New Mathematics and Natural Computation

ENDOGENOUS ECONOMIC CYCLES: AN AGENT-BASED MODEL OF CONSUMERS' CONFIDENCE

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The main goal of this paper is to present consumers' confidence as an important source of cyclical economic activity. We use a simplified agent-based model with a single production sector and consumers (agents). The confidence (optimism/stableness/pessimism) spreads by interactions among consumers and according to the macro state of the economy on the lattice of consumers. The aggregate level of confidence in society reflects the consumers' expectations about their future incomes together with their preferences between current and future consumption and determines aggregate demand for consumption spending. The aggregate supply is always formed with an attempt to satisfy aggregate demand, even at the price of growing amount of inventory goods.

We found that the model is capable of generating persistent endogenous business cycles. Peaks of waves of optimism/pessimism in the society correspond to the peaks of growth rate rather than the level of economic activity. The variable marginal rate of substitution between present and future consumption has a countercyclical and stabilizing influence on the growth rate of economic activity.

Keywords: ACE model; business cycle; consumer confidence.

1. Introduction

The experience with the economic situation, especially in the last years, brought the question about business cycle movement back to the centre of attention. The long lasting depression of economy, accompanied with the increased level of unemployment in a lot of European countries, has already caused lots of losses and pessimism. Understanding the business cycle movement of the economy is crucial in order to stimulate the economic growth again. Theories explaining fluctuations in economic activity are usually based either on the external shocks or on endogenous factors. The main goal of this article is to contribute to business cycle theories with

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an introduction of possible cyclical behavior coming from the consumers' confidence in the society.

The role of confidence in the determination of economic activity was already stressed by Keynes [2007], but for the difficulty of its measurement it took a long time to include it into the modelling of economic activity. Nowadays there are a variety of indicators on the basis of statistical surveys measuring the level of confidence in the society, the most known are Michigan's Index of Consumer Sentiment (ICS) for the US economy or Consumer Confidence Indicator counted as a part of The Joint Harmonised EU Programme of Business and Consumer Surveys published by the European Commission. By virtue of these data, the significance of the confidence indicator to model the behavior of economic activity was already confirmed in the studies of Acemoglu and Scott [1994], Bram and Ludvigson [1998], Carrol *et al.* [1994] and Souleles [2009].

In the recent years, the spread of the waves of optimism or pessimism in the society has started to be modeled also from the bottom up, by using agent-based models. This approach is mainly based on heterogeneity and interactions among agents in the formation of the optimistic or pessimistic attitude. The great work and explanation of the endogenous business cycle movement in the economic activity stemming from the optimistic/pessimistic attitude of the agents was described for example by Westerhoff [2010] or Westerhoff and Hohnisch [2010]. The most sophisticated and important macroeconomic agent-based models were done by Deissenberg *et al.* [2008], Delli Gatti *et al.* [2011] or by Dosi *et al.* [2006].

In this paper, we are introducing a possible additional source of cyclical movement coming from consumers' confidence. We model the spread of confidence in the society through interactions among consumers in an agent-based model in the sense of Westerhoff [2010]. We decided to use a simplified model with minimum additional factors to present the pure effect of consumers' confidence in economic activity.

The model consists of one economic unit (firm) and consumers. Consumers form their confidence on the basis of last macro states of the economy and level of confidence in their local neighborhood. We distinguish among three possible states of confidence - optimism, stableness and pessimism. We work with the term consumers' confidence in the broad sense. Consumers' confidence in the model represents not only the consumers' expectations about their future incomes, but includes also actual consumers' preferences for savings. The level of consumers' confidence in the society together with past values of consumption spending and incomes determines the aggregate demand for consumption in the model. The production part of the model is simplified. The unique producer - firm - forms the aggregate supply with the target to fully satisfy the expected aggregate demand even if it causes inventory. The aggregate supply is determined by the last level of realized consumption and the expectations about the future aggregate demand. We found that the model is generating a cyclical movement of consumers' confidence with the cyclical effect on aggregate demand and hence on economic activity.

The article is organized as follows. In section 2, the model is introduced. In

section 3, we present the simulation results of the model. In section 4, we present the sensitivity analysis on micro parameters of the model. Section 5 concludes.

2. The Model

The model is constructed to simulate the behavior of macroeconomic variables with respect to the level of consumers' confidence generated on micro economic level. We built the model slightly in accordance with the macroeconomic agent-based model of Westerhoff [2010], who modeled economic activity with respect to the waves of optimism/pessimism in the firms' expectations.

