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Agent-Based Simulations of Subjective Well-Being

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Abstract There has been extensive empirical research in recent years pointing to a weak correlation between economic growth and subjective well-being (happiness), at least for developed economies (i.e. the so-called 'Easterlin paradox'). Recent findings from the behavioural sciences and happiness literature link this paradoxical relationship to negative externalities on utility imposed by social comparison (i.e. relative income with respect to others) and adaptation (habituation to own income in the past). We believe that the type of economic growth (pro-poor, pro-middle, pro-rich, neutral), in combination with sensitivity to social comparison and past income, is a key determinant of happiness trajectories and future utility levels. With the use of agent-based simulations we examine the long-term dynamics of subjective-well-being by focusing attention on the type of growth process rather than the mere size of income growth. We generally find that pro-middle (and balanced) growth corresponds to much higher levels of long-term happiness in comparison to pro-rich growth.

Keywords Happiness · Income redistribution · Simulations

1 Introduction

There has been extensive empirical research in recent years (for an overview see Clark et al. 2008; Dolan et al. 2008; Frey 2008) pointing to a weak correlation between economic growth and subjective well-being (happiness), at least for developed economies (i.e. the

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so-called 'Easterlin paradox'). Most studies provide strong evidence identifying relative income and status comparison as major contributors to this weak correlation (Boyce et al. 2010; Easterlin 1995, 2004, 2005; Easterlin and Sawangfa 2008; McBride 2001; Di Tella et al. 2010). While the correlation is often stronger for low-income countries, where economic growth translates into increased capacity to meet some of the most basic human needs (e.g. in terms of nutrition, health and education), relative income and status play a more important role for richer nations (Akay and Martinsson 2011; Choudhary et al. 2011; Howarth 2003; Layard et al. 2010). Individuals make evaluative judgments of themselves compared to their reference group and value a high relative position with respect to their peers (e.g. colleagues, neighbours). For the society as whole, though, social comparison creates substantial negative welfare externalities—a rise in income or consumption of another person in one's reference group negatively affects his or her own subjective wellbeing. Given that relative status is by definition a 'scarce commodity' (van den Bergh 2009) average happiness does not necessarily improve over time during time spells of positive economic growth, unless income inequality simultaneously decreases. Persistent or increasing income inequality (that enhances social comparison) can result in stagnant or decreasing average subjective well-being despite improvements in income per capita—a phenomenon that has also been observed across some middle-income developing economies (Brockmann et al. 2009; Easterlin and Angelescu 2009; Easterlin et al. 2010; Knight and Gunatilaka 2010).

There is also empirical evidence suggesting that people evaluate their current economic situation not only in comparison to other people's situation (social comparison) but also with respect to their own in the past. Any increase in income, even when improving the relative position of the individual, is likely to have a temporary effect that will fade away over time (Di Tella et al. 2010; Easterlin 2007; Frederick and Loewenstein 1999; Graham 2011; Kimball and Willis 2006; Rayo and Becker 2007; Wolbring et al. 2011). As a matter of fact, one's evaluation of his/her current economic situation is normally negatively affected by his/her own past economic situation, a phenomenon commonly referred to as adaptation (Easterlin 2001; van Praag and Ferrer-i-Carbonell 2008; Welsch 2009). Individuals form aspirations relative to reference groups and while an improvement in status and income can temporarily raise subjective well-being, in the longer term it also generates new reference groups and raises aspirations accordingly (Arrow and Dasgupta 2009; Knight and Song 2009; Senik 2009; Stutzer 2004; van Praag and Ferrer-i-Carbonell 2008).

In this paper we contribute to the literature by examining the differentiated impacts of different types of economic growth (pro-poor, pro-middle, pro-rich, neutral or equal growth) on subjective well-being, in combination with sensitivity to social comparison and past income (adaptation). We make use of agent-based simulations to examine the long-term dynamics of subjective-well-being by focusing attention on the type of growth process rather than the mere size of income growth. We generally find that pro-middle (and neutral) growth corresponds to much higher levels of long-term happiness in comparison to pro-rich growth.

