On positional consumption and technological innovation: an agent-based model

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REGULAR ARTICLE

On positional consumption and technological innovation: an agent-based model

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Abstract Positional behaviour is arguably a source of social externalities. Remedies for this market failure are defended by some authors and rejected by others. One of the issues discussed is the role that the competition for positional goods may have in generating technological innovation. This article aims to contribute to the understanding of the dynamics of this process through the use of an agent-based model. Simulations show a plausible dynamics of the process of technological innovation as generated by consumption of positional nature. An interpretation of the results in the scope of the policy discussion in question is provided. The influence of key factors such as income inequality, the materialization of the Hirsch conjecture, and characteristics of the network of relative preferences, is analised. We also frame the potential interest of positional consumption and this model in particular in the context of the ongoing discussion among evolutionary economists on the behaviour of demand.

Keywords Positional consumption · Relative preferences · Innovation · Agent-based modelling · Demand behaviour · Evolutionary economics · Economic inequality · Hirsch conjecture · Social network effects

JEL Classifications D01 · D11 · O31 · C63

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1 Introduction

The *positional economy* refers to all aspects of goods, services, occupations, or other social relations that are either scarce in an absolute or socially imposed sense, or subject to crowding or congestion through more extensive use (Hirsch 1976). The idea of a positional economy differs from the *material economy*, in which the utility enjoyed with goods is directly independent of other consumers' choices.

In the material economy, the possibilities to increase the utility of members of society can ultimately be considered limitless, as long as the consumption of additional goods provides any marginal utility to individuals. In opposition, utility gathered in the positional economy depends on the scarcity of the items consumed, a scarcity imposed either physically or, most significantly, socially. With positional consumption, one's utility depends directly on the way other individuals consume the same product.

The consumption of status goods is the most eminent case of positional consumption.[1] The scarcer and more difficult to obtain are the status goods, services or occupations, the more utility they provide to the consumer. This satisfaction formation setup leads to a competition for goods which never satisfies the individuals on aggregate. By definition, the aggregate utility provided by status consumption is socially limited, because status is a relative concept. Any increase in satisfaction of an individual is formed at the expense of a correspondent decrease in the satisfaction of others. This competition thus results in a zero-sum game, at least in the short-run.

From a biological evolutionary perspective, such human behaviour is a result of natural selection. In the world of our ancestors, competition for status was a necessary condition for finding partners for reproduction and building useful social capital (Shermer 2008). This is still true. However, the dynamic purpose of that time, adaptation and survival of the species, does not seem to make sense in a present time where humans became dominant and all powerful within nature.

Yet the human emotional traits leading to such behaviour are still there. On the other hand, status behaviour is not only related with emotional instincts, but it does make sense in many activities from a rational perspective of the individual seeking the best for himself (Frank 1999, 2005). For instance, someone going to a job interview may have to signal his competence not only through its factual demonstration but also for example by the way he dresses.

Independently of the degree of rationality of positional behaviour, several economists have called attention to its negative consequences on wellbeing, even before the term was coined by Hirsch (Veblen 1899; Dusenberry 1949; Galbraith 1958). Given its zero-sum game nature, status consumption can consequently be regarded as resource wasteful, since individuals as a whole expend efforts with no aggregate returns for wellbeing.

Additionally, Hirsch (1976) conjectured that the inefficiencies caused by positional consumption increase with economic growth, since after the fulfillment of

[1] Literature on positional consumption commonly uses the term to refer simply to consumption where satisfaction is defined by social scarcity. Our work also adopts the nomenclature in this stricter sense.

basic needs (such as food) consumers tend to increase their share of spending towards consumption of positional nature. At the same time, empirical evidence came suggesting that absolute income did not contribute to happiness in developed societies, only relative income did (Easterlin 1974). These results originated one of the debates on the origin, consequences and possible remedies over the positional economy. Is indeed the quest for positional goods gaining eminence as the economy grows, thereby increasing inefficiency? Are there benefits from the positional economy offsetting its damage? Should policymakers regard this issue as a matter of state intervention?

Hirsch himself assumed a prudent position on policy remedies. His prudence was justified by the lack of knowledge on the costs and benefits of applying such kind of policies. Claims for policy actions for the recoil of the positional economy have come for example from Frank (Frank 1999, 2003), who proposes progressive (income or consumption) taxation as a policy remedy.[2] Such policy would discourage high-end consumption and erode the "expenditure cascades" that follow.

Criticism of various nature arised on the issue of collective intervention towards positional consumption. One of the relevant points raised is the role of positional consumption towards the generation of innovation (Kashdan and Klein 2006; Gershuny 1983). Internalizing the costs of the competition for positional goods would constrain positive externalities of this mechanism to innovation. In a reply to Kashdan and Klein, Frank (2006) countered the argument by noting that the alternative capital allocation caused by positional taxation would also drive technological innovation. It is therefore a matter of which kind of consumption and capital allocation does cause the higher level and the more useful innovation. On this, Duesenberry (1949, pp 104–10) argued that the "orthodox" theory of demand could not explain the phenomenon of adoption of new goods, basing this assessment on his aggregate model of interdependent preferences.

Several and complex matters interfere with the way positional consumption may or may not generate technological innovation, and how far. In this work we aim to achieve a better comprehension of the dynamics of the process of generation of technological innovation through positional consumption. For that, we develop an agent-based model which intends to represent the process.

The results of its simulation allow analysing in detail the dynamics of the process of generation of technological innovation through positional consumption. We also observe the influence of some key factors on the pace of innovation, namely, the level of income inequality, the materialization of the Hirsch conjecture and the structure of the consumer influence network. Besides the discussion on possible intervention over positional consumption, the results are interesting from the perspective of understanding a relevant type of dynamics of interdepencies between consumer needs development and innovation. This is the case particularly in the context of

[2] Authors like Layard (1980), Ng (1987) and others suggested income taxation to bring the balance of private and public expenditure to a level consistent with welfare objectives. Before Hirsch, Duesenberry (1949, pp 92–104) suggested the need for intervention in an economic system with interdependent consumer preferences, particularly through progressive income taxation.

the ongoing discussion among evolutionary economics on the drivers, dynamics and outcomes of demand behaviour.

