A quantitative evaluation of earnings risk and wealth inequality in the U.K.

Thesis by

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ABSTRACT

This thesis studies inequality in several dimensions, with an emphasis on the analysis of inequality within and between groups (including by social class, occupation and education). It aims to identify factors that affect inequality and how income and wealth are distributed within society.

In the first chapter, we examine the distributional effects of savings externalities. Incomplete markets models imply heterogeneous household savings behaviour which in turn generates pecuniary externalities via the interest rate. Conditional on differences in the processes determining household earnings for distinct groups in the population, these savings externalities may contribute to inequality. Working with an open economy heterogenous agent model, where the interest rate only partially responds to domestic asset supply, we find that differences in the earnings processes of British households with university and non-university educated heads entail savings externalities that increase wealth inequality between the groups and within the group of the non-university educated households. We further find that while the inefficiency effects of these externalities are quantitatively small, the distributional effects are sizeable.

In the second chapter we examine the distributional effects of social pressure. In particular, we develop a theoretical framework where the cross-sectional distributions of hours, earnings, wealth and consumption are determined jointly with a set of expenditure targets defining peer and aspirational pressure for members of different social classes. We show existence of a stationary socio-economic equilibrium, under stochastic productivity and socio-professional class participation. We calibrate a model belonging to this framework using British data and find that it captures the main patterns of inequality, between and within the social groupings. We discover a complex pattern of how peer and aspirational pressure affects within- and cross-group inequality depending on both group

membership and the inequality measure considered. A principal finding is that wealth and consumption inequality increase within groups who aspire to match social targets from a higher class, despite a reduction in within-group inequality in hours and earnings. Such aspirations can thus lead to social frustration, associated with increases in the dispersion of economic outcomes, and hence in the magnitude and likelihood of underachievement in meeting consumption targets.

The third chapter seek to characterise the nature and cyclicality of household income risk in Great Britain. This chapter establishes new evidence on the cyclical behaviour of household income risk in Great Britain and assesses the role of social insurance policy in mitigating against this risk. We address these issues using the British Household Panel Survey (1991-2008) by decomposing stochastic idiosyncratic income into its transitory, persistent and fixed components. We then estimate how income risk, measured by the variance and the skewness of the probability distribution of shocks to the persistent component, varies between expansions and contractions of the aggregate economy. We first find that the volatility and left-skewness of these shocks is a-cyclical and counter-cyclical respectively. The latter implies a higher probability of receiving large negative income shocks in contractions. We also find that while social insurance (tax-benefits) policy reduces the levels of both measures of risk as well as the counter-cyclicality of the asymmetry measure, the mitigation effects work mainly via benefits.

ALTERNATIVE THESIS FORMAT

This is an alternative format PhD Thesis and includes three papers which are a result of joint work with my supervisors. The papers are presented in the following order:

1. Angelopoulos, K., Lazarakis, S., and J. R. Malley (2019). Savings externalities and wealth inequality, *CESifo Working Paper* No. 7619.

2. Angelopoulos, K., Lazarakis, S., and J. R. Malley (2019). The distributional effects of peer and aspirational pressure, *CESifo Working Paper* No. 7838.

3. Angelopoulos, K., Lazarakis, S., and J. R. Malley (2019). Cyclical income risk in Great Britain, *CESifo Working Paper* No. 7594.

I declare that this thesis has not been submitted for any other degree at the University of Glasgow or any other institution.

Spyridon Lazarakis
Glasgow, September 30, 2019.

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This thesis is dedicated to my parents, Chrysanthos and Spyridoula

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I thank my parents, Chrysanthos and Spyridoula, and my brothers, Manos, Theodosis, Vaggelis and Aggelos, for their encouragement, company and unconditional love.

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INTRODUCTION

Motivation

Since the early work of Jean-Jacques Rousseau (1754), philosophers, scholars, politicians and economists have endeavoured to understand and tackle the issue of inequality.[1] Arguments against inequality, mainly by a moral perspective, there exist in the work of Adam Smith and John S. Mill, while Pareto (1896) is the first to discuss income inequality in a more "technical" way. More recently, a considerable amount of research has been conducted to investigate the economic causes and consequences of inequality. The main findings are that inequality dampens economic performance, triggers redistributive policies, amplifies the impact of aggregate shocks, distorts the effects of a policy reform and more importantly can affect the coherence of the society (see e.g. Stiglitz (2012), Cingano (2014), Ostry *et al.* (2014), Atkinson (2015), Krueger *et al.* (2016), Nolan *et al.* (2018)). Many potential causes of inequality have been discussed, including uninsured income risk, skill heterogeneity, risk-taking, policy, institutions, occupational choice and initial conditions among others (see, e.g. Imrohoroglu (1989), Galor and Zeira (1993), Aiyagari (1994), Quadrini (2000), Mookherjee and Ray (2003), Castaneda *et al.* (2003), De Nardi (2004) Pijoan-Mas (2006), Benhabib *et al.* (2011), Angelopoulos *et al.* (2019)). As a result, various approaches have been used to study income and wealth.

According to Mookherjee and Ray (2002), the theoretical analysis of income and wealth inequality can be separated into three broad groups. The first suggests that the initial conditions determine outcomes (see, e.g. Banerjee and Newman (1993), Galor and Zeira (1993), Ray and Streufert (1993)). The second shows how inequality can be gener-

[1] In earlier societies "*inequality was regarded as a normal condition and injustice as a personal misfortune...rather than a social evil*", see Trigger (2003, pp. 142).

ated through market or other mechanisms, even in the absence of stochasticity (see, e.g. Ljungqvist (1993), and Mookherjee and Ray (2003), Genicot and Ray (2017)). The third group, and the largest amongst the three, suggests that inequality is the outcome of a combination of luck and choices under incomplete markets (see, e.g. Becker and Tomes (1979), Davies (1986), Zhu (2019)). In the third group, we can also include the seminal works of Bewley (1986), Huggett (1993), Aiyagari (1994) and all the subsequent literature based on these papers. This literature is sometimes called the "macroeconomics of inequality" and examines the theoretical implications (mostly) quantitatively. This thesis concentrates on this final strand of the literature.

Within this framework, economists have added many new considerations to the benchmark model to examine factors that generate or amplify inequality. For example, the effects on inequality of higher idiosyncratic uncertainty, work effort, occupational choice, life cycle, bequests, economic policy and inheritance motives as well as differences in preferences have been considered. This thesis contributes to the macroeconomics of inequality literature by examining three topics: (i) the impact of savings externalities on aggregate wealth inequality as well as inequality within and between skill groups; (ii) the effects of social pressure on aggregate as well as between and within socioeconomic groups inequality; and (iii) cyclical variation in income risk.

The quantitative evaluation of these topics focuses on the United Kingdom (U.K.). The U.K. experienced an increase in income inequality over the past last 40 years. Income inequality was constantly increasing during the '80s, but stabilised at a much higher level during the '90s. Many studies try to explain the trends of income inequality in the U.K. (see, e.g. Jenkins (1995), Blundell and Etheridge (2010), Brewer and Wren-Lewis (2016), Atkinson and Voitchovsky's (2011) and Belfield *et al.* (2017)) and most of them suggest that the key driver behind the rise in income inequality, during the '80s, was earnings and wage differentials. Greater equality in investment and pension income along with higher redistribution during the '90s and '00s stabilized its trend around its current levels (Gini coefficient of around 0.34 for net income, Belfield *et al.* (2017)).[2]

In contrast, the debate about wealth inequality in the U.K. is relatively older (Atkinson 1971). Due to poor documentation on wealth information, the research evidence is relatively smaller compared to the analysis of income inequality. Nevertheless, Hills *et al.* (2013) analyse the historical evolution of wealth inequality in the U.K. and suggests an increase, though small, in wealth inequality from the late '70s to the mid '00s. Similarly, a small increase in wealth inequality is suggested by Piketty and Zucman (2015) using

[2] In recent decades, labour income, as opposed to income from rents, has been more important in explaining income inequality (see e.g. Picketty (2014)).

inheritance tax data.[3] Thus, it is fair to say that wealth inequality has been relatively steady the last 40 or more years, especially if we compare it with the big long-run changes in wealth inequality before the '70s, and especially before WWII (see Piketty (2015)).

Recently, new evidence for wealth inequality in Great Britain (GB) from the Wealth and Assets Survey (WAS) has become available. The WAS is a longitudinal survey for GB reporting information on earnings, income, the ownership of assets (financial assets, physical assets and property), pensions, savings and debt, as well as on socio-economic characteristics of the respondents over five waves between 2006 and 2016.[4]. In Table 1, we provide a current snapshot of household earnings, income and wealth inequality in the U.K..[5] In particular, we show four measures of aggregate inequality, the Gini coefficient, the mean over median ratio, the top 1% share, and the coefficient of variation. Furthermore, in Table 2, we show the distributions of wealth, earnings and income. The evidence in Tables 1-2 indicate the similarities and differences between earnings, income and wealth inequality. In addition, in Figure 1, we plot the wealth share of the top 10% of wealth distribution for the OECD countries, going from the smaller to the largest.

First, from Table 1 we see that wealth is more unequally distributed than earnings, and in turn, earnings are more unequally distributed than income. The same result holds independently of the aggregate measure of inequality. Second, all variables are more equally distributed than their U.S. counterparts (see Kuhn and Rios-Rull (2016)), and generally, the U.K. is standing around the middle of the 'distribution' of wealth inequality among the OECD countries, either in terms of the mean over median or top 10% shares (see Figure 1). Further note that the U.K. has lower wealth inequality than the Netherlands, Austria, Germany or even Denmark (which is often perceived as a country

[3]Piketty and Zucman (2015) construct a measure of wealth inequality by the wealth share of the top10% and top1%.

[4]Acknowledging that this might not be entirely accurate, we assume that the wealth inequality in Great Britain (GB) is a very good proxy for the wealth inequality in the United Kingdom (U.K.). In each chapter, we explicitly state which political union, U.K. or GB, we target for the analysis.

[5]Earnings are defined as the sum of labour income of all households members which can come from either employment and/or self-employment. We define income as the sum of labour income, minus taxes plus government and private benefits, plus capital income. We follow the vast majority of the literature and define wealth as net-worth, which is the sum of the net housing and net financial wealth. We further restrict the sample to the households of which the head is within the working age (25-60).

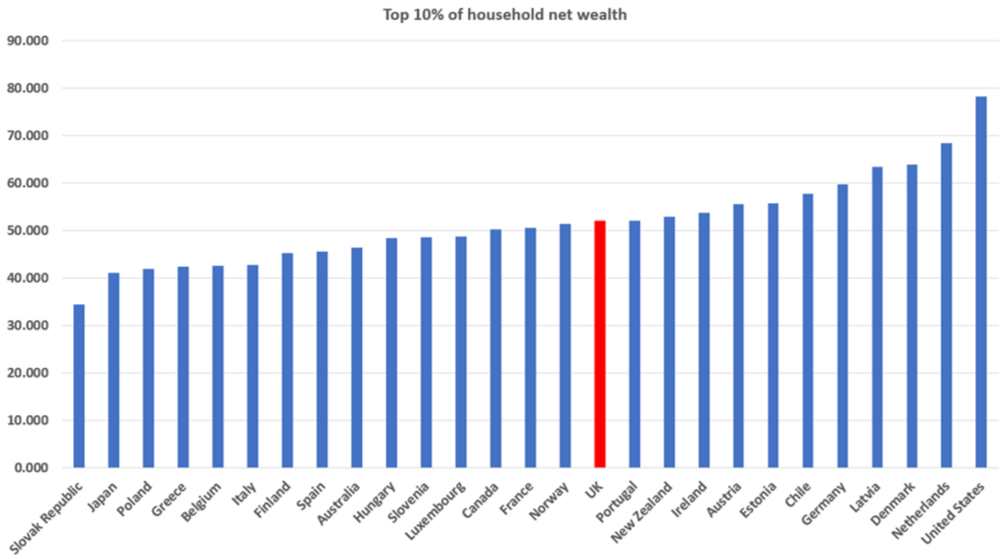
with low inequality).[6] *Yet, the level of wealth inequality is high in absolute terms.*

Table 1: Wealth distributions by group (WAS Data)

	wealth	earnings	income
Gini	0.71	0.47	0.35
mean/median	2.26	1.21	1.19
T 1%	16.5	8.1	6.3
CV	2.34	1.18	0.86

Note: WAS refers to the average statistics of waves 3 of the Wealth and Assets Survey.

Figure .1: Wealth Inequality across the OECD coutries.



Furthermore, in Table 2 and starting from wealth, we see that more than 50% of the total wealth in the economy is held by the richest 10%, while the richest quintile holds a staggering 70%. The top 1% holds a share of around 16% while the households in the bottom of the distribution are net debtors. Consistent with Table 1, we see the richest households in terms of income or earnings hold smaller shares of the total. However, the richest quintile in terms of earnings receives almost 50% of the total earnings. Meanwhile, the richest quintile in terms of incomes receives 41% of the total annual income. The magnitude of the latter is rather surprising given the fact that income contains the equalising effect of taxes and benefits. Note that a large number of households have zero earnings

[6] However, note that these values and comparison might change if it was possible to include some other wealth components such as pension wealth (public and/or private).

but positive income shares, which reflects the sources of incomes other than earnings.[7]

Table 2: Wealth distributions by group (WAS Data).

	net-worth	earnings	income
T 1%	16.4	8.1	6.3
T 10%	51.1	31.5	26.4
Q5 share	70.0	48.3	41.5
Q4 share	21.2	24.6	22.9
Q3 share	8.9	16.5	17.0
Q2 share	1.1	9.3	12.1
Q1 share	-1.2	1.3	6.5
B 10%	-1.1	0.0	2.4
B 0-1%	-0.5	0.0	0.0

Note: WAS refers to the average statistics of waves 3 of the Wealth and Assets Survey.

A crucial aspect is also the relationship between wealth, earnings and income. To shed light on this, in Table 3, we show the pairwise correlations between the three variables. We see that income and earnings are highly correlated, which means that payments other than earnings are on average, a small proportion of income. However, the correlation of wealth with either earnings or income is relatively low, indicating that different mechanisms are affecting these variables.

On the one hand, earnings, which are the largest part of income, are highly variable either for individual/household over time (idiosyncratic variability) or for the whole cross-section (aggregate inequality). In total, the variability of income, i.e. labour income plus income from other sources, depends on effort, luck, ability, occupational choice, policy and on uncertainty related to asset returns (see, e.g. Benhabib *et al.* (2015), Agol *et al.* (2019)).[8] On the other hand, wealth is a stock, and is a consequence of past incomes and saving choices as well as inherited wealth. Thus, current income only affects wealth in the current period. Accordingly, to examine wealth inequality, we need to understand how saving choices are made and how incomes evolve over time, and how both exogenous forces and conscious choices lead to the rise and fall of fortunes. *Since wealth inequality is*

[7] The share of the bottom 1% of the income distribution is not zero, but a very small number, i.e. 0.005%.

[8] In the long run, inequality is also driven by a wide variety of factors such as: globalisation, technological change, financial and monetary policy, labour market deregulation and de-unionisation, increasing market power of firms in both product and labour markets, demographic changes, and changes in redistributive policies (see Nolan *et al.* (2018)).

likely to persist over time it is paramount to examine what factors play a role in shaping it.

Table 3: Pairwise correlations (WAS Data)

	net-worth	earnings	income
net-worth	1		
earnings	0.36	1	
income	0.47	0.92	1

The evidence in Tables 1, 2 and 3 speaks to a considerable strand in the literature which attempts to identify and quantify the sources of economic inequality at the aggregate level (for more detail see the methodology section in the end of the introductory chapter and the reviews in Heathcote *et al.* (2009), Quadrini and Rios-Rull (2015), and De Nardi (2015)). The main idea is that households face idiosyncratic income risk, but due to (partial) absence of insurance markets, these risks cannot be diversified or hedged away. Therefore, as individuals experience different histories of shocks, there will be a cross-sectional distribution of wealth-holdings. The variation in the distribution is called wealth inequality. Naturally then, this literature has focused on the role of idiosyncratic risk under market incompleteness in creating wealth inequality.

The model captures the qualitative properties of the wealth distribution well. However, the quantitative properties fit less well so consequently researchers considered the role of initial conditions, among others, *ex ante* innate differences in preferences or ability, human capital formation, occupational choice, access to markets (e.g. barriers to education and borrowing), technological development (e.g. skill-biased technical change), aggregate fluctuations and labour market imperfections. Despite these significant developments, further analysis is still needed.

First, in this environment, where idiosyncratic shocks drive wealth accumulation, a positive relationship between earnings and wealth inequality is expected. In other words, higher earnings risk (and consequently higher earnings inequality) tends to increase wealth accumulation via precautionary savings, thus spreading out the wealth distribution. The importance of increased earnings risk/inequality in creating higher wealth inequality has long been noted in the literature (see, e.g. Castaneda *et al.* (2003) and Benhabib *et al.* (2017)). The main focus in this body of work is to explain the concentration at the top of the wealth distribution. However, mechanisms that affect whole distribution have not been examined to the same degree. In this thesis we pursue the latter. Moreover, as pointed out by Benhabib *et al.* (2017), in contrast to the expected relationship between income risk and wealth inequality, idiosyncratic uncertainty is not significantly correlated with wealth inequality in the data. Thus, other factors that might affect wealth inequality.

An important example comes from the work of Davila *et al.* (2012) in which they show the importance of pecuniary externalities for the efficiency properties of general equilibrium. In their examples, the agents are *ex ante* equal–something that might not happen in the real world. For example, we know from empirical studies that neither earnings risk or mean earnings are homogeneous across different sub-groups in the population (see, e.g. Meghir and Pistaferri (2004), Blundell and Etheridge (2010), Guvenen *et al.* (2014)). That is to say, there might be permanent (*ex ante*) differences between subgroups in the population. Even though the case of permanent differences have been considered in the literature, their effect on inequality depends on the problem at hand (see, e.g. Castaneda *et al.* (1998) and Guvenen (2006)). However, the literature has not examined the role of pecuniary externalities stemming from these permanent differences. Thus, we try to uncover new insights about the real world and macroeconomic modelling by examining the role of pecuniary externalities arising from permanent heterogeneity on shaping wealth inequality.

Second, social economics research suggests that many choices that individuals make, such as accumulation of productive skills, saving, type of occupation, are (at least in part) affected by societal factors which are beyond their control (see Benhabib *et al.* (2011) and references therein).[9] A recent study by De Giorgi *et al.* (2019) estimates consumption network effects in the Danish population. They estimate non-negligible and statistically significant endogenous and exogenous peer effects. Even though there is no study for the U.K. regarding consumption network effects, there is implicit evidence that these are also present in the U.K.. For example, Elliot and Leonard (2004) studied the behaviour of the school kids and found that if their trainers are branded and expensive, the children believe the owner is rich, seen as popular and able to fit with their peers. More importantly, they are seen as popular and able to fit in with their peers. Thus, given the importance of social pressure for inequality in earnings, income, and wealth, it is natural to include them into formal economic analysis.

Although economists have acknowledged the potential importance of social and cultural influences in many areas in economics, this has been limited in the context of general equilibrium models with incomplete markets. If substantial social or other factors are in place, to understand aggregate outcomes, it is not enough to understand the individual behaviour alone but requires the examination of the mechanisms that aggregate developments affect the individual behaviour as well. Put differently, there is a feedback mechanism from the micro level to the macro level and vice versa, which makes it both

[9]For a psychologists' perspective see Payne (2017) and references therein. The main topic of the book is the role of inequality and social comparison on causing distress, unhappiness and social evils.

interesting and important to explore.

Third, the dynamics of labour income and wages are the foundation for analysing the economic agents' decision making since they are the key ingredient in the calibration and computation of heterogeneous-agent incomplete-markets models (see next section). Income risk is the main "ingredient" to exploring the mechanisms used by families to 'insure' against labour market shocks and affects their decisions either *ex ante* or *ex post*. Therefore, there is a link between the literature of macroeconomics of inequality and the literature of income dynamics.

The economic choices depend on whether the shocks are persistent (or permanent) or purely transitory. Permanent shocks can be thought as job displacements, switching employers or permanent health problems (disability) while the transitory shocks can be thought as family structure changes, demand shocks, temporary health problems, unemployment or even overtime hours (see Meghir and Pistaferri (2011) for an excellent review in the literature of income dynamics). This distinction also has policy implications. On the one hand, if a policymaker aims to mitigate the effects of permanent shocks, then training programmes or induction programmes are required. One the other hand, if she aims to mitigate transitory shocks, then benefits and insurance schemes are in general the appropriate instruments. Thus, the characterisation of income risk is a very important issue.

On top of that, there is evidence from other studies for the U.S., Germany and other countries which suggest that income risk is also cyclical (see Storesletten *et al.* 2004, Guvenen *et al.* 2014, Busch *et al.* 2018).[10] Moreover, income risk is not cyclical in the usual fashion assumed in the theoretical literature, i.e. cyclical variability, but it is cyclical in higher moments. These findings changed the view of economists on how significant are the welfare losses from severe economic downturns. Furthermore, it also changed the perspective of how losses are distributed across the population. For example, in the context of macroeconomic modelling, the time-varying income risk can change the policy suggestions for the mitigation of the business cycle effects on welfare.

Considering the ideas mentioned above, in the first two chapters we develop heterogeneous agents incomplete markets models to numerically evaluate the effects on inequality of pecuniary externalities coming from fixed heterogeneity (Chapter 1) and social pressure (Chapter 2). The third chapter tests the hypothesis of time-varying income risk in Great Britain. The next section sets out the analytical contribution of each chapter.

[10] Note that in chapters two and three, we examine the stationary distribution of wealth, earnings and consumption. For this purpose, we assume that the labour income risk in the UK is stationary (time-invariant).

Review of Chapters

In Chapter 1 we develop an open-economy incomplete markets model, where the interest rate only partially responds to domestic asset supply, with fixed differences between groups based on their level of education. Specifically, we separate the household population according to the educational attainment of the head of household. One group consists of university degree holders, and the other group contains individuals without or any other achievement below a university degree. We calibrate the model to the U.K. data, and we show that the two groups differ significantly in both mean earnings and risk. The model's predictions are in accordance with key stylised facts of wealth inequality in the U.K.. Then, we examine how the asset supply of one group affects the asset supply of the other.

The key finding is that with this type of fixed differences, the model generates a between-group pecuniary externality which works through prices (here the interest rate). This externality works as an amplification mechanism to increase overall wealth inequality and affects the within-group inequality of each group. The savings of each group move the market interest rate away from the level that would be the equilibrium outcome consistent with the asset supply of each group. Consequently, households in the non-university and university-educated groups lower and raise their savings respectively, which in turn implies that within-group wealth inequality is increased for the non-university and decreased for the university-educated. Note that the pecuniary externalities are those externalities that work through the prices. Another way to think pecuniary externalities in macroeconomics is as general equilibrium effects. The main contribution of this chapter is that it demonstrates that even though this kind of fixed differences does not matter considerably for aggregate variables, they do matter for wealth inequality, and especially between and within-group inequality. Another contribution is that the *ex ante* skill heterogeneity helps the benchmark heterogeneous agent model predict inequality, which is closer to the inequality in the U.K. economy.

Chapter 2 focuses on how social pressure, in the form of peer pressure or aspirations, influences economic choices and ultimately, inequality. The main contribution of this chapter is the formal introduction of peer pressure into the incomplete markets model. Peer pressure takes the form of household consumption compared to a social class-related consumption target. The model is flexible enough to accommodate different types of social pressure. For example, we first consider peer-pressure, i.e. pressure to conform to a social-class related target for consumption, for example, the mean consumption of the peers. Then, we consider aspirational pressure, which takes the form of setting the social target to be a relevant measure (e.g. mean or median or 90th percentile) of a higher social group.

We do not formally model the emergence of peer pressure. Instead, we first aim to identify the properties of these social factors so that the existence of a socio-economic equilibrium exists in this type of model. We first show that given the social targets, the household problem admits a unique household-level invariant asset-shock distribution. We define the socio-economic equilibrium in this model as when the aggregated consumption choices of the households coincide with the social class-related consumption targets. We then prove the existence of a stationary recursive socio-economic equilibrium theoretically. However, we cannot exclude the possibility of multiple equilibria. Nonetheless, we explore multiplicity numerically and find no evidence of it.

Then to characterise the effect of peer pressure on the joint determination of aggregate economic outcomes and inequality, we calibrate the model to the U.K. economy to examine its predictions numerically. We find that in stationary equilibria characterised by "keeping up with the Joneses" type of peer pressure, when we consider groups with higher mean wages, within-group inequality is lower in terms of hours and earnings, and higher in terms of wealth and consumption relative to economies without peer pressure. In contrast, for lower mean wage groups, within-group inequality is higher in terms of wealth and consumption and lower in terms of hours and earnings. At the same time, between-group inequality is lower for hours, earnings and consumption, but higher for wealth.

Compared with peer pressure, aspirational pressure allows the groups with the higher aspirations (lower mean wage groups) to close the gap with the top mean wage group in terms of hours, earnings and consumption, while this increases in terms of wealth. However, within-group wealth and consumption inequality are higher, despite a reduction in within-group inequality in hours and earnings. Therefore, the improvement in average wealth that is implied by higher, above class, aspirations, can be associated with an increase in social dissatisfaction, as a result of increased inequality. In general, social pressure determined with reference to a group of peers, directly (peer pressure) or indirectly (aspirational pressure), has differential effects on households incentives to work and save, thus implying non-uniform effects on wealth and earnings inequality.

Chapter 3 examines the cyclicality and nature of income risk in GB. We measure idiosyncratic risk as the variance and skewness of the shocks to the idiosyncratic component of household income. We use parametric methods to characterise the distribution of the shocks and to examine the relationship between these moments and aggregate fluctuations. To achieve this, we use data from the British Household Panel Survey (BHPS) for 1991-2008, and we find that the variance is a-cyclical and left-skewness is counter-cyclical. The latter implies a higher probability of receiving large adverse income shocks in contractions. This result is similar to the findings for other countries, e.g. U.S., Germany and Sweden (see Busch *et al.* (2018)), but it is a new finding for GB.

Furthermore, we assess the role of social insurance policy in mitigating the cyclicality of household income risk. We find robust evidence that both social insurance instruments, tax and benefits, reduce the levels of both variance and skewness, as well as the countercyclicality of skewness. However, the mitigation in risk coming from benefits is more significant than the reduction coming from taxes. This effect in GB is distinct from results for the U.S., Germany and Sweden reported in Busch *et al.* (2018), which emphasised the importance of taxes in reducing income risk. In contrast, we found that cyclical asymmetric income risk was reduced mainly via benefits policy, confirming the importance of this instrument in mitigating income volatility and inequality previously noted by other U.K. studies using different methods than those employed here (see, e.g. Blundell and Etheridge (2010) and Belfield *et al.* (2017)).

Methodology

In Chapters 1 and 2, we seek to examine sources of wealth inequality. Thus, to explore and analyse wealth inequality, we need models that predict a wealth distribution endogenously. The neoclassical growth with perfect markets and idiosyncratic uncertainty is not the appropriate tool for this purpose. The reason is that in this model the initial distribution of wealth persists forever, and hence, the model predicts zero social or economic mobility (see Chatterjee (1994) and Caselli and Ventura (2000)). Or to put it with Aiyagari's own words "*With complete insurance markets, there would be no rags-to-riches or riches-to-rags stories of individual fortunes and misfortunes.*" (Aiyagari (1997)). However, evidence suggests considerable mobility of individuals across the wealth and income distributions (see, e.g. Kuhn and Rios-Rull (2016)).

The solution is to incorporate household heterogeneity in terms of luck, i.e. idiosyncratic uncertainty, into macroeconomic models used for dynamic analysis. Even though the key idea can be traced back to the '70s-'80s (see Bewley (1986)), more intensive research on heterogeneous-agents macroeconomic models started in the 1990s (see e.g. the key contributions of Huggett (1993), Aiyagari (1994) and Krusell and Smith (1998)) and developed vastly in recent years (see e.g. the reviews in Heathcote *et al.* (2009), Ljungqvist and Sargent (2018), Quadrini and Rios-Rull (2015), and De Nardi (2015)).

The key ingredients of heterogeneous agents incomplete markets models include: (i) a continuum of agents; (ii) uncertain agent earnings (or endowment) which follow an exogenous stochastic process, and; (iii) incomplete markets. The first assumption is to ensure that the choices of a single individual do not affect the aggregate. Without this assumption, each idiosyncratic shocks is also aggregate. The typical assumption for the earnings process is that it follows a Markov process. Typically, this process is time-invariant, and aggregate earnings are constant across time. Every period, each household receives idiosyncratic earnings. So, even though the agents are identical, in the sense that they have the same preferences and stochastic processes and face the same prices, they differ because of the differences in their realised earnings, i.e. every period, some agents are lucky and get high earnings, while others are unlucky and get low earnings. The third assumption means that there no insurance markets, so the agents cannot fully insure against earnings shocks. In the framework of complete markets, the agents would insure each other against the earnings shocks. Here instead, the agents can only partially self-insure against earnings shocks by borrowing and lending one-period obligation contracts (bonds) which yield a riskless return (i.e. there are many more goods (states), than markets). Furthermore, there are tight limits on how agents can borrow.

Under idiosyncratic income risk, each individual will be exposed to a different history of shocks in different periods. In turn, the agents accumulate wealth (bonds) to diversify or hedge away this risk partially. Thus, even though the agents are *ex ante* identical (i.e. same preferences, constraints, technology, opportunity and uncertainty), because they cannot fully insure against idiosyncratic risk so that they make different choices, i.e. they differ *ex post*. Therefore, as individuals experience different histories of shocks, there will be a cross-sectional distribution of wealth-holdings. Under certain assumptions for preferences and the exogenous process for income, the optimal household decision yields a stationary distribution. So, the central prediction of the model is an endogenously derived wealth distribution. Moreover, even though the aggregates are constant, the agents move freely within the distribution. The main advantage of these models is that it allows us to analyse wealth distribution (and other variables depending on the model assumptions) and examine the implications of this heterogeneity. However, the main disadvantage is that the problem at hand becomes more complicated to solve since we need to calculate the whole distribution of wealth holdings.[11] To close the model, for a general equilibrium, there are extra clearing conditions which have to be met, with the most typical example being the asset market clearing condition.

The benchmark incomplete markets model, as described above, can capture qualitative properties of the wealth distribution, but quantitatively it underpredicts the extent of inequality, both overall (e.g. as captured by measures such as the Gini index) and at

[11] There is also the possibility of aggregate risk induced by aggregate shocks, but for the purposes of this thesis, we assume that there is no aggregate risk.

the top end of the wealth distribution. The literature has explored several extensions aimed at improving the model's predictions relating to wealth inequality (see, e.g. the reviews in Quadrini and Rios-Rull (2015) and Krueger *et al.* (2016)). Naturally, the first approach in creating higher inequality was to calibrate models with higher idiosyncratic uncertainty (see, e.g. Castaneda *et al.* (2003), Hubmer *et al.* (2016), Benhabib *et al.* (2017)). Other factors have been explored as well such as: (i) work effort (Pijoan-Mas (2006)); (ii) occupational choice (Quadrini (2000)); (iii) life cycle considerations (Huggett (1996)); (iv) bequests and inheritance motives (De Nardi (2004)), and; (v) differences in preferences (e.g. Krusell and Smith (1998)). The case of *ex ante* differences, i.e. permanent differences between the agents have also been considered, but their effect on inequality depends on the problem at hand (see e.g. Castaneda *et al.* (1998) and Guvenen (2006)).

Typically, in most of the papers in this literature, the existence of stationary equilibria is just assumed or shown computationally and not established rigorously. Several attempts have been made to show the existence of stationary general equilibria in this class of models. Bewley (1986) and Huggett (1993) show existence for no production economies but under different assumptions. Bewley (1986) does not allow the agents to borrow and assumes an endowment process that is a stationary Markov with finite state space while Huggett (1993) allows for borrowing and considers a Markovian endowment process with two states and positive auto-correlation.

For economies with production, Aiyagari (1994) was the first to provide a proof of existence, though informal. He allows for borrowing and assumes that labour efficiency shocks are i.i.d, but the proof requires the assumption that the utility function is bounded. Miao (2002) shows the existence of stationary general equilibrium in an Aiyagari (1994) economy without a boundedness condition for the utility function (but imposing other curvature restrictions). However, his proof requires strong assumptions on the monotonicity and smoothness of the income process, which are particularly difficult to show in practice. Recently, Açikgöz (2018) shows existence in an Aiyagari (1994) economy under the assumptions that the income process is a generic multiple-state (but finite) irreducible aperiodic Markov chain and the utility function is unbounded. Nevertheless, the proof requires that the coefficient of absolute risk aversion tends to zero as consumption goes to infinity. Acemoglu and Jensen (2015) also show the existence of stationary general equilibria, not only for Bewley-Huggett-Aiyagari models but also for a more general class of models. They assume that the idiosyncratic income process follows a Markov process with the Feller property and compact support. However, they also assume that the choice set for assets is exogenously bounded.

Marcet *et al.* (2007) show the existence of a stationary general equilibrium for a model with production and endogenous labour supply. However, the results are shown only for the case in which: i) for the labour efficiency process follows a monotone two-state Markov chain, and; ii) the utility function is separable and homogeneous. Zhu (2018) extends the results of Marcet *et al.* (2007) to a model with more general utility assumptions and multiple-state Markov chain without the need of monotonicity. Nonetheless, the proof requires the boundedness of the utility function and the transition matrix to have only positive entries.

In Chapter 1, we specify a heterogeneous agent model with permanent differences between agents, in which there are two groups of agents which form the total population in the model. Individuals in each group face a group-specific earnings process, resulting in different mean earnings as well as risk levels across both groups. Both groups contribute to the production of goods, and they interact via the asset market (i.e. via the interest rate) and the labour market (i.e. via the wage rate). Finally, the economy trades in global financial markets taking the interest rate as given but pays a risk premium on top of a risk-free interest rate (see, e.g. Kraay and Ventura, (2000) or Schmidt-Grohe and Uribe (2003) for debt-elastic interest rate). The risk premium is a function of the foreign asset position relative to GDP. To the best of our knowledge, we are the first to consider an open economy in this class of models in a tractable way, where the interest rate only partially responds to domestic asset supply, and we show that such an open-economy general equilibrium exists.

In Chapter 2, we build on Zhu (2018) and we extend the notion of equilibrium in the context of heterogeneous agent models by taking into account the social interactions stemming from social pressure (peer or aspirational pressure). In our framework, aggregate outcomes and inequality are determined by individual responses to uninsured idiosyncratic income shocks and socio-economic class participation, as well as social pressure. Importantly, the extent of social pressure is an equilibrium outcome, determined jointly with the distributions of the economic outcomes that it contributes to.[12] The equilibrium is obtained when household-level decision-making is consistent with the aggregate-level social targets. Put differently, the equilibrium is obtained when the consumption target for each group equals the respective moment of the distribution of consumption that arises under the whole set of consumption targets. This chapter contributes methodologically to

[12] Note that we do not depart from methodological individualism which is the foundation of the methods employed in economics and implies that "all explanations must run in terms of the actions and reactions of individuals" (Arrow (1994)). In our framework, social pressure arises from targets set by the social groups and determined jointly with the distributions of the economic outcomes that it contributes to. This approach is consistent with modern, "microfounded" economic analysis and also consistent with the work in the Handbook of Social Economics, edited by Benhabib *et al.* (2011).

the literature on heterogeneous agent models in two respects. First, we extend the notion of equilibrium in the context of heterogeneous agent models by taking into account the social interactions stemming from peer and aspirational pressure. Second, we suggest an algorithm to compute the equilibrium and search for a uniqueness for the model with peer and aspirational pressure.

Chapter 3 is empirical and employs statistical parametric methods to characterise income risk in GB. Quantitative macroeconomists have recently adopted the models of earnings processes as a key ingredient in the calibration and estimation of heterogeneous-agent incomplete-markets models. The earning dynamics literature is motivated by Friedman's permanent income hypothesis and aims to distinguish between permanent and transitory shocks to income. Empirically this is not an easy task and is a key challenge is this field. There are two leading views about the nature of the income process in the current literature. The first suggests that individuals are subject to extremely persistent shocks, almost random walk, under the assumption that they face similar life-cycle income profiles (conditional on some observable characteristics like experience, education, gender). The second approach suggests that individuals are subject to shocks with modest persistence, under the assumption that facing life-cycle profiles that are individual-specific and can leave space for heterogeneity in initial conditions. Typical examples of the first approach are Abowd and Card (1989), Meghir and Pistaferri (2004), Blundell and Etheridge (2010) while for the second approach are Lillard and Weiss (1979), Baker (1997), Haider (2001) and Storesletten *et al.* (2004).

Storesletten *et al.* (2004) went one step further. They examined the cyclicality of income risk in the U.S.. The novelty is that they have exploited the available information embedded in the variability in incomes. Intuitively, if the agents face persistent income shocks, the current income variance is informative about the past shocks they have faced. Also, if the properties of the income shocks are cyclical as well, then under certain assumptions, we can test their cyclicality. This approach has been extended to higher moments, skewness and kurtosis, to examine the asymmetries and the "possibility" of extreme shocks Busch *et al.* (2016).

There are also alternative approaches in the literature to characterise idiosyncratic income risk and its cyclicality. One approach examines the nature and the properties of idiosyncratic income risk quantitatively and in a parametric-free way (see, e.g. Guvenen (2014), Angelopoulos *et al.* (2017), Busch *et al.* (2018)). Even though this approach has the advantage of imposing minimal restrictions on the data, it also has drawbacks. First, the researcher can exploit only information about the sample period (in contrast to Storesletten *et al.* 2004 and Busch *et al.* 2016), which means that other than the

U.S. there is limited availability of panel datasets with a time dimension long enough to examine cyclical variation. Second, the results cannot be used straight away to calibrate heterogeneous agent models and require one more step to do that, i.e. to calibrate a process to have the same properties to the parametric-free estimates. Arellano *et al.* (2017) and De Nardi *et al.* (2018) follow another approach. They employ an innovative quantile-based panel data framework to study the nature of income persistence and risk. Nevertheless, concerning our question at hand, namely cyclicality of income risk, this approach has the drawback that the researcher can exploit only information about the sample period. Thus, in this thesis, we follow the parametric approach, and mainly, we follow Storesletten *et al.* (2004) and Busch *et al.* (2016).

Formally, a typical specification for the labour income process is the addition of three components, a life cycle component, a deterministic part depending on invariable characteristics (such as the region of living, education, gender), and an idiosyncratic unexplained component. The most important component in this literature is the unexplained part since this is used (typically) to calibrate the macroeconomic models of inequality. The standard assumption for this unexplained component is that consists of two parts, a persistent component, which can be a random walk or a very persistent AR(1) process, and a transitory component which is a mean-reverting stochastic process. Moreover, these processes can be allowed to vary across time, cohorts or age.[13]

The properties of the permanent component or the corresponding transitory component in labour earnings and disposable income variance can be estimated using parametric econometric methods. In particular, we perform the estimation using the Minimum Distance Estimator (MDE) proposed by Chamberlain (1984), as it is the standard tool of estimation in this literature. The main idea is that we try to match the theoretical statistical moments of the model with the estimated statistical moments of incomes in the data. Using Theorems and results from Newey and McFadden (1994), it can be shown that the MDE estimator is consistent and asymptotically Normal.

Standard errors can be calculated either by using asymptotic theory or by using the Bootstrap and in particular, the block bootstrap. The procedure proposed by Hall and Horowitz (1996) is a resampling procedure and draws from the original samples at the individual level, so the time dimension is not affected. The time dimension is critical in our estimation because we want to measure the autocorrelation of incomes. Thus, the randomisation over the time dimension would have destroyed the temporal relationship of incomes. The resulting confidence intervals account for arbitrary serial dependence,

[13] Allowing them to vary in all three dimensions, age, time and cohort, results in perfect collinearity, which is known as "the age-period-cohort identification problem".

heteroskedasticity, and additional estimation error induced by the use of residuals from the first stage regressions.

On the contrary, to have robust standard errors with asymptotic theory, one would need to make brave assumptions about the types of autocorrelation and heteroskedasticity something that the block bootstrap does in a parametric free way. Thus, we choose to use the block bootstrap. Furthermore, we use bootstrap tests to examine the difference in risk (variance and skewness) between definitions of income to unveil the effects of taxes and benefits separately. To the best of our knowledge, this type of bootstrap tests has not been implemented in this literature before.

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CHAPTER 1

SAVINGS EXTERNALITIES AND WEALTH INEQUALITY

1 Introduction

Following the contributions by Bewley (1986), Imrohoroglu (1989), Huggett (1993) and Aiyagari (1994), an extensive literature has examined wealth inequality under idiosyncratic earnings shocks when agents cannot fully insure against uncertain income streams. In this framework, market incompleteness implies, via precautionary savings behaviour, inefficient asset accumulation at the aggregate level. Moreover, different histories of earnings shocks received by individuals imply heterogenous choices for asset accumulation, generating wealth inequality in the stationary equilibrium. The benchmark incomplete markets model features *ex ante* identical agents whose earnings are determined by the same stochastic process, leading to differences in savings. This heterogeneity in savings entails pecuniary externalities via the interest rate. For example, Greewald and Stiglitz (1986) in a model of incomplete markets and imperfect information and more recently Davilla *et al.* (2012) in an incomplete markets model with uninsurable idiosyncratic shocks study the efficiency implications of these savings externalities.

When economic agents are not *ex ante* identical, but instead belong to different groups distinguished by a key characteristic such as productivity, saving externalities can link behaviour in one group of agents with outcomes in another. In particular, significant differences in the level of productivity and earnings risk between groups of households could thus imply pecuniary externalities leading to sizeable wealth inequality between and within groups, in addition to potential effects on efficiency. Here, we examine savings externalities arising from skill heterogeneity, and analyse its implications for wealth inequality and efficiency in the U.K.. To the best of our knowledge, these issues have not been simultaneously addressed in the literature more generally nor have they been confronted for the U.K..

We focus on skill heterogeneity motivated by empirical evidence which documents differences between economic agents with respect to their earnings processes. For example, this evidence shows that earnings risk is not homogeneous across different groups in the population (see e.g. Meghir and Pistaferri (2004) and Chang and Kim (2006)) nor are mean earnings the same (see e.g. Heathcote *at al.* (2010) and Blundell and Etheridge (2010)). We approximate differences in ability and skills at the beginning of working life with university education since empirical evidence shows strong wage and earnings premia for university educated workers (see e.g. Blundell and Etheridge (2010) and OECD (2012) for the U.K.). Moreover, data from the Understanding Society Survey (USoc) 2009-2017 (University of Essex, 2018), suggests clear differences in earnings risk between the group of households whose head is university educated or not. As we explain in our analysis below, the stochastic component of income for university educated households has a higher variance and exhibits more persistence than for the non-university educated.[1]

To investigate how group heterogeneity in mean earnings, risk exposure and persistence (implying saving externalities) contributes to wealth inequality and to the efficiency of the resource allocation in the U.K., we specify an incomplete markets model with state-dependent (Markovian) stochastic earnings processes and let households belong to one of two groups. These groups differ in their earnings processes, both in the state-space and in the transition matrix for idiosyncratic earnings shocks. We calibrate the aggregate model using British data and estimate the earnings processes using USoc which is the latest extensive panel dataset for the U.K.. We then evaluate the model's predictions using wealth data from the Wealth and Assets Survey (WAS) 2006-2016 (ONS, 2018).[2]

Naturally, any effects from savings externalities work via the interest rate in general equilibrium, and are strongest in a closed economy framework. However, the interest rate in the U.K. is largely determined in international financial markets. Thus, we model the U.K. as an open economy, where the domestic interest rate differs from a global fixed interest rate by a function of the net foreign asset position of the country (demand minus

[1] Analysis of the importance of skills and education for inequality in a historical context for the US can be found in Goldin and Katz (2008). Several studies have also documented differences in earnings risk between groups associated with university education (see e.g. Castro and Coen-Pirani (2008) and Hagedorn *et al.* (2016)).

[2] The WAS dataset covers Great Britain only. For consistency, we use the sub-sample for Great Britain from USoc below. However, the results are very similar if we used the whole sample from USoc.

supply of assets), capturing premia charged by the international financial markets.[3] Using recent advances in theoretical research (see e.g. Acikgoz (2018)), we show that this model has a well-defined partial equilibrium with a unique invariant wealth distribution for each type of household given prices. We further show that an open economy general equilibrium exists, and that for the parameter values chosen in the calibration this is unique.

