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The fiscal implications of the UK's post-Brexit migration policy

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Abstract: This paper uses a sophisticated Overlapping Generations (OLG) model to examine the fiscal impacts of immigration to the UK, disaggregated by age, place of origin and degree status. We find that in 2019 alone, the flow of immigrants was worth a total of £370 billion to the UK government in terms of net present value. We also show that there remains considerable scope to increase this contribution by changing the demographic mix of immigrants, and we model a range of scenarios for the UK's post-Brexit migration policy to illustrate the potential gains.

We innovate and expand on previous approaches to this problem in some key respects. We are the first to capture the effects of falling mortality and fertility rates, and to quantify the indirect effects of migration on the budget via the savings and labour market channels on wages and interest rates. In the closed economy framework, we find that these effects are extremely strong and dominate the direct fiscal effects. Finally, we believe we are the first to consider the use of return migration as a potential policy variable.

Keywords: General equilibrium; Immigration; Population aging; Public Debt

JEL: H62; H63l E62; H55; J6; J1

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1 Introduction

This paper uses a sophisticated Overlapping Generations (OLG) model to examine the fiscal impacts of immigration to the UK, disaggregated by age, place of origin and degree status. Our central finding is that migration in the aggregate has made and will continue to make a positive contribution to the UK's public finances. We find that in 2019 alone, the flow of immigrants was worth a total of £370 billion to the UK government in terms of net present value. This strong result arises due to the interelated combination of a greying UK population and negative real interest rates. However, we also show that there remains considerable scope to increase this contribution by changing the demographic mix of immigrants, and we model a range of scenarios for the UK's post-Brexit migration policy to illustrate the potential gains. In line with both theory and the prior literature, we observe that migrants with degrees make a more strongly positive contribution than those without. However, we also uncover substantial age effects with younger migrants typically making a much more positive fiscal contribution.

We make extensive use of the UK Labour Force Survey (LFS), a quarterly rotating panel survey containing detailed information on wages, working hours, education and migration status. In section 4, we follow Dustmann et al. [2010] and Oxford Economics [2018] in using the LFS to estimate household characteristics and taxes at a granular level. Following Dustmann and Weiss [2007], we also use the LFS to estimate the extent of return migration and hence the typical duration of stay for a UK immigrant. We also take a range of data from the UK's Office for National Statistics (ONS) on historical and projected fertility, mortality and migration rates to simulate an accurate model of the UK's changing population structure. In section 5, we then feed this data into a non-stochastic OLG model in general equilibrium to obtain precise estimates of fiscal contributions by different demographics.

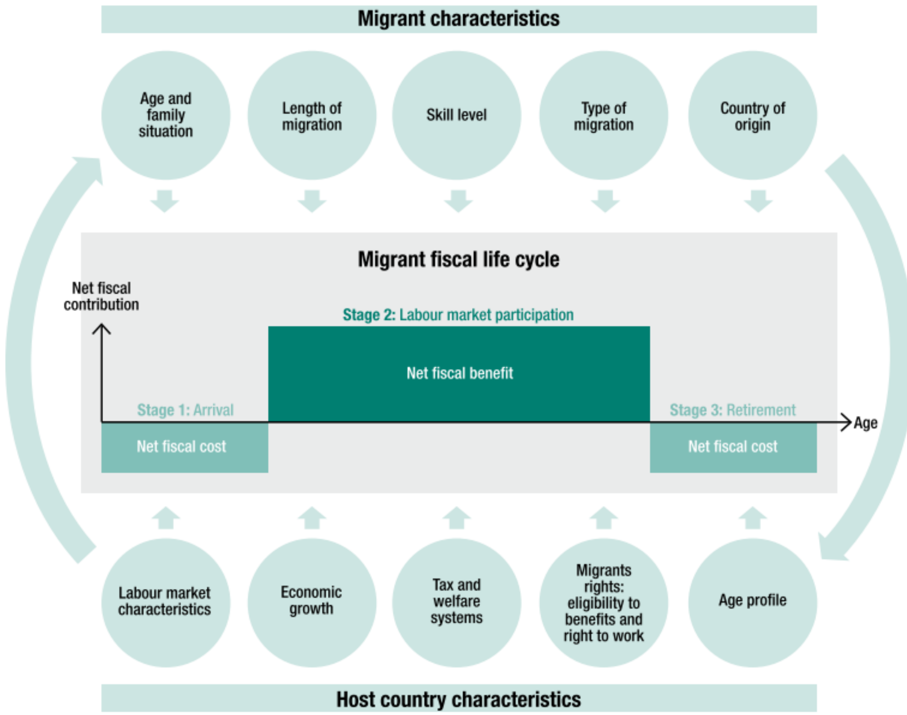
Our motivation is the change in migration policy planned by the UK government in the wake of exiting the European Union ("Brexit"). Migration was a crucial issue throughout the referendum campaign (see e.g. Portes, 2021b), and survey evidence suggests that UK voters care more about the fiscal impacts of migration than the labour market implications [Dustmann and Preston, 2007]. As noted by Dustmann and Frattini [2014], this makes it all the more curious that relatively little attention has been paid to the fiscal implication of migration compared with the high volume of work on the labour market implications. Although it is undoubtedly true that UK policymakers will also be considering non-fiscal factors when designing future migration policy, our work suggests migration has sufficiently large fiscal implications that this should be a major factor guiding their decision.

We expand and innovate upon the previous literature on the fiscal impacts of immigration in several key respects. We believe we provide the most detailed general equilibrium approach to date, and the first to capture the effects of falling mortality and fertility rates. We are also the first to quantify the indirect effects of migration on the budget via the savings and labour market channels on wages and interest rates. In the closed economy framework, we find that these effects are extremely strong and dominate the direct fiscal effects. Finally, we believe we are the first to consider the use of return migration as a potential policy variable and show that there is a clear fiscal argument for making long-term visas or "indefinite leave to remain" much more accessible to young migrants with degrees.

2 Literature Review

An excellent systematic review of the literature on the fiscal impacts of migration was recently conducted by Hennessey and Hagen-Zanker [2020], and this section draws heavily upon their work. Their primary conclusion was that surprisingly little work has been conducted into the fiscal impacts of migration as compared to the labour market impacts, and consequently there is a great deal of uncertainty. However, they do draw some lessons from the existing literature. Firstly, they find that the age and skill type of migrants matters a great deal, with younger and more highly-skilled migrants having a comparatively more positive fiscal impact for the receiving country. Secondly, the policy environment of the host country

Fig. 1: Factors influencing the fiscal impact of immigration



Source: Figure 3 in Hennessey and Hagen-Zanker [2020]

is also a huge influence, especially the flexibility of the labour market and the extent to which migrants can access formal employment and welfare benefits. Figure 1 illustrates the most important personal and national factors affecting a migrant's "fiscal life cycle".

Hennessey and Hagen-Zanker [2020] divide the existing work into four groups: "Static" , "Net Present Value" (NPV), "Generational Accounting" (GA) and "Macroeconomic". The first three approaches are all essentially backward-looking: they look at what migrants *have* cost and/or contributed in a particular year; the NPV and GA approaches then apply adjustments using the migrants age profile and the government's fiscal projections to produce an estimate of a lifecycle impact. The most comprehensive approach is what they term a "macroeconomic" assessment, which use a General Equilibrium (hereafter "GE") model to incorporate indirect effects through "changes in wages, employment, consumption and savings" (ibid). This is the methodology that will be adopted throughout this paper, and will be referred to as the GE approach. Section 5.2 provides an estimate of the direct effects only, which we then use in section 5.3 to quantify the indirect effects.

The only GE approach to include the UK is Berger et al. [2016], who use an open-economy GE model and a sophisticated demographic model including partial skill heritability to assess the impacts of migration on four "representative" European countries. They look at the impact of expected future flows, rather than the impact of an individual migrant, and conclude that migrants will make a positive fiscal contribution to the UK equivalent to raising labour income taxes by 2.1 percentage points. However, this paper improves upon their methodology in several respects. Firstly, Berger et al. do not account for re-migration, which is known to be especially important in a UK context [Dustmann and Weiss, 2007]. Secondly, they use an open economy model that removes the possibility of a changing interest rate and consequent effects on consumption and saving. And thirdly, they do not consider dynamic government spending, mortality or fertility, instead treating these variables as constant across time. We have not found any previous GE approach that addresses this third point with respect to mortality and fertility, and we believe this to be a significant point of innovation in this paper.

There are three other UK studies worth highlighting. Dustmann et al. [2010] and Dustmann and Frattini [2014] are the most comprehensive retrospective approaches, using data from the UK's Labour Force Survey to assess the actual impact of migrants over the 1995-2011 fiscal years. They find a positive effect of £4.4 billion for EEA migrants and a negative effect of −£117.9 billion for non-EEA migrants, which they partly ascribe to differences in the number of children and consequent schooling costs. They note that schooling costs are a controversial issue within the literature, as it is theoretically unclear whether these costs should be assigned to the migrant or their child, especially when the child is born to both a native and migrant parent. This issue is obviated by a GE approach, and so does not affect the results of this paper. As with all retrospective approaches, the results do not account for either the lifecycle impacts changing labour market behaviour and aging (a crucial omitted cost) or the indirect effects through labour market effects and interest rates. Rowthorn [2014] also notes that Dustmann and Frattini likely overstate some taxes paid by migrants, notably corporation tax, alongside a discussion of their treatment of marginal and average effects.

Oxford Economics [2018] does attempt to capture the lifecycle impacts. They use existing migrants at a given age as a predictor for new migrants once they reach that age, thus making the implicit assumption that there are age effects, but no cohort effects. They find that both EEA and non-EEA migrants have positive fiscal effects, with a marginal net-present-value of £78,000 and £28,000 per migrant respectively. This is still a fundamentally retrospective approach built upon what migrants have cost/contributed, and relies on the assumption that the characteristics of migrants today approximate those of migrants several decades ago. This is unlikely to be the case, due to significant shifts in gender dynamics, rising healthcare costs, the UK's pension structure and the skill composition of migrants. They again highlight the crucial role played by education; migrants have the significant fiscal advantages of being both more skilled (on average) and having no cost of education from a UK perspective.

Outside of the UK literature, we would also call attention to Storesletten [2000] which is to our knowledge the first and only paper to consider the effect of return migration rates on a lifecycle model of fiscal impact. In the context of the USA, Storesletten finds that the fiscally optimal migrant is highly skilled and aged 38, which strikes an ideal balance between expected number of children (a negative) and remaining tax-paying years of labour (a positive). As with the approach of this paper, Storesletten models return migration as exogenous[1] but decreasing in duration stay such that established migrants are very unlikely to leave. A lower rate of return migration is found to improve the fiscal balance for highly skilled migrants, but worsen it for less skilled groups.

There is also an extensive literature on the labour market impacts of migration, which this brief review will only touch upon as this issue is tangential to the core material of the paper. Dustmann et al. [2008] highlight that the effect on native wages can run in either direction, depending on the skill mix of the migrants, the elasticity of capital supply and the degree of substitutability between migrant and native labour. They find that in the UK, migrants have a positive impact on labour markets outcomes for skilled natives, and a negative impact for unskilled natives. This finding is echoed in Kleemans and Magruder [2018], who find that migrants reduce local wages and employment and this effect is strongest for low-skilled locals. Wage effects are most dramatic in the informal sector (−2.5 percentage points) and employment effects are most drastic in the formal sector (−0.32 percentage points); this suggests that in the highly formal UK economy employment effects are likely to be more important. However, this is only a short-run impact and we would expect no long -run change.

Conversely, Albert [2021] estimates a positive short-run effect of migration on native wages and employment. He calibrates a standard job-search model where natives and migrants are identically skilled, but migrants have reduced bargaining power due to reduced access to unemployment benefits and the risk of

[1] This is a simplification, but one supported by the evidence; Gröger [2019] finds that income shocks do not appreciably change the rate of return migration. This is likely due to the sunk costs of migration making migrants "sticky" once they have arrived

deportation. Lower migrant wages prompt a job-creation effect of more than one-for-one, which improves native labour market outcomes. In summary, the labour market effects of migration remain contested and are likely to be context-specific.

3 Model

The model is estimated in three components. Firstly, section 3.1 sets out a demographic transition model which we use to represent the underlying UK population across time and to capture the demographic impact of migration. Secondly, section 3.2 implements a non-stochastic neoclassical model to solve for agent behaviour in each demographic subgroup given prevailing wages and interest rates. Finally, section 3.3 sets out the macroeconomic model, and explains the solution strategy for obtaining prevailing wages and interest rates consistent with demography and optimal agent behaviour.

3.1 Demographic model

The demographic model stratifies the population by four factors:

- Age (0-99)
- Country of Birth (UK, EEA, or non-EEA)
- Age at migration (0 for UK natives, 0-45 otherwise)
- Skill type (High or Low)

This means that at any time t, there are a total of 200 subgroups of UK origin and 9200 each of EEA and non-EEA origin, for a total of 18600 subgroups. Migrants are split by age of migration to allow analysis of age-controls on migration such as in Storesletten [2000].

In each time period, the population is updated using mortality, fertility and migration rates. Mortality and fertility rates are held constant across country of origin and skill type, but vary by both age and model-year. A fraction γ_{it} of those aged i at time t survive to the subsequent year. γ_{99} is set to equal 0 to ensure death arrives promptly before age 100. γ_{it} varies by year to account for improvements in healthcare across the time horizon modeled. This is illustrated in figure 2.

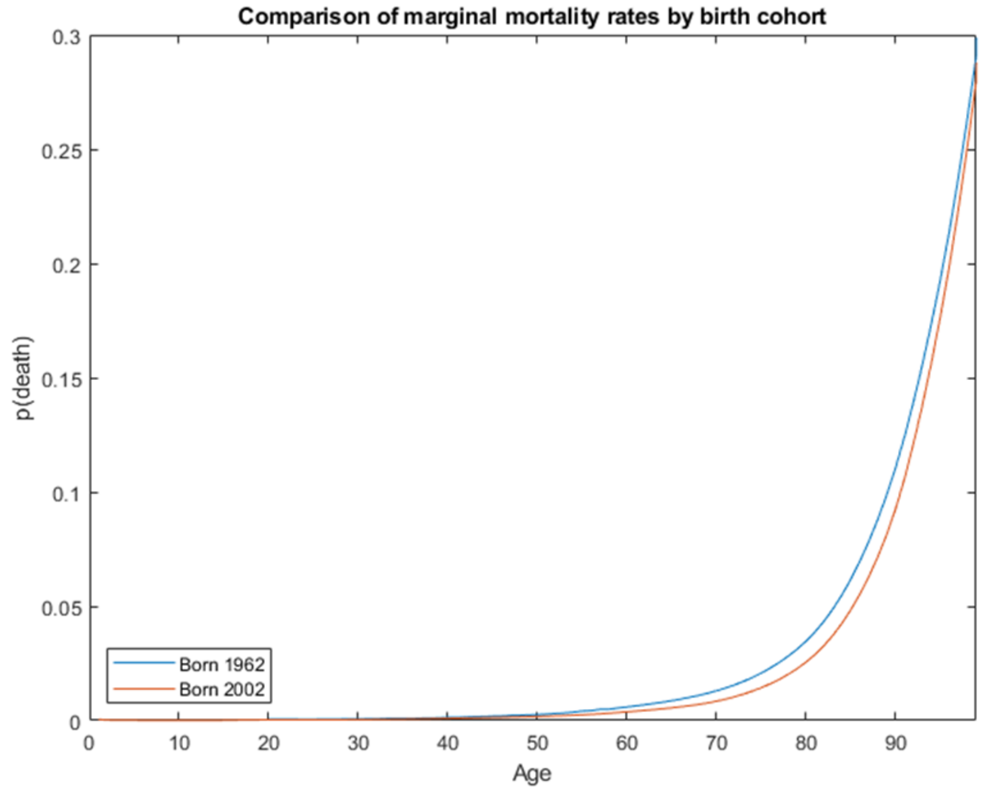
We believe it is important to model changing mortality and fertility rates, rather than holding them constant as is standard in the literature, due to the sheer scale of the implied demographic change across our period of analysis. In 1981, at the beginning of our simulation period, the UK has an Old Age Dependency Ratio (OADR)[2] of 0.24. By 2020 this has fallen slightly to 0.20 courtesy of significant immigration outweighing a generally declining fertility rate. However, by the end of our simulation horizon[3] in 2131, it is projected to have almost doubled to 0.37. This "greying" of the population has stark implications for government budgets, wages and interest rates, and we believe it is vital to capture this seismic demographic shift in our model.