The simulation of the model consists of two kinds of steps - macro steps and micro steps. The state of the economy, presented on macroeconomic variables such as an aggregate demand, an aggregate supply, a final consumption spending etc. is evaluated and observed during macro steps. Each macro step represents one quarter of the year and consists of T micro steps. During these micro steps the simulation of consumer confidence is driven. Heterogeneous agents (consumers) form their confidence opinion on the basis of their neighbors and state of economy from last macro step. After this simulation the new macro step follows. The new state of the economy is evaluated on the basis of the values of macroeconomic variables from the last periods and the simulated state of confidence in the society from the last macro step. Following this way values of macroeconomic variables are determined from the bottom up. The distinction between two kinds of steps was already used in Westerhoff [2010] and increases the transparency of the model.

2.1. *Forming the state of confidence*

This section describes the core of the agent-based model - the simulation of forming the state of the confidence. We follow and model the level of confidence in society from the bottom, in accordance with Westerhoff [2010]. The behavior of agents is observed in micro perspective and the interactions in neighborhood are allowed. We choose a lattice of agents, equally endowed with the same level of income. In this lattice every agent is forming his own state of confidence on the basis of two aspects: on the macroeconomic situation (the state of the global environment) and local microeconomic condition (the confidence in the neighborhood).

We distinguish among three possible states of confidence: optimist ($O^i_{t\tau}$), pessimist ($P^i_{t\tau}$) and stable agent ($St^i_{t\tau}$). Optimist is expecting an increase in the future incomes and wants to increase his consumption spending. Pessimist is expecting a decline in his future incomes and wants to decrease his consumption spending. The stable agent can have different expectations about his future incomes, but does not want to change the level of his consumption spending in no direction (proportional to his average income).

The business cycle is defined by the cyclical behavior of the confidence and divided with respect to inflex points into the four phases - two phases of expansion

and two phases of contraction. The scheme of the business cycle is presented in Figure 1.

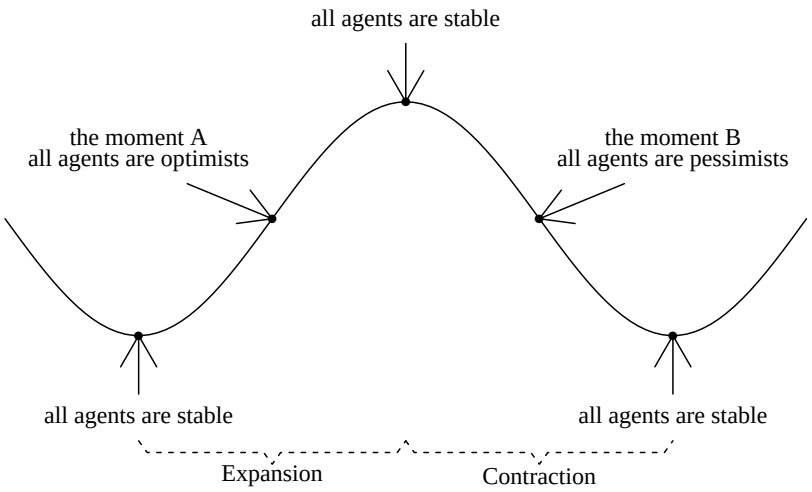

Fig. 1. The business cycle.

The first phase of expansion starts when all agents became stable after the contraction. In this phase the wave of optimism is spread and the confidence in the society is growing. The second phase of the expansion starts at the moment A, when all the agents became optimists. After this moment the agents start to stabilize their consumption spending. The beginning of the contraction (third phase) starts when all agents became stable. During this phase the wave of pessimism is spread. The fourth phase starts at the moment B, when all agents became pessimists. After this moment agents again start to stabilize their consumption spending until they are all stable again and the cycle begins anew.[a] The state of confidence is one of the key variables which determines aggregate demand. Thus the cyclical behavior of confidence is with some time lag followed also with the cyclical behavior of the aggregate demand and aggregate income.

Following the idea of Westerhoff [2010], the level of confidence is formed between every macro step t and $t+1$ during T micro steps. In the period t the state of the global environment is set. Agents know the information about the total aggregate income Y_t. In every micro step τ there is one agent randomly chosen. This agent

[a]The turning points of the business cycle are the moments when all agents are stable. This is different to Westerhoff [2010], where the turning points are the moments when all agents are optimists/pessimists.

