth in foreign compared to domestic higher education (HE) male and female students. It shows that much of the growth in this sector in recent years has been in the international market with foreign students in 2018 comprising about 20 percent of the student population, from under 2 percent in the early 1990s. The figure shows that growth in foreign students' numbers dominate in recent years, especially for females, whereas the numbers of domestic students show a pronounced increase after the financial crisis but have dipped since 2011.

Current national accounting practice treats the education of foreign students as services exports on the expenditure side of the accounts, and correspondingly, payments by domestic nationals to foreign degree-granting institutions are treated as imports. The latter are ignored in this paper because there are very small in our applications, though the issue is relevant in a broader international context. Regarding foreign students, although It makes sense in our framework to only include those students who return home after graduation as exports, doing so requires adjusting current national accounting practices. The logic in favor of such a change is strong, however. Foreign HE students who remain (a) add to societal assets upon entry per equation (4) and, (b) raise domestic investment by more than exports are lowered given a positive returns to education relative to costs per equation (3) and rising foreign HE enrollments, such as shown for the UK in figure 1.

Figure 1: **UK enrollments in higher education by domicile and gender, 1993–2018**



SOURCE: Authors' elaboration of data from the UK Department of Education.
NOTE: Domestic includes EU citizens.

5 Application

5.1 Data sources

We use standard data sources to carry out the computations described above for the UK. These are:

- The cross-sectional quarterly Labour Force Survey for earnings and employment rates by gender, age and qualification.
- The cross-sectional quarterly Labour Force Survey for population estimates by gender, age and qualification which are benchmarked to published ONS estimates by gender and age.
- The longitudinal quarterly Labour Force Survey for enrollment probabilities by gender, age and qualification.
- Department for Education and Skills for school and FE enrollment rates by gender and age.

- Higher Education Statistics Agency (HESA) for unpublished HE enrollment rates by gender, age and students' domicile prior to enrolling in HE.
- ONS Life Tables for survival probabilities.
- Education expenditures from national accounts Personal Consumption and Classification of the Functions of Government (COFOG) tables.
- Foreign student fees from HESA and ONS.
- ONS national accounts and EU KLEMS for education sector and whole economy outputs and inputs.

For the US we use the following data sources:

- The Current Population Survey (CPS) for hours worked and earnings by gender, age, qualification and year. The national minimum wage by age band and year is taken from the Bureau of Labour Statistics and the Department of Labor.
- The CPS for all enrolment rates by gender, age, students' domicile prior to enrolling in 4 year or post graduate degree and year. However, Door data is used to benchmark enrolments by foreign students.
- National Centre for Education Statistics for drop out and absenteeism rates by gender, grade and year.
- National Vital Statistics System for survival probabilities by gender, age and year.

In the US outputs and inputs for the Education sector in national accounts, and in international productivity comparative databases such as EU KLEMS, only include private education. This represents only about 1 per cent of GDP. Most education services are classified under State and Local Government but outputs and inputs for the education part of this sector are not readily available. We are working with a number of data sources and assumptions to estimate these series.

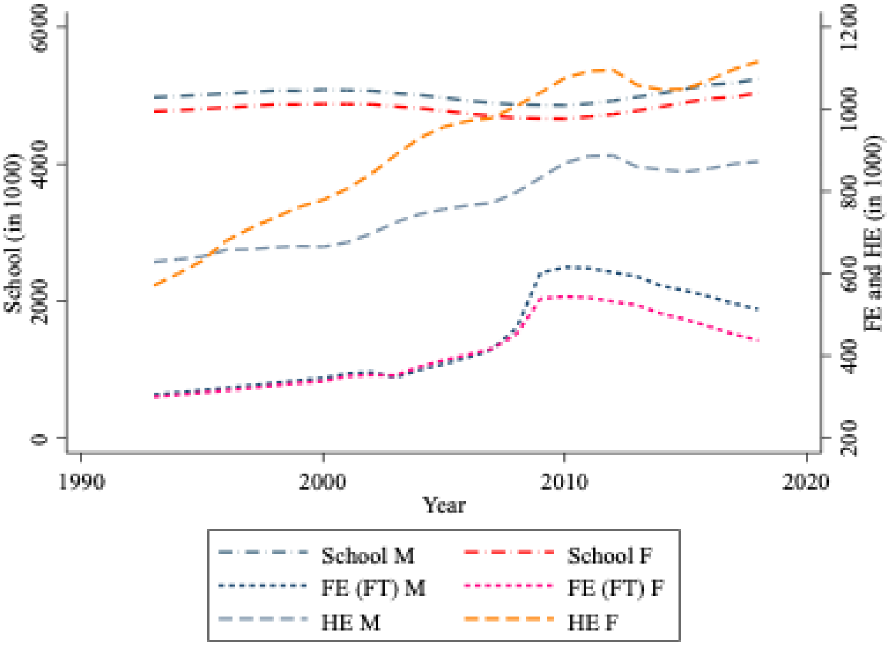
The results in the next sub-sections concentrate primarily on the UK as the data are close to being final. At the end of this section we briefly discuss results for the US.