Total births are calculated as $Births_{t+1} = \sum_{i=15}^{44} f_{it-1} \times n_{it-1}$, where f_{it} is the fertility rate at age i at time t and n_{it} is the number of people aged i at time t. Fertility is allowed to vary across time to reflect the decline in UK fertility since 1981. The children of migrants are treated as UK natives, a plausible approximation as children of migrants are very likely to assimilate. An exogenous fraction f_s of births are designated high-skill, and the remainder $1 - f_s$ are designated low-skill.

[2] Defined as the number of retired adults per adult of working age

[3] Our simulated OADRs are fractionally lower than the observed UK values, which according to Office For National Statistics [2018c] were 0.29 in 1981 and 0.28 in 2020. This is primarily because we do not model outward emigration by UK natives, which would tend to increase the OADR.

Fig. 2: Example mortality paths



f_s is not time-varying, and is constant across migration status and parental skill-type. This implicitly assumes that skill level is non-heritable. This is unlikely to be true and some previous work in this literature such as Berger et al. [2016] instead assume skill is partially heritable. We elect not to do this for two reasons. Firstly, no precise estimate of the degree of heritability exists, and such estimates are very sensitive to the metric of ability used. Second, we would prefer to avoid the possibility that migration improves the fiscal balance by improving the gene-pool as this would be an extremely contested finding.

Skill type does vary by country of origin however; a fraction f_{sE} and f_{sO} of EEA and non-EEA migrants are highly skilled. These are taken as exogenous and time-invariant. Total migration is modeled as a fraction of total population for each origin $M_t^O = m_t^O N_t$ for each origin O. This is allowed to time-vary to account for changing patterns of migration.

Recent migrants are then permitted to "re-migrate". As in Storesletten [2000], the fraction who re-migrate is taken as exogenous for each origin and return migration is assumed to only take place in the first seven years. This is an important feature of the model as a very high fraction of recent migrants to the UK choose to leave again [Dustmann and Weiss, 2007]. This is taken as time-invariant due to data limitations.

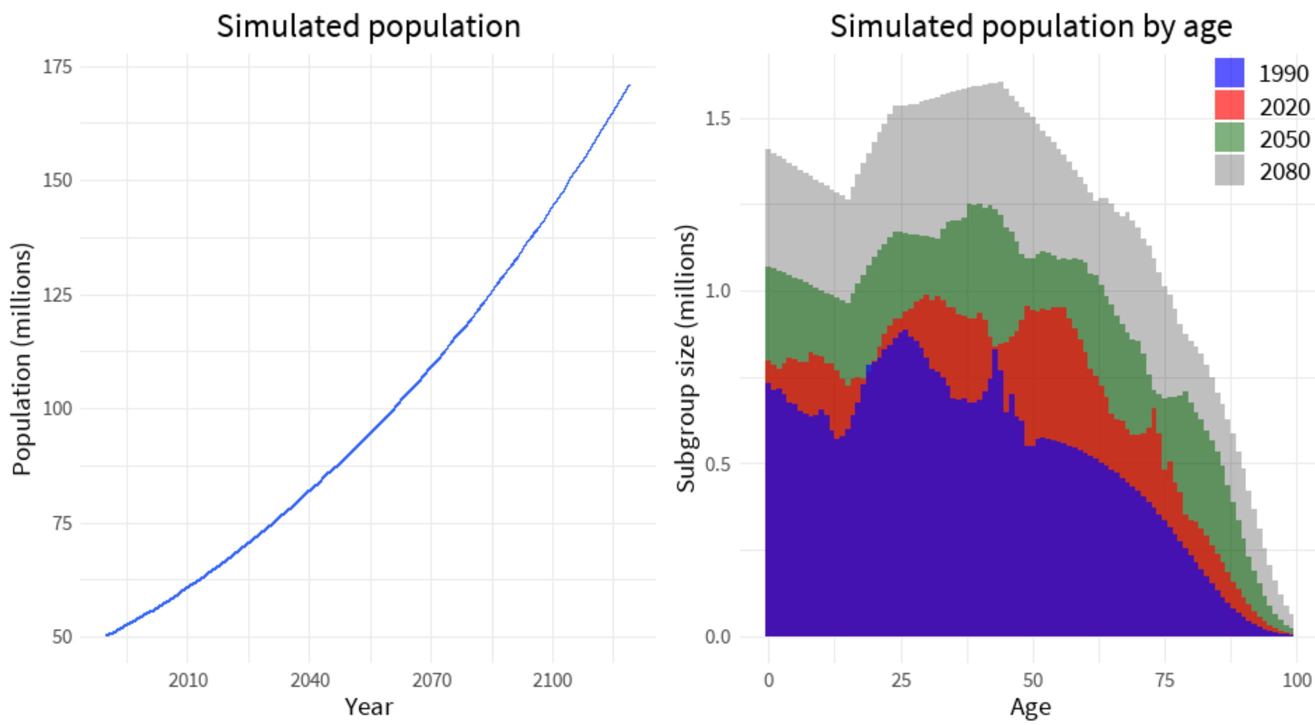
The model is calibrated to give the correct total population of 66.65 million in 2019. The fiscal impact of migration is calculated by modeling an unanticipated, exogenous arrival of 1000 migrants of the relevant demographic in 2020, the demographic model then updates to account for the long-term demographic impact of their arrival.

Figure 3 illustrates the total population N_t across time and the age distribution at selected dates.

3.2 Individual model

Individuals act to maximise expected lifetime utility given wages, interest rates, mortality and government spending/taxation. The utility function is based on Heijdra [1998]:

Fig. 3: Simulated demographics



$$U_j = \sum_{t=j}^{99} \Gamma_t \beta^{i-t} \left(\frac{\bar{c}_t^{1-\sigma}}{1-\sigma} \right) \tag{1}$$

Where $\Gamma_t = \prod_{i=1}^{t} \gamma_i \in [0,1]$ is the cumulative probability of survival to age t, $\beta \in (0,1)$ is the discount factor, and:

$$\bar{c}_t = c_t - \psi(h_t)$$
$$\psi(h_t) = \frac{\bar{h}_t^{-\eta} \cdot h_{j,t}^{1+\eta}}{1+\eta} - \tilde{h}$$

c_t and h_t are consumption and labour supply at time t, and $\bar{h}_t$, $\tilde{h}_t$, σ, η, κ and θ are all parameters. σ and η can be interpreted as the elasticities of intertemporal substitution and labour supply with respect to wages. $\bar{c}$ can be considered "labour adjusted" consumption, i.e. consumption net of some effort cost $\psi(h_t)$. This implies that utility is seperable in consumption and labour. $\bar{h}_t$ controls the effort cost of labour at age t, and $\tilde{h}$ is used to normalise the effort cost to zero at a particular age.

Individuals become economically active at 18 if they are low-skilled and 21 if they are high-skilled, and face mandatory retirement with $h_t = \psi = 0$ from retirement age A_r. They then face the budget constraints:

$$(1+\varphi) c_t + \gamma_t a_{t+1} + T_t = \tau w_t h_t + r_t a_t \tag{2}$$
$$a_{100} = 0 \tag{3}$$

Where φ is the rate of indirect taxation, τ is the rate of income tax on wages and T_t is lump sum taxation t, which may be negative if they pay less in lump-sum taxation than they receive in lump-sum benefits.

Individuals are assumed to leave no bequests, any assets remaining at death are distributed via reverse-life-insurance as in Blanchard [1985]. Note that c_t, h_t, $\tilde{h}_t$, $\bar{h}_t$, w_t a_t, τ and T_t will all vary across demographic subgroups but we omit the superscript for clarity of exposition.

Solving the model reveals a standard Euler equation and intratemporal labour supply:

$$\left(\frac{c_{t+1}}{c_t}\right) = (\beta r_{t+1})^{\frac{1}{\sigma}} \tag{4}$$

$$\left(\frac{h}{\bar{\bar{h}}}\right)^{\eta} = \frac{\tau w_t}{1+\varphi} \tag{5}$$

In which γ_t and all taxes have conveniently dropped out of the Euler equation, but enter via the labour supply decision and the budget constraint equation 2.

For a given set of wages and interest, the household problem is then solved numerically via backward shooting. Specfically, we apply the Euler equation to the household budget to obtain an equation for a_t as a function of a_{t+1}, a_{t+2} and parameters. We have as given that $a_{100} = 0$, so given a guess for a_{99} we can derive the implied lifetime path for household assets. We then solve for the a_{99} that gives $a_j = A_j$ using Julia 1.6.0 [Bezanson et al., 2017] and the Roots.jl package [Roots.jl, 2021], with an algorithm based on Steffensen's method[4]. This approach is viable since the model is nonstochastic.

We assume $A_j = 0$ for new entrants to the labour market whether newborns or immigrants. This amounts to an assumption that migrants do not bring any assets with them. This is plausible for younger migrants, but older migrants would realistically have some assets on arrival. If true, this would mean our primary estimates for older migrants potentially exhibit some downward bias.

Figure 4 illustrates example lifecycles for a UK native and an EA migrant who arrived age 35 without degrees.

We choose to model age in years, rather than in wider brackets, as this is both more precise and simpler to implement. Firstly, this coincides with the period length which greatly simplifies the algebraic structure of the model. Secondly, this is also how much of the data on mortality rates and healthcare costs and so on is provided, which simplifies the application to the data.

One limitation of the household model is that we are unable to explicitly model remittance flows from migrants back to friends and family at their origin. The implicit assumption is that such flows can be modelled as just a component of a migrants consumption, in reality this might manifest as altered consumption/savings behaviour, especially towards in the early years after arrival. Dustmann and Frattini [2014] do explore the potential effects of remittance flows and find only small direct effects, but it is possible that this could be distorting our results if it leads us to over-estimate migrants savings.

3.3 National model

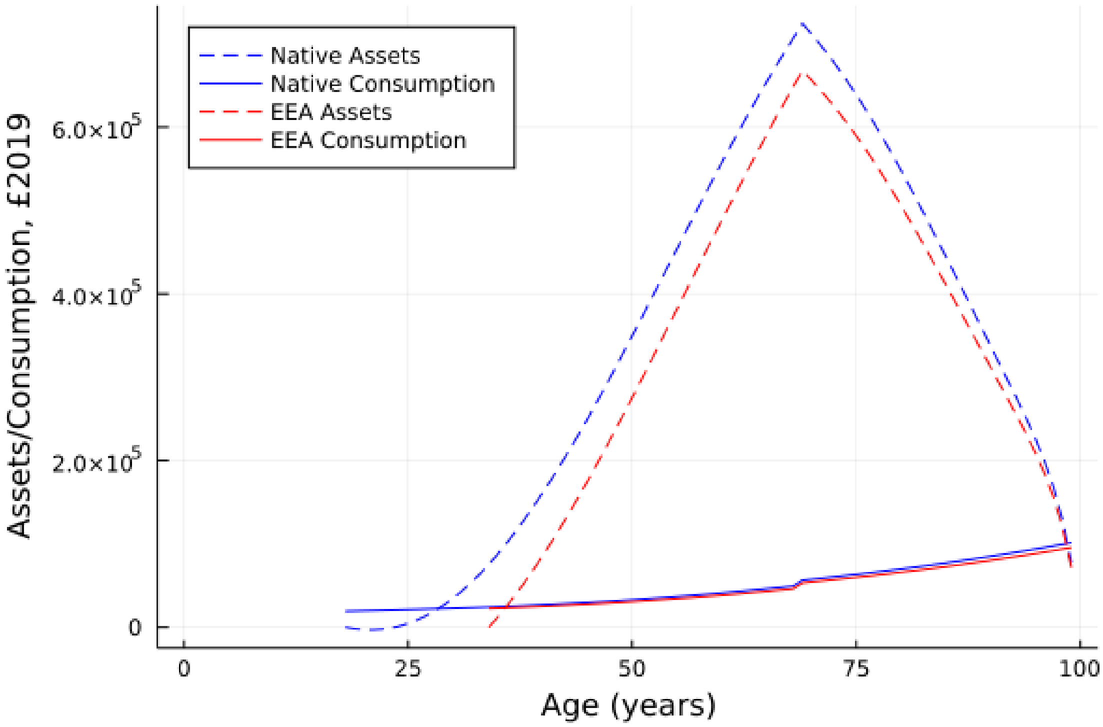
We form simple aggregates from the household variables:

$$A_t = \sum_{i=1}^{N_t} a_{it} \tag{6}$$

$$C_t = \sum_{i=1}^{N_t} c_{it} \tag{7}$$

[4] The problem is initially attempted using the Steffensen method. In the rare situation where convergence fails, the method is set to try again using the bisection method on the arbitrarily large interval $\left[-w_0 \times 10^{15}, w_0 \times 10^{15}\right]$ where w_0 is a simple average of income recieved in all periods.

Fig. 4: Example paths for consumption and assets over a lifecycle, native and EEA-migrant aged 35 on arrival without degrees



Firms have Cobb-Douglas production with labour augmentation:

$$Y_t = K_t^{\alpha} \left(Z_t H_t\right)^{1-\alpha} \tag{8}$$

$$H_t \equiv \sum_{i=1}^{N_t} H_{it} \times s_i \times \mathcal{A}j_i \tag{9}$$

Where H_{it} is the number of hours worked by individual i at time t, s_i is the skill premium for individual i and $\mathcal{A}j_i$ is the experience premium for an individual i of age j_i, modeled as a linear increase in productivity with age. The skill premium s_i varies by skill type and migration status; Z_t is total-factor-productivity which grows at a constant rate g.

Firms are owned by households and in turn purchase capital with gross investment I_t. Letting δ be the depreciation rate of capital:

$$K_{t+1} = (1-\delta) K_t + I_t \tag{10}$$

The stock market return is thus $r_t = 1 + \frac{\partial Y_t}{\partial K_t} - \delta$. The capital market clears so long as:

$$K_t + B_t = A_t \tag{11}$$

Government debt B_t evolves according to the dynamic:

$$B_{t+1} = D_t + (r_{kt} - \rho) B_t \tag{12}$$

Where D_t is the primary deficit and ρ is the equity premium. Since this is a model without risk, this best understood as resulting from regulation, a mandate for financial intermediaries to hold government bonds that results in a lower return on these assets. This is an empirically realistic feature of the model that keeps interest rates close to those observed in the real UK.