We find that the model predicts wealth inequality both within and between the university and non-university educated groups that is consistent with the data. More specifically, the university educated group has significantly lower within group wealth inequality than the non-university educated group, despite having more persistent and volatile stochastic earnings processes. The model effectively matches the difference in the wealth Ginis between the two groups that are observed in reality and predicts a mean wealth ratio that is close to the data. Therefore, the predictions of the model regarding empirical facts that are of particular interest in this analysis are notably good. As is commonly found using this class of models, the model under-predicts the extent of income inequality at the very top end (top 1 percent). However, it produces very good predictions for the remaining distribution, especially up to the top 5 percent.[4]

The mechanism by which the pecuniary externalities work to affect inequality is as follows. Earnings differences, both in terms of mean earnings and idiosyncratic uncertainty, imply different asset supply functions for the two groups. The equilibrium interest rate is determined by the per capita asset supply function, which is higher (lower) than the asset supply functions for the university (non-university) educated. In other words, the savings of each group move the market interest rate away from the equilibrium level that would be consistent with the asset supply of each group. Consequently, households in the non-university and university educated groups lower and raise their savings respectively. This in turn implies that within group wealth inequality is increased for the non-university and decreased for the university educated, conditional on the earnings shocks that the households in each group receive.

We quantify the effects of the externalities and find that, on average, the two groups increase (university) or decrease (non-university) their equilibrium wealth by about 5 to 6 percent as a result of savings externalities, compared with the counterfactual where

[3] The mechanism linking the domestic interest rate to the international rate and domestic conditions to close an open economy model is motivated by Kraay and Ventura (2000) and Schmidt-Grohe and Uribe (2003)).

[4] The standard incomplete markets model featuring stochastic labour income, one asset and *ex ante* identical agents captures qualitative properties of the wealth distribution, but quantitatively it under predicts the extent of inequality, especially at the top end of the wealth distribution (see e.g. De Nardi (2015), Quadrini and Rios-Rull (2015) and Krueger *et al.* (2016) who also review extensions that can improve the model's predictions in this respect).

the interest for each group was not affected by the actions of the other group. This implies that between group inequality, measured as the ratio of mean wealth, increases by approximately 11 percent. Drilling down below the average effects, externalities induce significant changes in wealth accumulation within each group. For example, the rise and fall in average wealth holdings for the university and non-university groups respectively is roughly 8 to 9 percent for the top quintile and 5 to 7 percent for the bottom quintile. In contrast, for the middle three quintiles, wealth changes range from about 0 to 4 percent. Finally, we find that the inefficiency effects of the externalities are much smaller than the distributional effects since they contribute to an over accumulation of average assets of about 0.8 percent at the aggregate level.

The rest of the paper is organised as follows. We first present the model and data/calibration in Sections 2 and 3 respectively. The model is discussed in some detail to formally introduce the economic environment and clarify the economic quantities used later. We next examine the quantitative implications of the model. We first evaluate the predictions of the model with respect to between and within group wealth inequality in Section 4. We then study the pecuniary externalities mechanism, focusing on its equity and efficiency implications in Section 5. Finally, we present our conclusions in Section 6.

2 A model with ex-ante heterogeneity

We next develop a model emphasising skill differences, pecuniary externalities and wealth inequality. To this end, we consider an economy that is populated by a continuum of infinitely lived agents (households) distributed on the interval $I = [0, 1]$. Time is discrete and denoted by $t = 0, 1, 2, ...$ Households differ in their level of skill. In particular, there are two levels of skill, high and low, and households are randomly and permanently allocated to one of the two. This implies that there are two types of households, high skilled (university educated, u) households, which belong to a set $I^u \subset I$ and low skilled (below university educated, b) households which belong to a set $I^b \subset I$, such that $I^u \cup I^b = I$ and $I^u \cap I^b = \emptyset$. The proportions of high and low skilled households are given respectively by n^u and $n^b = 1 - n^u$. Therefore, there is *ex ante* heterogeneity in the population determined by the skill level of the household, which is assumed to be given.

All households have exogenous labour supply and derive utility from consuming one good that can be acquired by spending either labour income or accumulated savings. Households are identical in their preferences. However, their labour income depends on their skill level, since it determines their productivity. More specifically, households' predictable earnings component differs, reflecting their different skill. This implies that the two groups of households face different effective wage rates. In addition, each household is subject to idiosyncratic shocks, which affect labour income, by determining the residual, unpredictable earnings component. Households draw idiosyncratic shocks independently from a Markov chain which differs for high and low skill households. Both the state-space and corresponding transition matrix differ across the two household types, implying that the level of labour income and the size and persistence of productivity shocks differ for each household type, reflecting different opportunities and earnings risk.

There is a single asset in the economy implying that households cannot fully insure themselves against shocks to labour income. We examine and compute a stationary equilibrium, in which aggregate quantities are constant. In what follows we present the problem for a "typical" high skill educated household and the problem for a "typical" low skill educated household.

2.1 Households

Households have different skill levels ζ^h, $h = u, b$. Denote the idiosyncratic component of labour income of a typical household $h = u, b$ at time t by s_t^h, so that labour income is given by $w\zeta^h s_t^h$, where w is an average wage rate. Therefore, the idiosyncratic earnings shock s_t^h contains shocks that may affect work hours in a time period and/or household productivity.[5] The idiosyncratic earnings shock follows a Markov chain. In particular, we assume that the process s_t^h is an m-state Markov chain with state space S^h and transition matrix Q^h. The state space $S^h = [\overline{s}_1^h, \overline{s}_2^h, ..., \overline{s}_m^h]$ is ordered according to $\overline{s}_1^h > 0$, $\overline{s}_{j+1}^h > \overline{s}_j^h$, $j = 1, ..., m-1$ and has the natural σ-algebra $\mathcal{S}^h$ made up of all subsets of S^h. The elements of the transition matrix Q^h are denoted $\pi^h\left(s_{t+1}^h | s_t^h\right) = Pr(s_{t+1}^h = \overline{s}_{j'}^h | s_t^h = \overline{s}_j^h)$. We follow Acikgoz (2018) and assume that $\pi^h\left(\overline{s}_1^h | \overline{s}_1^h\right) > 0$ and that the Markov chain is *irreducible* and *aperiodic*, i.e. there exists a $k_0 \in \mathbb{N}$ such that $\left[\pi^h\left(s_{t+1}^h | s_t^h\right)\right]^{(k)} > 0$ for all $\left(s_{t+1}^h, s_t^h\right) \in S^h$ and $k > k_0$. This implies that the Markov chain has a unique invariant distribution, with probability measure that we denote by ξ^h.

Households' earnings shock s_t^h is observed at the beginning of period t. They also receive interest income from accumulated assets ra_t^h, and use their income for consumption and to invest in future assets, subject to the budget constraint for each $h = u, b$:

$$c_t^h + a_{t+1}^h = (1+r)\, a_t^h + w\zeta^h s_t^h, \tag{1.1}$$

where $c^h \geq 0$, $a_t^h \geq -\phi^h$ and $-\phi^h < 0$ denotes a borrowing limit on the household. The

[5] Examples include the quality of the match between employer and employee, health shocks, or changes in personal circumstances.

set comprising a_t^h is defined as $\mathcal{A}^h = [-\phi^h, +\infty)$. The prices (interest rate r and wage rate w) are assumed to be fixed and non-random quantities. This holds if the household's actions take place in a stationary equilibrium, which is defined below. Households assess consumption streams with an intertemporal discount factor $\beta \in (0,1)$, using a per period utility function $u(c_t^h)$. The utility function $u : [0, +\infty) \to \mathbb{R}$ is bounded, twice continuously differentiable, strictly increasing and strictly concave.[6] Furthermore, it satisfies the conditions $\lim_{c\to 0} u_c(c) = +\infty$, $\lim_{c\to\infty} u_c(c) = 0$ and $\lim_{c\to\infty} \inf -\frac{u_{cc}(c)}{u_c(c)} = 0$. These assumptions are typically employed in the literature of partial equilibrium income fluctuation problems (see e.g. Miao (2014, ch. 8)) and in the literature relating to incomplete markets with heterogeneous agents in general equilibrium (see e.g. Aiyagari (1994) and Acikgoz (2018)) to ensure a well-defined stationary equilibrium. The assumption that $\lim_{c\to\infty} \inf -\frac{u_{cc}(c)}{u_c(c)} = 0$ implies that the degree of absolute risk aversion tends to zero as consumption tends to infinity.

The interest rate and wage rate are taken as given and satisfy $r > -1$ and $w > 0$. Moreover, as has been shown (see e.g. Aiyagari (1994), Miao (2014, ch. 8) and Acikgoz (2018)), a necessary condition for an equilibrium with finite assets at the household level in this class of models is that $\beta(1+r) < 1$. Borrowing limits are imposed following e.g. Aiyagari (1994), i.e. assets must satisfy:

$$\begin{aligned} & a_t^h \geq -\phi^h, \text{ where} \\ & \phi^h = \min\left[\gamma, \frac{\bar{s}_1^h \zeta^h w}{r}\right], \text{ if } r > 0 \text{ or} \\ & \phi^h = \gamma, \text{ if } r \leq 0, \end{aligned} \tag{1.2}$$

and $\gamma > 0$ is arbitrary parameter, capturing an *ad hoc* debt limit. This restriction implies that even if the financial markets have the power to confiscate all of the income of the household, they would never lend so much that the household reaches an asset position where its lifetime labour income (assuming the worst earnings shock is always realised) was not sufficient to repay debt. This requires that $-r\phi^h + w\zeta^h \bar{s}_1^h \geq 0$.

The problem of the typical household $h = u, b$ is summarised as follows. For given values of (w, r) and given initial values $(a_0^h, s_0^h) \in \mathcal{A}^h \times S^h$, the household chooses plans $\left(c_t^h\right)_{t=0}^{\infty}$ and $\left(a_{t+1}^h\right)_{t=0}^{\infty}$ that solve the maximisation problem:

$$V^h(a_0, s_0) = \max_{\left(c_t^h, a_{t+1}^h\right)_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t u(c_t^h), \tag{1.3}$$

[6] Boundedness is not needed for equilibrium (see Acikgoz (2018)). In the calibration and computation below we will use a CRRA utility function which is not bounded below. However, we will work there with a compact set for assets, needed for computation, which, given the continuity of the utility function, implies boundedness.

subject to (1.2), where $\beta \in (0,1)$, and $c_t^h \geq 0$ is given by (1.1). To obtain the dynamic programming formulation of the household's problem, let $v^h\left(a_t^h, s_t^h; w, r\right)$ denote the optimal value of the objective function starting from asset-earnings state $\left(a_t^h, s_t^h\right)$ and given the interest and wage rate. The Bellman equation is:

$$\begin{aligned} v^h\left(a_t^h, s_t^h; w, r\right) = \\ = \max_{\substack{a_{t+1}^h \geq -\phi^h \\ c_t^h \geq 0}} \{u(c_t^i) + \beta \sum_{s_{t+1}^h \in S^h} \pi^h\left(s_{t+1}^h | s_t^h\right) v^h\left(a_{t+1}^h, s_{t+1}^h; w, r\right)\}. \end{aligned} \tag{1.4}$$

In this case, we aim to find the value function $v^h\left(a_t^h, s_t^h; w, r\right)$ and the policy functions $a_{t+1}^h = g^h\left(a_t^h, s_t^h; w, r\right)$ and $c_t^h = q^h\left(a_t^h, s_t^h; w, r\right)$, which generate the optimal sequences $\left(a_{t+1}^{*h}\right)_{t=0}^{\infty}$ and $\left(c_t^{*h}\right)_{t=0}^{\infty}$ that solve (1.3).[7] Standard dynamic programming results imply that the policy functions exist, are unique and continuous.

Following e.g. Stokey *et al.* (1989, ch. 9), we define $\Lambda^h\left[(a,s), A \times B\right] : \left(\mathcal{A}^h \times S^h\right) \times \left(\mathcal{B}\left(\mathcal{A}^h\right) \times \mathcal{S}^h\right) \rightarrow [0,1]$, for all $(a,s) \in \mathcal{A}^h \times S^h$, $A \times B \in \mathcal{B}\left(\mathcal{A}^h\right) \times \mathcal{S}^h$, to be the transition functions on $\left(\mathcal{A}^h \times S^h\right)$, induced by the Markov processes $\left(s_t^h\right)_{t=0}^{\infty}$ and the optimal policies $g^h\left(a_t^h, s_t^h\right)$.[8] The transition function is given by:

$$\Lambda^h\left[(a,s), A \times B\right] = \begin{Bmatrix} \Pr\left(s_{t+1}^h \in B | s_t^h = s\right), \text{ if } g^h(a,s) \in A \\ 0, \text{ if } g^h(a,s) \notin A \end{Bmatrix}. \tag{1.5}$$

In this setup, Proposition 5 in Acikgoz (2018) implies that the Markov process on the joint state-space $\left(\mathcal{A}^h \times S^h\right)$ with transition matrix Λ^h has, for each $h = u, b$, a unique invariant distribution denoted by $\lambda^h(A \times B)$. Furthermore, Proposition 6 in Acikgoz (2018) implies that assets for the typical household tend to infinity when $\beta(1+r) \rightarrow 1$. Moreover, Theorem 1 in Acikgoz (2018) implies that the expected value of assets using the invariant distribution is continuous in the interest rate, r.

2.2 General equilibrium in an open economy

We analyse the general equilibrium in an open economy, following Angelopoulos *et al.* (2019) in modelling the latter within a heterogeneous agent model.

[7]In what follows, we suppress the explicit dependence of the value and policy functions on aggregate prices to simplify notation.

[8]For any set D in some n-dimensional Euclidean space $\mathbb{R}^n$, $\mathcal{B}(D)$ denotes the Borel $\sigma-$algebra of D.

Firm

A representative firm operates the technology to transform borrowed assets from the financial market to capital to be used in production, and an aggregate constant returns to scale production function, using as inputs the average (per capita) levels of capital K and employment L. The production function is given by $Y = F(K, L)$ and is assumed to satisfy the usual Inada conditions. More specifically, F is continuously differentiable in the interior of its domain, strictly increasing, strictly concave and satisfies: $F(0, L) = 0$, $F_{KL} > 0$, $\lim_{K\to 0} F_K(K, L) \to +\infty$ and $\lim_{K\to\infty} F_K(K, L) \to 0$. The capital stock depreciates at a constant rate $\delta \in (0, 1)$. The firm takes the interest and wage rate as given and chooses capital and employment to maximise profits, which gives the standard first order conditions, defining factor input prices equal to the relevant marginal products:

$$w = \partial F(K, L)/\partial L, \tag{1.6}$$

$$r = \partial F(K, L)/\partial K - \delta. \tag{1.7}$$

Open economy setup

The economy trades in global financial markets taking the interest rate as given, which implies that aggregate household savings, A^s, can be above or below the capital demanded by firms, K. The difference between domestic savings and domestic capital will give rise to a non-zero net foreign asset position, $NFA \equiv K - A^s$, for the domestic economy. Given the country's net foreign asset position, the country makes interest payments to foreign households equal to $rNFA$, where r is the interest rate at which the country can borrow from abroad. This determines the economy's aggregate resource constraint as:

$$Y = C + I + rNFA,$$

where C is aggregate consumption and I is aggregate investment.

We assume that each country pays a risk premium on top of a risk-free interest rate r^*. The risk premium is a function of foreign debt (see, e.g. Kraay and Ventura, (2000) or Schmidt-Grohe and Uribe (2003) for debt-elastic interest rate). In particular, we assume that the risk premium is positively correlated with foreign debt relative GDP i.e. with NFA over output:

$$r = r^* + \psi \left[\exp\left(\frac{NFA}{Y}\right) - 1 \right], \tag{1.8}$$

for $0 < \psi < r^* + \delta$, which is well defined for $r > r^* - \psi$. The parameter ψ measures the elasticity of the country specific interest rate premium relative to the net foreign asset position.[9] The requirement that $r > r^* - \psi$ is automatically satisfied for a country with negative net foreign assets when $\psi > 0$, as is the case in the calibration for the U.K. below. Household optimisation and (1.8) jointly define a constraint set for the interest rate in general equilibrium, R^{ge}, given by $r \in R^{ge} = \left(r^* - \psi, \frac{1}{\beta} - 1\right)$.

General equilibrium

In Appendix A we define formally the stationary general equilibrium in the open economy and show existence. We also present the computational algorithm. Note that while uniqueness of general equilibrium cannot be guaranteed in general, as is commonly the case in this class of models (see e.g. Aiyagari (1994) and Acikgoz (2018)), it is straightforward to confirm uniqueness for a specific calibration. We compute asset demand, as well as the invariant cross-sectional distribution and mean of asset supply for a typical household, for a range of interest rates consistent with the model, and confirm that the demand and supply curves intersect once (see Figure 2 below).

3 Data and calibration

We approximate the skill level of the households with the education level of the head of the household. More specifically, we consider two groups of households, those whose head has university education, and those whose head does not.[10] At the age of 25, which is the minimum age for heads of households in our sample, the education level is predetermined for the households in the sample, hence all households belong to one of the two types.

We estimate the parameters relating to the Markov processes for the idiosyncratic shocks for the university and non-university groups of households using data on net labour income from USoc. We use net labour income as the relevant quantity to calibrate the earnings processes, as this measure coheres well to earnings in the model. We then evaluate the predictions of the model regarding wealth inequality against data form the WAS.

3.1 Earnings dynamics

Household net labour income is our main measure of income that we use to estimate the extent and persistence of idiosyncratic earnings uncertainty since wealth inequality is

[9] Note that $\psi < r^* + \delta$, implying $r^* - \psi > -\delta$, ensures that domestic firm's demand is finite in the international market, and also guarantees that $r > -1$.

[10] See also Blundell *et al.* (2008) for a similar classification of households into two groups. Note that we also control below for the educational level of the spouse as part of potential observable variation of earnings within the groups of "university" and "non-university" groups of households.

measured using household-level data.[11] We estimate the parameters pertaining to idiosyncratic earnings uncertainty separately for the university and non-university educated groups.

3.2 USoc data

USoc is a large longitudinal survey which follows more than 25,000 households (on average in the first 8 waves) in the U.K.. USoc provides extensive information on sources of income for individuals and households, as well as on socio-economic characteristics, demographics and even health condition of the respondents. Data collection for each wave takes place over a 24-month period and the first wave occurred between January 2009 and January 2011. Even though the periods of waves overlap, the individual respondents are interviewed around the same time each year. Thus, there is no respondent who is interviewed twice within a wave or a calendar year (see Knies (2018)). Our main sample consists of the General Population Sample plus the former British Household Panel Survey sample (BHPS), and we exclude the Ethnic Minority Boost Sample and the Immigrant and Ethnic Minority Boost Sample. For consistency with the WAS dataset, we also drop the households located in Northern Ireland. The inclusion of the boost samples and Northern Ireland sample, or the exclusion of the former BHPS sample does not change our results either quantitatively or qualitatively.

We define net labour income as gross household labour income for employment or self employment net of taxes and national insurance contributions, plus social benefits and private transfers. Households are defined as the family or group of individuals who live in the same residence. The head is defined as the member of the household in whose name the accommodation is owned or rented, or is otherwise responsible for the accommodation. We focus on households whose the head is between 25-59 years and report positive net labour income. Furthermore, we trim the top and bottom 0.5 percent of observations of net labour income distribution in each year, to avoid extreme cases or possible outliers in recorded income. Then, we only keep households who are in the sample for at least three consecutive periods. The final sample consists of 38,844 observations from 7,665 unique households. In Appendix B, we report more information on the net labour income series and sample selection process.

[11] Note that in what follows, net labour income and earnings are used synonymously.

Idiosyncratic shocks

To focus on the idiosyncratic component of income, we follow the literature (see e.g. Meghir and Pistaferri (2004), Blundell *et al.* (2008), and Blundell and Etheridge (2010)) and assume that household net labour income is composed of three components, an element capturing aggregate conditions common to all households, a deterministic part depending on observable characteristics and the idiosyncratic component. By denoting the natural logarithm of the measure of income in period t as $y^h_{i,t}$, for $h = u, b$, we assume that it follows the process:

$$y^h_{i,t} = D^h_t + g(x_{i,t}) + \varepsilon^h_{i,t}, \tag{1.9}$$

where $g(x_{i,t})$ is a linear deterministic function of the observables, $x_{i,t}$, i.e. $g(x_{i,t}) = b^h x_{i,t}$. The vector of parameters for each h is given by b^h and $x_{i,t}$ is a set of dummy variables for experience (approximated by age), region of residence, gender of the head of household, marital status and the educational level of the spouse (if married). Note that the educational level of the spouse is defined in a similar way to the heads i.e. University educated and below University educated. Following Blundell and Etheridge (2010) we also include as a regressor the logarithm of the household size. Function D^h_t captures the aggregate conditions common to all households and is specified as calendar year time effects, i.e. $D^h_t = \sum_{t=2009}^{2017} \mathbf{1}_t d^h_t$, where $\mathbf{1}_t$ is an indicator function which is one when a household i is present at time t and zero otherwise.

For the region dummies we use the U.K. Government Office Regions classification which corresponds with the highest tier of sub-national division in England, Scotland and Wales. Furthermore, following Meghir and Pistaferri (2004) and to be consistent with our model, we estimate (1.9) separately for the households whose head has University education and those households whose head does not. Finally, since in our econometric analysis we employ household quantities for the arguments in (1.9), we define all the variables, apart from the spouse's educational level, in terms of the head of the household.

We next retain the residuals $\varepsilon^h_{i,t}$ for each t as a proxy for the unobserved component of $y^h_{i,t}$ and assume that they are determined by an exogenous $AR(1)$ process (see e.g. Chang and Kim (2006)):

$$\varepsilon^h_{i,t+1} = \rho^h \varepsilon^h_{i,t} + \mu^h_{i,t+1}, \tag{1.10}$$

where $\left|\rho^h\right| < 1$ and $\mu^h_{i,t}$ is a white noise process with variance $\left(\sigma^h_\mu\right)^2$. We further assume that the $AR(1)$ process is covariance-stationary with a zero mean and variance $\left(\sigma^h_\varepsilon\right)^2 = \frac{\left(\sigma^h_\mu\right)^2}{1-\left(\rho^h\right)^2}$.[12]

[12] We have also modelled the idiosyncratic component as consisting of a persistent and transitory

Following Chang and Kim (2006, 2007), we estimate (1.10) via OLS and we summarise the results for the Uni, Non-Uni and the whole sample in Table 1. This table shows that the estimated variance of shocks to net labour income for the Uni group is higher than that for the Non-Uni group. We approximate (1.10) by a discrete state-space process, by applying Rouwenhorst 's (1995) method to build a Markov chain with 15-states (see e.g. Kopecky and Suen (2010) and Krueger *et al.* (2016)).

Table 1: Markov Process Parameters

	Uni	Non-Uni
ρ	0.715	0.692
CI_{90}	[0.703,0.727]	[0.684,0.700]
$\frac{\sigma_\mu}{\sqrt{1-\rho^2}}$	0.445	0.431

The model predictions regarding earnings inequality in the stationary distribution resulting from this approximation are summarised in Table 2, which shows the Gini coefficient, Coefficient of Variation (CV) and variance of logarithms predicted by the Markov Chains with their counterparts calculated using the residuals earnings from equation (1.9). The AR(1) model and 15-state approximation capture well the quantitative differences in within group earnings inequality, as well as the overall level of earnings inequality in each group.

Table 2: Earnings Inequality

	Data		Model	
	Uni	Non-Uni	Uni	Non-Uni
Gini	0.230	0.226	0.244	0.237
$\sqrt{VarLog}$	0.459	0.439	0.445	0.431
CV	0.448	0.429	0.464	0.448

3.3 Wealth inequality

The WAS is a longitudinal survey for GB reporting information on earnings, income, the ownership of assets (financial assets, physical assets and property), pensions, savings and debt, as well as on socio-economic characteristics of the respondents over five waves between 2006 and 2016.[13] The sample corresponds to the households included in the wave, but the interviews in each wave are carried over a two year period, with the respondents providing information for the year of the interview.

component, but we found that this does not improve the model's approximation of residual earnings inequality, nor its predictions with respect to wealth inequality.

[13]The WAS does not provide information for Northern Ireland.

An important feature of WAS is that it uses a 'probability proportional to size' method of sampling cases. This means that the probability of an address being selected is proportional to the number of addresses within a given geographic area, with a higher number of addresses being selected from densely populated areas. The design of WAS recognizes the fact that wealth is highly skewed, with a small proportion of households owning a large share of the wealth. Thus, WAS over-samples addresses likely to be in the wealthiest 10 percent of households at a rate three times the average. Moreover, the large overall sample size (around 20,000 households) provides robust cross-sectional estimates. These features ensure both good coverage of the very wealthy and more precise estimates of overall household wealth. However, as in similar surveys, the very rich (e.g. Forbes 400) are not typically included and this can affect the estimates of the top 1 percent.

We harmonise the definition of the household and of the head of household as it is defined in the previous section. We select household heads between 25-59 years of age. We discard the households with imputed net income or missing educational information. We use household net worth as our measure for wealth. It is the sum of assets minus debt for all household members.[14] Net worth also admits a substantial proportion of the population which have negative current wealth. Details on the wealth data are in Appendix B, which includes key statistics summarising the wealth distributions for all five waves in Table B1.

3.4 Model parameters

The model parameters that do not relate to the Markov chains are summarised in Table 3. Regarding preferences, following the literature we use a CRRA utility function:

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma}, \tag{1.11}$$

and set $\sigma = 1.5$, which is the mid-point of values typically employed in calibration studies for the U.K. (see also Harrison and Oomen (2010) who econometrically estimate $\sigma = 1.52$).

The annual depreciation rate is set to $\delta = 0.0983$ which implies that the capital over income ratio, given the interest rate (see below), is 2.5 at the equilibrium.[15] We use a Cobb-Douglas production function with constant returns to scale with respect to its inputs:

$$Y = AK^{\alpha}L^{1-\alpha}. \tag{1.12}$$

[14] We do not add pension wealth to our measure of net-worth. This allows us to maintain comparability with the infinite horizon incomplete markets literature that generally excludes pension wealth. Further note that pension wealth is highly imputed in WAS.

[15] This is also very close to the values in Faccini *et al.* (2013) and Harrison and Oomen (2010).

We normalise $A = 1$ and set α to 0.3 (see, e.g. Faccini *et al.* (2013) and Harrison and Oomen (2010)). The value of n_u is set to 0.3 based on information on the percentage of university educated households in either WAS dataset or USoc dataset. Finally, we make use of the ratio of the predicted earnings components between the two groups to obtain the ratio ζ^u / ζ^b. We further normalise ζ^b to be equal to one. Note that for the computation we normalise the aggregate labour supply to one, and hence, the units of ζ^u and ζ^b do not matter, but only the ratio. Moreover, we set the international interest rate, r^*, to 0.0215 which is the average value of the real short-term yields in the data for 17 countries for the period 1990-2013 (see Carvalho *et al.* 2016).

Conditional of the above parameters, we calibrate β, ϕ and ψ to match the following data: (i) the value of debt over GDP $\frac{K_t - A_t}{Y_t} = 8.1$ percent which is the average value in the data for U.K. for the period 1990-2013 in the extended External Wealth of Nations Mark II database (see also Lane and Milesi-Ferretti (2007)); (ii) the percentage of indebted households (i.e. those with zero or negative net-worth) in the WAS data, which is 18.5 percent; and (iii) the interest rate in equilibrium, $r = 0.0217$, which is the average value of the real short-term yields in the data for U.K. for the period 1990-2013 (see Carvalho *et al.* 2016). However, note that given $\frac{K_t - A_t}{Y_t} = 8.1$ percent and $r = 2.17$ percent, and given $r^* = 2.15$ percent; ψ is determined by $\psi = \frac{r - r^*}{\left[\exp(\frac{NFA}{Y}) - 1\right]}$. Therefore, in effect we calibrate ϕ and β to match $\frac{K_t - A_t}{Y_t}$ and the percentage of indebted households.

Table 3: Model Parameters

β	σ	δ	A	α	n_u	ϕ	ψ	r^*	ζ^u/ζ^b
0.9718	1.50	0.0983	1.00	0.30	0.30	1.33	0.0024	0.0215	1.461

4 Wealth inequality: model vs. data

We first examine the model's predictions regarding wealth inequality within and between the groups of university and non-university educated and compare these to the data for the U.K.. We summarise the data and model predictions for key statistics of wealth inequality in Table 4, following standard practice in the choice of these statistics, see e.g. Quadrini and Rios-Rull (2015) and Krueger *et al.* (2016).

We complement this Table by Figure 1, which provides a graphical representation of the wealth distributions using the quintile measures of the proportion of total wealth owned by households in the relevant quintile (the first column) and the Lorenz curves (the second column). We also report summary measures of wealth inequality at the aggregate level in the last rows of Table 4 to contextualise the discussion on within and between group wealth inequality.

Table 4: Wealth distributions by group

	WAS Data		Model	
	Uni	Non-Uni	Uni	Non-Uni
Q1 share	-0.006	-0.015	-0.015	-0.051
Q2 share	0.037	0.003	0.066	0.045
Q3 share	0.101	0.075	0.154	0.148
Q4 share	0.205	0.226	0.272	0.283
Q5 share	0.663	0.712	0.523	0.575
T 90-95%	0.136	0.153	0.133	0.144
T 95-99%	0.191	0.205	0.139	0.155
T 1%	0.155	0.148	0.050	0.056
Gini	0.661	0.731	0.545	0.633
a_u/a_b	2.270		1.873	
Gini Total	0.720		0.615	

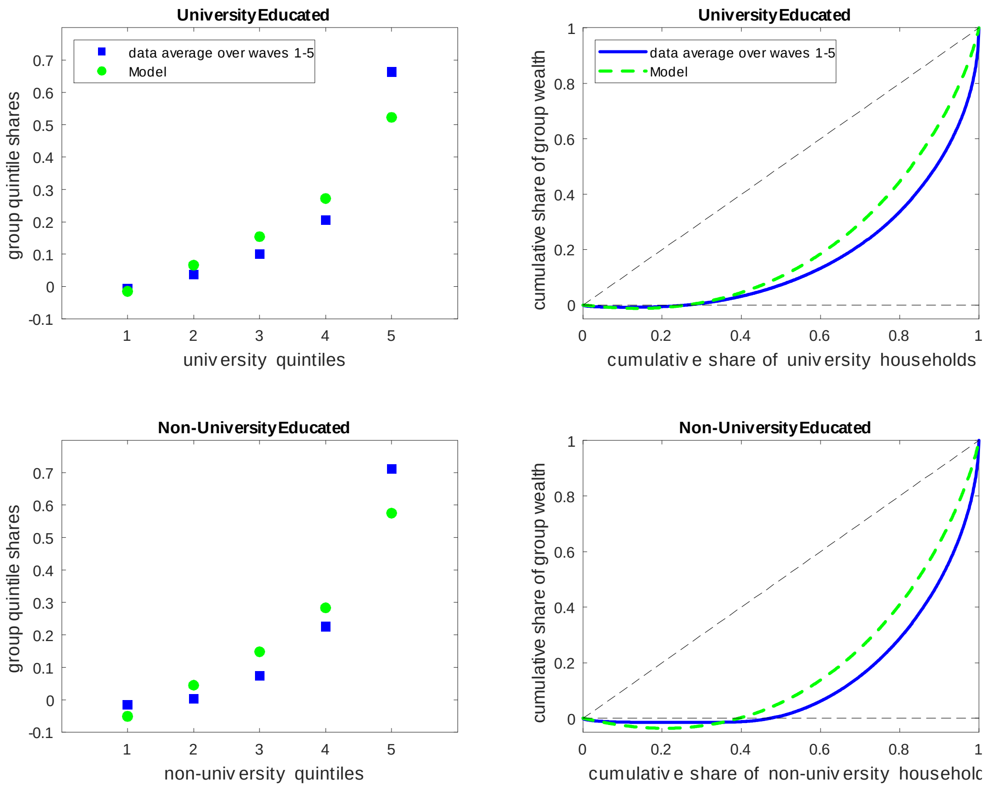
Note: "WAS Data" refers to the average statistics over waves 1-5.

The first two columns in Table 4 summarise wealth distributions in the data, by presenting the averages of the relevant quantities across the five waves of WAS. The main observation is that households whose head is university educated (denoted as Uni) has lower wealth inequality than households whose head is not university educated (non-Uni). This can be seen in Table 4 by comparing the wealth distributions (approximated by the quintile statistics), wealth ownership at the upper tail and the Gini indices.

The quintile shares suggest a relatively smaller concentration of wealth in the lower three quintiles and a relatively higher concentration of wealth in the upper two quintiles for the non-university educated. Given the implied spread between the lower and upper parts of the wealth distributions, all of these observations suggest that wealth inequality is higher for the non-university than for the university educated groups, which is confirmed by the summary Gini measures. Further note that the group of university educated has higher wealth on average, compared with the non-university educated, i.e. the relative wealth ratio, a_u/a_b, is at 2.27 on average across the five waves of data.

The next two columns in Table 4 summarise the predictions of the model in Section 2 and calibrated in Section 3. The calibration implies an average wealth ratio of Uni to Non-Uni households predicted by the model of about 1.9, which is consistent with (but lower than) between group wealth inequality in the data. Importantly, the model coheres

Figure 1: Quintle Shares and Lorenz Curves of the Wealth Distribution by Group



with key properties of within group wealth inequality for the two groups, i.e. higher wealth inequality for the Non-Uni group relative to the Uni group. This result can be seen by comparing the Gini indices, but is more comprehensively demonstrated by examining the relative rankings of the measures of wealth ownership for the two groups. The model predictions track those in the data. When the quintile shares are higher in the data for the Uni group (the Q1, Q2 and Q3 shares), they are also higher in the model. Whereas, when the quintile measures are higher in the data for the Non-Uni group they are also higher in the model. Overall, the model predicts a Gini index for the non-university educated that is significantly higher than the respective index for the university educated.

The model's predictions regarding the extent of wealth inequality relative to the data are close for both groups, with the exception of the predictions for the top 5 percent, and especially the top 1 percent, where the model significantly underestimates wealth inequality, consistent with other models of this class in the literature. The first column in Figure 1 shows the wealth distribution approximated by the quintile shares for the USoc calibration in Table 4. Both show that the model magnitudes are similar to the data for both groups. The second column of Figure 1 suggests that the level of predicted inequality within each group is lower compared with the data, reflecting that overall the model quantitatively under-predicts the extent of wealth inequality. This can also been seen by referring to the Gini index implied by the model for the aggregate economy in the last row of Table 4.

In contrast to the WAS data, the model predicts slightly higher wealth concentrations for the top 1 percent of the Non-Uni relative to the Uni groups. However, a closer look at each of the WAS waves shows that the wealth concentration ranking for the top 1 percent is not consistent over all the waves (see Appendix B). For example, in the first three waves, wealth ownership by the top 1 percent is higher for the Non-Uni while it is higher for the Uni in the last two waves.[16] In contrast, the ranking of the remaining statistics between the two groups in Table 1 does not change over the waves. On the other hand, the model's predictions regarding the relative ranking of the group wealth concentrations in the top percentiles below the top 1 percent (i.e. the shares owned by the top 90-95 percent and 95-99 percent) are very similar to the data.

Overall, the model's predictions regarding wealth inequality capture the main differences between the two groups and the overall extent of inequality, for the majority of the distribution. As is well known in the literature, this class of standard incomplete markets models does not match quantitatively the extent of wealth inequality that we observe in the data with respect to wealth ownership at the very top end.

5 Equality and efficiency implications

We next quantitatively analyse the equality and efficiency implications of the pecuniary externalities associated with the skill heterogeneity in an open economy context for the U.K..

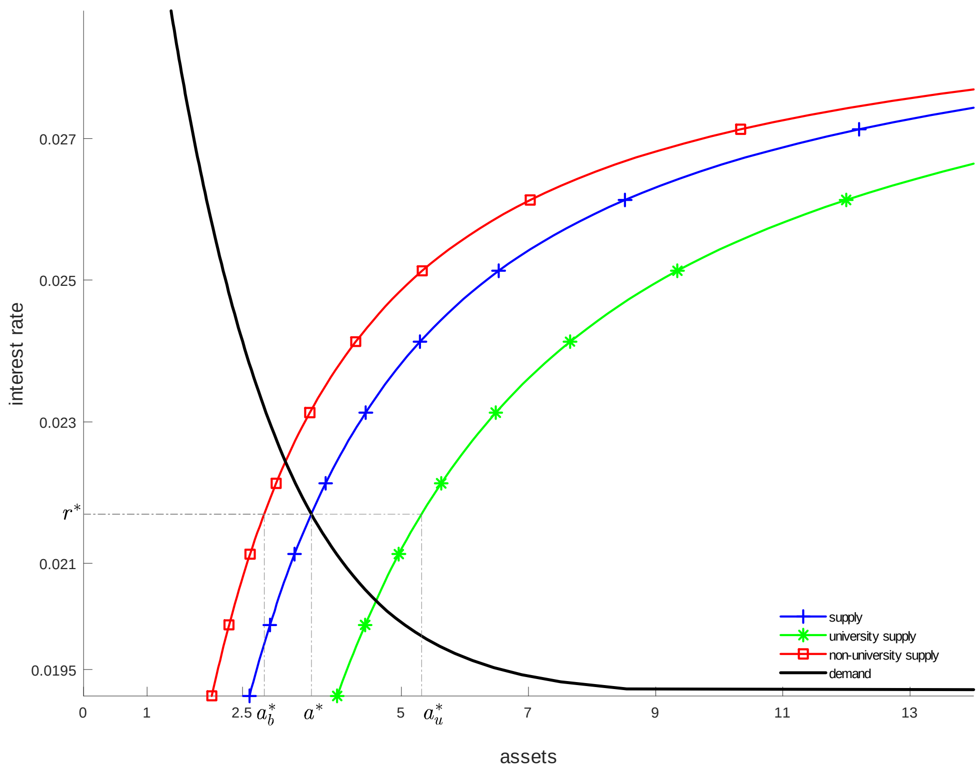
5.1 Equality

We first examine the mechanism by which pecuniary externalities generates wealth inequality and then evaluate the effects of these quantitatively. In particular, we investigate the importance of savings externalities in generating the within and between group inequalities that we observe in Table 4, by comparing inequality and key aggregate quantities for the model analysed above with those obtained in artificial economies. In these economies the two types of households do not interact via the financial market, thus

[16] For example, the ratios of the Non-Uni top 1 percent to the Uni top 1 percent for Waves 1-3 are 1.029, 1.13 and 1.06 respectively. Whereas the corresponding ratios for Waves 4-5 are 0.812 and 0.873 respectively.

eliminating the pecuniary externalities working via the interest rate.[17]

Figure 2: General Equilibrium



We start with the model analysed above and in Figure 2 we plot the asset supply curves for a typical household in both groups of university and non-university educated, as well as the asset supply and demand functions for the aggregate economy.[18] We summarise key quantitative information relating to this Figure in Table 5 under the column "Base". In addition, we add in Table 5 key statistics that capture model predicted earnings and wealth inequality. More specifically, we report the earnings inequality that is implied by the calibration in Section 3 and the wealth inequality in general equilibrium. The general equilibrium is obtained at the intersection point of the aggregate-level supply and demand curves for assets, giving an interest rate of $r^* = 0.0217$ and capital stock of $a^* = 3.583$.

[17]Strictly speaking, the economies without market interaction also shut down externalities via the wage rate. To control for this, we have repeated the experiments in this section by adjusting the wage rate for each group to be the same as in the baseline economy, and the results are very similar quantitatively, suggesting the savings externalities in this model economy work predominantly via the interest rate and not via wages.

[18]Note that the group-level and aggregate-level supply and demand functions are in per capita units. Thus, they refer to mean asset supply and demand functions.

Table 5: Pecuniary externalities and inequality per group

	Base	NI_u	NI_b
r^*	0.0217	0.0212	0.0220
a^*	3.583		
a_u^*	5.317	5.015	
a_b^*	2.839		2.980
Wealth Gini Uni	0.545	0.555	
Wealth Gini Non-Uni	0.633		0.620

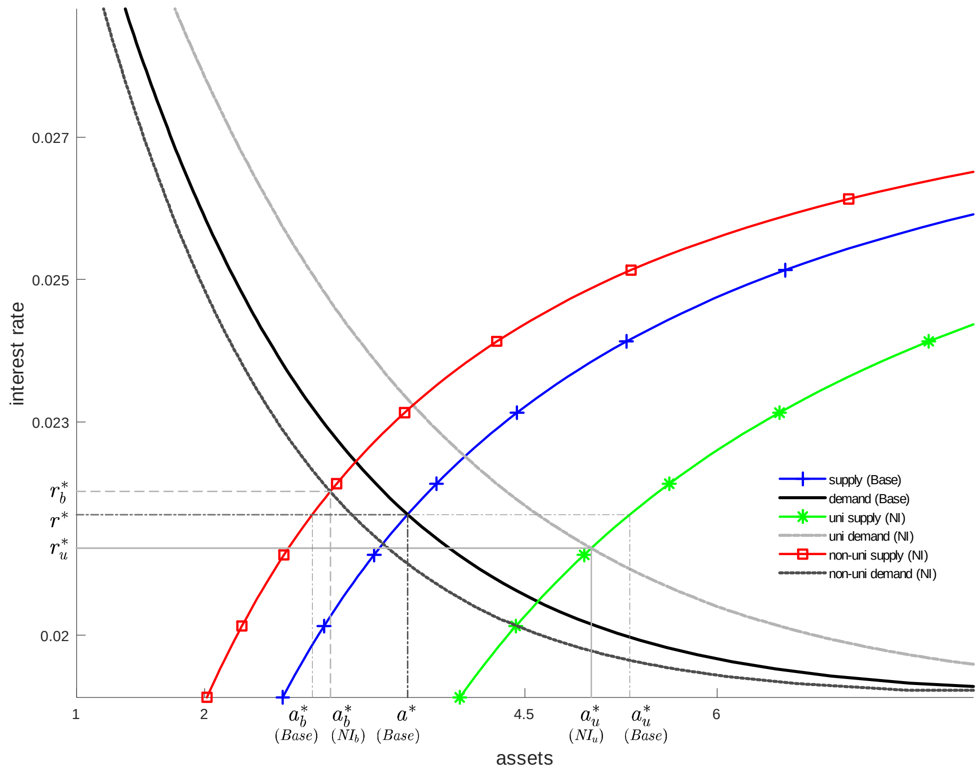
Notes: (i) the NI_h models are based on the same earning processes as in the Base model; (ii) $\frac{a_u}{a_b}$=2.27 in the data; (iii) $\frac{a_u^*}{a_b^*}$=1.87 for the model; and(iii) $\frac{a_u^*}{a_b^*}$=1.68 for NI.

In Figure 3, we again plot the supply and demand curves for this model, which provide the equilibrium (already shown in Figure 2) when the two groups interact via the market in a single economy. We complement this by plotting the asset supply curves for a typical household in each group, which capture mean asset supply per group, together with the mean asset demand curves that would apply if these two groups did not interact. In other words, we treat the two groups as separate economies, each populated with the *ex ante* identical university or non-university educated agents. We denote these as NI (non-interaction) supply and demand. The intersection points of the respective asset supply and demand curves represent the equilibrium interest rate and assets in the absence of group interaction, which are reported in Table 5 under the NI_h, $h = u, b$ columns. The asset supply curves for a typical household in each group in the Base model encapsulate their optimal policy functions and thus choices for savings given aggregate outcomes under market incompleteness. Therefore, from Figure 3 and Table 5, we can see that in the Base model the equilibrium interest rate $r^* = 0.0217$ implies mean assets for the Uni group that are equal to $a_u^* = 5.317$ and for the Non-Uni group that are equal to $a_b^* = 2.839$. Hence, compared with the case where the groups' savings do not affect each other (i.e. $r^* = 0.0212 \Rightarrow a_u^* = 5.015$ and $r^* = 0.0220 \Rightarrow a_b^* = 2.980$), the asset supply of the other group in the general equilibrium of Base economy, works to lower (increase) the interest rate for the Non-Uni (Uni) groups respectively.

