The Echo Chamber Effect: Segregation, Polarisation, and Discrimination

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Abstract: In this paper we analyze how echo-chamber effects drive the relation between segregation, polarisation of beliefs and discrimination. We study a model which allows for the coevolution of endogenous segregation in school choices and polarised beliefs about the educational merits of different schools. We show how initial levels of segregation and differences in beliefs can, with the echo chamber effect, develop into full polarisation of beliefs and long run labour market discrimination. The model suggests a new perspective on the long term effects of different policy interventions, such as integration in schools, on the spread of discriminatory beliefs.

1 Introduction

A recent literature highlights the role played by segregation and "echo chamber effects" in the polarisation of beliefs in society. The idea is simple: when individuals are segregated with like minded peers, beliefs might become polarised. This can arise as individuals are more likely to communicate with those similar to them and ignore this selection bias. Alternatively, polarised beliefs can arise with repeated communication coupled with a correlation neglect bias.[1]

Recent studies are indeed showing significant and increasing levels of segregation in the US and other western countries.[2] Reardon and Bischoff (2011) show the increased segregation in the US from 1970-2009. Chetty et al (2014) provide a snapshot of segregation in the US and its effect on social mobility.[3] Gentzkow and Shapiro (2011) compute an isolation index and show how face-to-face segregation -in voluntary associations, work, neighborhoods, family, trusted friends and political discussants- is much more significant as compared to the segregation implied by online and offline news consumption.

[1] See De Marzo, Vayanos and Zwiebel (2003) and Glaeser and Sunstein (2009) for theoretical models of echo chamber effects. See Sunstein (2001, 2007) and Jamieson and Cappella (2008) for the effects of seggregation on political views.

[2] *The Big Sort* by Bill Bishop illustrates how Americans are increasingly choosing to live with like-minded neighbours. Bishop claims that this is what behind the polarisation of beliefs in American society.

[3] See also the Pew Research centre report on http://www.pewsocialtrends.org/2012/08/01/the-rise-of-residential-segregation-by-income/.

Empirical research also supports the relation between segregation and beliefs: Algann *et al* (2015) show that students' political opinions converge among friends, and Boisjoly *et al* (2006) and La Ferrara *et al* (2014) show that living in mixed-race housing lowers students' prejudiced beliefs. Kaufmann and Harris (2015) study the rise in segregation along racial lines in the UK and find significant effects of segregation on attitudes about the benefits of immigration.

While segregation might affect beliefs, beliefs may also affect individuals' choices to segregate. Dustman and Preston (2001) show how attitudes to ethnic minorities affect location choices. They show that earlier studies that have only looked at the other causality, i.e., how segregation and social exclusion affect beliefs and attitudes, have biased results due to neglecting the selection bias in location choice. Using an instrument they show the importance of beliefs in affecting location choices. To better understand segregation and polarised beliefs, one has therefore to analyze the *coevolution* of segregation and beliefs. This is what we propose in this paper.

An important context in which segregation and beliefs influence each other is schooling. Schools are places where intense socialization takes place; beliefs are formed and moulded, by peers and by teachers. Moreover, in many countries, communities are segregated by the school choices of parents. One example is the "white flight" to the suburbs in the US which is considered to be motivated by the possibility of racial and socioeconomic segregation in schools.[4]

As a leading example, we focus on segregation between private and state schools.[5] Below we provide details on such segregation in the UK. We show that it is correlated with polarised beliefs on the educational merits of such schools, and provide details on the possible economic effects of this, namely labour market discrimination.

Private and state schools in the UK: School choices in the UK tend to be persistent and segregated. Evans and Tilley (2011) find that 43 per cent of the privately educated who have children have sent them to private schools, nearly five times the rate for parents who went to state schools. Among married individuals, 41 per cent of the privately educated are married to a privately-educated person, compared with six per cent of those who are state educated. Of those who are married with children, 65 per cent of couples who both went to a private school have sent a child to a fee-paying school, compared with only six per cent of state school couples.

Evans and Tilley (2011) also show systematic differences in political preferences and social attitudes among such graduates. Similarly, in a 2013 YouGov survey, when asked:

[4] See Bradford and Kelejian (1973).

[5] Private schools are termed independent or public in the UK, whereas state schools are termed public schools in the US. To avoid confusion we then use the terms private and state schools.

"Do state secondary schools give talented children a good education and allow them to achieve their full potential?", 58% of state school parents replied yes compared to only 48% of private school parents.[6] 21% strongly agree to: "Pupils at private schools are generally brighter than pupils at state schools", with responses exhibiting big differences across different political affiliations and socioeconomic status.

Using data on secondary school type from the 1970 British Cohort Study and on cognitive skills at age 16, Green et al (2005) investigate the effect of private schools on pupils' self-esteem and locus of control at ages 10 and 16. They find that private schools help to stimulate locus of control, to raise aspirations and to provide access to networks. One can interpret self-esteem and locus of control as the confidence that one is better than others.

Such beliefs may have consequences in the job market: While private school graduates are only 7% of the UK graduate population, they constitute 71% of senior judges, 62% of senior armed forces officers, 55% of top civil servants, and 43% of newspaper columnists. Private school male graduates are up to 10 per cent more likely to land top jobs than state school graduates with the same grades from the same university.[7]

Finally, there is some evidence that state school graduates outperform compared to the expectations about them, which is consistent with initial discrimination due to wrong beliefs and subsequent adjustment of beliefs due to learning. A report by HEFCE, following 130,000 students and controlling for background, finds that state school graduates outperform private school graduates at university.[8] In the workplace a recent study by the Sutton Trust found that while there are significant wage difference between privately and state educated employees, state school graduates are more likely to remain in high status jobs.[9]

Note that the above findings are not exclusive to the UK. In the US, private schools lead the tables in terms of placements into top universities. At the same time, a 2007 study of the Centre of Education Policy, using NELS data from 1988-2000, found that when family background was taken into account, students from private schools or selective state schools performed no better than those in standard state schools in achievements tests. Similarly, Abdulkadiroğlu et al (2014) and Dobbie and Fryer (2014) show that peers with high achievements or a school racial mix have no effect on pupils' attainment.

[6] http://www.ofsted.gov.uk/news/ofsted-too-many-of-englands-poorest-children-continue-be-let-down-education-system

[7] These facts are taken from a recent study by the Social Mobility and Poverty Commission which tracked 20,000 students.

[8] Of those students who achieved the same grades at high school (ABB at A-level, there is no other entry exam to university), 69% of students from private schools went on to gain 2:1 or above at university compared with about 77% of state schools students.

[9] See http://www.suttontrust.com/newsarchive/privately-educated-graduates-in-top-jobs-get-bigger-pay-rises/

We propose a model to analyze the coevolution of school segregation and polarised beliefs about labour market productivities attained by different school graduates. The model has non-overlapping generations with infinite periods and three stages at each period. In the *peer influence* stage, individuals' beliefs are shaped by their parents' beliefs and by their school peers. In the *labour market* stage, employers decide whether to hire an employee, given his school and their beliefs on schools' effect on productivities. Labour market experience entails some learning about true productivities. In the *school choice* stage, individuals choose which school -state or private- to send their offspring to. The private school admits a fixed share of the population with the highest willingness to pay for the school.

Our analysis relies on two important assumptions. First, to pin down how segregation affects beliefs, we assume that individuals exchange information only with those in the same school. By assuming that individuals have a selection bias, we therefore propose a model of echo chambers or peer influence in schools.

Second, to analyze how beliefs affect segregation, we assume that parents decide which school to send their child to by using "imperfect empathy", as in Bisin and Verdier (2001). Parents base their decisions on their expectation about how others will treat their children but also on their expectations about how the school will affect their child's future behaviour. Parents understand that the environment will influence their offspring's beliefs but think that the optimal course of behaviour is the one that follows their own beliefs (hence empathy is imperfect). This implies homophily, i.e., that parents would rather their children segregate with like-minded others so that their child's belief does not stray too much from their own. This endogenous homophily implies the segregation that breeds the "echo chamber effect".

Our main result considers the following question: Can wrong beliefs persist in the long run? That is, if some in society overestimate the productivity differences between state and private schools, can the echo chamber effect lead to polarised beliefs, labour market discrimination and school segregation in the long run? We characterize a simple necessary and sufficient condition that characterises when this happens. When the condition is satisfied, in all equilibria, there are polarised beliefs about the productivity of graduates from the different schools (over and above actual productivity differences). Parents who send their children to a private school believe that the difference between the schools is higher than what it really is. Parents who send their children to a state school realize that there is discrimination, believe it is not justified, and are priced out of the private school. Finally, those who went to the private (state) school will also send their children to the private (state) school. Thus, the "old boys" network is endogenously formed.[10]

[10]Network effects have also been mentioned as a possible reason for discrimination. Our analysis

The condition identifies environments in which the echo chamber effect outweighs true learning.[11] First, history matters; to create long run segregation and polarised beliefs, those in the private school have to start from a relatively low opinion about state school graduates. Second, the higher is the intensity of socialization in schools the easier it is to create segregation and polarisation. Finally, polarised beliefs are easier to sustain the less individuals learn about others from their labour market experience.

The model provides a rationale for school integration, over and above the one mainly explored in the Economics literature (which focuses mainly on academic achievement through peer effects):[12] In our model successful integration will change wrong stereotypes and the beliefs of individuals on one another, inducing less discrimination in the long-run.

