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Individual Satisfaction and Economic Growth in an Agent-Based Economy

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Abstract
We combine macro and microeconomic perspectives in an agent-based endogenous growth model that uses individual satisfaction as a driver of human capital accumulation. The micro perspective is based on individual satisfaction: an utility function computed from the income variation in space (relative to others) and time. The macro perspective emerges from micro decisions that, at an aggregate level, determine an important social decision about the share of the working population engaged in producing ideas (i.e. skilled workers). Underlying our analysis is the Easterlin hypothesis (Easterlin, in: David, Melvin (eds) Nations and households in economic growth: essays in Honor of Moses Abramowitz, Academic Press, New York, 1974, J Econ Behav Organ 27(1):35–47, 1995) which states that individuals care much more about their relative income than about increases in their own income, weakening the link between growth and income. Simulations show that growth and satisfaction levels are higher when relative and absolute incomes are equally weighted in satisfaction computation and are lower when satisfaction only depends on relative incomes.

Keywords Agent modeling · Education · Human capital · Economic growth · Individual satisfaction

JEL Classification C63 · E24 · E70 · O40

1 Introduction

Agent-based modeling is a growing research area in economics (Kirman 2004; Tesfatsion and Judd 2006; Farmer and Foley 2009). Applications in macroeconomics, albeit

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increasing, are still relatively rare. There are, however, some examples, even hybrid approaches mixing traditional DGSE models with other non-standard characteristics (LEBARON and Tesfatsion 2008; de Grauwe 2010; Gati et al. 2011). Financial crisis highlighted flaws in many models used in economic policy design, namely DGSE models. Homogeneity (representative agents) and rational expectations hypothesis are the two most criticized features. Agents are not, of course, homogeneous and economic reality is far more complex than this over simplistic assumption states. Rationality is disputed by several neurological and psychological experiments (Kahneman 2003; Camerer et al. 2011; Fehr and Rangel 2011) and agent-based models (ABM) are a feasible option to introduce bounded rationality and heterogeneous agents. Caiani et al. (2016), Riccetti et al. (2015) or Dawid et al. (2014) are good examples of macroeconomic applications of ABM in economic analysis and policy.

In this paper, we use an agent-based model to assess the relation between individual satisfaction, economic growth and human capital accumulation. According to the so called Easterlin hypothesis (1974, 1995), individuals care much more about their income relative to others (relative in space) than about increases in income that go along with a general upward trend (relative in time). Layard et al. (2010), for example, find some empirical supporting evidence for the United States, Western Germany and other developed countries. Luttmer (2004) concludes that relative incomes are important for happiness. In a panel data analysis, it confirms the idea that “lagging behind the Joneses” is relevant for individual satisfaction levels. Ferrer-i-Carbonell (2005) find that the income of the reference group is almost as important as the own income for individual happiness.

Blanchflower and Oswald (2004) also validates the Easterlin hypothesis empirically using a well-being function for US and UK considering, among other variables, a dollar value for events like unemployment and divorce. Two other studies confirmed that income increases can have, in the best case scenario, a slight positive impact in happiness: Oswald (1997) reported happiness gains along with economic growth but “almost undetectable” in an analysis for Western countries based on satisfaction surveys and suicide numbers; Frey and Stutzer (2000) documented a positive but small effect of higher income in happiness in a study based in 6000 residents in Switzerland. Kahneman et al. (2006) also had doubts about the income-happiness link and proposes a possible psicological explanation of the Easterlin hypothesis: ”When someone reflects on how additional income would change subjective well-being, they are probably tempted to think about spending more time in leisurely pursuits such as watching a largescreen plasma TV or playing golf, but in reality they should think of spending a lot more time working and commuting and a lot less time engaged in passive leisure (and perhaps a bit more golf)”. Some other researchers, however, do not share this view, and the relative importance of absolute income for happiness is not at all settled in the literature [see Deaton (2008) for a discussion of the positive relationship between life satisfaction and national income and Easterlin (2001) for a “unified theory” of income and happiness]. For example, Stevenson and Wolfers (2008), “analyzing multiple rich datasets spanning many decades”, find no threshold beyond which wealthier countries would experience no further increases in satisfaction.