Viewed from the perspective of the Non-Uni (Uni) group, the reduction (increase) in the interest rate resulting from pecuniary externalities, reduces (increases) their respective incentives to save.[19] Hence, mean assets are reduced (increased) for the Non-Uni

[19] Note that the (decrease) increase in the interest rate also creates income, in addition to substitution, effects. In this case, the substitution effects dominate in terms of mean savings (see also below for a

Figure 3: Externalities From Skill Heterogeneity

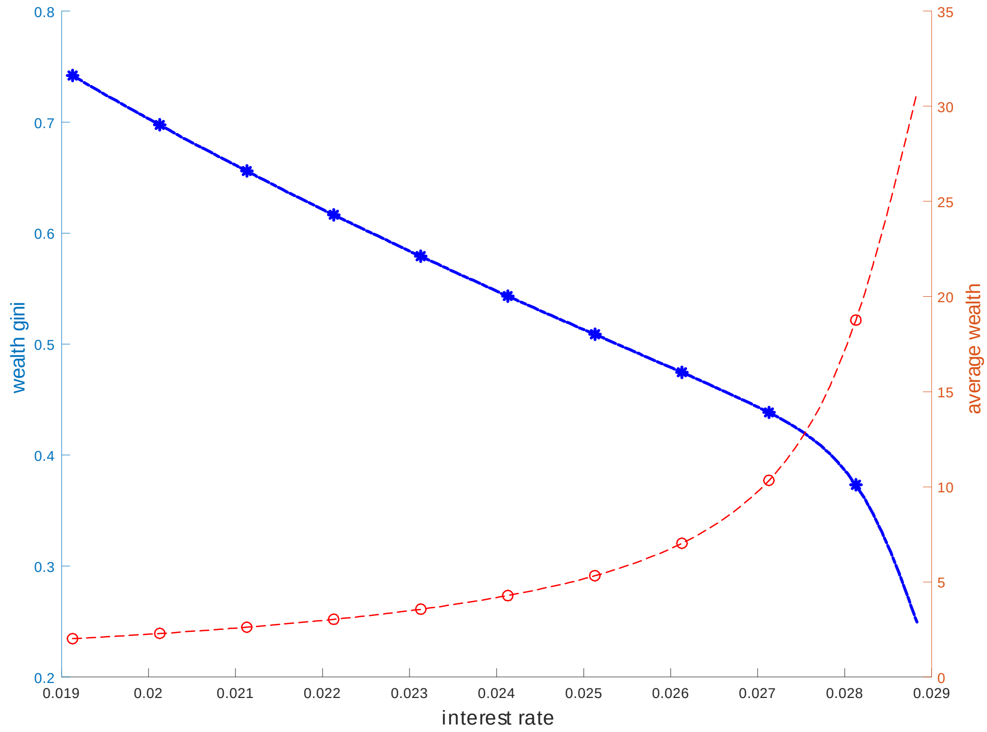


(Uni) group, leading to an increase in the ratio of mean wealth by about 11 percent. In turn, this under-accumulation (over-accumulation) of assets works to increase (decrease) wealth inequality in each group, by increasing (decreasing) the exposure to earnings variability. To illustrate the effect of the change in the interest rate on asset accumulation and inequality for a given group (in partial equilibrium), we plot in Figure 4 mean assets and the within group Gini index for wealth inequality for a range of interest rates, holding earnings risk and all other parameters fixed, for the non-Uni group. As can be seen, an increase in the interest rate, *ceteris paribus*, increases mean group savings and decreases within group inequality.

Therefore, the asset supply of each group creates savings externalities in the financial market which affects inequality in the other group. To quantify the externalities effect, we first summarise in Table 5 wealth inequality for the two groups in these two scenaria. Comparing the NI_h equilibria to the Base model equilibrium, the latter implies higher wealth inequality within the non-university educated, and lower wealth inequality within the university educated. We then further decompose the changes in the Gini index for the two groups in Table 5 into the changes in wealth implied per quintile.

decomposition).

Figure 4: Interest Rate Comparative Statics (non-Uni Group)



In Table 6, we report mean wealth per quintile for the Base economy and for the NI_h equilibria, and the percentage change due to pecuniary externalities. As can be seen, within the Uni (non-Uni) group, the top and bottom quintiles have significantly higher (lower) wealth accumulation under externalities (i.e. about 8 to 9 percent and 5 to 7 percent respectively), whereas the middle three quintiles have lower changes in wealth (i.e. about 0 to 4 percent). Note that the increase in the interest rate generates income and substitution effects for a typical household in the Uni group and the results indicate that the substitution effects dominate at the tails of the distribution, whereas the income effects are stronger in the middle. The changes in the tails are strong enough to determine the positive change in the mean, shown in the last line in Table 6.

The situation is reversed for the non-Uni group. For example, for the bottom quintile and the top two quintiles the decrease in the interest rate, due to pecuniary externalities, implies lower wealth accumulation (the effects are bigger for the top and bottom quintile). For the second and third quintile, the income effects dominate so that asset accumulation increases. However, the decrease in the other three quintiles is stronger and determines the negative change in the mean for the group. On average, the two groups increase or decrease their equilibrium wealth by about 5 to 6 percent as a result of pecuniary externalities. For example, given average net worth of £273,000 for the Uni group and

£121,000 for the non-Uni group across the five waves in the WAS, the results suggest that pecuniary externalities contributes to the average asset accumulation of the Uni by about £16,500 and decreases the average asset accumulation for the non-Uni by about £6,000.

Table 6: Mean assets per quintile by group

	Base		NI		% change $\left(\frac{NI-Base}{\lvert NI\rvert}\right)$	
	Uni	Non-Uni	Uni	Non-Uni	Uni	Non-Uni
$\overline{a}_{Q1}$	-0.495	-0.717	-0.530	-0.684	6.60	-4.82
$\overline{a}_{Q2}$	0.637	0.959	0.665	0.938	-4.21	2.24
$\overline{a}_{Q3}$	2.107	2.716	2.162	2.707	-2.55	0.33
$\overline{a}_{Q4}$	4.968	4.752	4.974	4.864	-0.12	-2.30
$\overline{a}_{Q5}$	19.37	6.486	17.80	7.074	8.82	-8.31
$\overline{a}$	5.317	2.839	5.015	2.980	6.02	-4.76

5.2 Efficiency

We next investigate the efficiency effects of savings externalities and whether they lead to higher or lower aggregate savings compared with an equivalent market allocation where externalities are not present.

The model in Section 2, taking the international markets and skill heterogeneity as part of the institutional setup, incorporates two main sources of inefficiency. The first inefficiency arises irrespective of *ex ante* skill heterogeneity (i.e. even in the case of *ex ante* identical households), as a result of incomplete financial markets, which imply that idiosyncratic earnings shocks lead to income and savings inequality and precautionary savings. This has been analysed extensively in the literature (see e.g. Aiyagari (1994) for theoretical and quantitative analysis in the class of general equilibrium models). These heterogeneous savings imply pecuniary externalities between the households, working from high savers to low savers and vice versa, via the financial markets and, in particular, the interest rate. The efficiency implications of pecuniary externalities incorporated in incomplete market models have been noted since Greewald and Stiglitz (1986) and examined in detail in Davila *et al.* (2012), who have shown that, depending on the stochastic environment, they can work to increase or decrease aggregate savings relative to a *constrained efficiency* benchmark where savings are chosen optimally to maximise aggregate welfare.

The second inefficiency arises because of skill heterogeneity, and also works via the interest rate. In this framework, as we saw in the previous sub-section, the higher savings of the high skill group tends to decrease the market interest rate, thus affecting savings of the low skill group (and vice versa for the savings of the low skill group). Here, we examine whether externalities tend to increase or decrease aggregate savings relative to a situation where in the same market economy savings are chosen optimally without externalities due to skill heterogeneity, and thus whether (and by how much) externalities generates additional inefficiency at the aggregate level.

To this end, we compute the aggregate quantities that characterise the equilibrium of an economy where consumption and savings are chosen to maximise the utility of a typical household in an economy with *ex ante* identical agents, i.e. of households who face the same earnings process, implying that they face the same mean earnings and earnings risk. This model is solved for the same parameter values as the model with the skill heterogeneity, except for those pertaining to the common stochastic process governing earnings for the *ex ante* identical household. To obtain these, we set $\zeta^u = \zeta^b = \zeta$, implying $\zeta = 1$, and assume that the earnings process for the typical household is given by:

$$\varepsilon_{i,t+1} = \rho\varepsilon_{i,t} + \mu_{i,t+1}, \tag{1.13}$$

where $\sigma_\mu^2 = n^u\left(\sigma_\mu^u\right)^2 + n^b\left(\sigma_\mu^b\right)^2$ and $\rho = \frac{n^u\rho^u(\sigma_\varepsilon^u)^2 + n^b\rho^b\left(\sigma_\varepsilon^b\right)^2}{n^u(\sigma_\varepsilon^u)^2 + n^b\left(\sigma_\varepsilon^b\right)^2}$. This gives $\rho = 0.699$ and $\sigma_\varepsilon^2 = 0.435$.

The results from this economy are summarised in Table 7 under the column "Identical". We also repeat for convenience in Table 7 the respective quantities from the base model. As can be seen, pecuniary externalities implies an increase in mean assets by about 0.8 percent compared to a model economy that eliminates this inefficiency. Given an average mean net worth across the four waves in the data from the WAS of about £166,000, this implies that about £1,300 of the average wealth accumulation is driven by pecuniary externalities. Compared with the inequality implications, the in-

Table 7: Inefficiency

	Identical	Base
r^*	0.0217	0.0217
a^*	3.556	3.583

efficiency arising from savings externalities is much smaller.

6 Conclusions

This paper set out to quantify the inequality and inefficiency implications of externalities due to the heterogenous savings behaviour of different groups in the population. To this end, we developed an open economy incomplete markets model with state dependent

(Markovian) stochastic earnings processes and *ex ante* heterogeneity corresponding to being university educated or not. The two groups were allowed to differ in their earnings processes, both in the state-space and in the transition matrix for idiosyncratic earnings shocks.

Using the Understanding Society and the Wealth and Assets Survey for Great Britain, we found that this model predicted wealth inequality both within and between the university and non-university educated groups that was consistent with the data. Although the university educated group faces higher risk in terms of the persistence and volatility of the idiosyncratic component of net labour income, the model predicts that it has significantly lower within group wealth inequality, consistent with the data. In fact, the model predicted a difference in the wealth Ginis between the two groups that is similar to that observed in the data and, more generally, it produced very good predictions for the wealth distribution up to the top 5 percent. Moreover, the model's predictions regarding between group inequality, captured by the mean wealth ratio, were close to the data.

The savings of the two groups generate pecuniary externalities which work via the financial market to increase (decrease) savings for the university (non-university) educated groups. This leads, at the aggregate level, to an inefficient increase in the accumulation of assets, which we find to be relatively small quantitatively, at about 0.8 percent. However, externalities also lead to an increase in inequality between the groups, and within the group of non-university educated, and to a decrease in wealth inequality within the group of university educated. These effects are sizeable with the ratio of mean wealth between the two groups increasing by approximately 11 percent due to the savings externalities. Moreover, there is a heterogeneous response in wealth accumulation within the groups, leading to the significant within group inequality effects. For example, the rise and fall in wealth for the university and non-university groups respectively was 8 to 9 percent for the top quintile and 5 to 7 percent for the bottom quintile. Overall, therefore, the inequality implications of pecuniary externalities are much bigger than their effects on efficiency.

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7 Appendix A

We define a stationary recursive equilibrium following e.g. Miao (2014, ch. 17) and Acikgoz (2018).[20]

`Stationary Recursive General Equilibrium`

For $h = u, b$, a *Stationary Recursive Equilibrium* is stationary distributions $\lambda^h(A \times B)$, policy functions $a_{t+1}^h = g^h(a_t^h, s_t^h) : \mathcal{A}^h \times S^h \to \mathcal{A}^h$, $c_t^h = q^h(a_t^h, s_t^h) : \mathcal{A}^h \times S^h \to \mathbb{R}_+$, value functions $v^h(a_t^h, s_t^h) : \mathcal{A}^h \times S^h \to \mathbb{R}$, and positive real numbers $K, w(K), r(K)$ such that

1. The firm maximises its profits given prices, so that the latter satisfy (1.6) and (1.7).

2. The policy functions $a_{t+1}^h = g^h(a_t^h, s_t^h)$ and $c_t^h = q^h(a_t^h, s_t^h)$ solve the households' optimum problems in (1.4) given prices and aggregate quantities, and the value functions $v^h(a_t^h, s_t^h)$ solve equations (1.4).

3. $\lambda^h(A \times B)$ is a stationary distribution:

$$\lambda^h(A \times B) = \int_{\mathcal{A}^h \times S^h} \Lambda^h[(a, s), A \times B] \, \lambda^h(da, ds),$$

   for all $A \times B \in \mathcal{B}(\mathcal{A}^h) \times \mathcal{S}^h$, where $\Lambda^h[(a, s), A \times B] : (\mathcal{A}^h \times S^h) \times (\mathcal{B}(\mathcal{A}^h) \times \mathcal{S}^h) \to [0, 1]$ are transition functions on $(\mathcal{A}^h \times S^h)$ induced by the Markov process $(s_t^h)_{t=0}^{\infty}$ and the optimal policy $g^h(a_t^h, s_t^h)$.

4. When $\lambda^h(A \times B)$ describe the cross-section of households at each date, i.e. $\overline{\lambda}^h(A \times B) = \lambda^h(A \times B)$, markets clear. In particular, the labour market clears, i.e. $L = L^s = 1$, where

$$L^s = n^u \zeta^u \sum_{j \in S^u} \overline{s}_j^u \xi^u(\overline{s}_j^u) + n^b \zeta^b \sum_{j \in S^b} \overline{s}_j^b \xi^b(\overline{s}_j^b),$$

[20] Aggregation over the households can be obtained by using the methods discussed e.g. in (see e.g. Uhlig (1996) and Al-Najjar (2004), Acemoglu and Jensen (2015)).

the world asset market clears, i.e.

$$r = r^* + \psi \left[\exp\left(\frac{K - A^s}{F(K, L)} \right) - 1 \right],$$

where

$$A^s = n^u \int_{\mathcal{A}^u \times S^u} g^u(a, s)\, \lambda^u(da, ds) + n^b \int_{\mathcal{A}^b \times S^b} g^b(a, s)\, \lambda^b(da, ds),$$

and the goods market clears, which, using factor input market clearing, implies:

$$\begin{aligned} &F(K, 1) - \delta K - r(K - A) = \\ &= n^u \textstyle\int_{\mathcal{A}^u \times S^u} q^u(a, s)\, \lambda^u(da, ds) + n^b \int_{\mathcal{A}^b \times S^b} q^b(a, s)\, \lambda^b(da, ds). \end{aligned}$$

Following standard arguments (commonly used in this class of models since Aiyagari (1994)), it can be shown that continuity of the asset supply and demand functions at the aggregate level with respect to the interest rate as well as the limit properties of supply and demand for assets, imply that a general equilibrium exists.[21] Using results in Acikgoz (2018) and adapting arguments from Angelopoulos *et al.* (2019), we can show the existence of a general equilibrium in the open economy with a unique stationary distribution at the household level that also determines aggregate quantities.

`Proposition 1`

For ψ sufficiently large, $\psi > \psi^{\min}$ satisfying $\frac{K}{Y}(r) > \ln\left(\frac{r - r^* + \psi^{\min}}{\psi^{\min}}\right)$, a stationary recursive general equilibrium exists.

Proof: The properties of the production function imply that the wage rate is a monotonic function of the interest rate, and, given that $L = 1$, K is a decreasing function of r, as are the ratios Y and $\frac{K}{Y}$. Given the interest rate, firm demand implies a demand for assets over labour via (1.8), given by:

$$A^d = \left[\left(\frac{K}{Y} \right) - \ln\left(\frac{r - r^* + \psi}{\psi} \right) \right] Y,$$

which is a continuous function in r. When $\frac{r - r^* + \psi}{\psi}$ is small enough such that $\frac{K}{Y} > \ln\left(\frac{r - r^* + \psi}{\psi}\right)$, $\frac{dA^d}{dr} < 0$. Moreover, when $r \to \frac{1}{\beta} - 1$, $A^d \to A^{\min} < +\infty$, whereas when $r \to r^* - \psi$, $A^d \to +\infty$. Given r (and $w(r)$), there is a unique partial equilibrium, implying a unique aggregate supply of assets, A^s. As shown in Acikgoz (2018), this is continuous

[21] A general proof of existence of equilibrium for this class of models can be found in Acemoglu and Jensen (2015).

with respect to r and when $r \to \frac{1}{\beta} - 1$, $A^s \to +\infty$.[22] Moreover, when $r \to -1$, $A^s \to 0$. Therefore, an intersection point of the supply and demand curves A^s and A^d exists. ■

Note that the sufficient condition $\phi > \phi^{\min}$ is easy to satisfy for realistic calibrations for developed economies, where the interest rate r does not differ much from the international interest rate and the capital to output ratio is higher than two, implying values for $\phi^{\min}$ in the third decimal point above zero.

`Computation`

To compute the stationary general equilibrium, we implement the following algorithm:

1. Guess a value for r^n, which, given the first-order conditions (1.6) and (1.7) implies a value for K^n, Y^n and w^n.

2. Calculate the demand for domestic assets to labour implied by the international asset markets via (1.8), given by

$$A^n = \left[K^n - \ln\left(r^n - r^* + \phi\right) + \ln\phi\right] Y^n.$$

3. Given r^n and w^n, solve the "typical" households' problem to obtain $g^h\left(a_t^h, s_t^h\right)$, for $h = u, b$.

4. Use $g^h\left(a_t^h, s_t^h\right)$ and the properties of the Markov processes $\left(s_t^h\right)$ to construct the transition functions $\Lambda_{K_j}^h$. Using $\Lambda_{K_j}^h$, calculate the stationary distributions λ^h.

5. Using λ^h, compute the aggregate values of $A^s\left(r^n\right)$ that is supplied by the domestic economy and the updated value of

$$r^{n^*} = r^* + \phi\left[\exp\left(\frac{K^n - A^s\left(r^n\right)}{Y^n}\right) - 1\right].$$

6. If $|A^s - A^n| < \varepsilon$, where ε is a pre-specified tolerance level, a stationary open economy general equilibrium has been found. If not, go back to step 1, and update $r^{n+1} = \left(1 - \varsigma\right) r^n + \varsigma r^{n^*}$ with $0 < \varsigma \leq 1$.

To solve the household problem we use the Endogenous Grid Method (Carroll (2006)). To implement this algorithm we first choose $a^{\min} = -\phi$. We then let $a^{\max} = 50$, which implies that, in the solution, the probability of asset holdings greater than 40 is less than

[22] For details see Acikgoz (2018), Theorem 1. Further note that continuity of mean assets with respect to the interest rate, for each type of household, also implies continuity for the weighted average between households.

$3.1 * 10^{-5}$. We discretise the space of household assets $\left[a^{\min}, a^{\max}\right]$ with a log scale by allowing for 1000 points. We have found that the obtained wealth distribution is robust to increasing $K^{\max}$ up to 100 and to decreasing it down to 40.

8 Appendix B

The WAS started in July 2006 with a first wave of interviews carried out over two years to June 2008. The WAS interviewed approximately 30,500 households including 53,300 adult household members in Wave 1. The same households were approached again for a Wave 2 interview between July 2008 and June 2010. In this wave 20,170 households responded (around 70 percent success) including 35,000 adult household members. Waves 3-5 covered the periods between July and June for the years 2010-12, 2012-14 and 2014-16 respectively. After Wave 2, due to sample attrition, the WAS started implementing boost samples in each wave to keep the number of interviewed households around 20,000 and 35,000-40,000 adult household members.[23]

USoc is a large longitudinal survey which follows approximately 40,000 households (at Wave 1) in the U.K.. USoc covers a wide range of social, economic and behavioural factors making it relevant to a wide range of researchers and policy makers. Data collection for each wave takes place over a 24-month period and the first wave occurred between January 2009 and January 2011. Note that the periods of waves overlap, but the individual respondents are interviewed around the same time each year. Thus, there is no respondent who is interviewed twice within a wave or a calendar year (see e.g. Knies (2018)).

8.1 Demographics (WAS)

1. **Head of the Household**: We define the head of household as the principal owner or renter of the property, and, when there is more than one head, the eldest takes precedence. This follows the reference person definition in USoc. We use of the following variables: (HhldrW), (HiHNumW), (DVAGEw) and/or (DVAge17w).

2. **Education level**: There are two educational attainment variables in the WAS. The first is the TEAw, which is the age that the individual completed education. The second is the EdLevelw which is a derived variable of the education level and represents the highest educational level that respondent has achieved. EdLevelw provides three categories: (i) degree level or above; (ii) below degree qualifications

[23]The WAS and USoc data sets employed in this paper refer to the free "End User Licence" versions of the datasets (i.e. WAS: SN-7215 and Understanding Society: Waves 1-8, 2009-2017, SN: 6614).

(iii) no qualifications. The TEAw has the disadvantage that it cannot distinguish the type of qualification that the respondent had achieved. Moreover, 33 percent of the TEAw observations of working-age adults have either missing values or partial answers. Thus, we choose to work with the EdLevelw which is a derived variable and has only 2,942 missing values, i.e. around 2.7 percent of working-age adult observations. However, using EdLevelw, we note that there are respondents for whom educational attainment changes in a way that indicates misreporting. For example, for some respondents, there is an increase of educational attainment just for one wave and then a return back to the previous level of education in subsequent waves. Thus, we have chosen to make some corrections to the educational level when a respondent's educational attainment changes. In particular, if we observe a respondent for all the 5 waves, we replace her educational attainment with the level that was reported the most times across the 5 waves. We follow a similar procedure if a respondent changes her educational attainment just once. More specifically, we require the respondents being present in the sample for at least 3 waves and we use the most commonly recorded education level across waves. These corrections were applied to 4,873 observations out of 107,320 total amount observations of adult respondents (around 4.5 percent) and only half of these 4,873 observations correspond to a head of a household. Despite these corrections, the results are very similar when they are not made.

8.2 Definition of wealth (WAS)

1. **Net property wealth**:[24] is the sum of all property values minus the value of all mortgages and amounts owed as a result of equity release. (HPROPWW).

2. **Net financial wealth**: is the sum of the values of formal and informal financial assets, plus the value of certain assets held in the names of children, plus the value of endowments purchased to repay mortgages, less the value of non-mortgage debt. The informal financial assets exclude very small amounts (less than £250) and the financial liabilities are the sum of current account overdrafts plus amounts owed on credit cards, store cards, mail order, hire purchase and loans plus amounts owed in arrears. Finally, money held in Trusts, other than Child Trust Funds, is not included. (HFINWNTW_sum)

3. **Net Worth:** is the sum of the net property wealth and net financial wealth.

[24] All monetary values are expressed in 2012 prices as measured by CPIH.

Table B1: Wealth Inequality in Great Britain

	Gini	$\frac{sd}{mean}$	$\frac{mean}{median}$	top 10%	$\frac{a_u}{a_b}$
			WAS (wave 1)		
Uni	0.644	1.948	1.846	0.460	
Non-Uni	0.702	1.972	2.073	0.480	2.085
Total	0.696	2.121	2.000	0.492	
			WAS (wave 2)		
Uni	0.632	1.697	1.798	0.442	
Non-Uni	0.714	1.983	2.404	0.481	2.148
Total	0.699	1.977	2.140	0.487	
			WAS (wave 3)		
Uni	0.655	1.995	1.997	0.476	
Non-Uni	0.733	2.488	2.619	0.507	2.247
Total	0.718	2.385	2.301	0.516	
			WAS (wave 4)		
Uni	0.691	2.854	2.267	0.522	
Non-Uni	0.748	2.315	3.410	0.530	2.499
Total	0.742	3.048	2.733	0.555	
			WAS (wave 5)		
Uni	0.685	2.359	2.281	0.514	
Non-Uni	0.761	2.400	3.849	0.538	2.372
Total	0.742	2.628	2.817	0.547	

8.3 Sample selection (WAS)

Table B2: WAS Sample selection, household observations per selection step

selection step	Uni	Non-Uni	Total
1. Whole sample of households			110,963
2. Drop households with misreported age variable			110,937
3. Drop households with duplicate hh grid numbers			110,910
4. Keep if heads' age ≥25, ≤59			59,457
5. Drop if no or misreported head's educational info	17,490	41,056	58,546
6. Drop if earnings of household members are imputed	17,037	40,235	57,272
Average net worth obs per wave	3,407	8,047	11,454

Table B2 shows the various sample selection steps. The household heads must be between 25-59 years of age, have full information for the relevant demographic information and their household earnings should be reported and not imputed.

8.4 Demographics (USoc)

1. **Head of the Household**: We use the USoc definition of the head of household. The head of household is defined as the principal owner or renter of the property, and, where there is more than one head, the eldest takes precedence. (whrpid, where the prefix w denotes wave)

2. **Education level**: We have used the variable whiqual_dv. To examine the potential heterogeneity of earnings risk in the main text, the sample is split into degree holders and non-degree holders. The former are the individuals who hold either a Higher Degree or 1st Degree, while the latter are the individuals who hold other highers or A-levels/AS level/Highers or GCSE/O level/other qualification or they have no qualifications.

3. **Marital Status**: Marital status of the head of the household. (wmastat_dv)

8.5 Definition of net income (USoc)

Household net labour income: is defined as household net labour earnings plus benefits, plus private transfers. It is equal to household total annual earnings, plus social benefits, plus annual transfers income minus taxes, NI contributions. Private transfers income totals all receipts from other transfers (including education grants, sickness insurance, maintenance, foster allowance and payments from TU/Friendly societies, from absent family members). Social benefits income totals all receipts from state benefits including national insurance retirement pensions. Household Net Labour Income=Net Labour Income (fihhmnlabnet_dv) + Private Transfers (fihhmnprben_dv and fihhmnmisc_dv) + Public Benefits (fihhmnsben_dv).

8.6 Sample selection (USoc)

Our sample selection for USoc is reported in Table B3. The household heads must be between 25-59 years of age, report non-zero net income and their household earnings should be reported and not imputed. Moreover, the head must not have missing values for region and educational attainment. We trim the top and bottom 0.5 percent of observations of net labour income distribution in each year, to avoid extreme cases or possible outliers in recorded income. We also require the households to be observed with positive incomes for at least 3 consecutive waves. As in the WAS, we exclude Northern Ireland.

Table B3: Households and household members USoc

selection step	Uni	Non-Uni	Total
1. Whole sample			208,200
2. Drop proxy & non-full interviews			157,187
3. Original sample & BHPS sample			122,193
4. Drop if no head's educational info			122,023
5. Drop if head's region missing			121,977
6. Drop if head's region is N. Ireland			121,958
7. Keep if heads' age ≥ 25, ≤ 60			68,003
8. Drop if head's marital status missing			67,913
9. Drop if gross labour income is missing or imputed			59,043
10. Drop if net labour income is zero	17,273	40,860	58,133
11. Drop top and bottom 0.5% of observations	17,107	40,461	57,568
12. Drop if they change educational groups	16,770	40,192	56,962
13. keep if present at least at 3 consecutive waves	11,783	27,061	38,844
Average obs per wave	1,472	3,383	4,855
Number of unique households	2,250	5,415	7,665

CHAPTER 2

THE EFFECTS OF PEER AND ASPIRATIONAL PRESSURE ON INEQUALITY

1 Introduction

There is a significant body of research examining the importance of social influences on economic outcomes (see e.g. Benhabib *et al.* (2011) for an overview of this literature). A subset of this literature has focused on the role of group pressure to achieve socially determined economic targets.[1] This has been motivated by long-standing theories of relative consumption and/or income, related to a desire for status (see Veblen (1899), Duesenberry (1949)), and empirical evidence that the implied social influence on one's preferences matters for economic decision making, including consumption, savings and labour supply choices (see e.g. Heffetz and Frank (2011) and De Giorgi *et al.* (2019)). At the same time, an extensive literature, building on the contributions by Bewley (1986), Huggett (1993) and Aiyagari (1994), shows that under incomplete markets, the distribution of these choices across individuals, in response to the idiosyncratic shocks that they receive, leads to hours, earnings, wealth and consumption (HEWC) inequality.

Combining the ideas underpinning these two strands of research, it is natural to expect

[1] See e.g. Akerlof (1980), Jones (1984), Abel (1990), Cole *et al.* (1992), Bernheim (1994), Gali (1994), Campbell and Cochrane (1999), Hopkins and Kornienko (2004), Postlewaite (2011) and Roussanov (2010) for examples in game theory, labour, macroeconomics, growth, finance, and reviews of the literature. A comparison of our work relative to the literature is the next section.

that social pressure should contribute to the patterns of observed inequality. There is a growing literature which theoretically examines the link between socially determined reference points (including those related to status-seeking and aspirations) with inequality and persistent poverty (see e.g. Becker *et al.* (2005), Mookherjee *et al.* (2010), Ray and Robson (2012), Dalton *et al.* (2016), Genicot and Ray (2017)). However, the distributional effects of socio-economic class-related peer and aspirational pressure, under stochastic productivity and class participation, have not been examined.[2]

This paper aims to fill this gap, focusing on a quantitative analysis of the distributional effects of these forms of social pressure on HEWC across the socio-economic spectrum both between and within the socio-economic classes. This allows us to examine heterogeneity in the effects of social pressure on inequality across social groups and economic outcomes, and thus obtain more information on the socio-economic implications of changes in the form and strength of social pressure. Such change may arise with socio-economic developments that characterise our times (e.g. greater social interaction and widespread access to social media) or as a result of intentional long-term policy interventions to instigate societal change (e.g. policies to support integration and confidence, or to provide role models and success stories, to increase aspirations). In particular, we are interested in identifying: (i) social groups that, following changes in social pressure, are more likely to experience increases in the dispersion of economic outcomes, despite potential material benefits in absolute terms; and (ii) economic outcomes in which we observe divergence/convergence between groups.

1.1 Theoretical framework and data fit

The theoretical framework we develop incorporates: (i) persistent, idiosyncratic shocks to productivity and socio-economic class participation, determining social mobility in addition to wages; (ii) flexible forms of peer and aspirational pressure related to class-relevant consumption targets, which are determined in equilibrium by the aggregation of relevant household-level consumption choices; and (iii) endogenously determined cross-sectional distributions of HEWC. A household's utility depends, in addition to its own consumption and leisure, on a socially determined target that is given by some aggregate measure of consumption (e.g. the mean or any percentile) of their peers' consumption (i.e. of households in their own socio-economic class), or of members of other socio-

[2] This is despite empirical evidence on (i) the strength of social pressure from the group of peers on savings, consumption and effort choices (see e.g. Brown *et al.* (2008), Mas and Moretti (2009), Mugerman *et al.* (2014), and De Giorgi *et al.* (2019)), and (ii) the extent and importance of the idiosyncratic component of earnings (see e.g. Meghir and Pistaferri (2011) for a review of this research and Blundell and Etheridge (2010) regarding evidence for the UK).

economic classes (allowing, e.g., for "upward looking" aspirations). Since households face the prospect of upward or downward mobility, the whole set of social targets matter for each individual's decision making, albeit with implicit weights determined by its current state and the conditional probabilities determining social mobility.

The flexibility in the determination of the consumption targets permits the study of varying strengths of peer pressure, and of different forms of aspirations. Motivated by empirical evidence in e.g. De Giorgi *et al.* (2019), who estimate significant "keeping-up-with-the-Joneses" effects of co-workers' aggregate consumption on a household's own consumption, the group of peers is defined as the group of households who have the same type of occupation. Moreover, existing research (see e.g. Appadurai (2004), Ray (2006), Dalton *et al.* (2016), Genicot and Ray (2017)) has analysed the importance of different forms of "upward looking" aspirations for decision making and economic outcomes. We differentiate between aspirations that are constrained to conform to peer behaviour and those where a household aspires to achieve outcomes typically associated with higher income classes.

In our framework, inequality is determined by individual responses to uninsured idiosyncratic shocks (defined here to include the social class shocks), as well as social pressure. In turn, the extent of peer or aspirational pressure is an equilibrium outcome, determined jointly with the distributions of the economic outcomes that it contributes to. The equilibrium is obtained when household level decision-making is consistent with the aggregate-level social targets. In other words, when the consumption target for each group equals the respective moment of the distribution of consumption that arises under the whole set of consumption targets.

We show existence of a stationary socio-economic equilibrium where social pressure targets are fixed quantities and are jointly determined with the (invariant) cross-sectional distributions. This extends the stationary equilibrium results in Bewley (1986) - Huggett (1993) - Aiyagari (1994) models (BHA) of wealth, earnings and consumption inequality (see e.g. Acikgoz (2018) and Zhu (2018)). The socio-economic equilibrium in our model is a generalisation of the stationary equilibrium concept in the Pijoan-Mas (2006), Marcet *et al.* (2007), and Zhu (2018) version of the BHA incomplete markets models with endogenous labour supply. We build on the approach in Zhu (2018) and show that under peer pressure a stationary socio-economic equilibrium exists and it is characterised by a unique household-level invariant asset-shock distribution.[3]

We then show that quantitative analysis based on this framework can match the stylised patterns of inequality between and within the professional groups that we observe

[3]The latter property of the equilibrium is very helpful in that it facilitates a feasible computation.

in the data for Great Britain. We consider four professional groups, based on the National Statistics Socio-Economic Classification (NS-SEC) (see Rose and O'Reilly (2005) for more detail). These groups are denoted as "routine" (including routine and semi-routine occupations), "intermediate" (including clerical, sales and service, as well as lower supervisory and technical occupations), "lower professional" (including lower management and professional occupations) and "higher professional" (including higher management and professional occupations). We choose these groups because the classification generates a discernible pattern for between and within group inequality. Using data on the distribution of: (a) hours and earnings from the Understanding Society dataset; (b) wealth from the Wealth and Asset Survey; and (c) consumption from the Living Cost and Food Survey, we find that: (i) mean hours, earnings, wealth and consumption increase with professional classes which have higher mean wages; (ii) within group hours, earnings and wealth inequality varies substantially between the groups, and decreases for groups with higher means. In contrast, within group consumption inequality does not vary much between groups; and, (iii) overall inequality (across the whole sample) is highest for wealth and lowest for consumption, as is typically found in the data (see e.g. Quadrini and Rios-Rull (2015) for the U.S.). We calibrate the model using data on professional class and wage dynamics from the Understanding Society dataset and, based on available econometric evidence from De Giorgi *et al.* (2019), peer pressure that implies "keeping-up-with-the-Joneses" and "jealousy" motives. Social targets are determined by the mean consumption of the socio-economic group to which the household belongs. We find that the model captures the main patterns of inequality in the data in hours worked, earnings, wealth and consumption, between and within the professional classes.

1.2 Peer pressure

We use our framework to shed light on the contribution of "keeping-up-with-the-Joneses" peer pressure on inequality in HEWC, between and within the socio-economic groups that we consider. Intuition suggests that social pressure to achieve a target that summarises behaviour in one's own class, which is implied by "keeping-up-with-the-Joneses" peer pressure, should create incentives to induce within-cluster convergence and, likely, cross-cluster divergence.[4] In other words, groups become more sharply distinguishable, while the individuals within the groups become more similar, as a result of the pressure

[4] Indeed, this is consistent with the results in Genicot and Ray (2017), who link aspirations-defining social targets to a type of clustering that is characterised by within-cluster convergence and cross-cluster inequality, when the clusters are defined based on similarity in terms of income. Likewise, Luo and Young (2009) find that a common preference for social status across the whole distribution (i.e. when there is "one cluster") implies a reduction in wealth inequality.

to conform to targets that differ between groups. While these effects are present in the economy that we consider, we uncover a richer interaction between peer pressure and distributional outcomes, characterised by the co-existence of (i) between group convergence in some outcomes with divergence in others; and (ii) within-group divergence for some groups and in some outcomes, with convergence for others. We find that, as a result of "keeping-up-with-the-Joneses" peer pressure, within group hours and earnings inequality falls for the higher mean wages groups and within group wealth and consumption inequality reduces for the lower mean wage groups. In contrast, within group wealth and consumption inequality increases for the higher mean wage groups and within group hours and earnings inequality rises for the lower mean wage groups. Hence, the inequality effects of peer pressure to meet social targets are not uniform across social groups. At the same time, between group inequality increases for hours, earnings and consumption, but falls for wealth.

The complexity in the effects of peer pressure summarised above arises because we study an environment with stochastic productivity and social transitions (which implies that all agents acknowledge that with some probability all social targets might become relevant), which distinguishes earnings from asset income. The prospect of upward mobility, associated with stochastic socio-economic class participation, embeds an upward looking element in peer pressure. Under peer pressure, the prospect of upward mobility implies a possibility for increased peer pressure. Thus, it stimulates savings, working to decrease between group wealth inequality and further contributing to the asymmetric change in within group inequality across groups and economic outcomes.[5] The added realism in our framework implies that, following changes in the type of peer pressure, the interaction of intra- and inter-temporal decision margins (under idiosyncratic productivity and the prospect of upward mobility) imply differential effects of social targets across groups. This leads to the asymmetric pattern of both convergence and divergence, between and within groups, depending on social class and the inequality measure considered.

1.3 Aspirations

Peer pressure incorporates an aspirational element, because it instills a desire to match a pre-specified level of success. We investigate the effects of a stronger aspirational aspect of peer pressure, associated with group members targeting the consumption of more successful members of their groups, instead of the "typical" member. We find that such social

[5] Stochastic socio-economic class participation also embeds a risk of downward mobility, which works in the opposite way to lower savings for the higher mean wage groups, further enhancing the effects described here.

behaviour is associated with significant and positive effects, on average, for all groups. It is related with falls in within group inequality as well as in the gap between the highest mean wage group and the other groups regarding hours and earnings. On the other hand, between and within group inequality in consumption and wealth do not change much and do not follow an obvious pattern. On balance, when aspirations are determined within the social class, there are positive implications of a more strongly aspirational peer pressure for hours and earnings, without significant and clear effects on wealth and consumption.

The form of aspirations discussed above can be thought of as more a result of pressure from peers to meet a group-level target (and is thus reflecting a form of social conformism), rather than a situation where an agent truly aspires to behaviour associated with "higher classes". We aim to understand the potentially different inequality implications of aspirations that are constrained by pressure to conform to peers, from an aspiration to succeed by doing better than the peers. To this end, we exploit the flexible form of target functions employed in the theoretical framework when comparing these two types of social pressure. We define above-peer aspiration as the situation where the social target is the mean consumption (or relevant percentile) of the socio-economic group that has a higher mean wage than the group of peers.

We find that above-peer aspiration, compared with peer pressure, has positive effects on mean quantities for all socio-economic classes. However, while it allows the groups with the raised aspirations (lower mean wage groups) to close the gap with the top mean wage group in hours, earnings and consumption, it increases the gap in terms of wealth.[6] However, when focusing on the three lower mean wage groups, for which there are truly "higher" aspirations, by disentangling asset income as a source of income from hours and earnings, we find that wealth and consumption inequality within-groups increases under higher aspirations. This is despite a reduction in within-group inequality in hours and earnings and thus highlights the importance of allowing for idiosyncratic earnings variation and the insurance value of wealth when examining wealth inequality. Therefore, the improvement in average material wealth that is implied by higher, above class, aspirations, can be associated with an increase in social dissatisfaction, as a result of an increased dispersion in the magnitude and probability of underachievement.

[6] The wealth inequality result has similarities to results in Genicot and Ray (2017), where stronger aspirations increase between group wealth inequality. However, in our model, this result is obtained even when aspirations have monotonic effects on savings, and is driven by an upper bound of aspirations to the level of peer pressure for the higher socio-economic class. In effect, there is a direct non-monotonic increase in aspirations across the classes that drives the specific result here.

2 Related literature

Our framework and analysis builds on the class of models with idiosyncratic shocks and incomplete markets, which, following the contributions by Bewley (1986), Huggett (1993) and Aiyagari (1994), has been used to study quantitatively wealth inequality in a stationary equilibrium (see e.g. Quadrini and Rios-Rull (2015) and Benhabib *et al.* (2017) for reviews and extensions; and Acikgoz (2018) for a proof of existence of stationary equilibrium under persistent shock processes in the benchmark model with exogenous earnings). Our extension is based on generalisations as in e.g. Pijoan-Mas (2006) and Marcet *et al.* (2007) and thus on a framework where HEWC inequality are jointly determined in response to exogenous shocks. Zhu (2018) shows existence of stationary equilibrium in the benchmark model with endogenous earnings and persistent productivity shocks.

Our modelling framework contributes to this research by adding peer pressure in an environment with professional mobility, defining a socio-economic equilibrium, and establishing its existence and its relevance for quantitative analysis of between and within group inequality.[7] An additional difference relative to the quantitative analyses in the literature relates to the characterisation of productivity shocks. Agents in our model receive shocks that determine their occupation type and their productivity in their occupation. In the model calibration, we use Understanding Society data to measure transitions from any occupation type, and any productivity level, to any other.

Existing research has introduced social effects in the form of "keeping-up-with-the-Joneses" relative consumption considerations in representative agent dynamic general equilibrium models, to study their effects on macroeconomic outcomes and asset pricing, following the contributions by e.g. Abel (1990), Gali (1994) and Campbell and Cochrane (1999). Instead, we are interested in the joint determination of distributions with socio-economic targets and we work in an environment with heterogeneous agents, who are subjected to idiosyncratic shocks and pressure from a specific group of peers. We focus on peer pressure associated with consumption targets. In our framework each social group has its own target, where all targets are jointly determined in equilibrium with the distribution for consumption for all groups and we establish existence of such a socio-economic equilibrium.[8] Roussanov (2010) introduces status seeking related wealth targets in the utility function in a model with heterogeneous agents but does not study peer pressure. Instead, the social target in Roussanov (2010) is average wealth across the whole distribution, and the model is used to quantitatively examine the effect of such

[7]Note that when defining the socio-economic equilibrium, social targets that influence economic decisions are determined jointly with the distributions that they affect.

[8]Note, given social mobility, all social targets matter for any individual agent's decision making.

social factors on financial decision-making and portfolio allocations.

Peer pressure, and analysis of the resulting socio-economic equilibrium, has been examined rigorously in static settings (e.g. Akerlof (1980), Jones (1984), Bernheim (1994), Calvo-Armengol and Jackson (2010) and Ghiglino and Goyal (2010)), and in conjunction with income inequality (e.g. Hopkins and Kornienko (2004)). We take the individual's desire to conform to socially-defined targets as given, and focus on the joint determination of inequality in HEWC with the level of the social targets (and thus the extent of peer pressure), in an environment where the agents are subjected to idiosyncratic productivity and social class shocks.

There is also a significant literature that has examined the importance of status seeking, aspirations and relative consumption considerations for economic growth and inequality, including the effect of such social factors on savings and growth, the qualitative properties of the distribution of wealth and/or income over generations and the possibility of poverty traps in the process for development (see e.g. Cole *et al.* (1992), Hopkins and Kornienko (2006), Ray and Robson (2012), Genicot and Ray (2017), who also review further contributions in this literature). In addition, the joint determination of inequality with occupational mobility has been theoretically examined in the literature, (e.g. Mookherjee and Ray (2003)) and quantitatively (e.g. Quadrini (2000) and Cagetti and De Nardi (2006)) without social pressure, and in a theoretical analysis of skill acquisition under aspirations in Mookherjee *et al.* (2010).

Our analysis complements this research, by: (i) focusing on the group of peers determined by (stochastic) socio-economic class participation, as opposed to proximity in measures of income to determine social pressure, either from peers, or in the form of above-peer aspirations (see e.g. Genicot and Ray (2017, p. 494) on the novelty of such extensions); (ii) examining the joint determination of the distributions of HEWC with the set of social targets, in a stationary equilibrium and under stochastic productivity; and (iii) focusing explicitly on a framework to be used for quantitative analysis in an empirically relevant model, calibrated using data on the distributions of idiosyncratic shocks, to examine the interplay between peer pressure and inequality between and within the socio-economic class, as well as the effect of changes in the aspirational value of social targets on these inequalities.

We focus on cross-sectional distributions with individual-level stochasticity and dynamics within a stationary equilibrium, and do not examine dynamics in aggregate quantities (see e.g. Aiyagari (1994), Pijoan-Mas (2006) and Benhabib *et al.* (2015) for analysis of stationary stochastic equilibrium). Moreover, since we are interested in the effects of social pressure on inequality under the possibility of upward or downward mobility, and not on the effects of social pressure on mobility, we keep the latter as a stochastic process which we calibrate to the data for the quantitative analysis. It would of course be a very interesting, and non-trivial, extension to this framework to analyse a situation where the prospect of upward mobility interacts with the prospect of increased peer pressure to determine jointly cross-sectional distributions, in addition to decision making that influences class participation.[9]

3 A general theoretical framework

We consider an economy that is composed of a continuum of infinitely lived agents (households) distributed on the interval $I = [0, 1]$. Households derive utility from consumption and leisure and by comparing their consumption with that of their different socio-economic groups, which can be the group of their peers. We define peers to be all the members of the same socio-economic group. Participation in a socio-economic group is determined by a stochastic process at the level of the household, which also determines the household's returns to hours worked. Households draw idiosyncratic shocks independently from each other and cannot fully insure against shocks to labour income, because financial markets are incomplete. More specifically, there is a single asset in the economy. We examine stationary equilibria in which aggregate quantities are constant. Time is discrete and denoted by $t = 0, 1, 2, ...$

3.1 Households

Each household is endowed with one unit of time which is allocated between leisure and labour. We do not explicitly model differences in labour productivity and earnings between household members and assume for simplicity that the household offers a uniform labour supply. Each household wishes to maximise her expected lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, l_t, C_t), \tag{2.1}$$

where $\beta \in (0, 1)$ is the time discount factor, c is consumption, l is leisure and C is a quantity capturing the property of the consumption distribution to which the household compares their level of consumption to derive utility. At the level of the household, the social targets are taken as given. Households may differ in the reference value for

[9]See e.g. Piketty (1995) and Benabou and Ok (2001) for examples of studies where the prospect of upward mobility can affect choices, in those cases relating to the demand for redistribution.

consumption, but they are identical in their deep preferences.