The average return on the household portfolio of assets thus becomes:

$$r_t = r_{kt} - \frac{(B_t/K_t)\,\rho}{1 + (B_t/K_t)} \tag{13}$$

The model is then estimated using a finite horizon approximation. At time $\Omega_1 = 1981$[5] the model is assumed to be on a balanced growth path at the prevailing parameters. At $\Omega_1 + 1$, the economy is shocked with the arrival of new fertility and mortality and we solve for a transition path to time $\Omega_3 = \Omega_1 + T$ when the model is assumed to be on the new balanced growth path. However, the model is then shocked again at time $\Omega_2 = 2020$ with the arrival of 1000 unanticipated migrants, and we then solve for the updated transition path to Ω_3. The years 1981-2020 therefore amount to a "warm up period" for the model, and our results focus exclusively on changes after this date.

The balanced growth path assumption is implemented by assuming that the interest rate at Ω_3 prevails for all subsequent periods, which additionally implies constant growth rates for output, capital and wages. A balanced growth is not guaranteed to exist in our framework, and for example will fail if the government debt/GDP ratio is on an explosive path, as would happen if $r > g$. This assumption is tested in section 5.1 and we find that a balanced growth path does exist given our parameters.

We then solve numerically for economy-wide wage/debt paths consistent with households optimising their asset holdings as in section 3.2. This was done in Julia 1.6.0 [Bezanson et al., 2017] with the NLsolve package [Mogensen et al., 2020], which uses a trust-region algorithm to solve the problem in $T \times 2$ variables.

The migrant arrival is made unanticipated since we wish we to make policy suggestions: a change in migration policy would likely be unanticipated by agents. We then estimate the net present value of this migration shock as the discounted change in government debt at time Ω_3 as discussed in section 5.1.

3.4 Theoretical impacts of migration

Immigration will have both direct and indirect fiscal effects in our model, and both short-run and long-run effects. We will examine each separately.

The direct fiscal effects will depend on the balance of taxes paid to costs incurred. Consumption and poll taxes/benefits are relatively stable over the lifecycle, whereas income taxes vary strongly due to the wage profile (see figure 5 below) and retirement. Children incur only costs until they reach the age of work, we therefore would expect child migrants to have a lower net fiscal benefit than adults. Similarly pensioners would incur higher costs in healthcare and pensions while not paying income taxes. The basic picture is that in any given year, we expect workers overall to make a positive contribution and children and pensioners to make a negative contribution; skilled workers will earn more and pay more taxes and therefore have a stronger contribution than unskilled workers. A stylised illustration can be seen in figure 1. The net present value will account for all of this, discounted by the appropriate interest rate.

The effect of age on net fiscal contribution is therefore ambiguous - older migrants will earn more and hence pay more taxes in the present, but have fewer working years before they begin incurring significant costs. Similarly, while we expect skilled workers to make a strongly positive contribution, is is unclear whether unskilled workers will make a weakly positive contribution or a negative one. For this, we turn to the quantitative framework.

[5] We choose 1981 as our starting point since before 1981 we lack good data on migration flows.

4 Data and model calibration

A comprehensive list of parameters used in the model and their origin can be found in appendix A. Many of these have been obtained directly from previous work; this section will focus on those parameters that have been derived or econometrically estimated.

The primary resource for the household parameters is the UK Labour Force Survey (LFS), a highly detailed quarterly rotating-panel survey of approximately 60,000 UK households. Following Dustmann et al. [2008] and Dustmann and Frattini [2014], we pool the four quarterly waves for each year and then trim the resulting dataset to ensure each household is only represented once. Readers seeking more details on the methodology and limitations of the LFS are referred to Dustmann et al. [2008]. Due to a methodological change to how wages and benefits are reported in 2011, we use the 2012-2019 editions of the LFS for all parameters except return migration (section 4.2.2). Throughout this section, all calculations weight observations using the variable "PWT" provided in the LFS to ensure they are representative of the whole population.

Section 4.1 explains the derivation of productivity, the labour supply, taxation and government expenditure for different demographics; Section 4.2 explains the derivation of mortality, fertility, and immigration rates as well as the rate of return migration.

4.1 Economic Parameters

4.1.1 Productivity and labour supply

Key parameters on the productivity and labour supply of different demographic groups were obtained through a simple pooled linear regression of wages and weekly working hours on key characteristics, with a time trend to control for changing demographics across the sample period. Weekly income and hours were calculated as a summation across all jobs worked (where applicable), and wages were then calculated as $\frac{Income}{Hours}$. The sample was restricted to adults of working age, and the wage specification was further restricted to capture only those in work. Both log and linear specifications were tried for both wages and hours, and both AIC and R^2 selection methods strongly preferred a log model for wages and a linear model for hours. The results[6] are shown in table 1. It should be stressed that no causal interpretation should be attached to any of the coefficients due to the extreme likelihood of correlation with omitted variables; they nonetheless provide a precise conditional mean for our relevant subgroups.

We explored the possibility that recent arrivals are substantially different to established groups as suggested in Dustmann et al. [2008] by including a "recency" dummy variable if the migrant had arrived within five years of being surveyed. Although the results were statistically significant, they were not implemented in the model since (i) their magnitude was small compared to the other variables and (ii) there is a significant risk of selection bias, since very recent migrants have a reduced probability of being selected for the survey.

We observe substantial differences between the three different origin groups on both wage and hour metrics. There is a wage penalty associated with both migrant groups, but whereas EEA migrants more than make up the difference by working more hours, non-EEA migrants appear to work fewer hours as well; this leads to a small rise/a large drop in total annual income for EEA/non-EEA migrants relative to natives. The differences in wages and working hours relative to natives are generally larger for low-skill migrants than high-skill ones.

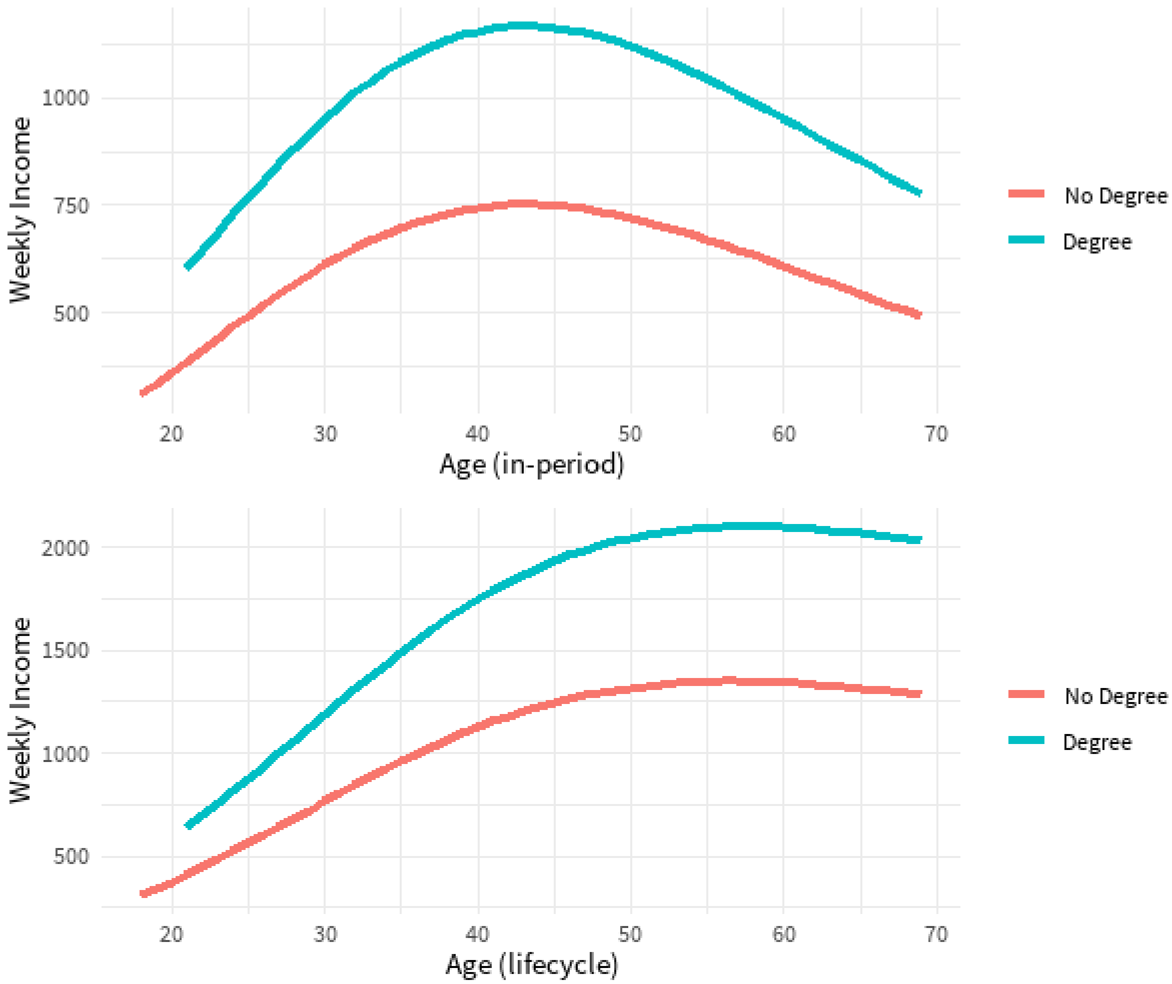
The demographic model is genderless, and so the results used are those without the "female" controls. Results with these controls are included to illustrate the impact that gender-correlation has with some of our key covariates; it is especially notable that impact of "degree" on working hours shrinks substantially once gender is controlled for, making it clear that this effect is far stronger for women. It is also interesting that while non-EEA men tend to work fewer hours than UK native men, non-EEA women tend to work

[6] All regressions were conducted using R 4.0.3, and output tables prepared using the Stargazer library [Hlavak, 2018].

Tab. 1: Wages and Labour Supply

	Dependent variable:			
	ln (*wage*)		Hours	
	(1)	(2)	(3)	(4)
Year	0.023***	0.023***	0.039***	0.041***
	(0.0004)	(0.0004)	(0.010)	(0.010)
Age	0.149***	0.140***	0.903***	0.484***
	(0.003)	(0.002)	(0.059)	(0.056)
Age^2	−0.003***	−0.003***	−0.010***	0.001
	(0.0001)	(0.0001)	(0.001)	(0.001)
Age^3	0.00002***	0.00001***	−0.00002	−0.0001***
	(0.00000)	(0.00000)	(0.00001)	(0.00001)
Female		−0.202***		−10.374***
		(0.003)		(0.062)
Degree	0.379***	0.390***	2.276***	0.729***
	(0.002)	(0.003)	(0.053)	(0.067)
EEA	−0.111***	−0.138***	2.150***	1.872***
	(0.006)	(0.007)	(0.136)	(0.152)
Non-EEA	−0.129***	−0.164***	−2.096***	−3.144***
	(0.005)	(0.006)	(0.127)	(0.139)
Female * Degree		−0.007*		3.780***
		(0.004)		(0.090)
Female * EEA		0.056***		0.372**
		(0.008)		(0.181)
Female * Non-EEA		0.066***		1.749***
		(0.007)		(0.156)
Degree * EEA	0.022***	0.027***	−1.348***	−0.976***
	(0.008)	(0.008)	(0.192)	(0.181)
Degree * Other	0.092***	0.086***	2.276***	2.223***
	(0.007)	(0.007)	(0.167)	(0.157)
Constant	6.431***	6.470***	33.927***	36.229***
	(0.014)	(0.014)	(0.343)	(0.323)
Observations	294,314	294,314	294,314	294,314
R^2	0.199	0.225	0.034	0.146
Note:				*p<0.1; **p<0.05; ***p<0.01

Fig. 5: Age effects



more than their UK peers. Taken together, it would appear likely that our results will be somewhat sensitive to the future gender balance of incoming migrants, but not concerningly so.

Figure 5 illustrates the age effect on total income for UK natives both across ages within a single year and for an individual lifepath (on the assumption that wages grow in line with total factor productivity). We observe that while the mid-forties are the highest earners in any particular year, an individual can expect their income to continue rising until their mid-fifties thanks to rising productivity in the economy as a whole. Age effects are substantial, and are likely to significantly affect timing of when an individual chooses to accumulate retirement savings. In particular, strong age effects help to explain why in our model some individuals go into debt during their early twenties and only begin saving later on (as observed in figure 4 above).

To address the potential concern that pooling across years is invalid due to structural changes in the parameters over the sample period, we conducted the regression separately for each year in the sample, and then conducted a graphical analysis of coefficient stability. These plots are shown in section B, with figure 22 displaying the wage coefficients and figure 20 displaying the labour supply coefficients. Figure 22 suggests there may have been a slight decline in the degree premium across the sample period, from 40.0% in 2012 to 34.5% in 2019 (with some uncertainty), which could reflect a change in the composition of degrees studied. If substantiated, our results would tend to slightly overestimate the value of high-skill individuals as well as the overall labour supply. However, we are not concerned that this significantly affects our results because (i) the change remains small, at only a couple of percentage points difference in productivity and (ii) it affects migrants and natives equally, which means it should almost entirely cancel out thanks to our double-differencing approach. Overall, we do not believe there are any major concerns raised by the stability analysis, and find pooling to be justifiable.

We then needed to convert the working hours in 2019 into the parameters $\bar{h}_{a,j,s}$, where a, j, s refers to age, country of origin and skill level. We started by obtaining the average annual decline in working hours as -0.393% per year [Boppart and Krusell, 2019]. Adjusting for average UK wage growth, we obtain $\eta = -5.08$, which we assume as constant across demographic groups. We can then calculate $\bar{h}_{a,j,s} = h^{2019}_{a,j,s} \left(\frac{\tau w_t}{(1+\varphi)}\right)^{\frac{1}{\eta}}$, where $h^{2019}_{a,j,s}$ is the hours worked in 2019 as calculated above, and normalise $\tilde{h}_{a,j,s}$ to give $\psi\left(h_{a,j,s}\right) = 0$ in 2019.

4.1.2 Tax wedge

In the UK, direct taxes on income are levied both through "Income Tax" and through "National Insurance" contributions. These are distinct taxes with differing thresholds and marginal rates, but they are applied at the same time and on broadly the same class of income. As of 2018, they together represent 48.9% of UK tax receipts [Office for Budget Responsibility, 2018a], and it is thus important to capture their effect precisely. We follow Dustmann and Frattini [2014] in calculating the effective tax wedge for each of our demographic groups by applying the 2019 thresholds and rates to the reported incomes in the 2019 labour force surveys, and thus calculate the effective weighted-mean tax wedge (including the portion of national insurance paid by the employer). Due to data limitations, we apply these rates to wage income of employees only and take this as representative. This is a slight simplification as (i) income taxes do also apply to some categories of non-labour income and (ii) it is conceivable that the self-employed pay a systematically different rate. Dustmann and Frattini [2014] conduct some robustness checks and find that there are no major changes when these effects are partially controlled for; we thus feel this simplification is justifiable.

Figure 6 illustrates the effective average tax wedge by degree status and country of origin. 95% confidence intervals were calculated using a non-parametric bootstrap with the percentile method[7] and $n = 1000$ replications, to allow for an asymmetric interval. We observe that there is remarkable stability in the tax wedge across demographic groups, with a rate of just over/under 30% for those with/without degrees. Based on the point estimates, it would seem that non-EEA degree holders face the highest wedge and non-EEA degree non-holders face the lowest; if substantiated (the differences between origins are not statistically significant at even the 10% level) this would likely be a consequence of gender composition.

