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Article (Published)
(Refereed)

Original Citation:

Rengs, Bernhard and Scholz-Wäckerle, Manuel (2018) Consumption & class in evolutionary macroeconomics. *Journal of Evolutionary Economics*. pp. 1-35. ISSN 1432-1386

This version is available at: <http://epub.wu.ac.at/6596/>

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Consumption & class in evolutionary macroeconomics

Bernhard Rengs¹ · Manuel Scholz-Wäckerle²

Published online: 18 October 2018
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Abstract

This article contributes to the field of evolutionary macroeconomics by highlighting the dynamic interlinkages between micro-meso-macro with a Veblenian meso foundation in an agent-based macroeconomic model. Consumption is dependent on endogenously changing social class and signaling, such as bandwagon, Veblen and snob effects. In particular, we test the macroeconomic effects of this meso foundation in a generic agent-based model of a closed artificial economy. The model is stock-flow consistent and builds upon local decision heuristics of heterogeneous agents characterized by bounded rationality and satisficing behavior. These agents include a multitude of households (workers and capitalists), firms, banks as well as a capital goods firm, a government and a central bank. Simulation experiments indicate co-evolutionary dynamics between signaling-by-consuming and firm specialization that eventually effect employment and consumer prices, as well as other macroeconomic aggregates.

Keywords Evolutionary macroeconomics · Agent-based modelling · Micro-meso-macro · Conspicuous consumption · Social class · Firm specialization

JEL classification B52 · C63 · E21 · E23 · L11

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1 Introduction

Evolutionary economists have traditionally focused on the supply side, following the Schumpeterian avenue of economic analysis (Schumpeter 1934). Nelson and Winter (1982), using this approach, created a theoretical core with an analytical apparatus that has inspired, among others, De Bresson (1987), Dosi et al. (1988), Saviotti and Metcalfe (1991) and Witt (1992). Recently, this Schumpeterian theoretical core was also embedded into a macroeconomic framework (in particular, an agent-based one) as shown by Dosi et al. (2010). Otherwise, evolutionary economics is deeply rooted in the Veblenian avenue of economic analysis that dealt originally with the interrelations of consumer behavior, social class and institutional change (Veblen 1899). Even though the latter research strand found continuous improvements (Tool 1977; Bush 1987; Gruchy 1990; Hodgson 1998), it did not develop a common analytical apparatus, nor has there been any proper application in a macroeconomic framework. Our contribution aims to close this research gap by highlighting Veblenian consumption dynamics in an agent-based macroeconomic model.

In this undertaking we basically follow the methodology of agent-based macroeconomics that received increased attention in the Great Recession. As argued by Stiglitz (2015), the design of macroeconomic theory has to change substantially in order to arrive at a meaningful economic policy. The idea to integrate complexity and heterogeneity into macroeconomics has been articulated at several occasions over the last ten years; see especially Tesfatsion and Judd (2006), LeBaron and Tesfatsion (2008), Farmer and Foley (2009), Delli Gatti et al. (2010), Kirman (2011), Stiglitz and Gallegati (2011) and Dosi (2012). Many have already followed this agenda and brought these claims to life in agent-based macroeconomic models; compare Dosi et al. (2010), Ciarli et al. (2010), Cincotti et al. (2010), Delli Gatti et al. (2011), Seppecher (2012), Lengnick (2013), Riccetti et al. (2013), Chen et al. (2014), Rengs and Wäckerle (2014, 2017) and Caiani et al. (2016) for the recent publication of a new benchmark model in this realm.

Evolutionary economists have started to develop their own theory of consumption within the last 15 years (compare Chai 2016), as illustrated by Witt (2001), Nelson and Consoli (2010), Chai and Moneta (2010), Valente (2012) and Kapeller et al. (2013). One of the first microeconomic models in this evolutionary direction was developed by Cowan et al. (1997) with a focus on bandwagon and snob effects in a heterogeneous population of consumers. Malerba et al. (2007) and Safarzyńska and van den Bergh (2010) provided a basic simulation model of the co-evolution of industries, technological innovation, niche markets and ‘experimental users’. The latter article already introduced a differentiation between a “snob” and a “network effect” in the social mediation of preferences. However, this line of research has never found integration into macroeconomic models, with the exception of Ciarli et al. (2010) and Lorentz et al. (2016). Technically speaking, we do not know much about the endogenous welfare effects of signaling-by-consuming effects. Elsewhere, macroeconomists have conducted similar welfare experiments following neoclassical (Fisher and Hof 2005; Wendner 2010) as well as post-Keynesian approaches (van Treeck and Sturn 2012; Kapeller and Schütz 2015). However, the latter approaches have only

limited explanatory potential for a deeper analysis of structuration processes at work, since they build on an aggregated representative agent model that has come under serious criticism for its explanatory limitations (Kirman 1992). To this extent, aggregated macroeconomic models face crucial limitations in addressing the interactive dynamics of imitating and innovating heterogeneous agents central to endogenous economic development (Veblen 1899; Schumpeter 1934).

Instead, we follow an evolutionary macroeconomic approach – considered as integral to the larger research program of evolutionary political economy (Hanappi and Scholz-Wäckerle 2017; Hanappi et al. 2017) – with endogenous consumer behavior dependent on social class. Economic agents are characterized as heterogeneous, diverse and boundedly rational. Their behavior depends on cognitive decision heuristics as well as on social norms and imitation. In this regard, we follow roughly a micro-meso-macro framework (Dopfer et al. 2004; Elsner 2007; Dopfer et al. 2016), highlighting the social mediation of consumer preferences as a meso foundation in a complex evolving macroeconomic system (Scholz-Wäckerle 2017). The approach of evolutionary macroeconomics was originally formulated by Foster (1987) and was revived quite recently by Verspagen (2002), Foster (2011), Dosi (2012) and Hanappi (2014). While Dosi et al. (2010) as well as Ciarli et al. (2010) do not explicitly refer to evolutionary macroeconomics, their models implicitly follow the elementary evolutionary blocks, as presented in Dosi (2012). The model presented in this article focuses on a Veblenian meso foundation and thereby contributes to evolutionary macroeconomics with a novel analysis of the dynamic implications of social distinction on the co-evolution of firm size, income/wealth distribution and macroeconomic aggregates such as unemployment and GDP growth. Computational simulation experiments indicate that a wide adoption of conspicuous consumption behavior in the household population drives the macroeconomic system into turmoil, leading to unsustainable unemployment as well as severe losses in aggregate demand. We also show the simultaneous microeconomic effects on firm specialization due to different consumption behavior.

The remainder of this article is organized as follows. The characteristics of the Veblenian meso foundation and the corresponding class dynamics are expressed in Section 2. The general structure of the agent-based macroeconomic model, the goods market, the labor market, the credit market as well as the government and the central bank are explained in Section 3. Section 4 discusses the computational simulation experiments and its results. Section 5 concludes.

2 Household behavior: the Veblenian meso foundation of the agent-based macroeconomic model

Veblen's (1899) 'Theory of the leisure class' provides a model of conspicuous consumption behavior with basic political economic origins where consumer preferences are a matter of social rank. In contrast to the Marxian model of social class based upon the conflict over the societal means of production and the further development of the productive forces (Marx 1867) – thereby reshaping the relations of production – Veblen's model focuses on leisure time and on

property-based status. ‘To own property is to have status and honor’ (Trigg 2001: 100). The noble leisure class consumes conspicuously and thereby aims to show its wealth in public, whereas the ignoble industrious class is always one step behind in emulating this behavior. As shown by Trigg (2001), this economic motive of ‘social distinction’ is not just bound to the American society of the nineteenth century. The sociologist Pierre Bourdieu empirically demonstrated that taste – conceived here as a consumer preference – is subject to social mediation and class fractions (Bourdieu 1984). To this extent, social distinction provides an illustrative example of cultural hegemony, a way for the ruling class to dominate the aesthetics of the working class. Consumer preferences represent cultural reflections of class conflict in capitalist societies and contribute to the social reproduction of economic inequality (Bourdieu 1998). Trigg (2001) explained that Thorstein Veblen considered this social emulation of consumer preferences simply as a trickle-down process, while Pierre Bourdieu pointed out that a trickle-around process was at work.

The model presented in Section 3 allows for the computational simulation of these features and therefore differs from other agent-based macroeconomic approaches in a number of ways, notably including distinct ownership (capitalist and working class) and consumption behavior following different norms. In addition, the model can generate the emergence of specialization patterns of firms reacting on variety in consumption. In particular, a firm can, for example, initially produce goods that mainly serve basic needs, and over time shift to serving wants. The demand elasticities for each individual firm’s goods are thus changing over time, resulting from shifts in the perception of individual households. This avoids the more common approach of starting with a fixed classification of firms or sectors with particular goods that permanently retain their character. Our approach is parsimonious (simplified) without sacrificing richness in explanatory power.

The meso foundation is described as dependent on agent networks and their dynamics. This causes consumption behavior to take the form of imitation (bandwagon effects) and signaling-by-consuming effects by different consumer classes. In the latter case, we consider Veblen effects (conspicuous consumption) and snob effects, both with a focus on luxury goods, where the first is about high price and the second about rare goods (Leibenstein 1950). Households do not optimize their consumption behavior (Valente 2012) but are instead assumed to be rather loyal, or rigid, in their choice of vendors, while also being open to new opportunities. Their decisions (namely, which firms’ products to buy) are linked to two different motivational aspirations: needs and wants (Witt 2001). The tendency to buy from a specific firm then depends on the respective aspiration, the current product’s relative price and the firm’s reputation. The latter two are based on well-documented consumer behaviors: bandwagon, Veblen and snob effects. The consumption decision differs with respect to social class, with capitalist households and wealthy workers having a higher saving rate than workers.

Households choose their sellers in a boundedly rational way, by having a shortlist of preferred ‘vendors’ at any given time (similar to Lengnick 2013). They try to buy equal amounts from each firm on their list, as firms’ stock and household budgets permit. Households actually employ two lists, one for needs

and one for wants. Initially, each of these lists consists of n randomly chosen firms. During the simulation, households change the composition of these lists based on their preferences, slowly improving them in each period (an artificial timespan which loosely represents a month). As preferences are assumed to be different for needs and wants, these two lists tend to contain different firms after some time. In the case of needs, households will replace a firm that could not deliver – because of insufficient production or inventory – by another, randomly chosen one. In the wants case, households do not immediately replace a firm that could not deliver, as wants involve goods that are highly sought after. Instead, they wait up to three periods before randomly choosing a new one.

If a seller (firm) is considered for potential replacement and is perceived to be better (by some small but noticeable degree) in terms of price and firm reputation (implying a utility premium for a household consuming that firm's good) than the one selected for potential elimination from the list, the replacement is effectuated. The rules employed in this comparison partially depend on prices and firm reputation (market shares) as well as on personal wealth, following the dynamics of imitation and signaling-by-consuming (conspicuous consumption à la Veblen 1899). Technically speaking, we assume that there are 'signaling-by-consuming' effects at work, i.e. '...households engage in consumption not only for intrinsic value but also for its value as a signal', following Heffetz (2011: 1101), who provides evidence in support of this household behavior.