decides about his state of confidence, according to probabilities

$$Prob(O^i_{t\tau}) = \begin{cases} \frac{\exp(\alpha^Y_t+\alpha^S_t+\beta^i_{t\tau})}{1+\exp(\alpha^Y_t+\alpha^S_t+\beta^i_{t\tau})} & \text{in expansion,} \\ 0 & \text{in contraction.} \end{cases} \tag{2.1}$$

$$Prob(P^i_{t\tau}) = \begin{cases} 0 & \text{in expansion,} \\ \frac{1}{1+\exp(\alpha^Y_t+\alpha^S_t+\beta^i_{t\tau})} & \text{in contraction.} \end{cases} \tag{2.2}$$

$$Prob(St^i_{t\tau}) = 1 - Prob(O^i_{t\tau}) - Prob(P^i_{t\tau}). \tag{2.3}$$

The probabilities depend on three parameters. α^Y_t and α^S_t are the global sensitivity parameters to income and savings, respectively, at time t, $\beta^i_{t\tau}$ is the local parameter of the sentiment in the considered neighborhood. The parameter α^Y_t is defined as

$$\alpha^Y_t = \begin{cases} \alpha^Y & Y_t > \frac{1}{4}(Y_{t-4}+Y_{t-3}+Y_{t-2}+Y_{t-1}), \\ -\alpha^Y & Y_t \leq \frac{1}{4}(Y_{t-4}+Y_{t-3}+Y_{t-2}+Y_{t-1}), \end{cases} \tag{2.4}$$

This parameter represents the sensitivity of consumer to the change in his income. The consumer compares his actual income to the average income from the last four periods to distinguish between temporal and permanent changes and reduce the effect of temporal fluctuations in income. The use of average annual income rather than the last income is in accordance with the Permanent Income Hypothesis of Friedman [1957]. The average income from the last four quarters was chosen according to the consumer confidence measurement by The Joint Harmonised EU Programme of Business and Consumer Surveys. The consumer confidence is measured by questionnaires asking the consumer about his expectations in comparison to the situation of the last year.

Differently from Westerhoff [2010] we introduce another global parameter α^S_t. This parameter represents the sensitivity to savings. If we consider that the utility function of consumer is a convex function of consumption, the marginal utility of consumption is decreasing. In the first phase of expansion, after the turn in economic activity, the consumers' needs are non saturated because of the long period of decreased incomes. Hence the marginal utility of consumption is high. The increasing income of consumers leads to increase of consumption spending. The individual aggregate demand is therefore affected just by the changes in income.

We assume, that after some period of increasing income and consumption spending, the marginal utility of consumption decrease (the utility function is the convex function of consumption, the majority of previous needs was mainly saturated) and the marginal utility of saving increase. We reflect this change of preferences of the consumer in the model by introducing the parameter α^S_t, which decreases the probability of an agent to be an optimist (with the will to increase the consumption spending) in favor to become a stable agent (with the will to stabilize the consumption spending, hence increase also savings). For the simplicity, we activate this parameter when every consumer became optimist, e.g. at the moment A. After this

moment the second phase with negative values of α_t^S starts. This parameter affects the aggregate demand in the opposite direction as α_t^Y, slowing down the aggregate demand for consumption spending.

The analogical situation is repeated during the contraction. In the first phase of decline, after the turn in economic activity, consumers adjust their demand for consumption according to the decreasing income. After some period of decreasing income, we assume that the marginal utility of consumption starts to be greater than the marginal utility of keeping the savings and consumers start to decrease their savings in favor of stabilizing consumption. This assumption is in accordance with Pollin [1988], who postulated that the decrease in income could lead to necessity to borrow to maintain the consumption, as well as with Ryoo [2014], also presenting the inelasticity of desired consumption to the income changes. By analogy to expansion, we activate the parameter α_t^S in the moment where all the agents are pessimists (moment B). After this moment the value of parameter α_t^S is positive, decreasing the probability of an agent to be a pessimist (with the will to decrease the desired consumption) in favor to be stable (with the will to stabilize the consumption spending). The parameter α_t^S is defined as

$$\alpha_t^S = \begin{cases} \alpha^S & \text{in expansion after the moment A,} \\ -\alpha^S & \text{in contraction after the moment B,} \\ 0 & \text{otherwise.} \end{cases} \tag{2.5}$$

In accordance to Westerhoff [2010] and the idea of agent-based modelling we introduce one local environment parameter $\beta_{t\tau}^i$. This parameter represents the local sensitivity on the mood around the chosen agent i, where β is sensitivity parameter to the local environment, $\#O_{t\tau}^i$ is the number of neighbors of agent i, which are optimists, $\#P_{t\tau}^i$ is the number of neighbors of agent i, which are pessimists and $\#St_{t\tau}^i$ is the number of neighbors of agent i, which are stable in macro step t, micro steps τ. This parameter runs the spread of optimism/stableness/pessimism among agents. The individual parameter is defined as

$$\beta_{t\tau}^i = \begin{cases} \beta(\#O_{t\tau}^i - \#St_{t\tau}^i) & \text{in expansion,} \\ \beta(\#St_{t\tau}^i - \#P_{t\tau}^i) & \text{in contraction.} \end{cases} \tag{2.6}$$