Independently, of the true nature of the relationship between growth and happiness, it is a relevant issue per se and this seemingly small distinction between two different kinds of happiness is of the utmost importance. It means that countries can experience income—or GDP—growth without corresponding increases in happiness levels or, on the contrary, growth rates can be affected by happiness and by how happiness depends on inequality levels. Ostry et al. (2014) provides some empirical and theoretical support to this two-way relationship between growth and inequality through health and education, political and economic instability that reduces investment and lack of social consensus to deal with shocks. Cingano (2014) analyzed OECD performance in OECD countries over that past 30 years and his "econometric analysis suggests that income inequality has a negative and statistically significant impact on subsequent growth". He concludes also that "what matters most is the gap between low income households and the rest of the population".

Because individual satisfaction is heterogeneous by definition an agent-based model can be, therefore, a useful tool to deal with this question. The individual satisfaction has obvious implications in microeconomic decisions but can have also important macroeconomic consequences, two dimensions that can be well captured within an ABM framework. Frey and Stutzer (2002) argue that happiness has quite relevant implications for both theory and economic policy. For a presentation of the "macroeconomics of happiness" see, for example, Tella et al. (2003).

We use a model derived from Jones (2005) with an economy with skilled and unskilled workers in an overlapping generation[1] environment to assess this Easterlin hypothesis and its impact on economic growth and human capital accumulation. Several endogenous growth models emphasize the role of "ideas" in economic growth. In this model, ideas are produced by a fraction of the working population—the skilled workers—and are used by the rest of the workers—the unskilled workers—to produce final goods. An agent decision to study is taken following a socially conditioned economic reasoning based on his or her individual satisfaction perspectives. Each agent decision will be based on the satisfaction level of his neigbor which, in turn, depends largely on the relative position of the agent's income in space (compared to others) and in time (variations of his own income).

This satisfaction-based education decision and its impact on economic growth is evaluated for different scenarios, based precisely on different weights given to individual relative income in space and time. Scenarios are tested against each other in terms of long term growth and satisfaction. Our results indicate that when personal wellbeing—i.e. satisfaction—depends exclusively on interpersonal comparisons—satisfaction becoming a kind of rival good—the economy grows less and, at the local level, there is almost no clustering between skilled and unskilled workers.

2 The Model

2.1 Population

Our economy has N agents: N/2 junior and N/2 senior. Each agent lives for two periods. Population size does not change and generations overlap. A young agent can be either

[1] It is an extension of Araújo and St. Aubyn (2008) and Martins et al. (2009) models using individual satisfaction as the key variable. In what follows, Eqs. (1)–(9) are very similar or equal to the corresponding ones in those models.

a student or an unskilled worker. Thus, population has always four groups: young students; junior unskilled workers; senior unskilled workers (those that did not study in the previous period) and skilled workers.

2.2 Space and Decision to Educate

There is a neighbour effect in the education decision. We can assume that, *ceteris paribus*, a children's education attainment depends positively on the average human capital stock in his or her neighbourhood. In our model, the decision is based on the observed relative satisfaction in skilled and unskilled workers. More precisely, is based on the number of satisfied skilled workers and satisfied unskilled workers on his neighborhood defined on a ring with a neighborhood size 2g. In formal terms, agents decide to study if:

$$nS_t^s > nS_t^u \tag{1}$$

where nS_t^s and nS_t^u are respectively, the number of satisfied skilled workers and satisfied unskilled workers in the neighborhood (i.e. agents with positive satisfaction levels).