2 Approach

Several authors have approached innovation systems from an agent-based model perspective. An exhaustive set of papers on agent-based economics can be found in The Handbook of Computational Economics, where an extensive survey of agent-based computational research dealing with issues of innovation and technological change is presented, particularly in the chapter by Dawid (2006). The multi-agent work developed there is built upon the lines of biologically-inspired models of social behavior, as also is most of work in evolutionary economics, initiated by Nelson and Winter (1982). Evolutionary economists interested in modeling innovation and growth (Dosi 1988) have been searching for the emergence of macro-invariants from the micro-level behavior. Studying innovation at the micro level is also the core issue of the seminal work by Freeman (1998). More recently, there have been cases of application of agent-based modelling to the study of the dynamics of demand (Aversi et al. 1999; Valente 2012).

The agent-based approach seems to be the most appropriate one for modeling the relation between positional consumption and technological innovation due to the fundamental role that interactions between agents (consumers and firms) have in the development of the process. Axelrod and Tesfatsion (2006) remark that "when the interaction of the agents is contingent on past experience, and especially when the agents continually adapt to that experience, mathematical analysis is typically very limited in its ability to derive the dynamic consequences. In this case, ABM [agent-based modelling] might be the only practical method of analysis".

The process of technological innovation generated by positional consumption corresponds to this area of problems. In fact, unlike in the classical material consumption, when positional consumers evaluate the expected utility from the acquisition of a given good they observe the distribution of goods possessed by all the other consumers in their relevant social network. Therefore the evolution of their decisions is fully interdependent with past decisions of other agents. A feedback loop occurs in this chain of events, whereby a decision of a consumer is determined by the decisions of the remaining consumers, which are later influenced by that same decision.[3]

The same is true for the decisions of firms to engage in the creation of new, more technologically advanced goods. They depend on their expectations on future revenues produced by the new goods, and therefore by the distributional structure of

[3]In fact, this type of non-linearity was possibly responsible for the neglect of economics research on the theory of consumer relative preferences. Dusenberry (1949) proposed a credited theory of consumer behaviour which took into account relative preferences. However, it soon became marginalized from mainstream analyses. Possibly, the mathematization of the economics discipline at the time rendered the consideration of relative preferences as undesirable from the point of view of the tractability of problems (Mason 2000).

goods possessed by the consumers in the social network(s), which is on its side also contingent on the possible previous creation of new goods.

In brief, the nature of the process is characterized by the existence of interacting agents, by the contingency of their decisions on past decisions and by the existence of feedback loops, all elements that make a mathematical approach difficult to realize and the agent-based modelling approach better able to deal with them. Although more aggregate approaches are possible—as provided by Reinstaller and Sanditov (2005) in the framework of relative preferences and innovation, and several authors in other frameworks related to positional consumption (e.g. Ng 1987)—several aspects captured by our model could not be covered under such a framework.

3 Model

3.1 Scope

An agent-based model representing a system of positional consumption and an inherent process of generation of technological innovation is developed. The focus is on representing:

i A valuation of goods by consumers grounded on status concerns, being status provided by attribute(s) of the good that can be enhanced through technological innovation;
ii Investment of firms on technological innovation contingent on expected revenues; and
iii Prices of existing goods decreasing with time due to increasing competition between firms and increasing production process efficiency.

Being the model specifically aimed at studying the interrelation between the dynamics of positional consumption and technological innovation, we found no similar approaches in the literature in relation to the general structure of this model. The qualitative behaviour of the main interrelations may be traced to stylised mechanisms established in the economics discipline or in particular in the positional consumption framework.

The model considers a utility function varying positively with the consumer's ranking in relation to other consumers. This feature is the landmark condition of positional consumption. An assumption that bounds the scope of the model is that the consumers value the good in question for attributes which depend exclusively on technological innovation for their improvement. The consideration of this type of good justifies the assumption that new goods decrease their price with time; being the positional attributes of the good in question of technological nature—i.e. they are improvable through technological innovation—its price is subject to a downward pressure due to competition—i.e. consumers are price-takers—and production process efficiency. This phenomenon would not necessarily happen with other types of attributes. Furthermore, profit maximizing firms invest more in R&D if their expectations on future revenues resulting from those investments are higher, and will do so whenever the expected revenue exceeds the R&D investment costs. In one of the tests conducted, the model incorporates social network structure effects. The approach was inspired, with no particular model as reference, on the fixed networks literature (Wilhite 2006).

3.2 Model structure

The model is characterized by the following **agents**:

- *C* consumers, characterized by different levels of income;
- The industry, a single agent representing the aggregate behavior of firms in the economy.

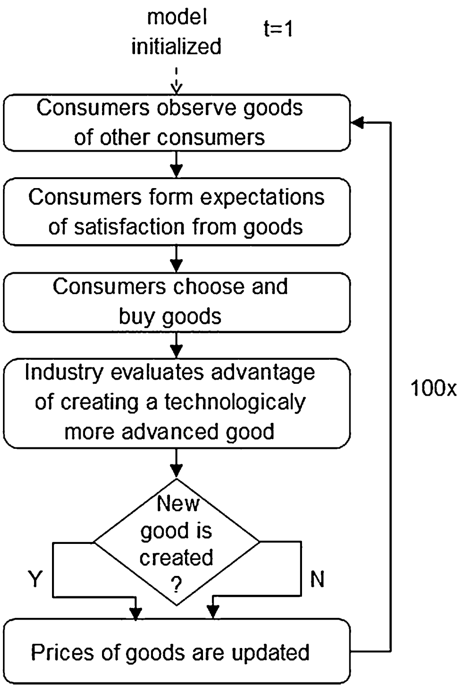
The fundamental structural **assumptions** of the model are outlined and explained in the following lines:

- There is one type of good, with a technological attribute that provides consumers with status;
- Consumers aim to maximize individual utility; utility is obtained through status;
- There is a *G* number of versions of that type of good,[4] each being characterized by having different levels of technological development;
- The utility provided by a good to a given consumer depends on the technological level of the good and on the choices of the other consumers; the higher is the technological hierarchy and the less consumers have that version or superior versions of the good, the higher is utility;
- The utility obtained in a simulation period is valid for that period only; consumers buy a good in each simulation period to obtain utility within that period;
- Consumers' choices depend on the expected utilities provided by the goods, their prices and their available incomes;
- The industry can create a technologically more advanced good; to do that it must incur in research & development (R&D) for its development; a technologically more advanced version is created if the expected revenues for the new good exceeds the R&D costs necessary for its development;
- When a new good is created, the industry sets its price at the level that maximizes revenues from sales, taking into account the number of consumers that would buy the good at each possible price;
- Prices of the existent goods decrease with time due to increasing competition of supply and production process efficiency.