Idiosyncratic shocks

The household is subject to idiosyncratic shocks that determine its professional class (or occupation type) and its productivity within that professional class, thus determining the overall labour efficiency of the household. We assume that the household can work in M professional classes (reflecting, e.g., higher and lower managerial or professional occupations, lower supervisory and intermediate jobs, or a routine and semi-routine jobs), and within each class there are N productivity states. For example, a household may work as a highly productive lower supervisory worker, thus earning more income than the average lower supervisory worker, or it may be a manager not meeting her targets and thus earning less than the average manager. The (M, N) specification may also capture the effect of the second earner in a household. In particular, we can let the M states capture the professional or socioeconomic class of the household, as determined by the higher earner/head of the household, and in turn allow the N states to determine the household's total earnings, from all members, within the M professional class. Together, M and N capture labour efficiency of the household, which, in conjunction with labour supply and the wage rate per labour efficiency unit, w, determine labour income. At the household level, and in a stationary equilibrium, w is constant and exogenously given.

The stochastic process for the joint distribution of idiosyncratic shocks $(z_t)_{t=0}^{\infty}$ is a Markov chain with transition matrix Q and state space $Z = [\overline{z}_1, \overline{z}_2, ..., \overline{z}_H]$, $H = M \times N$, where for $h = 1, ...H$, $\overline{z}_h \equiv \overline{z}_{m,n}$ for all $m = 1, ..., M$ and all $n = 1, ..., N$. The elements of the transition matrix Q are denoted $\pi(z_{t+1}|z_t)$, and $\sum_{z_{t+1}} \pi(z_{t+1}|z_t) = 1$ for all $z_t \in Z$. Additionally, we assume that $\pi(z_{t+1}|z_t) > 0$ for all $z_t, z_{t+1} \in Z$. Hence, the Markov chain has a unique invariant distribution, with probability measure that we denote by ξ.

The stochastic process (z_t) determines labour income as well as consumption related peer or above-peer pressure, by determining the relevant target level for relative consumption comparisons. Denoting $e(z_t) : Z \to E = [\overline{e}_1, \overline{e}_2, .., \overline{e}_H] \equiv [\overline{e}(\overline{z}_1), \overline{e}(\overline{z}_2), .., \overline{e}(\overline{z}_H)]$ as labour efficiency, labour income is given by $we(z_t)(1 - l_t)$. The elements $\overline{z}_h$ in Z can be ordered such that $0 < \overline{e}^{\min} = \min(E) < \cdots < \overline{e}^{\max} = \max(E)$. Moreover, socio-economic class participation is determined by $s(z_t) : Z \to [1, ..., M]$, where $s(\overline{z}_{m=j,n}) = j$, for $j = 1, ..., M$, and implies a reference point for consumption, relative to which individual level consumption is compared. In particular, $C(z_t) \equiv C(s(z_t)) : Z \to \widetilde{C}$, where $\widetilde{C} = \{\overline{C}_1, \overline{C}_2, .., \overline{C}_M\}$. The elements in $\widetilde{C}$ can refer to different percentiles or the mean of the distribution of consumption for the different classes.

At the level of the household, $\widetilde{C}$ is given. However, in equilibrium, the reference points

$\overline{C}_j$ are determined endogenously by the distribution of consumption in the specific class that the individual compares its consumption to. Note that this setup implies that there is a unique transition matrix Q that determines the evolution of both stochastic processes $e(z_t)$ and $C(s(z_t))$.

Peer and above-peer pressure

The social target can be defined as capturing pressure from one's peers to achieve a target related to group behaviour, or as capturing aspirations to achieve a target related to more successful groups. Under peer pressure, C can be, for example, the average consumption of the group of peers, or any percentile of that distribution that forms the appropriate level of comparison. Consistent with empirical evidence from De Giorgi *et al.* (2019), which suggests that the peer pressure effects are determined by the professional environment, we assume that the reference group, the peers, is the professional, socio-economic class to which the household belongs. Hence, under peer pressure, professional class determines the reference point for consumption, in addition to affecting labour income. In particular, under peer pressure, the function $C(s(z_t))$ is given by:

$$C(s(z_t) = j) = \overline{C}_j, \text{ for } j = 1, ..., M.$$

Alternatively, the social target may capture the aspirations of the household to achieve a consumption level of households of "higher", in terms of economic outcomes, socio-economic classes. Under such above-peer aspirations, C can be, for example, the average consumption of groups of households from classes with higher consumption, or any percentile of that distribution. In this case, the function $C(s(z_t))$ is given by:

$$\begin{aligned} C(s(z_t) = j) &= \overline{C}_{j+1}, \text{ for } j = 1, ..., M-1, \\ C(s(z_t) = M) &= \overline{C}_M, \text{ for } j = M. \end{aligned}$$

We assume that the instantaneous utility function $u(c, l, C)$ satisfies:

`Assumption 1`

$u : \mathbb{R}_+ \times [0,1] \times \mathbb{R}_+ \to \mathbb{R}$ is bounded and twice continuously differentiable; $u(c, l, C)$ is strictly increasing in (c, l) and strictly concave in (c, l, C); $\lim_{c \to 0} u_1(c, l, C) = +\infty$, $\forall l \in [0,1]$ and $\forall C \geq 0$, and $\lim_{l \to 0} u_2(c, l, C) = +\infty$, $\forall c \geq 0$ and $\forall C \geq 0$; $u_{12} \geq 0$ i.e. consumption and leisure are normal goods and complementary to each other.

The assumptions regarding leisure follow from Zhu (2018). Under peer pressure, the marginal effect of C determines its type: (a) either $\frac{\partial u}{\partial C} < 0$ ("jealousy"), or $\frac{\partial u}{\partial C} > 0$

("admiration"), and, (b) either $\frac{\partial^2 u}{\partial c \partial C} > 0$ ("keeping-up-with-the-Joneses"), or $\frac{\partial^2 u}{\partial c \partial C} < 0$ ("running-away-from-the-Joneses"). When peer pressure is consistent with jealousy and keeping-up-with-the-Joneses (see e.g. Gali (1994), Dupor and Liu (2003), and De Giorgi *et al.* (2019)), it creates incentives to increase consumption and under save. When peer pressure is consistent with admiration and running-away-from-the-Joneses (see e.g. Dupor and Liu (2003) and Roussanov (2010)), it creates incentives to decrease consumption. Under above-peer aspirations, the marginal effect of C satisfies $\frac{\partial u}{\partial C} < 0$ and $\frac{\partial^2 u}{\partial c \partial C} > 0$. Compared with the specifications of aspirations in Mookherjee *et al.* (2010), Dalton *et al.* (2016) and Genicot and Ray (2017), we focus here on the aspiration to achieve the consumption level of the higher, in terms of income, socio-economic class relative to one's own class.

Optimal choices

There is a single risk-free asset in the economy, which generates interest income from accumulated assets ra_t, where r is the interest rate and a denotes assets. Households' labour efficiency shock $e(z_t)$ is observed at the beginning of period t. Households use their income for consumption and to invest in future assets a_{t+1}. Moreover, the households cannot borrow assets from other households and thus $a_{t+1} \geq 0$.[10] Thus, the household's budget constraint is:

$$c_t + a_{t+1} = (1 + r)\, a_t + we(z_t)(1 - l_t), \tag{2.2}$$

with $c \geq 0$ and $a_{t+1} \geq 0$. The household's state can be described by $(a, z) \in A \times Z$, where $A = [0, +\infty)$. The interest rate and wage rate are taken as given and satisfy $r > -1$ and $w > 0$. To allow for an equilibrium with non-degenerate distributions in economic outcomes, we assume that $\beta(1 + r) < 1$ (see e.g. Marcet *et al.* (2007) and Zhu (2018)).

Taking prices and consumption targets as given, and given initial values $(a_0, z_0) \in A \times Z$, the household chooses plans $(a_{t+1})_{t=0}^{\infty}$, $(c_t)_{t=0}^{\infty}$ and $(l_t)_{t=0}^{\infty}$ that solve the maximisation

[10] Since the household can choose to set $l = 1$, the natural borrowing limit in this context is zero. We could allow for borrowing, if, for example, we made the additional assumption that even under zero labour income, net household income is positive (reflecting for example family support and/or public transfers). To keep the exposition compact we do not introduce such assumptions.

problem:

$$
\begin{aligned}
V(a_0, z_0) = \max_{(c_t, a_{t+1}, l_t)_{t=0}^{\infty}} & E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, l_t, C(s(z_t))), \\
& s.t. \\
c_t + a_{t+1} &= (1+r)\, a_t + w(1-l_t)e(z_t), \qquad (2.3) \\
c_t, a_{t+1}, l_t &\geq 0, \\
1 &\geq l_t.
\end{aligned}
$$

To obtain the dynamic programming formulation of the household's problem, let $V\left(a_t, z_t; \widetilde{C}\right)$ denote the optimal value of the objective function starting from asset-productivity state (a_t, z_t) and given the values of the reference points $\widetilde{C}$.[11] The Bellman equation is:

$$
V\left(a_t, z_t; \widetilde{C}\right) = \qquad (2.4)
$$

$$
= \max_{\substack{a_{t+1} \geq 0 \\ c_t, l_t \geq 0 \\ 1 \geq l_t}} \{u(c_t, l_t, C(s(z_t))) + \beta \sum_{z_{t+1} \in Z} \pi(z_{t+1}|z_t)\, V\left(a_{t+1}, z_{t+1}; \widetilde{C}\right)\},
$$

where $c_t + a_{t+1} = (1+r)\, a_t + w(1-l_t)e(z_t)$.

As discussed in more detail in Appendix A, building on analysis in e.g. Stokey *et al.* (1989), Miao (2014) and Acikgoz (2018), and applying results from Zhu (2018), it can be shown that there exists a unique value function $V\left(a_t, z_t; \widetilde{C}\right)$ that solves the problem in (2.4) and policy functions $a_{t+1} = g\left(a_t, z_t; \widetilde{C}\right)$, $c_t = q\left(a_t, z_t; \widetilde{C}\right)$ and $l_t = l\left(a_t, z_t; \widetilde{C}\right)$, which generate the optimal sequences $\left(a_{t+1}^*\right)_{t=0}^{\infty}$, $(c_t^*)_{t=0}^{\infty}$ and $(l_t^*)_{t=0}^{\infty}$ that solve (2.3), with properties including the following. The functions $g(a, z; \widetilde{C})$ and $l(a, z; \widetilde{C})$ are continuous and weakly increasing in a, and the function $q(a, z; \widetilde{C})$ is continuous and strictly increasing in a, while $l(a, z; \widetilde{C}) = 1\ \forall z \in Z$, when a is sufficiently large. Moreover, there is an upper bound for asset accumulation, denoted by $\overline{a}$, and there is $X = [0, \overline{a}] \times Z$ such that if a household starts with state (a, z) in X, then the agent stays in X, and if a household starts outside of X, it will arrive in X almost surely. Finally, by defining the transition

[11] To simplify notation, we suppress the explicit dependence of the value and policy functions on the interest and wage rates.

function $\Lambda^{\widetilde{C}}$ as:

$$\Lambda^{\widetilde{C}}\left[(a,z), A' \times \{z'\}\right] = \begin{Bmatrix} \pi\left(z'|z\right), \text{ if } g\left(a,z;\widetilde{C}\right) \in A' \\ 0, \text{ if } g\left(a,z;\widetilde{C}\right) \notin A' \end{Bmatrix}, \tag{2.5}$$

for all $(a,z) \in X$, $A' \times \{z'\} \in \mathcal{B}(X)$, the process $\{(a,z)\}_{t=0}^{\infty}$ with transition matrix $\Lambda^{\widetilde{C}}$ has a unique invariant distribution $\lambda^{\widetilde{C}}$ on X.

3.2 Socio-economic equilibrium

We define a socio-economic equilibrium given prices, where consumption reference points are consistent with household-level actions. Since there is a unique invariant distribution at the household level, $\lambda^{\widetilde{C}}$, which the same for all households, $\lambda^{\widetilde{C}}$ is also the cross-sectional distribution.[12] Therefore, the distributions of consumption, assets and labour supply per socio-economic class are invariant.[13] Thus, in a stationary equilibrium, given prices, (w,r), there are M consistency conditions, which will determine the elements in $\widetilde{C} = (\overline{C}_1, \overline{C}_2, .., \overline{C}_M)$:

$$\overline{C}_j = R\left(q\left(a_t, z_t; \widetilde{C}\right) : s\left(z_t\right) = j\right), \text{ for } j = 1, ..., M, \tag{2.6}$$

where the function $R(\cdot)$ refers to the relevant percentile of the distribution of consumption that defines the benchmark reference point for class s_t. When the reference point is determined by the mean consumption of the households in the social class that the household belongs to, the M consistency conditions will determine:

$$\overline{C}_j = \left(\frac{1}{\xi_{m=j}}\right) \int_X \left(q\left(a,z;\widetilde{C}\right) : s = j\right) \lambda^{\widetilde{C}}(da,dz), \text{ for } j = 1, ..., M, \tag{2.7}$$

where $\xi_{m=j}$ denotes the proportion of households that experience socio-economic class $m = j$ and is obtained as the relevant marginal distribution of the unconditional joint distribution ξ.

[12] See e.g. Uhlig (1996), Al-Najjar (2008) and Acemoglu and Jensen (2016) for versions of the Strong Law of Large Numbers that apply in this class of models.

[13] Note that since the unconditional joint distribution $\lambda^{\widetilde{C}}(a,z)$ is invariant, the marginal distributions $\lambda_j^{\widetilde{C}}(a,z) \equiv \lambda^{\widetilde{C}}\left(\{a,z : s = j\}\right) = \sum_{n=1}^{N} \lambda^{\widetilde{C}}(a, z_{j,n})$, for $j = 1, ..., M$, are also invariant.

Equilibrium and existence

We formally define a stationary recursive equilibrium with peer pressure given aggregate prices, which we term as socio-economic equilibrium.[14]

`Definition: Stationary Recursive Socio-economic Equilibrium`

For given prices r and w, a *Stationary Recursive Socio-economic Equilibrium* is an aggregate stationary distribution $\lambda^{\widetilde{C}}$ on X, policy functions $a_{t+1} = g\left(a_t, z_t; \widetilde{C}\right) : X \to A$, $c_t = q\left(a_t, z_t; \widetilde{C}\right) : X \to \mathbb{R}_+$ and $l_t = l\left(a_t, z_t; \widetilde{C}\right) : X \to [0,1]$, value function $V\left(a_t, z_t; \widetilde{C}\right) : X \to \mathbb{R}$, and positive real numbers in $\widetilde{C}$, such that:

1. Given the values in $\widetilde{C}$, the value function and the policy functions $g\left(a_t, z_t; \widetilde{C}\right)$, $c_t = q\left(a_t, z_t; \widetilde{C}\right)$, and $l_t = l\left(a_t, z_t; \widetilde{C}\right)$ solve the typical household's optimum problem in (2.4).

2. Given the values in $\widetilde{C}$, $\lambda^{\widetilde{C}}$ is a stationary distribution under the transition function $\Lambda^{\widetilde{C}}\left[(a,z), A' \times \{z'\}\right]$ implied by household's decision rules (determined by (2.5)). In particular, $\lambda^{\widetilde{C}}$ satisfies:

$$\lambda^{\widetilde{C}}([0,\overline{a}] \times \{z'\}) = \int_X \Lambda^{\widetilde{C}}\left[(a,z), A' \times \{z'\}\right] \lambda^{\widetilde{C}}(da, dz),$$

   for all $(a,z) \in X$, $A' \times \{z'\} \in \mathcal{B}(X)$.

3. When $\lambda^{\widetilde{C}}$ describes the cross-section of households at each date, the reference points in $\widetilde{C} = \left(\overline{C}_1, \overline{C}_2, .., \overline{C}_M\right)$ are given by the relevant percentiles of the distribution of consumption across the relevant social class in (2.6) or by the means in (2.7).

`Proposition 1:` *A stationary recursive socio-economic equilibrium exists.*

Proof: To show that an equilibrium allocation of $\left(\overline{C}_1, \overline{C}_2, .., \overline{C}_M\right)$, i.e. of the elements of the set $\widetilde{C}$, defining a stationary recursive socio-economic equilibrium exists, we use a fixed point theorem. In particular, define the set $\mathcal{C} \subseteq \mathbb{R}^m$ as the Cartesian product $\mathcal{C} = [0, c^{\max}] \times [0, c^{\max}] \times \cdots \times [0, c^{\max}]$. Note that for a given set $\widetilde{C}$ there is always an upper bound for consumption which is implied by the upper bound on assets, $\overline{a}_{\widetilde{C}}$, and is given by $c^{\max}_{\widetilde{C}} = (1+r)\,\overline{a}_{\widetilde{C}} + w\overline{e}^{\max}$. We define $c^{\max}$ as the maximum of all possible $c^{\max}_{\widetilde{C}}$'s. Thus, $\mathcal{C}$ is compact and convex, so that $\widetilde{C} \in \mathcal{C}$. Define the operator $T(\widetilde{C}) : \mathcal{C} \to \mathcal{C}$

[14] We also investigate later potential additional effects of social pressure on inequality via endogenously determined prices in the context of the calibration for the UK, by defining and establishing existence of a general equilibrium in an open economy setup.

to be given by the set of equations in the right hand side of (2.6) or (2.7). Lemma 1 in Appendix B establishes continuity of the policy function $c_t = q\left(a_t, z_t, \widetilde{C}\right)$ in $\widetilde{C}$, and thus continuity of the operator in (2.6). Moreover, Lemma B in Appendix 2 establishes continuity of the integrals in (2.7) in $\widetilde{C}$, thereby establishing that the operator in (2.7) is continuous. Then, Brouwer's fixed point theorem applies and implies that an allocation $\left(\overline{C}_1, \overline{C}_2, .., \overline{C}_M\right)$ to solve (2.6) or (2.7) exists. ■

We describe an algorithm to solve iteratively for this stationary equilibrium after we discuss the calibration of the model below. As is commonly the case with equilibrium in heterogeneous agent models, although existence of equilibrium can be shown, we cannot show that the equilibrium is unique in general (see e.g. Aiyagari (1994), Miao (2014), Zhu (2018) and Acikgoz (2018)). In this model, this happens because changes in the reference points, $\left(\overline{C}_1, \overline{C}_2, .., \overline{C}_M\right)$, need not have monotonic effects on household policy functions. For example, in the applications below, we find that an increase in $\overline{C}_m$ tends to increase consumption for households in the m^{th} social group. However, we also find that the increase in $\overline{C}_m$ also lowers consumption, to increase savings, for those is other groups who face the prospect of moving to that group and are thus faced with the prospect of higher peer pressure. In our applications, we have numerically explored the potential multiplicity of solutions for the set of parameter values that we use to calibrate the model. We have found a unique equilibrium for the set of parameters considered.[15] This is discussed in more detail below.

4 Data and stylised facts

We use British data on wages, hours worked, earnings, wealth, consumption and professional class participation, to calibrate the model and evaluate its predictions. In this section, we summarise the key properties in the data, To capture the uncertainty in labour productivity (wages) and socio-economic class participation, we use data from the Understanding Society Survey 2009-2017 (University of Essex, 2018), hereafter UnSoc. Data on the distributions of wealth are obtained from the Wealth and Assets Survey (ONS, 2018), hereafter WAS, on earnings and hours from the UnSoc, and consumption from the Living Cost and Food Survey (ONS, 2017), hereafter LCF.[16] Details on the data and sample selection are reported in Appendix C.

[15] This is similar to the variations of the Aiyagari (1994) model solved in the literature, in that although uniqueness typically cannot be established, a unique equilibrium for common calibrations is the norm.

[16] The WAS dataset covers Great Britain only. For consistency, we use the sub-sample for Great Britain from UnSoc and LCF below. However, the results are very similar if we use the whole sample from UnSoc and LCF.

4.1 Social class, wages and hours

We first calculate the socio-economic transition matrix and productivity risk within socio-economic classes. We make use of the UnSoc data, which is the latest longitudinal dataset for the U.K. containing information on individuals and households from 2009 to 2017 (8 waves). We keep households when the head[17] is an employee and, if there is a spouse who also works, when she/he is also an employee. We drop the households if either the head or the spouse (if any) is self employed. We keep households when both the head and the spouse (if any) have non-missing usual gross earnings per month at the current job and non-missing number of weekly hours normally worked. However, we keep households if one of the two spouses does not work i.e. if there is a spouse with zero earnings and zero hours. We also drop the households with positive incomes but reported zero hours. We further restrict the dataset by retaining households where the head of the households is aged 25-59 and dropping observations with missing values for socio-economic class (to be defined below).[18] To approximate the household's effective wage, we first translate the usual gross earnings per month at the current job to weekly gross earnings by multiplying by 12 and dividing by 52, and then, we divide the sum of weekly gross earnings of the spouses by the sum of typical total weekly hours of the spouses.[19] We drop the top 0.5% and the bottom 0.5% of the observations with positive household's effective wage, to avoid extreme cases (e.g. possible outliers in effective wages) which may affect results (see e.g. Blundell and Etheridge (2010) for similar treatment). This effectively means that we drop households that appear to be working for less than half the minimum wage. Finally, we keep those households that have at least two consecutive observations with positive household effective wage.

We approximate the socio-economic class of the household with the higher of the professional classes of the head or of the spouse. We use the National Statistics Socio-economic Classification (NS-SEC), which is the official socio-economic classification in the U.K.. In particular, starting from the Eight Class NS-SEC, we create the following groups in which we can allocate all heads and spouses: "Higher management and professionals occupations" (denoted *Higher Professional*), "Lower management and professional occupations" (denoted *Lower Professional*), "Intermediate occupations (clerical,

[17]We follow the ONS definition for the Household reference person (HRP) to define the head of the household. In particular, the HRP is the owner or renter of the accommodation in which the household lives. If there are multiple owners or renters, it is the eldest of them.

[18]Details on sample selection are in Appendix C. For similar sample selection criteria in terms of focusing on employees and working age groups, see, e.g. Blundell and Etheridge (2010), Heathcote *et al.* (2010)).

[19]Constructing an effective wage by dividing earnings by hours worked is common (see e.g. Blundell and Etheridge (2010), Blundell *et al.* (2007) or Bayer and Juessen (2012) for household effective wage).

sales, service) and lower supervisory and technical occupations" (denoted *Intermediate*), "Routine and semi-routine occupations" (denoted *Routine*). The first group merges two separate categories in the official NS-SEC since the higher managerial groups are small after the exclusion of employers. The third group is made up of two groups in the official NS-SEC categories, "Intermediate occupations (clerical, sales, service)" and "Lower supervisory and technical occupations", which we have added into one group because the statistics that we examine below for these two groups do not differ significantly, so that, for the purposes of our analysis, these two groups are observationally equivalent. For similar reasons, we add in one group the two groups "Routine occupations" and "Semi-routine occupations".

To approximate productivity risk within the socio-economic class, we first partial out the variation in wages between workers and over time that is not due to the professional class, but to other observable characteristics. Second, we discretise residual wages within each professional class. To implement the first step, we follow Kambourov and Manovskii (2009) and calculate the wages net of the predicted component based on observable characteristics. In particular, we consider a regression:

$$\ln W_{it} = \beta X_{it} + \pi Z_{it} + \epsilon_{it}, \tag{2.8}$$

where X_{it} includes a constant term, a quadratic in experience approximated by age, dummies for region of residence, dummy for gender and time fixed effects. Moreover, Z_{it} contains a set of dummy variables for the socio-economic classes as defined above. We do not include a variable for education because it is highly correlated to the socio-economic class and it will absorb all the differences between the groups. We pool the data and run an OLS regression to estimate the parameters. Then, we define the measure of residual (log) wages as:

$$\ln \widetilde{W}_{it} = \ln W_{it} - \beta X_{it}. \tag{2.9}$$

To implement the second step, we discretise the distribution of these residual wages, for each wave, by first splitting the households into the $M = 4$ groups according to their socio-economic class. Then, within each group we split the ordered wage distribution into $N = 3$ parts each containing a third of the socio-economic class. Thus, in each wave, we also allocate each household into one of the $H = 4 \times 3 = 12$ groups. We track transitions of households between the four professional classes and between the 12 wages states, and calculate the transition matrix for socioeconomic class (capturing underlying social mobility) and for wages (corresponding to the Q matrix in the model) by creating a pooled sample of all transitions over the 8 waves. The wage transitions matrix (reported in Appendix C) has higher probabilities along the diagonal, ranging between 0.55 to 0.77, and is associated with a unique stationary distribution. To derive the relevant state space E (also reported in Appendix C), we first calculate mean wages for each group $h \in H$ in each wave and then we calculate the average over the waves, which we normalise to one. The stationary distribution associated with the modelled stochastic process for wages predicts a coefficient of variation of 0.419 and a Gini index of 0.235, which are close to the respective statistics in the data, i.e. 0.483 and 0.257.

The social mobility transition matrix accompanying wage transitions (where R, I, LP and HP refer to *Routine*, *Intermediate*, *Lower Professional* and *Higher Professional* respectively), is given by:

$$\begin{bmatrix} & R & I & LP & HP \\ R & 0.9146 & 0.0577 & 0.0221 & 0.0056 \\ I & 0.0427 & 0.8746 & 0.0681 & 0.0146 \\ LP & 0.0125 & 0.0284 & 0.9218 & 0.0374 \\ HP & 0.0033 & 0.0111 & 0.0574 & 0.9282 \end{bmatrix}. \tag{2.10}$$

The diagonal of this matrix shows that there is high probability of remaining in the same professional class and thus is indicative of low social mobility. This is in line with previous findings on transitions between professional groups in the U.K. using the British Household Panel Survey (Upward and Wright (2007)), which is the precursor of UnSoc, and with evidence on occupational and wealth mobility in the U.S. (see e.g. Kambourov and Manovskii (2008) and Kuhn and Rios-Rull (2016)).

We also summarise in Table 1 the means and the Gini index per professional group of residual wages (normalised) and of the typical hours worked.[20] As can be seen, higher mean wages moving up the professional classes are generally accompanied by higher within class wage inequality (for the highest wage group the Gini does not increase relative to the second highest). Regarding typical hours worked, the relationship is reversed. In particular, groups with higher typical hours worked on average are characterised by a lower inequality in terms of hours. Moreover, there is a positive correlation between mean

[20] Typical hours in Table 1 are obtained by dividing usual weekly hours (the sum of hours worked by both spouses) by N_s*14*7, where N_s is the number of the spouses (i.e. assuming that a worker has up to 14 hours a day to choose to allocate to work or leisure).

wages and mean hours suggesting that on average higher wages encourage higher work.

Table 1: Summary statistics of wages & hours worked

NS-SEC	Mean	Gini
Effective wages		
routine and semi-routine	0.623	0.184
intermediate low supervisory	0.814	0.202
lower management and professional	1.081	0.212
higher management and professional	1.398	0.203
total	1.000	0.257
Average typical hours worked		
routine and semi-routine	0.296	0.223
intermediate low supervisory	0.330	0.152
lower management and professional	0.346	0.127
higher management and professional	0.346	0.121
total	0.333	0.153

Source: Understanding Society, own calculations. We report the average statistics over waves 1-8. All monetary values are expressed in 2015 prices as measured by CPIH.

4.2 Earnings, wealth and consumption inequality

We summarise the data predictions on earnings, wealth and consumption inequality between and within the professional classes in Table 2. Details on the data and samples are in Appendix C.[21] We calculate the mean of the relevant quantities (normalised so that the mean across the whole sample is one) and the within group Gini index for the four groups. A comparison of the means across groups provides an indication of between group inequality.

As expected, mean earnings, wealth and consumption increase with professional classes that have higher mean wages. However, within group earnings and wealth inequality decreases, whereas within group consumption inequality does not vary much between groups. Note that overall inequality is highest for wealth and lowest for consumption, as is typically found in the data (see e.g. Quadrini and Rios-Rull (2015) for the U.S.). In this case, this is evident both in terms of the Gini for the whole sample and by noting

[21] The measure of consumption includes non-durable goods, services and semi-durable goods. To have a user-cost measure of housing, we follow Blundell and Etheridge (2010) and include rent, mortgage interest payments and housing taxes.

that between group inequality is highest for wealth and lowest for consumption.

Table 2: Summary statistics of total earnings, net worth & consumption

NS-SEC	Mean	Gini
	total earnings*	
routine and semi-routine	0.549	0.314
intermediate low supervisory	0.794	0.263
lower management and professional	1.100	0.243
higher management and professional	1.454	0.235
total	1.000	0.308
	net worth†	
routine and semi-routine	0.387	0.775
intermediate low supervisory	0.696	0.662
lower management and professional	1.101	0.628
higher management and professional	1.702	0.593
total	1.000	0.670
	consumption‡	
routine and semi-routine	0.774	0.248
intermediate low supervisory	0.901	0.258
lower management and professional	1.068	0.260
higher management and professional	1.231	0.274
total	1.000	0.276

*Source: Understanding Society, own calculations. Total earnings refers to the sum of the weekly net earnings of the two spouses. We report the average statistics over waves 1-8.

†Source: Wealth and Assets Survey, own calculations. We report the average statistics over waves 1-5. Net-worth refers to the sum of property and net financial wealth of the household.

‡Source: Living Costs and Food Survey, own calculations. Consumption refers to equivalised weekly non-durable consumption plus real housing costs.
We report the average statistics over year 2009-2017. All monetary values for all three variables in this table are expressed in 2015 prices as measured by CPIH.

5 Calibration, solution and model fit

In this section, we discuss the calibration and numerical solution and establish that the model does a good job in capturing the key stylised facts on within and between group inequality summarised in the previous Section.

5.1 Calibration

We calibrate the model parameters to match underlying dimensions in the data. We capture stochasticity by using the transition matrix calculated from the UnSoc data as explained in the previous Section. Regarding the utility function, we use a CRRA utility function which is additively separable in consumption and leisure, augmented with relative consumption considerations (see also Jappeli and Pistaferri (2017) and De Giorgi *et al.* (2019)):

$$u(c,l,C) = \frac{c^{1-\sigma}}{1-\sigma}C^{\gamma} + \chi\frac{l^{1-\phi}}{1-\phi}, \tag{2.11}$$

where $\sigma, \phi > 1$, $\chi > 0$. This functional form has the advantage that it nests different possibilities regarding the type of social interactions that lead to peer pressure. In particular, conditional on $\sigma > 1$, for $\gamma > 0$ equation (2.11) implies that $\frac{\partial u}{\partial C} < 0$ ("jealousy") and $\frac{\partial^2 u}{\partial c \partial C} > 0$ ("keeping-up-with-the-Joneses"), whereas for $\gamma < 0$ equation (2.11) implies that $\frac{\partial u}{\partial C} > 0$ ("admiration") and $\frac{\partial^2 u}{\partial c \partial C} < 0$ ("running-away-from-the-Joneses").[22] Therefore, the sign of γ determines the type of peer pressure.[23] Naturally, when $\gamma = 0$, equation (2.11) delivers as a special case the benchmark model without social factors, and in this case the utility function used is the same as in Pijoan-Mas (2006). The elasticity of own consumption with respect to the target level of consumption is given by $\varepsilon_{cC} \approx \frac{\gamma}{\sigma}$ (see Appendix D for details). Hence, conditional on a value for σ, the absolute value of γ determines the size of the responsiveness of agent-level choices to social targets, i.e. it determines the strength of peer pressure.

We calibrate the utility function as follows. We first set $\sigma = 1.5$, which is a commonly used value (see e.g. Harrison and Oomen (2010) for the U.K.). Then, following e.g. Pijoan-Mas (2006), we choose ϕ and χ so that the model's predictions are consistent with working hours in the data, in terms of average and inequality in hours worked. More specifically, we calibrate χ so that mean hours worked equal 0.33 and ϕ so that the Gini in hours worked predicted by the model is equal to 0.153 (see Table 1 for the data targets). The calibrated values are shown in Table 3 (see also Table D1 in Appendix D which reports the long form of the rounded up entries in Table 3). Finally, for our base results we choose

[22] See Appendix D for details.

[23] Note that for $0 < \gamma < 1.5$ equation (2.11) does not satisfy the sufficient condition of joint concavity (the Hessian with respect to (c, l, C) is neither negative nor positive definite), although it is concave with respect to c, l for given C. The theoretical results at the level of the household in this case still hold, implying a unique invariant distribution. Moreover, although existence of a socio-economic equilibrium is not guaranteed by Proposition 1, an equilibrium is found for the calibrations used below.

a value for γ so that $\varepsilon_{cC} = 0.5$, which is in the range of the estimates of this elasticity from De Giorgi *et al.* (2019), who estimate the elasticity of own consumption with respect to that of peers to be between 0.3 and 0.6. The predictions of the model and main qualitative results are broadly similar in this range of elasticities.[24] To investigate the importance of peer pressure for the model's predictions, we analyse in detail below, in Section 5, the between and within group inequality implications of the type of peer pressure, by re-calibrating the model parameters when γ is such that $\varepsilon_{cC} = 0$ or $\varepsilon_{cC} = -0.5$.

Table 3: Calibrated parameters

β	σ	ϕ	α	γ	χ	r	w	δ
0.9655	1.50	1.6051	0.30	0.75	1.0347	0.0217	1.0367	0.0983

The prices r and w are set so that the model is consistent with a typical production sector assumed in calibrated models. In particular, the interest rate is set to be 0.0217, which is the average value of the real short-term yields in the data for U.K. for the period 1990-2013 (see Carvalho *et al.* 2016). We choose the wage rate so that is consistent with this interest rate under the assumption that the production sector is given by a profit maximising firm, using a Cobb-Douglas production function with constant returns to scale with respect to its inputs, capital K and labour L:

$$Y = F(K, L) = TK^{\alpha}L^{1-\alpha}, \tag{2.12}$$

$$\Rightarrow \frac{Y}{L} = T\left(\frac{K}{L}\right)^{\alpha}, \tag{2.13}$$

for which we normalise $T \equiv 1$ and set α to 0.3 (see e.g. Harrison and Oomen (2010)), and is subject to an annual depreciation rate, $0 < \delta < 1$, that is set to $\delta = 0.0983$ so that the capital over output ratio is 2.5.[25] In other words, the first order conditions for profit maximisation:

$$r + \delta = \partial F(K, L)/\partial K \equiv F_1\left(\frac{K}{L}, 1\right), \tag{2.14}$$

$$w = \partial F(K, L)/\partial L \equiv F_2\left(\frac{K}{L}, 1\right), \tag{2.15}$$

determine δ and w, given r and $\frac{K}{L}$ such that $K/Y = 2.5$ from equation (2.13).

Finally, the time preference parameter, $\beta = 0.9655$, is chosen so that the asset supply

[24] On balance, the model predictions are closer to the data for more inequality measures under $\varepsilon_{cC} = 0.5$, compared with a lower elasticity of e.g. $\varepsilon_{cC} = 0.33$ (see Appendix D, Table D2 for these results).

[25] This is very close to the values in Faccini *et al.* (2011) and Harrison and Oomen (2010).

predicted by the model given the remaining parameters matches the data, and, in particular, a net foreign asset (NFA) position, $\frac{K-A}{Y}$, of 8.1%.[26] Note that the aggregate resource constraint is given by $Y = C + I + rNFA$. In Appendix E, we explicitly integrate the socio-economic equilibrium in an open economy general equilibrium setup also employed in Angelopoulos *et al.* (2019), consistent with the above calibration for the U.K.. This allows us to investigate the quantitative implications of peer pressure on inequality by accounting for potential general equilibrium effects via prices. Since the main results are very similar, we focus on the case with fixed prices for the analysis which follows.

5.2 Numerical solution

We solve for the socio-economic equilibrium, given prices, using the following algorithm:

`Computational algorithm for the socio-economic equilibrium`

1. Guess values for $\widetilde{C}_n = \left(\overline{C}_1, \overline{C}_2, .., \overline{C}_m\right)$ from the domain $\mathcal{C}$.
2. Solve the "typical" household's problem to obtain $g\left(a, z, \widetilde{C}_n\right)$, $q\left(a, z, \widetilde{C}_n\right)$ and $l\left(a, z, \widetilde{C}_n\right)$.
3. Use $g\left(a, s, \widetilde{C}_n\right)$ and the properties of the Markov processes (z_t) to construct the transition function $\Lambda^{\widetilde{C}}$. Using $\Lambda^{\widetilde{C}}$, calculate the stationary distribution $\lambda^{\widetilde{C}}$.
4. Using $\lambda^{\widetilde{C}}$, compute the consumption reference points $\widetilde{C}_n^*$ using (2.6) or (2.7).
5. If $\left|\widetilde{C}_n^* - \widetilde{C}_n\right| < \varepsilon$, where ε is a pre-specified tolerance level, a stationary equilibrium has been found. If not, go back to step 1, and update $\widetilde{C}_{n+1} = (1 - \varsigma)\,\widetilde{C}_n + \varsigma \widetilde{C}_n^*$ with $0 < \varsigma \leq 1$.

An important theoretical result allowing the implementation of this algorithm is that $\lambda^{\widetilde{C}}$ is the unique invariant distribution for the typical household for given $\widetilde{C}_n$. This process implies that we assume an upper bound $c^{\max}$ in step 1, to determine $\mathcal{C}$. We check that in equilibrium this is not binding. To implement this algorithm, we set $\varepsilon = 10^{-4}$ and $m = 4$. To confirm uniqueness of the socio-economic equilibrium, we solve the model for a range of social targets $\widetilde{C} = \left(\overline{C}_1, \overline{C}_2, \overline{C}_3, \overline{C}_4\right)$ and check whether the corresponding equilibrium quantities, obtained using equation (2.6) or (2.7), equal the social targets used for that case in more than cases. We work as follows:

[26] This is the average value for the UK,1990-2013, in Extended External Wealth of Nations Mark II database (see also Lane and Milesi-Ferretti (2007)).

1. We find the socio-economic equilibrium following the computational algorithm described above.

2. We construct a grid of 20 values for each of the consumption targets, $\overline{C}_j$, $j = 1, 2, 3, 4$. We set a small value, 0.01 as the minimum of the grid, and three times the mean consumption as the maximum of the grid.

3. Since the grid does not need to contain the original solution, we add to the grid the equilibrium points we found in step 1. Thus, we have in total 21 grid points for each consumption target.

4. We construct the Cartesian product of all the possible combinations of consumption targets, i.e.

$$\underline{C} \equiv \overline{C}_1 \times \overline{C}_2 \times \overline{C}_3 \times \overline{C}_4 = \left[\overline{C}_1^1, \overline{C}_1^2, ..., \overline{C}_1^{21}\right] \times ... \times \left[\overline{C}_4^1, \overline{C}_4^2, ..., \overline{C}_4^{21}\right],$$

which implies 194,481 different combinations of consumption targets $\widehat{C}$, where $\widehat{C} \in \underline{C}$.

5. For each combination, $\widehat{C}$, we solve the "typical" household's problem to obtain $g\left(a, z, \widehat{C}\right)$, $q\left(a, z, \widehat{C}\right)$ and $l\left(a, z, \widehat{C}\right)$, construct the transition function $\Lambda^{\widehat{C}}$, calculate the stationary distribution $\lambda^{\widehat{C}}$, and compute the consumption reference points $\widehat{C}^*$ using equation (2.6) or (2.7).

6. Check whether $\left|\widehat{C}_j - \widehat{C}_j^*\right| < \varepsilon$, for all $j = 1, 2, 3, 4$ in more than one of the 194,481 combinations, and that for $\widehat{C}^*$ that satisfies this condition it is true that $\widehat{C}^* = \widetilde{C}_n^*$.

We find a unique equilibrium for all solutions presented in the tables with results below.[27] We represent this graphically in Appendix Figure D1, by noting that the condition $\left|\widehat{C}_j - \widehat{C}_j^*\right| < \varepsilon$, for all $j = 1, 2, 3, 4$, implies and is implied by the condition $\max_j \left|\widehat{C}_j - \widehat{C}_j^*\right| < \varepsilon$. Hence, we order the values of $\max_j \left|\widehat{C}_j - \widehat{C}_j^*\right|$ and plot the first 14,000 in Figure D1. There is always a unique value of $\max_j \left|\widehat{C}_j - \widehat{C}_j^*\right| < 10^{-4}$.[28]

[27] Each test for uniqueness, for each model solution presented below, requires approximately 36 hours on a cluster computer, using parallel processing (16 cores) with Matlab 2018a.

[28] Note that we repeat this exercise for each model solution in Figures D2-D5, except for the $\gamma = 0$ case for which we know that there is a unique equilibrium.

5.3 Within and between-class inequality predictions

We demonstrate the model's ability to capture the patterns in the data on inequality in HEWC, between and within socio-economic classes in Table 4.[29] In the first two columns of Table 4, we report the mean assets, earnings, consumption and hours worked for each of the four socio-economic classes in the data and for the model solution. For wealth, earnings and consumption, quantities are normalised relative to the mean for the aggregate economy. In the final two columns of Table 4, we report the Gini indices for the four variables, again for both the data and the model solution, for each of the four classes, as well as for the total economy. The figures for the data in Table 4 are the same as those in Section 3 (see Table 2), but are repeated here next to the model predictions for convenience.

Overall, the model captures the main patterns regarding between and within group inequality observed in the data. Starting with wealth, as discussed in Section 3, the data show higher mean wealth for the higher mean wage socio-economic classes, but lower within group wealth inequality. Both patterns are predicted by the model.[30] Notably, the lower Gini index in the model for higher mean wage classes is quantitatively significant, similar to what is observed in the data. On the other hand, the model under-predicts wealth inequality quantitatively, as is typically the case for this class of models, where wealth inequality is driven solely by uninsured idiosyncratic shocks that affect earnings (see e.g. Aiyagari (1994), Benhabib *et al.* (2017), and Stachurski and Toda (2019)).[31] Similarly to the existing research using incomplete markets heterogeneous agent models, the model here correctly predicts lower consumption inequality relative to wealth inequality, and under-predicts consumption inequality compared with the data.[32] The model predicts higher between group inequality compared with the LCF data, and lower within group inequality. The model does not predict a specific pattern for within group consumption inequality for groups with higher mean wages, while in the LCF data we see a small increase in within group Ginis.

[29] In the next section, we further explain in more detail the contribution of peer pressure, in an environment of stochastic social mobility, to generating the predicted patterns.

[30] About 11% of households have zero wealth in the model. In the WAS sample for which we calculate the distributional statistics, the proportion of households with non-positive wealth is about 15%. Note that the percentage of households with zero wealth is endogenously determined in the model, since we do not impose an *ad hoc* positive borrowing limit.

[31] A large literature has recently focused on extensions to this class of models aimed at improving predictions regarding the extent of wealth concentration at the upper end (see e.g. De Nardi (2015), Quadrini and Rios-Rull (2015), and Benhabib *et al.* (2017) for reviews). In this paper, instead, our interest is in the patterns of inequality between and within socio-economic groups.

[32] See e.g. Aiyagari (1994), De Nardi (2015) and Krueger *et al.* (2016) on the general properties of these models in this respect, in particular the success with respect to predicting lower consumption versus wealth inequality, despite predicting lower consumption inequality compared with the data.

The model's predictions regarding the overall earnings inequality are very similar to the base model with incomplete markets and endogenous labour supply in Pijoan-Mas (2006). In addition, the model also matches the main pattern of increasing means but decreasing Ginis for earnings for socio-economic classes with higher mean wages. In particular, the model matches between group earnings inequality to those observed in the data. It slightly over-predicts the earnings Gini for the aggregate economy, which is driven by a small exaggeration of the within group Gini for the two higher classes. In other words, the within group earnings Gini does not fall in the model by as much as in the data for the higher mean wage socio-economic classes.

The model has been calibrated to match mean hours worked of 0.333. Notably, the model predicts that hours worked fall with higher mean wages across the socio-economic classes. This success is important because the theoretical framework implies a negative correlation between hours worked and assets at the household level[33] (see Section 2, and also Zhu (2018) for theoretical analysis and Pijoan-Mas (2006) for a quantitative examination).

Since as already discussed (see Table 4) mean assets per group increase with mean wages, the negative correlation between hours and assets tends to generate a negative relationship between higher mean wages and mean hours across the groups, which is at odds with the empirical observations. Indeed, as will also be discussed below, in the absence of "keeping-up-with-the-Joneses" peer pressure, the model predicts lower mean hours for groups with higher mean wages relative to the groups with lower mean wages. In contrast, for sufficiently strong "jealousy" and "keeping-up-with-the-Joneses" effects, mean hours increase with mean wages across groups, despite the negative correlation between assets and hours at the household level. As explained in more detail below, under this form of social pressure, the relative importance of consumption versus leisure increases with professional class. In particular, households in socio-economic classes with higher mean wages, and thus higher mean assets and consumption, face an increased return from consumption relative to leisure. This encourages higher work hours relative to groups with lower mean wages, despite the effect of higher assets, which tend, *ceteris paribus*, to reduce hours. The model has also been calibrated to match the Gini index in hours of 0.153. Further disaggregating differences in hours worked within groups, the model predicts that the Gini index decreases with higher mean wages across the socio-economic classes. This is consistent with the data, although the relationship is steeper in

[33] This is in turn implied by the assumption that leisure is a normal good, leading to strong income effects, which is needed for boundedness (see Zhu (2018, Proposition 3)).

the data.

