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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 individuals to identify with others in their social group whereas marketable commodities are commonly the objects of social status comparisons, a tradeoff arises between in-group affiliation and inter-group status comparisons. 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 particular type of "decoupling" of social welfare from material prosperity. 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–by increasing material prosperity–can give rise to social fragmentation and how this affects social welfare. People are assumed to be more cooperative within a social group (such as a family, a friendship circle or a workplace team) than between groups. The reason is that people commonly identify their wellbeing with other members of their

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social group, but do not do so with regard to out-group members. We investigate how productivity increases that fall on marketable goods and services–rather than on prosocial relationships within social groups–can reduce the size of social groups by raising the return to positional comparisons across groups and thereby influence social welfare. Productivity increases therefore not only raise people's material standard of living, but also increase social fragmentation as measured by the size of social groups within the economy. We examine the conditions under which the second effect dominates the first, whereupon the productivity increases become welfare-reducing.

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 economic growth 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). 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 characterise humans as social creatures: positionally competitive 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; positionally competitive 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 falls more on market-traded commodities associated with individualistic and positionally competitive activities than 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 positionally competitive 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" (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 salient.

Under these two premises, we analyse how productivity growth promotes individualistic and positionally competitive 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 positionally competitive 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.[1] 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 globalisation 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 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.

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.

The rest of 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 positionally competitive activities rises in response to productivity growth and when there are diminishing returns to the production of market goods. Section 8 concludes.

[1] 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.

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*, whereby an individual's utility depends exclusively on her own payoff,
- *Positional competition*,[2] whereby her utility depends on her payoff relative to her relevant reference group, and
- *Prosociality*, whereby her utility depends positively on the utility of her in-group.

2.1 Motives in economic decision making

The underlying insight is taken from motivation psychology,[3] namely, that people have access to multiple "motives", which are psychological forces that give direction and energy to one's behaviour. 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 positionally competitive motives delineate and secure the individual's place within social hierarchies. The self-interested wanting motive drives the satisfaction of wants that pertain to oneself, without reference to any social relations.

All three motives are common in practice. Prosociality generates the desire to promote the wellbeing of others and to alleviate their suffering. It includes acts of benevolence, altruism, sympathy, as well as the need to be liked and the need for interpersonal relatedness. It occurs naturally among kin and is frequently extended to friends and other non-kin groups with whom one identifies. Positional competition 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 labour market, rankings of fund managers, tennis seeds, football leagues, and much more.

Our analysis focuses on positional competition 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.

Non-positional 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

[2] For example, Heckhausen (1989, 2000); Heckhausen and Heckhausen (2010).

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

describing how survival and procreation depends on one's social ranking. 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 positional competition and prosociality take place with respect to pre-existing 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 class groups. Specifically, each identity describes an in-group, the payoff of whose members we seek to promote, and a "competing out-group," the payoff of whose members we seek to surpass.[4]

People are assumed to be motivated by prosociality toward their in-group and by positional competition 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 positional competition 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 positionally competitive 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 whom we differentiate (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.[5] Galinski et al. (2005) show that this self-other overlap explains why close relationships foster social cooperation (prosocial motives). McFarland et al. (2001) find muted affective responses to social comparisons with close others. Gardner et al. (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 et al. (2010) show that both trait- and state-induced compassion is associated with increased perceived self-other similarity, while pride is associated with a decreased sense of similarity to weak

[4] 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.

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

others. Our assumption that there is more prosociality within groups and more positional competition between groups is therefore well founded.

2.3 Technological market bias

Our analysis rests on the hypothesis that productivity growth arising from technological advance 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.”[6] The amount of time input required by social relationships powered by prosociality – 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 positional competition 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 to the relationships, at least in comparison to the effect of technology on positionally competitive and individualistic pursuits. For example, advances in computer technologies have given rise to vast productivity improvements in the production of positional 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.

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.[7] Dealing specifically with a technology complementary to social relationships,

[6] 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 are market activities, to be distinguished from non-market relationships. Like many services, the labour productivity of non-market relationships – such as playing tag with one’s children, dancing with loved ones, playing tennis with friends – cannot be raised significantly through technological progress, since the time input of the participants is central to these activities. Unlike Baumol’s phenomenon however, this productivity difference between socially cooperative relationships and competitive and individualistic activities does not arise from the distinction between goods and services. Our distinction is rather between goods and services that meet competitive and individualistic goals versus those that meet socially cooperative goals.

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

Rotondi et al. (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.[8] The quest for positional 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 positionally competitive 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 positional 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-positional 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.[9]

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 positionally competitive 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 positional competition 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

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

[9] We consider this extension in Sect. 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.

in evenings spent with neighbours over a 20 year period in the United States, with some substitution towards other friends. Li et al. (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 heterogeneity 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 growth (Algan and Cahuc 2010), growth degrades interpersonal trust (Roth 2009; see also Mahdavi and Azizmohammadlou (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 wellbeing, 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; Becchetti et al. 2008, 2009; Gui and Stanca 2010).

The importance of positional competition 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 positionally competitive pursuits. Much corroborating evidence was found by subsequent contributors (e.g. Frank 1999).[10]

The adverse welfare consequences of positional competition have been investigated by contributors to ecological economics (e.g. Daly (1977, 1996); Durning (1992)), who explore how positional 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 positionally competitive activities

We now construct a simple model of prosocially-driven cooperation and positional competition. Consider a population of agents with measure 1. Each agent i is characterised by an ability index a_i, which is distributed uniformly on the unit interval: $a_i \sim UNIF[0,1]$. A *social group* is a subset of the ability distribution $G \subseteq [0,1]$ such that agents i with $a_i \in G$ are able to produce a public good, and only compare themselves with agents outside of the group. It is assumed that groups must be real intervals in $\mathcal{G} = 2^{[0,1]}$ which are mutually exclusive and together span the ability distribution: $\cup_{G\in\mathcal{G}} G = [0,1]$ and $\cap_{G\in\mathcal{G}} G = \emptyset$. This is meant to capture that groups are commonly understood social entities: no agent can enjoy the benefits of being in a group which does not recognise her, nor can she suffer the costs of being in a group which she does not recognise. Denote by G_i the group which contains i as a member: $a_i \in G_i$. Furthermore, let $\underline{a}_i = \inf G_i$ and $\overline{a}_i = \sup G_i$.