In particular, Heffetz (2011), on the one hand, extends the typical neoclassical consumption model by introducing the 'visibility of a consumption good' that is determining the agent's elasticity to purchase it. On the other hand, he shows the empirical validity of this model with U.S. household data on the relation between 'expenditure visibility' and 'elasticity estimates', where '...the former can indeed predict the latter' (Heffetz 2011: 1102). Otherwise, the author adds, '...the evidence is limited to one country, at one point in time, with consumer expenditures divided into only 29 categories' (Heffetz 2011: 1117). However, we are confident that these results will be replicated for other countries once the data on consumption expenditure become more robust and can be analyzed in depth.¹ The resulting Engel curves – relations between total expenditures and expenditure for a particular good – for a changing consumption basket (Heffetz 2011: 1108–1109) provide first evidence why a certain commodity is purchased as a necessity (need) and the other as a luxury (want). To this extent, the empirical analysis exercised by Heffetz (2011) delivers empirical correlations for Engel's law: '...the poorer the family is, the larger the budget share it spends on nourishment' (Chai and Moneta 2010: 225). In the following, we take this analysis as empirical foundation for the social mediation of consumer preferences in our model, i.e. we explicitly model the observed 'signaling-by-consuming' in an agent-based way and then further specify it following different effects such as bandwagon, Veblen and snob.

In this context, we follow, on the one hand Veblen's general suggestion of trickle-down effects in social structure (Trigg 2001), due to working-class

¹ Compare recent work on the "Household Finance and Consumption Survey for the European Union" by Fessler et al. (2014) and Rehm et al. (2016).

consumers imitating capitalist-class consumers. On the other hand, we are inspired by Leibenstein (1950), who specified consumption dynamics as resembling a bandwagon effect (imitation of other consumers) and contrasted it to the signaling-by-consuming effect described by Thorstein Veblen (luxury consumption) and snob effect (consumption striving for rare goods – ‘exclusiveness’). We model Veblenian consumer dynamics in a similar manner as Kapeller and Schütz (2015) but with substantially more details on differences in quantity and price effects as well as about the underlying social dynamics. Additionally, we employ a snob effect that roughly represents Bourdieu’s (1984) model of trickle-around (Trigg 2001). Snob consumption is modeled as pure distinction, as the opposite to the bandwagon effect. This distinction is crucial for our setting, because it avoids potential lock-ins in market dynamics. Due to this effect, even already established firms may crash after many years and allow for a complete restructuring of the economy.

‘Any real market for semi durable or durable goods will most likely contain consumers that are subject to one or a combination of the effects discussed heretofore.’ Leibenstein (1950: 205) concludes that there are four possible combinations, dependent on price (normal price and Veblen effect) and firm reputation (bandwagon and snob effect). We extend his framework by including needs and wants aspirations as well as social class. This leads us to combinations of aspiration (wants and needs) and social class (workers, wealthy workers, capitalists); compare Fig. 1.

Wright (2015) distinguishes between three different modes of class analysis: Marxian, Weberian and stratification class analysis. The Marxian class analysis associates classes with its ‘systemic level of power’ and the ‘locations within the relations of domination and exploitation in production’ (Wright 2015: 13); it links it to the ‘conflict over production’. The Weberian class analysis focuses on the institutional level of power and locates it in the ‘conflict over distribution’. Eventually, the stratification mode of class analysis highlights the ‘situational level of power’ and indicates class as ‘...how to best realize interests under fixed

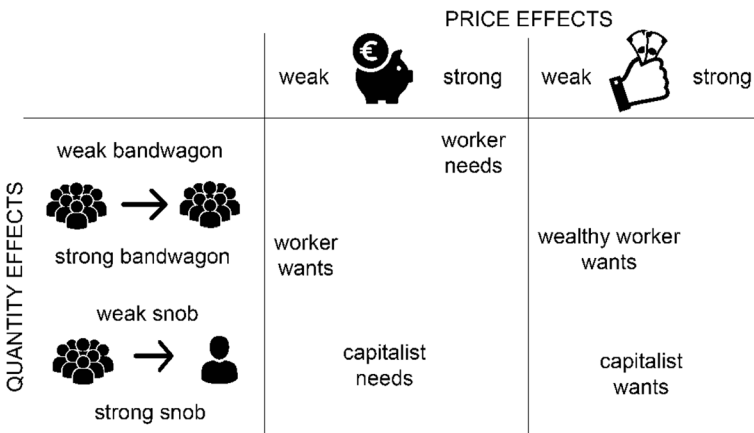


Fig. 1 Signaling-by-consuming effects dependent on social class

rules'. Wright (2015: x). The latter approach obviously works at the individual level and it would literally allow an infinite number of social classes. The Veblenian and Bourdieusian system of social class fits perfectly into this situational approach. The Weberian system addresses what Wright (2015: 6) calls 'opportunity hoarding' and is related to the meritocratic society that creates social closure via skills, education or other criteria of job exclusion. This model of social class is represented in the agent-based macroeconomic model of Ciarli et al. (2010) and Lorentz et al. (2016: 225), where 'firms are composed of distinct hierarchies of labor'. The consumer preferences differ with regard to these job levels, but are not socially mediated. The model we present here explicitly implements ownership and is thereby able to address conflicts over production as well. In particular, we implement a mixture of Marxian classes and Veblenian social stratification. McIntyre (1992: 43) emphasizes that 'Marx understood the social construction of needs in a manner that partly anticipates Veblen. ... Marx argues that conspicuous consumption can convince financiers of the likelihood of loans being repaid, giving capitalists access to more credit, or credit on better terms'. Eventually, our model features basic material as well as cultural properties of consumption in capitalist production systems (Fine 2002). Capitalists gain individual dividends from firm profits and workers gain income from wages. In our model, we do not distinguish workers by skill or education and job level, but by income and wealth; hence we feature a middle class representing wealthy workers.

Changes within social class are endogenously possible (capitalists may go bankrupt with their firm, wealthy workers may found a firm, etc.), which will not be recognized by the society immediately, meaning, in particular, that if there is a change in social class, it happens with a lag (set at three months). Workers, wealthy workers and capitalists have different preferences and behaviors, as highlighted in Fig. 1. Worker consumption has a high normal price effect (indicating a strong preference for the cheap over the expensive) and a low bandwagon effect. Workers imitate the behavior of all needs consumers. Worker want aspirations have a low normal price effect (indicating a weak preference for the cheap over the expensive) and a high bandwagon effect (they imitate the capitalist wants aspirations), while wealthy workers follow the same bandwagon and consume showing a weak Veblen effect (i.e. they weakly prefer the expensive over the cheap).

Finally, capitalist (firm and bank owners') needs are triggered partially by a snob effect (searching for rare goods – inverted imitation) and partially by a normal price effect. Capitalist wants work with the same partial snob effect but additionally with a Veblen effect (they prefer the expensive over the cheap). Consumption behavior is thus not static but a co-evolving process between behaviors of consumers and the social structure.

As indicated before, our model households employ shortlists of preferred firms for each consumption case. These lists are updated every period by considering a random firm, not yet part of the shortlist, and comparing the utility of purchasing from this specific firm with that of purchasing from a random firm on the shortlist. This evaluation follows the behavioral modes (as described above and sketched in Fig. 1) and thus differs for the household social class and consumption aspiration.

As an exemplary case for how the utility is derived for the worker needs in period t , see the following equations:

$$b_{1,i,t} = \left(\frac{p_{max,t} - p_{i,t}}{p_{max,t} - p_{min,t}} \right) \quad (1)$$

$$b_{2,j,t} = \left(\frac{m_{max,t} - m_{j,t}}{m_{max,t} - m_{min,t}} \right) \quad (2)$$

$$b_{3,i,t} = \left(\frac{v_{i,t} - v_{min,t}}{v_{max,t} - v_{min,t}} \right) \quad (3)$$

$$U_{i,j,t} = b_{1,i,t} b_{2,j,t} \xi + b_{3,i,t} (1 - \xi) \quad (4)$$

where i denotes a firm, j denotes the household and t the time period. Now $b_{1,i,t}$ represents the firm's normalized relative price in comparison to the prices of all other firms and $b_{2,j,t}$ represents the household's normalized relative wealth in relation to all other households. Furthermore, $b_{3,i,t}$ represents the firm's normalized reputation, while v is calculated from past sales; in this exemplary case of worker needs, it directly corresponds to firms' market shares to reflect the bandwagon effect. Finally, the utility $U_{i,j,t}$ is derived by weighting the price component $b_{1,i,t}$ with the relative wealth $b_{2,j,t}$ and the parameter ξ , then by adding the firm's reputation and weighting it with $(1 - \xi)$. By choosing ξ in a meaningful way ($\xi = 0.75$ in our simulations), we arrive at a combined utility, which makes households in the worker needs case strongly prefer cheaper firms (which is less important for wealthier households) and at the same time less strongly prefer relatively successful firms. The remaining four cases of worker wants, wealthy worker wants, capitalist needs and wants are defined similarly; compare Appendix 3.

3 The general structure of the agent-based macroeconomic model

In our model, agents are heterogeneous and endogenously adapt their behavior in terms of bounded rationality (Simon 1996: 38; 166), following satisficing rules (Simon 1996: 27–30). The model does not contain any aggregate exogenous (re)distribution function from top down, i.e. the markets are self-organizing systems and thus interdependently develop from the bottom up. The basic object categories and their relations are shown in Fig. 2.