There is a question as to whether we should also stratify the tax wedge by age, as with the wage and labour supply parameters. Figure 7 examines this possibility using LOESS smoothing. We do see some evidence of age effects, with a consistent upward trend for EEA migrants and a hump-shape for UK natives. The pattern for UK natives is consistent with the earnings distribution in 5, and indicates that individuals do face a higher tax wedge during their period of highest earnings. However, since the effect size is small (at most a couple of percentage points deviation from the mean), we believe treating the tax wedge as age-independent is a reasonable simplification. The upward trend on the tax wedge for EEA migrants could be indicative of differing age effects for migrants, but is more likely attributable to cohort effects. [8]

4.1.3 Welfare spending

The largest item of welfare spending by the UK government is the National Health Service (NHS). Data on the cost of healthcare by age in 2016 was obtained from Licchetta and Stelmach [2016], and adjusted to

[7] Jung et al. [2019] conclude that the percentile method is the most accurate way to bootstrap confidence intervals.

[8] Older EEA migrants will typically have arrived before the A8 accession of countries in 2004, and are thus likely to be structurally different to more recent arrivals.

Fig. 6: Estimated tax wedge by origin and skill

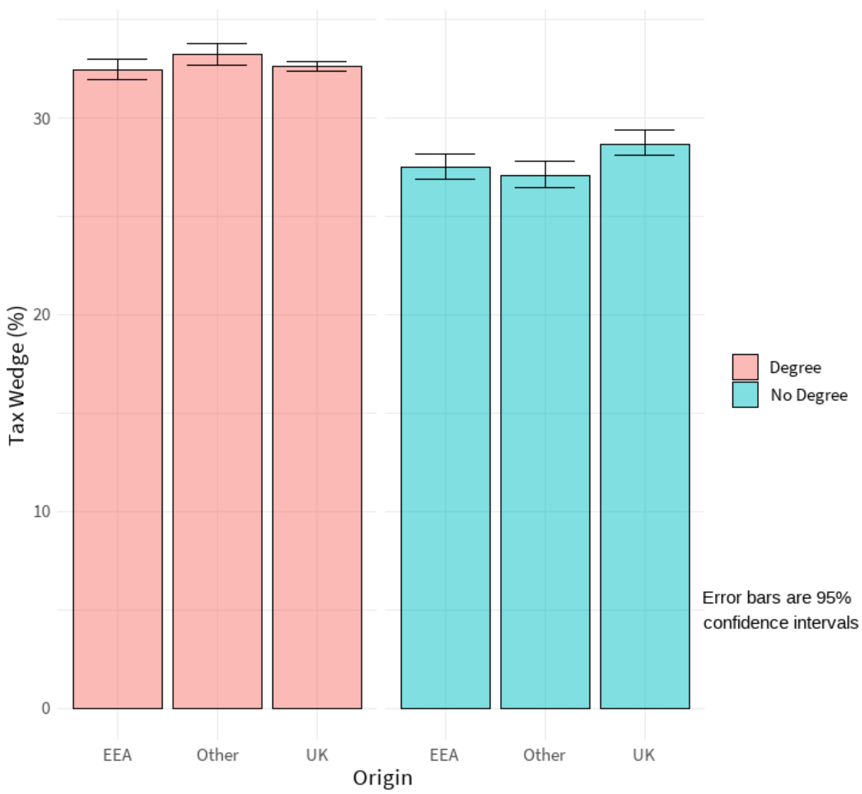
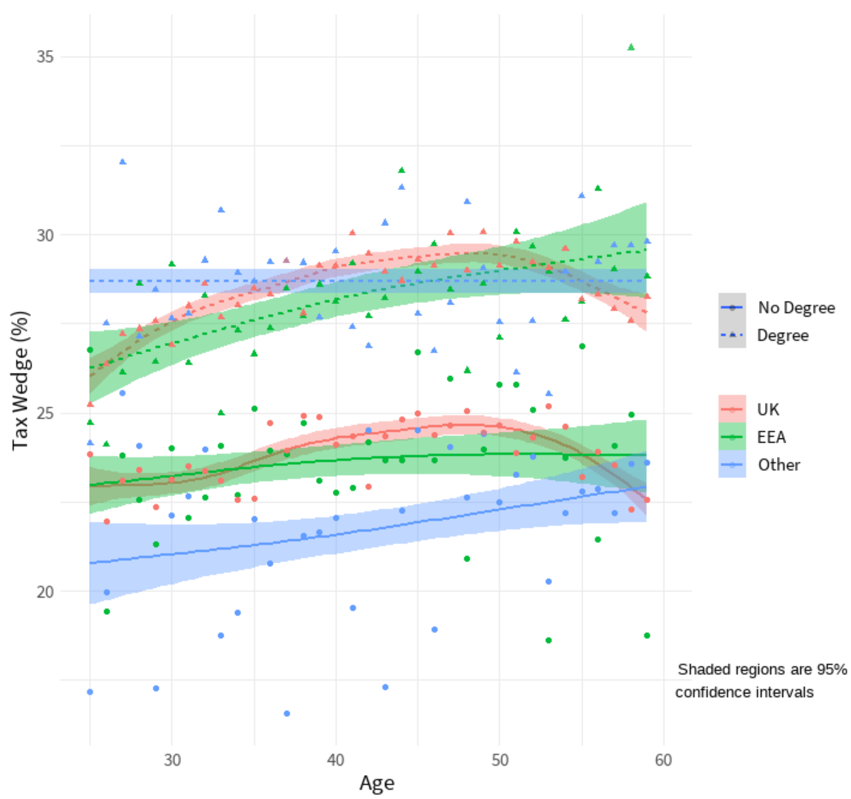


Fig. 7: Average tax wedge by age, origin and degree status



2019 prices. Following Dustmann et al. [2010] we assume that healthcare costs are independent of migration status and skill level. Healthcare costs are then projected to increase at a rate of $g_{Y,t} + x_t$, where $g_{Y,t}$ is the growth of per-worker GDP and x_t captures a cost disease [Baumol, 1996] due to slower productivity growth in the healthcare sector than elsewhere. Based on the analysis in Licchetta and Stelmach [2016], we assume that x_t equaled 1% until 2019, and that it will decline linearly from 1% in 2019 to 0% by 2060 to prevent an explosive, unsustainable path for health costs. Note that our model experiences a "natural" rise in healthcare costs due to demographic pressure, in line with economic forecasts such as the Office for Budget Responsibility [2018a].

The second largest item of welfare spending is the state education system. Total costs of education up until the age of 18 as of 2019 are obtained from HM Treasury [2020], and divided by the number of children in the age bracket to obtain a per-child cost of education each year, which is assumed to be equal for all children. This per-child figure is then assumed to rise in line with GDP. The financing of post-secondary and university education in the UK is complex, with the majority of undergraduates obtaining a special type of loan that in most cases acts akin to a 30-year graduate tax (see e.g. Lewis, 2020). In this paper, we neglect the tertiary education sector entirely, and assume the only cost to graduates is the loss of earnings during their degree[9]. This simplification implies that our estimate of the net fiscal contribution may be upward biased for UK native graduates. It should not substantially impact the estimate for non-natives above the age of 22 as the costs of their education were not bourne by the UK.

The remaining items of welfare are direct fiscal transfers, including pensions, unemployment benefits and housing benefit. Unfortunately, the LFS does not record the amount households receive in welfare spending, only dummy variables indicating whether they received "any amount" in each category of expenditure. For non-pension spending, we thus follow Dustmann and Frattini [2014] in combining the LFS data on which households are in receipt of which benefits with data from the Office for Budget Responsibility [2018a] on total expenditure on each benefit. Each demographic group[10] is assigned a per-household transfer based on the share of that group which receives a particular benefit relative to the national average share. Readers are referred to Dustmann and Frattini [2014] for a discussion of the merits and disadvantages of this approach. We project all of these items will rise in line with per-worker GDP. For pension spending, we instead assume that recipients are eligible for the full 2019 state pension, and then use the LFS to determine the fraction of retirees who claim it. This fraction is assumed to be constant across retirees of all origins and skill levels for simplicity[11]. Pensions are then projected to rise using the formula $g_{Y,t} + x_t$, where $g_{Y,t}$ is the growth of per-worker GDP and $x_{t|t<2040} = 0.36\%$ captures the estimated effect of the "triple-lock" pension guarantee[12] [Office for Budget Responsibility, 2018b]. We assume that the triple-lock is removed in 2040 to keep pensions on a sustainable path in the long run.

Figure 8 illustrates the estimated cost of non-pension welfare by subgroup, while figure 9 shows how migrants compare to natives for each individual component of welfare spending. Error bars were calculated using a non-parametric bootstrap with the percentile method and $n = 1000$ replications, as with the tax wedge. As expected, we observe that non-degree holders receive significantly more transfers. We also observe a strong disparity between EEA and non-EEA migrants, with EEA migrants receiving significantly less than UK natives while non-EEA migrants receive significantly more in welfare spending. From figure 9, we see that the biggest disparities are in child, housing and disability benefit. The higher housing benefit received by both EEA and non-EEA migrants likely reflects the fact that they are more likely to live in areas with high housing costs (such as London).

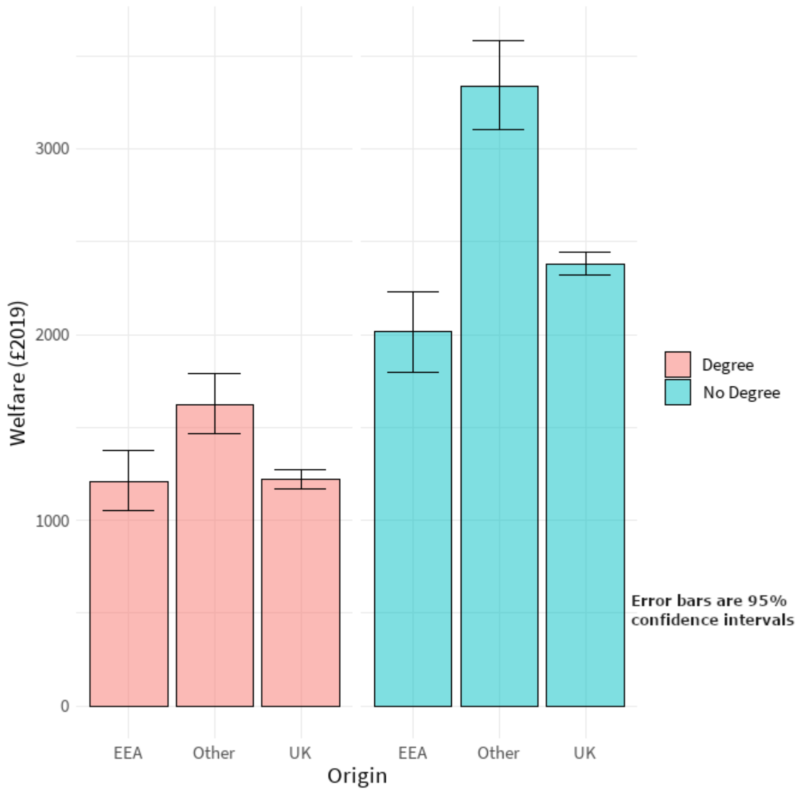
[9] One interpretation is a "parent pays" principle that the cost is captured in household expenditure by previous generations.

[10] Pension spending is assigned only to those older than 68, non-pension spending is assigned only to those younger. Due to data limitations, we were unable to disaggregate by age any further than this.

[11] Eligibility for the full state pension requires 30 years in the labour market, with the amount scaling down with fewer years of employment in the UK. As we only model migrants up the age of 45, we do not believe this assumption will substantially distort our results.

[12] The triple lock is a government commitment to increase the State Pension by the highest of wage growth, inflation or 2.5%.

Fig. 8: Fiscal Transfers ("Welfare") by origin and degree status



4.1.4 Other Taxes

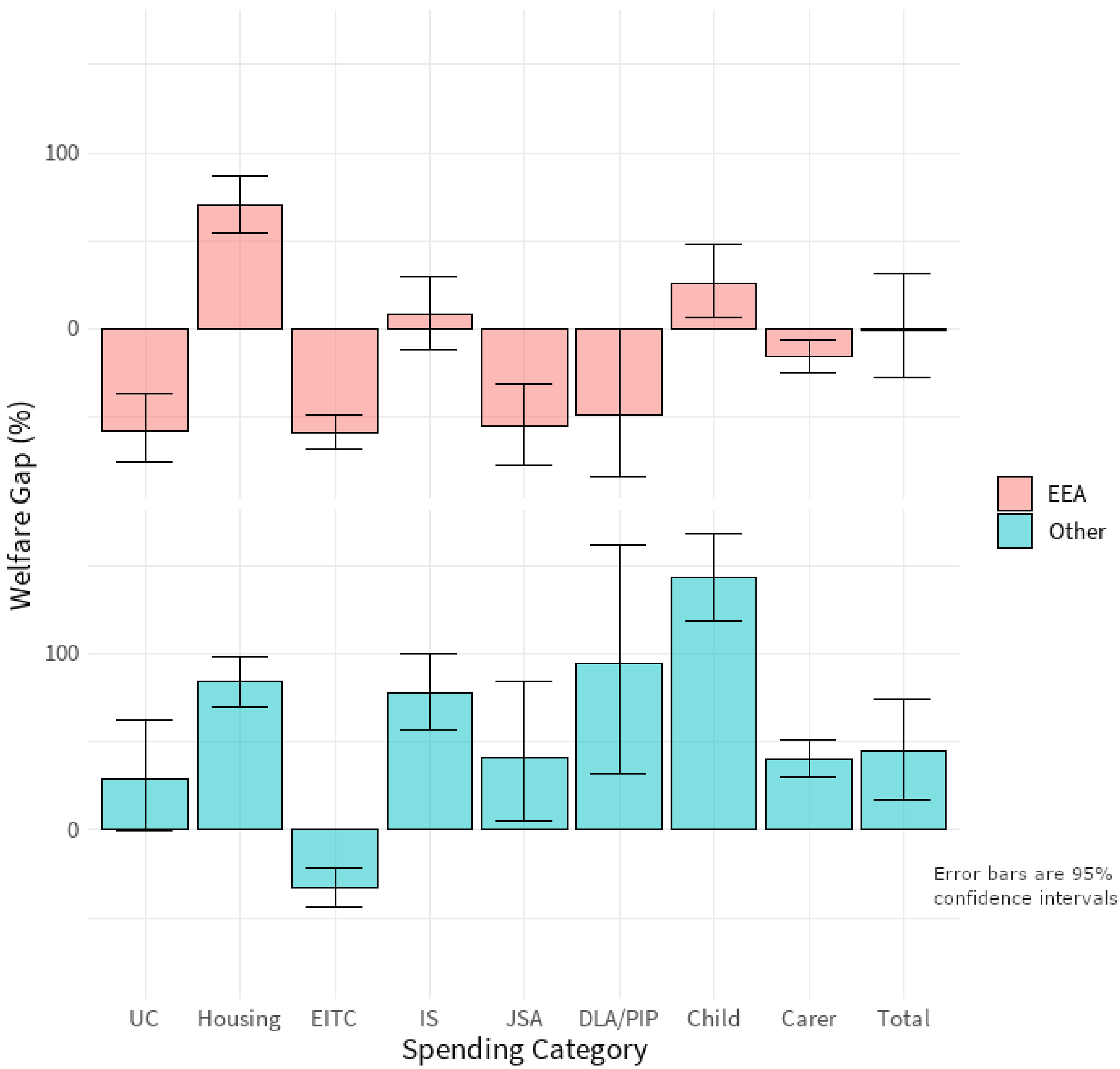
The primary indirect tax in the UK is Value Added Tax (VAT), with a standard rate of 20% but with variety of lower rates applied to specific goods. Other indirect taxes include Fuel Duty, and taxes levied on alcohol and cigarettes. We obtain an average rate of indirect tax by taking the revenue from all indirect taxes given in Office for Budget Responsibility [2018a] and total consumption expenditure given in Office For National Statistics [2020a], the average rate of 21% is thus their ratio. We make the simplifying assumption that this rate is constant across time and demographic groups. It is possible that migrants may pay systematically less VAT due to remittance payments; this possibility is explored in Dustmann et al. [2010]. Any such effects are likely to be quantitatively small.