3.1 Non-market activities

The members of each group together produce a non-market club good through socially cooperative relationships. Individual i in group G_i derives the following utility from her socially cooperative relationships with her other in-group members

$$U_i^c = \alpha N_i, \tag{1}$$

[10] 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; Mauss 1954. Only the time-series evidence, however, is relevant to our analysis.

where N_i is the size of individual i's in-group:

$$N_i = \int_{\underline{a}_i}^{\overline{a}_i} 1 \cdot da_j = \overline{a}_i - \underline{a}_i \tag{2}$$

and $\alpha > 0$ parametrises the productivity of the common good.

3.2 Market activities

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

$$x_i(a_i) = \beta\left(\frac{1}{2} + a_i\right), \tag{3}$$

where a_i represents i's individual ability and $\beta > 0$ is a productivity parameter.[11] As $a_i \sim UNIF[0, 1]$, the average production in society is

$$\int_0^1 x_i \, da_i = \beta. \tag{4}$$

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

$$U_i^n = \gamma\left(x_i - \lambda N_i\right), \tag{5}$$

where λ is the "consumption substitution parameter", measuring the degree of substitutability between the utility from market commodities and prosocial relationships: for every unit increase in prosocial activities, the enjoyment of market goods falls by λ. 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 consume. We justify this on the basis that the consumption of goods requires time as does the maintenance of prosocial relationships.[12]

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

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

[11] 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 Sect. 6 we assume that monetary income m corresponds to a market production of $x = m^\rho$ with $0 < \rho < 1$.

[12] 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. See also Corneo (2018).

where π is a *pride parameter*, ε is an *envy parameter*, and $\overline{U}^s$ is a reference level of status utility that each individual treats as constant.[13] 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

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

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 $\left(1 - \overline{a}_i\right)$ 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

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

i's overall expected utility from competition.

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

$$U_i^s = (1-\gamma)\left(\beta\left(\frac{\pi}{2}\underline{a}_i\left(2a_i - \underline{a}_i\right) - \frac{\varepsilon}{2}\left(1 - \overline{a}_i\right)\left(1 + \overline{a}_i - 2a_i\right)\right) - \lambda N_i - \overline{U}^s\right) \tag{9}$$

and

$$U_i^n = \gamma\left(\beta\left(\frac{1}{2} + a_i\right) - \lambda N_i\right). \tag{10}$$

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. Each individual i derives utility from three sources: non-market activities, positional status, and market-oriented private consumption. The expected utility of individual i is

$$U_i = U_i^c + U_i^s + U_i^n. \tag{11}$$

We can now stipulate two conditions that characterise an equilibrium distribution of social groups:

1. A group $G \in \mathcal{F} \subseteq 2^{[0,1]}$ is *feasible* if and only if, each prospective member a_i of G would not be better off in any other group G' which contained that person (a_i) as its ablest member.

[13] 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 direct social status utility cannot change over time. Note also that i gains more status utility the more intensely she is engaged in goods consumption vs. caring activities.

$$G \in \mathcal{F} \text{ iff } \forall a_i \in G, :\ U_i(G) \geq \max_{G'} U_i\big(G' \mid G' \subseteq [0, a_i]\big)$$

2. A group $G \in \mathcal{S} \subseteq \mathcal{F}$ is *stable* if and only if it is feasible and no proper subset of the group is also feasible.

$$G \in \mathcal{S} \text{ iff } 2^G \cap \mathcal{F} = \{G\}$$

4.1 Lemma 1

Feasible groups cannot be smaller than

$$N^*(\alpha, \beta, \gamma, \lambda, \pi) = \frac{\alpha - \lambda}{\beta\pi(1-\gamma)}. \tag{12}$$

.

Proof Suppose that a feasible group G_i was such that $\overline{a}_i - \underline{a}_i = N^* - \omega < N^*$.[14] The quantity[15]

$$\lim_{a_i \to \overline{a}_i} \big(U_i\big([a_i - N^*, a_i]\big) - U_i\big([\underline{a}_i, \overline{a}_i)\big)\big) = \frac{\beta}{2}(1-\gamma)\pi\omega^2 > 0. \tag{13}$$

Then for some $a_i = \overline{a}_i - \epsilon$, $U_i\big([a_i - N^*, a_i]\big) - U_i\big([\underline{a}_i, \overline{a}_i]\big) = \frac{\beta}{2}(1-\gamma)\pi\omega^2 - \delta > 0$ by continuity of 13 in a_i for appropriately small ϵ. But this is a contradiction as the group G_i is feasible and as such $U_i\big(G_i\big) \geq \max_{G'} U_i\big(G' \mid G' \subseteq [0, a_i]\big)$ by definition.

4.2 Lemma 2

No group larger than N^* can be stable.

Proof Suppose that a feasible group G_i was such that $\overline{a}_i - \underline{a}_i = N^* + \omega > N^*$. Let $\overline{a}_i - \omega < a_i < \overline{a}_i$. We will now proceed to show that the group $[a_i - N^*, a_i] \subsetneq G_i$ is feasible. Differentiating $U_i\big([\underline{a}'_i, a_i]\big)$ with respect to $\underline{a}'_i$ we get

$$\frac{dU_i\big([\underline{a}'_i, a_i]\big)}{d\underline{a}'_i} = \beta\pi(1-\gamma)\big(a_i - \underline{a}'_i\big) - \alpha + \lambda. \tag{14}$$

Setting equal to zero and solving for $\underline{a}'_i$ gives us

$$\underline{a}'_i = a_i - \frac{\alpha - \lambda}{\beta\pi(1-\gamma)} = a_i - N^* \tag{15}$$

with $d^2U_i/d\underline{a}'^2_i < 0$. The group $[a_i - N^*, a_i]$ therefore satisfies the definition of feasibility meaning that G_i cannot be stable.

