Technological Advance, Social Fragmentation and Welfare*

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Abstract

This paper models the welfare consequences of social fragmentation arising from technological advance. We start from the premise that technological progress falls primarily on market-traded commodities rather than prosocial relationships, since the latter intrinsically require the expenditure of time and thus are less amenable to productivity increases. Since prosocial relationships require an identification of the self with others, a tension arises between affiliation and social comparison. Technological progress raises the private return to social comparison relative to affiliation. People consequently narrow the bounds of their social groups, reducing their prosocial relationships and extending their status-seeking activities. As prosocial relationships generate positive externalities whereas status-seeking activities generate negative preference externalities, technological advance may lead to a "decoupling" of social welfare from material plenty. Once the share of status goods in total production exceeds a crucial threshold, technological advance is shown to be welfare-reducing.

1 Introduction

This paper explores how productivity-enhancing economic forces – such as technological advance or globalization – can give rise to social fragmentation and how this affects social welfare. Social fragmentation is measured in terms of the size of social groups within the economy. People are assumed to be relatively cooperative within groups, facilitated by individuals bringing group members inside the boundaries of the self and thereby muting within-group social comparison. We investigate how productivity-enhancing forces, falling on marketable goods and services, can influence social group formation by raising the return to social comparison and thereby influence social welfare.

Our paper seeks to capture a phenomenon that is receiving growing attention in the public debate, but is largely ignored in conventional economic analysis, namely, that around the world – in both developed and emerging market economies – we are witnessing how technological advance and globalization can be destructive of local, regional and national communities. In particular, we focus on the decline in people's close relationships documented by McPherson et al. (2006). The discontent arising from these socially corossive forces has been related to the recent rise of populism and nationalism, as well as an rising polarisation between those who benefit from technological advance and globalization and those who are left behind. Although our analysis does not consider the political implications of such discontent,[1] it does focus on how material progress may shrink the scope of our social ties and thus have an ambiguous influence on social welfare – raising welfare by promoting the production of more goods and services for a given set of factor inputs, while reducing welfare through the disintegration of social relationships.

For this purpose, we need to extend macroeconomic analysis beyond individualistic microfoundations to recognize to broad categories of economic activities that charcterize humans as social creatures: social comparison activities (satisfying status-seeking motives, for which one's welfare is assessed relative to the welfare of others) and cooperative activities within prosocial relationships (in which one's welfare depends positively on the welfare of others). The three activities differ in terms of their preference externalities: individualistic activities are associated with no such externalities; social comparison activities have negative externalities, and prosocial relationships have positive externalities.

Our analysis of how productivity growth affects on social fragmentation and welfare rests on two simplifying premises. First, the productivity growth from technological advance and globalization falls more on market-traded commodities associated with individualistic and social comparison activities than

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[1] Bosworth and Snower (2019) explore this in detail.

on prosocial relationships. Though prosocial relationships often benefit from technological innovations, their goals tend to be less closely associated with market commodities than are the goals of individualistic and social comparison activities. The reason is that these socially cooperative relationships typically, often intrinsically, require time spent in supportive social interactions and this time input cannot be substantially reduced through technological advance. The second premise is that prosocial relationships are more common for the relations within social groups than across social groups. Though many prosocial activities occur across social groups, prosocial relationships occur preferentially within social groups defined by a "we" (R. Akerlof, 2016). The choice of whom to extend "we" rather than "you" and "I" has two natural implications: it defines the relevant group within which one is able to most easily overcome cooperation problems, and without which social comparisons become more relevant.

Under these two premises, we analyze how productivity growth promotes individualistic and social comparison activities at the expense of prosocial activities. We examine how these incentives reduce the size of social groups, thereby generating social fragmentation. Consequently, productivity growth has an ambiguous influence on social welfare, since it promotes negative preference externalities (associated with social comparison activities) at the expense of positive preference externalities (associated with prosocial relationships). On the one hand, productivity growth promotes the production of individualistically want-satisfying commodities (thereby raising welfare); on the other, it promotes activities in which one person's welfare gain is another's welfare loss and discourages activities in which people gain from one another's welfare. In this context, we derive a condition under which productivity growth reduces aggregate welfare.[2] In these respects, this paper draws on and significantly extends the analysis of Snower and Bosworth (2016), which does not derive conditions for welfare-reducing technological advance. We also assess the empirical plausibility of this condition. In particular, we provide a rough calibration of our model for the United Kingdom, which indicates that welfare-reducing growth is indeed an empirical possibility, worthy of further examination.

In this light, technological advance and globalization can be associated with a well-known aspect of rising individualism (as described, for example, by Putnam, 2000 and McPherson et al., 2006), manifested through declining in willingness to engage in civic activities, to contribute to public goods and to make contributions to social allegiances. The technologically-driven rise in social fragmentation can lead to a "decoupling" of social welfare from material progress. We focus on two sources of such decoupling: (i) a rise in social comparison activities with negative preference externalities and (ii) a fall in prosocial relationships with positive preference externalities.

Our analysis points to the need for further investigation of the consequences of productivity growth for social communities and the need to bring macroeconomic policy and innovation policy into closer association with social policy. As indicated below, the possibility of welfare-reducing growth is not an argument for stopping technological advance and structural economic change, but rather for designing public policies and business strategies that sustain and nourish social communities.

Our paper is organised as follows. Section 2 summarises the motivational foundations of decision making in our analysis. Section 3 presents our analysis of comparative, individualistic and cooperative activities. Section 4 describes the general equilibrium. Section 5 derives the effect of productivity growth on aggregate production, social fragmentation and welfare. Section 6 calibrates the parameters of the model to existing stylised facts. Section 7 derives additional welfare implications when the proportion of social comparison activities rises in response to productivity growth and when there are diminishing returns to the production of market goods. Section 8 concludes.

2 Motivational foundations of decision making

The individualistic, comparative and prosocial activities in our analysis are generally recognised to be driven by distinct human motives:

- *Self-interested wanting*,[3] whereby an individual's utility depends exclusively on her own payoff,
- *Status-seeking*,[4] whereby her utility depends on her payoff relative to her relevant comparison group, and

[2] Our paper is certainly not the only to introduce a model wherein growth can be welfare-reducing. See Peng (2008) for a model in which envy can outstrip consumption utility. Our focus is rather specifically on the phenomenon of social fragmentation, and our results hold for an arbitrarily small disutility from envy.

[3] This motive can be represented by the utility function of the self-interested, rational agent of neoclassical microeconomics.

[4] For example, H. Heckhausen (1989); J. Heckhausen (2000); Heckhausen and Heckhausen (2010).

- *Prosociality*,[5] which covers Care[6] (whereby her utility depends positively on the utility of her in-group) and Affiliation[7] (whereby utility depends positively on the degree to which one conforms to the norms of the in-group). While Affiliation coordinates the actions of in-group members through adherence to norms and ideals, Care is a welfare-driven coordination device.[8]

2.1 Motives in economic decision making

The underlying insight is taken from motivation psychology,[9] namely, that people have access to multiple "motives", which are psychological forces that give direction and energy to one's behavior. Different motives can be associated with different utility functions. Which motives are active at any point in time depends on one's social context. Prosocial motives engender group cohesion, whereas status-seeking motives delineate and secure the individual's place within social hierarchies. Traditional economic theory has rather focused largely on the self-interested wanting motive, which drives the satisfaction of wants that pertain to oneself, without reference to any social relations, so that an individual's utility depends only on costs and benefits flowing to the individual herself.

All three motives are common in practice. Prosociality may be subdivided into the motives of Care and Affiliation. Care refers to the motive generating the desire to promote the wellbeing of others and to alleviate their suffering. It includes acts of benevolence, altruism, sympathy, and so on. It occurs naturally among kin and is frequently extended to friends and other non-kin groups with whom one identifies. Affiliation reflects the need to be liked and the need for interpersonal relatedness.

Status-seeking takes a wide variety of forms in market economies, including concern with one's wealth, physical appearance, possessions, political clout, business success, intellectual prowess, sports achievements, etc. relative to the other members of one's reference group. It is manifested as ostentatious consumption, keeping up with the Jones's, tournament contracts in the labor market, rankings of fund managers, tennis seeds, football leagues, and much more.

Our analysis focuses on Status-seeking and Prosociality since these motives exemplify two common, yet contrasting economic objectives. Under Status-seeking, one's payoff is diminished by the payoff of one's competitors; whereas under prosociality, one's payoff is enhanced by the payoff of the members of one's reference group. Although the motivation psychology literature has identified further motives – such as achievement,[10] aggression,[11] and fear[12] – these are not considered here. This is clearly a strong analytical simplification, since these other motives may also be relevant for identity formation within social groups. Furthermore, people's out-group behaviour may be driven by the motives of anger or fear, not just Status-seeking.[13]

Non-socially comparative activities arise when we satisfy our basic needs for food, shelter, clothing, and other essentials for the maintenance of life. Except for people living in extreme poverty, most of our consumption activities satisfy "wants" rather than "needs," and many of these wants arise from positional battles in social settings. The prevalence of such positional battles is clarified through evolution-based theories describing how survival and procreation depends on one's ranking within one's social group. Prosociality is common within families; no child would survive without it. Much of the evolutionary success of homo sapiens is due to our ability to extend prosociality to non-kin groups.

2.2 Motives pertaining to social groups

Both social comparison and prosociality take place with respect to preexisting reference groups, defined by our social identities. For the purposes of our analysis, we restrict our conception of social identity to the formation of social groups. Specifically, each identity describes an in-group, the payoff of whose

[5] In our analysis, for simplicity, these two motives are grouped together as "prosocial".

[6] This motive is concerned with nurturance, compassion, and care-giving, e.g. Weinberger et al., (2010). The caring motive is often distinguished from the affiliation motive, e.g. McDougall (1932), Murray (1938), McAdams (1980), H. Heckhausen (1989), and J. Heckhausen (2000).

[7] McClelland (1967), H. Heckhausen (1989), or Heckhausen and Heckhausen (2010).

[8] In the foundational models of identity economics (summarised in Akerlof and Kranton, 2010), people's in-group behaviour is governed by social categories, associated with distinctive norms and ideals, promoted by the motive of affiliation.

[9] Heckhausen and Heckhausen (2010) provide an excellent survey.

[10] See for example Atkinson and Feather (1966), Pang (2010).