To our knowledge this is the first time that agent-based models (ABM) are employed for simulating the evolution of subjective well-being with reference to economic policies and the relative income and adaptation externalities that we discussed above. The application of ABMs has grown consistently in the last 15 years, both in natural and social sciences (Breckling et al. 2006; DeAngelis and Mooij 2005; Hovel and Regan 2008; Macy and Willer 2002; Nonaka and Holme 2007). ABMs allow simulating a system from the bottom-up, that is, through an ensemble of individual entities called agents which then behave according to a predetermined set of rules and are subject to defined initial parameter

configurations (Bonabeau 2002; DeAngelis and Mooij 2005).[1] Understanding these dynamics can provide a description of a system as an emergent configuration of the interactions between individual agents (Macy and Willer 2002). In ABMs, at every simulation time-step, agents act according to their surrounding environment and take action following the rules defined, thus allowing the discovery of critical thresholds and the emergence of behaviour patterns not easily inferable when considering single agents (Bonabeau 2002; Breckling et al. 2006).

Agent-based models simulations can be a promising methodological tool for happiness studies (and social dynamics more broadly) and have the potential to set the agenda for a new research process exploring the evolution of happiness patterns, which can be better described by rule-based simulations that allow to differentiate agents' behaviours and responses to the surrounding environment (i.e. an intrinsic characteristic of an ABM) rather than mathematical and econometric models (the required assumptions and simplifications needed for tractable mathematical models often do not permit a correct representation of the unique and complex features of human behaviour, as, for example, agents' heterogeneity; for a discussion see Henrickson and McKelvey (2002). Naturally any agent-based model cannot retain all of the real world's details and it should be a simplified, although meaningful, representation of reality (Axelrod 1997; Bonabeau 2002). For example, the focus of our paper is on the differential impact of different types of economic growth, given the adaptation and social comparison externalities, on the evolution of happiness over time. Several other factors can also simultaneously influence the level of subjective well-being, ranging from social capital dimensions (e.g. family relations, trust in social circle, friendship; see Camfield et al. 2009; Dolan et al. 2008; Pugno 2009; Wilkinson and Pickett 2009; Vemuri and Costanza 2006), economic uncertainty (e.g. the extent of job security; see Blanchflower and Oswald 2000; Clark and Postel-Vinay 2009; Di Tella and MacCulloch 2008; Dockery 2005; Tsai 2009) and access to environmental assets (e.g. pollution; see Brereton et al. 2008; Moro et al. 2008; Kahneman and Krueger 2006; Levinson 2009; Luechinger 2009; Welsch 2006, 2009). The objective of our analysis is to highlight the potential of agent-based modeling as a methodological tool in the service of happiness studies and the investigation of social evolutionary patterns. This is a first step in this direction and future extension of our analysis should focus on complementary factors that can influence subjective wellbeing. Moreover, one should keep in mind that ABMs should be treated with caution, when looking at the quantitative aspects of the results (Bonabeau 2002), since the importance and the validity of ABMs relies on their ability to explain different configurations arising from the set of parameters used, and in allowing a (mainly) *qualitative* understanding of the system studied.

Section 2 describes the formulation and methodology of our ABM simulations. Section 3 provides our key findings and Sect. 4 concludes.

[1] A researcher who uses computer simulated ABM to represent a real system needs to undergo a model-building process that can be delineated in three stages (Galán et al. 2009). First of all, one needs to conceptualise the system that will be represented, thus defining the "research question" and identifying the crucial variables of the system and their interrelations. Subsequently, it is necessary to find a set of formal specifications that is able to characterise the conceptual model. Finally, the model needs to be coded and executed (Galán et al. 2009).

2 Methodology

We simulate a simple model in order to uncover the dynamic relationship between income growth and happiness.[2] Following the empirical literature on the determinants of subjective wellbeing (see Welsch 2009 for a discussion), we assume that a person's happiness depends positively on his/her own current income and negatively on his/her past income (adaptation externality) as well as average social income (social comparison externality). We devise a range of thresholds in order to classify individuals as happy or unhappy. We are aware of the arbitrary nature of such thresholds but, this has limited implications for the qualitative results of our analysis that focus in any case on continuous changes in happiness rather than its absolute level. Our model, ceteris paribus, is able to provide interesting insights and guide policy aimed at increasing happiness throughout the population.