Firms and households interact on goods and labor markets. Firms produce and sell a homogeneous good – representing a fictitious basket of diverse goods – to

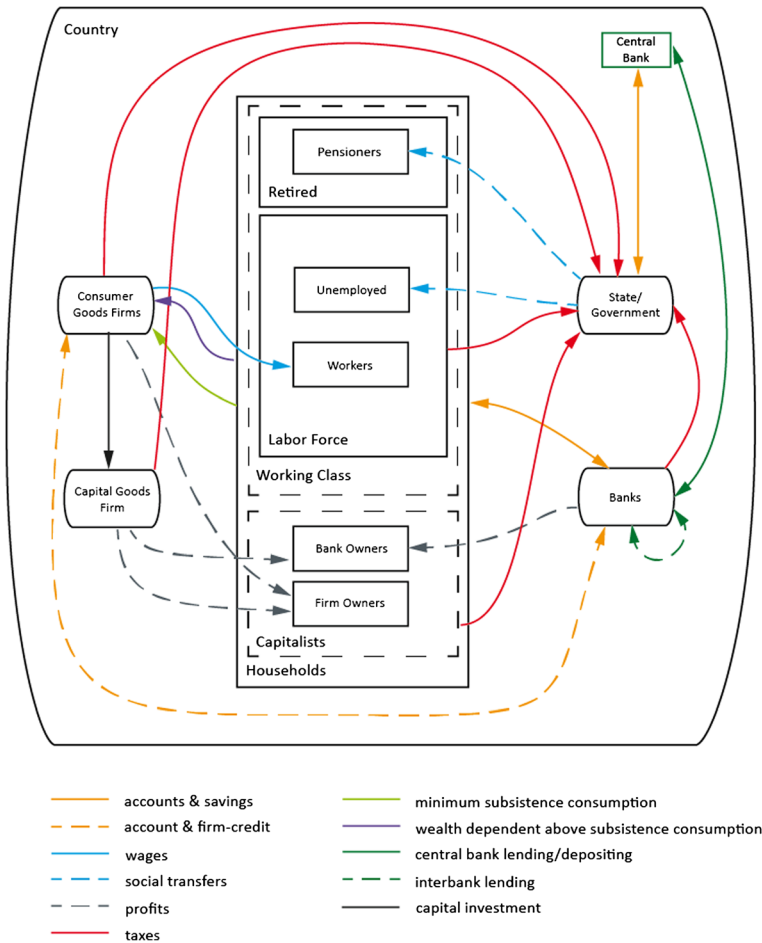


Fig. 2 General structure of the agent-based macroeconomic model

households. The good is produced with the same production inputs (physical capital and labor), but may differ with regard to branding and price from firm to firm. All households have to satisfy their basic needs in every period and thus always try to buy the minimum amount for subsistence consumption (while trying to keep a reserve worth one period of subsistence consumption). However, households can demonstrate their wealth in conspicuous terms and buy additional quantities above subsistence level (wants). Capitalist households do so in self-organization, determining which firm sells the same good in a conspicuous way, because worker households seek to imitate and follow this call for reputation by a given weighting, as explained in the previous section.

Firms and banks interact on a simplified credit market, and banks interact with the central bank. The state (government) collects taxes and uses them to finance social transfers to pensioners and unemployed households. Government surpluses are equally redistributed in the economy. As a very crude proxy to government bonds we assume that banks and households finance the sovereign debt that exceeds available funds.

3.1 Firms: consumer and capital goods production

We distinguish between two types of firms: producing capital goods and consumer goods. In the simulation experiments presented in Section 4, a single capital goods producing firm provides all consumer goods firms with machines and equipment, i.e. the physical capital input for production. We maintain stock-flow consistency since capital goods profits made on behalf of consumer goods producers' investments are redistributed equally among capitalists in the economy. We simply assume that investment goods are owned and thereby controlled collectively by the capitalist class.

Each consumer goods firm has only one private owner, who is the sole receiver of the firm's profits. We choose this contrary to other published mechanisms, such as dispersing profits to the whole population in relation to their wealth, as a proxy for shares; see Dosi et al. (2010), Cincotti et al. (2010) or Lengnick (2013). The latter, more aggregate and distributive, approach also leads to the rich getting richer but ignores the possibility of individual failure – i.e. rich households can never make a bad investment and thus go bankrupt more seldom than they should. We regard this mechanism as highly problematic given the huge impact that extreme developments of single agents can have in complex and highly interconnected adaptive systems.²

We assume that consumer goods firms are on a market with boundedly rational buyers who show satisficing rather than optimizing behavior, which on the household side has different implications for needs and wants, as previously elaborated in detail in Section 2. Firms initially determine the price on the basis of their costs, adding some individual random markup – as empirically shown by Fabiani et al. (2006) for the Euro area – while adapting price and output during the regular simulation solely based on changes in consumer demand. There is no such mechanism in mainstream macroeconomic theory; compared to traditional microeconomics, this assumption can be associated with basic market power – in our case, we would interpret the boundedly rational behavior in conjunction with a preference to buy locally, leading to a market form with monopolistic competition. Usually publications of macroeconomic ABMs avoid mentioning specific market forms, instead stating that the interaction on markets should be empirically micro-founded (Dosi et al. 2013), arguing that adding markup to costs is absolute common practice in most real firms; see, e.g. Fabiani et al. (2006). Lengnick (2013) stresses the argument even further that there is no market form in the traditional microeconomic sense, only the result of endogenous interactions of agents, which one could call a market.

Consumer goods firms use a simple short-run adaption strategy to determine required production and pricing, which is based on the assumption that overall demand might shift due to changes in consumer behavior, but that huge deviations from previous prices are too risky. Preliminary simulation experiments have shown that the influence of consumer behavior leads to much more stable economies when assuming that firms' production schedules are directly determined by expectations about sales rather than assuming only slight adaptations of previous

² Compare Lengnick (2013) who devoted a whole section to the consequences of a small individual shock.

production schedules based on previous sales. Thus, firms expect to sell as much as in the last period ($q_{i,t-1}^s$) but factor in excess demand ($q_{i,t-1}^{ed}$).

$$q_{i,t}^e = q_{i,t-1}^s + q_{i,t-1}^{ed} \tag{5}$$

Nevertheless, in the spirit of Godley and Lavoie (2012), each firm i 's target is to keep their inventory after sales (unsold goods) ($q_{i,t-1}^{ps}$) at the end of a period at an optimal reserve level ($q_{i,t-1}^{opt}$), proportional to the amount of goods previously produced ($q_{i,t-1}^{pp}$), as they are prepared that actual sales might deviate from their expectations, assuming that the firms all aim at the same constant proportion of the previous stock (parameter α_1):

$$q_{i,t-1}^{opt} = \frac{q_{i,t-1}^{pp} \alpha_1}{1 + \alpha_1} \tag{6}$$

Firms try to meet this level by, on the one hand, directly adjusting production and, on the other hand, consider slightly adapting prices. Produced goods can be sold in the same period as they are produced (firms produce and sell goods directly to consumers). Overproduction (unsold stock) is stored until the next period but depreciates. The intended production amount ($q_{i,t}'$) then factors in the expected sales in t ($q_{i,t}^e$), minding the desired reserve ratio after sales (α_1), the intended reserve stock as well as the depreciation of unsold goods. As $q_{i,t}^{ps}$ represents the amount of goods left after sales to households and parameter δ_1 represents the depreciation rate, we get:

$$q_{i,t}' = q_{i,t}^e(1 + \alpha_1) - q_{i,t}^{ps}(1 - \delta_1) \tag{7}$$

Thus, in the unique case that there are more goods in the reserve inventory than expected sales, the firm would even choose not to produce anything in this period.

Independently of the planned production schedule, firms base their prices on the previous period's price ($p_{i,t-1}$) and consider changing the price by a fraction of a simulation-specific maximum amount (p_b), which is based on the average initial price over all firms in $t=0$ ($p_{i_0}^m$).

$$p_b = p_{i_0}^m \alpha_2 \tag{8}$$

The price change depends on the parameter α_2 therefore, which is chosen rather small, assuming that firms will not increase or decrease the price strongly in one period, and on the deviation from the intended reserve stock ($q_{i,t}^{opt}$). If sales are much lower than expected ($q_{i,t-1}^{ps} > 2q_{i,t}^{opt}$), then the price is decreased strongly:

$$p_{i,t}' = p_{i,t-1} - (1 + \alpha_3)p_b \tag{9a}$$

If sales were noticeably lower than expected ($q_{i,t-1}^{opt}(1 + \alpha_4) < q_{i,t-1}^{ps} \leq 2q_{i,t}^{opt}$), then the price is decreased in relation to the deviation from the planned reserves:

$$p'_{i,t} = p_{i,t-1} - \frac{q_{i,t-1}^{ps} - q_{i,t-1}^{opt}}{q_{i,t-1}^{opt}} p_b \tag{9b}$$

If sales are roughly as expected, ($\frac{q_{i,t-1}^{opt}}{1 + \alpha_4} \leq q_{i,t-1}^{ps} \leq q_{i,t-1}^{opt}(1 + \alpha_3)$), then the old price is retained:

$$p'_{i,t} = p_{i,t-1} \tag{9c}$$

If sales are noticeably higher than expected ($0 < q_{i,t-1}^{ps} < \frac{q_{i,t-1}^{opt}}{1 + \alpha_4}$), then the price is increased in relation to the deviation from the planned reserves:

$$p'_{i,t} = p_{i,t-1} + \frac{q_{i,t}^{opt} - q_{i,t-1}^{ps}}{q_{i,t}^{opt}} p_b \tag{9d}$$

Finally, if sales are much higher than expected and there are no reserves left ($q_{i,t-1}^{ps} = 0$), then the price is increased strongly:

$$p'_{i,t} = p_{i,t-1} + (1 + \alpha_3)p_b \tag{9e}$$

The per-unit production costs ($AC_{i,t}$) serve as the lower limit of the new price.

$$p_{i,t} = \max\left(AC_{i,t}, p'_{i,t}\right) \tag{10}$$

Finally, the new price ($p'_{i,t}$) only becomes effective with a given probability ($X_1 > \theta_1$ with $X_1 \sim U(0, 1)$) to cope for the fact that firms do not change prices that often. Otherwise the old price ($p_{i,t-1}$) will be retained.

Consumer goods firms need physical capital (machines and equipment ($x_{i,t}^c$)) and labor ($x_{i,t}^l$) as input factors for the production of goods. As previously indicated, firms buy capital goods (i.e. physical capital in our model) from the capital goods firm. We employ a simple linear, transformative production function at the firm level which uses a simple capital intensity coefficient (α_6). Furthermore, the production function features an associated heterogeneous production-technology coefficient per firm ($a_{i,t}$) that was assumed to be constant ($a_{i,t} = \alpha_5$) for the performed simulation experiments presented in Section 4.

$$q_{i,t} = a_{i,t} \min\left(x_{i,t}^c \alpha_6, x_{i,t}^l\right) \tag{11}$$

After determining the intended production output as indicated, each firm i controls for the required production inputs in order to produce ($q'_{i,t}$), starting with labor input ($x'_{i,t}$):

$$x'_{i,t} = \frac{q'_{i,t}}{a_{i,t}} \tag{12}$$

If firm i has not employed enough workers for the planned production schedule in the last period ($li'_{i,t} > li_{i,t-1}$), then it scans the labor market for the current number of unemployed (UN_{t^*}). t^* indicates the point of time within the period t where a decision is made in random order. If the number of potential new employees is sufficient to realize its production plan, i.e. if $UN_{t^*} \geq (x'_{i,t} - x_{i,t-1})$, then the production schedule remains unchanged ($q'_{i,t} = q_{i,t}$). If it is not sufficient, then firm i reduces the planned production output ($q'_{i,t}$) to the highest possible quantity ($q'_{i,t}$), given the actual number of unemployed the firm is able to hire. Eventually it controls for the required physical capital input ($x'_{i,t}$):

$$x'_{i,t} = \frac{q_{i,t}}{a_{i,t}} \tag{13}$$

If firm i is confronted with less available physical capital than required ($x^c_{i,t-1} < x'_{i,t}$), then it seeks to reinvest. Firms finance investments into physical capital by means of loans, as assumed in the initial setup of the simulation. They obtain further loans as long as their expected short-term profitability remains high enough and their expected debt low enough. Thus, commercial banks will not grant additional credit to firms if the debt exceeds the bankable collateral, in order to limit their risk. To this effect, the aggregate loan volume so far (with o indicating the period in which the loan was granted and b indicating the respective bank) plus the newly requested loan amount ($cr'_{i,t,b}$) may not exceed the current value of their physical capital after investing. As the value of physical capital regularly depreciates (each year by a fixed percentage), the current value has to be calculated with $w_{i,t}$ representing the mean value of firm i 's machines and c^c_t being the price of one machine in t . Furthermore, as there is much uncertainty associated with the future performance of the firm and the consumer goods market in general, banks will only lend up to a fraction of this sum, which is obtained by factoring in a bank-specific risk aversion disposition (ra_b). The latter is identical ($ra_b = \phi_1$ for all banks b) for the simulation experiments explained in Section 4. Ergo, the first firm loan condition has to hold:

$$\sum cr_{i,o,b} + cr'_{i,t,b} \leq (x^c_{i,t-1} w_{i,t} + (x'_{i,t} - x^c_{i,t-1}) c^c_t) ra_b \tag{14}$$