Figure 1 describes the sequence of steps of the model run. It consists of a cyclical sequence in which consumers observe the choices of other consumers, form expectations of the utility derived from each possible version of the good and decide which to buy. Then the industry evaluates and decides whether to develop a

[4] Versions of the good under study are further simply designated as *goods*.

Fig. 1 Model structure



technologically more advanced good. Finally, the prices of goods are updated and the following period starts.

The formal specification of the model is described below.

3.3 Model specification

3.3.1 Consumer incomes

Consumers have different levels of income, which increase with index i representing individuals. Consumer incomes (W) follow a Weibull distribution curve, with a cumulative form given by:

$$F\big(W(i), \bar{W}, k\big) = 1 - exp\left(-\left(\frac{W(i)}{\overline{W}}\right)^k\right) \tag{1}$$

with $W(i) \geq 0$ and $\overline{W}$ being the average income.

The Weibull curve allows representing various configurations for the distributions of incomes, ranging from unequal to even distributions. The degree of (in)equality of the distribution depends on constant k. Figure 2 represents three possible curve profiles, depending on k.

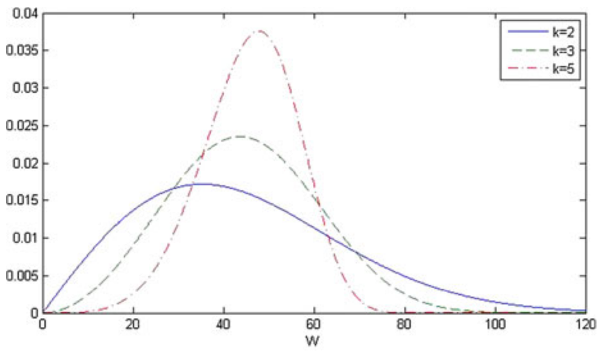


Fig. 2 Profiles of income distributions defined by a Weibull distribution

The income of each individual is available for consumption spending in each time period t and does not accumulate to following iterations.

3.3.2 *Prices of goods*

Each good g has a price $P(g,t)$. The prices of goods decrease with time due to increasing competition of supply and production process efficiency. Prices of goods evolve according to a negative exponential given by:

$$P(g,t) = P_{comp} + \left(P_{launch}(g) - P_{comp}\right).\exp\left(-\frac{t - t_0(g)}{k_p}\right) \tag{2}$$

where P_{comp} is the competitive market price—i.e. the price when there is full competition for the commercialization of the good and production efficiency is optimized in the long term—$P_{launch}(g)$ is the price of a good g set by the industry in the period of its launch in the market, $t_0(g)$ is the period of creation of good g and k_p is a constant that determines how slow the price decreases.[5]

3.3.3 *Consumer network*

Each consumer is influenced by a set of other consumers in his preferences over positional goods. The *neighbourhood* of a consumer is the group of consumers by which he is influenced. The model assumes that the neighbourhood of each consumer is composed by the set of individuals closest to her social class.

Social classes are defined here by income levels. The neighbourhood $N(i)$ of a consumer i consists of the set of his N_s closest individuals in their income ranking,[6]

[5] $k_p = 20$ in all simulations below.

[6] For the purposes of this work, a ranking characterizes the hierarchical order of subjects before a given attribute. The ranking is a sequence of integers between one (1) and the number of subjects characterized by the ranking (C). Rankings are attributed by decreasing order of the attribute values of subjects. In this case, the subjects are the consumers and the attribute is their income.

being N_s the size of the neighbourhood. The formal definition of neighbourhood is as follows:

$$N(i) := \begin{cases} N_p(i) & if \ \frac{N_s}{2} < i \leq C - \frac{N_s}{2} \\ N_p\left(1 + \frac{N_s}{2}\right) & if \ |i-1| < \frac{N_s}{2} \\ N_p\left(C - \frac{N_s}{2}\right) & if \ |C-i| < \frac{N_s}{2} \end{cases} \quad (3)$$

where $N_p(i)$ is the pseudo-neighbourhood of i and is given by:

$$N_p(i) := \left\{ j \in I : |i-j| \leq \frac{N_s}{2} \right\} \quad (4)$$

where I is the set of consumers.

As defined by the equations, the neighbourhood of each consumer depends on his relative position on the income ranking. All consumers have the same number of neighbours. Therefore low-end and high-end consumers have an asymmetric neighbourhood with more neighbours on one side of the income ranking than the other side, due to finiteness of the set of consumers. This definition implies that connections are unidirectional, i.e. where a consumer is influenced by the choices of another consumer the opposite may not necessarily happen. Figure 3 illustrates examples of consumer neighbourhoods.

3.3.4 Utilities

The positional utility provided by a good depends on how high that good is positioned in the technological hierarchy, and on the hierarchies of the goods possessed by other consumers. The value of the maximum achievable utility is one (1) and occurs if the consumer possesses the higher good in the technological hierarchy and no other consumers possess the same good. The minimum possible utility is zero (0) and occurs if all the remaining consumers possess goods of higher hierarchy than that of the

Fig. 3 Examples of neighbourhood in a network of 10 consumers with a neighbourhood size of 4

individual concerned. The positional utility for an individual i for buying a good g in time t is given by:

$$U(i, g, t) = \frac{N_{inf}(i, g, t) + \frac{1}{2} * N_{eq}(i, g, t)}{N_s} \tag{5}$$

where $N_{inf}(i, g, t)$ is the number of neighbours in the social influence network (the neighbourhood) of individual i who buy technologically inferior goods than g and $N_{eq}(i, g, t)$ is the number of consumers in the social influence network of individual i who buy equivalent goods (i.e. good g itself). In other words, having a superior good than that of another consumer within the influence neighbourhood provides twice the positional utility of having the same good as another consumer, while having an inferior good does not give any utility.

The model assumes that the utility provided by buying a good only lasts for the period of its acquisition, expiring at the beginning of the following period. Therefore the consumers have to buy a new good in a period to achieve any utility in that period. This corresponds to a system where consumers have to regularly renew their positional stakes, i.e. the positional utility conferred by a good expires after a certain time and to maintain the status the consumers need to buy another good. This assumption fits to a reality where the satisfaction conceded by purchasing status goods is temporary.