2.3 Production

Production is computed from the stock of ideas and from the unskilled labor supply. Unskilled workers provide regular work while skilled workers produce ideas. Production is defined as:

$$Y_t = A_t U_t + \varepsilon_t \tag{2}$$

where Y_t is production in period t, A_t the stock of ideas in period t, U_t the number of unskilled workers in period t and ε_t a productivity shock (with uniform distribution between -0.5 and 0.5) in period t. The evolution of the stock of ideas is given by:

$$\Delta A_t = A_{t-1}\delta S_t + \gamma D_t \tag{3}$$

where S_t represents skilled labor, δ is a parameter related with marginal productivity of skilled labor, D_t is a measure of distance between skilled workers and γ a parameter of the strength of the team effect. This means that production of ideas is higher when skilled workers are closer to each other and in the presence of a higher team effect. D_t is defined as:

$$D_t = \frac{1}{S_t}\sum_{i,j=1}^{S}\frac{1}{|i-j|} \tag{4}$$

with $i \neq j$ and being thus smaller when skilled workers are located far from each other and larger in the opposite situation. i and j are the positions of agents i and j in the ring.

2.4 Income Distribution and Wages

Production in each period is divided between skilled and unskilled workers. In mathematical terms:

$$Y_t = Y_t^U + Y_t^S \tag{5}$$

where Y_t^U denotes the total income of unskilled workers and Y_t^S the total income of skilled workers.

The income distribution—the social contract in this society—specifies that skilled workers receive the share related to the production of ideas and unskilled workers receive what would have been produced if ideas remained constant. Thus, the unskilled workers income is computed considering the previous period stock of ideas and all the additional income due to new ideas belongs to skilled workers. Productivity shocks are shared, in equal parts, by skilled and unskilled workers. The total income for unskilled (Y_t^U) and skilled workers (Y_t^S) is given by:

$$Y_t^U = A_{t-1}U_t + \frac{\varepsilon_t}{2} \tag{6}$$

$$Y_t^S = (A_t - A_{t-1})U_t + \frac{\varepsilon_t}{2} \tag{7}$$

Wages per worker are determined dividing the total income by the total number of skilled (L_t) and unskilled workers (U_t):

$$w_t^U = \frac{A_{t-1}U_t}{U_t} + \frac{\varepsilon_t}{2U_t} = A_{t-1} + \frac{\varepsilon_t}{2U_t} \tag{8}$$

$$w_t^S = \frac{Y_S^t}{L_t} + \frac{\varepsilon_t}{2L_t} = (A_t - A_{t-1})\frac{U_t}{L_t} + \frac{\varepsilon_t}{2L_t} \tag{9}$$

2.5 Satisfaction

Satisfaction is a measure of individual well-being that comprises relative position of the agent's income in space and in time but also takes into account the initial expectations of the agents when they decide about education. Initial expectations are randomly generated and they can be interpreted as a sort of fixed cost. The higher the expectation level of the agent, the harder the possibility of becoming satisfied with the options he made.[2] Educated workers are provided with some amount of satisfaction (α) for the simple fact of being educated. Therefore, and respectively for skilled and unskilled workers, individual satisfaction is computed as:

$$F_{i,t}^s = \alpha - c_i + (1-\omega)\left(w_t^s - \frac{w_t^u}{\beta(\rho)}\right) + \omega\left(w_t^s - w_{t-1}^s\right) \tag{10}$$

$$F_{i,t}^u = -c_i + -(1-\omega)\left(w_t^s - \frac{w_t^u}{\beta(\rho)}\right) + \omega\left(w_t^u - w_{t-1}^u\right) \tag{11}$$

[2] Biondo et al. (2012) presents a ABM model with an expectation component in agent's emigration decision that tends to disappear over time.

where c_i is the initial expectation of agent i , taking values in the interval $[-0.5, 0.5]$. w_s and w_u represents, respectively, skilled and unskilled wages. α is an exogenous parameter, ρ is a discount rate and $\beta(\rho)$ a monotonic function with $\frac{\delta\beta}{\delta\rho} > 0$ that is used to compare present values of skilled and unskilled workers future incomes.[3] ω is a parameter taking values between 0 and 1 that represents the weighted relative income (in space) and income growth (in time). When $\omega = 0.5$, both relative incomes have equal weight. Setting ω with different values allows for balancing the range of influences that determines individual satisfaction. This parameter is used to configure the three scenarios presented in the following section.

The Easterlin idea is modelled as the relative weight between cross section and time series imcome comparisons, i.e., ω. The Easterlin paradox would hold when ω becomes close to 1. In that case, income growth would not provide any satisfaction. Parameter c_i only purpose is to introduce some individual heterogeneity.