[11] This motive matches McDougall's (1932) concept of anger/rage, Murray's (1938) aggression and defendance, Heckhausen's (1989) aggression, and Reiss' (2004) vengeance.

[12] McDougall (1932), Thorndike (1898), Lewin (1935) and Hull (1943) use the term avoidance, whereas Murray (1938) refers to harm avoidance and Trudewind (2000) to anxiety.

[13] Like status-seeking, anger and fear are associated with negative preference externalities.

members we seek to promote, and a "competing out-group," the payoff of whose members we seek to surpass.[14]

People are assumed to be motivated by prosociality toward their in-group and by status-seeking toward their out-group. These assumptions are admittedly drastic simplifications of people's actual relationships, but they provide a simple analytical framework for exploring something important, which has received little if any attention in traditional economic analysis. In particular, the Care and Affiliation motives generate positive externalities, whereas the status-seeking motive generates negative externalities. This turns out to have potentially important implications for the influence of productivity growth on social welfare.

There is substantial psychological evidence that status-seeking and prosocial motives are in fundamental conflict due to their opposing internalisations of others' welfare. This conflict is mediated by identification: other people are categorised as "us", with whom we affiliate or "them", with whome we differentiate (R. Akerlof, 2016). Aron et al. (1991) characterise close relationships as featuring a high degree of overlap between conceptions of the self and the other person.[15] Galinski, Ku and Wang (2005) show that this self-other overlap explains why close relationships foster social cooperation (prosocial motives). McFarland, Buehler and MacKay (2001) find muted affective responses to social comparisons with close others. Gardner, Gabriel, and Hochschild (2002) experimentally prime interdependent self-constual (close identification with others) and find that unfavourable social comparisons become cause for celebration rather than envy, and favourable social comparisons cease to be cause for pride. Chen and Li (2009) induce group identity and measure social preferences using a number of strategic economic games, finding that in-group members display greater altruism and lower envy toward one another. Similarly, Oveis, Horberg and Keltner (2010) show that both trait- and state-induced compassion is associated with increased perceived self-other similarity, while pride iss associated with a decreased sense of similarity to weak others.

2.3 Technological market bias

Our analysis rests on the hypothesis that productivity growth arising from technological advance and globalization falls more on market activities than on non-market, prosocial relationships – what we shall call the "technological market-bias hypothesis". The reason underlying this hypothesis akin to the "Baumol effect."[16] The amount of time input required by social relationships powered by Care and Affiliation – such as socially supportive relationships with one's spouse and children – has changed much less over the past century than the huge technology-driven productivity improvements in the production of goods and services.

To be a good friend or good relative generally calls for substantial unmediated personal exchanges. We argue that though these social interactions can be promoted through technological advances, the latitude for doing so is far more limited than for goods and services devoted to the purposes of status-seeking and materialistic consumption. Though goods and services can serve many goals – comparative, individualistic and socially supportive relationships – we claim that the prosocial relationships invariably require much time to be spent together and technological advance cannot significantly reduce this time input without degrading the relationships. Goods and services are often consumed in the process of conducting socially supportive relationships and although these goods and services are complementary to these relationships, technological advances in the production of these goods and services do not significantly reduce people's time spent in tending the relationships, at least in comparison to the effect of technology on socially comparative and individualistic pursuits. For example, advances in computer technologies have given rise

[14] In practice, people also have "non-competing out-groups," the payoff of whose members is irrelevant to their decisions. For analytical simplicity, however, we ignore this category in our analysis. Genicot and Ray (2017) for example study the motivating effects of social comparisons with those of very close incomes. Our analysis is consistent with the view that social comparisons with out-group members of similar income are most important since our model's results hinge on optimisation with respect to who the *marginal* in-group member is.

[15] Gächter, Starmer and Tufano (2015) review an experimentally tractable and validated measure of perceived self-other closeness.

[16] Baumol's "cost disease of the services" refers to service sector jobs that experience wage growth though they do not benefit from technological progress. These service sector jobs – such as musicians performing quintets – are market activities, to be distinguished from the non-market, prosocial relationships in our analysis. Many of the services that used to exemplify Baumol's cost disease have, under the influence of information technology, experienced significant technologically driven rises in productivity. For example, while it is true that it still takes four musicians to perform a quintet, the size of the audience that can be reached by these four musicians has increased dramatically. By contrast, the labor productivity non-market, prosocial relationships in our analysis – such as playing tag with one's children, dancing with one's loved one, playing tennis with one's friends – cannot be raised significantly through technological progress, since the time input of the participants is central to these activities.

to vast productivity improvements in the production of status goods such as automobiles and jets, but we still require much the same amount of time to give socially supportive care to friends, children and the elderly.[17]

Maintaining socially cooperative relationships may be aided by technological developments – such as advances in communication technology – but these are incidental to the relationships themselves and must combine with time and attention devoted to others. This latter ingredient by its nature can hardly be economised on.[18] Dealing specifically with a technology complementary to social relationships, Rotondi, Stanca, and Tomasuolo (2017) show that smartphone adoption *degrades* the overall quality of one's social interactions and resulting wellbeing. Furthermore, socially cooperative relationships cannot typically be re-framed into material transactions without significantly diminishing the nature of the exchange.[19] The quest for status on the other hand, is very much tied in with material plenty. Showing others that one commands plentiful material resources generally promotes one's place in a social hierarchy. Conspicuous consumption is a prime example of a market activity, whose productivity is strongly affected by technological progress. But the domain of social comparison activities amenable to technological progress is far wider than this, because the benefits of technological progress fall more on high-earners than on low-earners and high earnings are a common source of status.

In our analysis, market-traded goods are divided into positional and non-positional consumption. For parsimony, we first assume that this fraction remains constant as society becomes more prosperous. This is a conservative assumption, as diminishing marginal utility for non-status consumption implies that income growth is most likely to be spent on positional consumption at the margin. People first satisfy their basic needs for nutrition, clothing, shelter and transportation, and only then seek out artisanal food, designer clothing, large houses for their possessions, and luxury cars.[20]

In this context, our analysis shows how productivity growth has an ambiguous influence on social welfare. This influence may be decomposed into a first- and second-order effect. In the first-order effect, productivity growth raises welfare by enabling the production of more non-positional commodities with given factor inputs, but it reduces welfare by reducing the scope of people's in-group identification, thereby promoting status-seeking relationships (which are zero-sum) at the expense of prosocial relationships (which are positive-sum). Whether this first-order effect is positive or negative depends on the relative strength of these two forces.

The second-order effect depends on preference and production changes that occur once social comparison has increased at the expense of prosociality. More positional competition may be expected to give rise to increased sensitivity to the gains from positional competition and diminishing returns in the production of positional and non-positional goods. Each of these effects further reduces the social welfare generated by productivity growth.

2.4 Positional competition and individualism

There is a large literature on the rise of individualism, particularly in the West (e.g. Rahn and Transue, 1998; Putnam, 2000; McPherson et al., 2006). Of particular concern for us is the time series evidence showing a narrowing of social relations in terms of socioeconomic heterogeneity. Paxton (1999) documents a decline in evenings spent with neighbors over a 20 year period in the United States, with some substitution towards other friends. Li, Savage and Pickles (2003) document increasing class polarisation of friendship networks in the United Kingdom from 1972 to 1998. This corroborates McPherson et al. (2006) who find that the number of people with whom General Social Survey respondents in the United States discuss personal matters has shrunk between 1985 and 2004, and that the average educational hetereogeneity of these close friendship networks has also fallen. McPherson et al. also show that the reason why time spent with close ones has not fallen by as much is that people socialise more intensely with a narrower range of people (pp. 361). There is also evidence that these trends are associated with rising levels of economic growth. Panel regressions show that even though interpersonal trust promotes

[17] Unlike Baumol's phenomenon, this productivity difference between socially cooperative relationships and competitive and individualistic activities does not arise from the distinction between goods and services. After all, there are many services (e.g. banking, gardening, medical diagnosis) that benefit enormously from technological advances. Our distinction is rather between goods and services that meet competitive and individualistic goals versus those that meet socially cooperative goals.

[18] This holds intrinsically, since the non-market, prosocial relationships rest centrally on the expenditure of time with others.

[19] For example, we do not show our appreciation for a friend's dinner party by paying the friend at the end of the party.

[20] We extend our analysis to include this consideration in Section 7, where our quantitative conclusions are strengthened while our qualitative results remain unchanged. The rebalancing of consumption towards more positional goods exacerbates, but is not a necessary condition for, the welfare-reducing effects of growth.

growth (Algan and Cahuc, 2010), growth degrades interpersonal trust (Roth, 2009; see also Mahdavi, 2013).

The implications of individualism for well-being have also been studied extensively, with much evidence indicating that a decline in social ties is inversely associated with self-reported happiness and various objective measures of well-being (e.g. Ogihara and Uchida, 2014). Bartolini and Bilancini (2010) track changes in socialisation and income across a panel of countries and find that income per capita predicts modest increases in subjective weelbeing, but only when controlling for the quality of people's social relations. A straightforward application of omitted variable bias means that these changes in income are correlated with drops in sociality. The reasons adduced for why individualism can reduce well-being are diverse: an erosion of trust, a decline in the sense of connectedness to others, and a rise in narcissism (e.g. Bosson et al., 2008; Putnam, 2000; Twenge, 2006; Twenge and Campbell, 2010).

There is much evidence that well-being depends significantly and substantially on personal relationships, starting with psychologists' recognition of such relationships as a basic human need (e.g. Baumeister and Leary, 1995; Kasser and Ryan, 1999; Ryff and Singer, 2000; Deci and Ryan, 2001) and proceeding to economists' studies on the correlation between self-reported happiness and personal relationships (e.g. Uhlaner, 1989; Gui, 2000; Frey and Stutzer, 2002; Helliwell, 2002; Bruni and Stanca, 2008; Bechetti et al., 2008; 2009; Gui and Stanca, 2010).

The importance of social comparison in market economies has received substantial empirical attention. For example, on the basis of social surveys and contingent choice studies, Easterlin (1974), Kahneman et al. (1999) and others have found that people's subjective well-being and life satisfaction were more closely associated with their relative material status than their absolute income. These findings are consonant with survey evidence that people voluntarily accept reductions in their absolute incomes in return for improvements in their rank within the income distribution (e.g. Solnick and Hemenway, 1998).