Finally, it is implicitly assumed that material utility does not influence choices; either the goods provide no material utility or they all provide the same.

3.3.5 Consumer choices

A consumer's choice of a good in each period depends on his willingness to pay for utility, which is a function of income. In each period the consumer chooses the good with the better trade-off between price and utility. It is assumed that consumers do not downgrade their previous choices, i.e. they do not consider buying a given good if they have previously bought a more technologically developed one at some point in time.

The model assumes that, when taking a decision, the consumer successively compares pairs of goods. In each comparison, his preference is determined by the differences of potential utilities provided by the goods being compared and by his willingness to pay for utility. When comparing between goods g_m and g_n, the consumer chooses g_m if the difference in utilities between g_m and g_n is higher than the ratio between their difference in prices and the consumer's maximum budget assignable to the positional functionality. Formally, the choice falls on g_m over g_n if the following condition is met:

$$U_e(g_m, t) - U_e(g_n, t) \geq \frac{P(g_m, t) - P(g_n, t)}{W(i) * qp} \tag{6}$$

where $U_e(g, t)$ is the expected utility of a good g in the time t in question. Consumers base their decisions on expected utilities, which are formed under the supposition that all other consumers maintain the options made in the previous period. $U_e(g, t)$ is thus computed on that assumption.

This choice mechanism implies that the consumer is willing to give a proportion qp of his income in return for $U_{max} = 1$, which configures a willingness to pay for utility of $W(i) * qp$.

3.3.6 *Innovation: creation of new goods*

Technological innovation is reflected in this model by the creation of new, technologically more advanced goods. In each period, a new and technologically more advanced good may be created by the industry. For that to happen, the industry must invest a given amount in R&D (Crd). A new good is developed if the potential revenue ($R_{pot}(t)$) derived by its expected sales in the following period is higher than the R&D costs that would be involved in its creation:

$$R_{pot}(t) > Crd \tag{7}$$

The cost of R&D efforts necessary to create the new good is given in the model as a ratio f of the total income of consumers in the economy (W_{total}).

$$Crd = W_{total} * f \tag{8}$$

Fixing R&D costs in terms of total income allows testing effects of income distribution without variations in total income affecting the relative R&D cost.

The potential revenue from a hypothetical new good is calculated on the basis of the price that would maximize the difference between revenues obtained from its sales and those obtained if the good is not created, considering the number of consumers that would be willing to buy the good at that price:

$$R_{pot}(t) = max_i \left\{ (P_{max}(i, g_{new}, t+1) - P(g_{high}), t+1) * (C - i + 1) \right\}, i \in H \tag{9}$$

where g_{new} is the hypothetical new good, g_{high} is the present good with the highest ranking, H is the group of consumers who consumed g_{high} and $P_{max}(i, g_{new}, t)$ is the maximum price that consumer i would be willing to offer for the new good in the next period. Deriving from Eq. 6, $P_{max}(i, g_{new}, t + 1)$ results in:

$$P_{max}(i, g_{new}, t+1) = P(g_{high}, t+1) + (U(g_{new}, t+1) - U(g_{high}, t+1)) * W(i) * qp \tag{10}$$

4 Results

4.1 Description of tests

The simulation of the model allowed to observe the structure of dynamics behind positionality driven technological innovation.

It also allowed testing the influence of relevant factors towards the pace of innovation, particularly:

– **Income inequality** (k); as described below, income inequality has been pointed out by authors as a factor that promotes the market generation of technological innovation, and an argument against the application of instruments to reduce positional consumption.
– **Proportion of income allocatable to positional consumption** (qp); testing this factor corresponds to testing the effects of the materialization of the the Hirsch hypothesis of growing relative positional spending with the increase of affluence.
– **Size and type of consumer network** (c); it is interesting, from a social network analysis perspective, to observe the effects over innovation that may arise from different sizes of and spread across different social classes of the social influence groups.

The set of simulations realized is constituted by a baseline simulation and by further sets of simulations aimed at studying the influence of factors outlined here. The term $innovation$, or pace of innovation, refers here to the total number of new goods created during the simulation time.

In the tested set of simulations some quantitative assumptions are applied: R&D costs for the creation of a new product are a fraction of total income (f) of 2 %; the competitive market price for each good (P_{comp}) is equal to zero (0), therefore prices of goods tend to zero in the long term; at the first period of simulation there are 3 goods with different prices and technological levels, and; the simulation runs for 100 periods of time.

The key parameters varied are k, qp, C and N_s, respectively income inequality, maximum fraction of income spent in positional consumption, size of the consumer population and size of the consumer social neighbourhood. The values of R&D costs (f) and consumption frequency are also changed in some subscenarios. Table 1 describes the set of tests made.

4.2 Baseline simulation—modelling positional competition and technological innovation

In the baseline simulation, the model takes an inequality coefficient (k) of 2 (a value similar to those found in typical societies[7]), a maximum fraction of consumer income potentially expendable in the positional functionality (qp) of 0.5, a population (C) of 100 consumers with all consumers influencing each other—i.e. with a social neighbourhood size (N_s) of 99—and R&D costs being a fraction of total income (f) of 2 %.

The results reveal a cyclical creation of new and technologically more developed goods, driven by a competition for positional goods. In the first periods of the simulation the consumers make their choices, according to their preferences, amongst the goods available in the market. After the matching between consumer preferences

[7] A k of 2 is equivalent to a Gini index of 0.251 or a Hoover index of 0.219.