5.2 Enrollments in the UK

Consider first the enrollment numbers in the period under study to get an idea of the composition of the UK education sector. Figure 2 shows the total numbers and the division by three groups, school, FE and HE. School is by far the largest group, reflecting that pupils typically spend 11 to 13 years in this form of education whereas they spend only three to four years in HE and about two years in FE. Enrollments in schools were relatively flat up to the mid 2000s but started to increase in recent years.

The enrollment trends in the UK in recent years are mostly determined by demographic trends. The UK followed a similar path to other countries in having a declining native population, but the large-scale immigration witnessed in the 1990s has had a knock-on effect a decade later in raising the school age population. The wave of migrants from EU countries following enlargement has increased the number of children of schooling age, as the migrant were typically young when they entered the UK, settled and then had slightly higher than average family sizes. There were increases in enrollments in HE up to 2012 but a slight dip thereafter, with the increases in foreign students not quite compensating for the dip in domestic students. This decline is likely to be a consequence of the introduction of full cost fees for most university programmes in 2012. Both FE and HE show a “financial crisis" effect, whereby students stay on in education in recessions, but it is more pronounced for FE. Figure 2 further suggests higher growth in school enrollments among females, a trend that is observed in many countries.

Figure 2: **UK enrollments, Composition by type 1993–2018**



SOURCE: Authors' elaboration of data from the UK Department of Education.

5.3 GDP adjustments

In existing GDP, education costs are counted as consumption. From the perspective of final demand, consumption of education services consists of an imputed component plus the actual tuition and fees that households pay to educational institutions for teaching and degree-granting services. On the production side, the products of the education services industry consist of (a) teaching and formal degree-granting services that are components of final demand, and (b) training and vocational services and (c) ancillary services. Products in (b) and (c) are a mix of intermediates and final demand. The major product groups in the industry are listed in columns (1) and (2) of table 2; column (3) indicates whether they are included in the analysis in this paper.

The products we work with in this paper are components of final demand. When GDP is expanded to include the contribution of formal schooling to current human capital production as investment, an estimate of the schooling-produced increment to human capital replaces the actual education outlays and cost-derived imputed services terms on the expenditure side. On the production side we add the net effect of this substitution to the gross output of the education industry. The addition is positive and generally substantial but not nearly as large as the value of investment in human capital relative to existing GDP in Jorgenson and Fraumeni (1992, 1994).

Table 1: **Products of the Education Industry in National Accounts**

Product Group	Product	Included in paper?	Comments
(1)	(2)	(3)	(4)
EP0-EP1	Pre-primary primary education	Y	Cannot reliably separate pre-primary, i.e., “reception", spending from primary education in the United Kingdom (UK). Pre-primary, i.e., “pre-school? in the United States (US) and primary are thus grouped in our analysis, and thus in included. Primary school years 1-6 in the UK correspond to elementary grades K-5 in the US.
EP2	Secondary education, and post-secondary non-tertiary education[a]	Y	Secondary school years 7-13 in the UK correspond to middle school grades 6-8 and high school grades 9-12 in the U.S. Secondary school grades in the U.S. and years in the U.K. thus are different but under normal progression, each system ends with students aged 17 and 18. Includes Further Education Colleges in the U.K.
EP3	Higher Education	Y	Includes Batchelor’s, Master’s and Doctoral degrees. Includes Associates degrees in the U.S.
EP4	Cultural and sport and recreation education services	N	Excludes the provision of such services by academic schools, colleges, and universities.
EP5	Vocational training and other education services	N	EP5 and EP6 include computer training and management training services and any type of vocational training that is provided by an employer.[b]
EP6	In-house training	N	Involves extension of the SNA boundary. Included in INTAN-Invest estimates of intangible investment.[b]

SOURCE: Authors’ elaboration of information from various sources. For more details on the specific activities in the product groups listed in column (1) and their correspondence to international industry classification codes and other classification schemes, see United Nations (2019), Annex 3.1, Tables 3.1.1, 3.1.2, and 3.1.3. Product names in column (2) reflect international terms.