Furthermore, banks will not grant more credit to firms if their estimated expected profit rate is lower than the bank's interest rate on firm loans ($i^c_{b,t}$), so the second firm loan condition has to hold additionally:

$$r_{i,t} \geq i^c_{b,t} \tag{15}$$

The expected profit rate is based on last period's revenues and total costs per period ($TC_{i,t-1}$). Thus banks are more risk-averse than firms and assume that

sales will remain constant ($q_{i,t-1}^s$), while factoring in the additional costs for new loans plus additional staff ($\Delta TC_{i,t}$).

$$r_{i,t}^e = \frac{12 \left(\left(q_{i,t-1}^s p_{i,t} \right) - (TC_{i,t-1} + \Delta TC_{i,t}) \right)}{x_{i,t}^c w_{i,t}} \quad (16)$$

Firms now apply for the biggest loan $cr'_{i,t,b} \leq (x_{i,t}^d - x_{i,t-1}^c) c_t^c$ that is not violating the two firm loan conditions set by the bank. Consequently, this notion might even result in not applying for additional credit. Firms use this credit to buy additional physical capital from the capital goods firm and thus arrive at a new level ($x_{i,t}^c$). Finally, firm i determines the highest possible production output ($q_{i,t} \leq q_{i,t}^p$), and derives the corresponding required labor input ($x_{i,t}^l$). As the job market is highly abstracted in this model, if firms need to hire additional workers (if $x_{i,t}^l > x_{i,t-1}^l$), the required number of households is randomly drawn from the number of unemployed households and employed at the respective firm. If the firm has not received any additional loan to finance the necessary physical capital or if it faces decreasing demand, labor input is reduced by firing random workers from its staff. Otherwise, workers are employed with a legal protection period (see Sepecher 2012 for an actual ABM that includes a labor market with legal protection periods), as wages have to be paid two more months, thus decreasing the effective production capacity.

If the situation worsens, and a firm's expected profit rate ($r_{i,t}^e$) is no longer positive while at the same time its net liabilities exceed a multiple of its bankable collateral, it goes bankrupt. As a consequence, the firm is foreclosed on, it leaves the market, its customer relations are dissolved and the remaining assets plus remaining loans are transferred to the bank where the firm had open credit liabilities. In addition, if the firm defaults, the capitalist household transforms into a worker agent but keeps its previous private account.

Workers in the same firm get the same wage, which may differ between companies, but there is a countrywide minimum wage that has to be obeyed. At the end of each year, firms with positive profits increase wages based on the increase of consumer prices, whereas firms without or with negative profits keep wages constant, i.e. wages are downward rigid.

At the end of a fiscal year, all firms calculate their profits, pay corporate taxes to the government/state and distribute a large part of profits (after taxes) to the firm's owner, while the rest remains with the firm to cover future operational costs (if positive profits existed).

3.2 Households

Additionally to the Veblenian meso foundation, explained in Section 2, households employ the following characteristics. In line with Lengnick (2013), wealthier households are inclined to consume less of their disposable income. Presupposing class-specific behavior, we assume (as a simplification) that workers

tend to consume a large share of their income (β_1), wealthy workers tend to consume a slightly smaller share (β_2), while finally capitalists tend to consume an even smaller share again than the wealthy workers (β_3). The disposable income ($m_{j,t}^a$) for workers is their monthly wage, whereas, for capitalists, we assume a fictitious income equal to one-twelfth of last year's dividends. Furthermore, we assume that households with positive savings of all classes set aside a very small share of their savings for additional consumption ($m_{j,t}^s \gamma_1$). Thus, depending on their class-specific consumption share (β_c , that is $\beta_1, \beta_2, \beta_3$, respectively), households set their intended savings ($s_{j,t}^e$) and consumption ($c_{j,t}^e$) to:

$$s_{j,t}^e = m_{j,t}^a (1 - \beta_c) \tag{17}$$

$$c_{j,t}^e = m_{j,t}^a - s_{j,t}^e + m_{j,t}^s \gamma_1 \tag{18}$$

As prices and stock vary between vendors, these are the ex-ante decisions of the household before consumption. The actual consumption therefore depends on the respective prices and available stock of goods of each firm on household j 's preference list in t :

$$c_{j,t}^{needs} = \sum_{k=1}^n p_{k,t} q_{k,t}^{needs} \tag{19}$$

Each household j tries to buy equal quantities ($q_{k,t}^{needs}$) from each firm k on its preference list as long as that firm is not yet out of stock ($n \leq \gamma_1$). In the special case that household j 's total wealth in t ($m_{j,t}$) is negative, i.e. when the household has no savings left ($m_{j,t}^s = 0$) and the bank account is empty or overdrawn ($m_{j,t}^a \leq 0$), which is the only form of household debt in the model, it is regarded as bankrupt. Households of all classes may in this case only satisfy their needs by minimal subsistence consumption (a fixed amount of goods purchased on overdraft) from their preferred vendors on the respective shortlist (as explained in Section 2), i.e. $c_{j,t} = c_{j,t}^{needs}$. In this context we refer only to the bankruptcy of household agents. Since the account of the capitalist household is listed separately from the firm's account, we need to distinguish between firm and household bankruptcy. Households that are not bankrupt try to satisfy their wants by buying from their preferred vendors on the respective shortlist until the remainder of their consumption budget (which was left after satisfying their needs) is spent or until their preferred vendors are outsold. To avoid unrealistic goods allocation situations, we split each period's consumption 'phase' in multiple simulation phases (as can be seen in Appendix 1), where, in a first phase, all households satisfy their needs ($c_{j,t}^{needs}$). The remainder of household j 's budget set aside for consumption left after this first phase is then available to satisfy their wants:

$$c_{j,t}^{wants,e} = c_{j,t}^e - c_{j,t}^{needs} \tag{20}$$

Thus, all households that still have some consumption budget left after satisfaction of their needs ($c_{j,t}^{wants,e} > 0$), enter a second phase, in which capitalist households may satisfy their wants first and worker households may satisfy their wants afterwards. Inside these phases and thus within classes, order is random. Similarly, households now try to buy the same quantity from all vendors on their respective preference lists, but have to obey a budget restriction ($c_{j,t}^{wants,e}$). They thus again pay different prices for goods of each vendor.³ As a result, actual want ($c_{j,t}^{wants}$) and finally total consumption ($c_{j,t}$) may be smaller than the originally intended consumption (i.e. $c_{j,t} \leq c_{j,t}^e$), where:

$$c_{j,t} = c_{j,t}^{needs} + c_{j,t}^{wants} \quad (21)$$

After the consumption phase, all households evaluate their preferred vendor lists as elaborated in Section 2, seeking to find firms that better match their preferences, which is a co-evolving process.

That part of household j 's income that was not set aside for consumption in t , i.e. intended savings ($s_{j,t}^e$), or could not be spent on consumption for whatever reason is transferred from the bank account ($m_{j,t}^a$) to the household's savings account ($m_{j,t}^s$), with:

$$s_{j,t} = s_{j,t}^e + c_{j,t}^e - c_{j,t} \quad (22)$$

With a low probability, which increases for a quarter of a year after a firm has gone bankrupt, a wealthy worker household may found a new firm of a given small initial size. The firm will only be founded if there are still enough unemployed workers available on the labor market. The wealthy worker who turned into a capitalist will then invest and thus transfer money to the newly founded firm, to the amount that equals the cost of the physical capital as well as operating cost for a given number of periods. In case the household does not have enough savings to cover these founding costs, as a simplification the bank will implicitly lend the money to the household (private debt) by allowing it to overdraw its bank account. The new firm will initially pay a wage equivalent to the average of all wages paid by firms in that period. Banks are assumed to act carefully rather than with greed regarding the granting of additional credit. As a consequence, newly founded firms can only grow slowly at best, as they would then have more credit than bankable collateral (i.e. physical capital).

3.3 Government and the state

The government assumes various roles in the model. It makes transfers to unemployed and retired households, and collects taxes on labor, income and capital gains, corporate profits made by banks and firms and by the capital goods firm, and value-added of sales. The government budget in the model is never in perfect balance because of uncertainty about both tax revenues and government expenditures – just as in reality. As unemployment benefits and pensions are downward rigid, the government has no means to cut costs and has to begin deficit spending if necessary. If indebted, it pays interest to banks and

³ In the simulation, this is achieved by consecutively buying small amounts from each vendor until the budget left for the satisfaction of needs ($c_{j,t}^{wants,e}$) is used up or the vendors on the list are outsold.

households (in relation to their wealth) as a proxy for government bonds. As a simplification, the government redistributes surpluses equally in the economy after every fiscal year.

3.4 The monetary sector: central bank and commercial banks

The central bank is lender of last resort for banks, and furthermore it provides commercial bank services for states as a minor secondary/tertiary function. The central bank keeps current accounts for the government (including overdraft functionality) and banks, as well as deposit facilities for banks, involving the paying or charging of interest. Banks keep current accounts for firms, the capital goods firm (which has equally sized accounts with every bank as not to distort the banking system) and households (allowing for deficits), as well as separate savings accounts for households. In addition, they grant firm loans as described in section 3.1, whereas households cannot apply for loans in a regular way, as described in section 3.2. They pay and charge interest for these different financial services applying distinct rates, limited by central bank interest rates. Banks have to refinance themselves by monitoring assets (loans) and liabilities (savings). If banks lack liquidity, they request loans at the central bank. Regular money is stored in bank accounts (which can – under specific conditions – also be overdrawn, i.e. be negative) or in savings accounts (households). At the end of a fiscal period, banks calculate their profits, pay corporate taxes to the government/state and transfer a large part of profits (after taxes) to the bank's owner.

4 Computational simulation experiments and results

In the following we choose a number of very different but highly artificial combinations of household consumption behavior to demonstrate the endogenous self-organized structuration of firm populations and corresponding macroeconomic outcomes. In order to show the implications of the co-evolutionary dynamics in this agent-based macroeconomic model,⁴ we have experimented with various configurations of consumption behavior, in particular effecting the households' replacement rules for needs as well as wants.