We hence assume that the happiness (h) of person i at period t is dependent positively on his/her own income at time t (Y_{it}) and negatively on the average social income for the same period ($\bar{Y}_t$) as well as his/her own income in the previous year ($Y_{i(t-1)}$):

$$h_{it} = Y_{it} - \beta Y_{i(t-1)} - \alpha \bar{Y}_t \tag{1}$$

where α and β are sensitivity parameters who assume values in the interval [0,1]. More precisely, α represents the sensitivity to average income; i.e. the higher the value of α, the larger the disutility attributed to the social comparison externality. β represents sensitivity to past income; higher values correspond to a larger degree of habituation (adaptation) to past income levels.

A person i is considered *happy* if his/her happiness level h at time t is larger or equal to the median happiness level at time t_0 (beginning period).[3] We assume that income is distributed according to a Poisson distribution with mean 5 and truncated at 1 and 10 or according to an exponential distribution assuming values in the interval [1,10]. At every time-step t the economy grows and income for every agent i is recalculated. We assume four different economic growth scenarios: equal (i.e. neutral), pro-poor, pro-middle and pro-rich. We consider as *poor* those agents whose income is at least $s * \sigma$ (i.e. a constant times one standard deviation) below the average income, *rich* those whose income is at least $s * \sigma$ above the average income, and *middle*-income those whose income falls between the two thresholds. The constant s takes either the value of 1 or 2. When s is equal to 2 (in comparison to 1), the relative size of the middle-income group increases at the expense of the poor and rich. To summarize:

$$\text{Agent } i = poor \quad \text{if } Y_i < \bar{Y} - s * \sigma \tag{2}$$

$$\text{Agent } i = middle - \text{income} \quad \text{if } \bar{Y} - s * \sigma < Y_i < \bar{Y} + s * \sigma \tag{3}$$

$$\text{Agent } i = rich \quad \text{if } Y_i > \bar{Y} + s * \sigma \tag{4}$$

we assume four different economic growth scenarios. If growth is balanced (*equal*), income for every agent i increases by an *equal* percentage (3 %) at every time-step. If growth is *pro-poor*, poor people benefit disproportionately: i.e. poor agents experience an increase of their income by 4 %, middle-class people by 2 %, while the rich do not benefit from income growth. If growth is *pro-middle*, middle-class agents experience an increase

[2] The model is implemented and simulated in Netlogo 4.1.2 (Wilensky 1999).

[3] In other words, we assume that at period t_0, the total population of agents is equally divided between happy and unhappy individuals.

Table 1 Types of growth (country examples)

Balanced (equal)	Pro-poor	Pro-middle	Pro-rich
Tanzania, 1992–2001 (2.68, 2.59, 3.15)	Sri Lanka, 1980–2000 (3.17, 2.05, 0.25)	Philippines, 2000–2003 (2.59, 3.42, 1.13)	Egypt, 1995–2004 (1.03, 1.68, 2.76)
Pakistan, 1979–1985 (3.00, 3.06, 3.11)	Russia, 1998–2002 (6.03, 2.49, −4.92)	Panama, 1969–1980 (1.07, 3.61, 1.78)	Laos, 1992–1997 (−1.97, 1.60, 4.96)

Data in parentheses refer to the growth in average GDP per capita for the 20 % poorest of the population, middle-income group (60 % of the population) and for the 20 % richest segment

in income by 4 %, while income for the poor and rich increases by 2 % respectively. Finally, in the case of *pro-rich* growth, rich agents experience an income increase by 4 %, middle-class people by 2 %, while poor people do not benefit from income growth.