The first major investigation of how economic growth is associated with a proportional growth of positional goods relative to non-positional goods was conducted by Hirsch (1976). He argued that rising affluence is associated with a rising proportion of expenditure devoted to status-seeking pursuits. Much corroborating evidence was found by subsequent contributors (e.g. Frank, 1999).[21]

The adverse welfare consequences of positional competition have been investigated by contributors to ecological economics (e.g. Daly, 1977; 1996; and Durning, 1992), who explore how status concerns are linked to environmental problems and resource depletion. Adverse welfare consequences of status seeking are one of the important rationales for the "hedonic treadmill" phenomenon (e.g. Kahneman et al., 1999; Frank, 2000; Frey and Stutzer, 2002). There is also a class of models in microeconomics exploring the static inefficiency arising from excessive consumption of positional goods (Frank, 1985; Corneo and Jeanne, 1997; Hopkins and Kornienko, 2004). Our paper highlights a different kind of inefficiency, since we consider the consumption of positional relative to non-positional goods to be exogenous in our model and focus on the welfare effects arising from agents' changes in affiliations with in- and out-groups. Our analysis shows how the rise of positional competition and the rise of individualism are related, how they are influenced by productivity growth, and the resulting social welfare consequences.

3 Cooperative, individualistic, and socially comparative activities

We now construct a simple model of prosocial-driven cooperation and status-driven competition.

3.1 Non-market activities

Each individual i contributes a production of q_i units to a non-market club good (socially cooperative relationships) in each period of analysis. The total amount of the club good available to each in-group member is

$$Q = \sum_i q_i = N_i q_i, \tag{1}$$

where N_i is the size of individual i's in-group. The production function for socially cooperative relationships is given by

$$q_i = \alpha \tag{2}$$

[21] This time-series evidence is not necessarily matched by cross-section evidence, as there is much anthropological and historical data indicating that positional competition is prevalent in various low-income societies (e.g. Boas, 1897; Maus, 1954). Only the time-series evidence, however, is relevant to our analysis.

where $\alpha > 0$ parameterises the productivity of the public good.

Consequently, individual i derives the following utility from her socially cooperative relationships of her other in-group members:

$$U_i^c = \alpha N_i. \tag{3}$$

3.2 Market activities

Each individual i produces x_i market goods according to the production function

$$x_i = \beta (1 + a_i) - \lambda N_i, \tag{4}$$

where a_i represents i's individual ability, uniformly distributed over the range $[0, 1]$; $\beta > 0$ is a productivity parameter; and λ is the "production substitution parameter," measuring the degree of substitutability between market commodities and prosocial relationships: for every unit increase in prosocial activities, the production of market goods falls by λ.[22] The smaller is individual i's social group N_i, the less prosocial relationships are generated and the more market goods the individual i is able to produce.[23]

For the x_i market goods produced by individual i, γx_i are non-positional and $(1 - \gamma) x_i$ are positional, where γ is a constant $(0 < \gamma < 1)$. The individual's utility from the non-positional good is

$$U_i^n = \gamma x_i. \tag{5}$$

She also compares herself with a random member from her out-group. Her utility from positional competition with the outsider j is

$$U_{i,j}^s \equiv \pi \max (x_i - x_j, 0) - \varepsilon \max (x_j - x_i, 0) - \lambda N_i - \overline{U}^s, \tag{6}$$

where π is a *pride parameter*, ε is an *envy parameter*, and $\overline{U}^s = \int_0^1 E_j[U_{i,j}^s]\, da_i$ is the average level of status utility in the population.[24] Boyce et al. (2010) suggest that $\varepsilon > \pi$, but our qualitative results do not hinge on this assumption.

Her expected utility from comparing herself with a random outsider is

$$\underline{a}_i U_i^{\underline{s}} + (1 - \overline{a}_i) U_i^{\overline{s}} \tag{7}$$

where $\underline{a}_i$ is the probability of encountering an inferior-ability outsider and $U_i^{\underline{s}}$ is i's pride-driven utility from this encounter, whereas $(1 - \overline{a}_i)$ is the probability of encountering a superior-ability outsider and $U_i^{\overline{s}}$ is i's envy-driven utility from that encounter. Denote by

$$U_i^s \equiv E\left(U_{i,j}^s\right) = (1 - \gamma)\left(\underline{a}_i U_i^{\underline{s}} + (1 - \overline{a}_i) U_i^{\overline{s}}\right) \tag{8}$$

i's overall expected utility from competition.

The utility from market goods production U_i^s and U_i^n are therefore equal to

$$U_i^s = \beta (1 - \gamma)\left(\frac{\pi}{2}\underline{a}_i (2a_i - \underline{a}_i) - \frac{\varepsilon}{2}(1 - \overline{a}_i)(1 + \overline{a}_i - 2a_i) - \lambda N_i\right)$$

and

$$U_i^n = \gamma (\beta (1 + a_i) - \lambda N_i).$$

[22] Corneo (2005) shows how increasing the returns to market production may reduce socialisation in the presence of leisure complementarities and a time constraint. The parameter λ encompasses his framework in reduced form, though this is not our main focus. Our main point concerns the extent of social connections across people and not their time use.

[23] Given the linear functional form of our utility functions below, we prefer to interpret x as units of material satisfaction rather than these goods' value at market prices. Money should produce material satisfaction at a diminishing rate, and even a highly skewed distribution of monetary income is likely to produce a much flatter dispersion of consumption utility. In the calibration of Section 6 we assume that monetary income m corresponds to a market production of $x = m^\rho$ with $0 < \rho < 1$.

[24] This is made for normalisation purposes. We assume that there is a fixed pie of status to account for the fact that social status is zero-sum and that the total level of social status cannot change over time. Note also that i gains more status utility the more intensely she is engaged in goods production vs. caring activities.

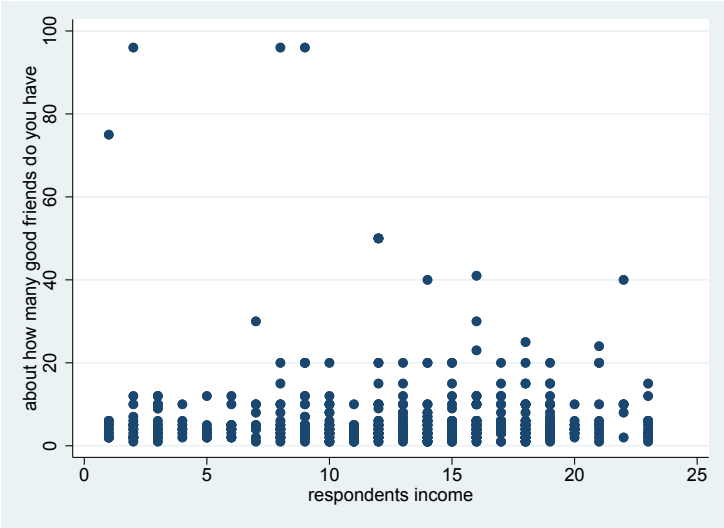

Figure 1: Number of close friends by income category from 1998 General Social Survey

4 The general equilibrium

Individual i encounters in- and out-group members with probabilities proportional to the number of in- and out-group members, respectively. The proportionality factors are A and $(1-A)$, respectively, measuring the degree of assortative matching.[25] Each individual i derives utility from three sources: non-market activities, social comparison, and market-oriented private consumption. The expected utility of individual i is

$$U_i = AU_i^c + (1-A)\,E\left(U_{i,j}^s\right) + U_i^n. \tag{9}$$

All individuals seek to join the highest-ranking group that will accept them, as U_i is increasing in $\overline{a}_i$. Since the highest-ability member of each group has the greatest incentive to leave the group with a subset of group members that would willingly follow, the lower boundary of each group maximises the utility of this highest-ranking member. When the lowest-ability members are successively expelled and the lower bound $\underline{a}$ rises, there is a progressively larger fall in the highest-ability member's utility from socially cooperative relationships and a progressively smaller rise in the highest-ability member's pride-driven utility from social comparison. At the margin, expelling the lowest-ability group member leads to a fall in the highest-ability member's utility from socially cooperative relationships that is exactly equal to the rise in that person's pride-driven utility from comparison.

For a group containing individual i, the ability of its lowest-ranked member is $\underline{a}_i$ and that of its highest-ranked member is $\overline{a}_i$. Thus, the size of the in-group can also be expressed $N_i = \overline{a}_i - \underline{a}_i$. Accordingly, it can be shown that, for group k with upper bound $\overline{a}_k$, the utility-maximising group size, N^*, is[26]

$$N^* = \overline{a}_k - \underline{a}_k^* = \frac{A\alpha - \lambda}{\beta\pi\,(1-A)\,(1-\gamma)}. \tag{10}$$

The upper bound of the highest-ability group is the upper bound of the ability distribution. The boundaries of each group may be derived recursively, moving down the ability ladder. Note that groups up and down the ability distribution have the same size, i.e. N^* does not depend on a_i. This result is contingent on the model's linearity assumptions, though it does however match the data. The 1998 wave of the General Social Survey asked respondents how many close friends they had. Figure 1 shows how this question varies by the survey's income categories (increasing). There is no discernible pattern by income, and a linear regression of number of close friends by income does not yield a coefficient statistically different from zero.

[25] $A = 1/2$ represents random matching and $A = 1$ stands for extreme in-group matching bias.

[26] The equilibrium group size may be derived by considering the incentives for a pivotal agent a_i to consider the lower marginal member $\underline{a}_i$ as part of her in-group: The first-oder condition $dU_i/d\underline{a}_i = \beta\pi\,(1-A)\,(1-\gamma)\,(a_i - \underline{a}_i) - A\alpha + \lambda = 0$ is satisfied by $\underline{a}_i^* = a_i - (A\alpha - \lambda)\,/\beta\pi\,(1-A)\,(1-\gamma)$. Note that $d^2U_i/d\underline{a}_i da_i > 0$, meaning that all agents with ability in $\left(\underline{a}_i^*, a_i\right)$ are willing to affiliate with this group. The first-order condition is satisfied for only the pivotal member $a_i = \overline{a}_i$. We assume that $\lambda < A\alpha$, in order to ensure that people sort into groups of size greater than zero.