[14] We assume that $\lambda < \alpha$, in order to ensure that people sort into groups of size greater than zero.

[15] See derivation in the appendix.

4.3 Lemma 3

Any feasible and stable group G must include all of the individuals who are at least as able as any member of G and who are not themselves included in other feasible and stable groups which they would find preferable.

Proof Suppose that individual i is a member of a feasible and stable group with $\overline{a}_i - \underline{a}_i = N^*$ (See Lemmas 1-2). The quantity

$$\begin{aligned} &U_i\left(\left[\underline{a}_i, \overline{a}_i\right)\right) - U_i\left(\left[a_i - N^*, a_i\right]\right) \\ &= \frac{1}{2}\left(\overline{a}_i - a_i\right)\left(\beta(1-\gamma)\left(\overline{a}_i - a_i\right)(\varepsilon - \pi) + 2(\alpha - \lambda)\right) \end{aligned} \tag{16}$$

must be positive in order for this group to be feasible.

Case 1 ($\varepsilon > \pi$): $U_i\left(\left[\underline{a}_i, \overline{a}_i\right)\right) - U_i\left(\left[a_i - N^*, a_i\right]\right) > 0$ trivially.
Case 2 ($\varepsilon < \pi$):

$$\begin{aligned} U_i\left(\left[\underline{a}_i, \overline{a}_i\right)\right) - U_i\left(\left[a_i - N^*, a_i\right]\right) &\geq \frac{1}{2}\left(\overline{a}_i - a_i\right)(\beta(1-\gamma)N^*(\varepsilon - \pi) + 2(\alpha - \lambda)) \\ &= \frac{1}{2}\left(\overline{a}_i - a_i\right)\left(\beta(1-\gamma)\left(\frac{\alpha - \lambda}{\beta\pi(1-\gamma)}\right)(\varepsilon - \pi) + \right. \\ &\quad \left. 2(\alpha - \lambda)\right) \\ &= \frac{1}{2}\left(\overline{a}_i - a_i\right)\left(\left(\frac{\alpha - \lambda}{\pi}\right)(\varepsilon - \pi) + 2(\alpha - \lambda)\right) \\ &= \frac{1}{2}\left(\overline{a}_i - a_i\right)(\alpha - \lambda)\left(\left(\frac{\varepsilon - \pi}{\pi}\right) + 2\right) \\ &= \frac{1}{2}\left(\overline{a}_i - a_i\right)(\alpha - \lambda)(\varepsilon/\pi - 1 + 2) \\ &= \frac{1}{2}\left(\overline{a}_i - a_i\right)(\alpha - \lambda)(\varepsilon/\pi + 1) \geq 0. \end{aligned}$$

For a group containing individual i, the ability of its lowest-ranked member is $\underline{a}_i$ and includes all agents with ability less than $\overline{a}_i$, though $\overline{a}_i$ herself is a member of the next-highest group (unless $\overline{a}_i = 1$, as 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.

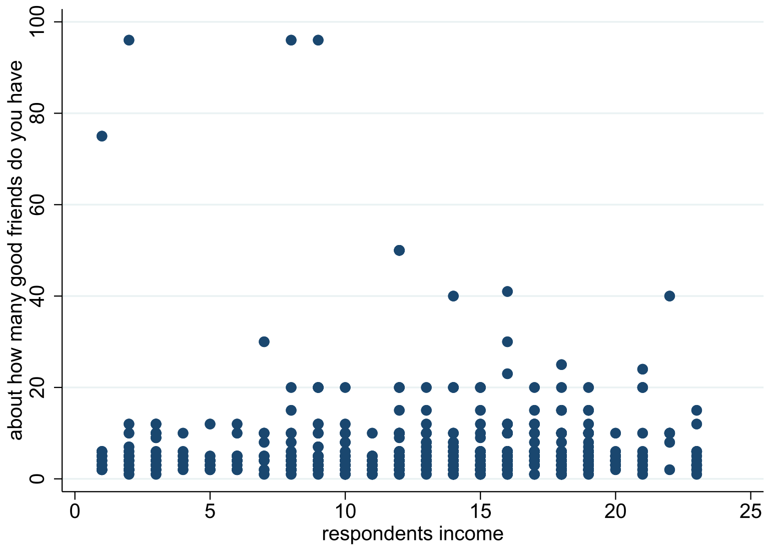

Fig. 1 Number of close friends by income category from 1998 General Social Survey

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 (12), this increase in productivity β reduces the equilibrium size of social groups, implying a rise in social fragmentation:

$$\frac{\partial N^*}{\partial \beta} = -\frac{\alpha - \lambda}{\beta^2 \pi (1 - \gamma)} < 0, \tag{17}$$

By increasing the productivity of engaging in positional competition, technological advance and globalisation 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 on material welfare (via the rise in market good production for a given amount of effort) and an indirect effect that operates via the rise in social fragmentation):

$$\frac{dU_i^n}{d\beta} = \gamma\left(\frac{1}{2} + a_i\right) - \left(\gamma\lambda\frac{\partial N^*}{\partial\beta}\right) = \gamma\left(\frac{1}{2} + a_i\right) + \frac{\gamma\lambda(\alpha - \lambda)}{\beta^2\pi(1 - \gamma)} > 0 \tag{18}$$

The direct effect is denoted by the first term $\left(\frac{1}{2} + a_i\right)$ 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 positional 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

$$W = \sum_{k=1}^{K+1} \int_{\underline{a}_k}^{\overline{a}_k} U_i da_i, \tag{19}$$

i.e. the sum of the utilities of all social groups. The economy contains $K + 1 \equiv \lceil 1/N^* \rceil$ social groups, with the upper $K = \lfloor 1/N^* \rfloor$ groups[16] 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^*):

$$\frac{dW}{d\beta} = \frac{\partial W}{\partial\beta} + \frac{\partial N^*}{\partial\beta} \cdot \frac{dW}{dN^*}. \tag{20}$$

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

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

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.