NOTES: a. Post-secondary “non-tertiary" education straddles the boundary between upper secondary and post-secondary education; see https://stats.oecd.org/glossary/detail.asp?ID=5408 for further information. b. These are investments in the Corrado et al. (2005, 2009) intangible investment framework; for further information, see www.intaninvest.net .

As mentioned previously, we believe costs and returns to formal schooling should be examined at different levels, and that doing so is likely to prove useful in international comparative analysis. The United Nation's Task Force on Satellite Accounts on Education and Training recently released a compilation guide for national statistical offices (United Nations Economic Commission for Europe, 2019). The work discusses the necessary data sources for measuring the costs of education by product type and for understanding how the financing of each type is set out in national accounts according to sector (Households, Nonprofits, For-profit business, Governments, Rest-of-world). The work was supported by pilot testing in five countries with different circumstances and organization of educational institutions. One of the countries was the UK, and the details and examples provided for the country suggest that level estimation is possible; corresponding data for the United States are under development.

Table 2 shows our estimated nominal value of education outputs, averaged from 2010 to 2018, and the implied uplift to GDP from replacing the current national accounts numbers by our estimates. In the original Jorgenson-Fraumeni analysis, and the more recent version in Christian, Fraumeni, and Samuels (2017), adding lifetime-income based measures for education services to national accounts more than doubles GDP, an adjustment that sits hard with national accounts statisticians. Note, the JF calculations value non-market time, i.e. time not spent in work or maintenance (sleeping and eating), which we avoid in this paper. In our basic calculations, adjusting for attribution using the Mincer regression approach, GDP is raised by about 16 percent, on average since 2010, which is not trivial. Table 2 then shows the results if adjust for school absence, HE dropouts and HE foreign students, where in the latter case we replace our estimated lifetime earnings by the tuition fees charged to these international students. The three adjustments combined imply a 12 per cent GDP uplift. Although significant, an adjustment of this size is more palatable and not higher than adding other intangibles, along the lines of those calculated by Corrado et al. (2005, 2009). The final two rows incorporate the more radical assumption that schooling lifetime earnings up to age 16 should be compared to earnings of a person on minimum wage throughout their lifetime. This has a very large impact, and combining this with the other adjustments in the table would imply an uplift to GDP of only 7 per cent.

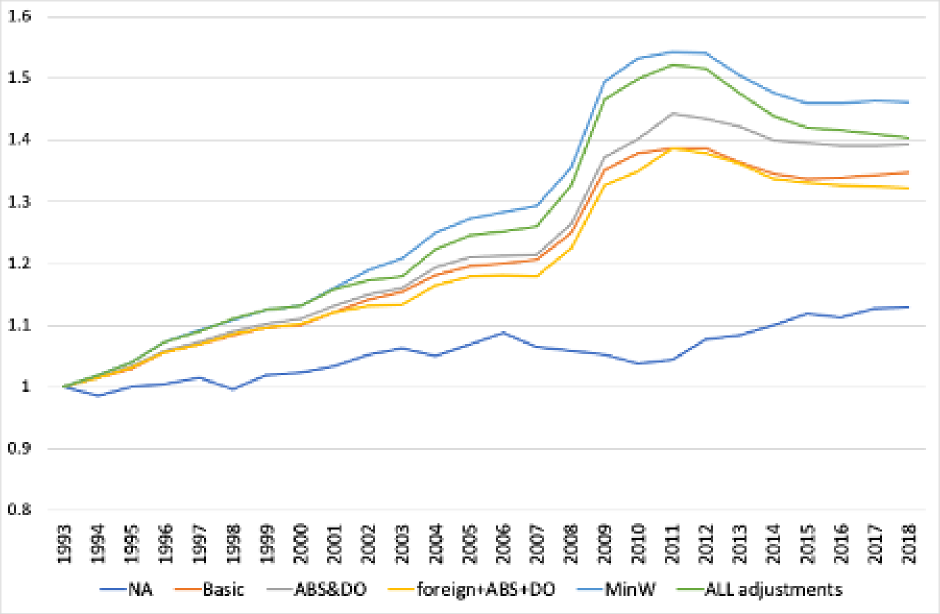
Table 2: **Value of education outputs, UK (average 2010 to 2018)**

	Value (£m)	Relative	GDP uplift
Mincer	503,364	1	1.16
Mincer adjusting for absence	487,704	0.97	1.15
Mincer adjusting for HE drop out	486,419	0.97	1.15
Mincer adjusting for absence and drop out	470,759	0.94	1.14
Mincer adjusting for foreign students	473,811	0.94	1.14
Mincer adjusting for absence, drop out and foreign	441,205	0.88	1.12
Mincer adjusting for min wage	402,578	0.80	1.10
All adjustments	348,685	0.69	1.07