The model also sheds light on some common practices in school admissions. Our condition identifies environments in which, when private schools admit pupils according to their willingness to pay, they will not necessarily survive in the long-run. Alternative selection criteria, based on beliefs, values or culture, will allow such schools to increase their long term survival. This accords with a common practice of many private schools and universities in the UK and in the US which hold interviews, often with parents as well, or have a legacy criterion for admission.

Finally note that in our model discrimination is according to an acquired trait, such as the school one had attended. The analysis can be extended to also include inherited traits such as ethnicity, race or gender. We discuss these issues in Section 6.

2 Related Literature

The paper is related to several strands of the literature. To the literature on political polarisation we contribute by providing a specific mechanism illustrating why groups with similar beliefs on others will tend to segregate, and how such segregation induces polarisation of beliefs. These issues have been considered in the literature on media consumption. Mullainathan and Shliefer (2005), Gentzkow and Shapiro (2006, 2010) and Gentzkow, Shapiro and Sinkinson (2014) focus on consumers who prefer to read newspapers that agree with their own views. Gentzkow et al (2014) show this empirically for a data set of newspapers in 1924. Gentzkow and Shapiro (2010) and Gul and Pesendorfer (2012) show how such demand from readers can polarise the media supply which can then potentially further polarise voters' opinions (see also Ortoleva and Snowberg 2015). While

endogenises such networks. See Granovetter (1974), Marmaros and Sacerdote (2002), and Simon and Warner (1992).

[11] Wrong beliefs arise in our model not because individuals stop "experimenting", as in Piketty (1995) or Fudenberg and Levine (1993), but because their peers' beliefs are pessimistic enough and thus the echo chamber effect outweighs any positive learning.

[12] See for example Sacerdote (2011)

polarisation of beliefs has been mainly considered to influence political outcomes,[13] here we focus on how segregation and polarisation of beliefs can have a direct and dynamically persistent effect on economic outcomes such as wages and employment.

The literature on labour market discrimination has provided many explanations for this phenomenon. Statistical discrimination models follow either Arrow (1973), who focuses on self-fulfilling beliefs, or Phelps (1972) who focuses on noisy information.[14] In all these models individuals' beliefs are correct at least on average. Our approach is different: We show how, even in the absence of differences, individuals may strongly believe that such differences exist. We provide a specific mechanism -segregation and the echo chamber effect- to illustrate how wrong beliefs overcome true information in the long run. Also in this literature, Austen-Smith and Fryer (2005) and Chaudhuri and Sethi (2008) show how investment in skills changes as a result of peer effects in segregated neighbourhoods.[15] Our analysis is complementary: We endogenise segregation, and allow *beliefs* to be what segregation exacerbates.[16]

Benabou (1993) and Epple and Romano (2008) focus on the relation between segregation in education and complementarities: Benabou (1993) shows how segregation inefficiently arises due to complementarities in education, and Epple and Romano (2008) use complementarities in education and income to derive segregation between state and private schools. We differ from this literature by focusing on beliefs as the key element that fuels -and is fuelled by- segregation.

Another strand of related literature is the one on homophily. Baccara and Yariv (forthcoming) consider endogenous segregation into groups who would share public goods. Peski (2008) derives an endogenous preference for similarity by assuming some properties of preferences on friendship. We instead derive homophily using the imperfect empathy assumption (see Bisin and Verdier 2001).

The imperfect empathy assumption is also related to papers looking at choices of beliefs

[13] See Barber and McCarty (2013) and Levy and Razin (2015).

[14] For a survey on models of statistical discrimination see Fang and Moro (2010). Coate and Loury (1993) and Moro and Norman (2004) are recent examples that follow Arrow (1973) to show how discrimination or segregation arise due to self fulfilling asymmetric equilibria. Fryer and Jackson (2008) is a recent example of a categorization model which can rationalize the use of stereotypes. Black (1995), and Lang, Manove and Dickens (2005) analyze labour market discrimination with wrong beliefs, which can result from noisier information. Peski and Szentes (2013) analyze "spontaneous" discrimination which arises from repeated game considerations, without beliefs on productivity.

[15] Calvo-Armengol and Jackson (2004) show how information about job opportunities flows in some networks but not in others, resulting in discrimination. This is also related to the literature on identity, as in Akerlof and Kranton (2000).

[16] Also related to self-fulfilling beliefs is the work on "social assets" by Mailath and Postlewaite (2006). In their work as in ours private education becomes valuable when others value it.

in social interactions. Benabou and Tirole (2006) describe a model in which individuals (or parents) censor information so as to distort their future selves' (or children's) beliefs. Levy and Razin (2012) model the choice of whether to be religious or secular as a choice that affects future beliefs. Benabou (2013) shows that the choices of individuals to ignore information depend in equilibrium on others' choices and on the complementarities of their actions with others.

Finally, the social learning literature is also concerned with the question of whether societies converge to have the right or wrong beliefs (see Eyster and Rabin 2010). One key difference is that individuals in our model do not misinterpret others' actions or beliefs, but instead do not take into consideration the selection bias in their information.

3 The model

We consider a non-overlapping generations model with a continuum of dynasties, each indexed by $i \in [0,1]$. Each dynasty consists of one individual at any period $t \in \{1,...\}$, which at the end of the period is replaced by one offspring.

There are two kinds of schools, state and private. The focus of our analysis will be on how (endogenous) segregation in different schools can foster polarised (and hence sometimes wrong) beliefs about the productivity of the graduates of the different schools. For the purpose of our analysis it is not important whether productivity arises through innate ability, standard peer effects, or through quality of teaching.[17] For simplicity, we assume that whatever the school an individual goes to, his actual productivity is the same and equal to one. We extend the analysis to different productivities later on.

We consider a simple form of beliefs. Assume that all dynasties believe that the productivity of private school graduates is 1. They also believe that the productivity of a state school graduate is in $\{1,0\}$. Specifically, at any date $t \geq 1$, each dynasty holds a belief that the productivity of graduates of state schools is 1 with probability $q_i^t \in (0,1]$ and 0 otherwise, with some $F^t(.)$ describing the distribution of $q_i^t \in (0,1]$. The beliefs of different dynasties will change within periods and across time as we describe below, and we will analyse where beliefs and behaviour will converge to.

At any period t, all individuals go through the following phases:

Stage 1: *Peer influence in schools.* Individuals start school with the belief q_i^t inherited from their parents. They communicate with peers and update their beliefs.

Stage 2: *Labour market.* School graduates become employees or employers and are

[17] There is a large literature on sorting in schools according to parental income and innate ability, which can potentially affect productivity. See for example Epple and Romano (1998). MacLeod (2009) shows that even if private schools select a higher ability students, they then might invest lower effort so that the value added of the private school is low and overall productivity will not be much higher.

randomly matched. Employers observe the schooling history of employees and make employment decisions given their beliefs. Employees and employers receive wage/profits respectively. Labour market experience is potentially informative about the productivity of state school graduates.

Stage 3: *Parental school choice.* Following labour market experience, individuals have one offspring each, to which they transmit their beliefs. They then choose a school, private or state, for their offspring, in order to maximize their offspring's payoff in the labour market.

Note that individuals receive utility only in stage 2, in the employment phase, in the form of wages or profits. Attending school does not in itself entail any utility.

We now describe the specific stages of the model. While the model described below has many moving parts, we would like to stress that two assumptions are crucial: peer influence within one's own school, and imperfect empathy that determines school choice. All other parts of the model, such as labour market interaction, learning in the labour market, and the schools market, are intentionally simplified and could be easily generalised.

3.1 Peer influence in schools

Our key assumption is that peer influence occurs among individuals in the same school only. As in the network literature which assumes that individuals communicate with those they are connected to, in our model as well information exchange arises only among those that interact with one another. An important difference however is that in our model the "network", i.e., the identity of the individuals in the different schools, will be endogenously determined by the parents, given their beliefs.

To model peer influence, we consider a simple communication model in which individuals -in the same school- transmit their beliefs q_i^t truthfully to each other. While individuals exchange beliefs over the productivity of state school graduates, this can be more generally thought of as exchanging views that "our school is better than other schools", or that "attending a private school is the only way to succeed in life". We take the view therefore that exchanges between individuals consist of transmission of beliefs, rather than signals, and, as in the social learning literature, that such transmission is sincere.

Specifically, let $f_J^t(.)$ denote the distribution over the inherited beliefs of pupils in school $J \in \{s, p\}$ at period t. We assume that individual i in school J is randomly matched and exchanges beliefs with n others in the same school. Sobel (2014) and Levy and Razin (2016) show that if individuals believe that they had all started with a common uniform prior, and that their posterior beliefs q_i^t were formed by receiving private conditionally independent signals, then these posterior beliefs are sufficient statistics for rational Bayesian updating. We can therefore describe the evolution of beliefs of an individual i in school

J at time t, from q_i^t, before he interacts with others, to $q_{i,g}^t$, after communicating with n peers and graduating, according to the following -Bayesian- process:

$$q_{i,g}^t \equiv \chi(\mathbf{q}^t, q_i^t) = \frac{q_i^t \prod_{k=1,..,n} q_k^t}{q_i^t \prod_{k=1,..,n} q_k^t + (1-q_i^t) \prod_{k=1,..,n} (1-q_k^t)}, \tag{1}$$

where $\mathbf{q}^t$ is a vector of beliefs $(q_1^t, ..q_n^t)$ of length n, each belief drawn from $f_J^t(.)$.