In Table 1, we present examples of countries that have experienced these four different types of economic growth in the past (for our calculations we made use of the UNU-WIDER World Income Inequality Database (UNU-WIDER 2008)—data on income share per group are rather fragmented and not available for all years). For example, Tanzania followed a path of *balanced growth* in the 1990s with the richest, poorest and middle-income groups of the population benefiting more or less equally. This was likely due to a mix of policies (see Treichel 2005), with some benefitting the poor and stimulating overall production (through market-oriented reforms and macroeconomic stabilization) and some disadvantaging them (e.g. through the introduction of fees and levies for primary education). On the other hand, Sri Lanka is an example of a country that pursued *pro-poor* growth between 1980 and 2000. Increased privatization and export-oriented growth (particularly in the 1990s) with an emphasis on pro-poor interventions (e.g. via generous public funding for education and healthcare) disproportionately benefited the poor (Kelegama 2004). The Philippines, instead, is an example where economic expansion benefited more the middle classes (between 2000 and 2003). President Arroyo had placed particular emphasis on trade liberalization and industrialization that benefitted more the middle urban classes, with little success in tackling rural poverty (Balisacan 2007). In the case of Egypt, Mubarak's policies appear to have disproportionately favoured the rich. The business-oriented elites received considerable political support from the regime, as well as substantial tolerance towards corruption—these often capitalists-turned-politicians have been often accused for appropriating a substantial share of public wealth for own benefit (Kandil 2012).

In general, policy measures that disproportionately favour the poor often include pro-poor agricultural development (e.g. provision of agricultural extension services, improvement of agricultural markets for the poor), liberalisation of labour-intensive sectors, investment in public infrastructure (e.g. health provision, education, energy supply), the establishment of a generous social security system and emphasis on progressive versus regressive taxes. Middle classes, instead, are generally supported through tax incentives and financial schemes that encourage SME development, lower corporate taxes, reduced bureaucracy and corruption, and investment in urban infrastructure. Last, pro-rich growth is often associated with local elites benefiting from favourable taxation conditions and appropriation of public funds—furthermore, investment in capital and high-skilled labour intensive sectors is likely to disproportionately benefit the richer segments of the population (for a discussion, see Ravallion 2004).

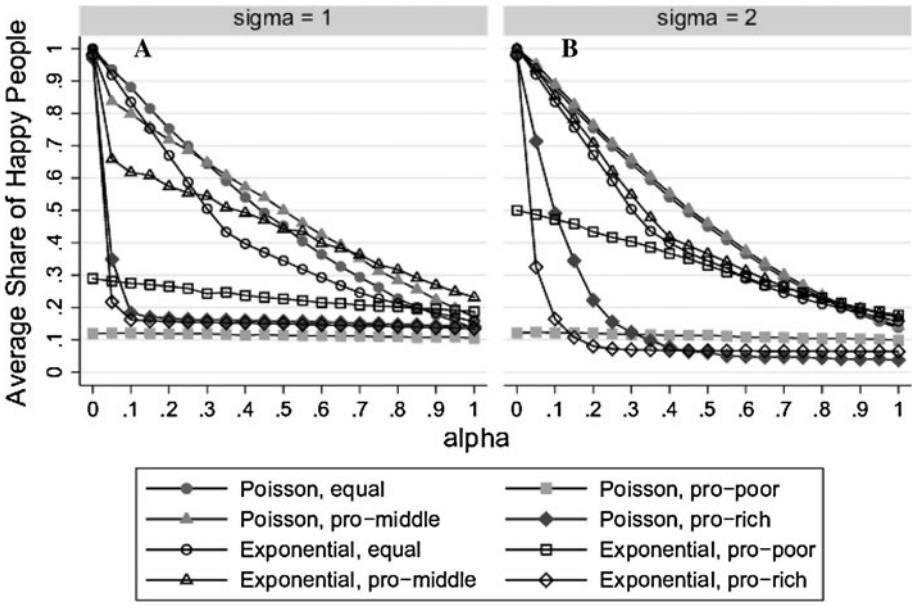

Fig. 1 Share of happy people versus alpha at $t = 200$ and under different economic growth scenarios for $s = 1$ (**a**) and $s = 2$ (**b**)

The model [that simulates Eq. (1)] is run 100 times per initial income distribution, economic growth scenario and the α and β sensitivity parameters. Data are collected after 200 time-steps so as to achieve stable configurations (in other words, the model reaches equilibrium after 200 time steps). The key results of our ABM simulations are presented in the following section.