2.2. *Macroeconomic part of the model*

The endogenous business cycle movement is presented on the simplified agent-based model of a closed economy, consisting of one type of heterogeneous agents - consumers, and of one production unit - firm. For the simplicity we do not consider any fiscal nor monetary authority. We take prices as constant (e.g., zero inflation), hence we can directly set the price of one unit of goods as 1, without loss of generalization. The investment is only in the form of inventory goods and the interest rate for saving is equal to 0. The reason for such simplification is that we want to investigate the influence of consumers' confidence in economic activity, without

any side effects caused by the stickiness of prices or wages, investment intentions, fluctuations in the monetary base, etc. All these effects could by themselves also cause fluctuations in economic activity and could make the influence of consumers' confidence on economic activity nontransparent. Once we locate the influence of consumers' confidence on economic activity, we can relax some of these assumptions and investigate the cyclical behavior of economic activity in the width dimension.

Consumers in the model determine by their consumption spending the aggregate demand for goods. In every period they obtain a salary from firms. Because of the absence of government, the salary is not decreased by tax. For the simplicity we take that the total income Y_t is always uniformly distributed among all agents (M), so the individual income of every consumer i in the time t is

$$Y_t^i = \frac{1}{M} Y_t \tag{2.7}$$

We assume that every consumer forms his decision about consumption spending, mainly according to the rational expectation permanent income hypothesis [REPIH, Hall, 1978]. [b] The consumer estimates his future stream of incomes and consistent with the life-cycle hypothesis [Modigliani, 1966] has an intention to smooth the consumption in future periods. We relax the assumption about considering the whole life-cycle and we rather assume that the consumer is estimating future incomes as well as distributing them for consumption spending over the undefined future horizon.

We built the expectations about future incomes of consumer on the basis of last incomes and consumer confidence. As well as by the definition of α_t^Y, we eliminate the effect of temporal fluctuations in consumer's income by using rather the value of average income from the last periods than the value of last income, in accordance with the permanent income theory [Friedman, 1957]. This is also supported by Ryoo [2014], who used in the formulation of desired consumption rather the stream of last incomes than the last value of income. Similarly to Carrol *et al.* [1994] we use the values of consumers' income from the whole last year, which in our model corresponds to four periods (quarters). With respect to the consumer confidence, we define his target consumption spending for future period $\bar{C}_t^i$. We use the consumer confidence as a proxy not only for the expectation of the consumer's future income, but also for his preferences between current and future consumption spending. Each consumer i is in the time t forming his target consumption spending for future period

[b]Carrol *et al.* [1994] were using the past stream of incomes together with the confidence indicators as a proxy of rational expectation for the future stream of incomes. In this paper, we are also using the past stream of incomes in combination with the consumer confidence. However, the confidence here is not the result of all information available to the consumer, but rather the simulated confidence which depends solely on the aggregate income and the confidence in the neighborhood and in the whole society. This way it could be questionable if the expectations are still rational or should be rather considered as adaptive.

$\bar{C}_t^i$ according to his state of confidence as

$$\bar{C}_t^i = \begin{cases} (1+x)\frac{1}{4}(Y_{t-3}^i + Y_{t-2}^i + Y_{t-1}^i + Y_t^i) & \text{optimist,} \\ \frac{1}{4}(Y_{t-3}^i + Y_{t-2}^i + Y_{t-1}^i + Y_t^i) & \text{stable,} \\ (1-x)\frac{1}{4}(Y_{t-3}^i + Y_{t-2}^i + Y_{t-1}^i + Y_t^i) & \text{pessimist,} \end{cases} \tag{2.8}$$

where x is an extrapolation constant denoting the effect of the presence of optimism/pessimism.

In accordance with Abel [1990], we assume that the consumer does not have the full control over the amount of his consumption spending and the share γ of the consumption is dependent on the individual consumption spending from the previous period C_{t-1}^i. The individual demand for consumption spending ID_t^i at time t is

$$ID_t^i = \gamma C_{t-1}^i + (1-\gamma)\bar{C}_t^i \tag{2.9}$$

Summing up individual demands for all agents, we obtain the aggregate demand for consumption AD_t

$$AD_t = \gamma C_{t-1} + (1-\gamma)(1 + \frac{x}{M}(\#O_t - \#P_t))\frac{Y_{t-3} + Y_{t-2} + Y_{t-1} + Y_t}{4}, \tag{2.10}$$

where $\#O_t$ is the number of optimists and $\#P_t$ the number of pessimists at time t.

We assume that there is a competitive environment of many small firms in the economy. Hence, the production sector could be represented by a unique producer (firm) with the zero profit and the intention to always try to fully satisfy the future aggregate demand even if it causes some involuntary inventory goods. This firm in the model forms the aggregate supply AS_t. Consumers are always immediately paid for their production (Q_t). Because the profit is zero, the price of the goods is equal to their costs and so the total income at time t is

$$Y_t = Q_t. \tag{2.11}$$

The firm obtains the payment from the sale of goods at the moment of selling. Thus, the firm firstly pays for the production of goods and in case of some inventory, could obtain the back payments with some time delay.