Note that individuals have a selection bias: They only learn from those that they interact with while not taking into account that those who chose to attend the other school may have different beliefs. This will play an important role if the school choice decision leads to segregation of beliefs. Apart from selection bias, the belief updating process follows from Bayesian updating assuming conditional independence in the initial beliefs.[18] Denote by $f_{J,g}^t(.)$ the distribution of beliefs of graduates from school J.

It is easy to see from (1) that the belief updating function satisfies the following properties, which are intuitive in the context of peer influence. First, confident individuals are persuasive. For example, if an individual k has extreme beliefs at one or zero, then he fully convinces all others. Second, beliefs upon graduation are monotone; they increase in the parent's beliefs and in peers' beliefs. Finally, belief updating can also exhibit *polarisation*: For a set of beliefs where all are higher (lower) than a half, then updated beliefs would be higher (lower) than the maximum (minimum) belief in the set. We will show later on that dynasties with pessimistic beliefs will tend to segregate together; the feature of polarisation will then facilitate the echo chamber effect as an agglomeration of pessimistic beliefs will overcome true learning in the labour market.

3.2 The labour market: employment and learning

In this model we show that polarisation and wrong beliefs can have real economic consequences, and specifically, we focus on labour market discrimination. As in Black (1995), discrimination due to wrong beliefs will typically be characterised by losses for employers and employees alike. State school employees will be discriminated against, whereas employers with wrong beliefs will incur loses due to suboptimal behaviour, e.g., they forgo opportunities to employ. We focus on the simplest labour market interaction that delivers these two features, but our results hold for a more general environment.

Specifically, let school graduates at time t make up the two sides of the labour market. Any individual, disregarding her education path, becomes an employer with probability

[18] Note that given the continuum of dynasties, two dynasties will meet with probability 0. Thus, conditional on initial beliefs being derived from independent sources, all future exchanged beliefs would still be conditionally independent.

γ and an employee with probability $1-\gamma$ (the analysis can be extended to asymmetric probabilities). Employers and employees are matched randomly. To fix ideas, let $\gamma < \frac{1}{2}$, so an employer is matched for sure, while an employee is matched with probability $\frac{\gamma}{1-\gamma} < 1$ (this is not important and can be reversed).

We assume that an employee always prefers to work, while the employer decides whether to employ the individual he is matched with. The gain for the employer is the productivity of the employee, and the cost is a wage w (paid to the employee) drawn independently for each match according to a uniform distribution on $[0,1]$.[19] The randomness of the wage is a simple way to model employers with wrong beliefs taking suboptimal actions. In particular, an employer who is matched with a private school graduate, about which all have correct beliefs, will always employ as $w \leq 1$. On the other hand, an employer from dynasty i will employ a state school graduate employee at time t only if $w \leq q_{i,g}^t$. If an employer decides not to employ, no profits or wages can be earned for that period. Thus, whenever $q_{i,g}^t < 1$, the behaviour of the employer is suboptimal as the true productivity of the worker is 1. In the Appendix we extend the analysis to an alternative labour market model in which wages are determined by Nash bargaining.

To stack the odds against wrong beliefs, we assume that the labour market experience entails learning: Following the employment phase, all private-school graduates who were either employed by or employed a state school graduate, receive a signal that increases their beliefs. To simplify the information structure, assume that the signal indicates that the productivity of the employee/employer is 1, and is correct with probability $\tau \in (0.5, 1)$. Post employment, individuals then update beliefs to $q_{i,e}^t$, which, by Bayes rule, is given by,

$$q_{i,e}^t = \frac{q_{i,g}^t \tau}{q_{i,g}^t \tau + (1-q_{i,g}^t)(1-\tau)} \text{ if } i \text{ was in an active match with a state school graduate,} \tag{2}$$

and $q_{i,e}^t = q_{i,g}^t$ otherwise. Denote by $f_e^t(.)$ the distribution of beliefs in the population as a whole following the employment activity at time t.

3.3 Parental school choice

Following employment, individuals become parents, transmit their beliefs to their children, i.e., $q_i^{t+1} = q_{i,e}^t$, and decide which school to send them to. Let Δ_i^t be the willingness to pay of a parent from dynasty i for the private school. In other words, Δ_i^t is the perceived future payoff of the child in the labour market in period $t+1$, conditional on attending the private school, relative to that payoff conditional on attending the state school. The parent will calculate this expected labour market payoff from each school given her forecast

[19] The assumption of a uniform distribution is not important for the results.

of how the offspring's beliefs will change in each school, and her forecast of the behaviour of employers in period $t+1$. Importantly, the parent would compute Δ_i^t given what she believes to be the "true" expected state school productivity, $q_{i,e}^t$. Note that a parent here only cares about her direct offspring.

The willingness to pay Δ_i^t (which we will derive formally in the next Section) will consist of two components. First, in the model, state school graduate employees may be discriminated against. If parents foresee this correctly, they will -disregarding their own beliefs- prefer to send their child to a private school. Second, parents may understand that their child's belief will change which will affect their behaviour as employers. They will therefore prefer to send them to the school that will induce the *best beliefs from their own point of view.* This assumption, of "imperfect empathy", implies that they would prefer their offspring beliefs to stay as close as possible to their own. Such induced homophily would facilitate the echo chamber effect and convergence to wrong beliefs.

Note that even though parents realize that their offspring will be influenced by others' beliefs, the parents themselves do not update their beliefs anymore. Imperfect empathy implies "old age rigidity" of beliefs. This phenomenon is recently documented in the literature (see Ortoleva and Snowberg 2015). In our model, young individuals are influenced by the environment they grow up in, but when they grow old and after they have accumulated job market experience, parents believe that their assessment is the correct one. They are aware however that the environment they choose to raise their children in (that is, the school they send them to), will affect their children's beliefs and hence their future behaviour.

We model "school choice" in the following simple way: We assume that at any time t, the private school admits a share ρ of individuals with the largest Δ_i^t, conditional on $\Delta_i^t \geq 0$ (and the largest share feasible subject to $\Delta_i^t \geq 0$ if this constraint is satisfied for a share lower than ρ). Thus, the school admits all those with the largest willingness to pay, subject to the school's capacity constraint.

Note that we abstract away from any income differences that might prevent some from attending the private school. Income differences will only exacerbate segregation (see the discussion in Section 5.1). For now, dynasties only differ in their beliefs, which will determine their willingness, but not their ability, to pay for the private school.

3.4 Equilibrium definition

An equilibrium in the infinite game given some initial state in Period 1 (an allocation of a measure ρ of dynasties to the private school) is a dynamic process of school peer influence, labour market behaviour, and parental school choice, in which, at any period t, the following is satisfied:

(i) *Optimal employers' behaviour*: At any period $t = 1, 2, ..,$ employers employ state school graduates only if $w \leq q^t_{i,g}$ and always employ private school graduates.

(ii) *Bayesian belief updating:* For each dynasty i, and period $t = 1, 2, .., , q^t_i$ is updated to $q^t_{i,g}$ according to (1) given the distribution of beliefs $f^t_p()$ and $f^t_s()$ in period $t = 1, 2...,$ and $q^t_{i,g}$ is updated following employment to $q^t_{i,e}$ according to (2).

(iii) *Correct parental beliefs and optimal school choice:* Parents at period $t = 1, 2, ...$ compute Δ^t_i using imperfect empathy and their own beliefs $q^t_{i,e}$, given a correct expectations of how their offspring's beliefs will change in each school, and the correct expectation of the equilibrium behaviour of employers in period $t + 1$.[20] The measure ρ of dynasties with the highest Δ^t_i are admitted to the private school.[21]

Proposition 0: *An equilibrium exists.*

4 Segregation, polarisation and discrimination

Where will society converge in the long run? To be more specific, we consider the following question: Suppose individuals have correct beliefs, but for a subset of them, which attends the private school and is endowed with beliefs that private school graduates are more productive. In the presence of parental school choice and peer influence in schools, will such wrong beliefs persist in the long run? Will it lead to polarisation of beliefs and long-run discrimination?

We therefore consider the following initial state: In Period 1 there is a proportion ρ in the private school with beliefs $q^1_i = q < 1$ and a proportion $1 - \rho$ in the state school with beliefs $q^1_i = 1$. Given this simple initial state, we will now characterise all long-run equilibria. We then extend the same result to other initial states as we remark below.

We start with a benchmark in which there is no echo chamber effect in schooling. This case can be modeled by assuming that peers do no affect each others' beliefs in school. In our model, this arises when $n = 0$. The next result characterises the long term distribution of beliefs in any sequence of equilibria.[22]

Proposition 1: *Let* $n = 0$. *In any sequence of equilibria all dynasties converge to have beliefs at* $q^\infty_i = 1$.

When there is no interaction in school, a dynastic belief can only change in the labour market, and this is due to true learning. As any dynasty with wrong beliefs will always

[20] That is, parents know the present distribution of beliefs $f^t_e(.)$, the equilibrium school choices of other parents (and hence the correct distribution of beliefs in school J in period $t + 1$, $f^{t+1}_J(.)$), and have the correct forecast of the distribution of beliefs following graduation from school J, $f^{t+1}_{J,g}(.)$.

[21] All proofs are in the Appendix.

[22] This result holds for any initial state.

learn with a strictly positive probability, all dynasties will converges to have beliefs which put probability one on the truth. Therefore, to sustain long run polarisation of beliefs, we must have an echo chamber effect in schools.

Assume now that $n > 0$. Our main result characterizes a simple necessary and sufficient condition on q : When it is low enough society will converge to polarised beliefs, and if it is high enough all will converge to have the same belief.