3 Simulation Results

In this section we present the main results of our agent based model. Figure 1a, b (for s equal to 1 and 2 respectively) depict the percentage of *happy* agents after 200 time steps for varying degrees of the status (relative income) effect (i.e. for different sizes of the α sensitivity parameter). As shown in Fig. 1, the share of happy people declines as α increases for all economic growth scenarios (and the decrease is particularly sharp in the lower range of the α parameter values, especially for the case of pro-rich economic growth). Depending on the degree of the status effect, different types of economic growth can result in substantially different degrees of average subjective well-being. In Fig. 1b, for example, one can see that pro-poor growth corresponds to higher levels of average happiness when compared to the pro-rich growth scenario when $\alpha > 0.05$ and initial income follows an exponential distribution (or when $\alpha > 0.30$ for the case of a Poisson distribution). Furthermore, both pro-middle and equal (balanced) growth strategies tend to result in

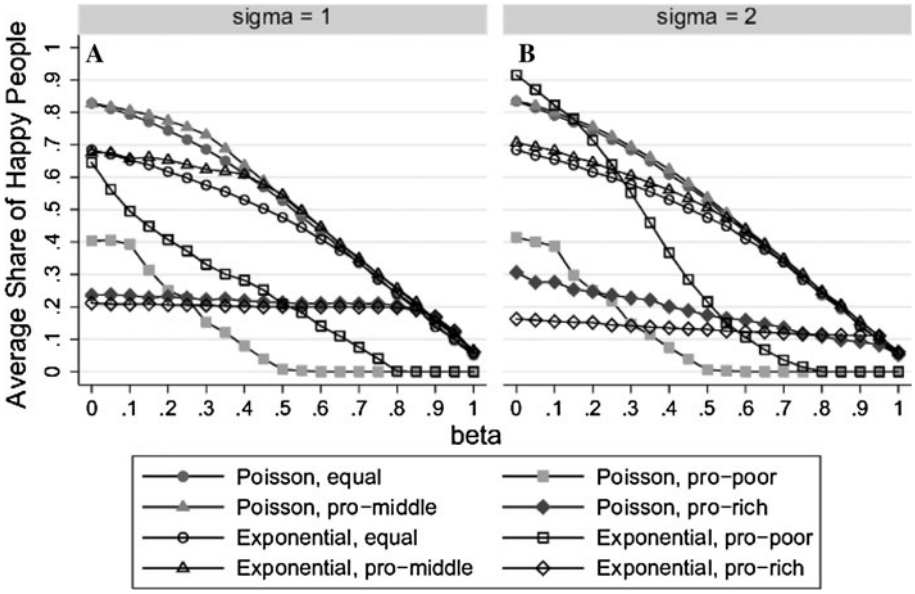

Fig. 2 Share of happy people versus beta at $t = 200$ and under different economic growth scenarios, for $s = 1$ (**a**) and $s = 2$ (**b**)

high levels of relative happiness (compared to other growth scenarios) for the majority of the α parameter values.[4]

Figure 2a, b (for s equal to 1 and 2 respectively) reveal a similar negative correlation between the percentage of happy agents and the degree of adaptation β. One can observe that now pro-poor growth results in higher levels of happiness on average compared to the pro-rich case for the lower range of values of β. If the parameter β, for instance, is closer to 0, this signifies that adaptation (and past income) only plays a relatively minor role in determining current happiness, and hence the role of relative income (status), and correspondingly of redistribution to the poorer segments of the population, becomes relatively more important. One can also observe that happiness levels tend to converge for the varying growth scenarios as β approaches 1. As earlier, both pro-middle and equal (balanced) growth scenarios tend to result in high levels of relative happiness (compared to other growth scenarios) for the majority of the β parameter values.

It is also of interest to assess the magnitude of *change* in happiness levels (rather than the level of happiness at $t = 200$, which was the focus of Figs. 1, 2, 3, 4). For this purpose, we calculate the difference in average happiness between $t = 200$ and $t = 1$ (i.e. $\widehat{h}_{200} - \widehat{h}_1$, where the hat denotes average values). We select $t = 1$ as the initial period, since this is the first time period for which the adaptation effect kicks in. As Fig. 3a, b portray (for s equal to 1 and 2 respectively), the pattern of dependence of the change in happiness on different values of α is qualitatively similar to those identified in Fig. 1a, b (where the focus was on long-term happiness levels). Several of the growth scenarios result in negative changes of

[4] One can also notice that pro-middle growth generally corresponds to higher levels of happiness in Fig. 1b compared to Fig. 1a for any given level of α. This is expected since a larger value for s (as it is the case in Fig. 1b) increases the relative share of the middle-income group in the total population.