3 Results and Discussion

When the economy starts, there are 50 unskilled agents, junior or senior. The other 50 individuals are either students, if they are junior, or skilled employees, if they are senior. In a typical, average, baseline simulation, the number of employees equals 75, 25 being skilled. The location (on the ring) of each agent, junior or senior and skilled or unskilled, is randomly determined. The neighbourhood range was set to 3 ($g = 3$), meaning that when an agent decides weather to pursue his or her studies by considering the satisfaction of his or her six closest senior neighbours (three to the left and three to the right). According to Eq. (1), the agent will chose to become educated if the number of satisfied skilled workers exceeds the number of satisfied unskilled workers. The discount rate equals five percent ($\beta = 0.05$), a value not very different from empirically observed real interest rates.

Simulations were performed for three scenarios of parameter ω: 0, 1 and 0.5. All scenarios start with 100 agents (50 skilled and 50 unskilled workers; 50 junior and 50 senior), for nine generations ($R = 9$), with no team effects ($\gamma = 0$). Satisfaction in the first period ($t = 1$) is randomly set for all agents with values between -0.5 and 0.5 . As they did not have wages in the previous period, junior students satisfaction is derived from senior workers satisfaction—it is randomly generated with values ranging between the maximum and the minimum values among senior workers. Stock of ideas $A(1)$ is initialized with a value above 0 determined by the average distance between educated workers in the initial spatial distribution. The skilled labour productivity parameter δ was set to 0.025 and the education satisfaction parameter α was set to 1.

Table 1 shows the model parameters values in each scenario.

Reported results are the average results after 1000 simulations. The baseline scenario is the best one in terms of economic growth. But, on the contrary, educated

[3] $\beta(\rho)$ function is given by $\beta = \frac{(1+\rho)^9-(1+\rho)^{8-\tau}}{1-(1+\rho)^{8-\tau}}$. τ represents the number of years to the end of active life and was set to 48. We considered that skilled agents spend nine more years at school than unskilled agents. When the discount rate is higher, the future is less valued and therefore the skilled labour wage has to be higher for agents to become indifferent between acquiring skills through education and to remain unskilled. $\beta(\rho)$ function is derived in the "Appendix".

Table 1 Simulation scenarios

	N	R	δ	α	γ	ρ	g	$U_{i,t=0}$	ω
Baseline	100	9	0.025	1	0	0.05	3	50	0.5
2									0
3									1

Table 2 The outcomes of the three scenarios after 1000 simulations

	Y growth	Final U	Final S	F^U (%)	F^S (%)	Final partitions
Baseline	0.65	50	25	100	98.7	6.6
2	0.61	46	23	78.7	21.3	33
3	0.64	43	29	100	100	6.3

workers satisfaction is slightly lower than in Scenario 3. Satisfaction and growth have the worst performances in Scenario 2, the scenario where only relative income (in space) matters. This is also the least clustered society, ending up with (on average) 33 partitions.

These results suggest that when satisfaction is totally derived from perceived differences from neighbours (scenario 2) then economic growth is lower. When there is at least some attention (baseline) or a total focus (scenario 3) on personal income changes then growth is stronger. Suppose that 'jealousy' (scenario 2) prevails. In periods of higher macroeconomic growth, agents may be doing choices concerning education that will imply slower future growth, derived from their relative perception position. In other scenarios, higher macroeconomic growth will be more valued by any agent, so that there are less incentives to change into a worse aggregate outcome.

It is possible to evaluate the degree of clustering (skilled/non-skilled) in this economy by counting the number of observed partitions. A small number of partitions corresponds to high local clustering. The final number of partitions for each scenario is presented in Table 2. The initial average number of partitions is 50. Final U and Final S indicate the final number of unskilled and skilled workers. F^U and F^S represent, respectively, the percentage of satisfied non-educated and the percentage of satisfied educated agents. Figure 1 depicts initial distribution of skilled and unskilled workers and also final partitions in each of the scenarios.