Proposition 2: *Let $n > 0$ and let*

$$q^*(\tau, n) \equiv \frac{(1-\tau)^{\frac{1}{n}}}{\tau^{\frac{1}{n}} + (1-\tau)^{\frac{1}{n}}}.$$

Then: (i) ***Polarisation****: Whenever $q \leq q^*(\tau, n)$, in all equilibria, a constant set of dynasties of measure ρ attends the private school, discriminates against state school graduates, and has beliefs that converge to a degenerate distribution on 0. (ii)* ***No Polarisation:*** *Whenever $q > q^*(\tau, n)$, in all equilibria, all individuals converge to have the same, correct, beliefs. (iii)* ***Comparative Statics:*** *The cutoff $q^*(\tau, n)$ decreases in τ, the intensity of learning in the labour market, and increases in n, the intensity of peer influence.*

Other initial states: (i) The result remains exactly the same if in the initial state the dynasties in the private school do not have the same beliefs but some distribution of beliefs over $(0, q]$. **(ii)** The result remains exactly the same if the initial state is generalized to allow initial wrong beliefs in the state school as well. We show this in Proposition 2A in the Appendix.

A sufficient level of initial segregation can therefore lead to long-run segregation, polarised beliefs, and labour market discrimination. Even if dynasties are exposed to many positive signals, or get relatively accurate information in the labour market (a higher τ), they are also exposed to many negative beliefs of peers about the productivity of state school graduates. The tendency of individuals to exchange information with like-minded individuals (which arises in our model due to imperfect empathy) leads to the echo chamber effect which overcomes new and true information that is learned the labour market.

When $q \leq q^*(\tau, n)$, in all equilibria the process of convergence to extreme beliefs is characterized by a constant set of private school dynasties that send their offspring to the private school, have beliefs that converge to the lowest value, and employ private school graduates with a higher probability than state school graduates. Note that observations of wage inequalities in equilibrium will just reinforce beliefs. Private school dynasties who observe wage inequalities and unemployment only among state school graduates reaffirm their belief that state school graduates have lower productivity, while state school dynasties will claim that this arises from discrimination.

How does segregation persist to polarise beliefs sufficiently in the long run? For this to arise, beliefs in the private school have to be sufficiently low throughout time. In other words, dynasties with sufficiently low beliefs need to have the highest willingness to pay for the private school (compared with others in the population). We then need to consider the trade-offs facing the parents.

Consider Δ_i^t, the relative labour market benefit from sending a child to the private school vis a vis the state school. The parent in dynasty i will compute her offspring's utility given her own beliefs, $q_{i,e}^t$, and her forecast of how the offspring's beliefs will change in each school, depending on her forecast of the behaviour of employers in period $t+1$.

Suppose that at period t the beliefs of those in the state school are still all at one, as in the initial state. In equilibrium, a parent realises that at period $t+1$, all employers hire a private school graduate employee, and that a state school employer hires all. There are therefore two events in which school choice is relevant. First, with probability $(1-\gamma)\frac{\gamma}{1-\gamma}\rho = \gamma\rho$ the offspring becomes an employee and is matched with an employer who is a private-school graduate. In this case, if she herself went to the private school she is employed for sure (and receives in expectations a wage equal to $\frac{1}{2}$), but if she went to the state school she will only be employed with some probability (and thus receive a lower wage on average). Specifically, she is employed by an individual from dynasty l only if $w \leq q_{l,g}^{t+1}$. Thus, given the (correct) equilibrium future distribution $f_{p,g}^{t+1}(.)$ of private-school graduates' employers from dynasties l and their beliefs $q_{l,g}^{t+1}$, the relative benefit from attending a private school in this case is:

$$\frac{1}{2} - \bar{w}^{t+1} \tag{3}$$
$$\text{where } \bar{w}^{t+1} \equiv \int_0^1 \left[\int_0^{q_{l,g}^{t+1}} w dw\right] f_{p,g}^{t+1}(q_{l,g}^{t+1})\, dq_{l,g}^{t+1} \leq \frac{1}{2}$$

This term $\frac{1}{2} - \bar{w}^{t+1}$, is non-negative and would induce *all* parents to prefer to send their child to the private school. As long as those in the state school have beliefs at one, and those in the private school have lower beliefs, state school graduates employees are discriminated against and it is better to attend a private school.

The second case in which a benefit or a loss from attending a private school arises, is when the offspring becomes an employer and is matched with an employee who is a state school graduate. This happens with probability $\gamma(1-\rho)$. If she is a private school graduate, she would employ the state school graduate if $w \leq q_{i,g}^{t+1} = \chi(\mathbf{q}^{t+1}, q_{i,e}^t)$. Upon employing, she would pay some $w \leq q_{i,g}^{t+1}$, and gain -from the point of view of her parent- an expected payoff of $q_{i,e}^t - w$. Taking expectations over all possible peer influence vectors, $\mathbf{q}^{t+1}$, going to the private school in this event would generate:

$$\pi_i^t \equiv \int_{\mathbf{q}^{t+1}} [\int_0^{\chi(\mathbf{q}^{t+1}, q_{i,e}^t)} (q_{i,e}^t - w)dw] \; f_{p,n}^{t+1}(\mathbf{q}^{t+1}) \; d\mathbf{q}^{t+1},$$

which depends on the school choices of other parents or in other words the expected equilibrium distribution over vectors of length n of peer beliefs in the private school, $f_{p,n}^{t+1}(\mathbf{q}^{t+1})$. If on the other hand the individual is a state school graduate, she would employ the matched state school graduate for sure, gaining -in the eyes of her parent- an expected net payoff of $q_{i,e}^t - \frac{1}{2}$. Thus, the relative gain/loss from attending a private school in this event is:

$$\hat{\Delta}_i^t \equiv \pi_i^t - (q_{i,e}^t - \frac{1}{2}). \tag{4}$$

This term $\hat{\Delta}_i^t$ embodies the imperfect empathy assumption, and can be negative or positive. If the beliefs of the parent are low, the induced behaviour of the offspring if she goes to the state school is far worse than that induced by the private school, yielding $\hat{\Delta}_i^t > 0$. However, if the beliefs of the parent are relatively high, sending the child to a private school might represent a loss as peer influence might substantially decrease the offspring's beliefs. When $q_{i,e}^t = 1$ then $\hat{\Delta}_i^t = 0$, as in this case $\chi(\mathbf{q}^{t+1}, q_{i,e}^t) = 1$ for all $\mathbf{q}^{t+1}$.

Putting (3) and (4) together, we have that given a parental belief $q_{i,e}^t$, the benefit from a private school vis a vis a state school is:

$$\Delta_i^t = \gamma(\rho(\frac{1}{2} - \bar{w}^{t+1}) + \hat{\Delta}_i^t \tag{5}$$

The value of $q^*(\tau, n)$ insures that dynasties in the private school, following peer influence and labour market experience, *will end up with lower beliefs than they had started with.* As this process continues, their beliefs will converge to zero. At the same time this also implies that these dynasties want to send their children to private schools more than state school parents do. Specifically, we show that when the beliefs of all dynasties i in the private school are low enough, then $\hat{\Delta}_i^t > 0$, implying that there will be no "contamination" or replacement by individuals with beliefs at 1.

When will segregation break down? suppose that initial beliefs are above $q^*(\tau, n)$. This implies that while the belief of some may decrease (if for example they do not hire a state school graduate), there would be a share of individuals for whom beliefs, following peer influence and labour market experience, will increase. But under a contemplated segregation, beliefs of many in the private school must converge to zero; this implies that for the dynasties whose beliefs keep increasing with time, peer influence in the private school would, at some point, induce a large swing in beliefs (and thus suboptimal labour market behaviour). In other words, we would have that for some private school dynasties, $\hat{\Delta}_i^t < 0$. But for state school parents $\hat{\Delta}_i^t = 0$, as their offspring is not influenced in the private school. Therefore, state school parents will have higher willingness to pay for the

private school and will be able to send their offspring there. A process of contamination of beliefs will start and segregation will eventually break down.[23]

In reality, segregation would not be that easy to break. It might be that new entrants to the private school from state school dynasties would not immediately interact with others and fully convince them, as the literature on "within school segregation" discusses (see Echenique *et al* 2006). Even informal interactions may depend on background, beliefs, or income. This implies that segregation is underestimated in the model or that its breakdown would be a slow process. We discuss in Section 5.1 other ways which make polarisation and segregation harder to break.

Unequal productivities: We now consider a simple extension of the model that illustrates that what is important in our analysis is not the fact that productivities in the two schools are equal, but that individuals might overestimate the differences.

Suppose that the true productivity of state school graduates is some $\theta < 1$ (while that of private school graduates is 1, known to all). Thus beliefs at period t are that the productivity of state school graduates is θ with some probability $q_i^t > 0$, and zero otherwise. We again start with the initial condition that in Period 1, a share ρ is in the private school and believe that state school productivity is θ with probability $q_i^1 = q < 1$ and a share $1 - \rho$ is in the state school and has beliefs $q_i^1 = 1$. We can then extend our proof of Proposition 2 in a straightforward way to show more generally:

Proposition 3: *Suppose that the true productivity of state school graduates is $\theta < 1$. Then Proposition 2 holds.*

Note that true beliefs in this case would imply that individuals would prefer to hire private school graduates. However, if we start from sufficient segregation in beliefs across schools, then in the long run wrong beliefs will persist and polarise, and would have discrimination over and above what it should be. This again would be a result of endogenous segregation of specific dynasties with sufficiently low beliefs.