5 The effect of productivity growth on social fragmentation, aggregate production, and welfare

In this context, we now investigate the effect of productivity growth on social fragmentation (measured in terms of social group size N^*), aggregate production x_i (where i denotes individual i and the number of individuals in the economy is normalised to 1) and social welfare W. Our analysis will show that (i) under the technological market-bias hypothesis, productivity growth promotes social fragmentation, which in turn (ii) raises the production of positional commodities at the expense of prosocial relationships and thereby (iii) leads to a "decoupling" of aggregate production from social welfare. In short, though productivity growth increases the aggregate production of positional and non-positional commodities, productivity growth has an ambiguous effect on social welfare due to the rise in positional commodities and the fall in prosocial relationships. The resulting increase in negative preference externalities from increased positional consumption and the fall in positive preference externalities from reduced prosocial relationships are the two sources of the decoupling phenomenon.

A productivity increase in the production of the market good is represented by a rise in the productivity parameter β. By Equation (10), this increase in productivity β reduces the equilibrium size of social groups, implying a rise in social fragmentation:

$$\frac{\partial N^*}{\partial \beta} = -\frac{A\alpha - \lambda}{\beta^2 \pi (1-A)(1-\gamma)} < 0, \tag{11}$$

By increasing the productivity of engaging in positional competition, technological advance and globalzation induce individuals to substitute status relationships for socially cooperative relationships, which explains the decline in group size.

Furthermore, the increase in productivity leads to a rise in the production of commodities x_i. There is a direct effect (the rise in market good production for a given amount of effort) and an indirect effect that operates via the rise in social fragmentation):

$$\frac{dx_i}{d\beta} = (1+a_i) - \left(\lambda \frac{\partial N^*}{\partial \beta}\right) = 1 + a_i + \frac{\lambda A\alpha - \lambda^2}{\beta^2 \pi (1-A)(1-\gamma)} > 0 \tag{12}$$

The direct effect is denoted by the first term $(1+a_i)$ and the indirect effect is denoted by the the second term $-\left(\lambda \frac{\partial N^*}{\partial \beta}\right)$. Since both effects are positive, note that the rise in social fragmentation augments the production-enhancing effect of the initial productivity stimulus from technological advance.

Next, we consider the welfare implications of productivity growth, accompanied by a growing quest for status, whereby people can gain only at each other's expense. These welfare implications may be assessed in terms of the following social welfare function

$$W = \sum_{k=1}^{K+1} \int_{\underline{a}_k}^{\overline{a}_k} U_i da_i, \tag{13}$$

i.e. the sum of the utilities of all social groups. The economy contains $K+1$ social groups, with the upper K groups having equilibrium size N^* and a smaller "rump group," of size size $1-KN^*$ at the bottom of the ability distribution, that is left over once the highest-ranking members of all the other groups have made their choices of group members.

The welfare effect of productivity growth is the sum of a direct effect $\frac{\partial W}{\partial \beta}$ (holding group size constant) and an indirect effect $\frac{\partial N^*}{\partial \beta}\frac{dW}{dN^*}$ (via the change in group size N^*):

$$\frac{dW}{d\beta} = \frac{\partial W}{\partial \beta} + \frac{\partial N^*}{\partial \beta} \cdot \frac{dW}{dN^*}. \tag{14}$$

The direct effect (by Eq. (5)) is

$$\frac{\partial W}{\partial \beta} = \gamma$$

The indirect effect represents the influence of a rise in productivity β on group size N^* and thereby on the three components of welfare: U^c from socially cooperative relationships , U^n from non-positional commodities, and U^s from positional commodities.

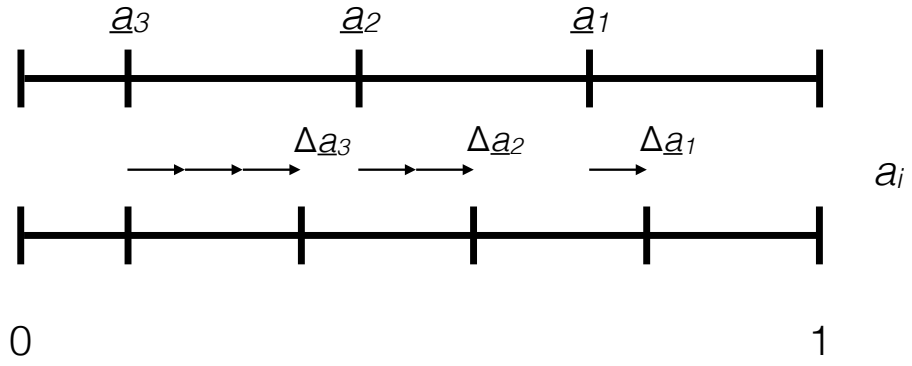

Figure 2: Visualising the cascade of social demotions

We begin by calculating the effect of a rise in group size on positional utility: dU^s/dN^*. We first consider discrete changes in group size, and then take a limit to derive the differential effect on welfare. The process of individualisation leads to a cascade of social demotions down the ladder of status, starting with a shrinking top-status group and rippling down to the progressively shrinking lower-status groups. Each step in the individualisation process generates "*demotees*" (who are relegated to the next-lower social position) and remaining "*incumbents*" (who maintain their previous social position). In our analysis, each social group is of equal size, comprising the incumbents and demotees from a higher-status group. This implies however that groups' lower membership boundaries will shift by more than their upper membership boundaries, and in fact the lower down the social stratum, the more demotees relative to incumbents there will be. Figure 2 illustrates. The highest-status group 1 shrinks by $\Delta\underline{a}_1$. The next-highest-status group both shrinks in size by $\Delta\underline{a}_1$ but also shifts to incorporate all the demotees from the first group. Therefore the lower membership boundary for this second group shifts by $\Delta\underline{a}_2 = 2\Delta\underline{a}_1$. Likewise $\Delta\underline{a}_3 = 3\Delta\underline{a}_1$. Taking the limit of $\Delta\overline{a}_k/\Delta\underline{a}_k$ as $\Delta y \to 0$, we know that $d\overline{a}_k/d\underline{a}_k = k/k+1 < 1$.

As noted, people are envious of higher-status groups and proud regarding lower-status groups, but they experience neither pride nor envy regarding members of their own social group. Suppose that the group size changes by ΔN^* and that this implies changes in group boundaries by $\Delta\overline{a}_k$, $\overline{a}_{k+1}$ by $\Delta\overline{a}_{k+1}$, and so on. Then the change in the aggregate status-driven utility U^s may be expressed

$$\Delta U^s = \sum_k \underbrace{\int_{\underline{a}_k+\Delta\underline{a}_k}^{\overline{a}_k} \Delta U_i^s da_i}_{incumbents} + \underbrace{\int_{\underline{a}_k}^{\underline{a}_k+\Delta\underline{a}_k} \Delta U_i^s da_i}_{demotees} \tag{15}$$

where the first term represents the change in utility of the people who have not switched groups, and the second term represents the change in utility of all those who have switched groups (i.e. those, for positive Δ_k, who were members of group k but are now members of group $k+1$).

Taking the limit of $\Delta U^s/\Delta N^*$ as ΔN^* approaches zero, we derive the effect of group size on welfare from positional commodities:[27]

$$\frac{dU^s}{dN^*} = \frac{\beta}{2}(1-A)(1-\gamma)K\left(N^{*2} - (1-KN^*)^2\right)(\varepsilon - \pi). \tag{16}$$

On this basis, the indirect effect may be derived as follows. By Eq. (11), the effect of productivity growth on group size is negative. Furthermore, it can be shown that the effect of group size on welfare is positive:[28]

$$\frac{dW}{dN^*} = \alpha A - \gamma\lambda + \frac{\beta}{2}(1-A)(1-\gamma)K\left(N^{*2} - (1-KN^*)^2\right)(\varepsilon - \pi) > 0. \tag{17}$$

Intuitively, only the highest-ability member of each group has a marginal utility from prosocial relationships equal to the marginal utility from commodity production. For all other members of the group, the

[27] A full derivation may be found in the attached workings.

[28] The positive effect follows from three conditions: (i) Eq. (10), (ii) the rump group is smaller than the other groups: $(K+1)N^* > 1$ (for otherwise the rump group would have formed as another social group), and (iii) the number of people in the rump group is positive: $KN^* < 1$. For a formal proof, see *Workings* in the supplementary materials.

marginal utility of prosocial relationships is greater than the marginal utility from commodity production. Thus for the group as a whole, welfare falls as group size falls.[29]

Thus the effect of productivity growth on social welfare may be expressed as follows:

$$\frac{dW}{d\beta} = \underbrace{\underbrace{\gamma}_{direct\ effect} + \underbrace{\frac{\gamma\lambda\left(A\alpha-\lambda\right)}{\beta^2\pi\left(1-A\right)\left(1-\gamma\right)}}_{effort\ effect}}_{increased\ non\text{-}positional\ commodities} - \underbrace{\frac{A\alpha\left(A\alpha-\lambda\right)}{\beta^2\pi\left(1-A\right)\left(1-\gamma\right)}}_{lost\ prosocial\ relationships} \tag{18}$$

$$- \underbrace{\frac{\left(A\alpha-\lambda\right)K\left(N^{*2}-\left(1-KN^*\right)^2\right)\left(\varepsilon-\pi\right)}{2\beta\pi}}_{increased\ positional\ commodities}.$$

As this equation shows, technology-driven growth affects social welfare via three channels:

1. **Non-positional commodities:** The productivity increase raises the production of non-positional commodities (i.e. the ones captured in conventional utility functions). This effect can be decomposed into a direct effect (more non-positional commodities produced for the same amount of effort) and effort-related effect (more effort is devoted to non-positional commodities, at the expense of prosocial relationships).

   (a) **Direct effect** (first term): productivity growth permits the production of non-positional commodities for the same amount of effort input. This is the effect in the absence of a change in effort on non-positional production and on prosocial relationships. In other words, it can be thought of as the traditional "manna from heaven" portrayal of productivity growth: people gain additional consumption at the margin from the effort they were already putting in. The resulting social welfare effect is, not surprisingly, unambiguously positive. The magnitude of this effect depends on γ, the proportion of non-positional commodities relative to GDP.