[16] In the comparative static exercises to follow we will treat K as fixed. Note that this restricts our attention to small changes in group alignments, from which the effects of larger changes may be approximated.

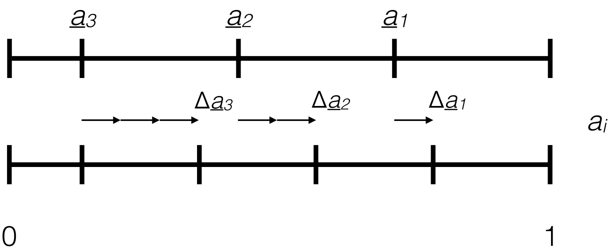

Fig. 2 Visualising the cascade of social demotions

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 positional 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 $\Delta\underline{a}_3 = 3\Delta\underline{a}_1$. In general, $d\overline{a}_k/d\underline{a}_k = k/k+1 < 1$.

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 positional status-driven utility U^s may be expressed

$$\Delta U^s = \sum_k \underbrace{\int_{\underline{a}_k+\Delta\underline{a}_k}^{\overline{a}_k} \Delta U_i^s da_i}_{incumbents} + \underbrace{\int_{\underline{a}_k}^{\underline{a}_k+\Delta\underline{a}_k} \Delta U_i^s da_i}_{demotees} \tag{21}$$

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 $\Delta\underline{a}_k$, 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[17]:

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

$$\frac{dU^s}{dN^*} = \frac{\beta\varepsilon}{2}(1-\gamma)K\left(N^{*2} - (1-KN^*)^2\right) - (1-\gamma)\lambda. \tag{22}$$

On this basis, the indirect effect may be derived as follows. By Eq. (17), 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[18]

$$\frac{dW}{dN^*} = \alpha - \lambda + \frac{\beta\varepsilon}{2}(1-\gamma)K\left(N^{*2} - (1-KN^*)^2\right) > 0. \tag{23}$$

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 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.

Unlike in the case of non-positional commodities, we suppose there is no *aggregate* direct effect of productivity growth on status utility U^s. *More specifically we assume tha* $\overline{U}^s$ *by definition satisfies*

$$\frac{\partial}{\partial\beta}\sum_{k=1}^{K+1}\int_{\underline{a}_k}^{\overline{a}_k} U_i^s da_i = 0; \tag{24}$$

and that there are only indirect effects of productivity β on positional utility U^s through its impact on equilibrium group size N^*, $dN^*/d\beta$. Were $\overline{U}^s$ not subtracted out of status utility we would observe scaling effects from increasing β which would amplify people's experienced pride or envy. We feel that from a welfare perspective it would not be appropriate to count this because status is inherently relative and its aggregate quantity cannot increase when the objects of status competition become more abundant.

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

$$\frac{dW}{d\beta} = \underbrace{\underbrace{\gamma}_{\text{direct effect}} + \underbrace{\frac{\gamma\lambda(\alpha-\lambda)}{\beta^2\pi(1-\gamma)}}_{\text{effort effect}}}_{\text{increased non-positional commodities}} - \underbrace{\frac{\alpha(\alpha-\lambda)}{\beta^2\pi(1-\gamma)}}_{\text{lost prosocial relationships}} \underbrace{- \underbrace{\frac{(\alpha-\lambda)\varepsilon K\left(N^{*2}-(1-KN^*)^2\right)}{2\beta\pi}}_{\text{excess envy}} + \underbrace{\frac{(1-\gamma)\lambda(\alpha-\lambda)}{\beta^2\pi(1-\gamma)}}_{\text{effort effect}}}_{\text{increased positional commodities}}. \tag{25}$$

[18] The positive effect follows from three conditions: (i) Eq. (12), (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.

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 both more positional and non-positional commodities, on account of the greater labour input and the increased productivity of this input.[19]

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: $-\frac{\alpha^2}{\beta\pi(1-\gamma)} < 0$. 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[20] does not obtain here, due to the club-good nature of prosocial relationships.[21]
3. Positional commodities: The productivity increase raises the production of positional commodities. This effect can be decomposed into an excess envy effect (individuals at the bottom of the social hierarchy have more people to feel envious

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

[20] 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.

[21] 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 consumption substitutability parameter λ.

of) and effort-related effect (more time is devoted to positional commodities, at the expense of prosocial relationships).

1. Excess envy (fourth term): the formation of smaller social groups leads to a rise in positionally competitive activities. When $\varepsilon > \pi$ (Boyce et al. 2010 provide empirical support for this claim) increased positional 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. 23. While it is true that for every person who gains from a relative rise in positional status, there is another person who loses from a relative loss in status,[22] 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).
2. Effort-related effect (fifth term): productivity growth also leads people to substitute more time into market activities, away from socially cooperative relationships. This generates greater consumption of positional commodities, on account of the greater labour input and the increased productivity of this input.

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

5.1 Proposition

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

$$\widehat{\gamma}(\alpha, \beta, \lambda, \varepsilon, \pi) \simeq \frac{1}{2} + \sqrt{\frac{1}{4} - \frac{\left(\pi + \frac{\varepsilon}{2}\right)(\alpha - \lambda)^2}{\beta^2 \pi^2}}. \tag{26}$$

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 Sect. 6 below for a rough calibration).