5 Discussion

We first discuss factors that increase the instances of polarisation, segregation and discrimination. We then discuss policies that can reduce the occurrence of such phenomena.

[23] The fact that the school has a capacity constraint and always admits a fixed share ρ is not important for this result. More generally, if the private school admits those with the highest willingness to pay (as all pricing mechanisms would), those with the "wrong" beliefs for the school will eventually enter.

5.1 The persistence of polarisation and segregation

Segregation and long run polarised beliefs may be underestimated in our model. We now discuss some factors which, in reality, may increase its occurrence.

Interviews and the legacy criterion: Proposition 2 had illustrated that segregation will eventually break down if the initial state does not consist of sufficiently many individuals with low beliefs in the private school. The reason for this is that the willingness to pay to the private school of some with intermediate beliefs will at some point become lower than those with very high beliefs, implying a contamination of the pool of beliefs in the private school. This would hold with more general pricing mechanisms that rely on willingness to pay.

One strategy of private schools to avert this is to base admittance on the actual beliefs held by the dynasty member. Accepting those with low enough beliefs may not maximize profits, but will certainly maximize the chances of survival of the private school. Our model can then shed light on why many private schools and top universities use interviews or legacy criteria for admissions. In the prism of our model, interviews allow schools to screen students according to views and family values, making sure that only those with the "right" beliefs or values are admitted.[24] A legacy criteria allows universities to maintain a significant cohort in the school coming from the same families, this allows the school to better control and protect specific values and belief systems.[25]

Income effects: We have abstracted away from income effects. It is clear that an unequal distribution of income or wealth would only exacerbate polarisation. The private school is the costly school. Even if a parent from a state school dynasty has a higher willingness to pay for the private school compared with a parent from a private school dynasty, she may not have the means to do it. This implies that it may not be as easy to break segregation as we had described above

Another element in our model which is affected by income is learning on the job market. If getting a placement in a company demands a period of unpaid internship, then those with low income -which by definition are more likely to be in state education- are less likely to be able to afford it. This means that there are less opportunities to learn about their type.

[24] Indeed, web sites that provide advice for private schools' prospective students in the UK explain that it is important to mention in an interview that previous generations in the family have attended the school. Interview advice for the parents themselves includes "expect to talk about yourself..remember to discuss long term values for your child".

[25] The Ivy League institutions are estimated to admit 10% to 30% of each entering class using this factor. The former president of Harvard University, Larry Summers, has stated: "Legacy admissions are integral to the kind of community that any private educational institution is."

Other segregated interactions and communication: We have allowed the environment to affect an individual's beliefs only through her school peers. But individuals in schools or universities may be affected by the school ethos more generally, as a result of information and messages transmitted by headteachers, university alumni, etc. This can further strengthen discriminatory beliefs.

Individuals also interact in other environments, such as the workplace or neighbourhoods. Neighbourhoods and hence workplaces can also be segregated by beliefs as location choices are often related to school choices.[26] Additional segregated communication will exacerbate polarised beliefs even more as we now show. Suppose for example that as adults, following their labour market experience, private school graduates interact with m other private school graduates and exchange their posterior beliefs. We then have:

Proposition 4: *Let*

$$q_m^*(\tau, n) = \frac{(1-\tau)^{\frac{m+1}{n+m+nm}}}{(1-\tau)^{\frac{m+1}{n+m+nm}} + \tau^{\frac{m+1}{n+m+nm}}} > q^*(\tau, n).$$

Then Proposition 2 holds. That is, whenever in the initial state $q \leq q_m^*(\tau, n)$ all equilibria are characterised by a constant set of dynasties of measure ρ having long run wrong beliefs and attending the private school, whereas when $q > q_m^*(\tau, n)$ all converge to have the same, true, beliefs. Moreover, $q_m^*(\tau, n)$ increases in m.

5.2 How to stop segregation and polarisation?

In our model, segregation and polarised beliefs induce inefficiencies: Discrimination is distortionary as state schools graduates miss employment opportunities, while private school employers miss opportunities to employ.

As discussed above, income effects, school ethos, or other network effects can all play a role to increase segregation. What can decrease its incidence? We discuss some possibilities below.

The long-term effects of integration: The literature on integration in schools has mainly focused on academic achievements of participants as the potential benefit of integration (see Sacerdote 2011 and Angrist and Lang 2004). Our analysis suggests that integration might have long-term effects: In our model, integration in schools would affect the beliefs of individuals through peer influence and so their behaviour in the labour market later on in their lives. A recent empirical literature shows how beliefs indeed evolve as a result of integration (see Boisjoly *et al* 2006, Kaufman and Harris 2015, La Ferrara *et al* 2014 and Algann *et al* 2015).

[26] See Gentzkow and Shapiro (2011).

As with the potential effect of integration on academic achievement, the actual level of interaction among the different students is important. If for example pupils from state school dynasties are integrated into a private school but interact only with one another, the beliefs of the private school dynasties will not be affected. Thus, integration has to be happening in practice for such policies to have an effect.

Labour market and anti-discrimination policies: Proposition 2 shows that better learning in the labour market (captured by the parameter τ) will increase the instances in which we have convergence to long run wrong beliefs. This can arise for example when we have a longer probation period for employees before they can be let off, so that employers can learn better about state school graduates.

Our framework also allows us to assess common anti-discrimination policy interventions. Consider a simple policy which induces private school employers to hire more graduates from state schools. One way to model the consequences of such a policy is to assume that a private school employer hires a state school graduate if $w < q^t_{i,g} + \lambda$, for some $\lambda > 0$. This can be thought of as a subsidy given to an employer who hires a state school graduate or a punishment for the employer who does not abide by anti-discrimination laws. In any case, the instances of hiring state school graduates by employers would increase.

While this policy will surely decrease discrimination, it will not have a direct effect on the incidence of segregation and polarisation. Specifically, the necessary and sufficient condition for segregation we had derived above will not be affected by λ. The condition is computed at the worst case scenario for segregation, in which a state school graduate is hired in any case. Whenever the condition is satisfied, then in all equilibria beliefs in the private school will converge to zero and state school graduates will be employed by private employers iff $w < \lambda$. As long as $\lambda < 1$, some discrimination will persist. Thus, anti-discrimination policies -as long as they are not absolute and fully enforced- would be more effective coupled with policies that also affect beliefs directly.

The winners and losers from segregation: One feature of the basic model is that when school fees are taken into account, then in the long term, private school dynasties have a lower per period utility than state school dynasties. While private school graduates enjoy a better employment market, they also pay private school fees which extract their willingness to pay. This willingness to pay however is in part based on wrong beliefs which is not recuperated in the market later on.

This may be an artefact of the simple model we are using, as we had stacked the model against segregation and its benefits. As discussed above, fees may be lower and still prevent state school dynasties from entering if for example admission policies are partly based on interviews. This would imply that the willingness to pay of private school parents

is not extracted. In addition, the constraint in our model that state school dynasties need to be deterred from entry with a low willingness to pay may be exaggerated: they may have high willingness to pay but no means to do so, due to income effects discussed above. In a more general model, wrong beliefs can also be two-sided, that is, state school dynasties may also overestimate the benefits of state schools. Thus state school dynasties can lose as employers as well.

Even so, it might be true that private education is indeed not beneficial in reality. Recent data in the UK supports the observation that private schools are not beneficial on average, when parental background and school fees are taken into consideration.[27]

6 Concluding remarks

In this paper we analyse a model of the coevolution of segregation and polarisation of beliefs. Our model is one of segregation along acquired traits which fits many applications including primary and secondary schooling (private versus state, secular versus religious). Higher education is another good example. The forces that shape segregation and beliefs in our model could be behind what some have dubbed "the higher education bubble".[28]

Segregation often occurs along inherited traits, such as race, ethnicity or gender. An interesting line of research would be to add inherited traits into our analysis. In a world in which it is illegal to discriminate along such traits, schooling and location choices might be used as proxies to allow *de facto* segregation and discrimination to persist.

In practice, the ADA and Title VII of the Civil Rights Act have been used to challenge alleged "educational discrimination" practices. A famous example is Griggs v. Duke Power Company from 1971, in which the employer had adopted a high-school diploma requirement for all positions in four of its five departments without "meaningful study" of its "relationship to job-performance ability", based on the untested belief that doing so would "improve the overall quality of the work force." The Court decided that the requirement was unlawful because it had a disparate impact on African Americans, who had high school diploma rates far lower than Whites in the relevant geographical area, and because the requirement was not job related for the positions in question and consistent with business necessity. The Court stated:[29] "The evidence...shows that employees

[27] A report by the Social Market Foundation calculated that the higher educational achievement and university degrees accrued by private school pupils translated to £193,000 in higher earnings between the ages of 26 and 42. After adjusting for family background and social circumstances, the private school pay advantage was £57,000. However, ten years' worth of average private school fees in 1980 would be similar in scale -around £56,000 in today's prices. See http://www.theguardian.com/education/2014/jul/03/subsidy-independent-school-fees.

[28] http://www.economist.com/blogs/schumpeter/2011/04/higher_education

[29] Griggs, 401 U.S. at 431-33.

who have not completed high school...have continued to perform satisfactorily and make progress in departments for which the high school...criterion [is] now used...The facts of this case demonstrate...the infirmity of using diplomas or degrees as fixed measures of capability. History is filled with examples of men and women who rendered highly effective performance without the conventional badges of accomplishment in terms of certificates, diplomas, or degrees. Diplomas and tests are useful servants, but Congress has mandated the commonsense proposition that they are not to become masters of reality." The courts and the EEOC have applied the holding in Griggs consistently, and Congress confirmed it when it amended Title VII in the Civil Rights Act of 1991.