Table 1 Model inputs

Tests		Population of consumers (c)	Consumer neighborhood size (Ns)	Parameter for income inequality (k)	Income dedicated to posit. cons. (qp)	R&D costs (as % of total income) (f)	Consumption frequency
Baseline	0	100	C-1	2	50 %	2 %	1
Income inequality	1.1	100	C-1	0.1 to 500	50 %	2 %	1
	1.2	100	C-1	0.1 to 500	50 %	1.25 %	1
Hirsch conjecture	2.1	100	C-1	2	0 % to 150 %	2 %	1
	2.1	100	C-1	2	0 % to 150 %	2 %	2
Number of consumers	3	1 to 500,000	C-1	2	50 %	2 %	1
Social neighborhood (function of f)	4.1.1	100	2 to C-1	2	50 %	0.5 %	1
	4.1.2	100	2 to C-1	2	50 %	1.25 %	1
	4.1.3	100	2 to C-1	2	50 %	2 %	1
	4.1.4	100	2 to C-1	2	50 %	3 %	1
Social neighborhood (function of k)	4.2.1	100	2 to C-1	0.5	50 %	2 %	1
	4.2.2	100	2 to C-1	1	50 %	2 %	1
	4.2.3	100	2 to C-1	2	50 %	2 %	1
	4.2.4	100	2 to C-1	3	50 %	2 %	1

and available goods, a latent demand for the consumption of a more technologically advanced good eventually surges and grows. As soon as the expected revenues for the industry by putting a more technologically advanced good into the market exceed the R&D costs necessary for its development, the good is developed. The matching between consumers and goods is renewed at each period, a process which dynamically evolves both with the change of positional valuation of the goods (which changes when any consumer alters its choice) and the decrease of prices of goods.

Figure 4 shows the number of existing goods in each period of time. New goods are added at a relatively stable rate, except during a warm-up phase of the simulation (until about the 20th period). At the end of the simulation, there are 30 goods in total, i.e. 27 new goods are created at a cycle of new product development of 3,7 periods. Figure 5 shows the match between consumers and goods after the last period of simulation. Consumers at the high-end of income are consuming goods at the high-end of sophistication, and consumers at the low-end of income are consuming the less sophisticated goods. The three initial goods have at this stage no longer any buyers. It is noteworthy that, in the last period, the good with the highest number of consumers is good number 29, which was, when consumers made their decisions, the most sophisticated one available. But as is possible to see in Fig. 4, a new good is finally created in this period (good number 30), which happens precisely as a result of the fact that many consumers were already consuming the highest level good, enabling a strong latent demand for a new good.

The main fact of this dynamics of consumer competition for positional goods together with a continuous price decrease is a cyclical creation of more technologically advanced goods.

4.3 Income inequality

To check for effects of inequality over the level of innovation in the model, simulations were run with different values of parameter k, which defines the level of

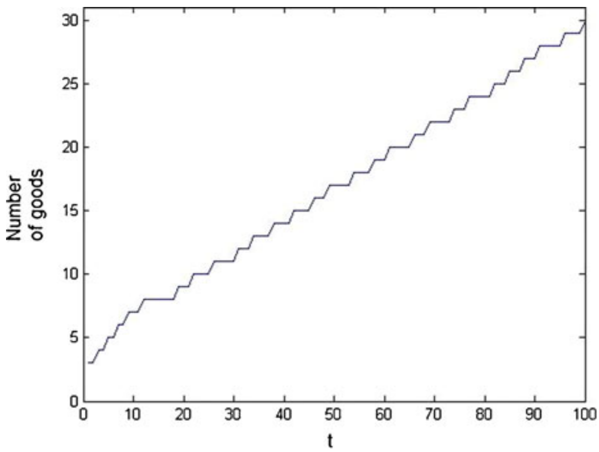


Fig. 4 Number of goods over time

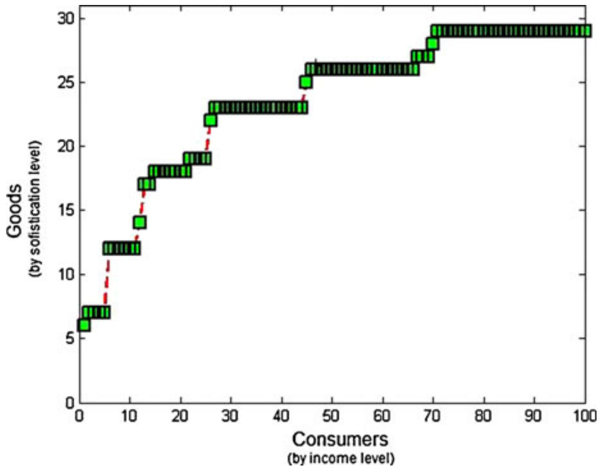


Fig. 5 Matching between consumers and goods, at $t = 100$

inequality. Figure 6 shows the results. It also shows the Hoover index—a measure of (in)equality—for the spectrum of tested k values. The higher is the Hoover index—and k—the most equitative is the defined income distribution.

4.4 Hirsch conjecture

A test is provided on the consequences of the materialization of the Hirsch conjecture, whereby "social limits to growth" are imposed by an increasingly important relative share of positional consumption. The result of simulations with different shares of consumption dedicated to positionality shows decreasing returns of innovation to the share of allocatable income to positional spending (see Fig. 7).

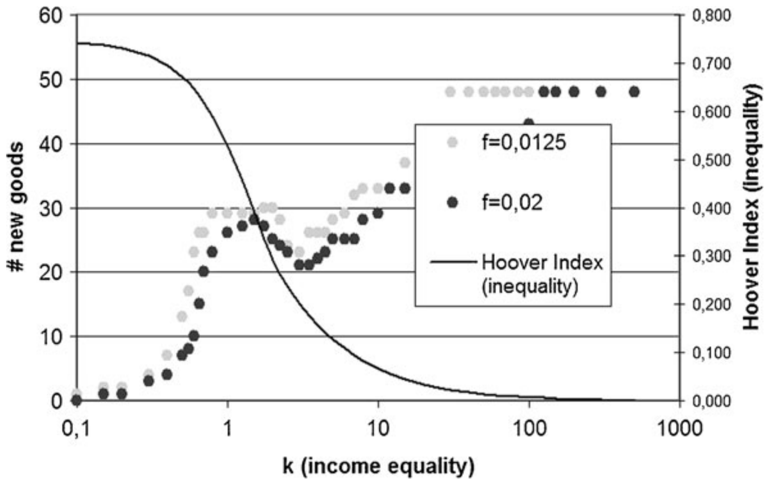


Fig. 6 Number of new goods with different income distributions

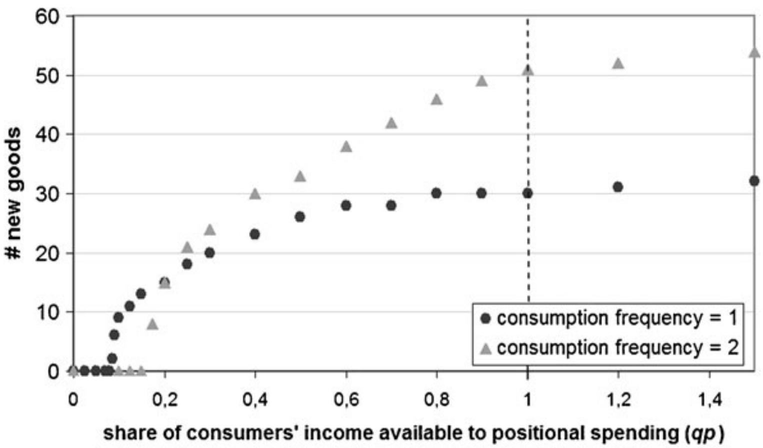


Fig. 7 Number of new goods as a function of the share of consumer income available to positional spending