4.1 Simulation experiments and scenarios

4.1.1 Scenario CB1

Scenario CB1 is characterized – in Veblen's terminology – by the instrumental proclivities of the industrial society.⁵ In this scenario, we simply assume that all agents consume according to the consumption behavior of 'worker needs', i.e. the needs and wants replacement rules for the individual agent's list of local firms follows Eqs. (1),

⁴ See Appendix 2 for technical details of the computational simulation.

⁵ Compare Tool (1977) for an introduction into Veblen's conception of two different institutional systems in the industrial society, "...they are institutions of acquisition or of production...they are pecuniary or industrial institutions..." (Tool 1977: 827) Instrumental proclivities are associated with the instinct of workmanship that characterizes, e.g., the engineer and the common production of goods. Otherwise, we find pecuniary proclivities associated with the business enterprise and the leisure class. The latter tend to crowd out the former in capitalist societies, a central thesis in Veblen's work.

(2), (3) and (4). Thus, all households consume only on behalf of a strong normal price effect and a weak bandwagon quantity effect.

4.1.2 Scenario CB2

Scenario CB2 follows the same assumptions as CB1 but introduces a stronger social mediation for wants. In this scenario, all households of all classes again replace their individual firms' preferences lists for needs as well as wants by Eqs. (1), (2), (3) and (4). Contrary to scenario CB1, all households now discern needs and wants consumption by assuming a stronger bandwagon effect for the latter ($\xi = 0.25$). Imitation of wants consumption thus affects the whole population of households.

4.1.3 Scenario CB3

Scenario CB3 introduces a distinct consumption behavior of capitalists to CB1, i.e. capitalists replace their firms' preferences lists concerning wants consumption with emphasis to snob-guided signaling-by-consuming. Capitalists replace their individual firm lists in both the needs and the wants case with regard to the snob effect, but follow a normal price effect. In this scenario, social distinction (Bourdieu 1984) dominates the capitalist consumers concerning their wants, i.e. they aim to buy at rare firms and thus act against the logic of bandwagon. Specifically, trickle-around effects (Trigg 2001) are at work here since the snob effect may drive capitalist households to firms that have previously been sought by workers.

4.1.4 Scenario CB4

Scenario CB4 represents a similar experiment as CB3 but with emphasis on signaling-by-consuming just via the Veblen effect, while not acting on behalf of the snob effect. In particular, capitalists aim to buy more expensive goods to satisfy their wants. This scenario represents the Veblenian meso foundation of the social mediation of preferences (Veblen 1899) at best, where snob effects are not at work and social mediation works just via trickle-down imitation (Trigg 2001). This scenario comes closest to the one used by Kapeller and Schütz (2015) in their aggregated model.

4.1.5 Scenario CB5

Scenario CB5 substantiates Veblen's dystopian vision of a society that has already crowded out the instrumental proclivities and conspicuous consumption dominates in the population. All households of all classes replace their firms' preferences lists for needs and wants as assumed for the capitalist needs and wants case; compare Fig. 1. In this scenario, neither bandwagon nor normal price effects are active any longer. Households aim to follow solely snob (quantity) and Veblen (price) effects.

4.1.6 Scenario CB6

Eventually, scenario CB6 is to be considered as the most likely scenario for Western industrialized societies, as illustrated in Fig. 1. We assume all four modeled consumer

behaviors are performed in this scenario, according to Leibenstein (1950). Workers imitate capitalists with regard to their wants, while wealthy workers follow a weak Veblen effect. Capitalists aim to act snobby in context of needs as well as wants but give emphasis to conspicuous consumption in the wants case only. This scenario combines all the mechanisms introduced in Section 2.⁶

4.2 Discussion of results

The data set generated via the previously described simulation experiments is characterized by a high degree of complexity that we aim to analyze in our following discussion of results. The simulation features high-granular ‘monthly’ data over 360 periods for a number of aggregated measures. Those figures that show micro data contain the results of all 30 repetitions for each scenario. A number of figures show annual numbers, which are averages over annual aggregates of each scenario’s repetitions.

In our model, we have highlighted the role of consumption and class in an evolving macroeconomic complex system. Social class was assumed – in line with Wright (2015) – as a result of conflict over production, on the one hand, and the expression of the situational level of power – ‘how to best realize interests under fixed rules’ – on the other hand. Figure 3a and b show the evolution of the Lorenz curve that is, first of all, characterized by a kink separating working from capitalist class as a function of ownership over the means of production. As we assumed a simple governmental social transfer mechanism in this experiment, which redistributes potential budget surpluses equally, it is to be expected that the distribution of wealth will become more equal over time under optimal economic conditions. Figure 3a shows that scenario CB5 leads to a less equal distribution of wealth over time, as unemployment reaches levels where considerable numbers of worker households are effectively bankrupt, as the level of unemployment benefits is less often increased than wages. Prolonged periods of high unemployment in CB5 eventually lead to the government budget going into deficit. Fig. 3b, on the other hand, shows that income, which is the sum of wages and capital gains per household, does not change that strongly after the initial phase and that scenario CB5 leads to income being more equally distributed than in the other scenarios (compare Fig. 4). The main reason for this starkly different development of CB5 is that there are not any regular price effects. Initially, the excess demand for the goods of individual firms lead to high prices and to more frequent increases in prices than in wages – as the former can change monthly and the latter is settled annually. Correspondingly, this effect decreases wants consumption, as an increasing share of the wages has to be paid for needs consumption. In consequence, we are dealing with excess labor capacities in the short run. Although these would even out in the long run, some households become unemployed and further reduce their demand before they would receive a wage increase (due to the cumulated increase in prices) countering the effect. The different speeds of adaptation – that our model centrally features – lead to lags and thus imperfections across the

⁶ Compare Appendix 3 for the analytical specifications of individual updating rules for signaling-by-consuming effects.

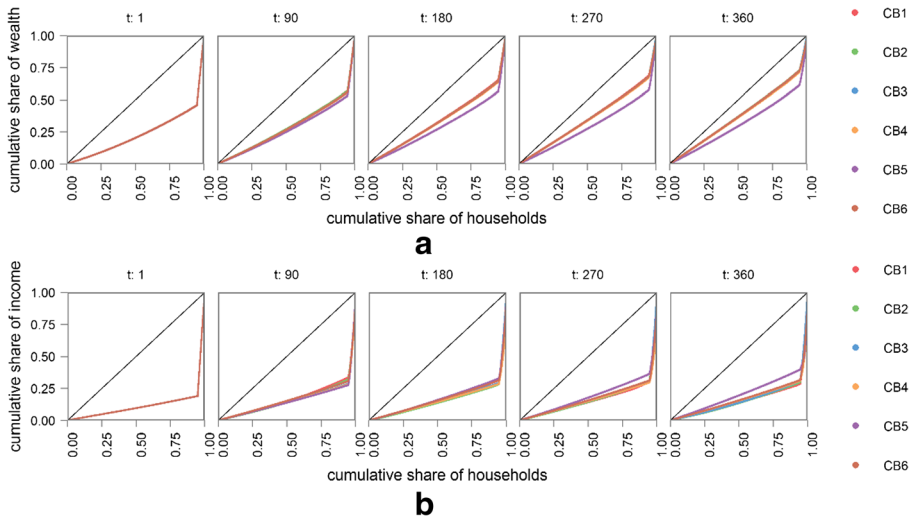


Fig. 3 **a** Evolution of the Lorenz curve – wealth. **b** Evolution of the Lorenz curve – income.

markets (goods, labor and credit). In addition, some firms go bankrupt and as all households show the same behavioral inclinations in CB5, their demand focuses on fewer firms, which, are unable to grow quickly enough – no Cobb-Douglas adaptation of input factors – to deal with the excess demand. Eventually, these effects lead scenario CB5 into stagflation until the economy stabilizes at higher nominal price and wage levels (compare Figs. 7, 8 and 9).

Social class conditions particular patterns of consumption behavior that otherwise influences firm specialization. Figure 5 illustrates micro data from the conducted experiments – including all repetitions – for relative price in relation to each firm's share of needs consumption. It especially highlights the different effects stemming from the meso foundation with regard to snob (CB3) as well as Veblen (CB4) consumption in the capitalist class on firm evolution. The resulting dynamics indicate, that, in general a high relative price corresponds to a low needs share in consumption. That said, we otherwise observe a high wants share if relative prices are high, with exception of scenario CB5, where households purchase needs in a conspicuous fashion as well. The specifications of CB5 undermine firm specialization and hence the emergence of a deeper structure in the industry. This conclusion is also true for CB1, where households follow just the normal price effect and a rather weak bandwagon effect. By contrast CB6 leads to the emergence of such a deeper structure in the industry and resembles a

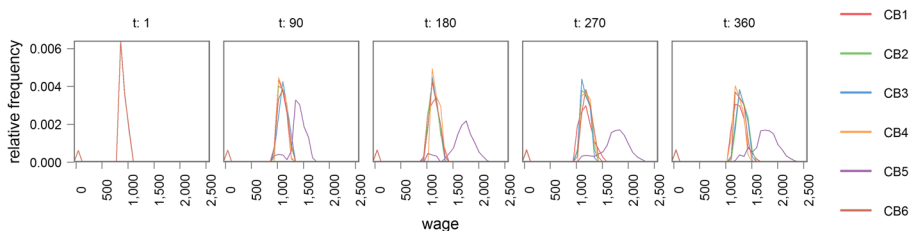


Fig. 4 Distribution of wages

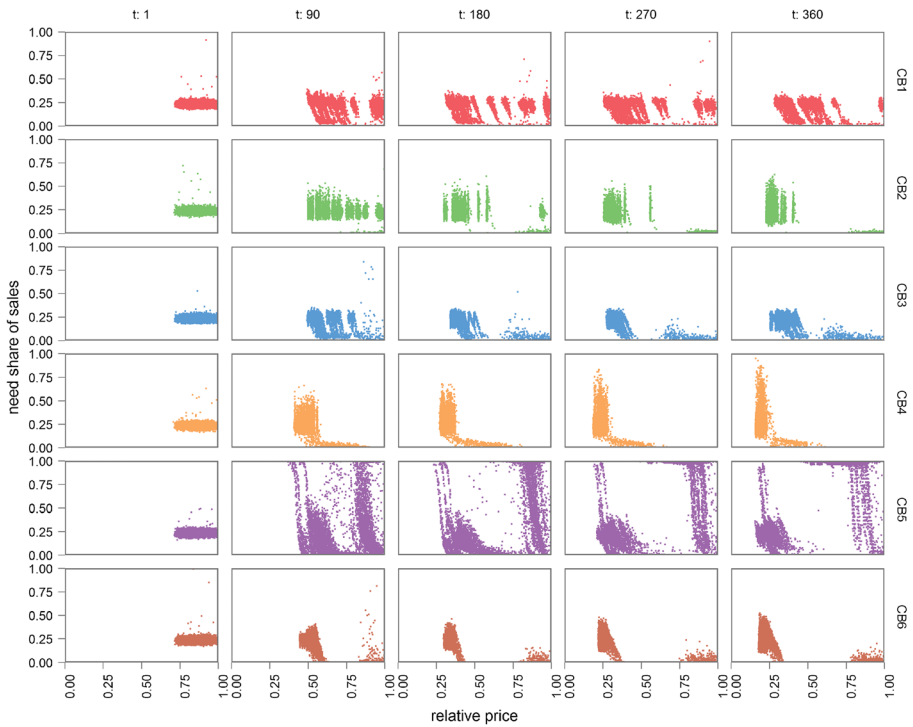


Fig. 5 Firm specialization: needs share vs. relative price

scenario of firm specialization as is common to Western industrialized societies. Firm populations endogenously evolve with broad price spreads where a sub-population of firms specializes on the production of expensive wants. This simulation result demonstrates the evolutionary core of this agent-based macroeconomic model.