It shall be noticed that in any of the three scenarios and at each time step (each generation), there is no direct interaction between the agents which, instead, react to collective variables (local and global), that they themselves create with their individual decisions. The dynamics of the model has two main mechanisms: a local mechanism that operates when the agents decide about education—where the collective variables are the number of satisfied-skilled and satisfied-unskilled workers in the neighborhood; and a global mechanism—operating when accounting for individual satisfaction—where the collective variables are the wages of skilled and unskilled workers. In this context, the interaction through global variables (wages) operates faster in the overall dynamics of the model. Simultaneously, the interaction through local variables (individual satisfaction) gives rise to a slower contribution, i.e., a contribution whose

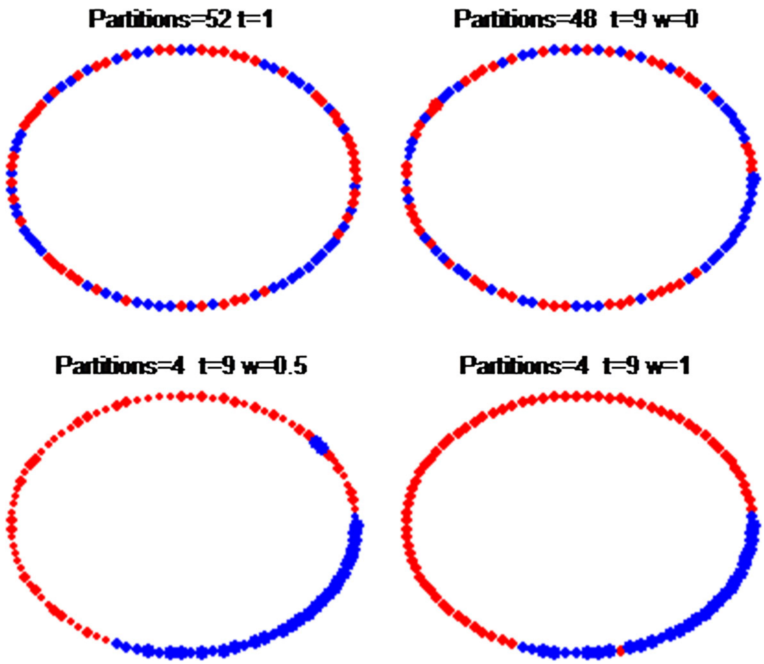

Fig. 1 The first plot shows the initial distribution of skilled and unskilled agents on a ring and the corresponding number of partitions of a typical run in any of the three scenarios. The second, third and fourth plots show the final distributions and the number of partitions in each different scenario. The size of the nodes is proportional to its satisfaction and the color identifies skilled (blue) and unskilled workers (red). (Color figure online)

consequences are not immediately incorporated, since changes in individual satisfaction will affect the decisions of the next generation.[4]

4 Conclusions

Agent-based modeling and endogenous growth are combined in a model that uses individual satisfaction as a driver of human capital accumulation. It is a macro model with micro foundations in an overlapping generation environment, where agents decide to study based on individual satisfaction of their peers (neighbors). Satisfaction is a kind

[4] The field of dynamical systems or, more precisely, its contributions to the understanding of the interplay of local and global variables (see for, instance, Vilela Mendes 2001) informs that in some systems, the essential mechanism driving the overall dynamics of the system is the slow dynamics, whereas the fast dynamics operates only as a background which is selected by the slow evolution. Our results are in line with the consequences of the above described interplay between local and global interactions. When personal wellbeing depends exclusively on the influence of interpersonal comparisons, there is almost no clustering as the way the agents organize themselves in space (number of partitions) approaches the random (initial) situation. This is due to the fact that when the influence of interpersonal comparisons dominates, the slow dynamics depending on a rival good drives the set of agents to an unstable situation in what concerns their satisfaction-based education decision. In this setting, neither local clustering nor any structural organization happens to take place.

of a utility function with two main pillars—relative income (skilled versus unskilled workers) and the evolution of income in time—and also the initial expectations of agents. We simulate three scenarios weighting differently the two main pillars of individual satisfaction in order to assess the Easterlin paradox. The baseline scenario, where both measures of income have equal weights, displays the best performance in the long run growth. Moreover, this scenario is characterized by a high level of local clustering. When only relative income matters for satisfaction, growth and local clustering are lower—the idea behind Easterlin hypothesis. In the other extreme scenario, when only income growth matters, local clustering and growth are similar to the baseline outcomes.