7 Appendix

7.1 Appendix A: Proofs

Proof of Proposition 0: At any period t, construct the self correspondence $\Gamma : [0,1] \to 2^{[0,1]}$ in the following way. For any set of beliefs S of measure ρ that is composed of intervals in $[0,1]$, the correspondence assigns a measure ρ of dynasties that have the highest Δ_i^t, given that the set S attends the private school.[30] To complete the description of the correspondence, assign any individual that is indifferent between attending the state and private school to the private school. For any S, $\Gamma(S)$ is never empty. Thus, this correspondence is closed. Moreover, the set $[0,1]$ is compact. By Ok (2004), the set $[0,1]$ has the fixed set property so that every closed self correspondence has a fixed set. We can therefore always construct a sequence of fixed sets for $t = 1, 2, ...$■

Proof of Proposition 1: At period 1 all dynasties in the private school have beliefs at $q_i^1 = q$ where $q > 0$. Note that as $n = 0$ for all such dynasties, $q_i^t \geqslant q$. Any dynasty at period t has a strictly positive probability, bounded below by $q\gamma(1-\rho)$, of employing a state school graduate and therefore updating their belief to $\frac{q_i^t\tau}{q_i^t\tau+(1-q_i^t)(1-\tau)} > q_i^t$. Therefore, all dynasties will converge to a belief q_i^∞ such that $q_i^\infty = \frac{q_i^\infty\tau}{q_i^\infty\tau+(1-q_i^\infty)(1-\tau)} \Leftrightarrow q_i^\infty = 1$.■

Proof of Proposition 2:

Preliminaries: For short, let $q^*(\tau, n) \equiv q^*$. Note that: (i) the condition in the Proposition implies that $q^* < 0.5$; (ii) When the individual with beliefs q^*, interacts in the worst case scenario with n other individuals with the same beliefs, his beliefs become $q_g^* \equiv \frac{q^{*n+1}}{q^{*n+1}+(1-q^*)^{n+1}} < q^*$ (as $q^* < 0.5$). If such an individual later on employs a state school graduate, his beliefs become $q_e^* = \frac{q_g^*\tau}{q_g^*\tau+(1-q_g^*)(1-\tau)}$. If $\frac{q_g^*\tau}{q_g^*\tau+(1-q_g^*)(1-\tau)} = q^*$, then the dynasty's beliefs are still at $q^* < \frac{1}{2}$. The condition in the Proposition insures that

[30] Note that at period t the domain of the set of beliefs is not necessarily connected but it is closed and bounded.

$\frac{q_g^*\tau}{q_g^*\tau+(1-q_g^*)(1-\tau)} = q^*$. Moreover, the mapping of q to $\frac{q_g\tau}{q_g\tau+(1-q_g)(1-\tau)}$ has a unique fixed point q^*, so that for all $q < q^*$, $\frac{q_g\tau}{q_g\tau+(1-q_g)(1-\tau)} < q$, and for all $q > q^*$, $\frac{q_g\tau}{q_g\tau+(1-q_g)(1-\tau)} > q$. Note that q^* represents the worst case scenario, so that dynasties that will not experiment, will have lower beliefs than q^*.

With some abuse of notation, let Δ_1^t denote the relative benefit from the private school of individuals with beliefs at 1.

Sufficiency: We know from the above that beliefs in the private school always remain below $q^* < \frac{1}{2}$. We will now show that for all $q_{i,e}^t < \frac{1}{2}$, given that beliefs in the private school are interior, then $\hat{\Delta}_i^t > \hat{\Delta}_1^t = 0$, and thus only the original set of dynasties will continue to attend the private school, and individuals from the state school will not "contaminate" beliefs in the private school. We therefore need to show that:

$$\begin{aligned}
&\hat{\Delta}_i^t \\
&= \pi_i^t - (q_{i,e}^t - \frac{1}{2}) \\
&= \int_{\mathbf{q}^{t+1}} (\int_0^{\chi(\mathbf{q}^{t+1}, q_{i,e}^t)} (q_{i,e}^t - w)dw) dF_{p,n}^{t+1}(\mathbf{q}^{t+1}) - (q_{i,e}^t - \frac{1}{2}) > 0,
\end{aligned}$$

where $F_{p,n}^{t+1}(\mathbf{q}^{t+1})$ is the distribution over vectors $\mathbf{q}^{t+1}$ of length n of beliefs of children in the private school as inherited from their parents (recall that $q_i^{t+1} = q_{i,e}^t$).

Note however that $q_{i,e}^t < \frac{1}{2}$, and that $\int_0^{\chi(\mathbf{q}^{t+1}, q_{i,e}^t)} (q_{i,e}^t - w)dw = \chi(\mathbf{q}^{t+1}, q_{i,e}^t)q_{i,e}^t - \chi(\mathbf{q}^{t+1}, q_{i,e}^t)^2/2 > 0$ as such function is strictly concave, is maximised at $q_{i,e}^t$, and $\chi(\mathbf{q}^{t+1}, q_{i,e}^t) \leq q_{i,e}^t$ as beliefs in the private school are lower than a half. This implies that $\hat{\Delta}_i^t > 0$.[31]

Finally note that the beliefs in the private school would converge to the singleton 0 as they are always below a half. This concludes the sufficiency part as the measure ρ of private school dynasties dynasties will have a strictly high willingness to pay for the private school compared with state school dynasties.

Necessity: Suppose that the condition in the proposition is violated so that $[\frac{q}{1-q}]^{n-1} > \frac{1-\tau}{\tau}$. This implies that $q > q^*$ and that at any point in time, all those in $(q^*, q]$, if they draw only peers from this set, will have new beliefs that are higher then what they started with. In particular, one can find sequences of dynasties whose beliefs will converge to one. We will show that this implies that we can find a positive measure of such dynasties, for whom eventually $\hat{\Delta}_i^t < \hat{\Delta}_1^t = 0$.

[31] We have used the uniform distribution of wages in computing $\int_0^{\chi(\mathbf{q}^{t+1}, q_{i,e}^t)} (q_{i,e}^t - w)dw$. In fact any distribution that first order stochastically dominates the uniform will satisfy the condition. For other distributions, one would potentially need to add another condition to insure that no "contamination" arises but there would always be a low enough initial q^* that would satisfy such condition. The necessary part does not depend on the uniform distribution at all.

Note that given the binary state of nature, dynasties must converge to have beliefs on zero, one or a half (the latter can arise as if all have beliefs at a half, then the updated beliefs will be half as well). We next show that long term segregation implies that a strictly positive measure of dynasties will converge to beliefs of zero.

First note that if long term segregation exists, it cannot be that almost all dynasties converge to have beliefs at one. If this is the case then the benefit from sending one's child to the private school, for any parent, will converge to that of state school parents.

The next step is to note that if the measure of dynasties whose beliefs converge to zero goes to zero, then it must be that the measure of dynasties whose beliefs converge to one, goes to one. To see this note that if there was in the limit a strictly positive measure of dynasties with beliefs converging to a half, this would unravel as these dynasties would learn from work experience with strictly positive probability, and their beliefs would drift towards one.

We will now look at the strictly positive measure of dynasties initially at $(q^*, q]$ whose beliefs are increasing and show that as a measure $\frac{\alpha}{2}$ of other dynasties have beliefs below ε, then their loss from peer influence in the private school is large.

To do so, we focus on such dynasties initially in $(q^*, q]$ whose beliefs increase sufficiently slow so that others can converge to have beliefs below ε. Specifically, note that by choosing which individuals in the private school members of a dynasty interact with each period, and whether they learn in the labour market, we can construct a feasible sequence of beliefs for a dynasty $\{q_i^t\}_{t=1}^{\infty}$ that lingers as long as we wish below a half, i.e. for any T we can find such a sequence such that $q_i^t \to 1$ but such that $q_i^t < 0.5$ for any $t < T$. Note further that by continuity of $\chi(\mathbf{q}^{t+1}, q_{i,e}^t)$ and full support we can also construct a whole set of such sequences all going to one in a similar rate.

Note now that for dynasty i at time t with beliefs $q_{i,e}^t$ we have:

$$\begin{aligned}
&\hat{\Delta}_i^t - \hat{\Delta}_1^t \\
&= \int_{\mathbf{q}^{t+1}} \left(\int_0^{\chi(\mathbf{q}^{t+1}, q_{i,e}^t)} (q_{i,e}^t - 1) dw \right) - \int_{\chi(\mathbf{q}^{t+1}, q_{i,e}^t)}^1 (1-w) dw \, dF_{p,n}^{t+1}(\mathbf{q}^{t+1}) + (1 - q_{i,e}^t) \\
&< - \int_{\mathbf{q}^{t+1}} \left(\int_{\chi(\mathbf{q}^{t+1}, q_{i,e}^t)}^1 (1-w) dw \right) dF_{p,n}^{t+1}(\mathbf{q}^{t+1}) + (1 - q_{i,e}^t)
\end{aligned}$$

Now choose ε and T_ε such that a measure $\frac{\alpha}{2}$ of dynasties have beliefs below ε. Note that if i interacts with n of these dynasties, the measure of all such interactions is $(\frac{\alpha}{2})^n$. Choose a sequence of a strictly positive measure of dynasties whose beliefs converge to one slow enough so that at T_ε their distance from one is $\eta > 0$ such that $\chi(\mathbf{q}^{t+1}, q_{i,e}^t)$ is at most 2ε. Then we will have:

$$\hat{\Delta}_i^t - \hat{\Delta}_1^t < -(\frac{\alpha}{2})^n \int_{2\varepsilon}^1 (1-w) dw + \eta < 0$$

whenever ε and η are low enough (note that α does not depend on ε). Thus in the next period a strictly positive measure of state school parents will send their kids to the private school.