   (b) **Effort-related effect** (second term): productivity growth also leads people to substitute more time into market activities, away from socially cooperative relationships. This generates more non-positional commodities, both on account of the greater labor input and the increased productivity of this input.[30]

2. **Socially cooperative relationships** (third term): productivity growth favours market activities relative to the non-market prosocial ones. Thereby it leads to increased individualisation, in the form of smaller social groups, which hurts socially cooperative relationships since these relationships are club goods. This resulting social welfare effect is unambiguously negative: $-\frac{A^2\alpha^2}{\beta\pi(1-A)(1-\gamma)} < 0$. Note that the standard microeconomic result that an increase in the productivity of one private good relative to another has substitution effects which sum to zero[31] does not obtain here, due to the club-good nature of prosocial relationships.[32]

3. **Positional commodities** (fourth term): The formation of smaller social groups leads to a rise in social comparison activities. When $\varepsilon > \pi$ (Boyce et al., 2010 provide empirical support for this claim) increased status competition has an unambiguously negative effect on social welfare. However, even under the assumption $\pi > \varepsilon$, the increased pride utility and effort-related goods production will not on net exceed the lost utility from socially cooperative relationships. This follows from the result in eq. 17. While it is true that for every person who gains from a relative rise in status, there is another person who loses from a relative loss in status, this does not mean that status seeking is socially neutral. The reason is that increased individualisation leaves the the worst-off group worse off than it was before (i.e. there is a rump group which gets bigger).[33]

[29] Note that as $\pi \to \infty$, $N^* \to 0$, meaning that this result holds for arbitrarily large values of π.

[30] If individuals were not allowed to change their effort, or if there were no tradeoff between goods production and caring relationships (when the production substitutability parameter is $\lambda = 0$), this term is zero.

[31] This would be justified by an application of the envelope theorem to U in the case of private goods. Note that here only a measure-zero subset of agents have their first-order conditions satisfied.

[32] The substitution effect away from caring activities may be greater or less than the substitution effect towards non-positional commodities, depending on the parameters of the model, including the production substitutability parameter λ.

[33] Recall that the total amount of status in society must remain constant, as indicated through the normalisation of status utility (subtracting $\overline{U}^s$ from $U^s_{i,j}$) in Eq (6): This means there is no direct effect from the increased productivity of status production.

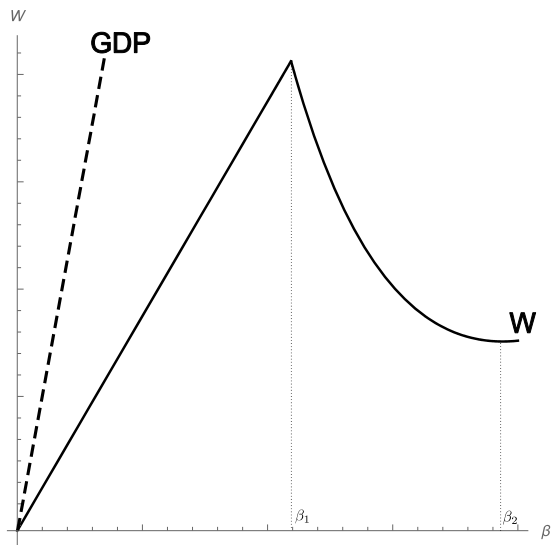

Figure 3: Effects of growth – Output vs. welfare for fixed γ

The "welfare implications of growth" equation has implications given in the following propositions:

1 *When the proportion γ of non-positional goods is lower than $\widehat{\gamma}$, then productivity growth unambiguously reduces social welfare, where the proportion of non-positional goods is approximately*

$$\widehat{\gamma} \simeq \tfrac{1}{2} + \tfrac{\lambda(A\alpha-\lambda)}{2(1-A)\beta^2\pi} + \sqrt{\tfrac{(A\alpha-\lambda)(A\alpha(\varepsilon+\pi)-\lambda(\varepsilon-\pi))}{2(1-A)\beta^2\pi} + \left(\tfrac{1}{2} - \tfrac{\lambda(A\alpha-\lambda)}{2(1-A)\beta^2\pi}\right)^2} \tag{19}$$

In general there is not a closed-form solution for $\widehat{\gamma}$ since N^* depends on the share $(1-\gamma)$ of positional goods in consumption. We can however use the edge cases $K = 1/N^*$ (population exactly partitioned into equal size groups, so that there is no rump group) as an approximation of $\hat{\gamma}$. In these cases, N^* drops out of the expression for W_β. By implication, if productivity growth is generating a higher proportion of positional goods than $\widehat{\gamma}$, then the welfare effects of growth must be negative. We consider this possibility empirically plausible (See Section 6 below for a rough calibration).

Note that Condition (20), under which economic growth (a rise in productivity level β) reduces welfare (W), is itself dependent on the current productivity β. Figure 3 illustrates how welfare depends on growth, under three scenarios.

(i) When β is small ($\beta < \beta_1$), there is no social fragmentation ($N^* = 1$) and thus growth in the level of productivity β raises welfare, since it raises the consumption of non-positional goods without raising social fragmentation. However welfare does not rises as fast as output, since the share of non-positional consumption is $\gamma < 1$.

(ii) When β is large ($\beta_1 \leq \beta < \beta_2$), increases in the level of productivity β lead to increased social fragmentation (K rises as N^* falls) and then correspondingly welfare falls, provided that Condition (20) is fulfilled (i.e., γ is sufficiently low).

(iii) When β is very large ($\beta \geq \beta_2$), there is hardly any social capital left to depreciate and then any rise in the level of productivity β again leads to an increase in the consumption of non-positional goods without further raising social fragmentation. Thus welfare starts to rise again, with a limiting slope $\lim_{\beta\to\infty} dW/d\beta = \gamma$. This upward-sloping region has little if any practical relevance, since it describes an economy in which social groups have virtually disappeared. Since social belonging is a fundamental human need (otherwise solitary confinement in prison would not be punishment), such an economy would be psychologically unbearable, leading social upheaval, associated with a change in the other parameters of our model.

Thus far, we have consider only the effect of productivity growth on social welfare, via reductions in the size of social groups (increased individualism). This of course is a comparative static analysis – assuming all other parameters remain constant. The model's other parameters will not in practise remain fixed as β increases. Recall that group size can be reduced even more through the consequences of the gains from increased positional competition (rises in π), and diminishing returns to the production of market

goods relative to prosocial relationships (falls in λ). Obviously, in the presence of these changes, the lower bound on the proportion of non-positional goods ($\widehat{\gamma}$) is even lower than that given by Eq. (19). Furthermore since the limiting slope of the welfare function W is equal to the share of non-positional goods γ in total output, the evolution of this share has important implications for the dynamics of growth and welfare, as explored in Section 7.

6 Calibration

As indicated above, productivity growth becomes welfare-reducing once the proportion of non-positional goods falls beneath the threshold level $\widehat{\gamma}$. We now make a rough assessment of the empirical plausibility of reaching this threshold level with regard to key data from published research.

For this purpose, we start with a simplifying assumption. We make the conservative assumption that the production substitution parameter is $\lambda = 0$, i.e. increases in prosocial activities does not reduce the production of market commodities.

Under these conditions, by Equation (10), the equilibrium group size is $N^* = \frac{A\alpha}{\beta\pi(1-A)(1-\gamma)}$ and the threshold proportion of non-positional goods $\widehat{\gamma}$ simplifies to

$$\widehat{\gamma} = \frac{A\alpha N^*}{\beta} \cdot \frac{\varepsilon + \pi}{2\pi} \tag{20}$$

Our analysis indicates that if the proportion of non-positional goods fall beneath this threshold value $\widehat{\gamma}$, productivity growth become welfare-reducing. Note that the threshold proportion $\widehat{\gamma}$ is the product of two terms: (i) the interaction-weighted "productivity ratio" ($A\alpha N^*/\beta$) is , i.e. the ratio of prosocial output ($A\alpha N^*$) to market productivity (β) and (ii) the "envy-pride parameter" $(\varepsilon + \pi)/2\pi$.[34]

The parameter ε can be normalised to 1. Boyce et al. (2010) suggest that π is equal to 1/1.75. While α is the productivity of an individual's contribution to maintaining her social relationships, $A\alpha N^*$ is her total utility, which is the output of her prosocial relationships. Naturally, both individual productivity and group size matter for how much individuals choose to invest in public/club goods – individual productivity because people consider the opportunity cost of their investment, and group size because contributing to the public good benefits everyone in the group.[35] In order to match the parameters with a moment from the data then, we need to know the total value that people place on their social relationships and set this equal to $A\alpha N^*$.

Wendner & Goulder (2008) suggest that status consumption is at least 20% of total consumption,[36] so that γ is at most 0.8.

The median income in the United Kingdom in 2017, £42,515. Social relationships may be valued along the following lines laid out by Powdthavee (2008): using data from the British Household Panel Survey, changes in life satisfaction arising from meeting with friends and family and speaking with neighbours are compared with the same changes arising from changes in income. Powdthavee assumes as his base category people who meet with their friends and relatives and speak to their neighbours less than once a month. Relative to these people, those who meet with friends or relatives once or twice a month (11% of the sample) experience an increase in life satisfaction equivalent to £57,500; those who meet with friends or relatives once or twice a week (40% of the sample) experience an increase in life satisfaction equivalent to £69,500; and those who meet with friends or relatives on most days (47% of the sample) experience an increase in life satisfaction equivalent to £85,000 of annual income (in 1996 pounds Sterling). Furthermore those who talk to their neighbours once or twice a week (40% of the sample) experience an increase in life satisfaction equivalent to £22,500; and those who talk to their neighbours on most days (36% of the sample) experience an increase in life satisfaction equivalent to £37,000 in annual income. We take these numbers to mean that the average value of each Briton's social relations is equal to £172,019 in 2017 pounds Sterling.

Per above, we do not interpret the relative valuation of income and social relationships in monetary terms (refer to sec. 3.2, footnote 23). The estimates above however are given in monetary terms. To transform this ratio back into utility terms, we make reference to the elasticity of social group size with respect to income. McPherson, Smith-Lovin and Brashears (2006) document a 33% reduction in the extent of people's close social groups over 1985-2004 in the United States. Real income per capita grew

[34] Note $d\left(\frac{\varepsilon+\pi}{2\pi}\right)/d\varepsilon > 0$ and $d\left(\frac{\varepsilon+\pi}{2\pi}\right)/d\pi < 0$.

[35] Weimann et al. (2018) provide evidence that both matter to experimental subjects.