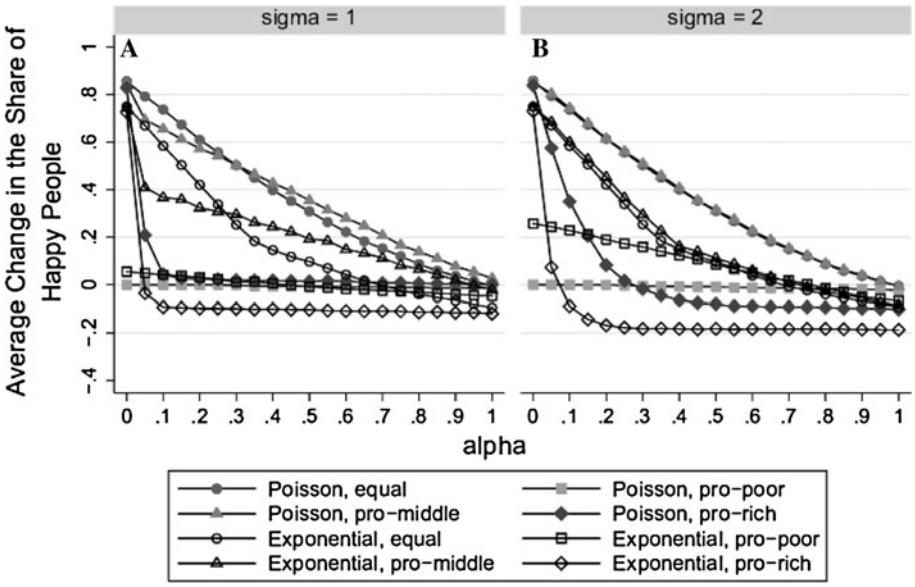

Fig. 3 Change in the share of happy people (between $t = 1$ and $t = 200$) versus alpha under different economic growth scenarios for $s = 1$ (**a**) and $s = 2$ (**b**)

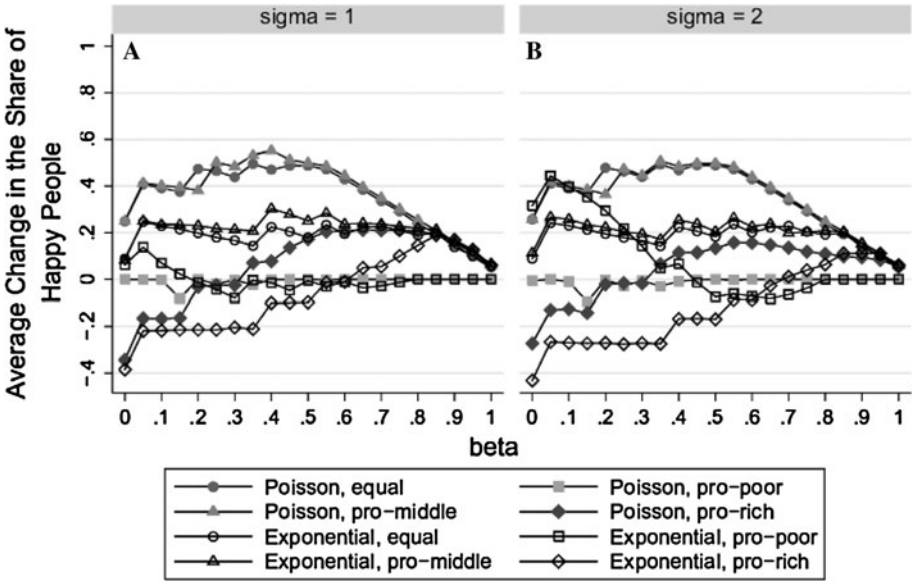

Fig. 4 Change in the share of happy people (between $t = 1$ and $t = 200$) versus beta for $s = 1$ under different economic growth scenarios

happiness over time for sufficiently high levels of α (i.e. for high degrees of adaptation), and this is particularly the case when we assume an exponential distribution of initial income. In both Figs. 1 and 2, for example, a pro-rich growth strategy (for the exponential