The real aggregate supply in the time t consists of the inventory goods of firm accumulated from previous periods I_t and of the current production Q_t, e.g.

$$AS_t = I_t + Q_t. \tag{2.12}$$

The firm always tries to satisfy the aggregate demand, but at the same moment does not want to let the amount of inventory goods grow too fast. For this reason the strategy of the firm about aggregate supply differs within the business cycle. The asymmetric behavior of the production setting was used also by Gualdi *et al.* [2015], motivated by the explanation that firing and hiring costs are not equal. In the case of contraction, the firm observes the decrease in the aggregate demand and thus setting the aggregate supply as the quantity of goods demanded at the

last period (AD_{t-1}) is sufficient to satisfy the next aggregate demand. At the same time, the firm wants to get clear of the inventory goods and starts to decrease it. The firm is than willing to produce just $AD_{t-1} - \kappa I_t$, where κ is the decreasing inventory parameter.[c]

On the other side, in the case of expansion, the firm observes the increase of aggregate demand. Setting the aggregate supply equal to past aggregate demand will therefore not be sufficient to satisfy the whole future aggregate demand. Thus, the firm has an intention to increase the production. We assume, that the expectations of consumers about the growth of production (e.g., also their income) in the next period are right, so the firm would like to produce $(1 + \frac{x}{M}(\#O_t - \#P_t))Q_{t-1}$ at time t. We define the target production of the firm $\bar{Q}_t$ at time t as the maximum value of these two different production settings

$$\bar{Q}_t = \max\{AD_{t-1} - \kappa I_t, (1 + \frac{x}{M}(\#O_t - \#P_t))Q_{t-1}\} \tag{2.13}$$

The production depends on the labor force and every big change in the labor force brings to the firm some adjustment costs. To reduce these costs the firm is adjusting production with some level of smoothing (δ). The aggregate production Q_t is then determined as

$$Q_t = \delta Q_{t-1} + (1-\delta)\max\{AD_{t-1} - \kappa I_t, (1 + \frac{x}{M}(\#O_t - \#P_t))Q_{t-1}\}. \tag{2.14}$$

The aggregate demand is compared with the aggregate supply. According to the matching on the goods market (which is also used in the agent-based model of Riccetti *et al.* [2014]) the final realized consumption at time t is determined as

$$C_t = \min\{AD_t, AS_t\}. \tag{2.15}$$

This result determines the future amount of inventory goods of the firm

$$I_{t+1} = AS_t - C_t \tag{2.16}$$

and the savings S_t and future assets A_{t+1} of consumers

$$S_t = Y_t - C_t \tag{2.17}$$

$$A_{t+1} = A_t + S_t. \tag{2.18}$$

Just to note that in case that the smoothing of consumption is stronger than the smoothing of production ($\gamma > \delta$), the final realized consumption is in most cases equal to the aggregate demand (e.g. the aggregate demand is fully satisfied).

[c]The target production function dependent on the amount of inventory was also used in the agent-based model of Riccetti *et al.* [2014].

3. Simulation Results

We programmed the whole model in the software R. We have constructed a simple lattice of 10000 agents in the form of a torus (like Westerhoff [2010]), so every agent has exactly four neighbors. We take one macro step as a quarter of a year and run the model for 300 macro steps. Between every two macro steps 10000 micro steps are driven, so on average every agent has a chance to change or maintain his opinion in a term.

In the model, the confidence of the consumer is dependent on the three sensitivity parameters. We have calibrated the model mainly in line with Westerhoff [2010]. After some calibration, we choose $\alpha_t^Y = 5$, $\alpha_t^S = -10$ and $\beta = 1$.[d] The extrapolation parameter is $x = 0.1$. Following the estimation of Štork *et at.* [2009] (from DSGE model) we set the smoothing parameter for consumption $\gamma = 0.8$. We assume, that the production is more flexible than consumption spending and set the production smoothing parameter $\delta = 0.7$. The inventory decreasing parameter $\kappa = 0.6$. Values of all parameters could be found in Table 1.

Table 1. Parameter setting.

Parameter	Description
$M = 10000$	Number of consumers
$T = 10000$	Number of micro steps
$TT = 300$	Number of macro steps
$\alpha^Y = 5$	Income sentiment parameter
$\alpha^S = -10$	Saving sentiment parameter
$\beta = 1$	Social sentiment parameter
$\gamma = 0.8$	Consumption smoothing parameter
$\delta = 0.7$	Production smoothing parameter
$\kappa = 0.6$	Inventory parameter
$x = 0.1$	Extrapolation parameter

As each run of the model is according to randomness generating business cycles with different lengths and timing, we cannot present the evolution of macroeconomic variables graphically with some average values. Hence, we will present the evolvement of the key macroeconomic variables on one simulation of the model. The average values from more runs will be introduced in the next chapter within the sensitivity analysis.