These results have obvious economic policy implications. First, inequality (or at least , the more extreme forms of inequality) should be among the priorities to avoid that relative income satisfaction component penalize economic growth and clustering. Second, clustering can have negative effects in social terms but, to some extent, can be a catalyst to human capital accumulation and authorities should bear that in mind.

Future work will deal with several improvements of the model specification in terms of extension (more than one economy and population dynamics), agent's decisions (return to school after some years in labor market or having different education degrees) and heterogeneity (different individual parameters α and ω or labor specialization).

5 Appendix: $\beta(\rho)$

At the beginning of period t, an agent has perfect knowledge of period $t-1$ wages, namely w^S_{t-1} and w^U_{t-1}, the skilled and unskilled labour wage, respectively. Assume that agents take these values as the ones that will prevail in the future, and, for the sake of simplicity, denote them by w^S and w^U. Suppose skilled agents spend nine more years at school than unskilled agents. For example, one can think they spend two more years at secondary school, four additional years to take a first degree, and finally three more years in some form of post-graduate studies. PVE, the present value of future wages for an agent that is starting his or her education to become skilled is then:

$$PVE = w^S\left[(1+\rho)^{-9} + (1+\rho)^{-10} + \cdots + (1+\rho)^{\tau}\right] \tag{12}$$

where ρ is a rate of time preference or discount rate, and τ is the number of years to the end of active life, likely to be comprised between 45 and 50.

At the same time a future skilled agent starts his or her education, unskilled agents start working. With the hypothesis above, this means they work nine more years when compared to skilled workers. Let PVU be the present value of all wages earned by unskilled workers:

$$PVU = w^U\left[1 + (1+\rho)^{-1} + (1+\rho)^{-10} + \cdots + (1+\rho)^{\tau}\right] \tag{13}$$

Comparing Eqs. (12) and (13), it is apparent that ws must be greater than wu for there to be any chance of PVE being greater than PVU. In this case, and from a pure income perspective, i.e., taking aside any subjective preference for education, the agent would chose to proceed into further education and not to remain unskilled. Let β be the ratio between w^S and w^U that makes the present value of skilled labour wages equal to the present value of unskilled labour wages:

$$\frac{w^S}{w^U} = \beta = PVE = PVU \tag{14}$$

From Eqs. (12), (13) and (14), it gives:

$$\beta = \frac{1 + (1+\rho)^{-1} + (1+\rho)^{-10} + \cdots + (1+\rho)^{\tau}}{(1+\rho)^{-9} + (1+\rho)^{-10} + \cdots + (1+\rho)^{\tau}} = \frac{A}{B} \tag{15}$$

with $A = 1 + (1+\rho)^{-1} + (1+\rho)^{-10} + \cdots + (1+\rho)^{\tau}$ e $B = (1+\rho)^{-9} + (1+\rho)^{-10} + \cdots + (1+\rho)^{\tau}$. Is is easy to show that $A = \frac{1+\rho-(1+\rho)^{-\tau}}{\rho}$ and that $B = \frac{(1+\rho)^{9}-(1+\rho)^{8-\tau}}{1-(1+\rho)^{8-\tau}}$. Replacing A and B in expression (15) and simplifying, it gives:

$$\beta = \frac{(1+\rho)^{9} - (1+\rho)^{8-\tau}}{1 - (1+\rho)^{8-\tau}} \tag{16}$$

Note thatβ approaches $(1+\rho)^9)$ when τ tends to infinity, and that β is an increasing function of ρ. When the discount rate is higher, the future is less valued, and therefore the skilled labour wage has to be higher for agents to become indifferent between acquiring skills through education and to remain unskilled. In our simulations, we set $\tau = 48$.

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