However, the result of decreasing returns of innovation to positional consumption is subject to the assumption of the model that consumers exert their positional stakes (by consuming) at a constant rate (one good is bought at each period; its utility is valid for one period). It is plausible to expect positional for stakes to be played more frequently as the budget available for positional consumption also increases. On this, the model shows that different frequencies of consumption may return different volumes of innovation; in comparing the initially assumed consumption frequency of 1 with a consumption frequency of 2 (two goods consumed in each period, with half the period's income devoted to each[8]), results show that the lower frequency returns more innovation for low levels of relative budget allocatable to positional spending, whereas the higher frequency returns more innovation for high levels of positional budget.

4.5 Consumer network

We firstly tested the level of innovation occurring with different sizes of the social population (still assuming a fully connected influence neighbourhood).

The model produces stable results (Fig. 8) before variations in population size, except for very low sizes of the social network (less than 10 consumer agents) where the number of goods produced varies no more than 25 % of the stabilized innovation output.

With a baseline population of 100 consumers, variations in neighbourhood size were simulated to account for its effects on the creation of new goods. In the first set

[8]In terms of formal model implementation, this was done simply by doubling the number of iterations and reducing to half the average income $\overline{W}$ in each period.

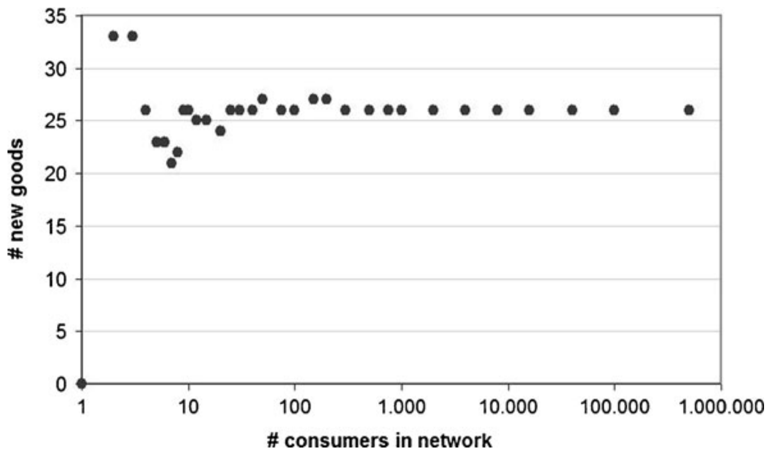


Fig. 8 Number of new goods as a function of number of consumers

of simulations, different levels of R&D investment costs were tried (f). The baseline value for inequality of $k = 2$ was assumed.

The results for this inequality scenario show a perfectly stable amount of new goods for neighbourhood sizes up to about 60 % of the total number of consumers, whereas higher neighbourhood sizes produced increasing levels of innovation (Fig. 9). This outcome is robust for different levels of required investment on R&D.

However, this result is not generalizable to other inequality profiles. Testing neighbourhood sizes with other inequality levels produces rather distinct results. As shown in Fig. 10, not only the partial non-dependence between neighbourhood size and

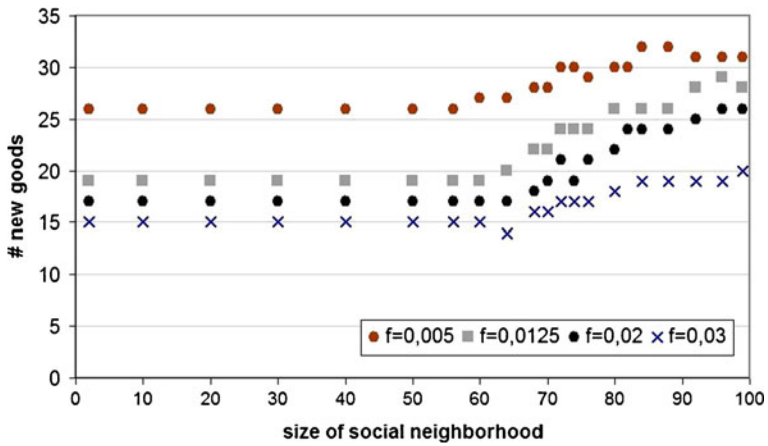


Fig. 9 Number of new goods as a function of size of social neighbourhood, with different investment costs of R&D

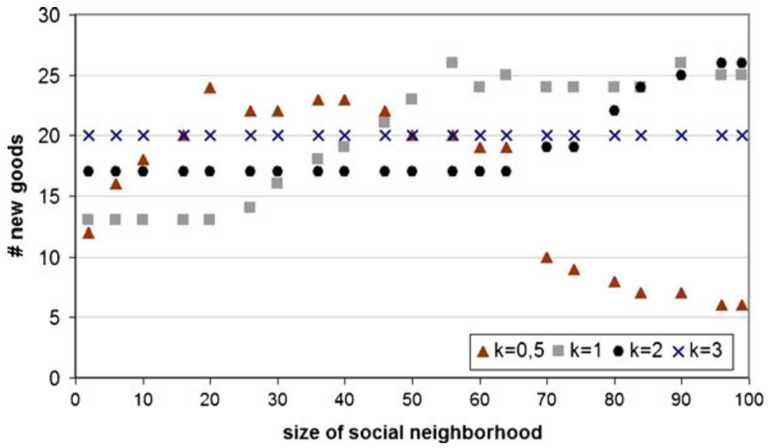


Fig. 10 Number of new goods as a function of size of social neighbourhood, with different income distributions

innovation does not occur for other income distributions, but also the direction of the relation varies largely with income distribution. A high equality level ($k = 3$) results in a null relation, with an invariable number of new goods produced. On the other hand, a society with a high inequality ($k = 0.5$) produces results with disparate differential relations between neighbourhood size and level of innovation.