After running the simulation an endogenous cyclic movement of economic activity appears. This could be best observed in the movement of the aggregate income Y_t in Figure 2. The irregularity of cyclic movement is caused by randomness in the spread of optimistic/stable/pessimistic mood among agents.

[d]The value of this parameter in the model of Westerhoff [2010] is 0.881. We did not find any explanation for this number so we used the first closest whole number 1. The results were stable also for this value.

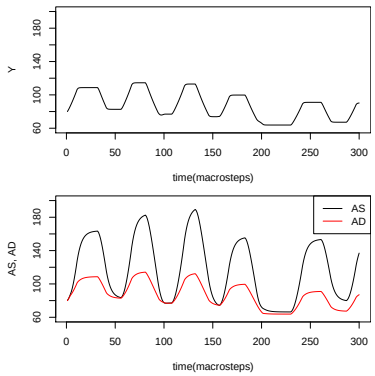

Fig. 2. Aggregate supply versus aggregate demand.

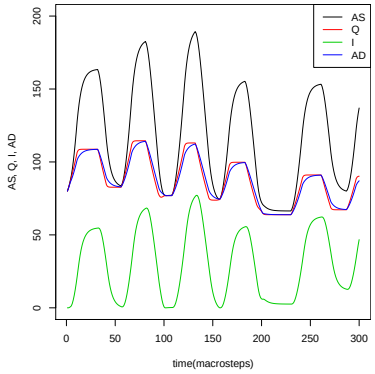

Fig. 3. The decomposition of the aggregate supply AS.

In Figure 2. we can see also the involvement of the aggregate demand AD and the aggregate supply AS. The aggregate supply is typically in excess of aggregate demand: this was somewhat expected, as the firm prefers to accumulate some controlled inventory instead of failing to meet the aggregate demand. This is also observable from Figure 3. In case of expansion, the aggregate supply is following the growing trend of aggregate demand, holding some inventory goods. In case of contraction the amount of inventory goods is decreasing and the aggregate supply again follows the trend of aggregate demand, this time decreasing.

Following the definition of the aggregate supply in the model (2.12) we decompose in Figure 3. the aggregate supply into the production part (Q) and inventory goods (I) left from the previous period. We can see that the production again follows the trend of business cycle movement and in comparison to the aggregate supply is much more stable. The swings in the supply are amplified by the adjustment of

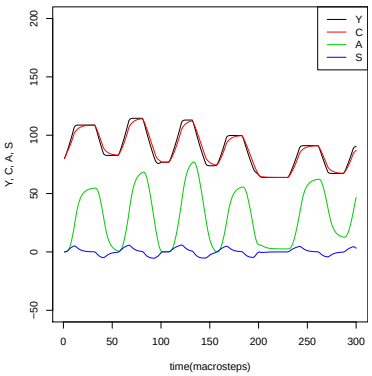

Fig. 4. The decomposition of income by consumer.

inventory goods following the expectations about the future aggregate demand. For comparison, we plot in the graph also the aggregate demand (AD). We can see that the production nearly coincides with the aggregate demand. The small deviations from the aggregate demand in the phase of expansion lead to accumulation of inventory goods and excess of aggregate supply. In opposite, the tendency of decreasing the inventory together with the production under the level of aggregate demand leads to decrease of the amount of inventory goods again.

In Figure 4. the decomposition of the aggregate income by consumers is presented. The aggregate income is redistributed according to (2.17) into the aggregate consumption and savings, the aggregate assets are formed as assets from previous period, adjusted for present saving/dis-saving following the equation (2.18). We can see from Figure 4. that the aggregate income Y and the aggregate consumption C are much more stable than assets.

In the phase of expansion the income dominates consumption spending and consumers, according to the assumptions, built their savings following their preferences. On the contrary, in the bottom of the business cycle, the higher level of consumption spending is achieved by reducing their savings (negative saving values), the income could not cover all the consumption spending anymore. More, we can see that the assets vary a lot during the business cycle. This follows from the accumulation of savings during the phases of expansion and diminishing of them during the phases of contraction.[e]

The last interesting results coming from the simulation are the one describing the spread of the waves of optimism (O)/stableness (ST)/pessimism (P) among agents. Firstly, we present the amount of each type of agents in the lattice in Figure 5.

[e]The model is set so that the assets at the beginning are 0. In practice, we could assume that there was already some level of assets at the beginning, obtained by inheritance, which will be passed to another generation again.