5.4 UK real education output

Figure 3 shows our new estimates of real UK education output (indexed to 1 in 1993) for some of the variants included in Table 2 and compares it with the trajectory of measures currently included in national accounts (labelled "NA"). The basic new measure, without any adjustments shows a steady growth, on balance, through about 2010 followed by slower growth thereafter. Over the entire period our measure of output growth significantly exceeds that in the national accounts. These estimates are used in our productivity calculations below. The highest growth is when we adjust the schooling outputs to take account of the minimum wage. In this case the weight on schooling is reduced and that on the faster growing HE is increased. Note that the national accounts education sector produces more than teaching pupils, e.g., hospitality services for HE students, but these additional outputs tend to be small.

Figure 3: **Real UK education output, 1993–2018**



Our preliminary estimates of the nominal value of output for the US suggests similar orders of magnitude to the UK, once we allow for the greater US population size and the exchange rate. The growth in real output for the US is also of a similar order of magnitude. However, in contrast to the UK, the US growth in education output based on increments to lifetime earnings, appears to be lower than in the national accounts. Some more work is needed to understand the latter and how it is measured.

6 Productivity analysis

This section presents preliminary estimates of productivity for both the education sector and aggregate GDP. These are based on the analysis in section 2 but here we adjust the outputs and inputs for the education sector rather than using the more detailed analysis of expenditures discussed above and, as noted earlier, we do not have time series data to properly adjust for foreign students at this time. Our basic data on outputs and inputs come from the most recent version of EU KLEMS, with the analysis carried out for the period 1993 to 2018. The main reasons for using EU KLEMS are that it includes nominal gross output figures, allowing us to remove intermediate expenditures from our education output figures, and the database calculates a capital services rather than a capital stock measure.

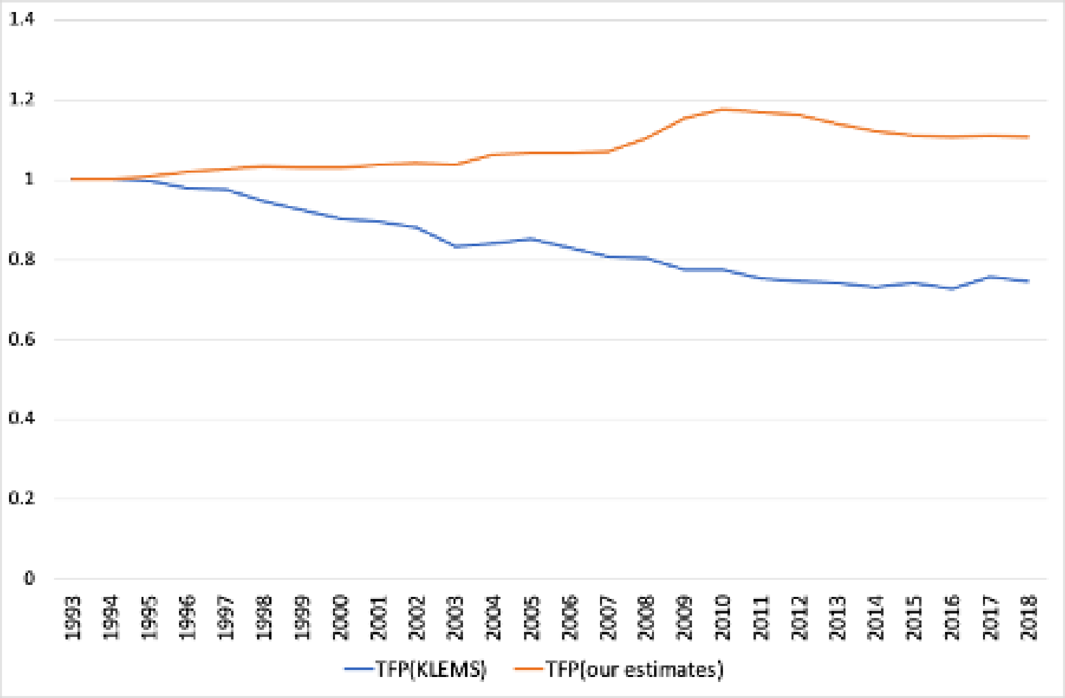
In the education sector both nominal and real output are replaced by our output measures and we include the real stock of human capital of students enrolled in schools as an additional input. Although we include the original EUKLEMS nominal payments for capital and labour, including our education output figures radically alters the shares of these inputs, with the highest share now being that associated with the education stocks term. For aggregate GDP we adjust nominal GDP by the difference between our measure and nominal output for education sector in the existing national accounts and calculate real GDP using a deflator that is a Tornqvist index of the existing GDP deflator and our derived education output deflator. Again nominal payments for labour and capital are unchanged. Labour services adjust for the composition of the labour force so human capital for the working population is taken into account. As for the education sector we add education human capital stocks as an additional input. In keeping with the TFP calculations in EU KLEMS the calculations use Tornqvist indexes throughout. Turning first to the education sector, Figure 4 shows TFP growth from EU KLEMS and our measure. In the UK, the national accounts based TFP growth has been falling steadily in the education sector over these two decades, which is a difficult result to explain. Our measure, in contrast, shows a little growth, although mostly up to 2010 is about zero, followed by a slight decline thereafter.