5 Discussion and some implications

5.1 Inequality: contradictory effects on innovation

Variations in the economic inequality produce a general trend of innovation increasing with equality, although with breaks in that trend along the spectrum of values tested.

The relation between pace of innovation and equality level depends on two opposing drivers. In an unequal society, high-end consumers are willing to individually spend very large amounts of money to buy innovative goods, but there are not many consumers in that position. In a fairly equal society, high-end consumers do not have, in relative terms, so much funds, but there is a much larger pool of consumers with incomes very close to the highest earnings level. In this situation, despite the fact that high-end consumers are not willing to spend as high as in the unequal society, together they have a powerful multiplying effect. It is the balance between these two variants—price of the new good and number of consumers willing to pay for it—that determines whether technological innovation increases or decreases with the level of equality. In the majority of income distribution setups of this model, the massification of high-end consumption results in a stronger driver of technological innovation than the relative wealth of the richest consumers. Zweimüller (2000) reaches a similar conclusion based on a model specifically designed to study the impact of inequality on growth when consumers have hierarchic preferences and technical progress is driven by innovations.

It is useful to confront this result with an argument put forward of Kashdan and Klein (2006), inspired by Hayek:

> "If today in the United States or western Europe the relatively poor can have a car or a refrigerator, an airplane trip or a radio, at the cost of a reasonable part of their income, this was made possible because in the past others with larger incomes were able to spend on what was then a luxury. The path of advance is greatly eased by the fact that it has been trodden before. (...)What today may seem extravagance or even waste, because it is enjoyed by the few and even undreamed of by the masses, is payment for the experimentation with a style of living that will eventually be available to many." (Hayek 1960)

Kashdan and Klein add that "in the dynamics of a growing economy, the wealthy provide a market for goods that must be expensive in order to supply to be viable. The wealthy pay extra to enjoy the benefits of new goods, which, if suitable to human existence, will later become inexpensive and widely adopted". This argument intends to oppose Frank's (1999, 2003) proposal of progressive taxation to reduce the "expenditure cascades" led by positional behaviour which, according to him, are amplified by inequality (for a detailed argument see Levine et al. 2010). To Kashdan and Klein, the introduction of progressive taxation would degrade positive externalities on innovation.

Contrarily to the direction of this argument, the results of this model show that the opposite case is also possible. There may be an even more viable market for new goods in a more equal society, as long as the multiplying effect of having a larger pool of consumers able to compete for the highest positional places offsets the lower individual economic capacity of high-end consumers.

5.2 The Hirsch conjecture and time constraints to innovation

The test on the consequences of the materialization of the Hirsch conjecture has shown decreasing returns of innovation to the share of allocatable income to positional spending. This would imply that "social limits to growth" also apply to the "innovation factor" of positional consumption. However, the explanation for this limit is the existence of time constraints. By allowing increased consumption frequencies in the model, the limits to innovation do not hold.

This suggests that, if the increment of positional spending carries with it an increase in consumption frequency, the result of decreasing returns of innovation to positional spending would not necessarily occur. However, we note that the increase of frequency of consumption must have its own limits, posed by the finite pace at which consumers are able to incorporate information on changes in the market (a discussion on the importance of time constraints on the dynamics of consumption is provided by Metcalfe 2001); only when consumers actually realize changes in their positional ranking and the available goods can they form and deliver their consumption decisions. Even if income tended to infinite, one would not expect frequency of consumption to tend to zero.

5.3 Consumer social networks affect the pace of innovation

The positional competition for goods occurs within a social context. When one individual evaluates his *position* or that of other individuals in the social ranking, he does so within his perceived social sphere, i.e. within the group of individuals with whom he regards as belonging to his group of influence.

One may question whether this social arena for positional competition is regarded by individuals as a large group of other individuals, like a region or a country, or on the contrary as a very small circle of close connections in her social context, like family and closest acquaintances.

A consumer neighbourhood defined by proximity in social class (or level of income) was tested in the model, whereby in his evaluation of the utilities given by different goods, a consumer is influenced by his closest neighbours in social ranking. This accounts for a world where people compare themselves to friends, work colleagues and residential neighbours, i.e. people who tend to belong to a similar income group.

Translating this question into the real world, the relevant focus would be less on the proportion and quantity of consumers within the whole population accounting for one's neighbourhood, but rather on the extension of one's influence group to social classes different than his own. At one extreme, a neighbourhood consisting of all the consumers in the network would translate into a society where an individual would be influenced indifferently by any other individuals, disregard of their social class. On the other hand, a small neighbourhood is analogous to a world where individuals compare their positional achievements with other individuals with a similar social class.

The results show disparate effects on innovation. The pace of innovation changes with the structure the social network, and does so in dramatically different ways for different levels of economic inequality of the society. The relation between types of networks of social interaction and the generation of innovation is thus complex, depending crucially on the income profile. It does not seem to be possible to clearly characterize this relation in the real world. And it plausily varies largely from place to place, depending on the socioeconomic structure of society.

5.4 Does positional consumption promote innovation and wellbeing?

The discussion between proponents of political action to confront the inefficiency of the positional economy and the opponents to such action which ground their opposition on the power of positional consumption to generate innovation is open for new developments. The model presented in this paper was aimed at achieving a better comprehension of the relation between consumption of positional type and technological innovation.

The model shows that the process of competition for positional goods improvable through technological innovation generates a cyclical creation of new, innovative goods. This occurs in particular because the utility provided to a consumer by consuming something special erodes when a mass of other consumers buy something similar or even more special, putting a pressure on consumers to seek ever more innovative goods. The same type of dynamics of pressure towards innovation does not occur in the case of material goods, which suggests that markets for material needs would not generate as much consumption and, inherently, pace of novelty. In relation to intensity of innovation, the model results have shown it to be qualitatively robust (even if with significant quantitative variations) to parameter changes like income inequality, the relative weight of preferences for positional goods over other types of spending, or different structures of the consumer preference interdependence network. It is particularly noteworthy that the dynamics still exists with very economically equal societies. Indeed, because the attribute of positional interest for consumers is technology related, the nature of competition among consumers does not depend on economic differences between them, as may be the case with objects of social competition related to social class (as tested by Reinstaller and Sanditov 2005).