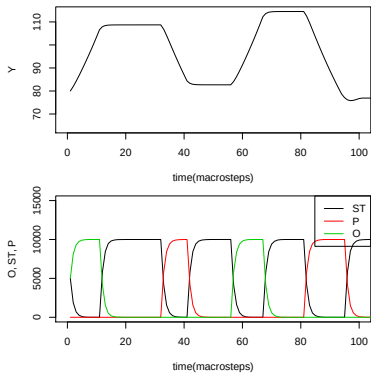

Fig. 5. The amount of optimists, stable ones and pessimists in the lattice.

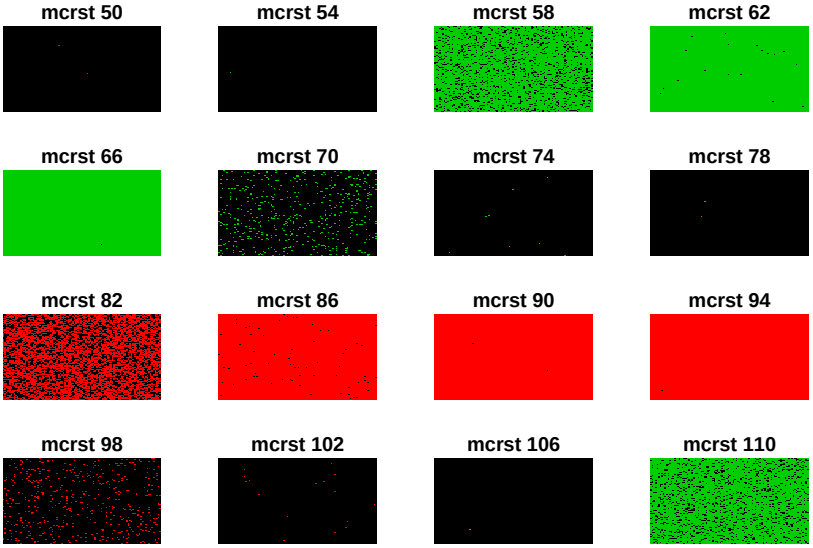

Fig. 6. The optimists, stable ones and pessimists in the lattice.

To make the results more readable, we have presented the evolvement just for 100 macro steps, e.g., about two business cycles. Secondly, we present the graphical spread of the mood in the lattice through the set of maps for the macro steps 50 till 110 in Figure 6. In both graphs the optimists are depicted in green, stable agents with the black and pessimists with the red one. In Figure 6. we can see how the mood is spreading firstly from a majority of stable agents (macro step 50) into the majority of optimists (macro step 66), back into the majority of stable agents

(macro step 78), then into the majority of pessimists (macro step 94) and again back into the majority of stable agents (macro step 106). Then the cycle repeats.

4. Sensitivity Analysis

The variability of the results depends strongly on the choice of model parameters. According to the influence we can distinguish between micro and macro parameters in the model. The values of macro parameters could be calibrated according to the regressions driven on time series of main macroeconomic variables or according to the studies made on these macroeconomic data. The micro parameters in the model are mainly calibrated according to Westerhoff [2010] and could be calibrated by some regressions made on micro economic data. However, to obtain such data for households could be more complicated. One of the options is to use the data of consumer confidence, which measure the level of confidence in the society on the basis of statistical surveys.

We do not estimate the most probable values of the micro parameters in this paper. On the contrary, we would like to present the sensitivity of obtained results on the choice of micro economic parameters, especially on α_t^Y, α_t^S and β. For each of these values we always fix two of these parameters on the initial value (from the Table 1.) and run the model for the third parameter for the net of 20 different values. The parameter setting of these variables are depicted in Table 2.

Table 2. Parameter setting for simulations.

Parameter	Sensitivity on α^Y	Sensitivity on α^S	Sensitivity on β
α^Y	$0 \dots 10$	5	5
α^S	-10	$-20 \dots 0$	-10
β	1	1	$0 \dots 2$

For each chosen value of the parameter we run the model 50 times with the macro horizon 200 quarters (50 years) and then make the statistical evaluation. After each run of the model we count the average income during the run, the average length of one business cycle and the average number of business cycles during the run.[f]

4.1. *Cyclical behavior*

Firstly, we are testing the sensitivity of cyclical behavior on the choice of micro parameters. In Figure 7. we present box plots of the average count of business cycles for different parameter setting. We can observe in all figures that for some choice of parameters' values there is no cycle. In case of α_t^S the cyclic behavior starts

[f]We are counting only full business cycles starting with the first phase of expansion after being in contraction and finishing with the end of fourth phase, at the end of the contraction.