Figure 6 shows the distribution of capitalist consumers over firms for all scenarios over time by showing the results of all repetitions (reruns). All scenarios start rather homogeneously in $t = 1$, while evolving quite distinct behavioral capitalist consumption patterns for the different scenarios, which are rather well defined with regard to the variation of the random element (repetitions). Here we can particularly differentiate the dynamics of CB3 and CB4. The snob effect drives capitalists to consume goods from smaller firms in CB3 and leads to the formation of a distinguished set of firms, which appears as an emerging peak in the relative frequency. Signaling-by-consuming leads hereby to a self-organized structuration process that is reshaping the almost normal distribution of capitalist consumers over firms in the very beginning. After 15–20 years, capitalist consumers are distributed differently, resulting in a bimodal distribution with two local maxima. Otherwise, in CB4 capitalists follow a Veblen effect and act conspicuously. As a consequence, capitalist consumers are more uniformly distributed in this scenario but prefer firms with higher prices, thus spreading over a higher number of firms. In scenario CB2, all households, including capitalists, are subject to a stronger bandwagon effect, which leads capitalist households to spread over an even higher number of firms.

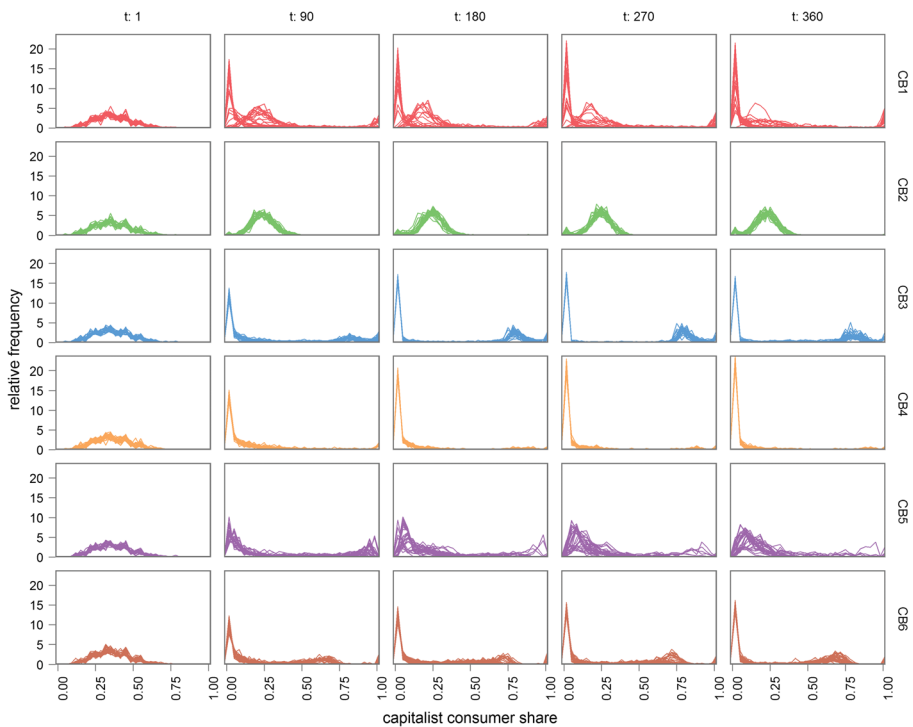


Fig. 6 Firm specialization: capitalist consumer share

In conclusion, the snob effect – as a contradictory force to bandwagon – may be even “innovative” in this regard – compare Tarde (1903: xiv) and Lepinay (2007: 531–535) for invention and imitation – since it creates variety and diversity. In this regard, our results reproduce the microeconomic conclusions drawn by Malerba et al. (2007) and Safarzynska and van den Bergh (2010) on larger scale. This diversity in firm specialization guarantees a steady movement of consumers and a replacement of firms by consumers if a bandwagon effect is at work (CB3 and CB6).

Analysis of the firm specialization processes (Figs. 5 and 6) reveals different path-dependent structuration patterns characterized by different price levels plus the share of needs and wants. That said, the investigated signaling-by-consuming effects – the Veblenian meso foundation – have a significant influence on the price level of the economy, which we aim to highlight in Fig. 7. It shows the development of the price level in terms of a weighted consumer price index. Due to the random initial household – firm matching, households’ initial behavior does not very well reflect their true preferences on the consumer goods market. As a result, households are unsatisfied and often change their firms’ preferences lists, since the firms’ specialization – and hence, its adaptation to differentiated demand – has not come through yet on the supply side. Thus, the price level rises quickly during the first five years, as firms often face excess demand during this period, which results in frequent price increases. Scenario CB5 is again special as it leads to a much longer phase of price increases that stabilizes only after 15 years of high price inflation. All the other scenarios indicate a rather steady development in the consumer price index.

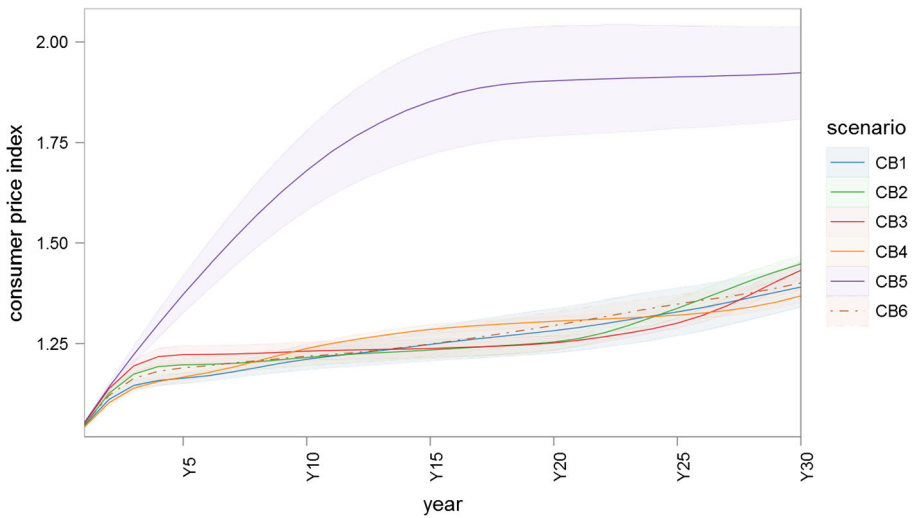


Fig. 7 Consumer price index

Moreover, the analysis of the dynamics in the consumer price index corresponds very well with the simulation data on excess supply. Since our model works without a market clearing mechanism, actual sales might deviate from the firms’ expectations. To this extent, the relative excess supply – shown in Fig. 8 – demonstrates the deviation from the planned reserve stock for the various scenarios. This notion means in particular that in all scenarios – except CB5 – firms are fighting with grave expectation mismatches in the very first years, but lock into an effective inventory reserve rate – 5.5% away from the intended rate ($\alpha_1 = 0.1$) – for the inventory of $\sim 4.5\%$ on average thereafter. By contrast, firms in CB5 are far away from their planned reserves in the inventory, i.e. they are regularly outsold. Only after 15 years do firms reach the same practical reserve rate of $\sim 4.5\%$, as achieved in the other scenarios. Within those first

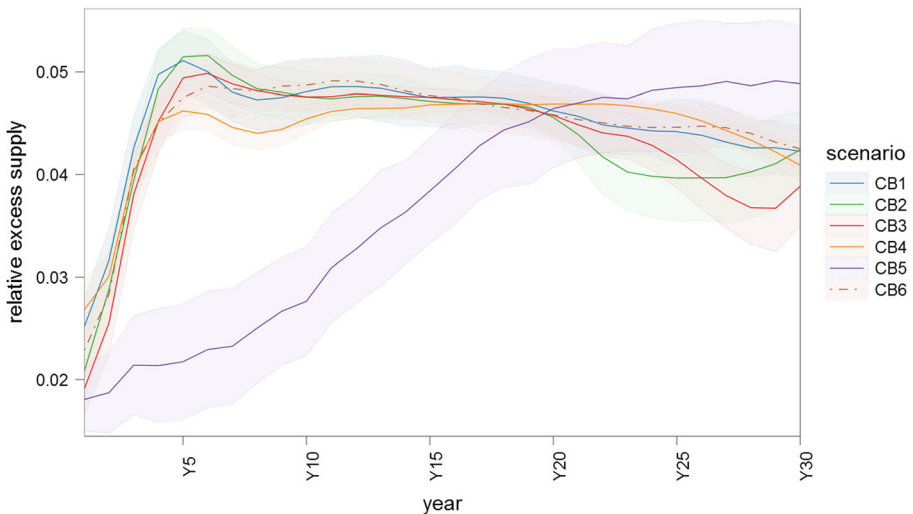


Fig. 8 Excess supply in relation to total supply

15 years, the demand for a specific firms' goods is too high due to the snob effect and conspicuous consumption prevalent in all classes. However, households change their firms' preference lists far too often and therefore prohibit steady capacity adjustments for the firms. The intuitive response on the supply side is given by substantial price increases, as we have already highlighted in Fig. 7.

Furthermore, the limited excess supply and the corresponding high price inflation in CB5 translate into higher firm profits, as shown in Fig. 9. The profit rates are in general rather low ($\sim 2\text{--}3\%$) if bandwagon and normal price effects are active in the working class. Otherwise in CB5 we see firms' profits growing very fast, peaking at a profit rate of $\sim 15\%$. These additional capital gains make the Veblen effect even more pronounced and luxury want consumption increases because of this feedback loop, and so the economy destabilizes endogenously.

Turning attention to a central macroeconomic measure – aggregate demand – reveals the structuration stemming from the dynamic interdependency of the endogenous social mediation of consumer preferences and firm specialization. Results are illustrated in Fig. 10 showing the aggregate demand for consumer goods in the economy, separated for the previously described artificial scenarios. The Veblenian meso foundation is decisive for the emergent outcome on the macro scale, since aggregate demand differs substantially around 5% between the different path-dependent developments. The exception is again given by CB5, where only the snob and Veblen effects are active. In this scenario, aggregate demand immediately decreases by 10% over the first 10 years, resulting in a difference of 15–20 percentage points to the other scenarios. Note that aggregate demand equals household consumption, but does not include unsatisfied demand of households, i.e. it does not equal the sum of the intended consumption of households.