Table 4: Base calibration

	Data	$\varepsilon_{cC}=$ 0.5		Data	$\varepsilon_{cC}=$ 0.5
$\frac{\overline{A}_R}{\overline{A}}$	0.387	0.409	Gini A_R	0.775	0.619
$\frac{\overline{A}_I}{\overline{A}}$	0.696	0.644	Gini A_I	0.662	0.573
$\frac{\overline{A}_{LP}}{\overline{A}}$	1.101	1.044	Gini A_{LP}	0.628	0.517
$\frac{\overline{A}_{HP}}{\overline{A}}$	1.702	1.515	Gini A_{HP}	0.593	0.470
$\overline{A}$		1.271	Gini A	0.670	0.557
$\frac{\overline{C}_R}{\overline{C}}$	0.774	0.563	Gini C_R	0.248	0.106
$\frac{\overline{C}_I}{\overline{C}}$	0.901	0.756	Gini C_I	0.258	0.110
$\frac{\overline{C}_{LP}}{\overline{C}}$	1.068	1.037	Gini C_{LP}	0.260	0.103
$\frac{\overline{C}_{HP}}{\overline{C}}$	1.231	1.362	Gini C_{HP}	0.274	0.088
$\overline{C}$		0.395	Gini C	0.276	0.186
$\frac{\overline{E}_R}{\overline{E}}$	0.549	0.516	Gini E_R	0.314	0.289
$\frac{\overline{E}_I}{\overline{E}}$	0.794	0.721	Gini E_I	0.263	0.286
$\frac{\overline{E}_{LP}}{\overline{E}}$	1.100	1.033	Gini E_{LP}	0.243	0.284
$\frac{\overline{E}_{HP}}{\overline{E}}$	1.454	1.418	Gini E_{HP}	0.235	0.272
$\overline{E}$		0.368	Gini E	0.308	0.335
$\overline{H}_R$	0.296	0.298	Gini H_R	0.223	0.180
$\overline{H}_I$	0.330	0.316	Gini H_I	0.152	0.159
$\overline{H}_{LP}$	0.346	0.337	Gini H_{LP}	0.127	0.147
$\overline{H}_{HP}$	0.346	0.358	Gini H_{HP}	0.121	0.131
$\overline{H}$		0.333	Gini H	0.153	0.153

6 Peer pressure with stochastic mobility

In this section we analyse how peer pressure and stochastic social transitions interact to contribute to the patterns of inequality summarised in the previous Section. Recall that the theoretical analysis and choice for the functional form allows for different forms of pressure from the peers in one's social class to influence economic decisions under stochastic social class participation. In particular, for $\gamma > 0$ the model incorporates "jealousy" ($\frac{\partial u}{\partial C} < 0$) and "keeping-up-with-the-Joneses" ($\frac{\partial^2 u}{\partial c \partial C} > 0$), whereas for $\gamma < 0$, social pressure takes the form of "admiration" ($\frac{\partial u}{\partial C} > 0$) and "running-away-from-the-

Joneses" ($\frac{\partial^2 u}{\partial c \partial C} < 0$). In Table 5 we summarise the between and within group inequality effects of peer pressure, by comparing results under the base calibration of "keeping-up-with-the-Joneses" peer pressure, $\varepsilon_{cC} = 0.5$, to a situation without peer pressure, $\varepsilon_{cC} = 0$, and to one where peer pressure is of the "running-away-from-the-Joneses" type (i.e. $\varepsilon_{cC} = -0.5$). In each case, we re-calibrate the model working as in Section 4. In particular, we re-calibrate χ, ϕ and β to ensure that all cases match average hours, hours inequality and assets as a share of output in the data respectively (the new parameters are recorded in the notes to Table 5).

6.1 Hours & earnings (intra-temporal margin)

Peer pressure has significant effects on hours and earnings. Starting with hours, we see in Table 5 (and Figure 1) that in an environment where $\varepsilon_{cC} = 0$ or $\varepsilon_{cC} = -0.5$, mean hours fall as we move from groups with lower to those with higher mean wages, whereas in the data and in the base case of $\varepsilon_{cC} = 0.5$, the relationship between mean hours and mean wages across the groups is positive. As was noted in the previous Section, the negative relationship between mean hours and mean wages when $\varepsilon_{cC} = 0$ and $\varepsilon_{cC} = -0.5$ is driven by a negative correlation between hours worked and assets at the household level, resulting from strong income effects. Hence, in these cases, higher mean wages, implying higher mean assets, lead to lower work hours on average. Peer pressure changes this relationship, because the relative importance of consumption versus leisure increases with professional class. As can be seen in the intra-temporal first order condition:

$$we(z_t)(C_t)^{\gamma} c_t^{-\sigma} = \chi l_t^{-\phi}, \tag{2.16}$$

when $\gamma > 0$, a higher consumption target C_t, for the higher mean wage classes, increases the relative weight to consumption between classes. In other words, social targets change the relative weights between consumption and leisure differentially across social groups, and in the case of $\varepsilon_{cC} = 0.5$, this makes consumption relatively more valuable (or else, leisure relatively less valuable) for the groups with higher consumption targets, which are the groups with higher mean wages. Therefore, under peer pressure, there are stronger incentives to work for the higher wage - higher assets groups. This effect disappears when $\varepsilon_{cC} = 0$, leading to the negative relationship between mean hours and mean wages across the groups in Table 5, and is reversed when $\varepsilon_{cC} = -0.5$, making this relationship stronger.

Table 5: Alternative calibrations

	Data	$\varepsilon_{cC}=$ 0.5	$\varepsilon_{cC}=$ 0	$\varepsilon_{cC}=$ −0.5		Data	$\varepsilon_{cC}=$ 0.5	$\varepsilon_{cC}=$ 0	$\varepsilon_{cC}=$ −0.5
$\frac{\overline{A}_R}{\overline{A}}$	0.387	0.409	0.333	0.302	Gini A_R	0.775	0.619	0.658	0.677
$\frac{\overline{A}_I}{\overline{A}}$	0.696	0.644	0.571	0.543	Gini A_I	0.662	0.573	0.602	0.612
$\frac{\overline{A}_{LP}}{\overline{A}}$	1.101	1.044	1.030	1.026	Gini A_{LP}	0.628	0.517	0.528	0.527
$\frac{\overline{A}_{HP}}{\overline{A}}$	1.702	1.515	1.629	1.672	Gini A_{HP}	0.593	0.470	0.464	0.457
$\overline{A}$		1.271	1.238	1.217	Gini A	0.670	0.557	0.576	0.581
$\frac{\overline{C}_R}{\overline{C}}$	0.774	0.563	0.678	0.742	Gini C_R	0.248	0.106	0.121	0.129
$\frac{\overline{C}_I}{\overline{C}}$	0.901	0.756	0.836	0.876	Gini C_I	0.258	0.110	0.121	0.126
$\frac{\overline{C}_{LP}}{\overline{C}}$	1.068	1.037	1.037	1.034	Gini C_{LP}	0.260	0.103	0.107	0.108
$\frac{\overline{C}_{HP}}{\overline{C}}$	1.231	1.362	1.241	1.181	Gini C_{HP}	0.274	0.088	0.086	0.085
$\overline{C}$		0.395	0.385	0.379	Gini C	0.276	0.186	0.149	0.133
$\frac{\overline{E}_R}{\overline{E}}$	0.549	0.516	0.634	0.697	Gini E_R	0.314	0.289	0.245	0.222
$\frac{\overline{E}_I}{\overline{E}}$	0.794	0.721	0.793	0.829	Gini E_I	0.263	0.286	0.264	0.249
$\frac{\overline{E}_{LP}}{\overline{E}}$	1.100	1.033	1.026	1.020	Gini E_{LP}	0.243	0.284	0.287	0.281
$\frac{\overline{E}_{HP}}{\overline{E}}$	1.454	1.418	1.313	1.259	Gini E_{HP}	0.235	0.272	0.296	0.300
$\overline{E}$		0.368	0.358	0.352	Gini E	0.308	0.335	0.317	0.302
$\overline{H}_R$	0.296	0.298	0.363	0.396	Gini H_R	0.223	0.180	0.133	0.109
$\overline{H}_I$	0.330	0.316	0.343	0.356	Gini H_I	0.152	0.159	0.140	0.123
$\overline{H}_{LP}$	0.346	0.337	0.326	0.320	Gini H_{LP}	0.127	0.147	0.154	0.146
$\overline{H}_{HP}$	0.346	0.358	0.319	0.300	Gini H_{HP}	0.121	0.131	0.161	0.165
$\overline{H}$		0.333	0.333	0.333	Gini H	0.153	0.153	0.153	0.153

Notes: For the case where $\varepsilon_{cC} = 0.5$ the parameters are as in Table 3. For the $\varepsilon_{cC} = 0$ case, $\beta = 0.9625$, $\chi = 2.2134$ and $\phi = 1.5446$ and the rest are as in Table 3. For the $\varepsilon_{cC} = -0.5$ case, $\beta = 0.9611$, $\chi = 4.4693$ and $\phi = 1.6632$ and the rest are as in Table 3.

A similar qualitative change is noted when we examine inequality in hours within the groups. As we see in Table 5, moving from an environment where $\varepsilon_{cC} = 0$ or $\varepsilon_{cC} = -0.5$ to one where $\varepsilon_{cC} = 0.5$, the relationship between within group hours inequality and mean wages across groups changes from positive to negative, consistent with the data. Peer pressure, when it has the "keeping-up-with-the-Joneses" form, implies a desire for likeness in terms of consumption and thus in terms of hours worked, to finance this closeness in consumption. In particular, as can be seen from equation (2.16), under peer pressure, there is a social factor, which is common to all households, in addition to idiosyncratic productivity. Under "keeping-up-with-the-Joneses" peer pressure, the higher social targets, for the higher mean wage groups, imply that this common social factor is relatively stronger, leading to a reduction in the spread of choices for these groups relative to lower mean wage groups. Hence, there is less within-group hours dispersion in higher mean wage groups, compared with lower mean wage groups.

The between group inequality in hours under "keeping-up-with-the-Joneses" peer pressure, under $\varepsilon_{cC} = 0.5$, leads to increased between group earnings inequality (Table 5 and Figure 1). In addition, the differences in within group hours inequality lead to the differences in within group earnings inequality. In particular, recall that the stochastic process (and thus productivity risk) is the same for all model versions. Hence, within group inequality in earnings follows within group inequality in hours. This is true for all types of peer pressure. Therefore, since under "keeping-up-with-the-Joneses" peer pressure ($\varepsilon_{cC} = 0.5$ case), the relationship between the Gini in hours and mean wages across the groups is positive, this is also the case for the relationship between the Gini in earnings and mean wages. This pattern is consistent with the data. Under $\varepsilon_{cC} = 0$ and $\varepsilon_{cC} = -0.5$, the absence of the social discipline mechanism associated with "keeping-up-with-the-Joneses", for the given stochastic environment, leads to the reverse relationship.

Overall, "keeping-up-with-the-Joneses" peer pressure works to lower the mean and increase the dispersion for both hours and earnings for the lower mean wage groups. However, there is no pattern for the higher mean wage group (see also Appendix D, Table D3 which shows the levels and of the means and variances). Note also that although mean hours across the population have not changed between the cases considered, as γ changes, since we have in each case re-calibrated to adjust the relative weights to consumption and leisure (see (2.16)), mean earnings increase when γ increases. This happens because the covariance between hours and wages across the population increases with γ (recall that mean effective wages have not changed), which is related to the positive relationship between mean hours and mean wages across the groups that is observed for higher values of γ, as discussed above.[34]

[34]Indeed, $cov(w, h) = \{0.022, 0.015, 0.012\}$ for $\varepsilon_{cC} = \{0.5, 0. - 05\}$ respectively. In contrast, there is no clear pattern between the covariance between hours and wages and γ within the socio-economic groups.

6.2 Consumption & wealth (inter-temporal margin)

We next examine the effect of increases in γ on between and within group inequality on consumption and wealth. In general, the higher earnings in the economy with "keeping-up-with-the-Joneses" peer pressure imply higher wealth and consumption on average. However, the results in Table 5 show that households in all groups, apart from the top mean wage group, increase their wealth (both in absolute terms and as a share of total assets), while households in the highest mean wage groups decrease savings on average and own a lower share of total wealth. This result is driven by a differential "prospect for upward mobility" and its implications for the expected future peer pressure.

The mechanism by which the "prospect for upward mobility" creates these effects can be illustrated by examining the inter-temporal first order condition:

$$(C_t)^{\gamma} c_t^{-\sigma} = \beta(1+r)E_t(C_{t+1})^{\gamma} c_{t+1}^{-\sigma}. \tag{2.17}$$

As can be seen, a type of "keeping-up-with-the-Joneses" ("running-away-from-the-Joneses") peer pressure, affects the weight attached to current consumption, as well as the weight attached to future consumption. The magnitude of the relative effect $E_t(C_{t+1})^{\gamma}/C_t)^{\gamma}$ depends on the current social class of the household, because this will determine the value of the conditional expectation relative to the current target. In particular, consider the case when $\gamma > 0$, relative to the base case of $\gamma = 0$ (and vice versa when $\gamma < 0$). In this case, the added effect on the valuation of future consumption relative to current consumption is higher conditional on being on a lower mean wage class, given that possible mobility is mainly upwards, thus towards a social group that will exert pressure for higher future consumption, relative to the current target. The effect is reversed for households in higher mean wage social classes. Hence, the prospect of upward mobility, under "keeping-up-with-the-Joneses" peer pressure, contributes to a decrease in between group wealth inequality. On the contrary, and despite the reduction in between group wealth inequality, between group consumption inequality is increased, under "keeping-up-with-the-Joneses" peer pressure. This is the result of the significant effect of such peer pressure to increase between groups earnings inequality, as was discussed in the previous subsection.

The effects of peer pressure on between group inequality in HEWC, as well as the effects on within group earnings inequality, contribute to explaining the changes in within group inequality in wealth and consumption. Note, first, that social groups with lower mean wages decrease mean earnings and increase mean wealth as γ increases. Therefore, in relative terms, asset income becomes more important than earnings, as γ increases.

Given that the stochastic environment has not changed, the increased share of asset income implies that the variation in earnings is less important for total income, and thus for savings, leading to a reduction in within group wealth inequality (which falls for the first two groups and increases for the top one). For the third one there is no pattern. These effects are reversed for the higher mean wage groups, leading to an increase in within group wealth inequality. At the aggregate level, the effects associated with the lower mean wage groups (i.e. the decrease in the importance of asset income), and the decrease in between group wealth inequality dominate, so that wealth inequality for the whole economy is lower. The effects on within group consumption inequality follow from the changes in within group wealth inequality, although they are significantly less pronounced. As a result, the increase in between group consumption inequality is strong enough to lead to an increase in overall consumption inequality.

7 Peer pressure and aspirations

The prospect of upward mobility, associated with stochastic socio-economic class participation, embeds an upward looking element in peer pressure. We examined the effects of this component of peer pressure on inequality in the previous Section, documenting that it works to decrease between group wealth inequality, further contributing to the asymmetric change in within group inequality. Moreover, peer pressure has an aspirational element, because it instills a desire to match a pre-specified level of success. In the previous section, this level was determined by mean group consumption. Here, we study forms of social pressure that imply stronger aspirational effects than those studied in the previous section, and we examine their inequality implications.

We first consider the case of an increase in the aspirational element embodied in peer pressure, and we then consider a situation where social pressure is explicitly aspirational in nature. Such differences may arise as social norms change following socio-economic development (e.g. greater social interaction, television, internet and social media) or long-term policy interventions to support integration and build confidence for higher aspirations (e.g. role models and success stories and well as increased information).[35]

[35] Examples of such policies in the UK include: "Careers strategy: making the most of everyone's skills and talents", see assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file /664319/Careers_strategy.pdf and "Learning to improve the lives and aspirations of young people in Scotland", see education.gov.scot/Documents/LearningtoImprove LivesYoungPeople.pdf.

7.1 The aspirational element of peer pressure

We consider the situation where the reference point for consumption in the utility function is the consumption of a specific type of the socio-economic class that a household belongs to, capturing social norms that define aspirations by promoting specific group-relevant attributes that the household aims to achieve. By defining social targets as those associated with the consumption of higher percentiles of the distribution of consumption, we examine the inequality implications of a stronger aspirational element of peer pressure.

Different aspirational strengths of peer pressure

To implement this, we plot, in Figures 1-2, mean quantities and Ginis, per socio-economic class, for HEWC, for a range of consumption targets, and in particular ranging from consumption at the 10th percentile, to consumption at the 90th percentile. To contextualise the effect of stronger aspirations, we compare the results when the target is a very successful type of the group of peers, namely the 90th percentile, to the situation in the previous Section, where the social target was determined by mean consumption, which captures average behaviour. In the columns of Table 6 under the heading p90, we summarise the between/within group inequality implications when the social target is given by the consumption of the household at the 90th percentile of the distribution of consumption for the class that the household belongs to. We compare these results to the base case of peer pressure analysed above, i.e. when the target is the mean consumption of the members of the socio-economic class (repeated in Table 6, in the columns under the heading $\varepsilon_{cC} = 0.5$).

Table 6: The effects of aspirational pressure

	ε_{cC}= 0.5	p90th	mean above	p90 above		ε_{cC}= 0.5	p90	mean above	p90 above
$\frac{\overline{A}_R}{\overline{A}}$	0.409	0.411	0.388	0.386	Gini A_R	0.619	0.616	0.633	0.634
$\frac{\overline{A}_I}{\overline{A}}$	0.644	0.641	0.601	0.598	Gini A_I	0.573	0.573	0.588	0.589
$\frac{\overline{A}_{LP}}{\overline{A}}$	1.044	1.039	1.010	1.013	Gini A_{LP}	0.517	0.518	0.524	0.522
$\frac{\overline{A}_{HP}}{\overline{A}}$	1.515	1.523	1.607	1.606	Gini A_{HP}	0.470	0.469	0.456	0.454
$\overline{A}$	1.271	1.317	1.457	1.518	Gini A	0.557	0.557	0.564	0.563
$\frac{\overline{C}_R}{\overline{C}}$	0.563	0.567	0.606	0.616	Gini C_R	0.106	0.106	0.111	0.113
$\frac{\overline{C}_I}{\overline{C}}$	0.756	0.765	0.810	0.815	Gini C_I	0.110	0.111	0.116	0.117
$\frac{\overline{C}_{LP}}{\overline{C}}$	1.037	1.041	1.061	1.057	Gini C_{LP}	0.103	0.104	0.106	0.106
$\frac{\overline{C}_{HP}}{\overline{C}}$	1.362	1.347	1.264	1.261	Gini C_{HP}	0.088	0.088	0.084	0.084
$\overline{C}$	0.395	0.428	0.422	0.453	Gini C	0.186	0.183	0.163	0.161
$\frac{\overline{E}_R}{\overline{E}}$	0.516	0.524	0.558	0.568	Gini E_R	0.289	0.272	0.265	0.25
$\frac{\overline{E}_I}{\overline{E}}$	0.721	0.731	0.763	0.769	Gini E_I	0.286	0.269	0.266	0.254
$\frac{\overline{E}_{LP}}{\overline{E}}$	1.033	1.036	1.044	1.042	Gini E_{LP}	0.284	0.269	0.273	0.263
$\frac{\overline{E}_{HP}}{\overline{E}}$	1.418	1.402	1.348	1.343	Gini E_{HP}	0.272	0.261	0.278	0.267
$\overline{E}$	0.368	0.399	0.390	0.420	Gini E	0.335	0.270	0.318	0.306
$\frac{\overline{H}_R}{\overline{H}}$	0.895	0.905	0.961	0.977	Gini H_R	0.180	0.159	0.153	0.135
$\frac{\overline{H}_I}{\overline{H}}$	0.951	0.962	1.000	1.006	Gini H_I	0.159	0.139	0.138	0.123
$\frac{\overline{H}_{LP}}{\overline{H}}$	1.013	1.014	1.014	1.009	Gini H_{LP}	0.147	0.128	0.135	0.121
$\frac{\overline{H}_{HP}}{\overline{H}}$	1.075	1.060	1.002	0.996	Gini H_{HP}	0.131	0.117	0.137	0.122
$\overline{H}$	0.333	0.365	0.359	0.389	Gini H	0.153	0.134	0.139	0.124

Figure 1: Success Stories Within Peers, between group inequality

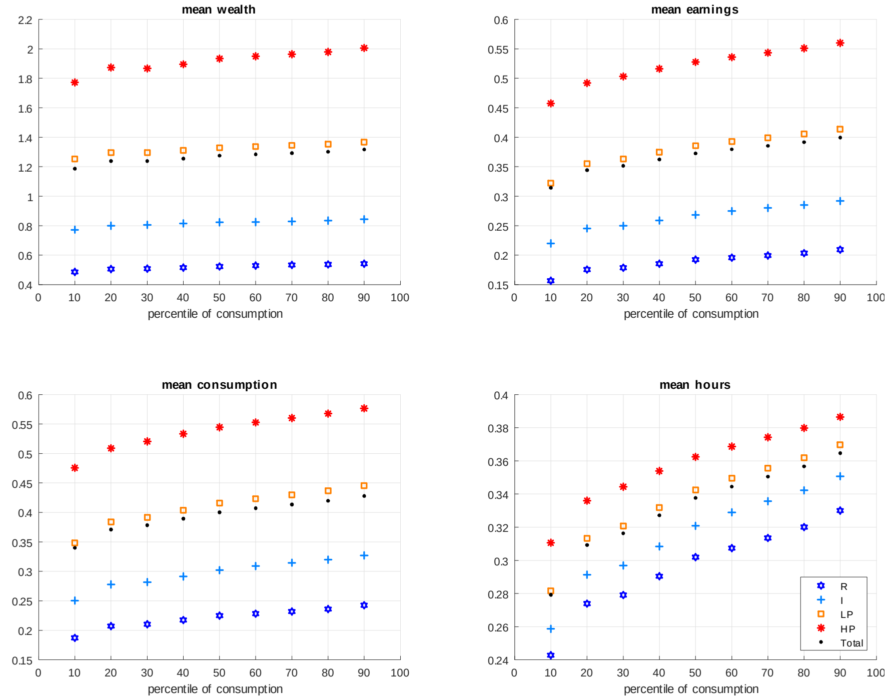
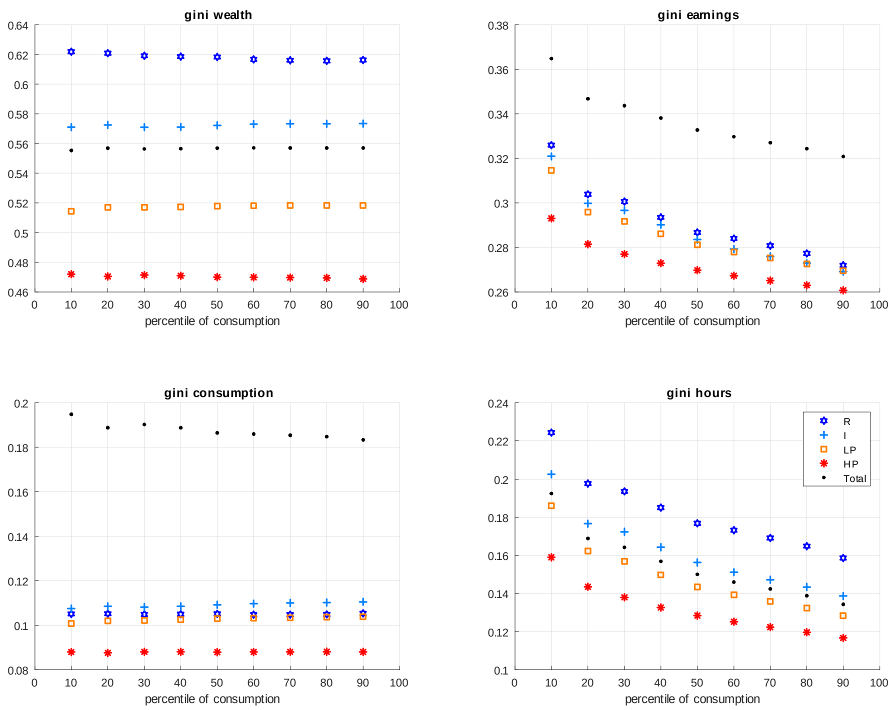


Figure 2: Success Stories Within Peers, within group inequality



As can be seen in Figures 1-2, a stronger aspirational element of peer pressure has a significant and positive effects on all mean quantities, while decreasing within group inequality in hours and earnings and between group inequality in hours and earnings, in terms of the gap between the highest mean wage group and the other groups. On the other hand, between and within group inequality in consumption and wealth do not change much and do not follow an obvious pattern. We analyse the mechanism behind the effects of a stronger aspirational element of peer pressure by comparing the results from the two specific experiments in Table 6, which summarise the patterns in Figures 1-2. Overall, the effects of stronger within class aspirations are quantitatively small when we move from the mean to the 90th percentile, consistent with Figures 1-2. However, given the monotonicity of the effects summarised in the figures, the direction of the effects is the same for bigger or smaller changes in the strength of aspirations.

As can be seen by comparing the two first columns of Table 6, the higher aspirations implied by social targets that refer to members with higher consumption encourage an increase in mean hours worked,[36] which leads to increases in mean earnings, wealth and consumption for all socio-economic groups. However, the increase in mean hours is stronger for the lower socio-economic classes (relative to the highest class). This is because the lower socio-economic classes have higher within group consumption inequality, which means that the distance of the 90th percentile to the mean is higher. Hence, when the social target changes from the mean to the 90th percentile, the increase in the social target is bigger, and thus the aspirational pressure for higher hours is greater for these classes. As a result, between group inequality in hours is reduced, and more specifically the three lower mean wage groups close the gap with the top mean wage group. Moreover, the increased pressure to converge to a higher target induces more similarity in terms of hours within the socio-economic classes, so that within group inequality is reduced for all.[37] The changes in hours pass through to earnings, for which between and within group inequality follows a similar pattern.

The pattern of wealth inequality between the groups is more complex. Mean wealth increases in absolute terms for all groups. However, relative mean wealth increases for the groups with highest and lowest mean earnings, while decreasing for the middle groups. Changes in the social target from the mean (or a lower percentile) to the 90th percentile of consumption have two effects on the consumption-savings margin. On one hand, the higher aspirational component in social pressure works to increase the relative weight of future consumption, and thus of savings. This works via the prospects for upward mobility that determine the expected value of the social target (and thus the relative weight of

[36]For example, via equation (2.16), we can see that the increase in the left hand side, as a result of the more aspirational social target, implies that leisure must fall, so that the right hand side increases too.

[37]In particular, the importance of the common (social) factor, relative to the idiosyncratic (productivity), in determining choices, is increased, leading to a reduction in the spread of choices.

future consumption) in equation (2.17). The strength of this channel differs between the social classes, depending on the social transition matrix. On the other hand, a higher social target increases the relative weight to current consumption too, and the strength of this channel depends of the extent of within group consumption inequality.

The trade-off that a more aspirational peer pressure introduces in the inter-temporal margin leads to relative increases in wealth for the highest and lowest mean wage groups and relative reductions for the others. For the highest mean wage groups, this happens because consumption inequality is relatively low, implying that the effect of a higher social consumption target on the left hand side of the Euler equation, described above, is low. On the other hand, for the lowest mean wage group this happens because the prospect for upward mobility implies that the next period effect, on the right hand side of the Euler equation described above, is relatively big. In contrast, for the two middle groups, both effects are relatively smaller, hence the increase in mean savings is not as big. The effects on within group wealth inequality are small and do not exhibit a clear pattern between the groups. Finally, consumption is affected by changes in both wealth and earnings, which together lead to a reduction in between group consumption inequality following the pattern of changes in earnings inequality, and, in effect, no change in within group inequality.

7.2 Above-peer aspirations

We next consider a scenario where social pressure is related explicitly to aspirations to achieve the consumption levels of a higher class, compared with aspirations constrained by pressure to conform to peers. In particular, we consider the case where the reference point in the utility function is given by the mean or the 90th percentile of the socio-economic group with the immediately higher mean wage than the current group. For the highest mean wage group, there is no change. In this sense, the consumption level that the household aspires to achieve is determined by the behaviour of higher socio-economic groups, for the first three mean wage groups, giving rise to upward looking aspirations.

We summarise the between group inequality effects of above-peer aspirations in the columns of Table 6 under the headings "mean above" and "P90 above". There are substantial quantitative differences between the distributional implications of aspirational targets and those of peer pressure. The results are similar when comparing the change of the target from mean of the group of peers to mean of the group above peers, with the change of the target from the 90th percentile of the group of peers to the 90th percentile of the group above peers.

To understand the effects of above-peer aspirations, relative to peer pressure, the following observation is helpful. Comparing peer pressure to above-peer aspirations, there is a difference between the first three and the highest mean wage groups regarding how the change in social targets affects decision making. In particular, for the first three groups, the intra-temporal decision margin is affected directly and most significantly, since only one side of it is affected, compared with the inter-temporal margin, where both sides of the Euler equation are affected. In contrast, the inter-temporal margin is not directly affected for the highest mean wage group, which means that the effects work first via the inter-temporal margin, and then affect the intra-temporal margin via the equilibrium effects on the social target that they imply. Therefore, to understand the effects of above-peer aspirations for the first three groups, we examine first hours and earnings, where the effect is direct; whereas, for the highest mean wage group, we examine the inter-temporal margin effects since they are stronger.

Differential effects on group averages

Mean hours and earnings increase when the social targets change from those determined by peers to those determined by the group that has a higher mean wage than the peers. On the other hand, the increase in mean hours and earnings for the highest mean wage group is relatively smaller, so that between group inequality in hours and earnings decrease, in that the lower mean wage groups close the gap with the top. As can be seen in equation (2.16), there is an increase in the relative weight to consumption for the lower mean wage groups (compared with the top mean wage group), since the new, aspirational, target refers to the higher mean consumption of the higher mean wage socio-economic group in each case and hence increases directly the relative weight to consumption. In contrast, for the highest mean wage group, there is no direct change in aspirations/social target, and thus in the relative weight to consumption. However, as will be explained below, mean wealth and mean consumption have increased in this group as well, implying, via equation (2.16), an effective increase in the social target $(C_t)^\gamma$, which tends to incentivise higher consumption and work hours (and thus earnings), leading to the changes in mean hours and earnings observed. Since this is only an equilibrium effect, this increase is relatively smaller for the highest mean wage group. As a result, between group inequality in hours and earnings is reduced.

The increased earnings tend to increase wealth and consumption for all groups. However, relative wealth falls for the three lower mean wage groups, leading to increased between group wealth inequality. Looking at equation (2.17), we can see that upward looking aspirations, compared to peer pressure, increase the relative weight to current consumption directly and thus create disincentives to save. On the other hand, this effect is not present for the highest mean wage group; on the contrary, the higher social targets for the lower groups increase the expected value of future consumption targets in equation (2.17) for this group, whilst leaving the current consumption target unchanged. Thus, for the highest mean wage group, the relative weight to current consumption falls, which works to increase savings. These effects combine to lead to the reduction in relative wealth for the three lower mean wage groups and the increase in the highest mean wage group. The increased wealth in the higher mean wage group further drives the increase in consumption in this group, setting in motion a consistent increase in hours and earnings, which was described above. Between group consumption inequality falls in terms of the relative consumption of the highest to the remaining groups, driven by the positive earnings effects for the three lower mean wage groups, which are very strong.

Overall, regarding between group inequality, stronger aspirations increase between group wealth inequality, by increasing the gap between the top earners and the remaining socio-economic classes. Although driven by a different mechanism, aspirations also lead to an increase in between group wealth inequality in Genicot and Ray (2017) (see also footnote 4 in the Introduction). However, in the framework employed in Genicot and Ray (2017), income is the wealth (inherited from the parents) and consumption follows only from wealth, i.e. there is no distinction between asset and labour income. By distinguishing asset from labour income, and studying wealth inequality in conjunction with hours, earnings and consumption, we find that above-peer aspirations lower between group inequality in these three economic variables, by closing the gap between the top group and the rest. The effect of aspirations on between group inequality is thus not symmetric across economic outcomes.

Within group inequality

Above peer aspirations, compared with the situation where social pressure implies conformity with peers, further lead to a complex pattern of changes in within group inequality. For the three lower mean wage groups, there is a reduction in hours and earnings within group inequality, because the higher social targets create stronger, and common to all households within a group, incentives to increase hours and earnings. There is thus an increase in the relative importance of the social, common factor driving hours and earnings, relative to the idiosyncratic, productivity related factor, which induces higher equity within the groups. However, the increased levels of earnings in absolute terms for these groups, mean that even a lower hours Gini implies a higher earnings variance. Thus, a greater difference in the level of earnings between those with high and those with low earnings. In turn, these greater differences in earnings lead to greater differences in savings. Hence, leading to an increase in within group wealth inequality for these groups alongside the increase in mean wealth. In turn, this feeds into an increase in within group consumption inequality.

For the highest income group, the substantial increase in mean wealth works to reduce the variation in income due to earnings risk (especially since the increase in the level of (mean) earnings is small). Thus, reducing wealth and consumption inequality. The higher level (mean) of consumption implies that the lower Gini in consumption is in fact consistent with a higher spread in terms of distance from the mean. Via equation (2.16), this is consistent with a higher spread in leisure, which leads to the marginally higher Gini in hours and earnings, despite the lower Gini in consumption for this group.

Overall, a qualitative strengthening of aspirations (by comparing above-peer aspirations to peer pressure) does not imply a universal decrease in within group inequality across all economic outcomes, suggesting instead a complex pattern of changes in within cluster inequality. Even when focusing on the three lower mean wage groups, for which there are truly "higher" aspirations, we note that by disentangling hours and earnings as sources of income that are subject to idiosyncratic shocks, from asset income, we find that wealth and consumption inequality within groups increases under above-peer aspirations, implying that social dissatisfaction may accompany the positive average effects for these groups that were discussed earlier.[38] This increase in within group asset and consumption inequality is obtained despite the reduction in within group inequality in hours and earnings, and thus highlights the importance of allowing for idiosyncratic variation and the insurance value of wealth when examining wealth inequality.

8 Conclusions

This paper developed a theoretical framework to examine inequality between and within groups of households (peers) that are defined based on socio-economic class. The model incorporated both peer pressure, where consumption levels achieved by members of the socio-economic class (the group of peers) determine a social target which acts as a reference point for consumption for each member of the class; and above-peer aspirations, defined as aspirations for consumption that are determined by the social class that has the next higher mean wage (and earnings) than the group of peers. We showed existence of stationary equilibrium, when the social targets are determined jointly with the distributions of HEWC, under stochastic social class participation and idiosyncratic productivity.

[38] Note that this is without introducing explicit aspiration failure and frustration as in e.g. Genicot and Ray (2017).

We calibrated a model that belongs to this framework to British data, under "keeping-up-with-the-Joneses" peer pressure, and we found that it predicts all main patterns in the data regarding between and within group inequality. In particular, the contribution of "keeping-up-with-the-Joneses" peer pressure, calibrated based on econometric evidence on peer pressure from De Giorgi *et al.* (2019), is critical in helping the model's predictions match the empirical patterns regarding between group hours inequality and cross-group qualitative differences with respect to within group hours and earnings inequality.

More generally, we find that in stationary equilibria characterised by "keeping-up-with-the-Joneses" peer pressure, for groups with higher mean wages, within group inequality is lower in terms of hours and earnings, and higher in terms of wealth and consumption, relative to economies without peer pressure. In contrast, for lower mean wage groups, within group inequality is higher in terms of wealth and consumption and lower in terms of hours and earnings. At the same time, between group inequality is lower for hours, earnings and consumption, but higher for wealth.

Compared with peer pressure, above-peer aspirations allow the groups with the higher aspirations (lower mean wage groups) to close the gap with the top mean wage group in terms of hours, earnings and consumption, while this increases in terms of wealth. However, wealth and consumption inequality within-group is higher, despite a reduction in within-group inequality in hours and earnings.

We conclude from our analysis of the properties of stationary equilibria under different social norms regarding peer pressure and above-peer aspiration that: (i) social pressure determined with reference to a group of peers, directly (peer pressure) or indirectly (above-peer aspirations), has a differential effect on households, depending on their class; and it incorporates forces that, other things equal, tend to generate convergence within cluster and divergence between classes; (ii) the prospect of upward/downward mobility also contributes to the effects of peer pressure and above-peer aspirations, tending to lower between group divergence; and (iii) there are important insights for the study of consumption/wealth inequality under peer pressure and aspirations, in a framework where wealth inequality reflects both the dispersion of earnings and motives for wealth accumulation stemming from inter-temporal smoothing and the insurance value of wealth. In this environment, peer pressure and above-peer aspirations affect incentives to work and save differently, thus implying non-uniform changes in wealth and earnings inequality, which in turn implies that there are opposite effects on consumption inequality and social dissatisfaction.

Our findings suggest that above peer aspirations, compared with a situation where households aim to meet targets defined by the behaviour of peers, lead to increased within group dispersion in economic achievement, despite improvements in material wealth and consumption on average. This finding implies that in a more socially connected world, when aspirations become more upward looking, improvements in wealth and consumption may nevertheless be accompanied by social dissatisfaction.

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9 Appendix A

We summarise the properties of the solution to the household optimisation problem, following the approach taken in Zhu (2018). The main idea is to study the problem of the household in two steps. First, we examine the intratemporal problem in which the consumer chooses consumption and leisure to maximize the intratemporal utility given expenditure. Second, we examine the intertemporal problem which determines the optimal expenditure and saving decisions over time. To do this, we use the indirect utility function from the first step as the objective function in the second step.

The intratemporal utility function is given by $u(c, l, C(s(z)))$, or $u(c, l, z; \widetilde{C})$, making explicit the dependence on the elements in $\widetilde{C}$. Define y as the expenditure on consumption

c and leisure l, i.e. $y = c + we(z)\, l$. The intratemporal problem is then given by:

$$\begin{aligned} J(y, z; \widetilde{C}) &= \max_{c,l} u(c, l, z; \widetilde{C}), \\ s.t.\ c + we(z)\, l &= y, \\ l &\leq 1, \\ c, l &\geq 0. \end{aligned} \tag{A.1}$$

The first order condition of this problem is:

$$\frac{u_2(c, l, z; \widetilde{C})}{u_1(c, l, z; \widetilde{C})} \geq we(z)\,, \text{ with equality if } l < 1. \tag{A.2}$$

Proposition 1 in Zhu (2018) also applies for the household problem in Section 2 and implies that for given z and $\widetilde{C}$, $J(y, z; \widetilde{C})$ is bounded, strictly increasing and strictly concave in y, and continuously differentiable in y, with $J_1(y, z; \widetilde{C}) = u_1(q(y, z), l(y, z), z; \widetilde{C})$, $\forall y \in (0, +\infty)$.

The original intertemporal optimisation problem (2.3) becomes:

$$\begin{aligned} &\max_{a_{t+1}, y_t} E_0 \sum_{t=0}^{\infty} \beta^t J(y_t, z_t; \widetilde{C}), \\ s.t.\ y_t + a_{t+1} &= (1 + r)a_t + we(z_t), \\ y_t &\geq 0, \\ a_{t+1} &\geq 0. \end{aligned} \tag{A.3}$$

Letting $V(a, z; \widetilde{C})$ be the value function, the Bellman equation that describes the household's decision problem is:

$$\begin{aligned} V(a, z; \widetilde{C}) = \max_{a' \in \Gamma(a,z)} &\{J\left((1 + r)a + we(z) - a', z; \widetilde{C}\right) + \\ &+ \beta E\left[V(a', z'; \widetilde{C})|z\right]\}, \end{aligned} \tag{A.4}$$

where

$$\Gamma(a, z) = \{a' : 0 \leq a' \leq (1 + r)a + we(z)\}\,. \tag{A.5}$$

Let $g(a, z; \widetilde{C})$ and $y(a, z; \widetilde{C})$ be the optimal decision rules of the asset for next period and the total expenditure for the current period respectively. Given the properties for the indirect utility function $J(y, z; \widetilde{C})$, Proposition 2 in Zhu (2018) then shows that $V(a, z; \widetilde{C})$ is continuous, strictly increasing, strictly concave in a; $V(a, z; \widetilde{C})$ is continuously differentiable in a, and $V_1(a, z; \widetilde{C}) = (1 + r)J_1(y(a, z; \widetilde{C}), z; \widetilde{C})$, $\forall a \in [0, +\infty)$; $g(a, z; \widetilde{C})$ is continuous and weakly increasing in a; and $y(a, z; \widetilde{C})$ is strictly increasing in a.

Let $q(a, z; \widetilde{C})$ and $l(a, z; \widetilde{C})$ represent $q(y(a, z; \widetilde{C}), z; \widetilde{C})$ and $l(y(a, z; \widetilde{C}), z; \widetilde{C})$. Then (see Proposition 3 in Zhu (2018)), we have that $q(a, z; \widetilde{C})$ and $l(a, z; \widetilde{C})$ are continuous and increasing with respect to a and that $l(a, z; \widetilde{C}) = 1$ $\forall z \in Z$, when a is sufficiently large. Finally, Lemmata 4-6 and Propositions 6-7 in Zhu (2018) provide the remaining properties of the joint distribution summarised in Section 2.

10 Appendix B

`Lemma 1:` The policy function $q(a, z, \widetilde{C}) : X \times \mathcal{C} \rightarrow [0, c^{\max}]$ is continuous in $(a, \widetilde{C})$.[39]

Proof:

Let $\widetilde{C} = \left(\overline{C}_1, \overline{C}_2, .., \overline{C}_M\right)$ take values in $\mathcal{C} = [0, c^{\max}] \times [0, c^{\max}] \times ... [0, c^{\max}]$ which is a compact and convex subset of $\mathbb{R}^M$. We write $C\left(z, \widetilde{C}\right) : Z \times \mathcal{C} \rightarrow [0, c^{\max}]$ as an indicator function:

$$C = \begin{cases} \overline{C}_1, \text{ if } s(z) = 1 \\ \vdots \\ \overline{C}_M, \text{ if } s(z) = M \end{cases}, \tag{B.1}$$

where the realisation of z determines which identity function is used. Note that for given z, $C\left(z, \widetilde{C}\right) = C\left(z, \overline{C}_1, \overline{C}_2, .., \overline{C}_M\right) = \overline{C}_m : s(z) = m$, i.e. a given z defines $C(z, \cdot)$ as an identify function which is continuous, strictly increasing and (trivially) concave. Given the assumptions on the utility function, for given z, $u\left(c, l, C\left(z, \widetilde{C}\right)\right) = u(c, l, \widetilde{C})$ is jointly concave with respect to $(c, l, \widetilde{C})$.

The intratemporal problem is then given by:

$$\begin{aligned} & J(y, z, \widetilde{C}) = \max_{c,l} u(c, l, \widetilde{C}), \\ & s.t. \ c + we(z)\, l = y, \\ & l \leq 1, \\ & c, l \geq 0. \end{aligned} \tag{B.2}$$

Following Zhu (2018) we can show that for given z, $J(y, z, \widetilde{C})$ is bounded and strictly concave in y and $\widetilde{C}$ for given z. To see the latter, note that given z for any $\left(y', \widetilde{C}'\right)$, $\left(y'', \widetilde{C}''\right) \in [0, c^{\max} + w\overline{e}(\overline{z}_H)] \times [0, c^{\max}]$ and for all $\kappa \in (0, 1)$, we have:

[39] Clearly, the policy functions and the value function depend also on the prices r and w. For notational convenience we omit them since these remain fixed at the level of the socio-economic equilibrium as defined here.

$$
\begin{aligned}
& J[\kappa y' + (1-\kappa)y'', z, \kappa\widetilde{C}' + (1-\kappa)\widetilde{C}''], \\
& = u(q(\kappa y' + (1-\kappa)y'', z, \kappa\widetilde{C}' + (1-\kappa)\widetilde{C}''), l(\kappa y' + \\
& \quad +(1-\kappa)y'', z, \kappa\widetilde{C}' + (1-\kappa)\widetilde{C}''), \kappa\widetilde{C}' + (1-\kappa)\widetilde{C}''), \\
& \\
& \geq u(\kappa q(y', z, \widetilde{C}') + (1-\kappa)q(y'', z, \widetilde{C}''), \kappa l(y', z, \widetilde{C}') + \\
& \quad +(1-\kappa)l(y'', z, \widetilde{C}''), \kappa\widetilde{C}' + (1-\kappa)\widetilde{C}''), \\
& \\
& > \kappa u(q(y', z, \widetilde{C}'), l(y', z, \widetilde{C}'), \widetilde{C}') + \\
& \quad +(1-\kappa)u(q(y'', z, \widetilde{C}''), l(y'', z, \widetilde{C}''), \widetilde{C}''), \\
& \\
& = \kappa J(y', z, \widetilde{C}') + (1-\kappa)J(y'', z, \widetilde{C}''),
\end{aligned} \tag{B.3}
$$

where the fifth line follows from optimality of $J(y, z, \widetilde{C})$, while the eighth line follows from the concavity of the utility function with respect to $(c, l, \widetilde{C})$.