[36] Wendner and Goulder (2008) provide a range of estimates.

by 132% over this period however. Note that our model is equivalent to Cobb-Douglas utility and as such the elasticity of group size N^* with respect to β is

$$\frac{dN^*}{d\beta} \cdot \frac{\beta}{N^*} = -1.$$

This means we need to map a 132% growth in income into a 33% growth in consumption utility. The simplest way to do this is with an exponential consumption utility of money function:

$$x_i = m^\rho$$

where m is the value of consumption at market prices with $0 < \rho < 1$. We therefore set $\rho = 33/132$ and set the ratio of social relationship utility ($u\,(£172,019)$) to income ($u\,(£42,515)$) equal to

$$\frac{A\alpha N^*}{\beta} = \frac{(172,019)^{33/132}}{(42,515)^{33/132}} \approx 1.42.$$

Setting $\pi = 1/1.75$, and $\varepsilon = 1$, we obtain the condition $\gamma < 0.64$ in order for productivity growth to be welfare-reducing. This is well within the range identified by Wendner & Goulder. This exercise shows that the phenomenon of welfare-reducing growth is an empirically plausible possibility; and merits further investigation by empirical economists.

7 Further welfare effects of productivity growth

In Section 5, we have seen how productivity growth leads to a reduction in the size of social groups, thereby promoting people's status-seeking activities with regard to those outside their social groups and reducing prosocial relationships within their social groups. Since the status-seeking activities are associated with negative preference externalities whereas the prosocial relationships are associated with positive preference externalities, productivity growth leads to a "decoupling" of social welfare from GDP (the sum of all market production). In fact, once the proportion of positional goods exceeds some threshold value, technological progress become welfare-reducing. This decoupling phenomenon can be reinforced through the effect of productivity growth on the following phenomena.

7.1 Rising proportion of status-seeking activities

Productivity growth increases GDP per capita and may thereby raise the share of positional goods in total production. The reason is that while the satisfaction of basic individual material needs is finite, the satisfaction of status needs is inherently infinite, since one individual's status needs must always be satisfied relative to those of others.[37]

In the context of our model, a rise in the share of positional goods reduces the size of social groups:

$$\frac{dN^*}{d\,(1-\gamma)} = -\frac{A\alpha - \lambda}{\pi\beta\,(1-\gamma)^2\,(1-A)} < 0 \tag{21}$$

The associated welfare effect is also negative:

$$\frac{dW}{d\,(1-\gamma)} = -\beta - \frac{A\alpha - \lambda}{\pi\beta\,(1-\gamma)^2\,(1-A)} \cdot \frac{dW}{dN^*} < 0. \text{ (see above)}$$

In accordance with our hypothesis that productivity growth raises the share of positional goods, we now assume that the proportion of non-positional goods γ is inversely related to the productivity parameter β:

$$\gamma\,(0) = 1$$

$$\lim_{\beta \to +\infty} \gamma\,(\beta) = 0$$

and

$$\frac{d\gamma}{d\beta} \equiv \gamma_\beta \leq 0$$

[37] Hopkins and Kornienko (2004) provide a theory for how this might arise endogenously.

for $\gamma(\cdot)$ continuous on $[0, +\infty)$. Figure 4a provides an example. These assumptions formalise the hypothesis that positional consumption rises in importance as people's basic material needs become increasingly satisfied.

Firstly, we re-express the aggregate marginal utility of growth (i.e. the welfare effects of increasing β holding group size fixed) as

$$\frac{\partial W}{\partial \beta} = \gamma + \gamma_\beta \beta + \frac{\lambda (1 - \gamma - \beta\gamma_\beta)(A\alpha - \lambda)}{\beta^2 \pi (1 - A)(1 - \gamma)^2}. \tag{22}$$

Note that, in comparison with the base case, there are effects on both the direct and effort-related effects of growth on non-positional consumption. The direct effect becomes $\gamma + \gamma_\beta \beta \leq \gamma$, meaning that each additional £/€/\$ of production will consist of $|\gamma_\beta| \cdot \beta$ fewer non-positional goods. Secondly however, the effort-related substitution effect increases because the tradeoff between group size and goods production becomes steeper.

As before we then express the total welfare implications of technology-driven economic growth by using the expression for the total derivative:

$$\frac{dW}{d\beta} = \frac{\partial W}{\partial \beta} + \frac{\partial N^*}{\partial \beta} \cdot \frac{dW}{dN^*},$$

now taking into account that knock-on effects from changes in γ:

$$\begin{aligned} \frac{dW}{d\beta} = & \underbrace{\underbrace{\gamma + \gamma_\beta \beta}_{direct\ effect} + \underbrace{\frac{\lambda (\gamma (1 - \gamma) - \beta\gamma_\beta)(A\alpha - \lambda)}{\beta^2 \pi (1 - A)(1 - \gamma)^2}}_{effort\ effect}}_{increased\ non\text{-}positional\ commodities} \\ & - \underbrace{\frac{A\alpha (1 - \gamma - \beta\gamma_\beta)(A\alpha - \lambda)}{\beta^2 \pi (1 - A)(1 - \gamma)^2}}_{lost\ prosocial\ relationships} \\ & - \underbrace{\frac{(A\alpha - \lambda)(1 - \gamma - \beta\gamma_\beta) K \left(N^{*2} - (1 - KN^*)^2\right)(\varepsilon - \pi)}{2\beta\pi (1 - \gamma)}}_{increased\ positional\ commodities}. \end{aligned} \tag{23}$$

As above, technology-driven growth affects social welfare via three channels. We compare the differences with the baseline model below:

1. **Non-positional commodities:** The productivity increase raises the production of non-positional commodities (i.e. the ones captured in conventional utility functions). This effect can be decomposed into a direct effect (more non-positional commodities produced for the same amount of effort) and effort-related effect.

   (a) **Direct effect** (first term): The direct effect, which is positive, becomes smaller if $\gamma_\beta < 0$, as fewer and fewer extra non-positional commodities are made with the same inputs.

   (b) **Effort-related effect** (second term): The effort-related substitution effect, also positive, becomes larger, since we have assumed $\lambda < A\alpha$ (positive group sizes in equilibrium). This is because the tradeoff between positional goods production and relationship maintenance becomes more tilted towards positional goods, decreasing the equilibrium group size and therefore increasing production.

2. **Socially cooperative relationships** (third term): Note that in contrast to the base, there is more substitution away from prosocial activities as γ shrinks. Therefore the effect on socially cooperative relationships becomes more negative.

3. **Positional commodities** (fourth term): The formation of smaller social groups leads to a rise in status-seeking activities. The increasing share of positional commodities in consumption makes the pivotal group members narrow their groups to be more exclusive, such that the rump group increases faster with β.

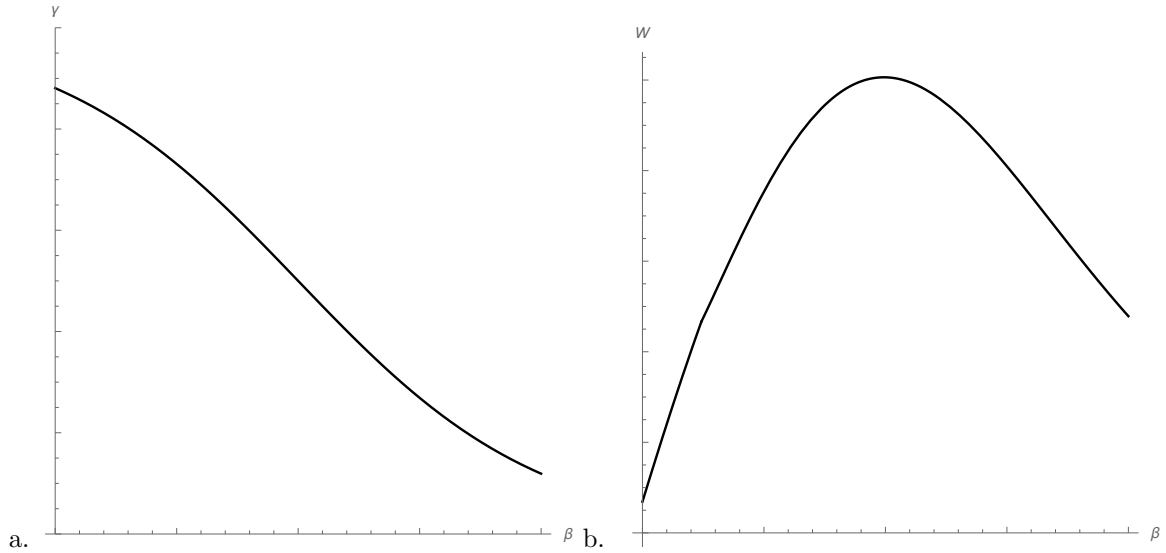

Figure 4: Effects of growth – Diminishing γ (a.) and its effects on welfare (b.)

Figure 4 revises the analysis of welfare-growth dynamics to account for a shrinking proportion of non-positional goods. In panel a. $\gamma(\cdot)$ is plotted as a function of β.[38] Panel b. again shows the path of welfare as the economy grows. Just as in the fixed-γ case of Figure 3, welfare initially rises as output grows due to limited social fragmentation. Once the point $\beta^{-1}(\hat{\gamma})$ is reached however, welfare starts to decline as the social fragmentation effect swamps non-positional goods production. Welfare continues to decline as γ approaches zero in the limit.

The figure illustrates a gradual "decoupling" of welfare from market production. The rising share of positional commodities in total production worsens the welfare-reducing effects of technological progress.[39]

$$\frac{d^2W}{d\beta d\gamma_\beta} = \beta + (A\alpha - \lambda) \cdot \left(\begin{array}{c} -\frac{\lambda}{\beta\pi\theta(1-A)(1-\gamma)^2} + \frac{A\alpha}{\beta\pi(1-A)(1-\gamma)^2} \\ + \frac{K\left(N^{*2} - (1-KN^*)^2\right)(\varepsilon-\pi)}{2(1-\gamma)\pi} \end{array} \right) \geq 0. \tag{24}$$

7.2 Diminishing returns to the production of market-traded commodities

As productivity growth promotes substitution from socially supportive relationships to production of market-traded commodities, the opportunity cost of commodity production may rise on account of diminishing production returns. If it becomes more costly (λ) to spend time with group members in terms of lost commodity production and status, groups become smaller in equilibrium:

$$\frac{\partial N^*}{\partial \lambda} = -\frac{1}{\beta\pi(1-A)(1-\gamma)} < 0. \tag{25}$$

As a result, social welfare falls:

$$\frac{dW}{d\lambda} = -\frac{(1-A)(1-\gamma)K(\varepsilon-\pi)\left((A\alpha-\lambda)^2 - ((1-A)(1-\gamma)\beta\pi - K(A\alpha-\lambda))^2\right)}{2(1-A)^3(1-\gamma)^3\beta^2\pi^3} < 0. \tag{26}$$

If we were to assume that the opportunity cost λ is positively related to the productivity parameter β, then a further decoupling of welfare from market production could be derived, along the lines above.