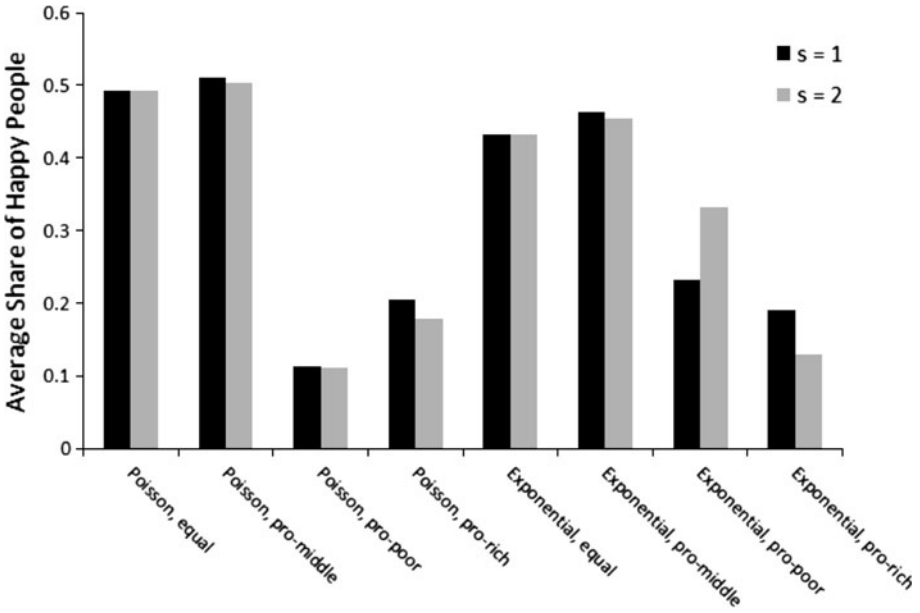

Fig. 5 Share of happy people independently from sensitivity parameters for $s = 1$ and $s = 2$

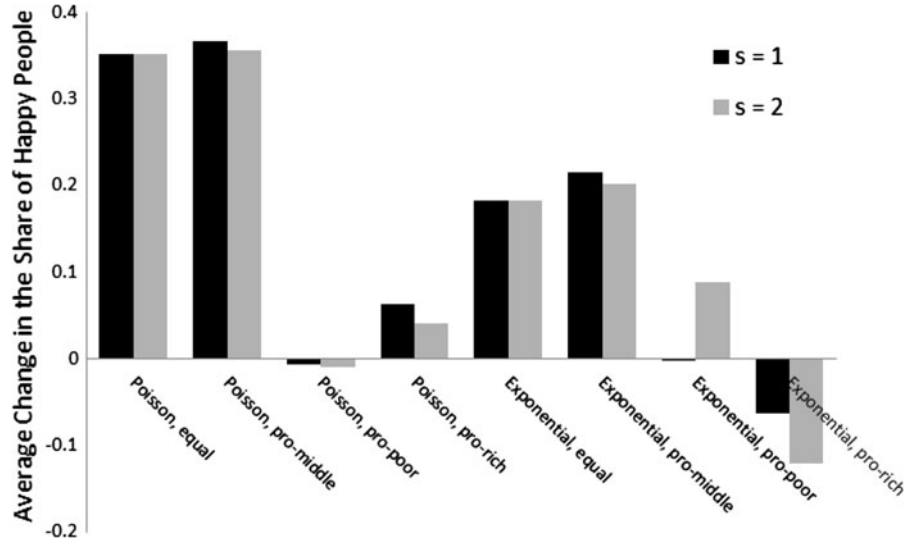

Fig. 6 Change in the share of happy people independently from sensitivity parameters for $s = 1$ and $s = 2$

income distribution) leads to decreases of happiness levels over time even for very low levels of adaptation. The pro-middle and equal (balanced) growth scenarios tend to perform better in terms of changes in average happiness levels over time.