Consider then the maximisation problem:

$$
\begin{aligned}
V(a, z, \widetilde{C}) = \max\nolimits_{a' \in \Gamma(a,z)} \{ & J\left((1+r)a + we(z) - a', z, \widetilde{C}\right) + \\
& +\beta E\left[V(a', z', \widetilde{C})|z\right]\},
\end{aligned} \tag{B.4}
$$

where

$$
\begin{aligned}
& \Gamma(a, z) = \{a' : 0 \leq a' \leq (1+r)a + we(z)\} \text{ and} \\
& \widetilde{C} = \left(\overline{C}_1, \overline{C}_2, .., \overline{C}_M\right).
\end{aligned} \tag{B.5}
$$

Given continuity and concavity of $J(y, z, \widetilde{C})$, Theorem 9.8 in Stokey *et al.* (1989) implies that $V(a, z, \widetilde{C}) \equiv V(a, z, \overline{C}_1, \overline{C}_2, .., \overline{C}_M)$ is concave in $(a, \widetilde{C})$ and $a' = g(a, z, \widetilde{C}) : X \times \mathcal{C} \to \Gamma(a, z)$ is single-valued (a function) that is continuous in $\left(a, \widetilde{C}\right)$ for given z. Therefore, the optimal expenditure function $y = y\left(a, z, \widetilde{C}\right) = (1+r)a + we(z) - g(a, z, \widetilde{C})$ must be also continuous in $(a, \widetilde{C})$. By the Theorem of the Maximum, which implies that $q(a, z, \widetilde{C})$ and $l(a, z, \widetilde{C})$ are continuous in $(y, \widetilde{C})$ in the intratemporal problem of the household, $q(a, z, \widetilde{C})$ and $l(a, z, \widetilde{C})$ are continuous in $(a, \widetilde{C})$ as well. ■

`Lemma 2`: The integrals $\int_X \left(q\left(a, z, \widetilde{C}\right) : s = j\right) \lambda^{\widetilde{C}}(da, dz)$, $j = 1, ..., m$, are continuous in $\widetilde{C} \in \mathcal{C}$.

Proof: The proof follows similar arguments as in Acikgoz (2018, Appendix G). First, note that $\Lambda^{\widetilde{C}}\left[(a, z), A' \times \{z'\}\right]$ in (2.5) is continuous in $\widetilde{C} \in \mathcal{C}$. To see this, recall from (2.5) that $\widetilde{C}$ affects $\Lambda^{\widetilde{C}}\left[(a, z), A' \times \{z'\}\right]$ via the policy function $g(a, z, \widetilde{C})$, which is dependent on $\widetilde{C}$, while $Q(z, \{z'\})$ is independent of $\widetilde{C}$. Since, by Lemma 1

$g\left(a,z,\widetilde{C}\right)$ is continuous in $\widetilde{C}$ (and thus measurable), we can write $\Lambda^{\widetilde{C}}\left[(a,z), A'\times\{z'\}\right] = \mathbf{1}_A\left(g\left(a,z,\widetilde{C}\right)\right)Q\left(z,\{z'\}\right)$ (see Theorem 9.13 in Stokey *et al.* (1989), which requires measurability of $g\left(a,z,\widetilde{C}\right)$ to define $\Lambda^{\widetilde{C}}\left[(a,z), A'\times\{z'\}\right]$ as the transition function for the joint Markov process in $[0,\overline{a}]\times Z\times\mathcal{C}$). By Stokey *et al.* (1989, Exercise 12.7), convergence of $\left\{\Lambda^{\widetilde{C}_n}\left[(a_n,z_n), A'\times\{z'\}\right]\right\}$ to $\Lambda^{\widetilde{C}}\left[(a,z), A'\times\{z'\}\right]$ for every sequence $\left\{\left(a_n,z_n,\widetilde{C}_n\right)\right\}$ in $[0,\overline{a}]\times Z\times\mathcal{C}$ that converges to $\left(a,z,\widetilde{C}\right)$ is equivalent to the operator $\left(T_\Lambda f\right)(a,z)$ $= \int_X f\left(a',z'\right)\Lambda^{\widetilde{C}}\left[(a,z), d\left(a',z'\right)\right]$ having the Feller property, i.e. for every continuous function f, $(T_\Lambda f)$ is also continuous. By Stokey *et al.* (1989, Exercise 9.15),

$$\int_X f\left(a',z'\right)\Lambda^{\widetilde{C}}\left[(a,z), d\left(a',z'\right)\right] = \int_Z f\left(g\left(a,z,\widetilde{C}\right), z'\right)Q\left(z,dz'\right) \equiv \left(T_Q f\right)(a,z),$$

so that $\left(T_\Lambda f\right)(a,z) = \left(T_Q f\right)(a,z)$. By Stokey *et al.* (1989, Lemma 9.5), $\left(T_Q f\right)(a,z)$ has the Feller property, i.e. if f is continuous, so is $\left(T_Q f\right)(a,z)$ and thus so is $\left(T_\Lambda f\right)(a,z)$. We have thus shown that $\Lambda^{\widetilde{C}}\left[(a,z), A'\times\{z'\}\right]$ satisfies the required condition.

Second, continuity of $\Lambda^{\widetilde{C}}\left[(a,z), A'\times\{z'\}\right]$ in $\widetilde{C}$, implies, using Theorem 12.13 in Stokey *et al.* (1989), that the invariant distribution $\lambda^{\widetilde{C}}$ is continuous in $\widetilde{C}\in\mathcal{C}$. In particular, since (i) $[0,\overline{a}]\times Z$ is compact, i.e. closed and bounded, which is here as the Cartesian product of compact sets; (ii) the sequence of the transition function $\left\{\Lambda^{\widetilde{C}_n}\left[(a_n,z_n), A'\times\{z'\}\right]\right\}$ converges weakly (pointwise) to $\Lambda^{\widetilde{C}}\left[(a,z), A'\times\{z'\}\right]$ for every sequence $\left\{\left(a_n,z_n,\widetilde{C}_n\right)\right\}$ in $[0,\overline{a}]\times Z\times\mathcal{C}$ that converges to (a,z,C); and (iii) there exists a unique invariant λ for each value of $\widetilde{C}$, which has been shown in this context. Then, Theorem 12.13 in Stokey *et al.* (1989) establishes that the measure, λ is continuous in $\widetilde{C}$, i.e. as $\widetilde{C}_n\to C$, $\lambda^{\widetilde{C}_n}\to\lambda^{\widetilde{C}}$.

Finally, given that $q\left(a,z,\widetilde{C}\right)\leq c^{\max}$, the Lebesgue Dominated Convergence Theorem and Theorem 12.3 in Stokey *et al.* (1989) establish that continuity of $\lambda^{\widetilde{C}}$ and of $q\left(a,z,\widetilde{C}\right)$ in $\widetilde{C}\in\mathcal{C}$ imply continuity of $\int_X q\left(a,z,\widetilde{C}\right)\lambda^{\widetilde{C}}(da,dz)$ and thus of

$$\int_X \left(q\left(a,z,\widetilde{C}\right): s=j\right)\lambda^{\widetilde{C}}(da,dz).\blacksquare$$

11 Appendix C

Understanding Society (UnSoc) is a large longitudinal survey which follows approximately 40,000 households (at Wave 1) in the U.K.. UnSoc covers a wide range of social, economic and behavioural factors making it relevant to a wide range of researchers and policy makers. Data collection for each wave takes place over a 24-month period and the first wave occurred between January 2009 and January 2011. Note that the periods of waves overlap, but the individual respondents are interviewed around the same time each year. Thus, there is no respondent who is interviewed twice within a wave or a calendar year (see e.g. Knies (2018)).

The Wealth and Assets Survey (WAS) started in July 2006 with a first wave of interviews carried out over two years to June 2008. The WAS interviewed approximately 30,500 households including 53,300 adult household members in Wave 1. The same households were approached again for a Wave 2 interview between July 2008 and June 2010. In this wave 20,170 households responded (around 70 percent success) including 35,000 adult household members. Waves 3-5 covered the periods between July and June for the years 2010-12, 2012-14 and 2014-16 respectively. After Wave 2, due to sample attrition, the WAS started implementing boost samples in each wave to keep the number of interviewed households around 20,000 and 35,000-40,000 adult household members.

The Living Costs and Food Survey (LCF) is a repeated cross section survey which follows approximately 13,000 households in the U.K.. The Living Costs and Food Survey (LCF) began in 2008, replacing the Expenditure and Food Survey (EFS) and is conducted by the Office for National Statistics. Data collection for each wave takes place over a 12-month period, across the whole of the U.K., and is the most significant survey on household spending in the U.K.. The LCF not only covers a wide range of social, economic measures and making it relevant to a wide range of researchers, policy makers, but also provides key information for the consumer prices index and for National statistics regarding consumption expenditure.

The WAS, UnSoc and LCF data sets employed in this paper refer to the free "End User Licence" versions of the datasets. In particular, we use the following datasets:

- WAS: SN-7215.
- UnSoc: SN: 6614.
- LCF: SN-6655, SN-6945, SN-7272, SN-7472, SN-7702, SN-7992, SN-8210, SN-8351, SN-8459.

11.1 Demographics (WAS)

1. **Head of the Household**: We define the head of household as the principal owner or renter of the property, and, when there is more than one head, the eldest takes precedence. This follows the ONS definition for the Household reference person (HRP). We use of the following variables: (HhldrW), (HiHNumW), (DVAGEw) and/or (DVAge17w).

2. **Socio-Economic Class:** Eight Class NS-SEC (NSSEC8W). We approximate the socio-economic class of the household with the higher of the professional classes of the head or of the spouse.

3. **Employment Status:** We use the variables for economic activity: (ecactw) for Waves 1-3 and (DVecactw) for Waves 4-5.

11.2 Definition of income variable (WAS)

1. **Individual earnings**:[40] it is the sum of gross annual earnings from first and second job. We use of the following variables: (DVGrsPayW), (DVGrsJob2W1) for wave 1 and (dvGrsempsecjobW) for waves 2-5.

11.3 Definition of wealth (WAS)

1. **Net property wealth**: is the sum of all property values minus the value of all mortgages and amounts owed as a result of equity release. (HPROPWW).

2. **Net financial wealth**: is the sum of the values of formal and informal financial assets, plus the value of certain assets held in the names of children, plus the value of endowments purchased to repay mortgages, less the value of non-mortgage debt. The informal financial assets exclude very small amounts (less than £250) and the financial liabilities are the sum of current account overdrafts plus amounts owed on credit cards, store cards, mail order, hire purchase and loans plus amounts owed in arrears. Finally, money held in Trusts, other than Child Trust Funds, is not included. (HFINWNTW_sum).

3. **Net Worth:** is the sum of the net property wealth and net financial wealth.

[40] All monetary values are expressed in 2012 prices as measured by CPIH.

11.4 Sample selection (WAS)

We keep households when the head is an employee and, if there is a spouse who also works, when she/he is also an employee. We keep households when both the head and the spouse (if any) have non-missing earnings. However, we keep households if one of the two spouses does not work i.e. if there is a spouse with zero earnings. We drop the households when either the head or the spouse (if any) is self employed and we drop the households with no labour income (i.e. neither the head nor the spouse (if any) having positive individual earnings). We further restrict the dataset by retaining households where the head of the households is aged 25-59 and dropping observations with missing values for socio-economic class.

Table C1: Household sample selection WAS

selection step	Total
1. Whole sample of households	110,963
2. Drop households with mis-reported age variable	110,937
3. Drop households with duplicate hh grid numbers	110,910
4. Drop if head or spouse is self-employed	99,562
5. Drop if head or spouse has missing earnings	98,601
6. Drop if NS-SEC is missing	92,094
7. Keep if heads' age $\geq$25, $\leq$59	47,328
8. Keep if positive household labour income	39,731
Average net worth obs per wave	7.946

11.5 Demographics (UnSoc)

1. **Head of the Household**: We use the UnSoc definition of the head of household which follows the ONS definition for the Household reference person (HRP). The head of household is defined as the principal owner or renter of the property, and, where there is more than one head, the eldest takes precedence (w_hrpid, where the prefix w denotes wave).

2. **Socio-Economic Class:** Eight Class NS-SEC (w_jbnssec8_dv). We approximate the socio-economic class of the household with the higher of the professional classes of the head or of the spouse.

3. **Employment Status:** we use the variable reporting if the respondent is employed or self-employed at the current job (w_jbsemp).

11.6 Definition of wages, hours and earnings (UnSoc)

1. **Weekly Gross Earnings**: we use the usual gross pay per month at the current job (w_paygu_dv) and we to weekly gross earnings by multiplying by 12 and dividing by 52.
2. **Typical Weekly Hours:** number of hours normally worked per week (w_jbhrs).
3. **Total Hours**: sum of typical total weekly hours of the spouses.
4. **Total Earnings**: sum of weekly gross earnings of the spouses.
5. **Effective Wages**: it is the total household earnings over total household hours.
6. **Average typical hours worked**: sum of typical total weekly hours of the spouses.

11.7 Sample selection (UnSoc)

Our main sample consists of the General Population Sample plus the former British Household Panel Survey sample (BHPS), and we exclude the Ethnic Minority Boost Sample and the Immigrant and Ethnic Minority Boost Sample. For consistency with the WAS dataset, we also drop the households located in Northern Ireland. The inclusion of the boost samples and Northern Ireland sample, or the exclusion of the former BHPS sample does not effectively change our results either quantitatively or qualitatively. We keep households when the head is an employee and, if there is a spouse who also works, when she/he is also an employee. We keep households when both the head and the spouse (if any) have non-missing usual gross earnings per month at the current job and non-missing number of weekly hours normally worked. However, we keep households if one of the two spouses does not work i.e. if there is a spouse with zero earnings and zero hours. We also drop the households with positive incomes but reported zero hours. We further restrict the dataset by retaining households where the head of the households is aged 25-59 and dropping observations with missing values for socio-economic class. We also drop the households when either the head or the spouse (if any) is self employed. We drop the top 0.5% and the bottom 0.5% of the observations with positive household's effective wage, to avoid extreme cases (e.g. possible outliers in effective wages) which may affect results (see e.g. Blundell and Etheridge (2010) for similar treatment). This effectively means that we drop households that appear to be working for less than half the minimum wage. Finally, we keep those households that have at least two consecutive observations with positive household effective wage.

Table C2: Household sample selection UnSoc

selection step	Total
1. Whole sample	208,200
2. Drop proxy & non-full interviews	157,187
3. Original sample & BHPS sample	122,193
4. Drop if relevant information is missing from either the head or spouse	116,261
5. Drop if either the head or spouse is self employed	103,731
6. Drop if total earnings are zero	51,884
7. Drop if total hours are zero	51,764
8. Keep if heads' age $\geq$25, $\leq$59	43,056
9. Drop top and bottom 0.5% of observations per wave	42,635
10. Keep if present at least at 2 consecutive waves	35,812
Average obs per wave	4,476
Number of unique households	8,303

Table C3: State space and invariant distribution

	s	e	ξ
	Q1	0.4031	0.049218
R	Q2	0.5351	0.050822
	Q3	0.8076	0.053517
	Q1	0.5015	0.058192
I	Q2	0.6966	0.058168
	Q3	1.0840	0.064639
	Q1	0.6337	0.120355
LP	Q2	0.9430	0.13237
	Q3	1.4508	0.145599
	Q1	0.8366	0.080876
HP	Q2	1.2272	0.088263
	Q3	1.8541	0.097982

Note: $e' \times \xi = 1$.

11.8 Markov Chain (UnSoc)

Table C4: Transition Matrix

		R			*I*			*LP*			*HP*		
		Q1	Q2	Q3	Q1	Q2	Q3	Q1	Q2	Q3	Q1	Q2	Q3
	Q1	0.6721	0.1938	0.0598	0.0443	0.0066	0.0018	0.0150	0.0012	0.0006	0.0036	0.0006	0.0006
R	Q2	0.1960	0.5540	0.1670	0.0369	0.0205	0.0023	0.0170	0.0017	0.0023	0.0023	0.0000	0.0000
	Q3	0.0508	0.1674	0.6831	0.0179	0.0248	0.0179	0.0144	0.0110	0.0029	0.0069	0.0023	0.0006
	Q1	0.0269	0.0317	0.0158	0.6605	0.1653	0.0269	0.0623	0.0037	0.0016	0.0048	0.0000	0.0005
I	Q2	0.0040	0.0101	0.0196	0.1611	0.5761	0.1430	0.0539	0.0156	0.0010	0.0141	0.0015	0.0000
	Q3	0.0021	0.0031	0.0155	0.0259	0.1236	0.7408	0.0150	0.0295	0.0217	0.0124	0.0047	0.0057
	Q1	0.0077	0.0096	0.0099	0.0232	0.0170	0.0059	0.7089	0.1710	0.0279	0.0155	0.0019	0.0015
LP	Q2	0.0015	0.0009	0.0043	0.0018	0.0067	0.0141	0.1497	0.6198	0.1655	0.0217	0.0119	0.0021
	Q3	0.0015	0.0003	0.0018	0.0028	0.0018	0.0120	0.0208	0.1520	0.7497	0.0055	0.0208	0.0310
	Q1	0.0000	0.0021	0.0026	0.0026	0.0109	0.0078	0.0197	0.0322	0.0099	0.7208	0.1675	0.0239
HP	Q2	0.0015	0.0000	0.0021	0.0000	0.0026	0.0062	0.0015	0.0118	0.0436	0.1446	0.6343	0.1518
	Q3	0.0005	0.0005	0.0005	0.0005	0.0005	0.0021	0.0037	0.0021	0.0477	0.0175	0.1363	0.7881

11.9 Demographics (LCF)

1. **Head of the Household**: We use the LCF definition of the head of household which follows the ONS definition for the Household reference person (HRP). The head of household is defined as the principal owner or renter of the property, and, where there is more than one head, the eldest takes precedence. (A003)

2. **Socio-Economic Class:** NS - SEC 8 Class of household reference person (A094).We do not have information for the NS-SEC of the spouse, and consequently we cannot approximate the socio-economic class of the household with the higher of the professional classes of the head or of the spouse.

11.10 Definition of income (LCF)

1. **Weekly Gross Earnings**: is usual labour earnings plus any bonuses (p008 + p011 + b312).

2. **Total Earnings**: sum of weekly gross earnings of the spouses.

3. **Total Hours**: sum of typical total weekly hours (a220) of the spouses.

11.11 Definition of Consumption(LCF)

1. **Household Consumption**: includes non-durable goods, services and semi-durable goods. We use the classification of household consumption headings from ONS to categorise the household expenditures into non-durable goods, services and semi-durable goods. To have a user-cost measure of housing, we follow Blundell and Etheridge (2010) and include rent, mortgage interest payments and housing taxes. One drawback is that the LCF does not easily permit a calculation of imputed rents for homeowners as it does not include house prices, and this might affect the calculation of the consumption inequality, especially for the richer households. Analytically, household consumption includes the following variables - COICOP: total food and nonalcoholic beverage (P601t); COICOP: total alcoholic beverages and tobacco (P602t); COICOP: total clothing and footwear (P603t); COICOP: total housing, water, electricity (P604t); COICOP: total health expenditure (P606t); COICOP: total transport costs (P607t) minus acquisitions of cars/vans/motorcycles (b244, b2441, b245, b2451, b247, c71111c, c71112t, c71121c, c71122t, c71211c, c71212t, c71411t); COICOP: total recreation (P609t) minus acquisitions of durable recreation equipment (c92111t, c92112t, c92114t, c92115c, c92116t, c92117t, c92211t,

c92221t); COICOP: total restaurants and hotels (P611t); COICOP: total miscellaneous goods and services (P612t).

2. **Equivalence scale:** We follow Blundell and Etheridge and we use the OECD (1982) equivalence scale. This assigns a value of 1 to the first household member, of 0.7 to each additional adult and of 0.5 to each child. (OECD (1982), The OECD List of Social Indicators, Paris.)

3. **Equivalised Consumption:** is household consumption divided by the equivalence scale.

11.12 Sample selection (LCF)

We keep households when the head is an employee and, if there is a spouse who also works, when she/he is also an employee. We keep households when both the head and the spouse (if any) have non-missing earnings. However, we keep households if one of the two spouses does not work i.e. if there is a spouse with zero earnings. We drop the households when either the head or the spouse (if any) is self employed and we drop the households with no labour income (i.e. neither the head nor the spouse (if any) having positive individual earnings). We also drop the households with positive incomes but reported zero hours. We further restrict the dataset by retaining households where the head of the households is aged 25-59 and dropping observations with missing values for socio-economic class. Note that from 2015 and on, LCF changed to financial year data collection (Apr-Mar) instead of a calendar year data collection (Jan-Dec). Nevertheless, in 2015 LCF also collected the data for first quarter of this year, and hence, we can calculate the measures of interest in calendar year frequency for the whole sample.

Table C5: Household sample selection LCF

selection step	Total
1. Whole sample	49,326
2. Drop if 2018	47,856
3. Drop if head's region is N. Ireland	45,580
4. Drop if food consumption is zero	45,294
5. Drop if either the head or spouse is self employed	40,093
6. Drop if Total Earnings are zero	23,064
7. Drop if Total hours are zero	22,852
4. Drop if the socio-economic class of the head is missing	21,800
7. Keep if heads' age $\geq$25, $\leq$59	18,574
11. Drop top and bottom 0.5% of observations	18,159
Average obs per year	2,018

Table C6: Summary statistics of total earnings from LCF

NS-SEC	Mean	Gini
	total earnings*	
routine and semi-routine	0.555	0.371
intermediate low supervisory	0.821	0.328
lower management and professional	1.121	0.301
higher management and professional	1.459	0.283
total	1.000	0.358

‡Source: Living Costs and Food Survey, own calculations. Consumption refers to equivalised weekly non-durable consumption plus real housing costs.

We report the average statistics over years 2009-2017. All monetary values for all three variables in this table are expressed in 2015 prices as measured by CPIH.

12 Appendix D

The utility function is given by:

$$u(c, l, C) = \frac{c^{1-\sigma}}{1-\sigma} C^{\gamma} + \chi \frac{l^{1-\phi}}{1-\phi}, \tag{D.1}$$

where $\sigma, \phi > 1$, $\chi > 0$. Note that:

$$\frac{\partial u}{\partial C} = \gamma \frac{c^{1-\sigma}}{1-\sigma} C^{\gamma-1}, \text{ and} \tag{D.2}$$

$$\frac{\partial^2 u}{\partial c \partial C} = \gamma c^{-\sigma} C^{\gamma-1}. \tag{D.3}$$

Assuming that there is no uncertainty, the elasticity $\varepsilon_{cC} \equiv \frac{\%\Delta c}{\%\Delta C}$ can be approximated from the Euler equation as follows:

$$\begin{aligned}
&(C_t)^{\gamma} c_t^{-\sigma} = (1+r)\beta (C_{t+1})^{\gamma} c_{t+1}^{-\sigma}, \\
&\Rightarrow \gamma \ln(C_t) - \sigma \ln(c_t) = \ln((1+r)\beta) + \gamma \ln(C_{t+1}) - \sigma \ln(c_{t+1}), \\
&\Rightarrow \sigma \Delta \ln(c_{t+1}) = \ln((1+r)\beta) + \gamma \Delta \ln(C_{t+1}), \\
&\Rightarrow \Delta \ln(c_{it+1}) = \tfrac{\ln((1+r)\beta)}{\sigma} + \tfrac{\gamma}{\sigma} \Delta \ln(C_{t+1}),
\end{aligned} \tag{D.4}$$

but since $\frac{\ln((1+r)\beta)}{\sigma}$ is a very small number, we can approximate ε_{cC} as follows:

$$\begin{aligned}
&\Delta \ln(c_{it+1}) \approx \tfrac{\gamma}{\sigma} \Delta \ln(C_{t+1}), \\
&\Rightarrow \Delta \ln(c_{it+1}) / \Delta \ln(C_{t+1}) \approx \tfrac{\gamma}{\sigma}, \\
&\Rightarrow \varepsilon_{cC} \approx \tfrac{\gamma}{\sigma}.
\end{aligned} \tag{D.5}$$

The parameters (in long form) used for the base results in Tables 4 are in Table D1.

Table D1: Calibrated parameters

β	σ	ϕ	α	γ	χ	r	w	δ
0.965479	1.50	1.603704	0.30	0.75	1.035185	0.0217	1.036678	0.0983

Figure D1: Uniqueness, Benchmark Case

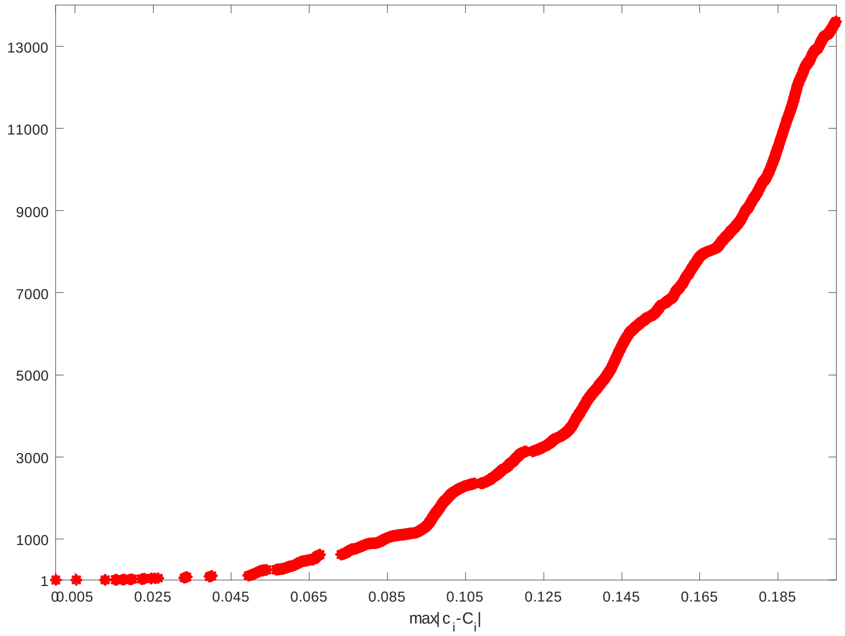


Figure D2: Uniqueness, Negative Elasticity Case

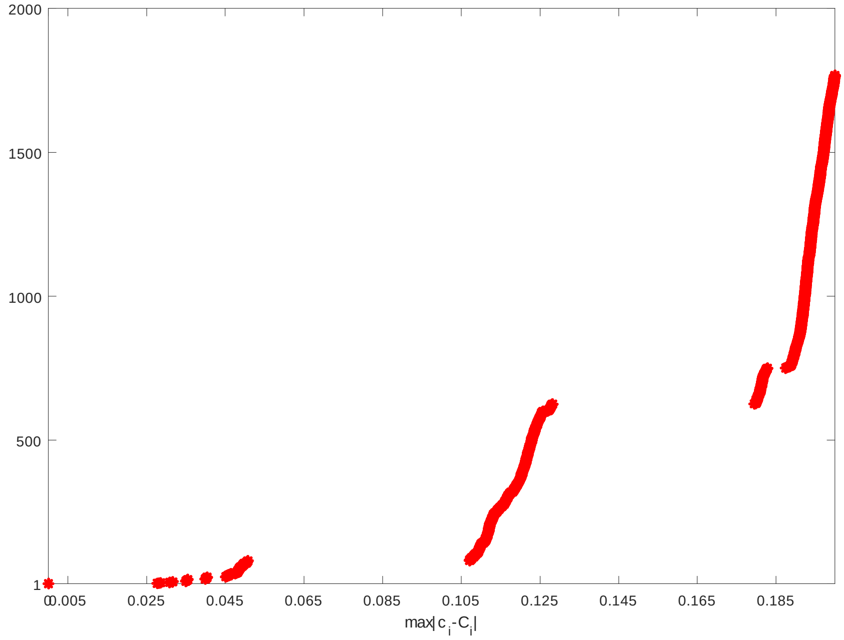


Figure D3: Uniqueness, 90th Percentile Case

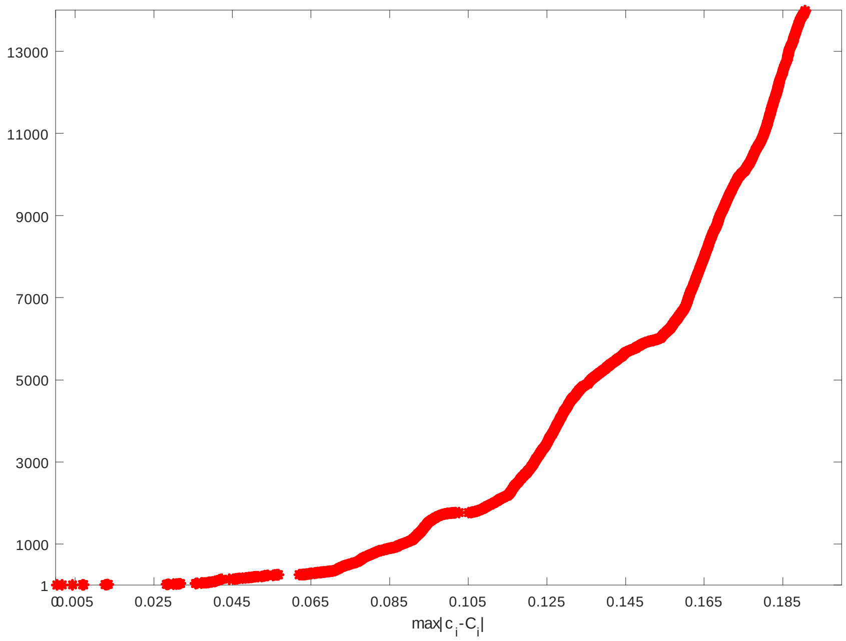


Figure D4: Uniqueness, Mean Above Case

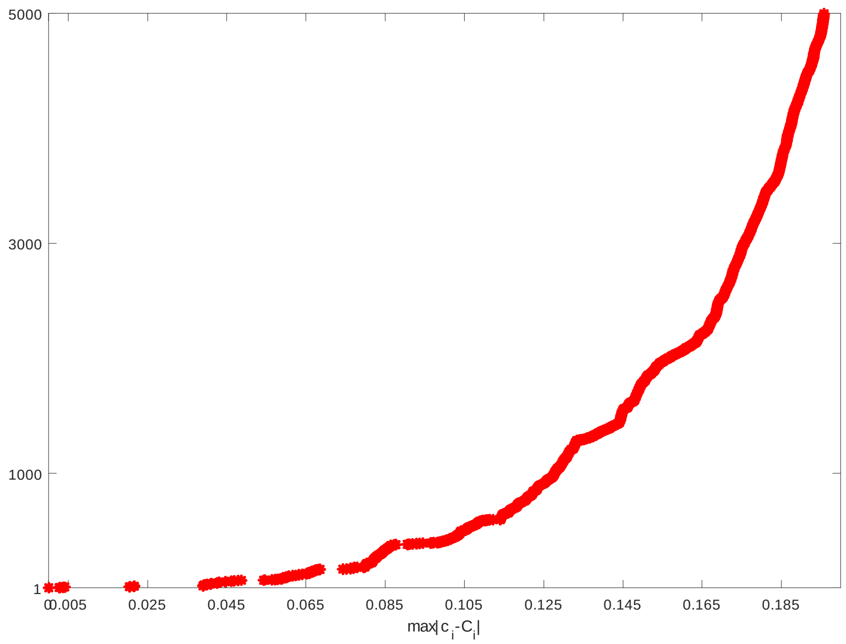


Figure D5: Uniqueness, 90th Percentile Case above

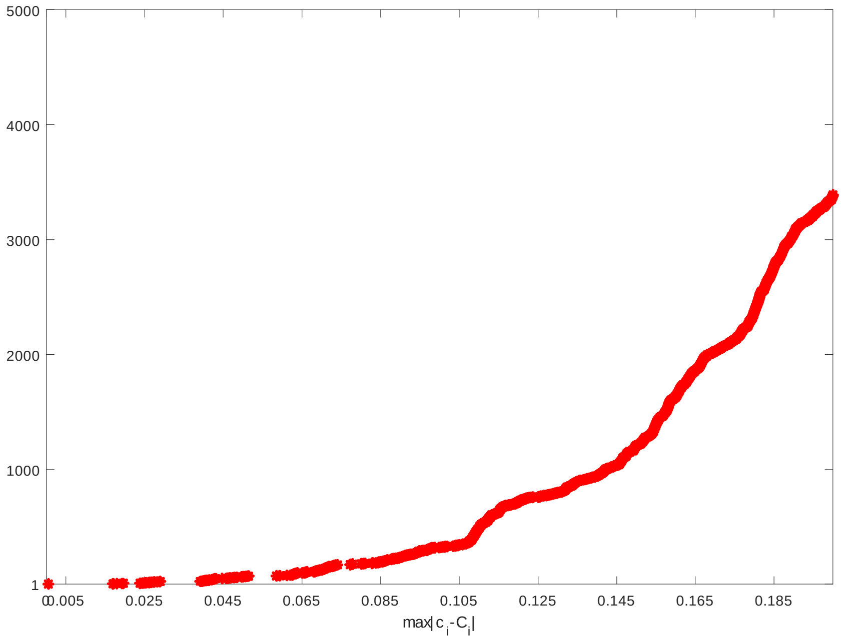


Table D2: Calibration with lower elasticity

	Data	$\varepsilon_{cC}=$ 0.333		Data	$\varepsilon_{cC}=$ 0.333
$\frac{\overline{A}_R}{\overline{A}}$	0.387	0.373	Gini A_R	0.775	0.637
$\frac{\overline{A}_I}{\overline{A}}$	0.696	0.610	Gini A_I	0.662	0.587
$\frac{\overline{A}_{LP}}{\overline{A}}$	1.101	1.037	Gini A_{LP}	0.628	0.523
$\frac{\overline{A}_{HP}}{\overline{A}}$	1.702	1.569	Gini A_{HP}	0.593	0.469
$\overline{A}$		1.256	Gini A	0.670	0.567
$\frac{\overline{C}_R}{\overline{C}}$	0.774	0.610	Gini C_R	0.248	0.112
$\frac{\overline{C}_I}{\overline{C}}$	0.901	0.789	Gini C_I	0.258	0.115
$\frac{\overline{C}_{LP}}{\overline{C}}$	1.068	1.037	Gini C_{LP}	0.260	0.105
$\frac{\overline{C}_{HP}}{\overline{C}}$	1.231	1.311	Gini C_{HP}	0.274	0.087
$\overline{C}$		0.392	Gini C	0.276	0.170
$\frac{\overline{E}_R}{\overline{E}}$	0.549	0.564	Gini E_R	0.314	0.271
$\frac{\overline{E}_I}{\overline{E}}$	0.794	0.750	Gini E_I	0.263	0.279
$\frac{\overline{E}_{LP}}{\overline{E}}$	1.100	1.031	Gini E_{LP}	0.243	0.288
$\frac{\overline{E}_{HP}}{\overline{E}}$	1.454	1.374	Gini E_{HP}	0.235	0.284
$\overline{E}$		0.364	Gini E	0.308	0.329
$\overline{H}_R$	0.296	0.325	Gini H_R	0.223	0.161
$\overline{H}_I$	0.330	0.328	Gini H_I	0.152	0.154
$\overline{H}_{LP}$	0.346	0.333	Gini H_{LP}	0.127	0.153
$\overline{H}_{HP}$	0.346	0.341	Gini H_{HP}	0.121	0.147
$\overline{H}$		0.333	Gini H	0.153	0.153

Table D3: Levels of the means and variances

	ε_{cC}= 0.5	ε_{cC}= 0	ε_{cC}= -0.5		ε_{cC}= 0.5	ε_{cC}= 0	ε_{cC}= -0.5
$\overline{A}_R$	0.520	0.412	0.367	var_{A_R}	49.26	39.68	35.44
$\overline{A}_I$	0.819	0.707	0.661	var_{A_I}	86.02	75.55	70.216
$\overline{A}_{LP}$	1.327	1.275	1.249	$\text{var}_{A_{LP}}$	163.16	159.51	153.47
$\overline{A}_{HP}$	1.926	2.017	2.035	$\text{var}_{A_{HP}}$	265.46	283.36	278.38
$\overline{A}$	1.271	1.238	1.217	var_A	182.99	190.84	188.24
$\overline{C}_R$	0.223	0.261	0.281	var_{C_R}	0.152	0.254	0.330
$\overline{C}_I$	0.299	0.322	0.332	var_{C_I}	0.296	0.399	0.458
$\overline{C}_{LP}$	0.410	0.399	0.392	$\text{var}_{C_{LP}}$	0.516	0.522	0.515
$\overline{C}_{HP}$	0.539	0.478	0.447	$\text{var}_{C_{HP}}$	0.672	0.505	0.433
$\overline{C}$	0.395	0.385	0.379	var_C	1.645	1.001	0.773
$\overline{E}_R$	0.190	0.227	0.246	var_{E_R}	0.933	0.971	0.939
$\overline{E}_I$	0.265	0.284	0.292	var_{E_I}	1.772	1.752	1.649
$\overline{E}_{LP}$	0.380	0.368	0.359	$\text{var}_{E_{LP}}$	3.592	3.436	3.146
$\overline{E}_{HP}$	0.522	0.470	0.444	$\text{var}_{E_{HP}}$	6.227	5.994	5.447
$\overline{E}$	0.368	0.358	0.352	var_E	4.873	4.139	3.616
$\overline{H}_R$	0.298	0.363	0.396	var_{H_R}	1.025	0.928	0.772
$\overline{H}_I$	0.316	0.343	0.356	var_{H_I}	0.908	0.861	0.733
$\overline{H}_{LP}$	0.337	0.326	0.320	$\text{var}_{H_{LP}}$	0.852	0.88	0.767
$\overline{H}_{HP}$	0.358	0.319	0.300	$\text{var}_{H_{HP}}$	0.735	0.876	0.802
$\overline{H}$	0.333	0.333	0.333	var_H	0.899	0.906	0.877

Notes: For the case where $\varepsilon_{cC}= 0.5$ the parameters are as in Table 3. For the $\varepsilon_{cC} = 0$ case, $\beta = 0.9625$, $\chi = 2.2134$ and $\phi = 1.5446$ and the rest are as in Table 3. For the $\varepsilon_{cC} = -0.5$ case, $\beta = 0.9611$, $\chi = 4.4693$ and $\phi = 1.6632$ and the rest are as in Table 3. All var terms are multiplied by 100.

13 Appendix E: Endogenous prices

We integrate the socio-economic equilibrium in a small open economy general equilibrium also employed in Angelopoulos *et al.* (2019), since our calibration is for the U.K.. In particular, we consider an open economy trading in global capital markets taking the real interest rate as given, where aggregate household savings, A, can differ from capital demanded by firms, K. The difference between domestic savings and domestic capital defines the net foreign asset position, $NFA \equiv K - A$, for the domestic economy. Given the country's net foreign asset position, the country makes interest payments to foreign households equal to $rNFA$, where r is the interest rate at which the country can borrow from abroad.

We assume that the country faces a world risk-free interest rate r^* plus a risk premium which is a function of the net foreign asset position (see e.g. Kraay and Ventura, (2000) for foreign-assets-elastic interest rate or Schmidt-Grohe and Uribe (2003) for debt-elastic interest rate). In particular, we assume that the risk premium is positively correlated with foreign debt relative GDP i.e. with NFA over output:

$$r = r^* + \psi \left[\exp(\frac{NFA}{Y}) - 1 \right], \tag{2.18}$$

for $0 < \psi < r^* + \delta$, which is well defined for $r > r^* - \psi$, and where ψ measures the elasticity of the country specific interest rate premium relative to the net foreign asset position.[41] Household optimisation and (2.18) jointly define a constraint set for the interest rate in general equilibrium, R^{ge}, given by $r \in R^{ge} = \left(r^* - \psi, \frac{1}{\beta} - 1 \right)$. Firms borrow assets at the rate r to maximise profits, giving rise to the usual first-order conditions in (2.15)-(2.14) and technology is given by a constant returns to scale production function satisfying usual Inada conditions $Y = F(K, L)$. Formally, we require that F displays constant returns to scale, with $F_1, F_2 > 0$, $F_{11}, F_{22} < 0$, and it satisfies the conditions $\lim_{K \to +\infty} F_1(K, 1) = 0$ and $\lim_{K \to 0} F_1(K, 1) = +\infty$. Note, then, that the condition that $\psi < r^* + \delta$, implying $r^* - \psi > -\delta$, and given that $r > r^* - \psi$, ensures that domestic firm's demand is finite in the international market, and also guarantees that $r > -1$.

We define a stationary recursive general equilibrium in the open economy, establish existence and present an algorithm to compute the equilibrium.

[41] Note that $r > r^* - \psi$ is automatically satisfied for a country with negative net foreign assets when $\psi > 0$, as is the case in the calibration for the UK.

`Stationary Recursive Open Economy Equilibrium`

A *Stationary Recursive General Equilibrium* is an aggregate stationary distribution $\lambda^{\widetilde{C}}$ on X, policy functions $a' = g\left(a, z; \widetilde{C}\right) : X \rightarrow A$, $c_t = q\left(a, z; \widetilde{C}\right) : X \rightarrow \mathbb{R}_+$ and $l = l\left(a, z; \widetilde{C}\right) : X \rightarrow [0, 1]$, value function $V\left(a, z; \widetilde{C}\right) : X \rightarrow \mathbb{R}$, positive real numbers in $\widetilde{C}$, and real numbers K, L, $w(\frac{K}{L})$ and $r(\frac{K}{L})$ such that:

1. The firm maximises its profits given prices, so that the latter satisfy (2.15) and (2.14).

2. The value function and the policy functions $g\left(a, z; \widetilde{C}\right)$, $q\left(a, z; \widetilde{C}\right)$, and $l\left(a, z; \widetilde{C}\right)$ solve the household's optimum problem in (2.4), given prices and aggregate quantities in $\widetilde{C}$.

3. Given prices and aggregate quantities, $\lambda^{\widetilde{C}}$ is a stationary distribution under the transition function $\Lambda^{\widetilde{C}}\left[(a, z), A' \times \{z'\}\right]$ implied by household's decision rules (determined by (2.5)). In particular, $\lambda^{\widetilde{C}}$ satisfies

$$\lambda^{\widetilde{C}}([0, \overline{a}] \times \{z'\}) = \int_X \Lambda^{\widetilde{C}}\left[(a, z), A' \times \{z'\}\right] \lambda^{\widetilde{C}}(da, dz)$$

   for all $(a, z) \in X$, $A' \times \{z'\} \in \mathcal{B}(X)$.

4. When $\lambda^{\widetilde{C}}$ describes the cross-section of households at each date, the reference points in $\widetilde{C} = \left\{\overline{C}_1, \overline{C}_2, .., \overline{C}_m\right\}$ are given by the relevant percentiles of the distribution of consumption across the relevant social class in (2.6) or by the means in (2.7). Additionally, the domestic labour market clears:

$$L = \int_X e(z)\left(1 - l\left(a, z, \widetilde{C}\right)\right) \lambda^{\widetilde{C}}(da, dz) \equiv L^s; \tag{2.19}$$

and the world asset market clears, satisfying

$$r = r^* + \psi\left[\exp\left(\frac{K - A^s}{F(K, L)}\right) - 1\right],$$

where

$$A^s \equiv \int_X g\left(a, z; \widetilde{C}\right) \lambda^{\widetilde{C}}(da, dz). \tag{2.20}$$

Given that we have shown the existence of a socio-economic equilibrium given r and w, what needs to be shown is that r and w exist for market clearing. Conditions for this are specified in the proposition below.

`Proposition 2`

Assume that there exists a unique socio-economic equilibrium given r and w. Then, for ϕ sufficiently large, $\phi > \phi^{\min}$ satisfying $\frac{K}{Y}(r) > \ln\left(\frac{r-r^{*}+\phi^{\min}}{\phi^{\min}}\right)$, a stationary recursive general equilibrium exists.