Table 3 reports figures for TFP growth in the aggregate economy and the education industry sector. There are, we believe, several interesting findings. First, our adjusted total economy TFP growth is below the national accounts measure. Second, including our new education sector measure has little to no impact on aggregate TFP growth since 2007. Third, while incorporating our new TFP measures for education lowers UK total economy TFP growth, they also imply less of slowdown in TFP growth since 2007.

These results reflects several counteracting influences: Although our estimates of the education sector's TFP performs better than the measure in the national accounts, our estimate of the education sector's TFP growth is still lower than that for other sectors. Given this, and that our calculations substantially increase the share of education in aggregate GDP, it is not surprising that the impact of our new measures is to lower TFP growth for the economy overall.

Our first estimates for the US show a similar pattern. Aggregate TFP growth is lower after adjusting the education sector output. However the slowdown after 2007 is less pronounced.

Figure 4: **Index of TFP, UK education sector, 1993–2018**



NOTE: For definitions and sources of series, see text.

Table 3: **TFP in the UK education sector and total economy (1993 to 2018, percent change, annual rate)**

	Education Sector		Total Economy	
	Original	Adjusted	Original	Adjusted
1995-2018	-1.17	0.29	0.60	0.53
1993-2007	-1.52	0.46	1.05	0.87
2007-2018	-0.72	0.07	0.01	0.10

7 Conclusion

This paper treats spending on formal schooling as investment, i.e., as social infrastructure, and finds that the framework yields estimates of potential interest to productivity analysts and national accountants. The Jorgenson-Fraumeni lifetime income framework is adapted to develop estimates of (a) education output as the increment to lifetime income due to this year's schooling and (b) "schooling knowledge inventory," the amount of knowledge held within the school system until students graduate (or dropout) and enter the labor force. This inventory is an additional factor of production in the economy, and GDP is raised by the value of the return to these stocks. In a case study for the UK (US estimates are under development as of this writing), the new estimates of real education output imply higher estimates for TFP in the industry. The value added by the education industry is substantially larger in the social infrastructure framework than it is in existing GDP, and our results suggest that incorporating the new TFP estimates for the education industry lowers UK total economy TFP growth for the 1993 to 2018 period as a whole. That said, we also find that incorporating our new TFP measures for the UK education sector imply less of a slowdown (about 0.3 percentage points per year) in the country's TFP growth since 2007.

The underlying trends in the estimates for education output services for the UK that this paper develops reflect, at least in part, declining enrollments in schools coinciding with increased expenditure. But we still do not have all aspects of the story for the UK (international trade flows, and a full breakdown of costs and investments across levels of education), nor have we completed the comparison with the US that we believe will provide insights into some of the drivers of, and interactions between, school system performance and national labor markets. Expanding the social infrastructure approach to include training would help in developing those insights. The intangibles framework already takes the employer-provided training component on board as investment, including it as a component of "economic competencies," for which estimates of purchases and own-account production are available via INTAN-Invest.

We also wish to examine the robustness of the assumption that the best estimate of a person's future income is that of a similar person one year older. This may not hold in practice due to changes in demand and supply affecting different cohorts. On the supply side if there is a large expansion of education in some cohorts, their returns will likely decrease, and their expected future income might not be equivalent to older cohorts with the same education. Against this if new technology increases the demand for younger people, they might earn more than older cohorts. Bowlus and Robinson (2012) suggest a method to estimate vintage effects whereby new graduates may differ in terms of the labor services per hour that they supply, relative to previous cohorts. Their results for the US suggest large positive cohort effects for college educated workers. Papakonstantinou (2017) estimates similar results for the UK. See also Jones (2014) for a cross country analysis.

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