Figure 4a, b depict (for s equal to 1 and 2 respectively) the pattern of dependence of the change in happiness on different values of β (relative income/status externality). Although

Table 2 Summary of results

	Happiness level	Change in happiness
Alpha (social comparison): high values of alpha capture the level of dissatisfaction that arises from income comparison with peer groups	Higher values for pro-middle and equal growth when alpha is sufficiently low. Pro-poor growth results in more happiness than pro-rich growth, unless alpha is close to 0	Pro-rich growth results in negative changes (reduction in happiness). Pro-middle and equal growth correspond to the largest increases in happiness
Beta (adaptation): higher values of beta correspond to habituation to own income in the past and, thus, lower happiness	Higher values for pro-middle and equal growth when beta is sufficiently low. Pro-poor growth results in more happiness that pro-rich, when beta is sufficiently low	Pro-rich growth results in negative changes, when beta is sufficiently low. Pro-middle and equal growth correspond to the largest increases in happiness

changes in happiness do not seem to follow a general pattern as in Fig. 3a, b, some generic conclusions can be drawn. First, most types of growth scenarios converge to a similar level of happiness change (close to 0.05) as the size of the social comparison externality β approaches unity. For low values of β, there is much more variation across different growth strategies and in general pro-rich economic development results in the biggest happiness losses. Once again, the pro-middle and equal (balanced) growth scenarios tend to perform better in terms of changes in average happiness levels over time.

Below, we take the *average* level of both long-term happiness (Fig. 5) and change in happiness (Fig. 6) per economic growth scenario and income distribution across the whole range of the α and β sensitivity parameters. In effect, this is an average of averages, that represents average values across both different agents as well as sensitivity parameters. Naturally, the results are less precise given the higher level of aggregation across the whole spectrum of sensitivity parameters. Nevertheless, this can be particular useful as a rule of thumb exercise, whenever there are no empirical estimates for the adaptation and social comparison (status) externalities based on sampled populations. We observe that in general pro-middle and equal (balanced) growth strategies perform better both in terms of long-term levels of happiness as well as changes over time (particularly when initial income follows a Poisson distribution and is hence more equally distributed from the beginning). When s increases from 1 to 2 (i.e. when the defined middle-class groups accounts for a larger share of the population), unbalanced growth scenarios that either favour the rich or the poor result in smaller levels of long-term happiness.

4 Conclusion

There has been an increasing interest in recent years in the determinants of subjective well-being and use of appropriate indicators to inform policy debates (Dasgupta and Mäler 2000; Diener 2006; Johns and Ormerod 2007; Veenhoven 2002). There is also a widespread acknowledgement of the inadequacy of GDP per capita as a sole measure of a country's well-being (Kahneman et al. 2004; Ng 2003; Sen 1976; van den Bergh 2009). Policy-makers have also started to pay more attention to happiness research—a Commission on the Measurement of Economic Performance and Social Progress has been created in 2008 on the initiative of the French government, which brought many prominent economists together (Joseph Stiglitz, Amartya Sen, Jean-Paul Fitoussi) to produce a report

on the limitations of GDP as a measure of well-being and ways to address it (see Stiglitz et al. 2010). Premier Wen Jiabao of China also emphasised the need to make prosperity more balanced and pay more attention to happiness at a recent meeting of the National People's Congress.

In this paper we contribute to the literature on happiness by examining with the use of agent-based simulations the differentiated impacts of different types of economic growth (pro-poor, pro-middle, pro-rich, neutral) on subjective well-being, in combination with sensitivity to social comparison and past income (adaptation). To our knowledge, this is the first time that agent-based modeling and simulations have been employed to examine the long-term dynamics of subjective well-being. We generally find that pro-middle (and neutral) growth corresponds to much higher levels of long-term happiness in comparison to pro-rich growth. Higher levels of social comparison and adaptation (captured by alpha and beta respectively) tend to result in lower levels of happiness. Pro-poor growth typically results in lower happiness compared to pro-rich growth, unless social comparison plays a minor role in explaining happiness (i.e. alpha takes very small values). A summary of the key results is provided below in Table 2.

The purpose of this paper is not to research in an exhaustive manner all possible determinants of happiness or provide an extensive analysis based on a broader range of growth scenarios. We acknowledge that there are limitations and our analysis is simply a first step that needs further development and refinement. The main objective of this paper is to draw attention to agent-based simulations as a promising methodological tool in the field of happiness studies.

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