[22] 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.

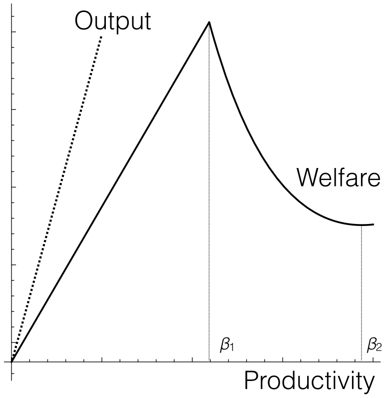

Fig. 3 Effects of growth – Output vs. welfare for fixed γ

Note that the condition $\gamma < \hat{\gamma}$, 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 rise 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 the condition $\gamma < \hat{\gamma}$ is fulfilled.

(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 considered 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 consumption 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 ($\hat{\gamma}$) is even lower than that given by Eq. (26). 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 Sect. 7.

6 Calibration

As indicated above, productivity growth becomes welfare-reducing once the proportion of non-positional goods falls beneath the threshold level $\hat{\gamma}$. 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 consumption substitution parameter is $\lambda = 0$, i.e. increases in prosocial activities does not reduce the consumption and therefore production of market commodities.

Under these conditions, by Equation (12), the equilibrium group size is $N^* = \frac{\alpha}{\beta\pi(1-\gamma)}$ and the threshold proportion of non-positional goods $\hat{\gamma}$ simplifies to

$$\hat{\gamma} = \frac{\alpha N^*}{2\beta} \cdot \left(2 + \frac{\varepsilon}{\pi}\right) \tag{27}$$

Our analysis indicates that if the proportion of non-positional goods falls beneath this threshold value $\hat{\gamma}$, productivity growth becomes welfare-reducing. Note that the threshold proportion $\hat{\gamma}$ is the product of two terms: (i) the interaction-weighted "productivity ratio" $(\alpha N^*/\beta)$ is, i.e. the ratio of prosocial output (αN^*) to market productivity (β) and (ii) the "envy-pride parameter" ε/π.[23]

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, αN^* 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.[24] 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 αN^*.

Wendner & Goulder (2008) suggest that positional consumption is at least 20% of total consumption,[25] so that γ is at most 0.8.

The median income in the United Kingdom in 2017 is £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

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

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

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

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.

In the analysis above, we do not interpret the relative valuation of income and social relationships in monetary terms (refer to sec. 3.2, footnote 11). 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 et al. (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 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 mean income ($u(£42, 515)$),[26] equal to

$$\frac{\alpha N^*}{2\beta} = \frac{(172, 019)^{33/132}}{(42, 515)^{33/132}} \approx 1.42.$$

Setting $\pi = 1/1.75$, and $\varepsilon = 1$, we obtain the condition $\gamma \leq \frac{\alpha N^*}{2\beta} \cdot \left(2 + \frac{\varepsilon}{\pi}\right) < 5.32$ in order for productivity growth to be welfare-reducing. This exercise shows that the phenomenon of welfare-reducing growth is an empirically plausible possibility; and merits further investigation by empirical economists.

[26] Per Eq. 4 the mean income in this economy is β, therefore $\beta = 42{,}515$.

7 Further welfare effects of productivity growth

In Sect. 5, we have seen how productivity growth leads to a reduction in the size of social groups, thereby promoting people's positionally competitive activities with regard to those outside their social groups and reducing prosocial relationships within their social groups. Since the positionally competitive 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). This decoupling phenomenon can be reinforced through the effect of productivity growth on the following phenomena.

7.1 Rising proportion of positionally competitive activities

Productivity growth increases GDP per capita and may thereby raise the share of positional goods in total production. The reason is that while basic individual material needs may be satisfied with finite resources, *positional* status needs are inherently insatiable, since one individual's status needs must always be satisfied relative to those of others.[27]

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

$$\frac{dN^*}{d(1-\gamma)} = -\frac{\alpha-\lambda}{\pi\beta(1-\gamma)^2} < 0 \tag{28}$$

The associated welfare effect is also negative:

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

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

$$\gamma(0) = 1$$
$$\lim_{\beta\to+\infty} \gamma(\beta) = 0$$

and

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

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.

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

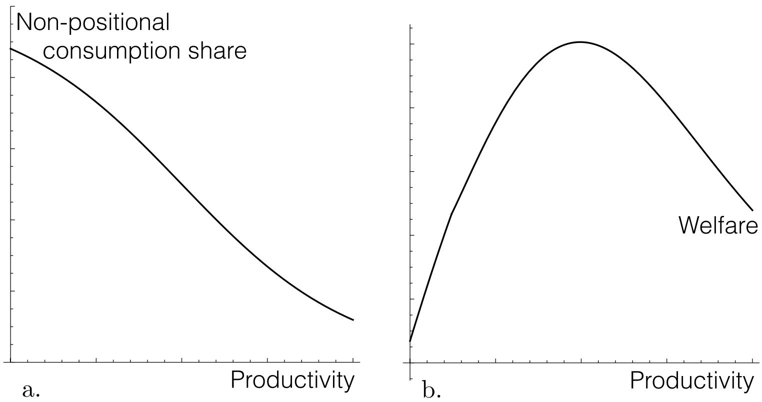

Fig. 4 Effects of growth–diminishing γ (**a**) and its effects on welfare (**b**)