Proof: The properties of the production function imply that the wage rate is a monotonic function of the interest rate. Hence, w, and indeed the general equilibrium quantities, can be expressed as a function of r. In particular, the capital to labour ratio demanded by the firms, $\frac{K}{L}$, is a decreasing function of r, as are the ratios $\frac{Y}{L}$ and $\frac{K}{Y}$. Given the interest rate, firm demand for assets and production implies a demand for assets over labour, $\left(\frac{A}{L}\right)^{d}$, via the international market and in particular (2.18), given by

$$\left(\frac{A}{L}\right)^{d} = \left[\left(\frac{K}{Y}\right) - \ln\left(\frac{r-r^{*}+\phi}{\phi}\right)\right]\left(\frac{Y}{L}\right),$$

which is a continuous function in r. When $\frac{r-r^{*}+\phi}{\phi}$ is small enough such that $\frac{K}{Y} > \ln\left(\frac{r-r^{*}+\phi}{\phi}\right)$, $\frac{d\left(\frac{A}{L}\right)^{d}}{dr} < 0$. Moreover, when $r \to \frac{1}{\beta} - 1$, $\left(\frac{A}{L}\right)^{d} \to \left(\frac{A}{L}\right)^{\min} < +\infty$, whereas when $r \to r^{*} + \phi$, $\left(\frac{A}{L}\right)^{d} \to +\infty$. Given r (and $w(r)$), there is a unique socio-economic equilibrium, implying a unique aggregate supply of assets, $A^{s} = \int_{X} g\left(a, z; \widetilde{C}\right) \lambda^{\widetilde{C}}(da, dz)$ and a unique aggregate supply of labour $L^{s} = \int_{X} e(z)\left(1 - l\left(a, z, \widetilde{C}\right)\right) \lambda^{\widetilde{C}}(da, dz)$, and thus implying an asset-to-labour supply $\left(\frac{A}{L}\right)^{s} \equiv \frac{A^{s}}{L^{s}}$. As shown in Zhu (2018), this is continuous with respect to r and $r \to \frac{1}{\beta} - 1$, $\left(\frac{A}{L}\right)^{s} \to +\infty$. Moreover, when $r \to -1$, $\left(\frac{A}{L}\right)^{s} \to 0$. Therefore, an intersection point of the supply and demand curves $\left(\frac{A}{L}\right)^{s}$ and $\left(\frac{A}{L}\right)^{d}$ exists. This pins down r and $\left(\frac{A}{L}\right)^{s} = \left(\frac{A}{L}\right)^{d} \equiv \frac{A}{L}$; these determine $\frac{K}{L}$ (from (2.14)), w (from (2.15)), A^{s} (from (2.20)), L^{s} and L (from (2.19)), which, in turn, determine K and $F(K, L)$. ■

Note that the sufficient condition $\phi > \phi^{\min}$ is easy to satisfy for realistic calibrations for developed economies, where the interest rate r does not differ much from the international interest rate and the capital to output ratio is higher than two, implying values for $\phi^{\min}$ in the third decimal point. To solve the model allowing for feedback from the supply of assets to the interest rate, we implement the following algorithm (which follows from Proposition 2):

`Computational algorithm for the open economy equilibrium`

1. Guess a value for r^{n}, which, given the first-order conditions (2.15) and (2.14) implies a value for $\left(\frac{K}{L}\right)^{n}$ and w^{n}.

2. Calculate the demand for domestic assets to labour implied by the international asset markets via (2.18), given by

$$\left(\frac{A}{L}\right)^n = \left[\left(\frac{K}{Y}\right)^n - \ln\left(r^n - r^* + \phi\right) + \ln\phi\right]\left(\frac{Y}{L}\right)^n,$$

where $\left(\frac{Y}{L}\right)^n = T\left(\left(\frac{K}{L}\right)^n\right)^a$.

3. Given r^0 and w^0, we solve the socio-economic equilibrium (implementing the algorithm for the socio-economic equilibrium), check that it is unique, and calculate the aggregate values of $L^s\left(r^n\right)$ and $A^s\left(r^n\right)$ and thus of $\left(\frac{A}{L}\right)^s\left(r^n\right)$ that is supplied by the domestic economy.

4. Calculate the updated value of

$$r^{n^*} = r^* + \phi\left[\exp\left(\frac{(K/L)^n - (A/L)^s}{(Y/L)^n}\right) - 1\right].$$

5. If $\left|\left(\frac{A}{L}\right)^s - \left(\frac{A}{L}\right)^n\right| < \varepsilon$, where ε is a pre-specified tolerance level, a stationary open economy general equilibrium has been found. If not, go back to step 1, and update $r^{n+1} = (1-\varsigma)\,r^n + \varsigma r^{n^*}$ with $0 < \varsigma \leq 1$.

To calibrate the open economy general equilibrium model, we use the same parameters and procedure as above for the socio-economic equilibrium. In addition, we set the world interest rate, r^*, equal to 2.15% which is the average short-run world real interest rate over all the countries in the dataset in Carvalho *et al.* (2016). Moreover, we choose ψ so that the interest rate is 0.0217 in equilibrium, as in the socio-economic equilibrium. In particular, for given targets $\frac{K-A}{Y} = 8.1\%$, $r = 2.17\%$, and given $r^* = 2.15\%$, ψ is given by $\psi = \frac{r-r^*}{\left[\exp\left(\frac{NFA}{Y}\right)-1\right]} = 0.0024$. This implies that the predictions of the model for the base calibration of $\gamma = 0.75$ are identical to those from the socio-economic equilibrium in Section 4. We then use this equilibrium to re-compute the results in Tables 5 and 6. Results are very similar in both cases.

CHAPTER 3

CYCLICAL INCOME RISK IN GREAT BRITAIN

1 Introduction

This paper provides new evidence on the cyclical behaviour of household income risk in Great Britain (GB) from 1991-2008 and assesses the role of social insurance policy in mitigating against this source of income risk. To achieve this, we decompose stochastic idiosyncratic household income into its transitory, persistent and fixed components.[1] We measure risk by the second and the third central moment of the probability distribution of shocks to the persistent component. Following the parametric approach of Storesletten *et al.* (2004) and Busch and Ludwig (2016), we allow these two moments to depend on the aggregate state and, in particular, to vary between expansions and contractions of the aggregate economy. The advantage of this methodology is that we can identify the differences between booms and slumps by exploiting history dependent cross-sectional moments that incorporate aggregate shocks outside the panel data sample period.[2]

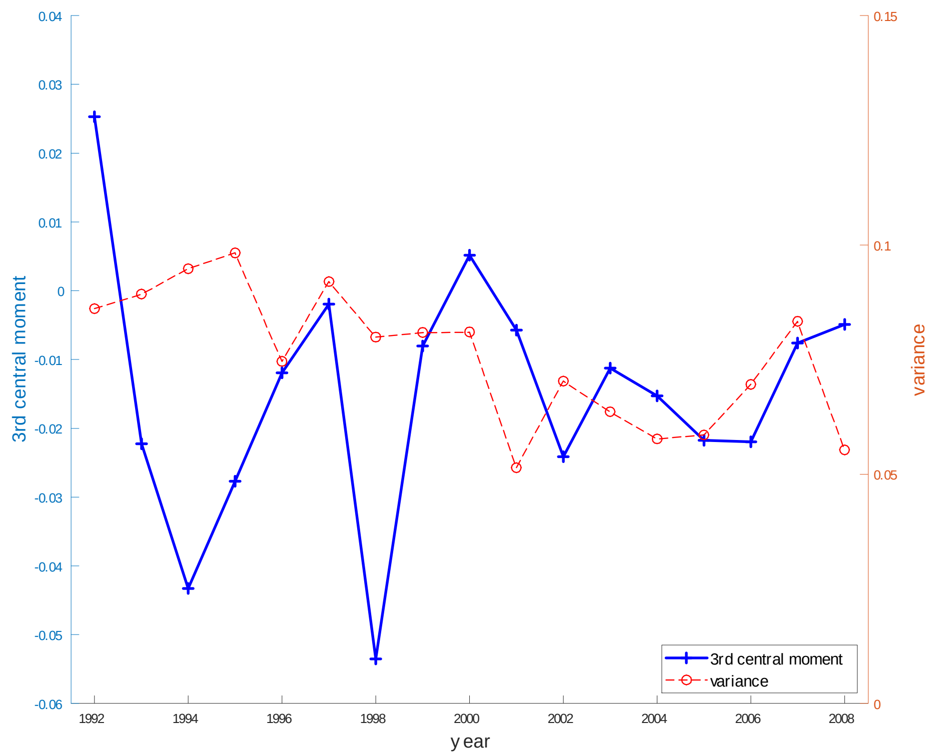
Idiosyncratic risk has implications for the household, the aggregate economy and social insurance policy. Our interest in investigating the cyclical variation in third moments for Great Britain is motivated by recent evidence for a number of countries, suggesting

[1] See, e.g. Meghir and Pistaferri (2011) for a review of the earnings dynamics models.

[2] Note that in earlier work, see Angelopoulos *et al.* (2017), we examined similar issues studied in this paper for Great Britain using parametric free methods and alternative measures of skewness based on quantile-based metrics. Whilst we draw broadly similar conclusions with respect to the time variation of earnings risk, the method employed did not allow us to exploit past information to separately identify the cyclicality of transitory and persistent shocks.

that the skewness of the distribution of the growth of earnings is counter-cyclical (see e.g. Guvenen *et al.* (2014) and Busch *et al.* (2018)). A preliminary investigation of the distribution of the growth of annual labour income across households, using British Household Panel Survey (BHPS) data, reveals that the third central moment has significantly more variability over time than the variance of the same distribution.[3]

Figure 1: Volatility and Asymmetry of Labour Income Growth



First note in Figure 1 that the overall time evolution of the variance is similar with that reported in Blundell and Etheridge (2010) for shocks to the permanent component of household earnings. The time variation of the third central moment, on the other hand, is suggestive of a more volatile distribution of income growth with respect to its asymmetry. Moreover, since it refers to changes to the overall labour income, we cannot infer from this whether persistent shocks, which have stronger effects on the household (see e.g. Meghir and Pistaferri (2011) and references therein), exhibit cyclicality. The relative importance of these shocks motivates our interest in whether cyclical variation is present in the third

[3]Details relating to the data, sample selection, and variable definitions used in Figures 1-2 and throughout the paper are reported in Appendix A. Note that we use the third central moment in Figures 1-2 to correspond to what we estimate in Tables 1-6 below. Also note that the conclusions we draw from these Figures and Tables are qualitatively the same when we instead calculate the standardised third moments (see Appendix C). In light of this, we use the term skewness when referring to both the third central moment and the standardised third moment or Pearson's moment coefficient of skewness.

moments of shocks to the permanent component of household income. Busch and Ludwig (2016) find evidence of such cyclicality in Germany.

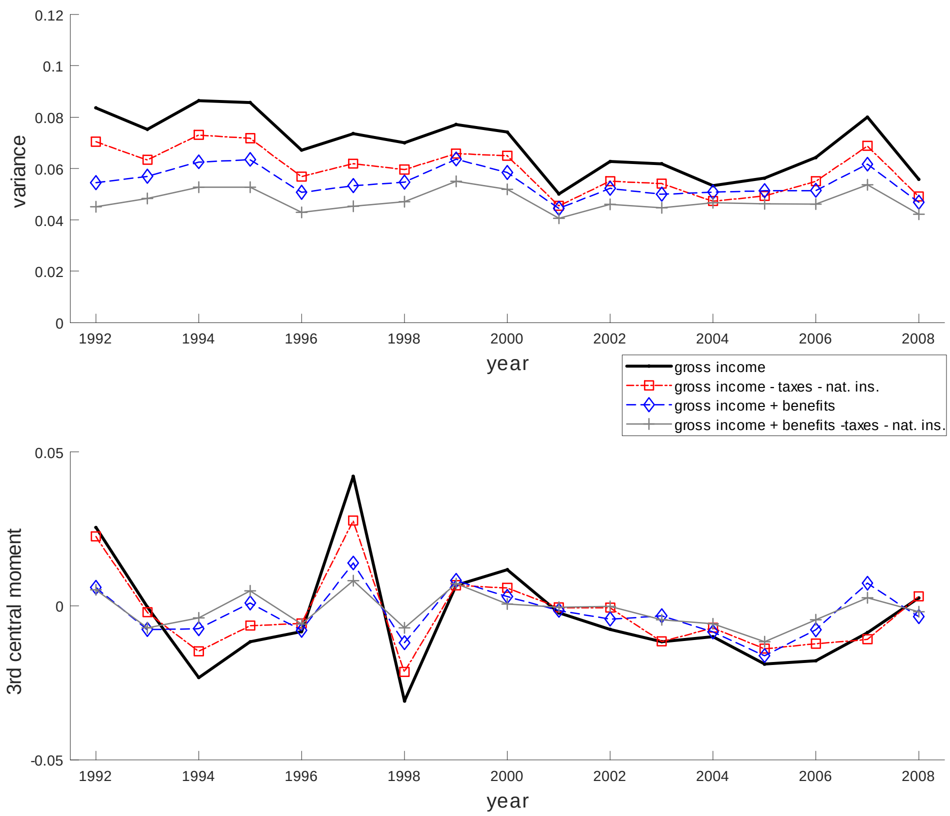
An evaluation of the extent to which different components of economic policy reduce risk exposure, and in particular the increase in vulnerability during contractions, is important in informing policy making, as it suggests which policy instrument is likely to be more effective when insurance is most required. The evidence for Germany in Busch and Ludwig (2016) and for U.S., Germany and Sweden in Busch *et al.* (2018) shows that social insurance policy does reduce the increase in risk exposure associated with changes in skewness. However, it also suggests that, at least when looking at distributions of growth in earnings (Busch *et al.* (2018)), this is mainly driven by taxes, compared with transfers. On the other hand, evidence from the U.K. (see e.g. Belfield *et al.* (2017)) suggests that benefits have a stronger effect in mitigating an increase in inequality, especially in contractions. Moreover, when we plot the variance and third moment of different measures of pre- and post-government household income growth in GB, in Figure 2, we also see that benefits seem to be dominant in smoothing the time variation of household income risk.

Figure 2 shows that policy does reduce the level of second and third moments in the first and second subplots respectively, as well as their volatility over time. Moreover, these effects are driven primarily by benefits. This evidence further motivates our interest in whether these effects maintain when evaluating the ability of policy to provide insurance by smoothing the cyclicality of shocks to permanent risk.

To assess whether cyclical variation is present in the second and third moments of shocks to the permanent component of household income and whether these effects remain post policy we use the British Household Panel Survey (BHPS). This dataset has been used extensively for income dynamics analysis in the U.K. (see, e.g. Blundell and Etheridge (2010), Bayer and Juessen (2012), Capellari and Jenkins (2014) and Etheridge (2015)), since it provides measures of annual earnings at the individual and household levels, in addition to observable characteristics. The latter allow us to partial out observable deterministic components (i.e. time, experience, education, region of residence and household size effects) to isolate idiosyncratic labour income in the data. We then employ an estimation procedure that aims to match the theoretical moments of the model of state-dependent income dynamics, with their empirical counterparts. To examine the effect of social insurance, we estimate risk for different measures of pre- and post-policy household income, using the data in Bardasi *et al.* (2012) and evaluate the effect of tax and benefits policies on the level and cyclicality of risk.

We find that the volatility and left-skewness of the shocks to the permanent component

Figure 2: Tax and Benefits Effects on Asymmetry and Volatility of Income Growth



of income are a-cyclical and counter-cyclical respectively. The latter implies a higher probability of receiving large negative income shocks in contractions. In addition, we find that while taxes and benefits help to reduce the levels of both measures of risk, it is benefits that significantly reduce the increase in risk exposure associated with skewness during bad times. More generally, benefits have stronger risk mitigation effects.

The rest of the paper is organised as follows. In the next section we review the relevant literature to provide the context motivating the approach used in our analysis. In Section 3 we discuss the methods employed to obtain the two measures of income risk and in Section 4 the data and econometric estimation procedure. The results are presented in Section 5 and Section 6 contains the conclusions.[4]

[4]Further details on the data are reported in Appendix A. Additional empirical results can also be found in Appendices C and D relating to the robustness of our findings.

2 Related literature

Idiosyncratic risk matters for individual (or household) level behaviour and outcomes. In response to labour income risk, individuals or households engage in a number of *ex ante* precautionary and *ex post* corrective economic activities, which ultimately can affect aggregate economic outcomes (see e.g. Low *et al.* (2010) and Meghir and Pistaferri (2011)). For example, precautionary behaviour related to higher labour income risk may lead to increases in savings and labour supply as well as portfolio adjustments to include more lower-risk lower-return assets. These responses are stronger under incomplete markets. In contrast, *ex post* responses to negative shocks to labour income might include the liquidation of assets and durable goods, changing jobs and family labour supply, and adjustments in consumption. The effects of idiosyncratic risk are typically stronger for persistent, relative to purely transitory, income shocks. This has motivated a decomposition of income risk into persistent (or permanent) and transitory components, emphasising the importance of the former. The absence of market opportunities for insurance against negative shocks to labour income typically motivates public insurance.[5]

The cyclical behaviour of labour income risk, and in particular the extent to which risk exposure increases during periods of contraction, is thus important for individual behaviour and outcomes. Moreover, the relationship between income risk and aggregate economic conditions is also important for understanding macroeconomic phenomena. Theoretical work has focused on the role of counter-cyclical risk in explaining asset prices and economic fluctuations (see e.g. the research reviewed in Storesletten *et al.* (2004) and Guvenen *et al.* (2014)). The main idea is that idiosyncratic labour income risk is increasing with respect to negative aggregate shocks. In this literature, some studies have concentrated on the importance of the counter-cyclical variance of earnings shocks (e.g. Constantinides and Duffie (1996) and Storesletten *et al.* (2007)) while others have highlighted the significance of the counter-cyclical left-skewness of earnings shocks (e.g. Mankiw (1986), Brav *et al.* (2002), Krebs (2007), and McKay (2017)). From a policy perspective, understanding the cyclical properties of household income risk, and the extent to which social insurance can mitigate increases in risk exposure, is important for the evaluation of alternative policies.

These considerations have motivated empirical research which examines the relationship between higher moments of the distribution of individual and household labour income shocks and changes in aggregate outcomes. Given the importance of persistent

[5] Such negative shocks can take the form of unemployment or health shocks that reduce employment, or shocks that reduce returns to work, e.g. shocks that lower productivity, technology shocks that make skills less valuable and shocks leading to employer-worker mismatch.

income shocks, a small number of studies have directly examined the cyclical properties of the shocks to the persistent component of individual or household income. In a seminal contribution, Storesletten *et al.* (2004), estimated a model for income dynamics with a state dependent variance using U.S. survey data from the Panel Study of Income Dynamics (PSID) and found that the variance of the persistent component of household labour income (earnings plus benefits) is counter-cyclical. Following the same approach and dataset, Bayer and Juessen (2012) find that household wages have countercyclical variance in the U.S., but that the variance of idiosyncratic shocks to wages is a-cyclical in GB, using BHPS data.[6] Busch and Ludwig (2016), using data for Germany for individuals and households, extend the approach in Storesletten *et al.* (2004) and estimate a model for income dynamics that allows for regime-switching variance and skewness. They find that both the variance and left-skewness of shocks to the permanent components of income are counter-cyclical.

A relatively larger set of studies has studied the cyclicality of the distribution of income shocks across individuals or households, approximating shocks with growth rates of relevant measures of income, without statistically decomposing shocks to those affecting the persistent and the transitory component of income. For example, Ziliak *et al.* (2011) used the U.S. matched Current Population Survey and found that the volatility of individual male and female earnings growth are counter-cyclical and pro-cyclical respectively, whereas Cappellari and Jenkins (2014), using BHPS data, find that the variance of individual earnings growth shows little time variation over the 1991-2008 period. In an influential contribution, Guvenen *et al.* (2014), using U.S. Social Security Administration data without imposing restrictions on the shape of the distribution of shocks to individual earnings, discover that the left-skewness is counter-cyclical and variance is a-cyclical. The counter-cyclical property of the skewness of income risk has been further documented in the literature using panel data surveys for Germany, Sweden and the U.S. in Busch *et al.* (2018). These findings have important implications for the cyclical properties of risk exposure, as they suggest that in periods of contraction the probability of receiving large negative shocks increases. Given the importance of shocks to the persistent component of income relative to the transitory part, these results further motivate research into examining the cyclical variation of such income shocks.[7]

The literature has also examined the risk mitigation performance of social insurance

[6] BHPS data have been frequently used to decompose earnings risk into its transitory and persistent components in Great Britain (see also Blundell and Etheridge (2010) and Etheridge (2015)).

[7] Guvenen *et al.* (2014) approximated permanent shocks by 5-year differences in income. However, for shorter time series, this approach becomes more difficult and a statistical decomposition as in Busch and Ludwig (2016) is required.

policies. Regarding the cyclicality in risk exposure associated with changes in skewness of the distribution of earnings growth, Busch *et al.* (2018) provide evidence from the U.S., Germany and Sweden that social insurance policy does reduce the increase in risk exposure. Their results suggest that taxes have the biggest effect in reducing the cyclicality of skewness. Their finding for the U.S. is in line with the results in Kniesner and Zilliak (2002) who show that taxes have similar effects in reducing the variance of the distribution of household earnings growth than transfers. The effects of the tax-benefit social insurance system in reducing the variance of permanent and transitory income shocks has been demonstrated in e.g. Blundell and Etheridge (2010) for GB and in Domeij and Floden (2010) for Sweden. However, evidence from e.g. Blundell and Etheridge (2010) and Belfield *et al.* (2017) demonstrates that, in the U.K. benefits have stronger effects than taxes in mitigating household income inequality.

Regarding risk mitigation associated with the cyclicality of the third moment of shocks to the persistent component of income, Busch and Ludwig (2016) show that the tax and transfer system in Germany reduces the increase in risk exposure arising from shocks to permanent income in contractions. However, they do not disaggregate the effects of taxes and transfers. The importance of shocks to the persistent component of income relative to the transitory part motivates us to further investigate which policy instrument is likely to be more effective in mitigating the increase in risk exposure in periods of contraction.

3 Idiosyncratic Income Risk

We next set out the method used to derive the measures of idiosyncratic income risk which vary depending on the aggregate state of the economy. The basic object of analysis for the various measures of income and risk is households whose head is aged between 25 to 60 in the time period 1991-2008.

3.1 Idiosyncratic income shocks

Following the literature on modeling earnings dynamics (see e.g. Meghir and Pistaferri (2011)), we assume that idiosyncratic component of income, $\mu_{i,h,t}$, for household i of age h, $h \in \{1, 2, ..., H = 36\}$, in period t, $t \in \{1, 2, ..., T = 18\}$, is driven by stochastic fixed effects, χ_i, persistent effects, $z_{i,h,t}$, and transitory shocks, $\varepsilon_{i,t}$:

$$\mu_{i,h,t} = \chi_i + z_{i,h,t} + \varepsilon_{i,t}, \tag{3.1}$$

$$z_{i,h,t} = \rho z_{i,h-1,t-1} + \eta_{i,t}, \tag{3.2}$$

where $0 < \rho < 1$ and $\eta_{i,t}$ captures innovations to the persistent effects.

Following Busch and Ludwig (2016), the distributional assumptions for the three components in (3.1) and (3.2) are:

$$\chi_i \underset{i.i.d.}{\sim} F_\chi(0, m_2^\chi, m_3^\chi), \tag{3.3}$$

$$\varepsilon_{i,t} \underset{i.i.d.}{\sim} F_\varepsilon(0, m_2^\varepsilon, m_3^\varepsilon), \tag{3.4}$$

$$\eta_{i,t} \underset{i.i.d.}{\sim} F_\eta\left(0, m_2^{\eta,f(t)}, m_3^{\eta,f(t)}\right), \tag{3.5}$$

where F_χ, F_ε, and F_η denote the density functions of χ_i, $\varepsilon_{i,t}$ and $\eta_{i,t}$ respectively. All the moments for the fixed effects, (m_2^χ, m_3^χ) and the transitory shocks, $(m_2^\varepsilon, m_3^\varepsilon)$, are constant. In contrast, the innovations to the persistent shocks, $\left(m_2^{\eta,f(t)}, m_3^{\eta,f(t)}\right)$ are assumed to be time dependent since we wish to test whether they are driven by the aggregate state of the economy.

Furthermore, following e.g. Storesletten *et al.* (2004), we assume that it is the history of persistent shocks only after the age $h = 1$ that matters for idiosyncratic income. In particular, we assume that $z_{i,0,t} = 0$, implying that prior to joining the labour market there are no persistent shocks that matter for earnings dynamics after $h = 1$ other than the fixed effects. In other words, the fixed effects capture factors that matter for income dynamics prior to joining the labour market.

Following Storesletten *et al.* (2004) and Busch and Ludwig (2016) we allow $m_2^{\eta,f(t)}$ and $m_3^{\eta,f(t)}$ to take two values each depending on the aggregate state, $f(t)$, which is either an expansion, e, or a contraction, c. For example, we define an indicator variable $I_{f(t)=e}$ to be equal to 1 if period t is an expansion and $I_{f(t)=c}$ to be equal to 0 if period t is a contraction, i.e.:

$$m_2^{\eta,f(t)} \equiv \left(I_{f(t)=e}\right) m_2^{\eta,e} + \left(1 - I_{f(t)=c}\right) m_2^{\eta,c}, \tag{3.6}$$

$$m_3^{\eta,f(t)} \equiv \left(I_{f(t)=e}\right) m_3^{\eta,e} + \left(1 - I_{f(t)=c}\right) m_3^{\eta,c}. \tag{3.7}$$

3.2 Theoretical moments

The above assumptions imply a particular structure on the covariance matrix of the stochastic processes $z_{i,h,t}$ and $\mu_{i,h,t}$. Applying expected value, variance, co-variance and co-skewness rules to the above model for $\mu_{i,h,t}$ yields the following set of theoretical moments which will be employed in our empirical analysis:[8]

$$E\left(\mu_{i,h,t}\right) = 0, \tag{3.8}$$

$$E\left(\mu_{i,h,t}^2\right) = m_2^{\chi} + m_2^{\varepsilon} + E\left(z_{i,h,t}^2\right), \tag{3.9}$$

$$E\left(\mu_{i,h,t}^3\right) = m_3^{\chi} + m_3^{\varepsilon} + E\left(z_{i,h,t}^3\right), \tag{3.10}$$

$$\begin{aligned} Cov(\mu_{i,h,t}, \mu_{i,h+\kappa,t+\kappa}) &= E(\mu_{i,h,t}\mu_{i,h+\kappa,t+\kappa}) \\ &= m_2^{\chi} + E\left(z_{i,h,t}^2 z_{i,h+\kappa,t+\kappa}\right), \end{aligned} \tag{3.11}$$

$$\begin{aligned} CoSk(\mu_{i,h,t}, \mu_{i,h+\kappa,t+\kappa}) &= E(\mu_{i,h,t}^2, \mu_{i,h+\kappa,t+\kappa}) \\ &= m_3^{\chi} + E\left(z_{i,h,t}^2 z_{i,h+\kappa,t+\kappa}\right), \end{aligned} \tag{3.12}$$

where

$$E\left(z_{i,h,t}^2\right) = \sum_{j=0}^{h-1} \rho^{2j} m_2^{\eta,(f(t-j))},$$

$$E\left(z_{i,h,t}^3\right) = \sum_{j=0}^{h-1} \rho^{3j} m_3^{\eta,(f(t-j))},$$

$$E\left(z_{i,h,t} z_{i,h+\kappa,t+\kappa}\right) = \rho^{\kappa} \sum_{j=0}^{h-1} \rho^{2j} m_2^{\eta,(f(t-j))},$$

$$E\left(z_{i,h,t}^2 z_{i,h+\kappa,t+\kappa}\right) = \rho^{\kappa} \sum_{j=0}^{h-1} \rho^{3j} m_3^{\eta,(f(t-j))}.$$

The moments of the idiosyncratic component of income, $\mu_{i,h,t}$, are thus a function of past moments of innovations to the persistent component. Therefore, the estimation of the parameters of interest requires knowledge of whether $H-1$ years prior to those in the observed sample of the households were expansionary or contractionary. In turn, this implies that more time variation in the aggregate state is exploited in the estimation, thus helping to increase the accuracy of estimating moments separately for periods of expansion and contraction (see also Storesletten *et al.* (2004), who introduced this identification approach).

[8] We use the convention here that $h = 1$ when the age is 25, and goes through to $h = 36$ when the age is 60.

3.3 Empirical moments

To obtain the idiosyncratic component of household income, $\mu_{i,h,t}$, we follow the literature on earnings dynamics and run a Mincerian-type regression to partial out non-stochastic effects from labour income. In particular, we assume that the process determining the logarithm of annual household income, $y_{i,h,t}$, is comprised of an observable deterministic part, $d_t + bx_{i,h,t}$, and the unobservable random component, $\mu_{i,h,t}$:

$$y_{i,h,t} = d_t + bx_{i,h,t} + \mu_{i,h,t}, \tag{3.13}$$

where b is a vector of parameters. In particular, the regressors in (3.13) include calendar year time effects, d_t, and a set of dummy variables, $x_{i,h,t}$, for experience (approximated by age), region of residence and household size. For the region dummies we use the U.K. Government Office Regions classification which corresponds with the highest tier of sub-national division in England, Scotland and Wales. Furthermore, following Meghir and Pistaferri (2004) we allow for the returns to the observable deterministic characteristics to be skill specific. Hence, we estimate (3.13) for two separate skill groups, i.e. households whose head has University education and those households whose head does not. Finally, since in our econometric analysis we employ household quantities for the arguments in (3.13), we define the age and regional effects in terms of the head of the household. We denote by $\widehat{\mu}_{i,h,t}$ the estimated idiosyncratic component of household income.

Using a panel dataset of household incomes for time $t \in \{1, 2, ..., T\}$, age $h \in \{1, 2, ..., H\}$ and $i \in \{1, 2, ..., N\}$ we first calculate the empirical moments of the idiosyncratic income shocks using the residuals from the Mincer regression. In particular, every year t, we group agents in the sample into 5-year adjacent age cells indexed by h, i.e. we define an individual or a household as belonging to the age group h if her true age was between $h-2$ and $h+2$. For example, the first cell, i.e. age group 25, contains all workers between 23 and 27 years old, the second cell, i.e. age group 26, contains all workers between 24 and 28 years old, while the last cell, i.e. age group 60, contains all workers between 58 and 62 years old. Our sample length and age grouping imply $T = 18$ and $H = 36$ which implies a total of $2 \times 5,187$ empirical moments. In particular, the empirical moments are given by:

$$\begin{aligned}
&\tfrac{1}{I_{h,t,\kappa}} \textstyle\sum_{i=1}^{N} \iota_{i,h,t,\kappa} \left[\left(\widehat{\mu}_{i,h,t} \right)^{\phi} \left(\widehat{\mu}_{i,h+\kappa,t+\kappa} \right)^{\psi} \right] = \\
&\quad = \tfrac{1}{I_{h,t,\kappa}} \textstyle\sum_{i=1}^{N} \iota_{i,h,t,\kappa} \Big[\left(y_{i,h,t} - \widehat{d}_t - \widehat{b} x_{i,h,t} \right)^{\phi} \times \\
&\quad \times \left(y_{i,h+\kappa,t+\kappa} - \widehat{d}_t - \widehat{b} x_{i,h+\kappa,t+\kappa} \right)^{\psi} \Big],
\end{aligned} \tag{3.14}$$

where $(\phi, \psi) \in \{(1,1), (2,1)\}$, $\kappa = 0, ..., \min[T-t, H-h]$, $I_{h,t,\kappa} = \sum_{i=1}^{N} \iota_{i,h,t,\kappa}$ and ι is an indicator function which is one when an individual i of age group h at time t is also present in time $t + \kappa$, and zero otherwise.

4 Data and estimation

In this section we provide information on the dataset and variables used for the analysis as well as a brief description of the sample selection criteria, followed by a description of the econometric methods used to estimate the model parameters.

4.1 Data

The BHPS is a comprehensive longitudinal study for GB, covering 1991 to 2008.[9] It includes information for up to 5000 households on earnings and other sources of income for individuals and households over an annual period starting in September, as well as on socio-economic characteristics of the respondents. These characteristics include gender, education, age, social (professional) class and region.[10] BHPS was replaced in 2010 by a new panel data survey, Understanding Society, which however does not include information on annual earnings, and thus cannot be used to analyse earnings risk. We also make use of the auxiliary dataset Derived Current and Annual Net Household Income Variables (DCANHIV), compiled by Bardasi *et al.* (2012), which contains derived data on household disposable income. Note that the Bardasi *et al.* (2012) dataset tracks the same individuals/households for the same time as the BHPS i.e. 1991-2008.

Household level

We start with the allocation of individuals to households from BHPS and keep households with a spouse/partner relationship (hence discarding those households comprised of a single member or those that involve cohabiting but not family-related members) as well as those where the head is between 23-62 years and reports non-zero labour income.[11] Following e.g. Blundell and Etheridge (2010) we define the head to be the older married (or in partnership) male. We also have measures on annual earnings of the household's individual members.

[9] Further details on the datasets and the definition and construction of variables and information on sample selection can be found in Appendix A.

[10] Data on Northern Ireland are available from 1997 via the additional BHPS sub-sample European Community Household Panel Survey. However, we focus on Great Britain to not restrict further the time dimension, which is important for our analysis.

[11] Some households defined as such have additional members, e.g. other family members living in the same household.

Using the DCANHIV dataset we have consistent series of household labour income, gross income, gross income less taxes and national insurance contributions, gross income plus benefits, and gross income plus benefits less taxes and national insurance contributions. Labour income is the sum of annual earnings of the household members. Gross income is equal to household's labour income plus annual investment income, occupational pension income and annual private transfers income. Taxes are the annual household income taxes after credits, while benefits are the annual social benefits income, which totals all receipts from state benefits from all household's members (including national insurance retirement pensions).

To ensure strong attachment to the labour marker, we follow e.g. Guvenen *et al.* (2014), Busch *et al.* (2016) and include in any year households in which their head reports annual earnings greater than half of the product between the minimum legal hourly wage times 520 hours, implying at least a few months of work during the year. For each year, we order the households according to their labour income and we discard the observations who are in the top 1%.

Aggregate Shocks

As a proxy for the aggregate state of the economy, we use the OECD Composite Leading Indicators (CLI) for the United Kingdom "from the peak through the trough" which can be found in Fred St. Louis website.[12] The OECD identifies months of turning points without designating a date within the month that the turning points occurred. The dummy variable adopts an arbitrary convention that the turning point occurred at a specific date within the month. To be consistent with the BHPS data, we have chosen the annual frequency and as an aggregation period the end of period (from September to September). We aggregate on the monthly indices and set as contractions the years with 6 or more months of contraction.[13] The OECD based aggregate cycle indicator can be extended into the past until 1956 which corresponds with the year (i.e. 1991) that the oldest individuals in the sample entered the labour market at age 25.

4.2 Estimation

The moment conditions employed in the GMM estimation are:

[12] The components of the CLI are time series which exhibit leading relationships with the reference series (GDP) at turning points. Country CLIs are compiled by combining de-trended smoothed and normalized components. The component series for each country are selected based on various criteria such as economic significance; cyclical behaviour; data quality; timeliness and availability.

[13] Note that, alternatively, following Busch and Ludwig's (2016) method to characterise years as either contractionary or expansionary periods gives us exactly the same classification.

$$E\left[\widehat{\mu}_{i,h,t}^{2}-\mu_{i,h,t}^{2}\left(\theta\right)\right]=0, \tag{3.15}$$

$$E\left[\widehat{\mu}_{i,h,t}^{3}-\mu_{i,h,t}^{3}\left(\theta\right)\right]=0, \tag{3.16}$$

$$E\left[\widehat{\mu}_{i,h,t}\widehat{\mu}_{i,h+\kappa,t+\kappa}-\mu_{i,h,t}\left(\theta\right)\mu_{i,h+\kappa,t+\kappa}\left(\theta\right)\right]=0, \tag{3.17}$$

$$E\left[\widehat{\mu}_{i,h,t}^{2}\widehat{\mu}_{i,h+\kappa,t+\kappa}-\mu_{i,h,t}^{2}\left(\theta\right)\mu_{i,h+\kappa,t+\kappa}\left(\theta\right)\right]=0, \tag{3.18}$$

where θ is the vector of parameters to be estimated:

$$\theta=\left\{\rho,m_2^{\chi},m_3^{\chi},m_2^{\varepsilon},m_3^{\varepsilon},m_2^{\eta,c},m_2^{\eta,e},m_3^{\eta,c},m_3^{\eta,e}\right\}.$$

The empirical moments in conjunction with the theoretical ones given by (3.8)-(3.12) allow us to identify: (i) the persistence parameter ρ; (ii) the second and third moments of distribution of the fixed effects, m_2^{χ} and m_3^{χ}; (iii) the second and third moments of distribution of the transitory shocks, m_2^{ε} and m_3^{ε}; and (iv) the time dependent higher moments for innovations to the persistent component i.e. $m_2^{\eta,f(t)}$, $m_3^{\eta,f(t)}$. We show analytically in Appendix B that the parameters in θ can be identified if we have at least four time periods and four age groups.[14] In the data, we have 18 periods and 36 age groups, which implies that the system (3.15)-(3.18) is over-identified.

Let $\mathbf{m}$ be the vector with all the available empirical moments constructed as above and $\mathbf{G}(\theta)$ the vector of the respective theoretical moments. The goal is to estimate a model for **m:**

$$\mathbf{m}=\mathbf{G}(\theta)+\boldsymbol{\Upsilon}, \tag{3.19}$$

where $\boldsymbol{\Upsilon}$ captures sampling variability. For the estimation, we minimize the distance between the empirical and the theoretical moments. Formally, we numerically minimize the following objective function:

$$Q(\theta)=\min_{\theta}\left(\mathbf{m}-\mathbf{G}(\theta)\right)'\mathcal{W}\left(\mathbf{m}-\mathbf{G}(\theta)\right), \tag{3.20}$$

where $\mathcal{W}$ is a weighting matrix. Following Altonji and Segal (1996), the typical choice of $\mathcal{W}$ in the literature is the identity matrix. However, notice that each moment is calculated by a different number of observations. Moreover, since we are calculating higher moments,

[14] In particular, in Appendix B, we illustrate how to identify the persistence parameter, ρ, using the minimum number of consecutive time periods and age groups, i.e. 4 for each. Using equation, (3.14), this example implies 60 empirical moments. The Appendix also illustrates, conditional on a given value of ρ, how to identify: m_2^{χ}, m_3^{χ}, m_2^{ε}, m_3^{ε}, $m_2^{\eta,f(t)}$ and $m_3^{\eta,f(t)}$, again using the minimum number of consecutive time periods and age groups, i.e. 3 for each. Using equation, (3.14), this example implies 28 empirical moments.

it is well known that bigger samples give more accurate results. Hence, we weight each moment equation by the number of observations used to calculate its empirical part since the panel is unbalanced.[15]

To compute the standard errors, we follow MaCurdy (2007), and use the block bootstrap procedure for 1000 replications. The resulting confidence intervals account for serial correlation of arbitrary form, heteroskedasticity as well as for the fact that we use pre-estimated residuals.[16] Formally, the bootstrap p-values for an estimator θ are calculated as:

$$2 * \left[1 - \Phi\left(\frac{\widehat{\theta}}{\sigma_{\widehat{\theta}}}\right)\right], \tag{3.21}$$

where $\widehat{\theta}$ is the GMM estimator and $\sigma_{\widehat{\theta}}$ its bootstrap standard errors. Φ denotes the Normal cumulative distribution function.[17]

5 Results

The estimated parameters $\theta = [\rho, m_2^{\chi}, m_3^{\chi}, m_2^{\varepsilon}, m_3^{\varepsilon}, m_2^{\eta,c}, m_2^{\eta,e}, m_3^{\eta,c}, m_3^{\eta,e}]$ are reported in Tables 1 and 2. Table 1 concentrates on the main parameters of interest, i.e. the second and third moments of the probability distribution of shocks to the persistent component of idiosyncratic income during expansions and contractions. Whereas, Table 2 reports the remaining parameter estimates relating to the transitory shocks and stochastic fixed effects. Tables 3-6 then report the results of statistical tests relating to the effect of tax and benefit policy on the levels of persistent and transitory income risk as well as on the cyclicality of persistent income risk.

5.1 Cyclical risk

Columns 1-2 and 4-5 in Table 1 present estimates of $[m_2^{\eta,c}, m_2^{\eta,e}, m_3^{\eta,c}, m_3^{\eta,e}]$ for households across five different measures of labour income. Columns 3 and 6 in Table 1 also report the difference between each moment in expansions and in contractions to test whether income risk increases in bad times.

[15]For similar treatment see Heathcote *et al.* (2010) and Domeij and Floden (2010).

[16]See also Hall and Horowitz (1996) and Horowitz (2003).

[17]Note that the histograms of the estimated parameters are approximately normally distributed. Further note that our results are robust to the use of either percentile or bias corrected confidence intervals.

Table 1: Cyclical household income risk

	$m_2^{\eta,e}$	$m_2^{\eta,c}$	$m_2^{\eta,e} - m_2^{\eta,c}$	$m_3^{\eta,e}$	$m_3^{\eta,c}$	$m_3^{\eta,e} - m_3^{\eta,c}$
			labour income			
est	0.0370***	0.0389***	-0.0019	-0.0105	-0.0336***	0.0231*
s.e.	(0.0110)	(0.0128)	(0.0073)	(0.0076)	(0.0124)	(0.0154)
			gross income			
est	0.0346***	0.0402***	-0.0056	-0.0049	-0.0373***	0.0324***
s.e.	(0.0083)	(0.0095)	(0.0072)	(0.0071)	(0.0098)	(0.0126)
			gross income −taxes −NI			
est	0.0286***	0.0329***	-0.0043	-0.0031	-0.0273***	0.0242***
s.e.	(0.0065)	(0.0079)	(0.0061)	(0.0051)	(0.0076)	(0.0099)
			gross income +benefits			
est	0.0240***	0.0267***	-0.0027	-0.0005	-0.0076**	0.0072*
s.e.	(0.0046)	(0.0068)	(0.0050)	(0.0031)	(0.0032)	(0.0050)
			gross income +benefits −taxes −NI			
est	0.0185***	0.0214***	-0.0029	0.0001	-0.0049**	0.0051*
s.e.	(0.0038)	(0.0060)	(0.0042)	(0.0022)	(0.0023)	(0.0036)

The Bootstrap standard errors are included in parentheses (1000 sims) and the Bootstrap p-values are denoted as $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$. Note that the p-values for all columns are for a two-tailed test, except the difference tests which are for a one-tailed test. The notation adopted here for the statistical tests apply throughout the paper. NI refers to national insurance contributions.

5.2 Second moments

Columns 1 and 2 in Table 1 reveal statistically significant second moments, m_2^{η}, across all five income measures in both expansions and contractions. Counter-cyclical volatility, implies that income risk is higher in contractions than in expansions, i.e. $m_2^{\eta,e} < m_2^{\eta,c}$ or that $m_2^{\eta,e} - m_2^{\eta,c} < 0$. The signs associated with the difference, $m_2^{\eta,e} - m_2^{\eta,c}$, in column 3 of Table 1 qualitatively suggest counter-cyclical volatility for all measures. However, a one-sided test of the null hypothesis that $H_0 : m_2^{\eta,e} - m_2^{\eta,c} \geq 0$ against the alternative hypothesis that $H_A : m_2^{\eta,e} - m_2^{\eta,c} < 0$ implies an a-cyclical volatility for all measures since the null cannot be rejected for any case considered.

These results broadly cohere with the finding of Bayer and Juessen (2012) who also find a-cyclical volatility of wage risk for the U.K.. However, it should be noted that our results are not directly comparable to Bayer and Juessen (2012) given that we employ different measures of household compensation. In particular, we use labour income which includes both wages and employment for households, whereas Bayer and Juessen (2012) use the average hourly wage of the head and spouse. Nonetheless, evidence from both papers points in the same direction. These findings are also generally consistent with evidence for GB reported in Blundell and Etheridge (2010) who decompose household earnings shocks into permanent and transitory components. The estimated variances of both earnings shocks components over 1991-2003 in their Figure 6.1 do not show evident co-movement with the aggregate conditions.

5.3 Third moments

Column 4 in Table 1 shows statistically insignificant third moments, m_3^{η}, across all five income measures in expansions. Whereas, column 5 in Table 1 shows statistically significant (negatively signed) third moments, m_3^{η}, for all five income measures in contractions. Several observations regarding the third moment results are worth pointing out. First, the time variation in m_3^{η} between expansions and contractions implies that the idiosyncratic income shocks are clearly drawn from a non-normal distribution. Second, two distributions of income shocks with the same variance can imply very different amounts of risk if they differ in m_3^{η}. For example, the asymmetry in the distribution of idiosyncratic income shocks implied by a non-zero third moment suggests that, depending on its sign, one of the two tails of the distribution is longer.

A negative third moment signifies that the distribution is skewed to the left and the left tail is longer than the right tail. In our case, since the left tail represents the bad shocks to income, a longer left tail in contractions than in expansions implies that there is a higher probability of a household receiving a large negative income shock in bad times. Thus, income risk which is higher in contractions than in expansions, i.e. $m_3^{\eta,e} > m_3^{\eta,c}$ or that $m_3^{\eta,e} - m_3^{\eta,c} > 0$ can be characterised as pro-cyclical asymmetry. Note that Guvenen *et al.* (2014) refers to this relationship as counter-cyclical left-skewness since left-skewness is simply defined as the negative of skewness. Nonetheless, the interpretation is the same, in a contraction the third moment is smaller (i.e. more negative) than in an expansion.

A one-sided test of the null hypothesis that $H_0 : m_3^{\eta,e} - m_3^{\eta,c} \leq 0$ against the alternative hypothesis that $H_A : m_3^{\eta,e} - m_3^{\eta,c} > 0$ suggests a significant pro-cyclical asymmetry or counter-cyclical left-skewness across all five income measures since we can reject the null in all cases considered. This constitutes new evidence for GB and coheres with international evidence, as discussed in Section 2. Notably, Busch and Ludwig (2016) is the only other study that we are aware of that explicitly decomposes shocks to earnings to investigate statistically the counter-cyclicality of third moments of shocks to the permanent component separately from possible fixed effects and transitory shocks. Although we allow for persistent, as opposed to permanent shocks (see Table 2 below for evidence in support of this), our findings for GB are similar to those in Busch and Ludwig (2016) for Germany.