Once a strictly positive measure of dynasties with beliefs at 1 enter the school, this will be the case for all future periods (as from that point onwards, the measure of dynasties with beliefs less than 1 is smaller than ρ). They will then "infect" whoever they meet and so all dynasties will converge to beliefs of 1 which is a contradiction to long term segregation.■

Proof of Proposition 2A: We now prove the results stated following Proposition 2 in the text, extending the initial condition to two cases. First, note that as case (i) states, if initial beliefs are in $(0, q^*]$, then nothing in the proof above changes. We now consider case (ii), where the initial beliefs in the state school are in $[\bar{q}, 1]$ and the initial beliefs in the private school are in $(0, q^*]$.

Let now Δ_1^t denote the relative benefit from the private school to a dynasty with beliefs at 1. Note first that whenever q^* is sufficiently low and $\bar{q}$ is sufficiently high, then $\hat{\Delta}_l^t - \hat{\Delta}_1^t \leq 0$ for any dynasty l with $q_{l,e}^t > \bar{q}$.

To see why note that in the state school, the beliefs of a dynasty always increase, as all other beliefs are greater than a half. This implies that the lowest bound on utility is attained when $\chi(\mathbf{q}^{t+1}, q_{l,e}^t) = 1$. For $q_{l,e}^t = 1 - \eta$, this utility for the event of becoming an employer and hiring a state school graduate amounts to $1 - \eta - \frac{3}{4}$. On the other hand, the best utility for this type in the private school would be when the interaction is with the highest type, q^*. If the resulting beliefs, satisfy $\frac{q^{*n}(1-\eta)}{q^{*n}(1-\eta)+(1-q^*)^n\eta} < 1 - 2\eta$, then the utility from this best interaction is lower implying that $\hat{\Delta}_l^t < \hat{\Delta}_1^t = 0$. This arises when $\frac{q^{*n}}{(1-q^*)^n} < \frac{1-2\eta}{2(1-\eta)}$. For a small enough η, this holds for all small enough $q^* < \frac{1}{2}$, which is satisfied by our condition. Thus $\hat{\Delta}_l^t - \hat{\Delta}_1^t \leq 0$.

This implies that for long term segregation, we need $\hat{\Delta}_l^t > \hat{\Delta}_1^t = 0$, for all $q_{l,e}^t \leq q^*$, while we know that segregation breaks down if $\hat{\Delta}_l^t < \hat{\Delta}_1^t = 0$ for some $q_{l,e}^t > q^*$ which had attended the private school at period t.

Consider the sufficiency then. If in equilibrium the same original dynasties in the private school remain in the private school, beliefs only decrease and converge to zero. To see that these dynasties remain in the school we need to show for any dynasty i in the private school, that $\hat{\Delta}_i^t > \hat{\Delta}_1^t = 0$ at any t, conditional on the set of dynasties in the private school remaining below q^*. Taking into consideration the distribution over vectors of beliefs in the state school, $F_{s,n}^{t+1}(\mathbf{q}^{t+1})$, the condition then becomes:

$$\int_{\mathbf{q}^{t+1}} \left(\int_0^{\chi(\mathbf{q}^{t+1}, q_{i,e}^t)} (q_{i,e}^t - w) dw \right) dF_{p,n}^{t+1}(\mathbf{q}^{t+1}) - \int_{\mathbf{q}^{t+1}} \left(\int_0^{\chi(\mathbf{q}^{t+1}, q_{i,e}^t)} (q_{i,e}^t - w) dw \right) dF_{s,n}^{t+1}(\mathbf{q}^{t+1}) > 0$$

Note that as above, the left element (the gain from the private school) is bounded from below by 0. On the other hand, for $\bar{q}$ sufficiently high, the best case scenario is for beliefs to end up at $\frac{q_{i,e}^t \bar{q}^n}{q_{i,e}^t \bar{q}^n + (1-q_{i,e}^t)(1-\bar{q})^n} \to 1$ yielding a limit of a negative utility of $q_{i,e}^t - 0.5$. Thus the condition above is satisfied.

Now consider the necessity. When segregation arises, as in the proof of Proposition 2, we can repeat the same proof as above, as for segregation to hold in the long term it is a necessary condition that $\hat{\Delta}_i^t - \hat{\Delta}_1^t \geq 0$. The only issue may arise if the dynasty whose beliefs increase and we follow is being replaced by a state school dynasty with some $q < 1$; we then continue to follow this new private school dynasty with these beliefs.■

Proof of Proposition 3: There are now three events in which the education path is relevant on the equilibrium path. First, with probability $(1-\gamma)\frac{\gamma}{1-\gamma}\rho = \gamma\rho$ the individual becomes an employee and is matched with an employer who is a private-school graduate. In this case, if she herself went to a private school she is employed for sure (and receives an expected wage of a half), but if she went to a state school she will only be employed with some probability. Specifically, she is employed by an individual from dynasty l only if $w < \theta q_{l,g}^{t+1}$. Thus, given some conjectured $f_g^{t+1}(.)$, the future distribution of employers' beliefs, the relative benefit for attending a private school in this case is:

$$\frac{1}{2} - \bar{w}^{t+1} \geq 0 \tag{6}$$
$$\text{where } \bar{w}^{t+1} \equiv \int_0^1 (\int_0^{\theta q_{l,g}^{t+1}} w dw) f_{p,g}^{t+1}(q_{l,g}^{t+1}) dq_{l,g}^{t+1}$$

Second, with probability $(1-\gamma)\frac{\gamma}{1-\gamma}(1-\rho) = \gamma(1-\rho)$, a graduate would meet a state school employer who would always employ a private school graduate but would only employ the state school graduate if $w < \theta$, i.e., the difference is:

$$\frac{1}{2} - \int_0^{\theta} w dw = \frac{1}{2} - \frac{\theta^2}{2}.$$

The third case in which a benefit or a loss from attending a private school arises, is when an individual becomes an employer and is matched with an employee who is a state school graduate (which happens with probability $\gamma(1-\rho)$). If she is a state school graduate herself, she would employ him if $w < \theta$, gaining -in the eyes of her parent- expected productivity of $\theta q_{i,e}^t$ while paying in expectations $\frac{\theta}{2}$. On the other hand, if she is a private school graduate, she would employ only if $w < \theta q_{i,g}^{t+1}$. Upon employing, she would pay some $w < \theta q_{i,g}^{t+1}$, and gain -from the point of view of her parent- productivity of $\theta q_{i,e}^t$. Thus we have that in this event the gain/loss from attending a private school, is:

$$\hat{\Delta}_i^t \equiv \pi_i^t - \int_0^{\theta} (\theta q_{i,e}^t - w) dw = \pi_i^t - \theta(\theta q_{i,e}^t - \frac{\theta}{2}) \tag{7}$$

where π_i^t is the expected gain, in the eyes of the parent, from the offspring being a private school graduate employer:

$$\pi_i^t \equiv \int_{\mathbf{q}^{t+1}} [\int_0^{\theta\chi(\mathbf{q}^{t+1},q_{i,e}^t)} (\theta q_{i,e}^t - w)dw] f_{p,n}^{t+1}(\mathbf{q}^{t+1})d\mathbf{q}^{t+1}$$

We therefore have that for a parent with belief $q_{i,e}^t$, the benefit from a private school vis a vis state school is:

$$\Delta_i^t = \gamma\rho(\frac{1}{2} - \bar{w}^{t+1}) + \gamma(1-\rho)(\frac{1}{2} - \frac{\theta^2}{2}) + (1-\gamma)(1-\rho)\hat{\Delta}_i^t. \tag{8}$$

Sufficiency: We know from the above that beliefs in the private school always remain below $q^* < \frac{1}{2}$. We will now show that for all $q < \frac{1}{2}$, given that beliefs in the private school are interior, then $\Delta_i^t > \Delta_1^t \Leftrightarrow \hat{\Delta}_i^t > \hat{\Delta}_1^t$. This implies that only the original dynasties remain in the school. We therefore need to show that:

$$\int_{\mathbf{q}^{t+1}} [\int_0^{\theta\chi(\mathbf{q}^{t+1},q_{i,e}^t)} (\theta q_{i,e}^t - w)dw] f_{p,n}^{t+1}(\mathbf{q}^{t+1})d\mathbf{q}^{t+1} - (\theta^2 q_{i,e}^t - \frac{\theta^2}{2}) > 0 = \hat{\Delta}_1^t.$$

A sufficient condition for this is that for any $\mathbf{q^{t+1}}$:

$$\int_0^{\theta\chi(\mathbf{q^{t+1}},q_{i,e}^t)} \theta q_{i,e}^t dw - \int_0^{\theta\chi(\mathbf{q^{t+1}},q_{i,e}^t)} w dw - \int_0^{\theta} \theta q_{i,e}^t dw + \int_0^{\theta} w dw > 0 \Leftrightarrow \tag{9}$$

$$\int_{\theta\chi(\mathbf{q^{t+1}},q_{i,e}^t)}^{\theta} (w - \theta q_{i,e}^t) dw > 0 \Leftrightarrow$$

where the last inequality holds whenever $q_{i,e}^t < \frac{1}{2}$ and $\chi(\mathbf{q^{t+1}},q_{i,e}^t) < 1$. This concludes the sufficiency part as the measure ρ of private school dynasties dynasties will have a strictly high willingness to pay for the private school compared with state school dynasties. Finally note that the beliefs in the private school would converge to the singleton 0 as they are always below a half.