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

$$\frac{\partial W}{\partial \beta} = \gamma + \gamma_\beta \beta. \tag{29}$$

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 $\left|\gamma_\beta\right| \cdot \beta$ 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:

$$\begin{aligned} \frac{dW}{d\beta} = \underbrace{\gamma + \gamma_\beta \beta}_{\textit{direct effect}} + \underbrace{\frac{\lambda(\alpha - \lambda)\left(1 - \gamma - \gamma_\beta \beta\right)}{\beta^2 \pi (1 - \gamma)^2}}_{\textit{effort effect}} - \underbrace{\frac{\alpha\left(1 - \gamma - \beta\gamma_\beta\right)(\alpha - \lambda)}{\beta^2 \pi (1 - \gamma)^2}}_{\textit{lost prosocial relationships}} \\ - \underbrace{\frac{(\alpha - \lambda)\left(1 - \gamma - \beta\gamma_\beta\right)\varepsilon K\left(N^{*2} - (1 - KN^*)^2\right)}{2\beta\pi(1 - \gamma)}}_{\textit{excess envy}}. \end{aligned} \tag{30}$$

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 more positive, since we have assumed $\lambda < \alpha$ (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 consumption of both non-positional and positional goods. Note we have summed the positional and non-positional effort effects here for presentation.

2. Socially cooperative relationships (third term): Note that in contrast to the base case, there is more substitution away from prosocial activities as γ shrinks. Therefore the effect on socially cooperative relationships becomes more negative.
3. Excess envy (fourth term): The formation of smaller social groups leads to a rise in positionally competitive activities. The increasing share of positional commodities in consumption makes the pivotal group members narrow their groups to be more exclusive, such that the size of the rump group increases more steeply with β. Therefore the effect on excess envy becomes more negative as well.

Fig. 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.[28] Panel b. again shows the path of welfare as the economy grows. Just as in the fixed-γ case of Fig. 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.[29]

$$\frac{d^2W}{d\beta d\gamma_\beta} = \beta + \frac{(\alpha - \lambda)}{\pi(1-\gamma)}\left(\frac{\alpha - \lambda}{\beta(1-\gamma)} + \frac{\varepsilon K\left(N^{*2} - (1 - KN^*)^2\right)}{2}\right) \geq 0. \tag{31}$$

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

[29] See the supplementary materials.

7.2 Diminishing returns to the consumption of market-traded commodities

As productivity growth promotes substitution from socially supportive relationships to consumption of market-traded commodities, the opportunity cost of commodity consumption 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 consumption and positional status, groups become smaller in equilibrium:

$$\frac{\partial N^*}{\partial \lambda} = -\frac{1}{\beta\pi(1-\gamma)} < 0. \tag{32}$$

As a result, social welfare falls:

$$\frac{dW}{d\lambda} = -\frac{1}{\beta\pi(1-\gamma)} \cdot \frac{dW}{dN^*} < 0. \tag{33}$$

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

$$\frac{\partial N^*}{\partial \pi} = -\frac{\alpha-\lambda}{\beta\pi^2(1-\gamma)} < 0. \tag{34}$$

The resulting welfare effect is again negative:

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

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 positional competition, but less on socially supportive relationships, then productivity growth narrows people's bounds of social affiliation and extends their positionally competitive activities. Since positional competition 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 positional 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 positionally competitive 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.

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 and sociology and motivation psychology. 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).

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 globalisation, 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 is not an argument for stopping technological advance. Each of the model's parameters is amenable to policy intervention. More empirical research needs to be done on the determinants of positional status-biased growth and consumers' response to status incentives. Corneo and Jeanne (1998) for example show that the price elasticity of demand for positional 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[30] 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 to Operate, and other social initiatives may have the potential to redress the socially destructive implications of technological advance, enabling us to reap the rewards of productivity growth without paying the social costs.

Appendix

Derivation of $\lim_{a_i \to \overline{a}_i} \left(U_i\left(\left[a_i - N^*, a_i\right]\right) - U_i\left(\left[\underline{a}_i, \overline{a}_i\right)\right)\right)$

Refer to equations (1), (5), (9), and (11). Suppose $\overline{a}_i - \underline{a}_i = N^* - \omega$. Then:

$$
\begin{aligned}
U_i\left(\left[\underline{a}_i, \overline{a}_i\right)\right) = (\alpha - \lambda)(N^* - \omega) + \gamma\beta\left(\frac{1}{2} + a_i\right) \\
+ (1-\gamma)\left(\beta\left(\frac{\pi}{2}\left(\overline{a}_i - N^* + \omega\right)\left(2a_i - \overline{a}_i + N^* - \omega\right)\right.\right. \\
\left.\left. -\frac{\varepsilon}{2}\left(1 - \overline{a}_i\right)\left(1 + \overline{a}_i - 2a_i\right)\right) - \overline{U}_s\right)
\end{aligned}
$$

and

[30] There are numerous examples, such as European Commission (2013); Norden (2015), and OECD (2011).

$$U_i\left(\left[a_i - N^*, a_i\right]\right) = (\alpha - \lambda)N^* + \gamma\beta\left(\frac{1}{2} + a_i\right).$$
$$+ (1-\gamma)\left(\beta\left(\frac{\pi}{2}\left(a_i - N^*\right)\left(2a_i - a_i + N^*\right) - \frac{\varepsilon}{2}\left(1 - \overline{a}_i\right)\left(1 + \overline{a}_i - 2a_i\right)\right)\right.$$
$$\left. - \overline{U}_s\right)$$

Therefore $\lim_{a_i \to \overline{a}_i}\left(U_i\left(\left[a_i - N^*, a_i\right]\right) - U_i\left(\left[\underline{a}_i, \overline{a}_i\right)\right)\right) =$

$$\omega(\alpha - \lambda) + (1-\gamma)\left(\beta\left(\frac{\pi}{2}\omega(\omega - 2N^*)\right)\right)$$

and using Eq. (12) we get $\lim_{a_i \to \overline{a}_i}\left(U_i\left(\left[a_i - N^*, a_i\right]\right) - U_i\left(\left[\underline{a}_i, \overline{a}_i\right)\right)\right) =$

$$\omega(\alpha - \lambda) + (1-\gamma)\beta\frac{\pi}{2}\omega^2 - \frac{2\beta\pi(1-\gamma)}{2\beta\pi(1-\gamma)}\omega(\alpha - \lambda)$$
$$= (1-\gamma)\beta\frac{\pi}{2}\omega^2.$$

Derivation of the aggregate status utility from group realignment

We have shown that in equilibrium groups are always of of uniform size. Let us consider a discrete change from an equilibrium with groups of uniform size N^0 to a new equilibrium with groups of uniform size $N' < N^0$ such that $\Delta N^* \equiv N' - N^0 < 0$. This change entails a whole set of changes to the boundaries $\underline{a}_k$, $\overline{a}_k$ of each group k which we summarise as follows.