Table 2: Persistence and remaining moments

	ρ	m_2^{ε}	m_3^{ε}	m_2^{χ}	m_3^{χ}
			labour income		
est	0.8530***	0.0320**	-0.0441***	0.0556***	-0.0156
s.e.	(0.0580)	(0.0132)	(0.0066)	(0.0136)	(0.0122)
			gross income		
est	0.8358***	0.0268***	-0.0339***	0.0654***	-0.0152*
s.e.	(0.0493)	(0.0081)	(0.0049)	(0.0113)	(0.0090)
			gross income −taxes −NI		
est	0.8473***	0.0239***	-0.0233***	0.0521***	-0.0099
s.e.	(0.0450)	(0.0068)	(0.0037)	(0.0096)	(0.0071)
			gross income + benefits		
est	0.8572***	0.0206***	-0.0116***	0.0487***	-0.0059
s.e.	(0.0394)	(0.0059)	(0.0021)	(0.0083)	(0.0041)
			gross income +benefits −taxes −NI		
est	0.8697***	0.0188***	-0.0064***	0.0361***	-0.0031
s.e.	(0.0397)	(0.0056)	(0.0017)	(0.0067)	(0.0033)

Note that the p-values for all columns are for a two-tailed test.

5.4 Persistence and remaining moments

Table 2 above presents the results relating to the AR(1) parameter, ρ, for the persistent component of idiosyncratic income given in equation (3.2) as well as the second and third moments of the probability distribution of shocks to the transitory and fixed effects parts of idiosyncratic income in equations (3.3) and (3.4) respectively. These result suggest that the vast preponderance of the 30 parameter estimates are significantly different from zero at the 1% level of significance. Only the third moment of shocks to stochastic fixed effects appears to play little role in the estimation.

The estimates reveal that the distribution of transitory shocks is also skewed to the left and the left tail is longer than the right tail. Finally, the estimate for the persistence parameter is significantly lower than 1, implying that shocks to the persistent component have high persistence but are not permanent.

5.5 Effects of policy on the levels of risk

Using row-wise comparisons of the moment estimates reported in Table 1, starting with gross income, we next test whether policy significantly lowers the levels of risk that households face. To this end, Table 3 reports the results of a one-sided test of the null hypothesis that H_0 : $[m_2^{\eta,f(t)}]^g \leq [m_2^{\eta,f(t)}]^{pp}$ against the alternative hypothesis that $H_A : [m_2^{\eta,f(t)}]^g > [m_2^{\eta,f(t)}]^{pp}$, where $f(t) = e$ for expansions and $f(t) = c$ for contractions; g refers to gross income; and pp refers to post-policy income. Table 4 repeats this test for the third moments.

Table 3: Policy effects on income risk (volatility)

	expansions	contractions
[1]	$[m_2^{\eta,e}]^g - [m_2^{\eta,e}]^{g-t-ni}$	$[m_2^{\eta,c}]^g - [m_2^{\eta,c}]^{g-t-ni}$
est	0.0060	0.0073
s.e.	(0.0105)	(0.0124)
[2]	$[m_2^{\eta,e}]^g - [m_2^{\eta,e}]^{g+b}$	$[m_2^{\eta,c}]^g - [m_2^{\eta,c}]^{g+b}$
est	0.0106	0.0135
s.e.	(0.0095)	(0.0117)
[3]	$[m_2^{\eta,e}]^g - [m_2^{\eta,e}]^{g+b-t-ni}$	$[m_2^{\eta,c}]^g - [m_2^{\eta,c}]^{g+b-t-ni}$
est	0.0161**	0.0189**
s.e.	(0.0091)	(0.0113)

The superscripts g, b, t and ni refer to gross income, benefits, taxes, and national insurance respectively in Tables 3-6.

The positive differences between gross income and the various measures of income net of policy reported in Table 3 indicate, qualitatively, that tax and benefit policy is working in the right direction and reduces the spread of the distribution of shocks to the persistent component of idiosyncratic income. However, when considering the effects of public insurance, only gross income plus benefits net of taxes and national insurance is statistically significant in both expansions and contractions (see row [3]). In other words, it is the combination of taxes and benefits that reduces the variance of risk, in either aggregate state. The results regarding the overall effect of social insurance policy in reducing the level of the variance of shocks to income are consistent with the findings in Blundell and Etheridge (2010), who also find big reductions in the variance of shocks to the permanent component of household income when comparing household earnings with disposable income (see their figure 6.1).

Turning to Table 4 we can see that public policy has not statistically significantly reduced the level of income risk reflected by left-skewness during expansions. This is not surprising since we learned from the fourth column in Table 1 that during expansions the third central moments are not significantly different from zero. However, during contractions, public benefits on their own and public benefits net of taxes and national insurance have significantly reduced this level of risk (see rows [2] and [3] respectively in Table 4).

Table 4: Policy effects on income risk (asymmetry)

	expansions	contractions
[1]	$[m_3^{\eta,e}]^{g}-[m_3^{\eta,e}]^{g-t-ni}$	$[m_3^{\eta,c}]^{g}-[m_3^{\eta,c}]^{g-t-ni}$
est	-0.0018	-0.0100
s.e.	(0.0087)	(0.0125)
[2]	$[m_3^{\eta,e}]^{g}-[m_3^{\eta,e}]^{g+b}$	$[m_3^{\eta,c}]^{g}-[m_3^{\eta,c}]^{g+b}$
est	-0.0044	-0.0296***
s.e.	(0.0078)	(0.0102)
[3]	$[m_3^{\eta,e}]^{g}-[m_3^{\eta,e}]^{g+b-t-ni}$	$[m_3^{\eta,c}]^{g}-[m_3^{\eta,c}]^{g+b-t-ni}$
est	-0.0050	-0.0323***
s.e.	(0.0076)	(0.0101)

Finally, using a row-wise comparisons of the moment estimates reported in Table 2, starting with gross income, we next test whether policy significantly lowers the levels of transitory risk that households face. The results in Table 5 suggest that while policy qualitatively reduces the level of risk for the volatility measure of transitory income risk, this change is not statistically significant. In contrast, taxes and national insurance on their own, benefits on their own and benefits net of taxes and national insurance all contribute to significantly to lowering the asymmetry measure of transitory income risk.

Table 5: Policy effects on transitory income risk

	volatility	asymmetry
[1]	$[m_2^{\varepsilon}]^{g} - [m_2^{\varepsilon}]^{g-t-ni}$	$[m_3^{\varepsilon}]^{g} - [m_3^{\varepsilon}]^{g-t-ni}$
est	0.0029	-0.0105**
s.e.	(0.0107)	(0.0061)
[2]	$[m_2^{\varepsilon}]^{g} - [m_2^{\varepsilon}]^{g+b}$	$[m_3^{\varepsilon}]^{g} - [m_3^{\varepsilon}]^{g+b}$
est	0.0062	-0.0222***
s.e.	(0.0103)	(0.0053)
[3]	$[m_2^{\varepsilon}]^{g} - [m_2^{\varepsilon}]^{g+b-t-ni}$	$[m_3^{\varepsilon}]^{g} - [m_3^{\varepsilon}]^{g+b-t-ni}$
est	0.0080	-0.0274***
s.e.	(0.0099)	(0.0051)

Overall, our findings regarding the beneficial impact of social insurance policy generally are consistent with existing evidence for GB in Blundell and Etheridge (2010), for Sweden in Domeij and Floden (2010), for Germany in Busch and Ludwig (2016), for the U.S. in Kniesner and Ziliak (2002), and for the U.S., Germany and Sweden in Busch *et al.* (2018), among others. Importantly, we find that in all cases of second and third central moments considered, for both persistent and transitory shocks, the effects of benefits in reducing risk exposure are bigger than taxes and national insurance. This is consistent with evidence from different analysis in the U.K. (see e.g. figure 7a Belfield *et al.* (2017) and figures 4.5 and 4.6 in Blundell and Etheridge (2010)), which suggests that benefits have stronger effects in reducing household income inequality than taxes. In contrast, Kniesner and Ziliak (2002) find that, in the U.S., the effects of taxes and transfers are quantitatively similar when studying the reduction in the variance of household earnings growth.

5.6 Effect of policy on the cyclicality of risk

In Table 6 we compare the cyclical behaviour of income risk (based on the third moment) pre- and post-policy to assess the effectiveness of social insurance to mitigate this risk.[18]

[18] Note that since the cyclical income risk measures, based on the second moments, were not significantly different from zero in Table 1, we do not test for post policy effects in this case.

To this end, we make row-wise comparisons of the moment estimates in the last column reported in Table 1 in columns 1 and 2 in Table 6, starting with gross income. In column [3] of this Table we formally test whether the cyclical asymmetry of gross income risk is greater than the cyclical asymmetry of income risk post-policy. In other words, has counter-cyclical left-skewness been reduced by social policy? To this end, we employ a one-sided test of the null hypothesis that H_0 : $[m_3^{\eta,e} - m_3^{\eta,c}]^g \leq [m_3^{\eta,e} - m_3^{\eta,c}]^{pp}$ against the alternative hypothesis that H_A : $[m_3^{\eta,e} - m_3^{\eta,c}]^g > [m_3^{\eta,e} - m_3^{\eta,c}]^{pp}$.

Table 6: Policy effects on the cyclical asymmetry of income risk

	[1]	[2]	[3]
	$[m_3^{\eta,e} - m_3^{\eta,c}]^g$	$[m_3^{\eta,e} - m_3^{\eta,c}]^{g-t-ni}$	[1]-[2]
est	0.0324***	0.0242***	0.0082
s.e.	(0.0126)	(0.0099)	(0.0159)
	$[m_3^{\eta,e} - m_3^{\eta,c}]^g$	$[m_3^{\eta,e} - m_3^{\eta,c}]^{g+b}$	[1]-[2]
est	0.0324***	0.0072*	0.0252**
s.e.	(0.0126)	(0.0050)	(0.0132)
	$[m_3^{\eta,e} - m_3^{\eta,c}]^g$	$[m_3^{\eta,e} - m_3^{\eta,c}]^{g+b-t-ni}$	[1]-[2]
est	0.0324***	0.0051*	0.0273**
s.e.	(0.0126)	(0.0036)	(0.0132)

The results reported in column 3 in Table 6 first suggest that taxes and national insurance contributions do not significantly reduce the pro-cyclical asymmetry of gross income. In contrast, the degree of pro-cyclical asymmetry in gross income has been significantly reduced when benefits on their own are taken into account and when benefits net of taxes and national insurance are considered.[19]

These results underline the importance of benefits as a policy instrument to mitigate the increase in risk in contractions. This effect is distinct from existing results for the U.S., Germany and Sweden in e.g. Busch *et al.* (2018) which emphasise the importance of taxes in reducing income risk. The different results may be driven by differences in risk measures and methodological approaches employed. In particular, we study the effect of policy on the cyclicality of the skewness of the distribution of shocks to the persistent

[19] To assess the robustness of our key results reported in Tables 1, 2 and 6, we use the time-series information to restrict the number of moments to estimate. In particular, we average the moments across the age groups for each period t (see Domeij and Floden (2010)). This procedure produces $2 \times T \times (T+1)/2 = 2 \times 171$ moments to match instead of $2 \times 5,187$ moments. These results are reported in Appendix D and cohere very well with our key results.

component of household income, whereas Busch *et al.* (2018) examine the effect of policy on the reducing the cyclicality of the skewness of the distribution of annual earnings growth across households. Nonetheless, as discussed above, our results for GB cohere well with the data reported in Figure 2 and provide evidence which complements other U.K. findings relating to the importance of benefits in reducing income volatility and inequality in the U.K. (see e.g. Blundell and Etheridge (2010) and Belfield *et al.* (2017)).

6 Conclusions

Using the BHPS data from 1991-2008, this paper confirmed existing findings in the literature and established new evidence relating to the cyclical behaviour of idiosyncratic household income risk and the effect of social insurance (tax-benefits) policy in reducing this risk. State dependent persistent income risk was measured by the variance and the skewness of the probability distribution of shocks to the persistent component of idiosyncratic income in both expansions and contractions of the aggregate economy. In contrast, constant transitory income risk was measured by the variance and the skewness of the probability distribution of shocks to the transitory component of idiosyncratic income. To examine the consequences of social insurance, we estimated risk for different measures of pre- and post-policy household income and evaluated the effects of tax and benefits policies on the level and the cyclicality of risk.

Our key finding for GB is that household income risk rises in contractions implying a higher probability of receiving large negative income shocks during this state. This finding confirms, using British data, similar findings for other countries. It adds to this literature by providing evidence that in GB it is the skewness of the distribution of the shocks to the persistent component of idiosyncratic income that falls in contractions.

However, we also find that a large part of the increased risk in bad times is mitigated by social insurance policy. This effect in GB is distinct from results for the U.S., Germany and Sweden reported in Busch *et al.* (2018), which emphasise the importance of taxes in reducing income risk. In contrast, we find that cyclical asymmetric income risk is reduced mainly via benefits policy, confirming the importance of this instrument in mitigating income volatility and inequality previously noted by other UK studies using different methods than those employed here (see e.g. Blundell and Etheridge (2010) and Belfield *et al.* (2017)).

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7 Appendix A: Data

7.1 BHPS

The main dataset used in this paper is the British Household Panel Survey (BHPS). The BHPS is a comprehensive longitudinal study for the U.K. running from 1991 to 2008. As a panel data survey, the BHPS tracks individuals across households over time. In the first wave, the BHPS achieved a sample size of around 5000 households (10,000 adult interviews) or a 65% response rate. After the first wave, due to sample attrition, the sample size shrank slightly. For example, in 2000 it achieved around 4200 complete interviews or a 75% response rate (see Taylor *et al.* 2010).

Since the start of BHPS in 1991, a number of additional sub-samples have been added to the survey. For example, the European Community Household Panel Survey (ECHP) sub-sample started in 1997. It was added mainly to include respondents from Northern Ireland and a low-income sample from the U.K. Moreover, in 1999 two more additional boost samples, for Wales and Scotland, have been added. Since the focus is on GB, to maintain the longest possible time-series dimension in our analysis, we only use the data starting in 1991 i.e. the original panel dataset. Finally, following Blundell and Etheridge (2010), we also make use of an auxiliary dataset called "Derived Current and Annual Net Household Income Variables" compiled by Bardasi *et al.* (2012).

The BHPS contains detailed information on key magnitudes of interest for this paper. In particular, earnings, hours worked and other income. Compared to other U.K. panel datasets for earnings, e.g. the New Earnings Survey (NES) for the period 1975-2002 and the Annual Survey of Hours and Earnings (ASHE), for the period 1997-2015, BHPS is much smaller in the cross-sectional dimension. The obvious advantages of NES and ASHE are the accuracy and the sample size, which covers the 1% of the total working population. Additionally, the time span is large enough for time series analysis since it covers the years from 1974 to 2015. However, these datasets do not provide information relating to: (i) household physical and human capital; (ii) why individuals disappear from the survey, e.g. due to an injury, unemployment spell or move to self-employment; (iii) self-employed individuals, which are a considerable percentage of the working population (approximately 14%); and (iv) individual *annual* earnings which are only available from 1999 onwards.

In contrast to the NES and ASHE, the BHPS has information on both individual and household characteristics. Therefore, it allows the examination of compositional effects (i.e. differences between individuals and households) and thus issues relating to household insurance mechanisms. Moreover, BHPS provides important human capital variables such as educational attainment. Another, important advantage of the BHPS relates to hourly pay. As noted by Stewart and Swaffield (2002), the BHPS does not suffer from the potentially serious sample selection bias that exists in the NES. Workers earning below the pay-as-you-earn tax threshold are under-represented in the NES sample. Furthermore, BHPS also covers the self-employed, the unemployed or even those who do not participate in the labour market for any reason. Finally, it provides a consistent measure of annual earnings/incomes over the whole period at hand.

7.2 Demographic and socioeconomic variables

1. **Head and relationship to head**: For each individual in the sample, BHPS reports the relationship to the head of household in any given wave. In our analysis we focus on households whose head is married. Following Blundell and Etheridge (2010), the

head of the household is defined as the oldest married (or living in partnership) male within the household.

2. **Education level**: BHPS includes information on educational attainment. For the BHPS we have used the variable wQFEDHI (where the prefix w denotes wave). To examine potential heterogeneity of earnings risk in the main text, the sample is split into degree holders and non-degree holders. The former are the individuals who hold either a Higher Degree or 1st Degree, while the latter are the individuals who hold either Higher National Certificate/Diploma or teaching qualifications or A-levels/AS level/Highers or GCSE/O level/other qualification or they have no qualifications.

7.3 Income and hours variables

1. **Labour income:** is obtained from the Derived Current and Annual Net Household Income Variables dataset (Bardasi *et al.* 2012) and is equal to total household annual labour income, wHHYRLG. Imputed values can be included in "Household total earnings" only if they do not correspond to the head of the household earnings.

2. **Gross income:** is obtained from the Derived Current and Annual Net Household Income Variables dataset (Bardasi *et al.* 2012). Gross income is equal to "Labour income", plus annual investment income, wHHYRI, plus annual private transfers income, wHHYRT, plus annual occupational pension income, wHHYRP. Private transfers income totals all receipts from other transfers (including education grants, sickness insurance, maintenance, foster allowance and payments from TU/Friendly societies, from absent family members) while occupational pension income totals all receipts from non-state pension sources. Investment income sums the estimated income from savings and investments, and all receipts from rent from property or boarders and lodgers.

3. **Gross income − taxes − NI:** is obtained from the Derived Current and Annual Net Household Income Variables dataset (Bardasi *et al.* 2012) and is equal to "Labour income" minus annual national insurance contributions, wYRNI, minus annual income tax after credits, wYRTAXNT, plus annual investment income, wHHYRI, plus annual private transfers income, wHHYRT, plus annual occupational pension income, wHHYRP.

4. **Gross income + benefits:** is obtained from the Derived Current and Annual Net Household Income Variables dataset (Bardasi *et al.* 2012) and is defined as "Gross

income" plus annual social benefits income, wHHYRB. Social benefits income totals all receipts from state benefits including national insurance retirement pensions.

5. **Gross income + benefits − taxes − NI:** is obtained from the Derived Current and Annual Net Household Income Variables dataset (Bardasi *et al.* 2012) and is defined as "Gross income −taxes −NI" plus annual social benefits income, wHHYRB.

7.4 Sample selection

For all of the measures discussed below, to employ a consistent sample throughout, we use the original BHPS sample excluding the observations from the boost samples after 1997.

7.5 Household income

We construct households from 1991-2008 by starting with the allocation of individuals to households from BHPS and retain households with a spouse/part-ner relationship. The household heads must be between 23-62 years of age, report non-zero labour income and their individual earnings should be reported, not imputed and above than half of the product between the minimum legal hourly wage times 520 hours. Households comprised of a single member or those that involve cohabiting but not family-related members are discarded. Moreover, the head must not be in the military and must not have missing values for region and educational attainment. Then, we discard the observations belonging to the highest 1% of the household earnings observations in each year. For the remaining households, we only keep households who are in the sample for at least three consecutive periods.

Table A.1: Sample selection in steps

selection step	households (obs.)
1. Whole sample	130,974
2. Drop proxy & non-full interviews	128,348
3. Original sample	82,355
4. Full interview of all members in household	74,602
5. Drop if no head's educational info	73,739
6. Drop if head in military	73,662
7. Drop if head's region missing	73,638
8. Keep if more than 2 adults	48,912
9. Keep if head's earnings>threshold & living with spouse	27,304
10. Keep if heads' age $\geq$23, $\leq$62	25,794
11. Drop if top1% of household total earnings	25,545
12. Keep if present at least 3 consecutive observations	21,870
ave. N obs per wave	1,215
N of unique households	2,483
ave. obs per household	8.8

Table A.2: Summary of Selected BHPS Data (1991-2008)

Variable	mean	s.d.	min	max
Head's age	41.1	9.8	23	62
HH size	3.3	1.1	2	9
Head's earnings	31,163.5	16,590.6	1,128.9	152,725.3
labour income	46,667.1	22,140.4	1,128.9	160,989.5
gross income	48,752.5	23,480.0	1,128.9	487,313.9
gross income −taxes −NI	38,328.0	17,427.0	1128.9	463,554.8
gross income +benefits	50,553.6	22,965.3	2,246.1	488,819.7
gross income +benefits −taxes −NI	40,129.2	16,955.3	2246.1	465,060.7

Note: All monetary values are expressed in 2012 prices using the RPI deflator.

The summary statistics refer to sample selection step 12 in Table A.1.

8 Appendix B: Persistence and Identification

The persistence parameter ρ is identified as:

$$\rho = \left[\frac{Cov\left(\mu_{i,1,1}, \mu_{i,4,4}\right) - Cov\left(\mu_{i,1,1}, \mu_{i,3,3}\right)}{Cov\left(\mu_{i,1,1}, \mu_{i,3,3}\right) - Cov\left(\mu_{i,1,1}, \mu_{i,2,2}\right)} \right]. \tag{3.22}$$

This expression implies that we need *at least* 4 consecutive time periods and age groups of data to estimate ρ, otherwise the model is under-identified.

However, in order to keep the exposition tractable, for the rest of the exercise we assume that $t \in T = \{1,2,3\}$ and $h \in H = \{1,2,3\}$ and that ρ is given.[20] This additional restriction implies a total of 28 empirical moments to identify 8 parameters, m_2^{χ}, m_2^{χ}, m_2^{ε}, m_3^{ε}, $m_2^{\eta,c}$, $m_2^{\eta,e}$, $m_3^{\eta,c}$, and $m_3^{\eta,e}$. To illustrate this example, we next need to specify the function that splits the time periods into expansions and contractions, e.g.:

$$\begin{bmatrix} \text{-1:} & \text{contraction} \\ \text{0:} & \text{expansion} \\ \text{1:} & \text{contraction} \\ \text{2:} & \text{expansion} \\ \text{3:} & \text{contraction} \end{bmatrix},$$

which implies

$$\begin{bmatrix} m_2^{\eta,f(-1)} = m_2^{\eta,c} & m_3^{\eta,f(-1)} = m_3^{\eta,c} \\ m_2^{\eta,f(0)} = m_2^{\eta,e} & m_3^{\eta,f(0)} = m_3^{\eta,e} \\ m_2^{\eta,f(1)} = m_2^{\eta,c} & m_3^{\eta,f(01)} = m_3^{\eta,c} \\ m_2^{\eta,f(2)} = m_2^{\eta,e} & m_3^{\eta,f(2)} = m_3^{\eta,e} \\ m_2^{\eta,f(3)} = m_2^{\eta,c} & m_3^{\eta,f(3)} = m_3^{\eta,c} \end{bmatrix}.$$

Note that the time periods 0 and -1, i.e. past periods appear in the table above. The reason is that since an agent's income has a persistent component, then she is accumulating shocks. In turn, this means that some of the agents in the sample bring with them these past shocks, and thus, the central moments of these past shocks appear in the theoretical moments. Consequently, we have extra information which we exploit to get more accurate estimates for $m_2^{\eta,c}$, $m_2^{\eta,e}$, $m_3^{\eta,c}$, and $m_3^{\eta,e}$.

[20]Recall in the model estimated in the main body of the paper $T = 18$ and $H = 36$.

8.1 Second and third moments for transitory shocks

Using periods $t = 1, 2$ and ages $h = 1, 2$, m_2^{ε} is identified via equations (3.9) and (3.11):

$$m_2^{\varepsilon} = E\left(\mu_{i,1,1}^2\right) - \rho^{-1} Cov\left(\mu_{i,1,1}, \mu_{i,2,2}\right), \tag{3.23}$$

and likewise m_3^{ε} is found employing equations (3.10) and (3.12):

$$m_3^{\varepsilon} = E\left(\mu_{i,1,1}^3\right) - \rho^{-1} CoSk\left(\mu_{i,1,1}, \mu_{i,2,2}\right). \tag{3.24}$$

8.2 Second moments for fixed effects

Using periods $t = 1$ and ages $h = 1$, m_2^{χ} is identified via equation (3.9):

$$m_2^{\chi} = E(\mu_{i,1,1}^2) - m_2^{\varepsilon} - m_2^{\eta,c}, \tag{3.25}$$

and likewise m_3^{χ} is determined employing equation (3.10):

$$m_3^{\chi} = E(\mu_{i,1,1}^3) - m_3^{\varepsilon} - m_3^{\eta,c}. \tag{3.26}$$

Thus, we can pin down m_2^{χ} and m_3^{χ} conditional on the identification of $m_2^{\eta,c}$ and $m_3^{\eta,c}$.

8.3 Moments for innovations to the persistent component

Using equation (3.11) along with periods $t = 1, 2, 3$ and $h = 1, 2, 3$, $m_2^{\eta,c}$ at $t = 1$ is identified as:

$$m_2^{\eta,c} = \frac{Cov\left(\mu_{i,1,1}, \mu_{i,3,3}\right) - Cov\left(\mu_{i,1,1}, \mu_{i,2,2}\right)}{\rho\left(\rho - 1\right)}. \tag{3.27}$$

Likewise, using equation (3.12) for the same t and h, $m_3^{\eta,c}$ is given by:

$$m_3^{\eta,c} = \frac{CoSk\left(\mu_{i,1,1}, \mu_{i,3,3}\right) - CoSk\left(\mu_{i,1,1}, \mu_{i,2,2}\right)}{\rho\left(\rho - 1\right)}. \tag{3.28}$$

Thus, having identified $m_2^{\eta,c}$ and $m_3^{\eta,c}$, we have implied m_2^{χ} and m_3^{χ} via (3.25) and (3.26) as well. Indentifying equations (3.27) and (3.28) are crucial in order to determine m_2^{χ} and m_3^{χ} which will help us pin down the rest of the parameters. Without these two conditions we cannot proceed further. That is the reason why we need *at least* 3 consecutive time periods and age groups of data to identify $m_2^{\eta,c}$ and $m_3^{\eta,c}$.

So, based on the values for m_2^{χ}, m_3^{χ}, m_3^{ε} and m_2^{ε}; $m_2^{\eta,e}$ is identified via equation (3.9) using

$t = 2$ and $h = 1$:

$$m_2^{\eta,e} = E(\mu_{i,1,2}^2) - m_2^{\chi} - m_2^{\varepsilon}, \tag{3.29}$$

and likewise $m_3^{\eta,e}$ is identified employing equation (3.10):

$$m_3^{\eta,e} = E(\mu_{i,1,2}^3) - m_3^{\chi} - m_3^{\varepsilon}. \tag{3.30}$$

Finally, note that when $T = H = 3$, and conditional on assumption that ρ is given, we have 8 parameters to identify, m_2^{χ}, m_2^{χ}, m_2^{ε}, m_3^{ε}, $m_2^{\eta,c}$, $m_2^{\eta,e}$, $m_3^{\eta,c}$, and $m_3^{\eta,e}$, and a total of 28 moment conditions. However, in demonstrating identification we have used exactly 8 moments, (3.23)-(3.30), but many parameters of the statistical model are already over-identified even with the minimal requirements, i.e. $size(T) = size(H) = 3$. Clearly the parameters will be even more over-identified as T and H increase.

9 Appendix C: Standardised third moments

Table C.1: Cyclical household income risk

	$\widetilde{m}_3^{\eta,e}$	$\widetilde{m}_3^{\eta,c}$	$\widetilde{m}_3^{\eta,e} - \widetilde{m}_3^{\eta,c}$	$\widetilde{m}_3^{\varepsilon}$	$\widetilde{m}_3^{\chi}$
			labour income		
est	-1.473*	-4.381*	2.908*	-7.717*	-1.190
	[-4.762,-0.291]	[-7.997,-2.075]	[0.642,+∞)	[-24.937,-3.364]	[-1.940,1.171]
			gross income		
est	-0.757	-4.620*	3.863*	-7.719*	-0.912
s.e.	[-2.255,0.888]	[-7.322,-2.834]	[1.834,+∞)	[-17.830,-4.341]	[-1.532,0.188]
			gross income −taxes −NI		
est	-0.634	-4.578*	3.944*	-6.336*	-0.831
s.e.	[-2.331,0.909]	[-7.378,-2.811]	[1.878,+∞)	[-12.460,-3.376]	[-1.464,0.465]
			gross income +benefits		
est	-0.129	-1.748*	1.619*	-3.930*	-0.552
s.e.	[-1.865,1.033]	[-3.400,-0.545]	[0.007,+∞)	[-7.737,-1.700]	[-1.011,0.316]
			gross income +benefits −taxes −NI		
est	0.045	-1.585*	1.630	-2.497*	-0.445
s.e.	[-2.202,1.295]	[-3.196,-0.321]	[-0.230,+∞)	[-5.022,-0.869]	[-0.955,0.741]

Note that the CI_{90}'s for all columns are for a two-tailed test, except the difference tests which are for a one-tailed CI_{90}. Also note that the standardised measures in this and the next two tables are defined as $\widetilde{m}_3^{\eta,e} = \frac{m_3^{\eta,e}}{\left(m_2^{\eta,e}\right)^{1.5}}$; $\widetilde{m}_3^{\eta,c} = \frac{m_3^{\eta,c}}{\left(m_2^{\eta,c}\right)^{1.5}}$; $\widetilde{m}_3^{\varepsilon} = \frac{m_3^{\varepsilon}}{\left(m_2^{\varepsilon}\right)^{1.5}}$ and $\widetilde{m}_3^{\chi} = \frac{m_3^{\chi}}{\left(m_2^{\chi}\right)^{1.5}}$.

Table C.2: Policy effects on income risk (asymmetry)

	expansions	contractions	transitory
[1]	$[\widetilde{m}_3^{\eta,e}]^g - [\widetilde{m}_3^{\eta,e}]^{g-t-ni}$	$[\widetilde{m}_3^{\eta,c}]^g - [\widetilde{m}_3^{\eta,c}]^{g-t-ni}$	$[\widetilde{m}_3^{\varepsilon}]^g - [\widetilde{m}_3^{\varepsilon}]^{g-t-ni}$
est	-0.123	-0.042	-1.383
s.e.	(-∞,1.727]	(-∞,2.484]	(-∞,3.725]
[2]	$[\widetilde{m}_3^{\eta,e}]^g - [\widetilde{m}_3^{\eta,e}]^{g+b}$	$[\widetilde{m}_3^{\eta,c}]^g - [\widetilde{m}_3^{\eta,c}]^{g+b}$	$[\widetilde{m}_3^{\varepsilon}]^g - [\widetilde{m}_3^{\varepsilon}]^{g+b}$
est	-0.628	-2.872*	-3.7891
s.e.	(-∞,1.292]	(-∞,-1.029]	(-∞,0.285]
[3]	$[\widetilde{m}_3^{\eta,e}]^g - [\widetilde{m}_3^{\eta,e}]^{g+b-t-ni}$	$[\widetilde{m}_3^{\eta,c}]^g - [\widetilde{m}_3^{\eta,c}]^{g+b-t-ni}$	$[\widetilde{m}_3^{\varepsilon}]^g - [\widetilde{m}_3^{\varepsilon}]^{g+b-t-ni}$
est	-0.802	-3.035*	-5.223*
s.e.	(-∞,1.366]	(-∞,-1.217]	(-∞,-1.864]

Table C.3: Policy effects on the cyclical asymmetry of income risk

	[1]	[2]	[3]
	$[\widetilde{m}_3^{\eta,e} - \widetilde{m}_3^{\eta,c}]^g$	$[\widetilde{m}_3^{\eta,e} - \widetilde{m}_3^{\eta,c}]^{g-t-ni}$	[1]-[2]
est	3.863*	3.944*	-0.081
s.e.	[1.834,+∞)	[1.878,+∞)	[-3.182,+∞)
	$[\widetilde{m}_3^{\eta,e} - \widetilde{m}_3^{\eta,c}]^g$	$[\widetilde{m}_3^{\eta,e} - \widetilde{m}_3^{\eta,c}]^{g+b}$	[1]-[2]
est	3.863*	1.619*	2.244
s.e.	[1.834,+∞)	[0.007,+∞)	[-0.161,+∞)
	$[\widetilde{m}_3^{\eta,e} - \widetilde{m}_3^{\eta,c}]^g$	$[\widetilde{m}_3^{\eta,e} - \widetilde{m}_3^{\eta,c}]^{g+b-t-ni}$	[1]-[2]
est	3.863*	1.630	2.233
s.e.	[1.834,+∞)	[-0.230,+∞)	[-0.257,+∞)

10 Appendix D: Robustness

The following results are based on the restricted set of 2 × 171 moments discussed in footnote 17 of the main text.

Table D.1: Cyclical household income risk

	$m_2^{\eta,e}$	$m_2^{\eta,c}$	$m_2^{\eta,e}-m_2^{\eta,c}$	$m_3^{\eta,e}$	$m_3^{\eta,c}$	$m_3^{\eta,e}-m_3^{\eta,c}$
			labour income			
est	0.0546***	0.0560***	-0.0014	-0.0155*	-0.0341***	0.0186*
s.e.	(0.0077)	(0.0093)	(0.0077)	(0.0084)	(0.0101)	(0.0133)
			gross income			
est	0.0460***	0.0498***	-0.0038	-0.0054	-0.0335***	0.0282**
s.e.	(0.0064)	(0.0087)	(0.0073)	(0.0069)	(0.0096)	(0.0123)
			gross income −taxes −NI			
est	0.0378***	0.0401***	-0.0023	-0.0030	-0.0241***	0.0210**
s.e.	(0.0047)	(0.0072)	(0.0063)	(0.0050)	(0.0075)	(0.0096)
			gross income +benefits			
est	0.0295***	0.0339***	-0.0044	0.0005	-0.0061*	0.0066*
s.e.	(0.0031)	(0.0058)	(0.0053)	(0.0031)	(0.0035)	(0.0050)
			gross income +benefits −taxes −NI			
est	0.0232***	0.0280***	-0.0048	0.0010	-0.0040*	0.0050*
s.e.	(0.0022)	(0.0044)	(0.0045)	(0.0022)	(0.0024)	(0.0034)

Table D.2: Persistence and remaining moments

	ρ	m_2^{ε}	m_3^{ε}	m_2^{χ}	m_3^{χ}
			labour income		
est	0.7846***	0.0170**	-0.0439***	0.0683***	-0.0246**
s.e.	(0.0388)	(0.0068)	(0.0058)	(0.0123)	(0.0104)
			gross income		
est	0.7907***	0.0166***	-0.0343***	0.0722***	-0.0222**
s.e.	(0.0392)	(0.0059)	(0.0050)	(0.0124)	(0.0099)
			gross income −taxes −NI		
est	0.8059***	0.0157***	-0.0242***	0.0587***	-0.0162**
s.e.	(0.0352)	(0.0045)	(0.0037)	(0.0104)	(0.0080)
			gross income + benefits		
est	0.8222***	0.0146***	-0.0129***	0.0536***	-0.0090**
s.e.	(0.0325)	(0.0037)	(0.0021)	(0.0105)	(0.0035)
			gross income +benefits −taxes −NI		
est	0.8301***	0.0131***	-0.0074***	0.0419***	-0.0057**
s.e.	(0.0275)	(0.0026)	(0.0016)	(0.0080)	(0.0024)

Table D.3: Policy effects on the cyclical asymmetry of income risk

	[1]	[2]	[3]
	$[m_3^{\eta,e} - m_3^{\eta,c}]^g$	$[m_3^{\eta,e} - m_3^{\eta,c}]^{g-t-ni}$	[1]-[2]
est	0.0282**	0.0210**	0.0071
s.e.	(0.0123)	(0.0096)	(0.0159)
	$[m_3^{\eta,e} - m_3^{\eta,c}]^g$	$[m_3^{\eta,e} - m_3^{\eta,c}]^{g+b}$	[1]-[2]
est	0.0282**	0.0066*	0.0216*
s.e.	(0.0123)	(0.0050)	(0.0133)
	$[m_3^{\eta,e} - m_3^{\eta,c}]^g$	$[m_3^{\eta,e} - m_3^{\eta,c}]^{g+b-t-ni}$	[1]-[2]
est	0.0282**	0.0050*	0.0231**
s.e.	(0.0123)	(0.0034)	(0.0128)

SUMMARY AND FUTURE RESEARCH

This thesis studied inequality in several dimensions, with an emphasis on the analysis of wealth inequality within and between groups (including by social class, occupation and education). It aimed to identify factors that affect inequality and how income and wealth are distributed within society. In the first two chapters, we considered the role of saving externalities and peer pressure on wealth and income inequality, both at the aggregate and at the within- and between-group levels. We found that the distributional effects, especially between and within groups can be substantial, even if efficiency (Chapter 1) or aggregate distributional effects (Chapter 2) are small. In the third chapter, we focused on a major determinant of income and wealth inequality, namely unexplained income risk. This chapter found that household income risk rises in contractions and that social benefits play a bigger role in mitigating the increased risk than taxes.

Chapter 1

This chapter quantified the implications of pecuniary externalities on inequality and inefficiency due to the heterogenous savings behaviour of different groups in the population. We developed an open-economy incomplete markets model with idiosyncratic earnings risk and *ex ante* skill heterogeneity. We focused on differences in skill, proxied by education, more specifically, whether individuals hold a university degree or not. The two groups differed with respect to their specific earnings processes. In particular, with respect to their expected earnings and the conditional and unconditional risk associated with their earnings streams. We calibrated the model to the U.K. and find that its predictions regarding between and within-group inequality are consistent with the data.

The key finding of this chapter is the different savings behaviour of the university and non-university educated groups generates a form of pecuniary externality. This externality operates via the interest rate. Intuitively the savings of each group affect the saving behaviour of the other groups via the interest rate. Specifically, the equilibrium interest rate is determined by the aggregate asset supply function, which is higher (lower) than the asset supply functions of the university (non-university) group. Consequently, households in the university (non-university) groups raises (lowers) their savings. As a result, within-group wealth inequality increases for the non-university group and decreases for the university group, while between-group inequality rises. Although the effects of the externality on within and between-group inequality are significant, its effects on efficiency are marginal.

The key contribution of this chapter is that it demonstrates that these types of fixed differences have a significant impact on between and within-group as well as aggregate wealth inequality despite having only modest effects on aggregate savings. Another contribution is that the *ex ante* skill heterogeneity helps the benchmark heterogeneous agent model predict inequality, which is closer to the observed inequality in the U.K.. Finally, the modelling of the open-economy with a partially elastic interest rate in this class of model is novel.

Chapter 2

In this chapter we set out to synthesize the theory of macroeconomics of inequality with the theory of social economics. We specified a theoretical framework that allowed us to study how social phenomena such as peer pressure and aspirational pressure affect individual choices, and as a result the distributions of earnings, incomes, consumption and wealth. We defined *peer pressure* as the case where consumption levels achieved by members of the socio-economic class (the group of peers) determine a social target that acts as a reference point for consumption for each member of the class. Whereas we defined *aspirational pressure* (or *above-peer aspirations)* as aspirations for consumption that are determined by next highest socio-economic class (as defined by the mean wage/earnings). We showed existence of a stationary equilibrium, when the social targets are determined jointly with the distributions of hours, earnings, wealth and consumption, under stochastic social class participation and idiosyncratic productivity.

Motivated by recent empirical studies on peer pressure we calibrated a benchmark model to the British data under "keeping up with the Joneses" peer pressure and we found that it predicts all main patterns in the data regarding between and within group inequality. We further examined alternative forms of peer pressure. However, we found that "keeping up with the Joneses" peer pressure is critical in helping the model's predictions match the empirical patterns regarding between group hours inequality and cross-group qualitative differences with respect to within group hours and earnings inequality.

In the quantitative analysis we made two broad comparisons, in terms of inequality. First, we compared economies under "keeping up with the Joneses" peer pressure, with economies with no peer pressure. We found that for groups with higher mean wages, within group inequality is lower in terms of hours and earnings, and higher in terms of wealth and consumption. Conversely, for lower mean wage groups, within group inequality is higher in terms of wealth and consumption and lower in terms of hours and earnings. Whereas, between group inequality is lower for hours, earnings and consumption, but higher for wealth. Second, we compared economies under "keeping up with the Joneses" peer pressure, with economies under aspirational pressure. We found that aspirational pressure allows the groups with the higher aspirations (lower mean wage groups) to close the gap with the top mean wage group in terms of hours, earnings and consumption, but the gap becomes bigger in terms of wealth. At the same time, although there is a reduction in within-group inequality in hours and earnings, wealth and consumption inequality within-group are higher.

We concluded that the effects of social pressure are not uniform across the socio-economic groups, either when we consider peer pressure or above-peer aspirations. We saw that social pressure incorporates forces that, other things equal, tend to generate convergence within cluster and divergence between classes. We further concluded that the prospect of upward/downward mobility matters in determining the effects of peer and aspirational pressure, tending to lower between group divergence. Moreover, we established that peer and aspirational pressure affects incentives to work and save differently. Thus, social pressure implys non-uniform changes in wealth and earnings inequality, which in turn implies that there are opposite effects on consumption inequality and consequently social frustration. The reason is that in the proposed framework wealth inequality reflects both the dispersion of earnings and motives for wealth accumulation stemming from inter-temporal smoothing and the insurance value of wealth.

The importance of examining within and between group inequality has been emphasized within the economics literature. This thesis stressed the importance of examining, not only aggregate inequality, but also its between and within group components. Such a focus might help economists identify policies that can moderate inequality and in turn its consequences. For example, policies aimed at mitigating aggregate inequality might have different effects on between group inequality and within group inequality. Moreover, policies tackling between group inequality might have adverse effects on within group inequality, and ultimately might increase social dissatisfaction. As we have suggested in this chapter, above peer aspirations, compared with a situation where households aim to meet targets defined by the behaviour of their peers, lead to increased social frustration, despite improvements in material wealth and consumption on average. This finding implies that in a more socially connected world, when aspirations become more upward looking, improvements in wealth and consumption may nevertheless be accompanied by social dissatisfaction.

This chapter filled a gap in the literature of macroeconomics of inequality by formally introducing social–peer or aspirational–pressure into the heterogeneous agents incomplete markets model. We extended the notion of equilibrium in this context by taking into account the social interactions stemming from social pressure. We have shown that given the social targets, the household's problem admits a unique household-level invariant asset-shock distribution and that a socio-economic equilibrium exists. Also, we suggested an algorithm to compute the equilibrium and verify uniqueness. Most importantly, this model allowed us to examine the richness of distributional effects of social pressure and hopefully may be used for policy analysis in the future.

Chapter 3

In this chapter, we examined the cyclical behaviour of idiosyncratic household income risk and the effect of social insurance, i.e. tax-benefit policy, in reducing this risk. Our key variable is the unexplained or idiosyncratic component of household income. Following the literature, this component was assumed to be a composition of three subcomponents, a fixed, a persistent and a transitory. We measured income risk by the variance and skewness of the probability distribution of shocks to the persistent component of idiosyncratic income in expansions and contractions of the aggregate economy. The transitory income risk was assumed to be time invariant and measured by the variance and skewness of the probability distribution of transitory shocks. Using the BHPS dataset from 1991 to 2008, information about the aggregate state of the economy from 1952 to 2008, and the seminal approach of Storeslettern *et al.* (2004) and Busch and Ludwig (2016), we estimated the risk for different measures of pre- and post-policy household income and evaluated the effects of tax and benefits policies on the level and the cyclicality of risk. The advantage of this methodology is that we can identify the differences between booms and slumps by exploiting history dependent cross-sectional moments that incorporate aggregate shocks outside the panel data sample period.

Our key findings for Great Britain (GB) was that household income risk rises in contractions driven by a higher probability of receiving large negative persistent income shocks during this state. This finding is similar to findings for other countries, but is new for Great Britain. We also found that social insurance policy plays a bigger role in mitigating the increased risk in contractions than taxes. This effect is in stark contrast to findings for U.S., Germany and Sweden reported in Busch *et al.* (2018), which emphasises the importance of taxes in reducing income risk.

Future Research

This thesis identified factors that generate or amplify inequality. However, it did not deal with the problem of how to reduce inequality in environments with those factors at place. Thus, a possible future path of research could be to make use of the frameworks (in chapters one and two) and perform policy analysis. For example, since in chapter one inequality is to some extent a result of an externality, we can consider policies that reduce overall inequality and within group inequality and examine possible trade-offs. This exercise could be extended to cover cases where the exogenous income processes exhibit higher order risk, cyclical risk, alternative production function or endogenous educational choice.

In the same vein, as we saw in chapter two, the effects of social pressure are not uniform, and hence, the effect of taxes and benefits might not be uniform as well. For example, we could consider having taxes and benefits, possibly income dependent, and examine the effects on between and within group inequality. Since peer pressure works through consumption, we could even consider non-mainstream policy schemes such as progressive consumption taxes or a universal basic income.

Furthermore, in chapter two we focused on the effects of social pressure on inequality and we took the upward or downward mobility as exogenous. A very interesting, and non-trivial, extension to this framework is to analyse a situation where the prospect of upward or downward mobility interacts with the prospect of increased peer pressure to determine jointly cross-sectional distributions, in addition to decision making that influences class participation.

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