Why is there such a slump in aggregate demand in CB5 within the first 10 years while all the other scenarios indicate a steady growth in aggregate demand? On the one hand it is not possible for all households to consume rare and luxury goods in an economy that starts out with medium-sized firms. On the other hand, the bandwagon

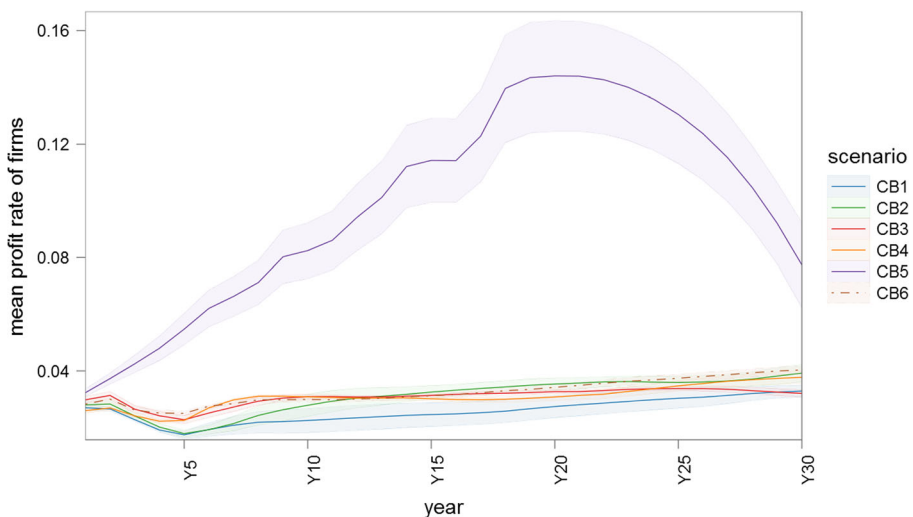


Fig. 9 Mean profit rate of firms

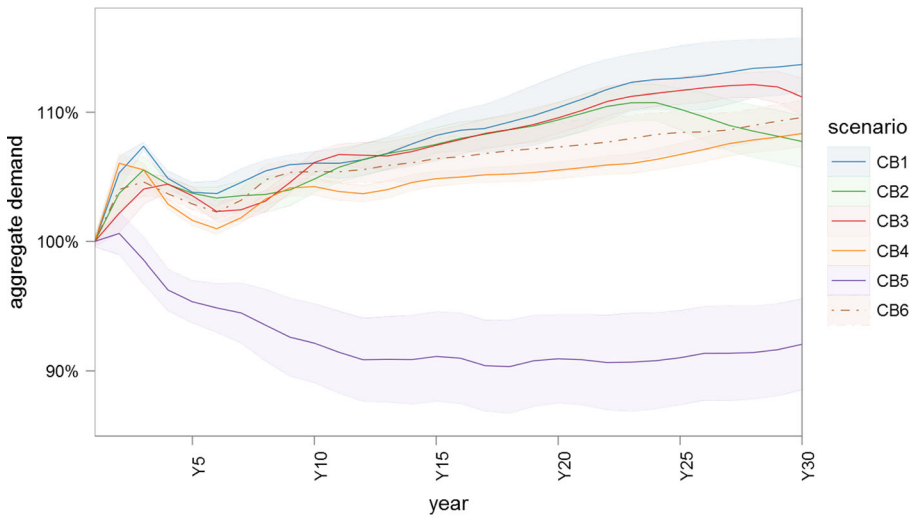


Fig. 10 Aggregate demand – annual

effect – active in all scenarios except CB5 – functions as a social stabilizer for the macroeconomic performance, it guarantees a persistent flow of household consumption. Thus firms followed by a critical mass of households – ‘jumping on the bandwagon’ – can grow steadily into large-scale corporations with a high needs share and a low price (see Fig. 5 again). Furthermore, these firms are then able to sustain the slowly increasing demand via continuous capacity adjustments in comparison to smaller firms selling a higher wants share with relatively higher prices. These latter firms serve the capitalists’ desires and do not contribute to an increase in aggregate demand as great as the larger firms that are followed on the basis of the bandwagon effect. Otherwise, this notion means that in the absence of bandwagon and normal price effects accompanied by a stark presence of snob and Veblen effects – as it is the case in CB5 –, the economy destabilizes dramatically owing to snob effect and conspicuous consumption. Firms, on the one hand, cannot expect a comparable persistence in consumption flows and, on the other, they cannot increase steadily their prices as a reaction to the demonstrative spending behavior in all social classes now, as shown in the previous figures. The increasing inflation (Fig. 7) eventually leads to the slump in aggregate demand, since prices are adjusted monthly (see Fig. 11) but wages only annually. As a consequence, we can observe these fundamentally different macroeconomic developmental paths.

In addition, we aim to highlight the fact, that these macroeconomic conclusions are significantly robust, having been drawn from the analysis of stable system behavior generated by our simulation experiments. The robustness of such results depends, of course, on the complexity of the agent-based model, but more specifically on the proportional relations of assumptions made. Monthly data as presented in Fig. 11 for aggregate demand show the slight seasonal fluctuations. These are also influenced by annual changes in capital gains, which are distributed once per year and thus affect capitalist household consumption behavior more strongly. Moreover, repetitions of the same parameter combinations (scenarios) fluctuate less strongly between repetitions of more stable scenarios, e.g. CB6, and more strongly for rather unstable scenarios, e.g. CB5.

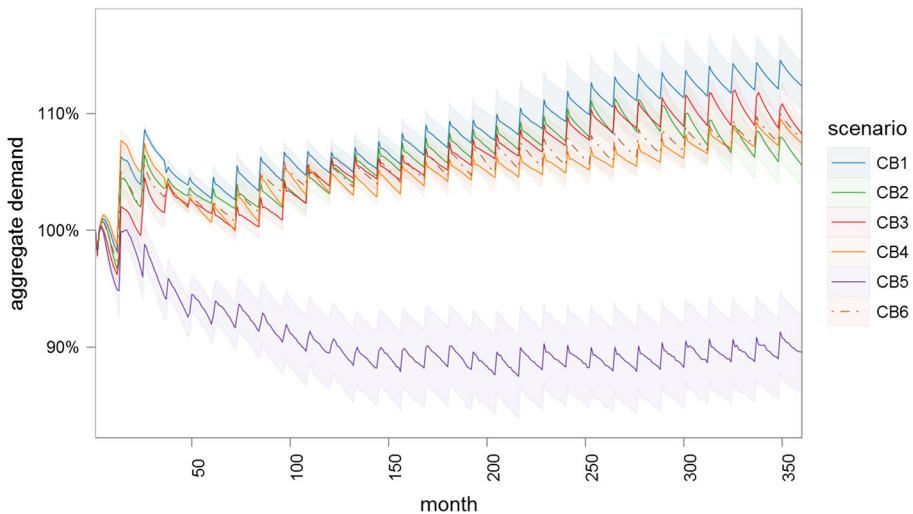


Fig. 11 Aggregate demand – monthly

Eventually, Fig. 12 shows the path-dependent development in the labor market by indicating the unemployment rate in the economy. The differences among the scenarios are pronounced and substantiate the previous analysis. A close inspection of scenario CB5 shows a maximum unemployment rate peaking at 16%, and, more specifically, a higher variance between repetitions than in other scenarios. Although reducing to lower levels in the long run, this particular social mediation of consumer preferences turns the economy into severe macroeconomic turmoil. Otherwise, all other scenarios tend to stabilize after peaking between years five and 10 to very low unemployment rates between two and 4%. The comparatively volatile developments during the first ten years represent the manifestations of the self-organization process restructuring the market for consumer goods, as it

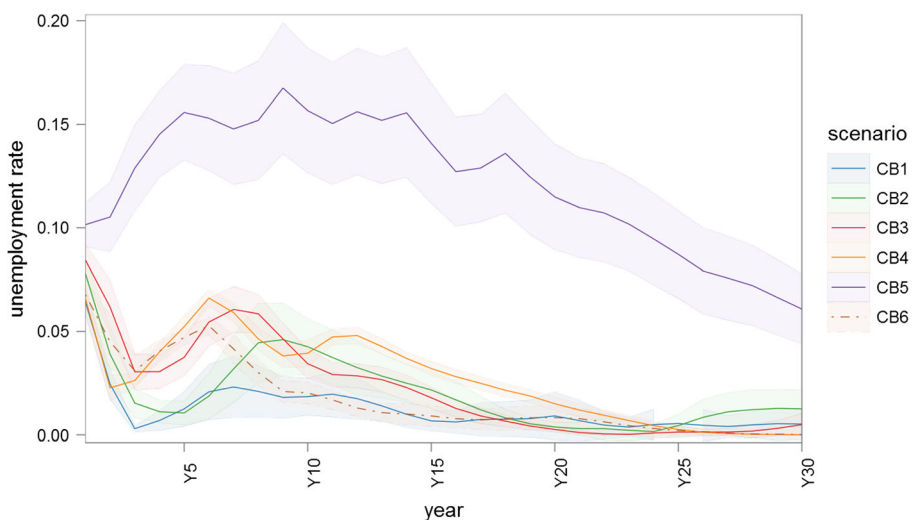


Fig. 12 Unemployment rate

develops away from the artificial initial conditions. Furthermore, the analysis of the unemployment rate substantiates our previous conclusions about the role of the bandwagon effect for evolutionary macro dynamics. We can report its stabilizing role, this time with regard to long-run employment.

At this point, we could project that a further introduction of a complementary Schumpeterian meso foundation – on innovation and technological change – would increase labor productivity and counteract the bandwagon effect. This setting would lead to technological unemployment, at least in the short run – caused, e.g., by increasing automation – and counteract the bandwagon effect in terms of aggregate demand and employment. However, a clear comparative analysis of both evolutionary meso effects (Veblenian plus Schumpeterian) in action goes far beyond the scope of this article, but indicates stimulating research potential for the future.

5 Concluding remarks

Evolutionary macroeconomics offers a new approach by employing computational social simulation of dynamic micro-meso-macro frameworks. We understand evolutionary macroeconomics as an integral part of evolutionary political economy that can shed light on the dynamic effects of specified agent heterogeneity and diversity for typical macro aggregates. These measures imply welfare effects for individual agents in political economy terms, with actual losers and winners. In our article, we presented such an evolutionary macroeconomic model – specified along a Veblenian meso foundation – and analyzed the long-run welfare effects for capitalists as well as workers by means of artificial simulation experiments.