7.3 Increased competitiveness

The wider scope of positional competition that accompanies productivity growth may be expected to lead to increased competitiveness in terms of increased sensitivity to the gains from positional competition. An increased sensitivity to the gains from such competition (rising π), also leads smaller in-groups and more positional competition as

$$\frac{\partial N^*}{\partial \pi} = -\frac{A\alpha - \lambda}{\beta\pi^2(1-A)(1-\gamma)} < 0. \tag{27}$$

[38] The form $\gamma = 1 - 1/(1 + \exp(2-\beta))$ was chosen as an example which satisfied the above assumptions.
[39] See the supplementary materials.

The resulting welfare effect is again negative:

$$\frac{dW}{d\pi} = -\frac{(1-A)(1-\gamma)K(\varepsilon-\pi)(A\alpha-\lambda)\left((A\alpha-\lambda)^2-((1-A)(1-\gamma)\beta\pi-K(A\alpha-\lambda))^2\right)}{2(1-A)^3(1-\gamma)^3\beta^2\pi^4} < 0$$

If we were to assume that the sensitivity π are positively related to the productivity parameter β, the decoupling of social welfare from market production could once again be derived.

8 Conclusion

This paper addresses social consequences of productivity growth. In particular, it shows how productivity growth can lead to greater social fragmentation, associated with unfavourable consequences for social welfare. When productivity growth falls primarily on market activities involving individualistic consumption and status seeking, but less on socially supportive relationships, then productivity growth narrows people's bounds of social affiliation and extends their status-seeking activities. Since status seeking has negative preference externalities whereas socially supportive activities have positive preference externalities, productivity growth need not necessarily raise social welfare. In fact, we show that once the share of status-oriented goods in total production exceeds a particular threshold, productivity growth becomes welfare-reducing.

In this sense, the paper makes a contribution to the analysis of the social implications of economic activities. This analysis has a long history, although it appears to have fallen into disregard since the advent of neoclassical economics, reaching its culmination with the publication of Samuelson's *Foundations of Economic Analysis* (1947). Ferdinand Tönnies (1887) formalised a distinction between the traditional *Gemeinschaft*, in which social relations are mediated primarily through personal relationships and the *Gesellschaft* emerging from the 19th century wherein more and more human needs are met through instrumental, transactional and often impersonal institutions. Weber (1922) articulated the role that command of material resources had in establishing status hierarchies in modern societies organised around impersonal market and bureaucratic institutions. The reorganisation of society around impersonal, third-party mediated exchange has without doubt improved human welfare in innumerable ways. Whereas these material gains are easily recognisable through conventional economic analysis, this analysis has been largely blind to the possibility of accompanying social costs. Though Durkheim (1895) was already worried about social disintegration, welfare economics has given little formal treatment of this phenomenon.

Research into the determinants of life satisfaction reveal that primarily relative, not absolute, income increases life satisfaction in developed countries (e.g. Boyce et al., 2010); higher materialism is associated with lower well-being (e.g. Roberts and Clement, 2007); and improvements in the quality of social relations yield welfare gains comparable to very large changes in relative income (e.g. Powdthavee, 2008). In this context, our analysis makes the following contributions. First, we extend the conventional macroeconomic analysis, which is rigidly individualistic, to consider two vitally important aspects of people as social creatures: their prosocial and socially comparative abilities. The prosocial abilities satisfy people's need for care and social affiliation, primarily within their social in-groups, generating positive preference externalities. Their positionally competitive abilities satisfy their need for achieving positional goals, generating negative preference externalities. While preference externalities are either ignored or consigned to special cases in conventional economic theory, they occupy centre-stage our analysis, where each individual belongs to a social group and the boundaries of the social group affect the boundaries of the individual's cooperative and competitive goals.

Second, we explicitly model the process of social fragmentation, elucidating the mechanisms whereby this process affects economic decisions, in terms of easily-interpretable parameters. In highlighting social consequences of market activities, the analysis bridges the gap between conventional economic theory (on the one hand) and sociology and motivation psychology (on the other). Understanding the links between social fragmentation and economic policy is of critical interest to economic policy makers concerned with social problems arising from economic growth (such as the dissatisfactions which fuelled the election of Donald Trump and Brexit).

Third, in contrast with neoclassical and most behavioural economics, we recognise that people are driven by different motives across different contexts. We are therefore able to reckon with the observation that many people are driven to pursue social status and prosocial goals alongside material well-being. Widening the purview of people's objectives in this way provides broader perspective on people's economic and social decision making.

Finally, our analysis points to the need for further investigation of how productivity growth affects social communities. It is commonly observed, in both developed and developing countries, that globalization, as well as technological changes such as automation and AI, have promoted low-wage jobs and unemployment and undermined social communities. The material losses suffered as a result of low-wage job creation and unemployment are linked to, but distinct from, the welfare losses suffered on account of social fragmentation. The latter welfare losses are commonly implicated as explanations of the popular dissatisfactions that have lead to nationalist and populist swings in many countries around the world. Our analysis is a step towards understanding the economic causes and welfare consequences of such social fragmentation.

Needless to say, the possibility that social welfare may be reduced by productivity growth, such as that arising from technological advance and globalization, is not an argument for stopping technological advance and globalization. Each of the model's parameters is amenable to policy intervention. More empirical research needs to be done on the determinants of status-biased growth and consumers' response to status incentives. Corneo and Jeanne (1998) for example show that the price elasticity of demand for status goods may be either negative or positive depending on the shape of consumers' marginal status utility. Policymakers could correspondingly raise gamma by taxing, or allowing mass reproduction of luxury goods respectively. Within the domain of productivity growth, our analysis points to the need for a combination of economic and social policies to strengthen social communities and to pursue innovation policies[40] that promote social integration. Government policies aimed at regenerating local communities, support for SMEs with strong local ties, social enterprise, Certified B Corporations, Social License of Operate, and other social initiatives may have the potential to redress the socially destructive implications of technological advance and globalization, enabling us to reap the rewards of productivity growth without paying the social costs.

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Extended workings

1. Derivation of the aggregate status utility from group realignment

We must take the limit of $\Delta U^s/\Delta N^*$ as ΔN^* approaches zero:

$$\begin{aligned}\frac{dU^s}{dN^*} &= \lim_{\Delta N^*\to 0}\frac{\Delta U^s}{\Delta N^*}\\ &= \lim_{\Delta N^*\to 0}\sum_k\int_{\underline{a}_k+\Delta\underline{a}_k}^{\overline{a}_k}\left(\frac{\Delta U_i^s}{\Delta\overline{a}_k}\cdot\frac{\Delta\overline{a}_k}{\Delta N^*}+\frac{\Delta U_i^s}{\Delta\underline{a}_k}\cdot\frac{\Delta\underline{a}_k}{\Delta N^*}\right)da_i\\ &+\int_{\underline{a}_k}^{\underline{a}_k+\Delta\underline{a}_k}\left(\frac{\Delta U_i^s}{\Delta\underline{a}_k}\cdot\frac{\Delta\underline{a}_k}{\Delta N^*}\right)da_i.\end{aligned}$$

Now consider the determinants of the term $\Delta\underline{a}_k/\Delta N^*$. Since the upper boundary of the highest-status group, $\overline{a}_1$, is equal to 1, we know that $\Delta\overline{a}_1/\Delta N^*=0$, as it does not depend on N^*. The lower boundary of this group, $\underline{a}_1$, is equal to $1-N^*$ and therefore $\Delta\underline{a}_1/\Delta N^*=-1$. Equivalently, $\Delta\overline{a}_2/\Delta N^*=-1$. Similarly, the lower boundary of the second-highest group, $\underline{a}_2$, is equal to $1-2N^*$ and therefore $\Delta\underline{a}_2/\Delta N^*=-2$. We can see in general that $\Delta\underline{a}_k/\Delta N^*=-k$ and $\Delta\overline{a}_k/\Delta N^*=-(k-1)$. Finally, since the lower bound of the rump group, $\underline{a}_{K+1}$, is equal to zero we therefore know that $\Delta\underline{a}_{K+1}/\Delta N^*=0$.

This allows us to express the above:

$$\begin{aligned}\frac{dU^s}{dN^*} &= \int_{\underline{a}_1}^{1}\left(-\frac{\partial U_i^s}{\partial\underline{a}_k}\right)da_i+\Delta U^s_{\underline{a}_1}\\ &+\sum_{k=2}^{K-1}\left(\int_{\underline{a}_k}^{\overline{a}_k}\left(-(k-1)\frac{\partial U_i^s}{\partial\overline{a}_k}-k\cdot\frac{\partial U_i^s}{\partial\underline{a}_k}\right)da_i+k\cdot\Delta U^s_{\underline{a}_k}\right)\\ &+\int_{\underline{a}_K}^{\overline{a}_K}\left(-(K-1)\frac{\partial U_i^s}{\partial\overline{a}_K}-K\cdot\frac{\partial U_i^s}{\partial\underline{a}_K}\right)da_i+K\cdot\Delta U^s_{\underline{a}_K}\\ &+\int_0^{\overline{a}_{K+1}}\left(-K\cdot\frac{\partial U_i^s}{\partial\overline{a}_k}\right)da_i\end{aligned}$$

where

$$\Delta U^s_{\underline{a}_k}=\frac{\beta}{2}(1-A)(1-\gamma)(\pi+\varepsilon)N^{*2}$$

was the discrete jump in utility experienced by the marginal group member by moving from group $k+1$ to group k; and $\Delta U^s_{\underline{a}_{K+1}}=0$ as the rump group has no expellees. We can further simplify the above to