We treat all remaining taxes, including corporation and council taxes, as equivalent to lump-sum taxation applied equally to all adults. The sum total of these taxes was obtained from the Office for Budget Responsibility [2018a], and divided by the adult population. As with welfare expenditure, we assume these taxes grow in line with per-worker GDP. This procedure may overestimate net fiscal contributions (see Rowthorn, 2014), and we will later (in section 5.1) calibrate lump sum taxes to match the observed government deficit.

4.1.5 Other Expenditure and Equity Premium

The remaining items of expenditure (such as defense expenditure, policing and administration costs) are treated as "public goods", with total expenditure obtained from HM Treasury [2020]. There is some discussion in the literature as to whether public goods should be treated as per-capita or fixed-cost variables, on the grounds that there is no *a priori* reason why defence spending or governance costs should increase along with population size. We follow Dustmann and Frattini [2014] in treating them as per-capita, on the grounds that this is the observed pattern empirically. Thus, the total costs were divided by the size

Fig. 9: Fiscal Transfers ("Welfare") relative to UK natives



of the adult population and then projected forwards in line with per-worker GDP.

We obtain the equity premium from Meyer et al. [2019] as the difference between average yield on the stock market and average yield on short-term UK government debt since 1990, yielding $\rho = 4.95\%$.

4.2 Lifecycle parameters

4.2.1 Mortality and Fertility

Both mortality and fertility rates are assumed to be constant across demographic groups. Gruer et al. [2016] find that ethnic minorities in Scotland appear to have a higher life expectancy than white natives, by perhaps 5-6 years for men and 2-3 years for women. If replicated across the UK, this could imply that migrants cost more than our estimates. For fertility Wilson [2020] concludes that completed female fertility (total children at age 45) is similar for natives and migrants, with some exceptions such as migrants from India or Pakistan. Overall however, we do not feel these differences will significantly distort our main results.

Period mortality rates were obtained from the Office For National Statistics [2018a], which supplies projected mortality rates for 1951-2113. For years after 2113, we used the 2113 values. The data disaggregates mortality by sex; we used a simple simulation to calculate average cohort mortality for every year of birth[13]. Some example mortality paths were shown in figure 4 above.

Fertility rates were similar obtained from the Office For National Statistics [2018b], which provides female fertility rates in five-year age brackets for 1938-2018. For years after 2018, we follow the Office for Budget Responsibility [2018b] in projecting that fertility will rise linearly from 1.7 births per woman in 2018 to 1.84 by 2030 and then stabilises. We assume that skill levels are non-heritable, shutting down any "eugenics channel" for migration. If skill levels are indeed heritable, then our results would slightly underestimate the net contributions of high-skill migrants and overstate those of low-skill migrants.

4.2.2 Migration

Estimates of migrant numbers from each origin in each year were obtained from the Long-Term International Migration study [Office For National Statistics, 2020b] for 1981-2019. We then adjust by the UK population in each year to obtain migration from each origin as a share of the UK population. The 2019 figure was taken as representative of future migration, and projected forwards[14]. The age distribution of migrants from each origin was then estimated using the International Passenger Survey [Office For National Statistics, 2020c], the distribution is illustrated in figure 10. Net migration by UK natives is small and we neglect it, assuming implicitly that inflows and outflows of natives cancel out.

Secondly, we followed Dustmann and Weiss [2007] in estimating the distribution of return migration using the LFS. We used the same methodology to obtain survival rates using the 2004-2019 editions of the LFS for each subgroup independently. The results are shown in figure 11. Unfortuntately, the method gives an implausible result for skilled EEA migrants, with survival rates higher than 1. The Office for National Statistics has written a report [Office For National Statistics, 2019] providing some explanations for this issue, which could include sampling bias or irregular household sizes. In addition to their suggested explanations, we would also note that our bootstrapped[15] 95% confidence intervals are very high and so much of the issue with the point estimates may simply be traditional sampling error. In any case, based on figure 11we chose to use only non-EU migrants to estimate the survival regression:

$$\ln\left(SR_t\right) = (1-\varsigma)\ln\left(SR_{t-1}\right) + \epsilon \tag{14}$$

[13] A simple average is insufficient, as we require a weighted average based on the surviving population in each period.

[14] This affects the aggregate population, but not specifically our key results as we estimate the marginal effect of additional migrants, not the effect of the expected flow.

[15] A nonparametric bootstrap using the percentile method

Fig. 10: Age distribution of UK immigrants (2019)

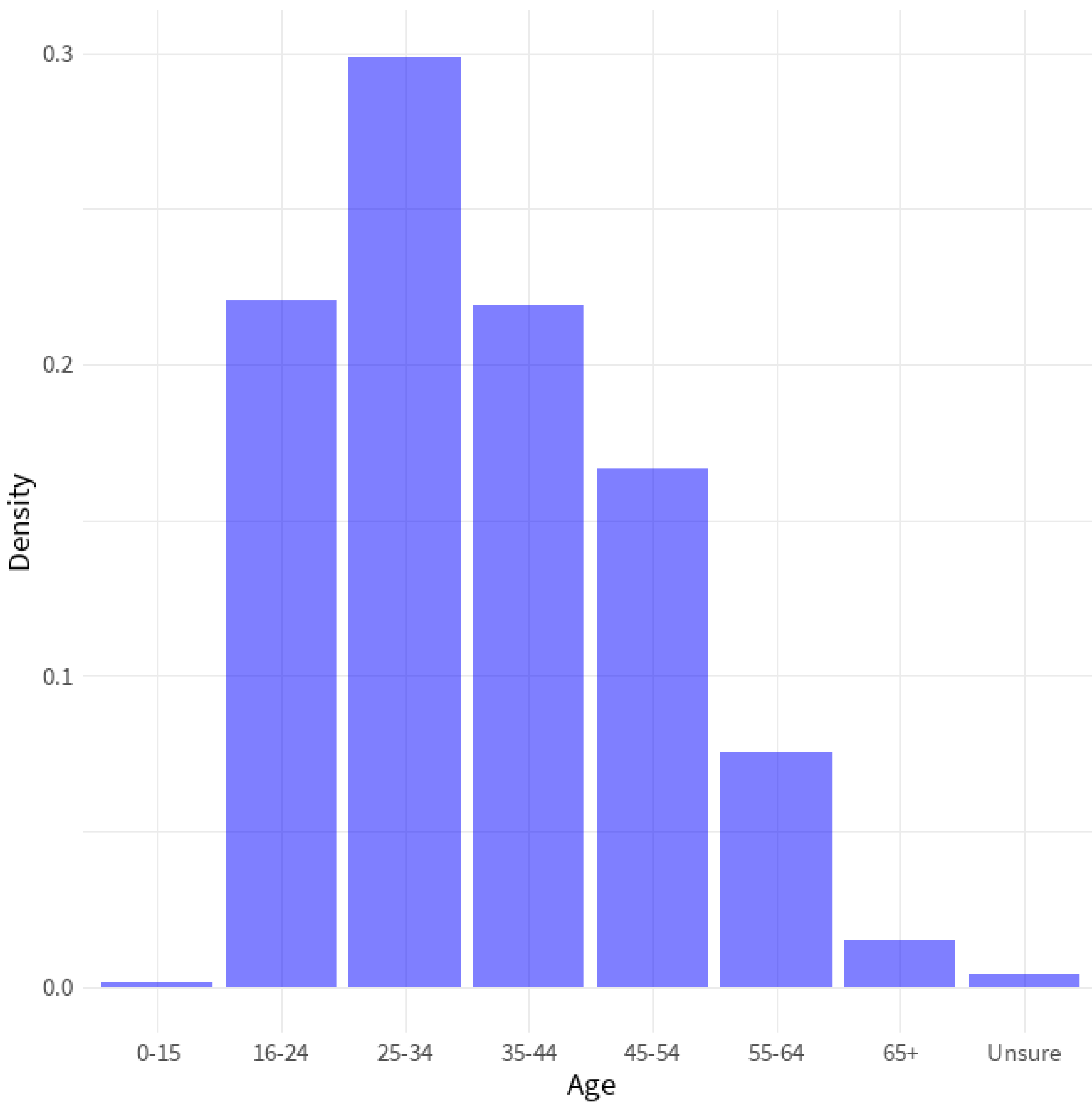
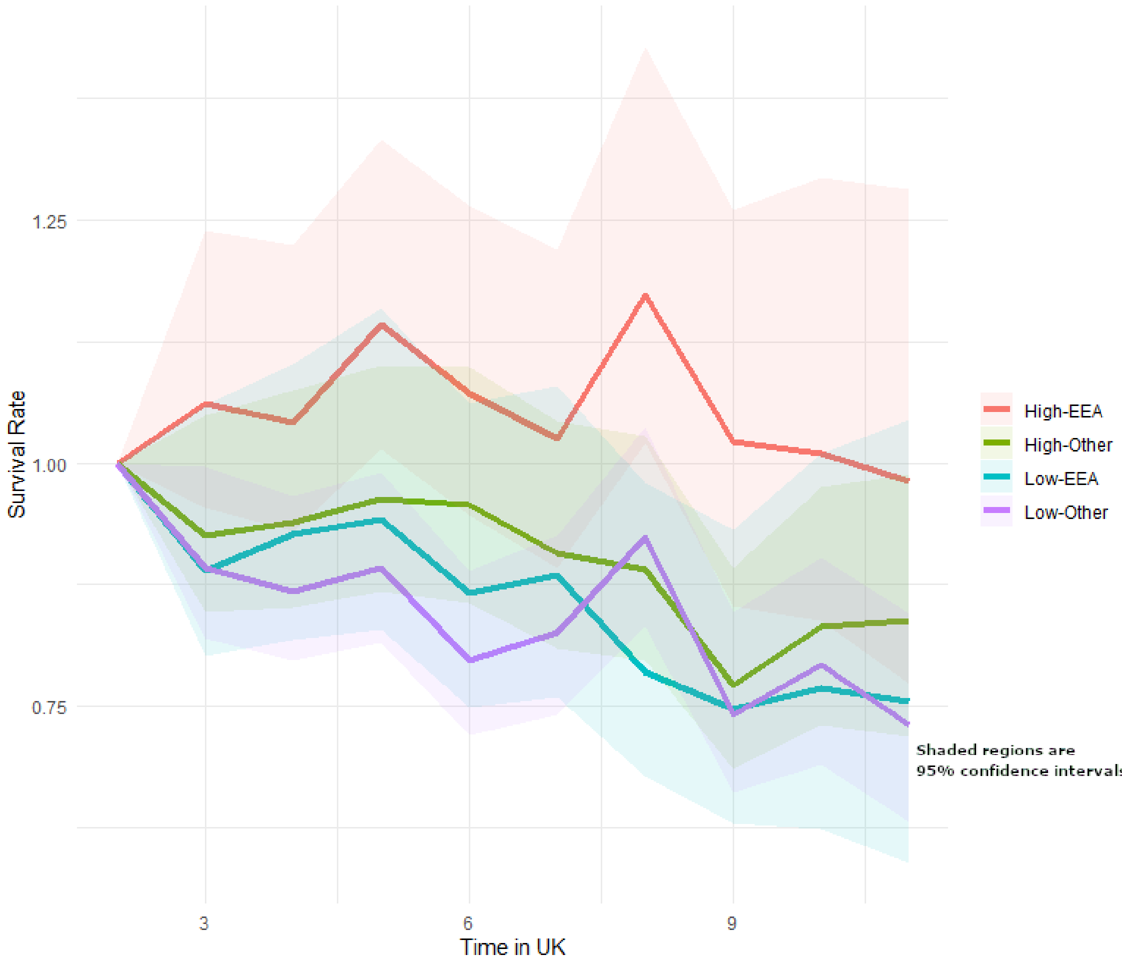


Fig. 11: Return Migration survival rates by origin and skill level



With $SR_1 = 1$, and where ς can be interpreted as the percentage of migrants who return home each year. We then treat ς as universal for all migrants subtypes, but conduct a crude sensitivity analysis in section 5.4. Our primary results thus use a value of $\varsigma = 2.7\%$ of migrants leaving the UK each year for five years, with the five-year window based upon Dustmann and Weiss [2007]. This is comparable to the estimates in Oxford Economics [2018], although they disaggregate ς by age bracket.

5 Results

5.1 Calibration and Model Output

Given the data above, we calibrated the model to deliver a GDP of £2.21 trillion and a government deficit worth 1.2% of GDP in 2019, matching the observed values for the UK. We did this by calibrating both total factor productivity A_t and an additional lump-sum tax XF_t. We use lump sum taxation for this calibration for two reasons. Firstly, as mentioned in section 4.1.4 the procedure used for estimating lump-sum taxation in the data likely overstates the net tax, so there is clear motivation for calibrating this. Secondly, if Ricardian equivalence holds then lump-sum taxation will not affect the other macroeconomic aggregates such as the capital stock, and will only change the balance between government and household wealth. We calibrate $A_{2019} = 15.03$ and $XF_{2019} = -£5,995$.

The macroeconomic output of the model with $T = 300$ periods is illustrated in appendix C. Overall, we observe convergence in all the key variables towards the end of the simulation horizon. We project government debt to rise across the period, stabilising at around 200% of GDP by 2282. This is consistent with the warnings by the OBR in Office for Budget Responsibility [2018b] that the UK's government debt is on course to rise substantially without a fiscal correction, as a consequence of both demographic change and rising per-capita pension and healthcare costs. Our model predicts that this will be partially offset by rising household savings, but that nonetheless the capital stock is expected to decline and interest rates expected to raise. It also worth highlighting that the interest on government debt is projected to be negative for most of the simulation horizon, typically at $\sim -1\%$ or so. We consider this to be reasonable, as returns on UK government debt have been persistently negative for more than a decade now.

The remainder of this section presents the Net Fiscal Contributions (hereafter "NFCs") of migrants by age, origin and degree status. These results are presented relative to the fiscal contribution of the average UK newborn. There are two reasons for this. The first reason is that the UK has a structural deficit bias: since the deficit per capita is positive, increasing the population will tend to increase the overall debt. Differencing with respect to the average UK newborn removes this downward bias in our estimates. This has the additional advantage of removing or reducing any structural bias in our model caused by imprecise estimates of the taxes/benefits estimated in section 4.

All results show the change in government debt at the end of the simulation, discounted by the product of government interest rates. It should be noted that the magnitudes of our net present value estimates are much higher than is typical in the literature. For example, Oxford Economics [2018] found an average marginal net-present-value of £78,000 and £28,000 for EU and non-EU migrants respectively, about 1-2 orders of magnitude lower than our results. This discrepancy arises from the choice of discount rate. Oxford Economics [2018] assert discount rates of $2.5 - 3.5\%$ as per the UK Green Book [HM Treasury, 2018], and similar approaches are taken by much of the literature. We instead choose to discount by the government rate interest rate, rather than the Green Book rate or the portfolio/equity rates. We do this because the results should theoretically be approximately invariant to the simulation time horizon, whereas discounting by anything other than the government interest rate would make the results highly sensitive to the arbitrarily chosen cutoff date, since the fiscal legacy of the migrant would be growing at a slower rate than the discount factor. It is also worth noting that the choice of discount factor only affects the magnitudes of the results, not the direction or pattern.