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

We first examine the change in status utility of a representative *incumbent* $a_{i:I^k}$ of group k from the regime of equilibrium group size N^0 to that of equilibrium group size N'. Her utility under N^0 is

$$U^s_{i:I^k}\left(N^0\right) = \frac{\beta}{2}(1-\gamma)\left(\pi\left(\overline{a}_k - N^0\right)\left(2a_{i:I^k} - \overline{a}_k + N^0\right) - \varepsilon\left(1 - \overline{a}_k\right)\left(1 + \overline{a}_k - 2a_{i:I^k}\right)\right)$$
$$- (1-\gamma)\lambda N^0 - \overline{U}^s$$

(note that the substitution $\underline{a}_k = \overline{a}_k - N^0$ has been made since we are looking at utility in equilibrium). Her utility under the new regime N' is

$$U^s_{i:I^k}\left(N'\right)=\frac{\beta}{2}(1-\gamma)\Big(\pi\left(\overline{a}_k-N^0-k\Delta N^*\right)\left(2a_{i:I^k}-\overline{a}_k+N^0+k\Delta N^*\right)$$
$$-\varepsilon\left(1-\overline{a}_k+(k-1)\Delta N^*\right)\left(1+\overline{a}_k-2a_{i:I^k}-(k-1)\Delta N^*\right)\Big)$$
$$-(1-\gamma)\lambda N'-\overline{U}^s$$

The change in utility from the old to the new regime for the incumbent is

$$\Delta U^s_{i:I^k}\equiv U^s_{i:I^k}\left(N'\right)-U^s_{i:I^k}\left(N^0\right)=$$

$$-\frac{\beta}{2}(1-\gamma)\Delta N^*\Big(\pi k\left(2\left(a_{i:I^k}-\overline{a}_k+N^0\right)+k\Delta N^*\right)$$
$$+\varepsilon(k-1)\left(2\left(\overline{a}_k-a_{i:I^k}\right)-(k-1)\Delta N^*\right)\Big)-(1-\gamma)\lambda\Delta N.$$

Now let us consider the change in status utility of a representative *demotee* $a_{i:D^k}$ of group k from the regime of equilibrium group size N^0 to that of equilibrium group size N'. Her status utility under N^0 is

$$U^s_{i:D^k}\left(N^0\right)=\frac{\beta}{2}(1-\gamma)\Big(\pi\left(\overline{a}_k-N^0\right)\left(2a_{i:D^k}-\overline{a}_k+N^0\right)-\varepsilon\left(1-\overline{a}_k\right)\left(1+\overline{a}_k-2a_{i:D^k}\right)\Big)$$
$$-(1-\gamma)\lambda N^0-\overline{U}^s$$

(note that the substitution $\underline{a}_{k+1}=\overline{a}_k-2N^0$ has been made since we are looking at utility in equilibrium). Her status utility under the new regime N' is

$$U^s_{i:D^k}\left(N'\right)=\frac{\beta}{2}(1-\gamma)\Big(\pi\left(\overline{a}_k-2N^0-(k+1)\Delta N^*\right)\left(2a_{i:D^k}-\overline{a}_k+2N^0+(k+1)\Delta N^*\right)$$
$$-\varepsilon\left(1-\overline{a}_k+k\Delta N^*+N^0\right)\left(1+\overline{a}_k-2a_{i:D^k}-k\Delta N^*-N^0\right)\Big)$$
$$-(1-\gamma)\lambda N'-\overline{U}^s$$

The change in utility from the old to the new regime is

$$\Delta U^s_{i:D^k}\equiv U^s_{i:D^k}\left(N'\right)-U^s_{i:D^k}\left(N^0\right)=$$

$$\frac{\beta}{2}(1-\gamma)\Big(\pi\left((k+1)\Delta N^*+N^0\right)\left(2\left(\overline{a}_k-a_{i:D^k}\right)-3N^0-(k+1)\Delta N^*\right)$$
$$-\varepsilon\left(k\Delta N^*+N^0\right)\left(2\left(\overline{a}_k-a_{i:D^k}\right)-k\Delta N^*-N^0\right)\Big)-(1-\gamma)\lambda\Delta N.$$

Let us now sum over the change in status utilities for all agents:

$$\Delta U^s\equiv\sum_{k=1}^{K}\left(\int_{\overline{a}_k-N^0-k\Delta N^*}^{\overline{a}_k}\left(\Delta U^s_{i:I^k}\right)da_{i:I^k}+\int_{\overline{a}_k-N^0}^{\overline{a}_k-N^0-k\Delta N^*}\left(\Delta U^s_{i:D^k}\right)da_{i:D^k}\right)$$
$$+\int_0^{1-KN^0}\left(\Delta U^s_{i:I^{K+1}}\right)da_{i:I^{K+1}}$$

$$= \sum_{k=1}^{K} \left(\frac{\beta}{2}(1-\gamma)\Big(-\Delta N^* \left(N^0 + k\Delta N^*\right)\left(\pi k N^0 + \varepsilon(k-1)\left(N^0 + \Delta N^*\right)\right) \right.$$

$$\left. + k\Delta N^* \left(\varepsilon N^0 \left(k\Delta N^* + N^0\right) + \pi\left(N^0 + \Delta N^*\right)\left(N^0 + (k+1)\Delta N^*\right)\right)\Big)\right)$$

$$- \frac{\beta\varepsilon}{2}(1-\gamma)K\Delta N^* \left(1 - K\left(N^0 + \Delta N^*\right)\right)\left(1 - KN^0\right) - (1-\gamma)\lambda\Delta N$$