While it seems clear that absolute consumption and creation of novelty are higher under positional than material consumer preferences, at least two questions remain as to the contribution to wellbeing of the innovations generated in this way. Firstly, it should be considered that innovation occurs at the expense of resources and we should therefore try to assess relative rather than absolute innovation in relation to the resources spent. For this aim, our model cannot be of help; if innovation is higher at the expense of also higher consumption, nothing can be said of the efficiency with which it is generated. In this respect, it is also relevant to note the model has shown also limits to growth of innovation derived by increasing levels of consumption, due to time constraints.

The second issue refers to the type of innovation that is generated and its related goodness to wellbeing. The model assumes that consumers value a technological attribute of the product, whereas in the cases where goods are valued on positional grounds for attributes which are not subject to technological innovation, other types of novelty will be incentivised—like brand positioning—which do not bring the economic benefits that technical innovation may do. In relation to this, Witt (2010) suggests that unlike consumption not serving social signalling purposes, the technological characteristics of the goods and services valued by their socially symbology may be secondary in relation to other aspects. Indeed, since the innovations in question address positional needs, they do not deliver to wellbeing in that way—since positional needs entail zero-sum games—but only do so if they simultaneously address material needs.

The two issues should be further addressed for a concrete response to the fundamental question on the comparative benefits of positional and material consumption types in relation to the issue of innovation creation.

5.5 Positional consumption and the debate on the behaviour of demand

The economics discipline, particularly evolutionary economists, has recently started to dedicate to the study of the micro foundations of household demand behaviour. The main ambition is to explain the aggregate behaviour of demand through assumptions on the behaviour towards consumption of individuals which are more coherent with the reality than the traditional assumption in the economics discipline rational behaviour (like Aversi et al. 1999, Metcalfe 2001, Witt 2001, Nelson and Consoli 2010,Valente 2012).

The features of individual behaviour under consideration are inspired on psychological and sociological views of the consumer behaviour, where social aspects of consumption have a predominant role. Individual processes like those of imitation and consumer innovation, habits and routine, learning and time constraints have been considered. Modelling work departing from individual micro assumptions has produced aggregate system behaviour that is consistent with observed phenomena, like the S-shape commonly found on diffusion patterns and others (Aversi et al. 1999).

This new chain of literature has generally not explicitly considered behaviour of positional type in the micro characterization of consumer behaviour, even if it includes elements that at least partly result from it, like imitation or consumer innovation. For example, a notable paper of Witt (2001) which discusses the persistence of economic growth in face of the satiation of wants does not explicitly consider phenomena of positional type in the explanation. An exception is the model developed by Reinstaller and Sanditov (2005), which considered positional behaviour to study the effects of social class and behavioural variety on consumer goods diffusion. The sociological field, on the other hand, has since long regarded status behaviour and/or search for distinction as a crucial (in different forms, perhaps the most discussed) aspect of consumer behaviour within the construction of individual identities (Swann 2002; Nelson 2007).

The results of our model allow stressing the relevance of positional behaviour with regard to the discussion on the micro foundations of household consumption. By including positional concerns on the utility function, an eternal thirst for consumption and innovation is generated. Indeed, what makes the phenomenon cyclical and everlasting is the fact that individual utility from the acquisition of certain products erodes as soon as the mass of consumers adopt the same behaviour, taking away what is *special* in it and driving the consumers to seek other sources of positional based satisfaction. This seems to represent a real mechanism in markets, possibly one of the most important ones in the generation of innovation.

Another important insight coming from the positional consumption perspective is that it carries clear policy implications. The utility derived from it is dependent on other consumers' preferences implying a zero-sum game, featuring a case of negative externality. Like among sociologists (Nelson 2007), the study of consumer behaviour among evolutionary economists has to date been relatively neutral in relation to policy implications. Even if the criticism of the rationality assumption shakes the economic edifice that relates consumer choices with wellbeing, no clear conclusions have emerged in relation to economic policy. The positional consumption framework results in a strong case for policy prescription.

6 Summary and conclusions

An agent-based model was created to represent the process of technological development generated by the competition for consumption of positional goods. In this model, the positional utility provided by a type of good depends on its technological attributes, and consumers periodically play their stakes in the positional game by consuming that good. More technologically advanced versions of the good are developed and put into the market by the industry in each time period if the expected revenues from sales are higher than the costs of the necessary R&D. Prices of new goods decrease with time due to increasing competition and productive efficiency. In a time period, each consumer selects one good on the basis of the expected positional utility and the consumer's economic capacity to pay the price of each good.

The main fact resulting from the process of competition for positional goods improvable through technological innovation is a recurrent cyclical creation of new goods. This type of pressure for novelty seems to be higher with positional than material consumption, since the later does not possess the same effect of ever insatiable search for goods. However, this outcome says nothing on the efficiency of such generation of novelty towards wellbeing. In this, at least two issues should be considered and further studied. The first is that innovation as generated by positional consumption occurs at the expense of a higher volume of consumption, which implies spending more resources. The assessment of the amount of innovation should focus on the efficiency with which it is generated—in relation to the resources spent—rather than on absolute volume. The second issue questions if the innovation coming from positional consumption is beneficial to wellbeing, considering on one side that such innovation might not be technological in nature—as assumed by the model—but refer to other types of product innovation possibly less beneficial for wellbeing, and on the other side that innovations are in theory only directly beneficial to wellbeing if they also address material needs besides the positional needs that generated the innovations.

The model has also shown interesting specific results on parameters characterizing income inequality and consumer influence networks. A global negative relation between income inequality and the number of new goods created is observed, showing that the market for innovation may happen to be higher in less unequal societies, contradicting the existing arguments against the policy intervention towards positional consumption. As for the relation between the configuration of the social group of influence of each consumer's preferences and the generation of innovation, it is shown to be a complex one, and highly sensitive for example to income distribution. The profile of this relation in the real world plausibly varies largely from place to place, depending on the local socioeconomic structure.

Finally, we highlight the relevance of the positional consumption perspective for the current debate among economists on the micro foundations of household demand behaviour. At the modelling level it provides an explanation, grounded on observed social aspects of consumer behaviour, for the existence of markets with insatiable consumption needs and a continuous search of novelty by consumers and producers. At the policy level, it entails clear policy implications—in relation to positional externalities—that the debate in question has yet not fully covered.

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