Necessity: We can repeat the same proof as in Proposition 2 to show that whenever long term segregation arises and the condition is violated, then we can look at the strictly positive measure of dynasties at $(q^*, q]$ whose beliefs are increasing and show that as a measure $\frac{\alpha}{2}$ of other dynasties have beliefs below ε, then their loss from peer influence in the private school is large. To do so, we again focus on such dynasties in $(q^*, q]$ whose beliefs increase sufficiently slow so that others can converge to have beliefs below ε. Note

now that,

$$\begin{aligned}
&\hat{\Delta}_i^t - \hat{\Delta}_1^t \\
&= \int_{\mathbf{q}^{t+1}} \left(\int_0^{\theta\chi(\mathbf{q}^{t+1}, q_{i,e}^t)} (\theta q_{i,e}^t - \theta) dw \right) - \int_{\theta\chi(\mathbf{q}^{t+1}, q_{i,e}^t)}^{\theta} (\theta - w) dw \, dF_{p,n}^{t+1}(\mathbf{q}^{t+1}) + \theta^2 (1 - q_{i,e}^t) \\
&< - \int_{\mathbf{q}^{t+1}} \left(\int_{\theta\chi(\mathbf{q}^{t+1}, q_{i,e}^t)}^{\theta} (\theta - w) dw \right) dF_{p,n}^{t+1}(\mathbf{q}^{t+1}) + \theta^2 (1 - q_{i,e}^t)
\end{aligned}$$

Now choose ε and T_ε such that a measure $\frac{\alpha}{2}$ of dynasties have beliefs below ε. Note that if i interacts with n of these dynasties, the measure of all such interactions is $(\frac{\alpha}{2})^n$. Choose a sequence of a strictly positive measure of dynasties whose beliefs converge to one slow enough so that at T_ε their distance from one is $\eta > 0$ such that $\chi(\mathbf{q}^{t+1}, q_{i,e}^t)$ is at most 2ε. Then we will have:

$$\hat{\Delta}_i^t - \hat{\Delta}_1^t < -(\frac{\alpha}{2})^n \left(\int_{\theta 2\varepsilon}^{\theta} (\theta - w) dw \right) + \theta^2 \eta < 0$$

whenever ε and η are low enough (note that α does not depend on ε). Thus in the next period a strictly positive measure of state school parents will send their kids to the private school. We can then follow the remainder of the proof of Proposition 2.■

Proof of Proposition 4: Consider again how we had defined the cutoff q^* in Proposition 2 and let us modify it to the current extension of peer influence in the labour market. Specifically, as in Proposition 2, for segregation to hold we need that the dynasty at the upper bound of beliefs, following interaction in the school, learning through employment, and peer influence in the labour market, will end up with beliefs not higher than what they had started with. Thus, if there are m beliefs that an individual observes in the labour market, we need $\frac{(q_e^*)^{m+1}}{(q_e^*)^{m+1} + (1-q_e^*)^{m+1}} = q^*$ where $q_e^* = \frac{q_g^* \tau}{q_g^* \tau + (1-q_g^*)(1-\tau)}$, and $q_g^* = \frac{q^{*n+1}}{q^{*n+1} + (1-q^*)^{n+1}}$. The new cutoff becomes then

$$q_m^*(\tau, n) = \frac{(1-\tau)^{\frac{m+1}{m+n+mn}}}{\tau^{\frac{m+1}{m+n+mn}} + (1-\tau)^{\frac{m+1}{m+n+mn}}} > q^*(\tau, n) = \frac{(1-\tau)^{\frac{1}{n}}}{\tau^{\frac{1}{n}} + (1-\tau)^{\frac{1}{n}}}. \blacksquare$$

7.2 Appendix B: Endogenous wages

In this section of the Appendix we offer an alternative formulation of the labour market in which wages are determined by Nash bargaining. Suppose that in any period, for any employer, a position is made vacant. The new position requires a cost to train any new hire. The cost c is drawn unifromly from $[0, 1]$. If hired for the position, an employee with productivity $\theta \in \{0, 1\}$ will yield a net rent for the employer of $\theta - c$. If the employee is not hired, both the employer and the employee get zero in that period.

Given a belief $q^t_{i,g}$ of the employer, if the employee is hired, the total rents in the eyes of the employer are $q^t_{i,g} - c$. For simplicity of exposition we assume that the employee and the employer equally share these perceived rents generated by the match. Any (fixed) interior allocation is fine for our analysis.[32] Thus, a private school graduate will be employed by all, whereas a state school graduate employee will be employed by an employer from dynasty i at period t if and only if $c \leq q^t_{i,g}$.

With this formulation we can now prove Proposition 2:

Sufficiency: We know from the above that beliefs in the private school always remain below $q^* < \frac{1}{2}$. We will now show that for all $q < \frac{1}{2}$, given that beliefs in the private school are interior, then $\hat{\Delta}^t_i > \hat{\Delta}^t_1$. This implies that only the original dynasties remain in the school. We therefore need to show that:

$$\begin{aligned}
&\hat{\Delta}^t_i \\
&= \pi^t_i - (q^t_{i,e} - \frac{3}{4}) \\
&= \int_{\mathbf{q}^{t+1}} (\int_0^{\chi(\mathbf{q}^{t+1}, q^t_{i,e})} (q^t_{i,e} - c - \frac{\chi(\mathbf{q}^{t+1}, q^t_{i,e}) - c}{2}) dc) dF^{t+1}_{p,n}(\mathbf{q}^{t+1}) - (q^t_{i,e} - \frac{3}{4}) > 0 = \hat{\Delta}^t_1.
\end{aligned}$$

A sufficient condition for this is that for any $\mathbf{q^{t+1}}$:

$$\int_0^{\chi(\mathbf{q}^{t+1}, q^t_{i,e})} (q^t_{i,e} - c - \frac{\chi(\mathbf{q}^{t+1}, q^t_{i,e}) - c}{2}) dc) dF^{t+1}_{p,n}(\mathbf{q}^{t+1}) - (q^t_{i,e} - \frac{3}{4}) > 0,$$

and this holds as $q^t_{i,e} < \frac{1}{2}$. Finally note that the beliefs in the private school would converge to the singleton 0 as they are always below a half. This concludes the sufficiency part as the measure ρ of private school dynasties dynasties will have a strictly high willingness to pay for the private school compared with state school dynasties.

Necessity: We can repeat exactly the same proof as in Proposition 2, to show that eventually we would have a dynasty in the private school for whom $\Delta^t_i < \Delta^t_s$. Specifically, to show this, the condition would become:

[32] When the employer makes a take-it-or-leave-it offer he will offer a wage of zero to the employee leaving the whole surplus $q^t_{i,g} - c$ to himself. When the employee makes a take-it-or-leave-it offer he will offer a wage of $q^t_{i,g} - c$ leaving the employer with zero rents. When the bargaining power of the two sides is more even, they will share the surplus $q^t_{i,g} - c$ more evenly.

$$
\begin{aligned}
&\hat{\Delta}_i^t - \hat{\Delta}_1^t \\
&= (1 - q_{i,e}^t) + \int_{\mathbf{q}^{t+1}} \Big(\int_0^{\chi(\mathbf{q}^{t+1}, q_{i,e}^t)} (q_{i,e}^t - 1 + \frac{1 - \chi(\mathbf{q}^{t+1}, q_{i,e}^t)}{2}) dc \Big) \\
&\quad - \int_{\mathbf{q}^{t+1}} \int_{\chi(\mathbf{q}^{t+1}, q_{i,e}^t)}^1 (1 - c - \frac{1-c}{2}) dc \Big] f_{p,n}^{t+1}(\mathbf{q}^{t+1}) d\mathbf{q}^{t+1} \\
&< \chi(\mathbf{q}^{t+1}, q_{i,e}^t)(\frac{1 - \chi(\mathbf{q}^{t+1}, q_{i,e}^t)}{2}) - \int_{\mathbf{q}^{t+1}} \int_{\chi(\mathbf{q}^{t+1}, q_{i,e}^t)}^1 (\frac{1-c}{2}) dc \Big] \; f_{p,n}^{t+1}(\mathbf{q}^{t+1}) \; d\mathbf{q}^{t+1} + (1 - q_{i,e}^t)
\end{aligned}
$$

Now choose ε and T_ε such that a measure $\frac{\alpha}{2}$ of dynasties have beliefs below ε. Note that if i interacts with n of these dynasties, the measure of all such interactions is $(\frac{\alpha}{2})^n$. Choose a sequence of a strictly positive measure of dynasties whose beliefs converge to one slow enough so that at T_ε their distance from one is $\eta > 0$ such that $\chi(\mathbf{q}^{t+1}, q_{i,e}^t)$ is at most 2ε. Then we will have:

$$\hat{\Delta}_i^t - \hat{\Delta}_1^t < 2\varepsilon - (\frac{\alpha}{2})^n \int_{2\varepsilon}^1 (\frac{1-c}{2}) dc + \eta < 0$$

whenever ε and η are low enough (note that α does not depend on ε). Thus in the next period a strictly positive measure of state school parents will send their kids to the private school. This would imply a breakup of segregation.■

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