To this effect, the micro level of the macroeconomic system is not reduced to a representative micro foundation but entails a population of heterogeneous interacting agents and so evolves as a complex adaptive system. Basic information sharing among agents via simple communication structures is a necessary characteristic for a meso foundation that is socializing agent collectives through common patterns of political economic behavior. The significant difference between a micro and a meso foundation relates to this latter property. Micro may guarantee for heterogeneity but cannot involve diversity in a population of economic agents. Otherwise, a meso foundation generates a diversity of distinguishable agent collectives within the whole population (Scholz-Wäckerle 2017). It thereby modularizes the full set of heterogeneous agents into different subsets (Simon 1962) and creates social structure. In our model, this social structure is characterized by the endogenous development of Marxian social classes and Veblenian social stratification.

The agent-based methodology allows the implementation of such an evolutionary macroeconomic complex adaptive system with a specified meso foundation. In addition, this approach enables the complementary performance of bottom-up self-organization (households, firms, banks) vis-à-vis top-down governance (government, central bank). In this article, we have demonstrated the explanatory power of evolutionary macroeconomics with a concrete example, in particular a Veblenian meso foundation with signaling-by-consuming effects, dependent on social class. We

have shown that the co-evolutionary dynamics between household behavior and firm specialization lead to the emergence of some deeper structure in the consumer goods market, on the one hand, and to significantly different macroeconomic outcomes in simulation experiments, on the other. The social mediation of consumption plays a crucial role for the path-dependent development of an economy.

First, the bandwagon effect acts as an endogenous stabilizer for the macroeconomic system. It facilitates steady growth in aggregate demand. Second, the snob effect leads to a bimodal distribution – by endogenously restructuring the market for consumer goods – of firms, with larger and relatively low-price firms serving the needs of the working class and smaller and relatively high-price firms serving the wants of the wealthy workers and capitalists. Third, the combination of snob and Veblen effect in the capitalist class is the only signaling-by-consuming mix that may cause stagflationary economic turmoil on the macro scale if it is not compensated by a normal price and bandwagon effect in the working class. To sum up, the working class stabilizes the macroeconomic system by consuming in accordance with a normal price effect with its bandwagon-guided needs consumption. The capitalist class destabilizes it by consumption according to the Veblen effect with its snob-guided wants consumption. Although the latter keeps the economy in continuous change, creates variety and diversity in patterns of consumption and changes the firm population endogenously, it needs to get complemented by working-class consumption behavior or it turns the economy down. If the banks are modeled as being risk-averse, grant loans quite conservatively and firms therefore do not grow explosively – as is the case in our conducted simulation experiments – these complementary (and to some extent co-evolutionary) dynamics lead to a stable macroeconomic development path. However, the achieved stability may get disrupted once the working class switches to snob and Veblen effects in their needs consumption as well. This notion may be problematic in an economy where consumption is made exclusively on easily available private loans, as it is a tendency in financial capitalism.

In conclusion, evolutionary macroeconomics – following the agent-based methodology – provides new insights on the inner dynamics of an economy with regard to its multileveled structure. The advantage of the presented approach lies in the simultaneous analysis of micro, meso and macro components. One can test social theories of endogenous change – such as Veblen's theory of the leisure class – in macroeconomic environments. The individual agents are modeled under terms of bounded rationality and satisficing rules of thumb, but social adaptation characterizes them as heterogeneous and diverse decision makers within a complex evolving system.

Acknowledgements The authors would like to thank Hardy Hanappi for his influence on first versions of this model.

Funding Open access funding provided by Vienna University of Economics and Business (WU). This study was partly funded by the Anniversary Fund of the Oesterreichische Nationalbank (OeNB, grant number 15299).

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Appendix 1 – Timing of events

Monthly simulation phases

Founding phase

Households evaluate and initiate firm founding

Production phase

Firms make demand estimation and pricing
Firms make credit adjustment and production
Firms adapt prices

Sales and consumption phase

Households check financial status
Households decide consumption budget
Households buy needs goods
Households (capitalists) buy wants goods
Households (workers) buy wants goods
Households update needs vendor lists
Households update wants vendor lists
Households balance accounts with savings if indebted or declare bankruptcy

Wages payment phase

Firms pay wages
Government pays pensions
Government pays unemployment subsidies

Saving phase

Households transfer money to savings accounts

Interest and consolidation phase

Banks collect loans interest
Banks collect loans repayments
Banks calculate accounts interest
Banks calculate savings interest
Banks pay central bank loans interest
Banks pay central bank loans repayments
Firms' monthly accounting
Banks verify firms' solvency
Banks' monthly accounting

- Banks calculate refinancing demands
- Banks refinance themselves at central bank
- Banks transfer funds to facilities at central bank
- Central bank pays reserve interest
- Central bank pays deposit facilities interest

Government refinancing phase

Update macro indicators

- Banks' monthly accounting
- Central bank's monthly accounting
- Government's monthly accounting
- Country updates macro indicators

Annual simulation phases

Annual accounting phase

- Banks collect and pay accounts interest
- Banks pay savings interest
- Firms calculate profits and pay taxes
- Banks calculate profits and pay taxes
- Firms distribute profits
- Banks distribute profits
- Capital goods firms distribute profits

- Government updates annual statistics (annual taxes)
- Country compiles annual report
- Government checks minimum wage increase
- Government increases unemployment subsidies if minimum wage increased
- Government evaluates pension increase based on CPI
- Firms evaluate wage increases based on CPI
- Capital goods firm adapts prices based on CPI

Firms depreciate production capital

Appendix 2 – Technical details of the computational simulation

To implement the computational simulation of the presented model we chose the widely used Netlogo simulation environment (Wilensky 1999) in the version 5.2 without any special Netlogo extensions.

The presented experiment was set up using Netlogo's built-in BehaviorSpace experiment management engine to repeat each scenarios 30 times, each time using a different random seed to account for the random factors in the model. This resulted in 180 different simulation runs, which were calculated in parallel on multiple computers. Aggregate time series data were generated directly by BehaviorSpace for each period,

whereas micro data were only saved for selected periods. Data analysis and visualization was realized using the R language (with the ggplot2 package). Annual data shown are either means over the periods representing a year (flows) or the state in the last period of an artificial year (stocks).

The experiments were run with 5000 households including workers, pensioners and capitalists, and started with an initial firm population of 250 firms. Additionally the experiment included five banks and a rudimentary capital goods firm, the government and a central bank. Other relevant simulation parameters are shown in the table below.

Main simulation parameters

Households

Number of vendors on preferred lists (γ_2)	7
Number of regular replacement checks per month	1
Reserves of needs	1 period
Intended consumption rate, worker households (β_1)	0.1
Intended consumption rate, wealthy worker households (β_2)	0.15
Intended consumption rate, capitalist households (β_3)	0.2
Rate of consumption with respect to savings (γ_1)	0.05 / 12
Initial savings endowment of worker households	$X_2 * \text{annual wage}_{\text{household}} X_2 \sim U(1, 2)$
Initial savings endowment of capitalist households	10 * (initial minimum wage)

Firms

Initial ratio capital (individual firm level) to wages (annual)	2
Production reserve stock rate (α_1)	0.1
Unsold stock depreciation rate (per period) (δ_1)	0.5
Capital depreciation rate (annual)	0.1
Firm founding probability (monthly)	1/18
Price adjustment rate (α_2)	0.01
Maximum price adjustment (α_3)	0.1
Stock adjustment indifference rate (α_4)	0.25
Common fixed production technology coefficient (α_5)	1
Capital intensity parameter (α_6)	0.2
New price adoption probability (θ_1)	1/3

Banks

Credit term	5 years
Credit interest rate (annual)	0.04
Account interest rate (annual)	0.01
Account overdraft rate (private credit, annual)	0.05
Savings interest rate (annual)	0.015
Firm credit risk parameter (ϕ_1)	0.5
Central bank deposit interest rate (annual)	0.01
Central bank loans interest rate (annual)	0.02

Government

Initial minimum wage	1000
Initial unemployment subsidy	1000
Minimum wage increase minimal interval	5 years
Employment protection duration	2 months
Value added tax rate	0.1
Labor tax rate (flat for all worker households)	0.15
Income tax rate (flat for all capitalist households)	0.15
Capital gains tax rate	0.15
Corporate tax rate (banks, firms, capital goods firm)	0.15

Appendix 3 – Signaling by consuming effects (Section 2/Fig. 1)**Worker needs**

$$b_{1,i,t} = \left(\frac{P_{max,t} - P_{i,t}}{P_{max,t} - P_{min,t}} \right) \quad (23)$$

$$b_{2,j,t} = \left(\frac{m_{max,t} - m_{j,t}}{m_{max,t} - m_{min,t}} \right) \quad (24)$$

$$b_{3,i,t} = \left(\frac{v_{i,t} - v_{min,t}}{v_{max,t} - v_{min,t}} \right) \quad (25)$$

$$U_{i,j,t} = b_{1,i,t} b_{2,j,t} \xi + b_{3,i,t} (1 - \xi) \quad (26)$$

As presented in Section 2, $\xi = 0.75$ in this case.

Worker wants

Signaling-by-consuming in the case of worker wants is defined according to Eqs. (23), (24), (25) and (26) by setting $\xi = 0.25$. In this case we put a much stronger weight on the bandwagon effect than on the price effect.

Wealthy worker wants

$$b_{1,i,t}^v = \left(\frac{P_{i,t} - P_{min,t}}{P_{max,t} - P_{min,t}} \right) \quad (27)$$

$$U_{i,j,t} = b_{1,i,t}^v b_{2,j,t} \xi + b_{3,i,t} (1 - \xi) \quad (28)$$

Signaling-by-consuming in the case of wealthy worker wants is defined according to Eqs. (27), (24), (25) and (28). Again $\xi = 0.25$, assigning a much stronger weight on the bandwagon effect than on the price effect. Additionally the price effect (now b_1^v) is now a Veblen effect and thus reversed in comparison to cases 1 and 2.

Capitalist needs

$$b_{3,i,t}^s = \left(\frac{v_{max,t} - v_{i,t}}{v_{max,t} - v_{min,t}} \right) \quad (29)$$

$$U_{i,j,t} = b_{1,i,t} b_{2,j,t} \xi + b_{3,i,t}^s (1 - \xi) \quad (30)$$

Signaling-by-consuming in the case of capitalist needs is defined according to Eqs. (23), (24), (29) and (30). In the capitalist cases $\xi = 0.5$, thus putting equal weights on the bandwagon and price effects. The price effect is again a regular price effect as in cases 1 and 2 (though less strong as ξ is chosen differently), but will implicitly get less important for very wealthy capitalists, as the wealth weight b will reduce its effect. Furthermore, c^s now represents a snob effect.

Capitalist wants

$$U_{i,j,t} = b_{1,i,t}^v b_{2,j,t} \xi + b_{3,i,t}^s (1 - \xi) \quad (31)$$

Signaling-by-consuming in the case of capitalist wants is defined according to Eqs. (27), (24), (29) and (31). Again $\xi = 0.5$ thus putting equal weights on the bandwagon and price effects. The price effect (now b_1^v) is a Veblen effect like in the case of capitalist needs while b_3^s again represents a snob effect.

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