Section 5.2 sets out the direct effects of migration without general equilibrium effects. Section 5.3 then goes on to set out both the total effects and the decomposition of general equilibrium effects. Sections 5.4 and 5.5 go on to explore how the results change with a different rate of return migration or with reduced migrant-native wage gaps respectively.

5.2 Constant wages and interest

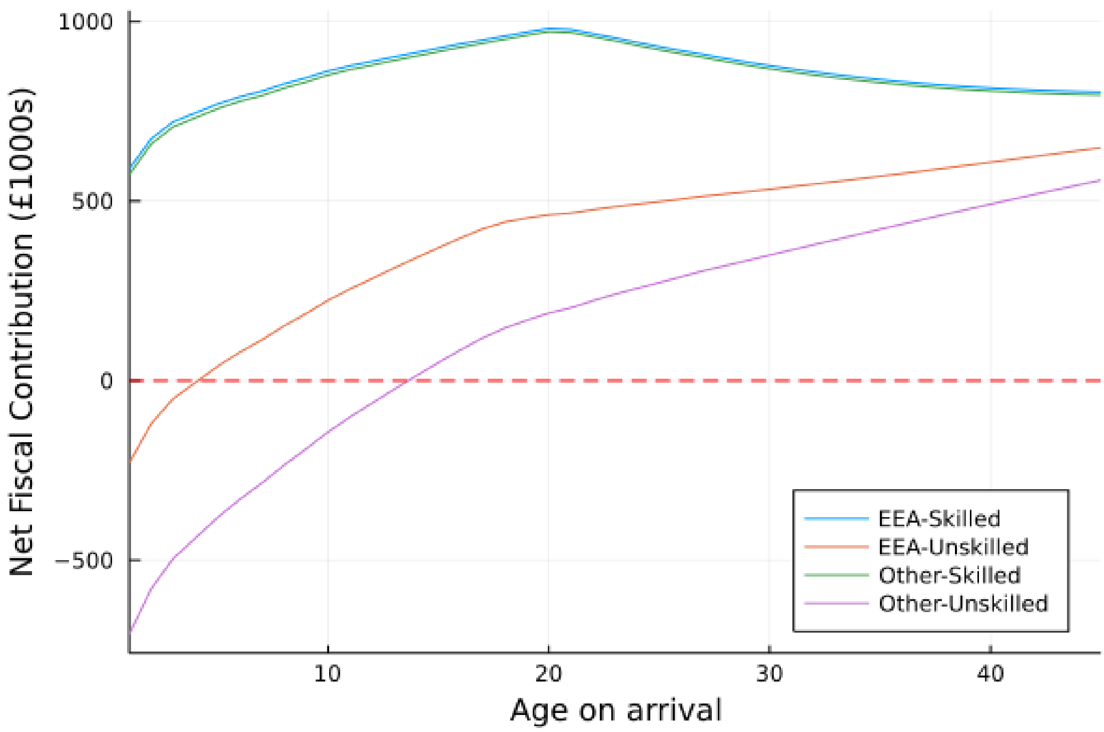
We initially estimated only the direct effects of migration, neglecting GE effects. That is, we held wages, interest rates and the per-person government variables[16] constant and so we isolate the direct costs and contributions of migrants. There are two reasons for doing this. Firstly, it is interesting to decompose the total effect of migration into its component parts for its own sake. Secondly, the assumption that indirect effects are negligible is essential in justifying the use of the "static" approaches such as Dustmann et al. [2010], Dustmann and Frattini [2014] and Oxford Economics [2018]. By estimating the relative importance of direct and indirect effects, we can evaluate the plausibility of these approaches.

The results are shown in figure 12, which plots the NFC against age of arrival for each skill/origin pairing. There are few things that are worth highlighting.

Firstly, we observe that the trend is similar for all migrants regardless of age of arrival, a consequence of our earlier assumption that age did not interact with origin or skill in the section 4 regressions. We see that the NFC initially rises with age; migrant children carry educational costs in the present and do

[16] In the full model, per-capita pensions, education and healthcare increase along with per-worker GDP, and so respond slightly to migration

Fig. 12: Net Fiscal Contributions by age, origin, and skill level without GE effects



not pay any taxes until they reach adulthood, so older children and adults will cost less and contribute more in present-value terms. The trend then diverges by skill group; the NFC shows a mild decline for post-21 skilled migrants, but increasing with age for unskilled migrants. The reason for this is the relative importance of the state pension. The state pension is the same for all origin-skill pairings, and so is a much higher *percentage* of earnings for unskilled migrants than for skilled migrants (the replacement rate is higher). Hence unskilled migrants save a lower proportion of income than skilled migrants. Since older migrants earn more in-period (see figure 5), this leads to a rising NFC for unskilled migrants but not for skilled migrants.

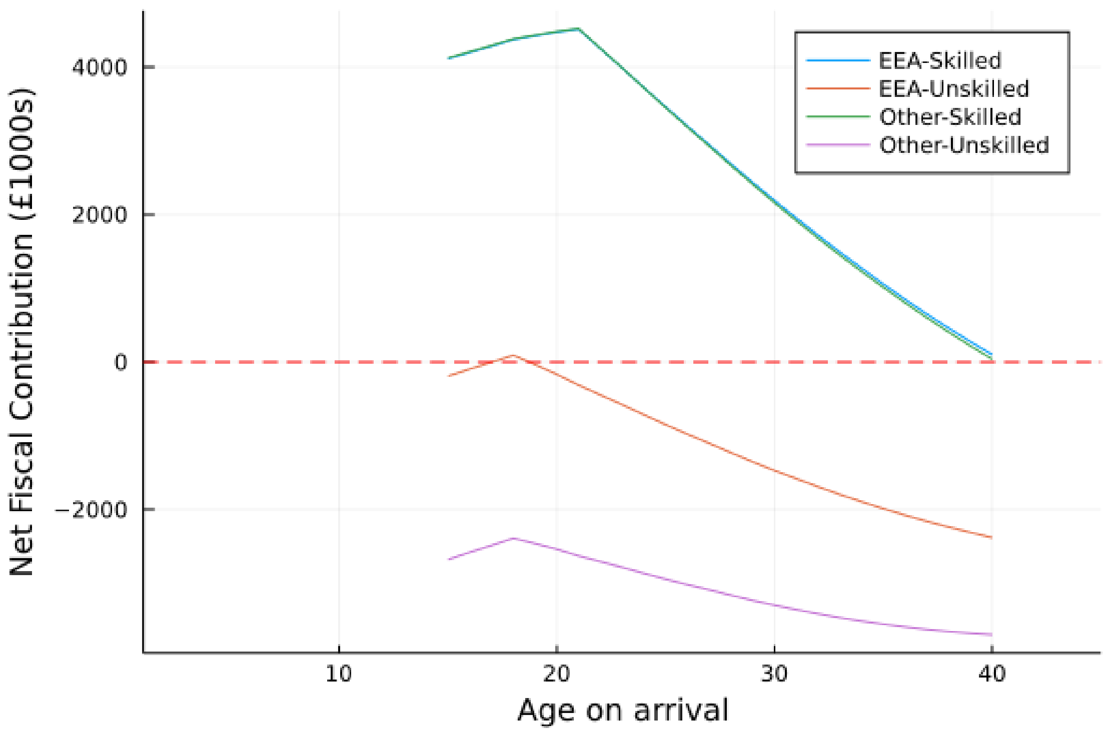
Secondly the skilled migrants from both origins have almost identical fiscal effects at every age, while the unskilled migrants differ by origin. All skilled migrants have strongly positive fiscal contributions (varying between $\approx £500,000$ and $\approx £980,000$ depending on arrival age), in line with expectations. The picture is very different for unskilled migration. Unskilled migrants from the EEA still have mostly positive fiscal contributions, with only those aged ≤ 4 on arrival having a net negative contribution, which reflects the fact that they tend to work longer hours and claim fewer benefits than their native counterparts. By contrast, unskilled migrants from outside the EEA under-perform not only the native average, but unskilled natives as well (an NFC of $-£689,903$ for an unskilled non-EEA migrant aged 0 on arrival, compared with $-£505,169$ for an otherwise identical native). This reflects the lower propensity to work, and a higher propensity to claim benefits among this demographic observed in section 4. Even here however, unskilled non-EEA migrants make a positive fiscal contribution after the age of 14, illustrating the huge fiscal savings by gaining workers without needing to educate them.

5.3 In General Equilibrium

Due to computational constraints, we calculate GE effects for only the $16-40$ demographic, who comprise the overwhelming majority ($> 95\%$) of UK immigrants.

In this subsection, we present two figures. Figure 13 is the twin of figure 12 above, showing the full net

Fig. 13: Net Fiscal Contributions by age, origin, and skill level with GE effects



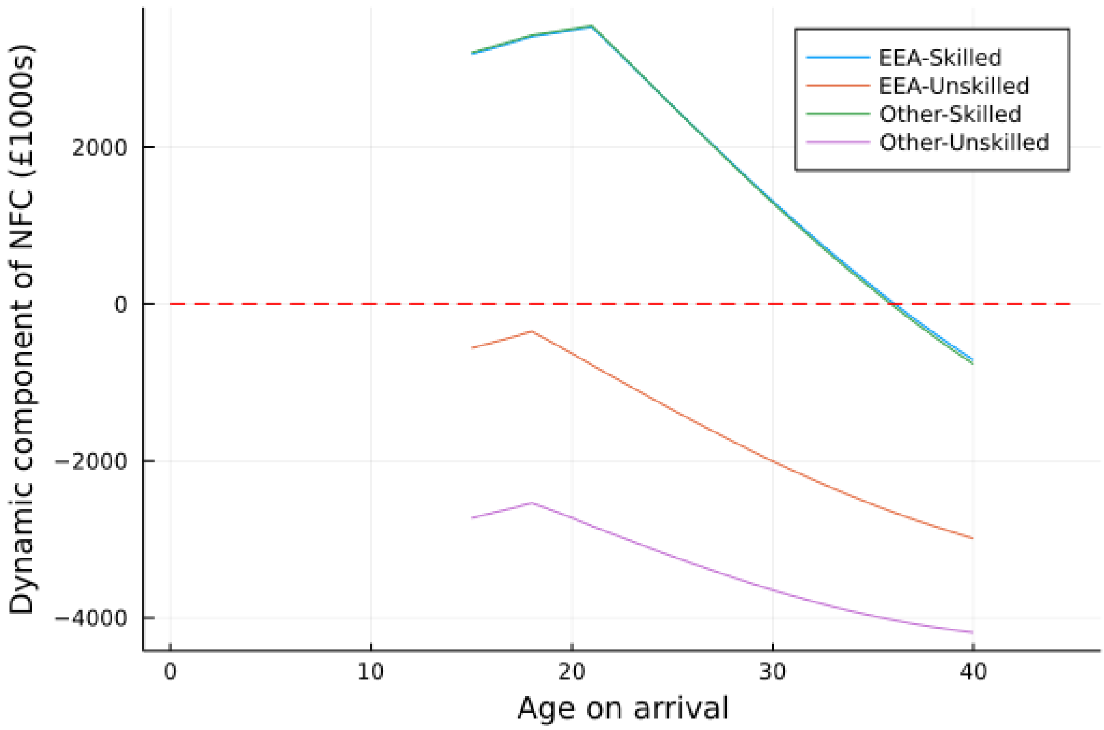
fiscal contribution by age relative to that of a newborn native. We note three significant changes once we include GE effects. Firstly, the NFCs of unskilled migrants have dropped dramatically, with non-EU migrants strongly negative and EU migrants either just breaking even or negative. Secondly, the "peak" for skilled migrants is much higher, with an NFC of £4,000,000 for a skilled migrant of either origin. And thirdly, the age effects for skilled migrants are much stronger, with NFCs declining extremely quickly as the migrant ages.

Figure 14 instead shows the difference between figures 13 and 12, thus isolating the size of the GE effects at each age. This makes it clear that the dynamic effects via wages and interest are typically stronger than the direct effects, though this does vary by demographic. GE effects are entirely negative for unskilled migrants, and positive for younger skilled migrants.

The key to understanding the GE results is to consider the effect on savings. If a migrant raises the average savings rate in the UK, they will tend to raise wages and lower interest, which are both positive for the fiscal balance. The reverse holds if the migrant lowers the average savings rate. This now makes clear the pattern observed in figure 14: unskilled migrants reduce the savings rate as they earn less and are strongly dissuaded from saving by the state pension. The opposite applies to young skilled migrants. Older skilled migrants tend to reduce the savings rate over their lifetime since they do not have time to accumulate significant assets before retiring, and so have below-average wealth across their lifetime despite making above-average annual savings during their working life.

It is worth noting that the strength of the GE results arises because we have assumed the UK is a completely closed economy, with the result that wages and interest rates respond strongly to the savings rate. A more sophisticated model that allowed the UK to be partially open would dampen the GE effects, and would likely find results somewhere between our no-GE and GE results. Nonetheless, our results suggest the studies that only look at the direct effects of migration, like Dustmann and Frattini [2014] and Storesletten [2000] will will tend to underestimate effect magnitudes - there is a greater divergence between skilled and unskilled migrants than the direct effects alone would suggest, and age upon arrival

Fig. 14: Dynamic effects



is much more important when we consider wage and interest effects.

5.4 Changing the rate of return migration

Dustmann and Weiss [2007] observe that the UK has an unusually high rate of return migration. However, as discussed in section 4.2.2 and illustrated in figure 11, there is considerable uncertainty surrounding the exact rate of return migration. This is also a potentially potent policy tool; since policymakers have considerable scope to influence the rate of return migration both directly through visa durations, renewal conditions and citizenship requirements and also indirectly via access to the welfare state.

In this section, we conducted dual policy and sensitivity analyses by exploring the consequences of changing the rate of return migration from $\varsigma = 2.7\%$ per year to $\varsigma = 13\%$. This was chosen such that approximately half of migrants would have left within the five-year interval. This is indicative of the impacts either of a deliberate policy decision to encourage migrants to return home sooner, or of the 2.7% figure being a significant underestimate.

Figures 15 and 16 display the change in NFC relative to the above results without and with GE effects respectively. Perhaps unsuprisingly, the GE results show a clear convergence compared with our earlier graphics: the value of unskilled migrants moves upwards, the value of skilled migrants moves down. This suggests that the fiscally optimal policy would be to keep low-skilled migrants on short term visas and encourage them to leave before incurring pension and healthcare costs, while doing the reverse for skilled migrants. It is also worth noting the age of the migrant is a factor as well: older migrants are better on shorter contracts, while young ones should be encouraged to stay. One policy application might to be ease the financial and/or administrative costs of converting “skilled worker” visas into “indefinite leave to remain” (ILR) for younger skilled migrants while increasing them for unskilled migrants; another might be to make ILR automatic upon graduation from a UK university.