$$
\begin{aligned}
\frac{dU^s}{dN^*} =& -\frac{\beta}{2}(1-A)(1-\gamma)N^{*2}\pi + \frac{\beta}{2}(1-A)(1-\gamma)N^{*2}(\pi+\varepsilon) \\
&+ \sum_{k=2}^{K-1}\left(-\frac{\beta}{2}(1-A)(1-\gamma)N^{*2}(k\pi+(k-1)\varepsilon) + \frac{\beta}{2}(1-A)(1-\gamma)N^{*2}k(\pi+\varepsilon)\right) \\
&- \frac{\beta}{2}(1-A)(1-\gamma)N^{*2}(K\pi+(K-1)\varepsilon) + \frac{\beta}{2}(1-A)(1-\gamma)K\left((1-KN^*)^2\pi + N^{*2}\varepsilon\right) \\
&- \frac{\beta}{2}(1-A)(1-\gamma)K(1-KN^*)^2\varepsilon \\
=& \frac{\beta}{2}(1-A)(1-\gamma)N^{*2}\varepsilon \\
&+ \frac{\beta}{2}(1-A)(1-\gamma)N^{*2}\sum_{k=2}^{K-1}(-k\pi+(1-k)\varepsilon+k(\pi+\varepsilon)) \\
&- \frac{\beta}{2}(1-A)(1-\gamma)K(1-KN^*)^2\varepsilon \\
=& \frac{\beta}{2}(1-A)(1-\gamma)N^{*2}\varepsilon \\
&+ \frac{\beta}{2}(1-A)(1-\gamma)N^{*2}(K-2)\varepsilon \\
&+ \frac{\beta}{2}(1-A)(1-\gamma)N^{*2}\varepsilon - \frac{1}{2}(1-A)(1-\gamma)K\left(N^{*2}-(1-KN^*)^2\right)\pi \\
&- \frac{\beta}{2}(1-A)(1-\gamma)K(1-KN^*)^2\varepsilon \\
=& \frac{\beta}{2}(1-A)(1-\gamma)K\left(N^{*2}-(1-KN^*)^2\right)(\varepsilon-\pi).
\end{aligned}
$$

2. Proof that $dW/dN^* > 0$

We must show that

$$
\frac{dW}{dN^*} = \alpha A - \gamma\lambda + \frac{\beta}{2}(1-A)(1-\gamma)K\left(N^{*2}-(1-KN^*)^2\right)(\varepsilon-\pi) > 0
$$

given the equilibrium group size condition $N^* = (A\alpha-\lambda)/\beta\pi(1-A)(1-\gamma)$ and the definition of the number of groups K, with $KN^* \leq 1$ and $(K+1)N^* > 1$. We know that the first term $\alpha A = N^*\beta\pi(1-A)(1-\gamma)+\lambda$, so making this substitution and collecting terms we have

$$
\begin{aligned}
\frac{dW}{dN^*} &= (1-\gamma)\lambda + \beta(1-A)(1-\gamma)\left(\pi N^* + \frac{1}{2}K\left(N^{*2}-(1-KN^*)^2\right)(\varepsilon-\pi)\right) \\
&\geq \beta\pi(1-A)(1-\gamma)\left(N^* - \frac{1}{2}K\left(N^{*2}-(1-KN^*)^2\right)\right) \\
&= \beta\pi(1-A)(1-\gamma)\left(N^* - \frac{1}{2}K(N^*-(1-KN^*))(N^*+(1-KN^*))\right) \\
&\geq \beta\pi(1-A)(1-\gamma)\left(N^* - \frac{1}{2}K(N^*-(1-KN^*))(N^*+N^*)\right) \\
&= \beta\pi(1-A)(1-\gamma)N^*(1-K(N^*-(1-KN^*))) \\
&= \beta\pi(1-A)(1-\gamma)N^*\left(1-KN^*+K^2N^*\right) \\
&\geq \beta\pi(1-A)(1-\gamma)(KN^*)^2 \\
&> 0.
\end{aligned}
$$

3. Derivation of $\widehat{\gamma}$

Recall that the expression $dW/d\beta$ involved an expression for the number of groups $K+1$ which depends on γ in a non-linear fashion. For this reason, we evaluate this expression at the edge case where $K = 1/N^*$:

$$\begin{aligned}
\left.\frac{dW}{d\beta}\right|_{K=1/N^*} &= \gamma + \frac{\gamma\lambda\left(A\alpha-\lambda\right)}{\beta^2\pi\left(1-A\right)\left(1-\gamma\right)} - \frac{A\alpha\left(A\alpha-\lambda\right)}{\beta^2\pi\left(1-A\right)\left(1-\gamma\right)} - \frac{\left(A\alpha-\lambda\right)N^*\left(\varepsilon-\pi\right)}{2\beta\pi}. \\
&= \gamma + \frac{\gamma\lambda}{\beta}N^* - \frac{A\alpha}{\beta}N^* - \frac{\left(A\alpha-\lambda\right)N^*\left(\varepsilon-\pi\right)}{2\beta\pi} \\
&= \gamma - \left(\frac{A\alpha-\gamma\lambda}{\beta}\right)N^* - \left(\frac{\varepsilon-\pi}{2\pi\beta}\right)\left(A\alpha-\lambda\right)N^* \\
&= \gamma - \left(\frac{A\alpha-\lambda}{\beta}\right)N^*\left(1+\frac{\varepsilon-\pi}{2\pi}\right) - \frac{\left(1-\gamma\right)\lambda}{\beta}N^* \\
&= \gamma - \left(N^*\right)^2\left(1-A\right)\left(1-\gamma\right)\left(\frac{\pi+\varepsilon}{2}\right) - \frac{\left(1-\gamma\right)\lambda}{\beta}N^* \\
&= \gamma - N^*\left(1-\gamma\right)\left(N^*\left(1-A\right)\left(\frac{\pi+\varepsilon}{2}\right) - \frac{\lambda}{\beta}\right) \\
&= \gamma - \frac{N^*}{2\pi\beta}\left(\left(A\alpha-\lambda\right)\left(\pi+\varepsilon\right) - 2\pi\left(1-\gamma\right)\lambda\right) \\
&\gamma - \frac{N^*}{2\pi\beta}\left(A\alpha\left(\pi+\varepsilon\right) - \lambda\varepsilon - \lambda\pi\left(2\gamma-1\right)\right).
\end{aligned}$$

Setting $\left.dW/d\beta\right|_{K=1/N^*} = 0$ and solving for γ gives us

$$\begin{aligned}
\widehat{\gamma} &= \frac{N^*}{2\pi\beta}\left(A\alpha\left(\pi+\varepsilon\right) - \lambda\varepsilon - \lambda\pi\left(2\widehat{\gamma}-1\right)\right) \\
\rightarrow \widehat{\gamma}\left(1+2\pi\lambda\cdot\frac{N^*}{2\pi\beta}\right) &= \frac{N^*}{2\pi\beta}\left(A\alpha\left(\pi+\varepsilon\right) + \lambda\left(\pi-\varepsilon\right)\right) \\
\rightarrow \widehat{\gamma}\left(\frac{1}{N^*}+\frac{\lambda}{\beta}\right) &= \frac{1}{2\pi\beta}\left(A\alpha\left(\pi+\varepsilon\right) + \lambda\left(\pi-\varepsilon\right)\right) \\
\rightarrow \widehat{\gamma}\cdot\left(\frac{\beta\pi\left(1-A\right)\left(1-\widehat{\gamma}\right)}{A\alpha-\lambda}+\frac{\lambda}{\beta}\right) &= \frac{1}{2\pi\beta}\left(A\alpha\left(\pi+\varepsilon\right) + \lambda\left(\pi-\varepsilon\right)\right) \\
\rightarrow -\frac{\beta\pi\left(1-A\right)}{A\alpha-\lambda}\widehat{\gamma}^2 + \left(\frac{\beta\pi\left(1-A\right)}{A\alpha-\lambda}+\frac{\lambda}{\beta}\right)\widehat{\gamma} &= \frac{1}{2\pi\beta}\left(A\alpha\left(\pi+\varepsilon\right) + \lambda\left(\pi-\varepsilon\right)\right).
\end{aligned}$$

An application of the quadratic formula gives us

$$\widehat{\gamma} = \tfrac{1}{2} + \tfrac{\lambda(A\alpha-\lambda)}{2(1-A)\beta^2\pi} + \sqrt{\tfrac{(A\alpha-\lambda)(A\alpha(\varepsilon+\pi)-\lambda(\varepsilon-\pi))}{2(1-A)\beta^2\pi} + \left(\tfrac{1}{2} - \tfrac{\lambda(A\alpha-\lambda)}{2(1-A)\beta^2\pi}\right)^2}.$$

4. Proof that $dW/d\pi$, $dW/d\lambda < 0$

Note that both of these quotients are trivially negative if the quantity

$$\left(A\alpha-\lambda\right)^2 - \left(\left(1-A\right)\left(1-\gamma\right)\beta\pi - K\left(A\alpha-\lambda\right)\right)^2 > 0.$$

Let us divide the above expression by $\left(A\alpha-\lambda\right)^2 > 0$:

$$1 - \left(\frac{1}{N^*} - K\right)^2 > 0$$

as $K \leq 1/N^* < K+1$ by definition.

5. Proof that $d^2W/d\beta\, d\gamma_\beta \geq 0$

Recall the cross-partial derivative of welfare with respect to technological progress β and the gradient of the share of status goods with respect to technological progress γ_β was

$$\begin{aligned}
\frac{d^2W}{d\beta d\gamma_\beta} &= \beta + (A\alpha - \lambda) \cdot \left(\begin{array}{c} -\frac{\lambda}{\beta\pi(1-A)(1-\gamma)^2} + \frac{A\alpha}{\beta\pi(1-A)(1-\gamma)^2} \\ +\frac{K\left(N^{*2}-(1-KN^*)^2\right)(\varepsilon-\pi)}{2(1-\gamma)\pi} \end{array} \right) \\
&= \beta + (A\alpha - \lambda) \cdot \left(\frac{N^*}{1-\gamma} + \frac{K\left(N^{*2} - (1-KN^*)^2\right)(\varepsilon - \pi)}{2(1-\gamma)\pi} \right) \\
&\geq (A\alpha - \lambda) \cdot \left(\frac{N^*}{1-\gamma} - \frac{K\left(N^{*2} - (1-KN^*)^2\right)}{2(1-\gamma)} \right) \\
&= \frac{A\alpha - \lambda}{1-\gamma} \cdot \left(N^* - \frac{1}{2}K\left(N^{*2} - (1-KN^*)^2\right) \right) \\
&\geq 0 \qquad \text{(see above).}
\end{aligned}$$