Finally, we can take the limit of the total change in status utility above as $\Delta N^* \to 0$ at $N^0 = N^*$:

$$\frac{dU^s}{dN^*} \equiv \lim_{\Delta N^* \to 0} \frac{\Delta U^s}{\Delta N^*} = \sum_{k=1}^{K} \left(\frac{\beta\varepsilon}{2}(1-\gamma)N^{*2} \right)$$

$$+ \frac{\beta\varepsilon}{2}(1-\gamma)K(1-KN^*)^2 - (1-\gamma)\lambda$$

$$= \frac{\beta\varepsilon}{2}(1-\gamma)K\left(N^{*2} - (1-KN^*)^2\right) - (1-\gamma)\lambda.$$

Proof that $dW/dN^* > 0$

We must show that

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

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

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

$$= (1-\gamma)\left(\beta\left(\pi N^* + \frac{\varepsilon K}{2}\left(N^{*2} - (1-KN^*)^2\right)\right)\right).$$

Note from the condition $(K+1)N^* > 1$ that $N^* \geq 1 - KN^*$ and thusly $N^{*2} - (1-KN^*)^2 \geq 0$. Since the expression for dW/dN^* above contains only non-negative elements, we therefore know that $dW/dN^* > 0$.

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 $K = 1/N^*$:

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

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

$$\begin{aligned}
\hat{\gamma} &= \frac{\left(\pi+\frac{\varepsilon}{2}\right)(\alpha-\lambda)^2}{\beta^2\pi^2\left(1-\hat{\gamma}\right)} \\
\rightarrow \hat{\gamma}\left(1-\hat{\gamma}\right) &= \frac{\left(\pi+\frac{\varepsilon}{2}\right)(\alpha-\lambda)^2}{\beta^2\pi^2} \\
\rightarrow \hat{\gamma}-\hat{\gamma}^2 &= \frac{\left(\pi+\frac{\varepsilon}{2}\right)(\alpha-\lambda)^2}{\beta^2\pi^2} \\
\rightarrow \hat{\gamma}^2-\hat{\gamma}+\frac{\left(\pi+\frac{\varepsilon}{2}\right)(\alpha-\lambda)^2}{\beta^2\pi^2} &= 0.
\end{aligned}$$

An application of the quadratic formula gives us

$$\begin{aligned}
\hat{\gamma} &= \frac{1+\sqrt{1-4\cdot\frac{\left(\pi+\frac{\varepsilon}{2}\right)(\alpha-\lambda)^2}{\beta^2\pi^2}}}{2} \\
&= \frac{1}{2}+\sqrt{\frac{1}{4}-\frac{\left(\pi+\frac{\varepsilon}{2}\right)(\alpha-\lambda)^2}{\beta^2\pi^2}}.
\end{aligned}$$

Solving for $\hat{\gamma}$ in the calibration

We have, from Eq. 26 that

$$\widehat{\gamma} = \frac{1}{2} + \sqrt{\frac{1}{4} - \frac{\alpha^2(\varepsilon + 2\pi)}{2\beta^2\pi^2}}$$

and from Eq. 12 that

$$\alpha = \sqrt{\beta(1-\gamma)\pi \cdot \alpha N^*}.$$

So we must solve

$$\begin{aligned}
\widehat{\gamma} &= \frac{1}{2} + \sqrt{\frac{1}{4} - \left(\frac{\sqrt{\beta\left(1-\widehat{\gamma}\right)\pi \cdot \alpha N^*}}{\beta}\right)^2 \frac{(\varepsilon + 2\pi)}{2\pi^2}} \\
&= \frac{1}{2} + \sqrt{\frac{1}{4} + \left(\frac{\left(1-\widehat{\gamma}\right) \cdot \alpha N^*}{\beta}\right)\frac{(\varepsilon + 2\pi)}{2\pi}}.
\end{aligned}$$

Subtracting 1/2 from both sides and squaring we get

$$\begin{aligned}
\widehat{\gamma}^2 - \widehat{\gamma} + \frac{1}{4} &= \frac{1}{4} + \left(\frac{\left(1-\widehat{\gamma}\right) \cdot \alpha N^*}{\beta}\right)\frac{(\varepsilon + 2\pi)}{2\pi} \\
\widehat{\gamma}\left(1-\widehat{\gamma}\right) &= \left(\frac{\left(1-\widehat{\gamma}\right) \cdot \alpha N^*}{\beta}\right)\frac{(\varepsilon + 2\pi)}{2\pi} \\
\widehat{\gamma} &= \left(\frac{\alpha N^*}{2\beta}\right)\left(2 + \frac{\varepsilon}{\pi}\right).
\end{aligned}$$

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

$$\frac{d^2W}{d\beta d\gamma_\beta} = \beta - \frac{\lambda(\alpha-\lambda)}{\beta\pi(1-\gamma)^2} + \frac{\alpha(\alpha-\lambda)}{\beta\pi(1-\gamma)^2} + \frac{(\alpha-\lambda)\varepsilon K\left(N^{*2}-(1-KN^*)^2\right)}{2\pi(1-\gamma)}$$
$$= \beta + (\alpha-\lambda)\cdot\left(\frac{N^*}{1-\gamma} + \frac{\varepsilon K\left(N^{*2}-(1-KN^*)^2\right)}{2\pi(1-\gamma)}\right)$$
$$> 0.$$

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