The results without GE effects instead show an unambiguous gain from increasing the rate of return migration, though the effect is much stronger for unskilled migrants. This difference arises because direct

Fig. 15: Higher return migration without GE effects ($\varsigma = 0.13$)

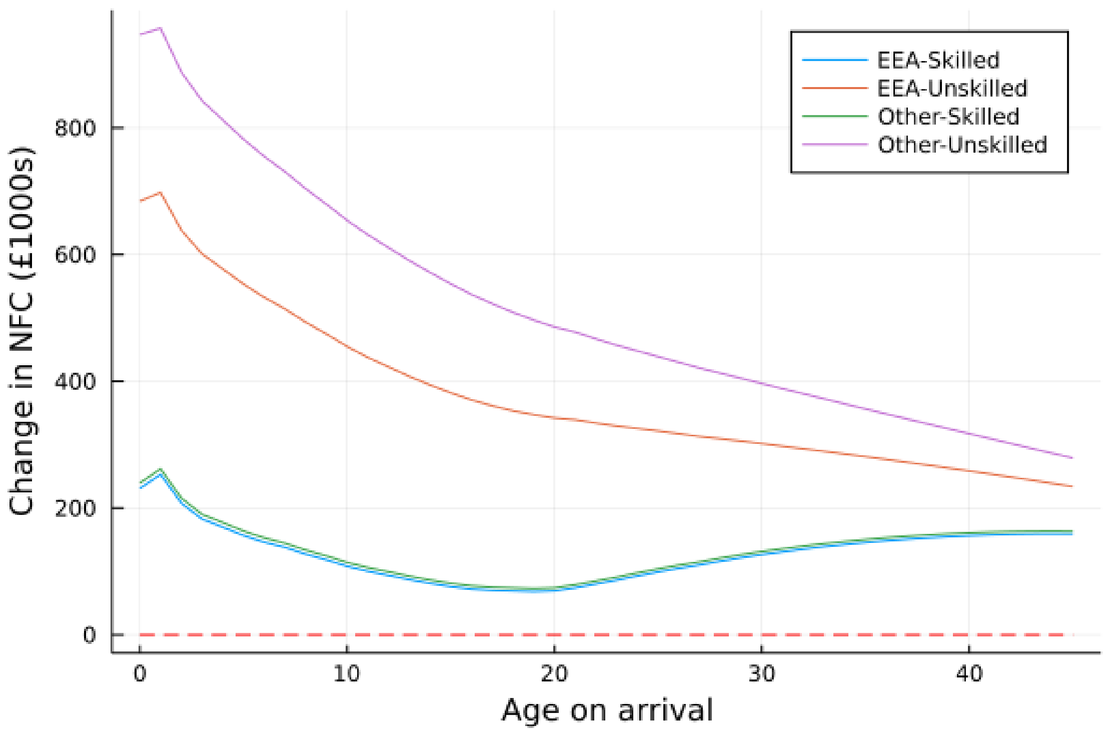
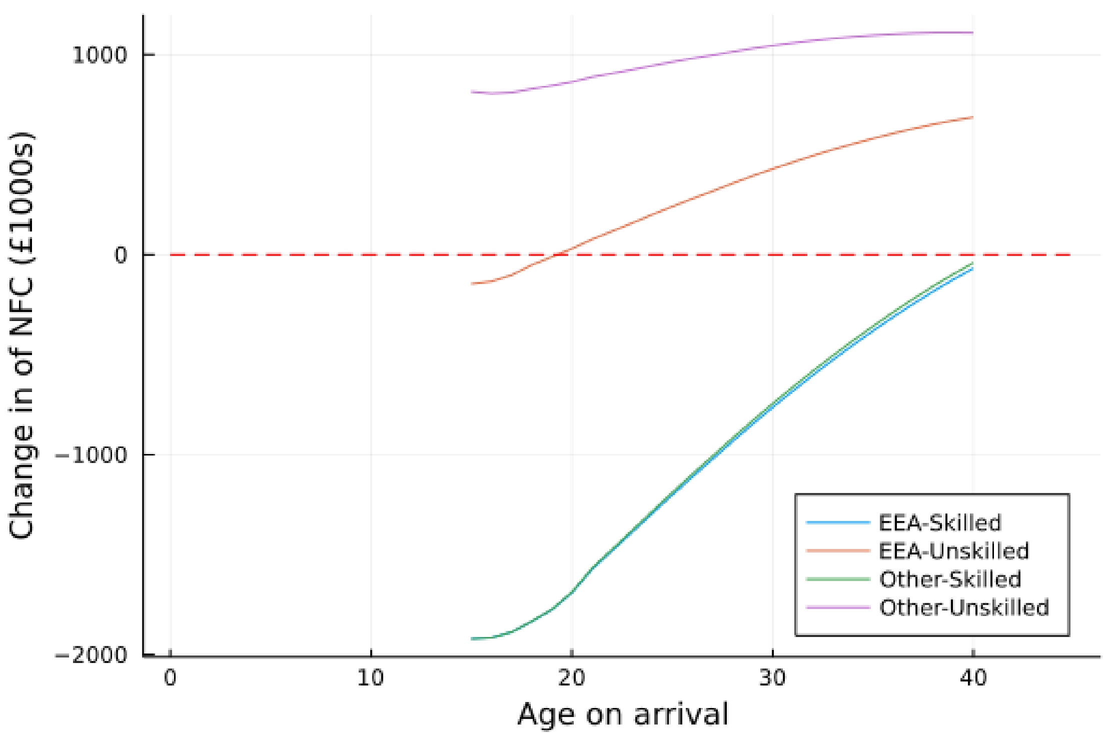


Fig. 16: Higher return migration with GE effects ($\varsigma = 0.13$)



Tab. 2: Wage gap

	EU	Other
No Degree	-8.83%	-8.37%
Degree	-10.32%	-2.01%

effects are most positive when young and steadily decline with age, as illustrated in figure 12, whereas the indirect effects are initially negative and rise with age and wealth. Looking at direct effects alone, it would appear beneficial to invite migrants only for short periods and then to encourage them to return home before incurring healthcare and pension costs. However figure 16 makes it clear that doing this (at least for skilled migrants) means losing out on the indirect effects via their higher savings rate.

5.5 Closing the earnings gap

Table (1) makes it clear that there are significant income disparities between migrants and UK natives, even after controlling for age and education. There are many potential explanations for this, such as lower reservation wages, lower English language skills and difficulties navigating the UK labour market. Friedberg [2000] argues that qualifications earned abroad are less respected than those earned in the home country, and so skilled migrants struggle to "take it with them". In her results for Israel, the earnings gap is larger for more qualified migrants.

The differences are summarised in table 2 as a percentage of the wage of an otherwise identical native. We note that the wage gap is about 8% for unskilled migrants of both origins, but diverges for skilled migrants, with EU skilled migrants earning substantially less than non-EU migrants and natives. It is not immediately obvious why this pattern emerges or why our results for the UK are different to Friedberg [2000]'s results for Israel, and a full explanation is beyond the scope of this paper. We do suggest that part of the differential between skilled EU migrants and skilled non-EU migrants may be because non-EU migrants are more likely to have attended university in the UK and hence to possess UK qualifications, in line with the theory in Friedberg [2000]. An alternative explanation might be that relatively higher barriers to entry for non-EEA migrants before Brexit created a positive selection effect, although it is not immediately obvious why this would only apply to skilled migrants.

Regardless of the cause of these wage gaps, it is interesting to examine the potential fiscal gains of reducing them. For example, this could take the form of policy interventions to help migrants job-match to make the best use of their skills, better provision of English language lessons, or improving employer awareness of foreign qualifications. Our analysis below does assume that these wage gaps represent productivity differentials and hence wasted potential. If instead they stem from bargaining power, then the fiscal gains would be smaller or even negative since any gains to the migrants would largely be at the expense of UK firm-owners. Offsetting this, our analysis does not show the additional gains from reduced welfare spending on tax credits, housing benefit and so on, nor the potential for higher average tax rates as migrants move into higher tax brackets. Overall, we believe our results will be imprecise but still provide a good indication of the potential fiscal gains.

The changes to NFC after eliminating the wage differentials are shown in figures (17) and (18) without and with GE effects respectively. Without GE effects, the intervention is unambiguously positive, and we see gains to the NFC of between $£25,000$ and $£100,000$. As expected, the biggest gain is from skilled EU migrants, who have the largest wage gap in both relative and absolute terms. The effect is straightforwardly declining in age, with younger migrants gaining most. This arises partly because of wage growth, with a 10% gain to a 2040 wage larger in absolute terms than a 10% gain to a 2020 one, and partly because of negative interest rates making future income more valuable.

With GE effects included, the picture becomes more complicated. The gains remain unambiguously positive for unskilled migrants, but are reduced for skilled workers. This is induced by a sharp rise in the

Fig. 17: Reducing the wage gap (no GE)

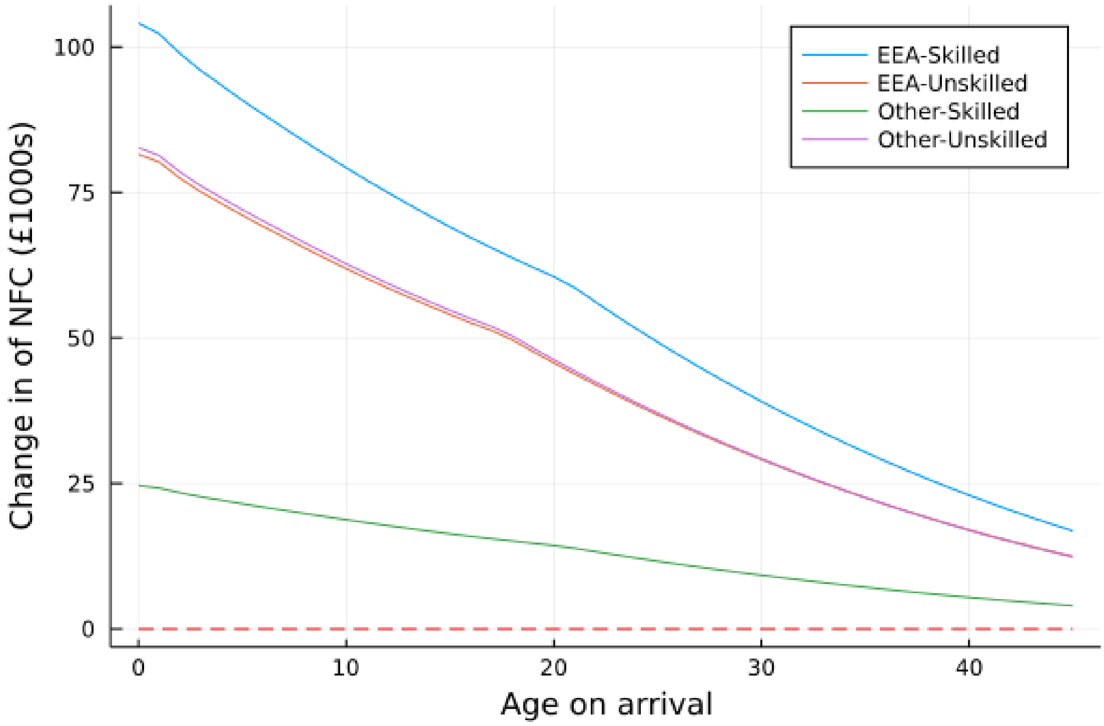
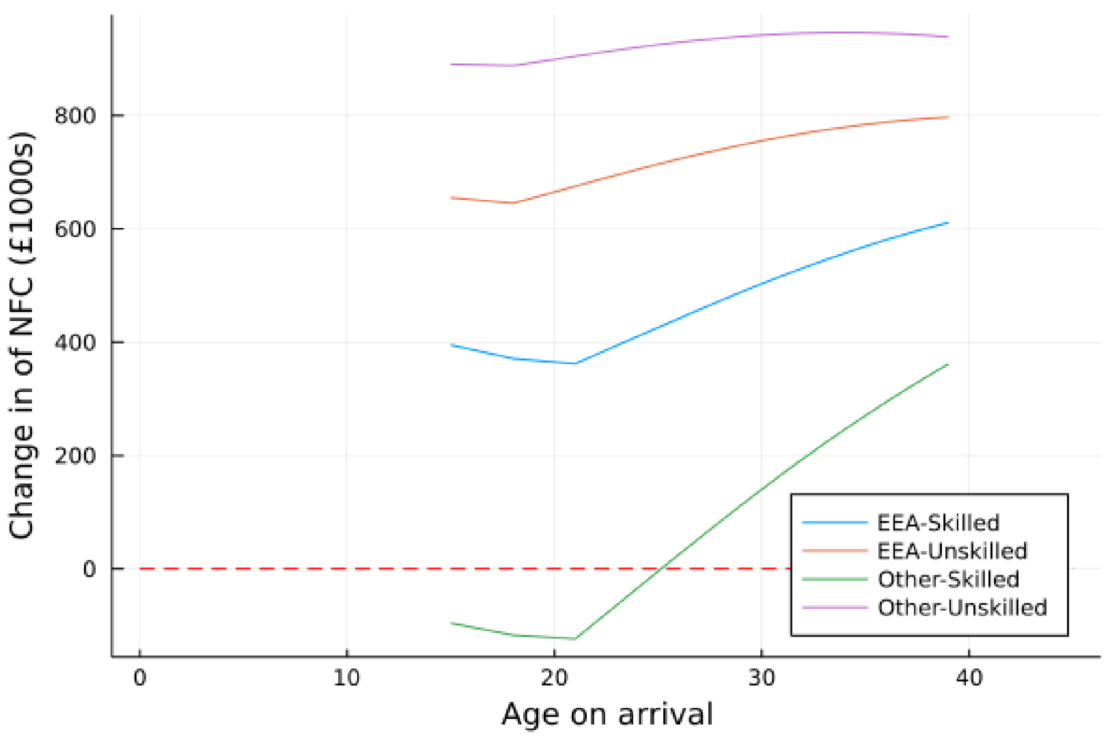


Fig. 18: Reducing the wage gap (GE)



Tab. 3: Brexit Scenarios

		No GE	Full	Short stay (all)	Short Stay (only unskilled)	Ability gap
	Baseline	*304.6*	*370.2*	*202.3*	*497.8*	*588.6*
Scenario	-50% EU unskilled	-21.1	38.5	27.9	28.31	6.4
	-25% EU skilled	-20.2	-67.9	-42.1	-67.9	-77.4
	+25% non-EU skilled	37.7	127.1	79.1	127.1	128.2

"Scenario" rows show the change relative to the baseline. All numbers are in 2019 £ billions.

interest rate: with labour suddenly more productive, the cost of capital rises and increases the interest paid on government debt. For all but young, skilled non-EU workers, this is more than offset by a rise in household net savings which reduces interest rates in later periods. It is worth reiterating that the strength of the interest rate response is exaggerated both by the closed-economy modeling and by the fact that both the productivity gains and the migration shock are unanticipated. Were these shocks announced in advance, there would be time for a savings response to partly offset these effects.

6 Brexit Scenarios

We combine the estimates above with different scenarios for the volume and distribution of migrants. Unfortunately, the impact of Brexit on migration remains unknown. While there was some initial disruption in the years following the vote, we only have one year of data after the end of free movement. In turn, the end of free movement following the expiry of the transitional period coincided almost exactly with the beginning of the Covid-19 global pandemic, which severely confounds the migration statistics. Indeed, since March 2020 the UK has not been collecting data on migration flows [Portes, 2021a].

We therefore suggest a range of plausible scenarios to get an indication of the potential fiscal effects of the post-Brexit migration policy. Since the end of the transition period, the UK government has outlined a new points-based immigration system designed to favour skilled workers. Both a job offer and a high level of English are mandatory, with additional points scored based on salary, qualifications and whether the job is a designated "shortage occupation" [UK Home Office, 2021]. This is in line with the government's stated intention to attract the "best and brightest" [BBC News, 2020], while reducing low-skilled migration.

Our baseline scenario is that migration remains the same as in 2019, as a share of population. We then look at a scenario in which unskilled migration from the EU declines by 50%, on the assumption that the points-based system works as intended, and a further scenario in which skilled migration from the EU also declines by 25% on the assumption that the additional paperwork and administration caused by Brexit discourages some skilled migrants as well as excluding unskilled ones. Finally, we also consider a scenario where non-EU migrants rise by 25%. This could be the case if, for example, reducing immigrants from the EU made the UK more inclined/able to increase non-EU migration.

To obtain the value of migration in each scenario, we take the straightforward approach of mutliplying the number of migrants with the appropriate NFC. This will not be completely accurate, since the effects of migration are partially nonlinear, but may be considered a first-order approximation to the some value. This has the important advantage that each scenario can be considered additively, allowing us to readily compare across scenarios and

consider them in conjunction. When computing the "short stay" (with high return migration as in section 5.4) and "ability gap" (with removed productivity differentials as in section 5.5) versions of the model, we use the general equilibrium results.

Results are shown in table 3. The first row shows the baseline scenario with 2019 migration statistics, the other rows show the additive changes relative to this baseline. For example, the table shows us that in the full model, the UK public finances would 38.5 billion stonger with -50% unskilled EEA migration. The figures are all very large, with a headline estimate of £370 billion with the full GE model, or about 16% of GDP. This arises due to the combination of high immigration (roughly as many immigrants as newborns each year) and the negative discount rate strongly pushing up the value of future income. This row also makes it clear how valuable it would be to close the ability gap (worth £218 billion), or to increase return migration by unskilled migrants (worth £127 billion).

Moving down the rows, we see that taking advantage of Brexit to reduce unskilled migration from the EU would indeed be positive for the budget, once GE effects are taken into account. However, these gains are dwarfed by the potential costs if the UK loses out on skilled EU migrants; a smaller reduction has a much larger impact. This is because EU unskilled migrants (especially young unskilled migrants) are reasonably close to budget-neutral, whereas their skilled counterparts are strongly budget-positive. If in the process of tightening the rules on unskilled migrants, the UK loses even one skilled migrant for every 3 unskilled migrants then the fiscal impact will be negative (using the GE model). This could easily arise if, for example, restrictions on unskilled migrants made it harder for the family of a skilled worker to come with them. Finally, we do see that there are large potential gains to be made if the UK was able to increase the numbers of skilled non-EU workers, such as through the new "Global Talent Visa" scheme. It may seem paradoxical that the effect of increasing non-EU skilled migration is so much stronger than for EU skilled migration when their NFCs were so similar throughout section 5; this is because non-EU migrants are on average much younger than EU migrants.

Taken together, these results indicate both that migrants are extremely valuable to the UK and that the UK does have considerable scope to improve the fiscal balance further by number of migrants, their length of stay and the demographic mix. Of course, finding and implementing policies that precisely achieve these targets without unfortunate side effects may prove complex in practice.

7 Conclusion and scope for further research

Our central conclusion is that migration in the aggregate has made and will continue making a positive contribution to the UK's public finances. However, we have also demonstrated that there are significant differences between immigrant subtypes that could be exploited to improve the fiscal balance further. The UK government's post-Brexit emphasis on skilled migration regardless of origin is fiscally sensible, but we suggest there has not been sufficient attention paid to the age of immigrants in light of the strong age differentials observed in this paper. Similarly, the volume of immigration has recieved much more attention than the duration of immigration. Our results in sections 5.4 and 6 show that while there are indeed potential advantages to discouraging unskilled migrants either from coming or staying for long, such policies should be limited and targeted to avoid disuading skilled migrants, who make exceptionally large and positive fiscal contributions.

We have also shown that the estimated impact of migration is starkly different when we consider the closed-economy GE effects compared with the direct fiscal impacts alone. Above and beyond the direct taxes and benefits paid/incurred by migrants, their savings behaviour must also be taken into account. This has implications for the wider literature examining the fiscal effects of migration, which frequently neglects the savings channel. More research is needed to examine the savings behaviour and time-preferences of migrants in detail, idealing including evidence on how this interacts with remittance flows.

Our research does have two important limitations. Firstly, we have considered only a completely closed economy. A more sophisticated model could use a "partially open" framework with some financial frictions to capture GE effects more realistically, muting the strength of the interest and wage responses observed throughout section 5. Secondly, we have considered skilled and unskilled labour as being pure substitutes.

A richer model could use a capital-skill complementarity framework such as in Griliches [1969], which we expect would somewhat reduce the stark differences in fiscal effects between skilled and unskilled migrants.

Further research might also consider accounting for migrant “clustering” in specific locations or sectors. It is well understood that migrants are attracted to areas and jobs which already have a sizeable community of people from the same origin[17]. If labour is not perfectly mobile across locations and sectors, this would tend to exagerate the negative initial disruption after the migrant shock, implying that our estimates above may overstate the net fiscal contributions. There is certainly scope to build a richer labour market framework able to capture the potential role played by migrant clustering.

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[17] See e.g. Munshi [2003] or McKenzie and Rapoport [2010]

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A Parameter Tables

Fig. 19: Economic Parameters

Parameter	Description	Value	Source
σ	Elasticity of utility w.r.t income	1.3	HM Treasury (2018, p.79)
β	Time utility factor	0.995	Freeman et al., 2018
δ	Depreciation rate of capital	0.04	Derived from *Office for National Statistics – Capital stocks and fixed capital consumption (2020)*
α	Capital share of income	0.34	Derived from Stehrer et al. (2019)
g_y	Growth rate of productivity	0.019	Derived from post-1981 data in Thomas & Dimsdale (2017)
g_p	Growth rate of state pension	$g_n + 0.0036$	Office for Budget Responsibility FSR (2018)
ρ	Equity premium	0.0497	Meyer et al. (2019)
VAT	VAT plus all other indirect taxes	0.21	See section 4
$\mathcal{H}_{i,y}$	Healthcare costs for someone aged i in year y	-	See section 4
SW	Age of joining the labour market	18	Assumed
$Retire$	Age of retirement	69	Planned UK retirement age for someone born in 2000
h_a	Decline in hours of work with age	0.991	See section 4
e_a	Years of experience premia	1.003	See section 4
Pen	Full state pension in 2019	£6968	Basic UK state pension for 2019-20 fiscal year
$Claim$	Fraction of individuals aged 70+ that claim the state pension	0.63	Derived from *Office for National Statistics - UK Labour Force Survey (2012-19)*
Pub	Per-capita spending on public goods in 2019	£3920	See section 4
Edc	Per-child spending on education in 2019	£6542	See section 4

Fig. 20: Demographic Parameters

Parameter	Description	Value	Source
$F_{i,y}$	Average children born per individual aged i in year y	-	Pre-2019, derived from *Office for National Statistics – Births in England and Wales*. Post-2019, assumed to converge linearly to a rate of 1.84 by 2030 as per Office for Budget Responsibility FSR (2018)
$\gamma_{i,y}$	Probability that someone aged i in year y survives to $i+1$	-	*Office for National Statistics – Mortality rates (qx), principal projection, England and Wales*. All ages 90+ have been treated identically due to data limitations.
$f_{e,y}$	EEA migrants as a share of UK population in year y	-	*Office for National Statistics Quarterly Report (August 2019)*. Assumed to be equal to the 2019 values for post-2019.
$f_{o,y}$	Non-EEA migrants as a share of UK population in year y	-	Ibid.
N_{19}	UK population in 2019	66.5 mil	*Office for National Statistics – Estimates of the population for the UK, England and Wales, Scotland and Northern Ireland*
fs_{UK}	Fraction of UK natives designated "high skill"	0.457	Derived from *Office for National Statistics – UK Labour Force Survey (2012-19)*, share with a degree or equivalent qualification
fs_e	Fraction of EEA migrants designated "high skill"	0.511	Ibid.
fs_o	Fraction of non-EEA migrants designated "high skill"	0.597	Ibid.
PRM	Probability of re-migration in a given year	0.027	See section 4
MRM	Duration the re-migration is a possibility, PRM = 0 if "time in UK" ≥ MRM	5 years	Following Dustmann & Weiss (2007)

Fig. 21: Tax Parameters before calibration

Variable: Skill	UK Native	EEA	Non-EEA
Poll taxes (net, 2019): Degree	**£1206**	**£1222**	**£805**
Poll taxes (net, 2019): No Degree	**£46**	**£410**	**-£912**
Income Taxes: Degree	*32.6%*	*32.6%*	*33.3%*
Income Taxes: No Degree	*28.7%*	*27.6%*	*27.0%*

B Stability Plots

Fig. 22: Stability of coefficients in the wage regression

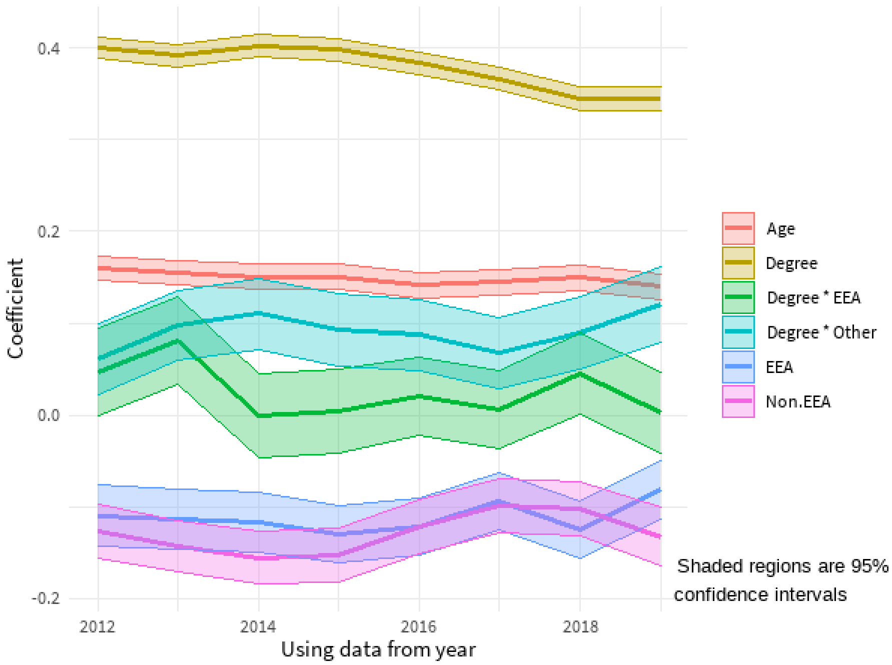
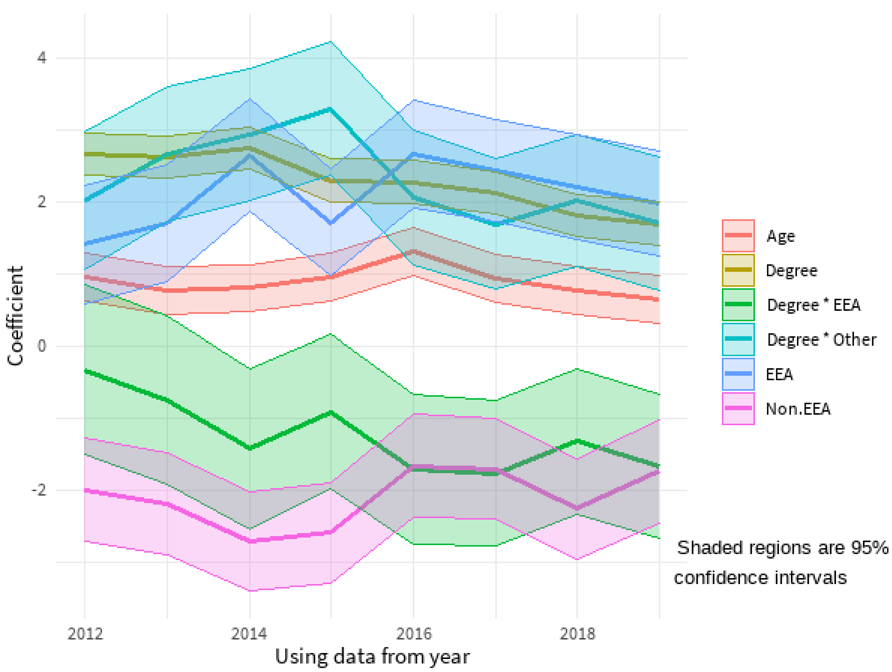


Fig. 23: Stability of coefficients in the hours regression



C Model Output

Fig. 24: Model output: Assets, capital and government debt as shares of GDP

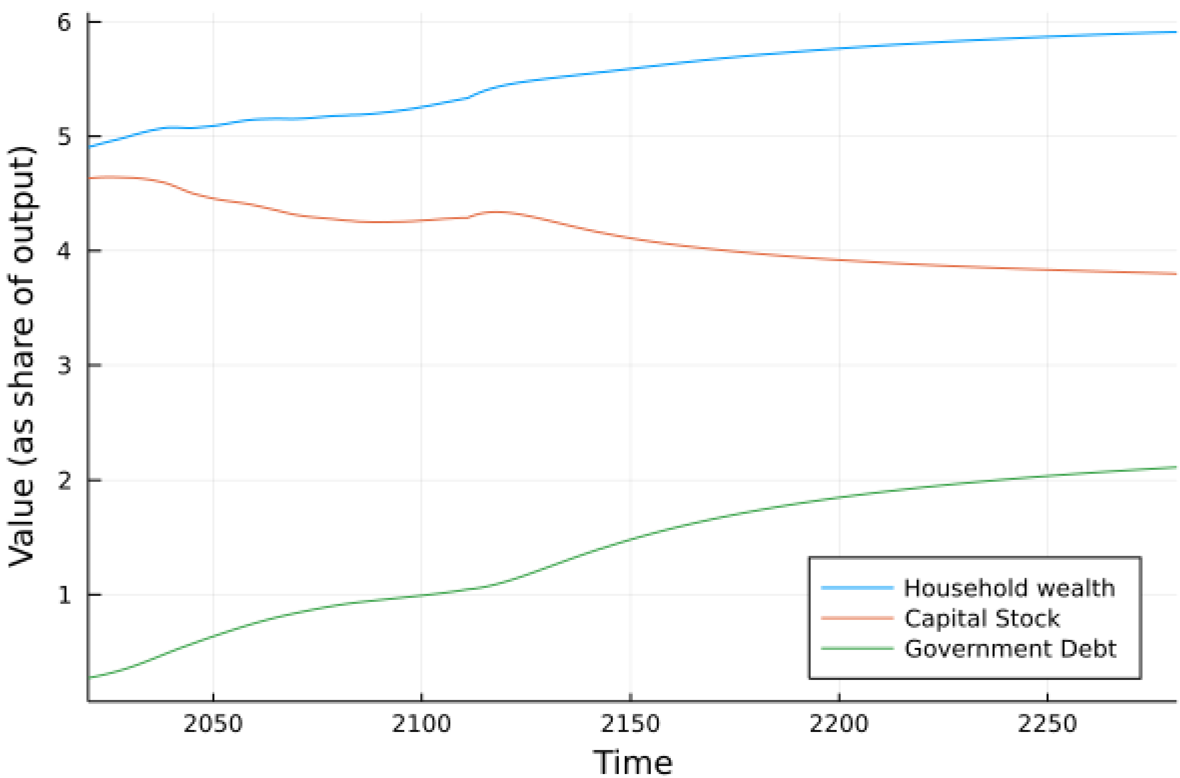


Fig. 25: Model output: Interest rates on equity, bonds and the household portfolio