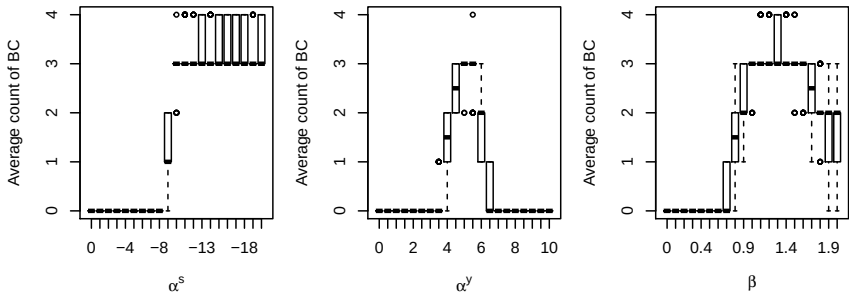

Fig. 7. Average count of business cycles.

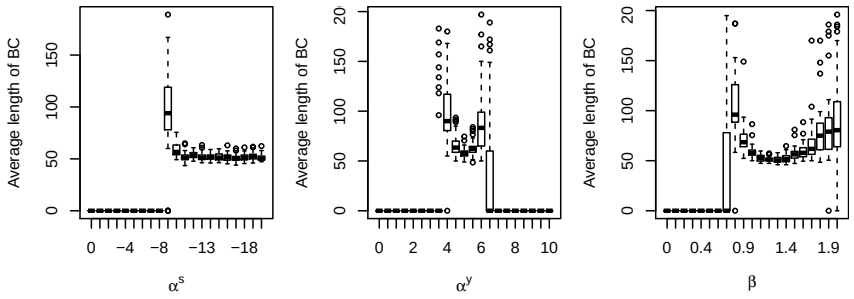

Fig. 8. Average length of business cycles.

from the value -9. This is in accordance with the theoretical assumption, that in case the agent is stable, even if he expects future growth in his income (expressed by the parameter $\alpha_t^Y = 5$) he is willing not to increase his consumption spending (this works only in case when $\alpha_t^S > \alpha_t^Y$). In addition, the cyclical behavior occurs only for α_t^Y from 4 till 7 and $\beta > 0.7$ (e.g., at least with some level of sensitivity on neighbors' confidence).

In Figure 8. we present the average length of business cycle for different values of parameters expressed in quarters. Again, we can observe that there is a length 0 for some cases, this corresponds to the situations without cycling behavior. The average length of business cycle for $\alpha_t^S < -9$ is around 50 quarters, which is 12.5 years. The sensitivity of length of business cycle on changes in parameters α_t^Y and β is much bigger. But from the boxplots in Figure 8. we can observe that for our model setting of these parameters ($\alpha_t^Y = 5$ and $\beta = 1$, in Table 1.) the volatility is low.

4.2. *Average income*

Finally, we are interested in the average income during the business cycle. We investigate only the cases where the cyclical behavior occurs, we plot the results for

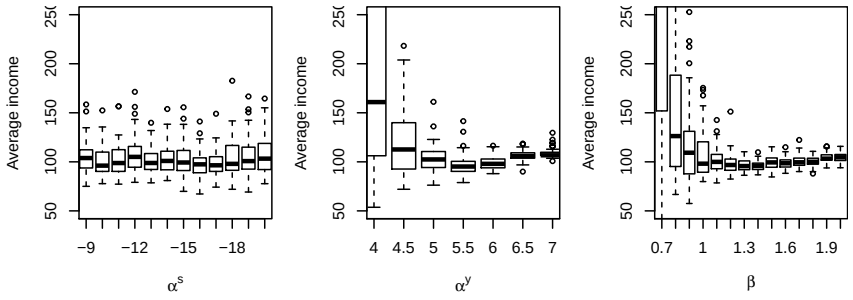

Fig. 9. Average income during the run.

$\alpha_t^S \in (-9, -20)$, $\alpha_t^Y \in (4, 7)$ and $\beta \in (0.7, 2)$ in Figure 9. The boxplots confirm that model setting of parameters keep quite stable results, with an average value of income around 100 (this was also starting point for simulations). Higher volatility of average income for limit values of α_t^Y and β corresponds to higher volatility in the cyclical behavior of economic activity.

5. Conclusion

The paper introduces a possible endogenous source of business cycle movement in the economic activity. This source was presented on the simple agent-based model with heterogeneous consumers and one production unit - firm. The cyclical movement was, according to the model setting, coming up from the spread of consumer confidence associated with variable marginal rate of substitution between current consumption and savings. These two factors consequently cause time delay between the payment of costs of production and the collecting payments for the goods by the firms.

The model was set so that in the phases of expansion the growth of consumption is firstly supported by the growth of income, but after some period slowing by the preference of savings (increasing income is rather saved, keeping the desired consumption spending constant proportional to the last average income). This preference in the combination with the firm's expectations finally leads to the stopping of the consumption growth. Then the economic activity turns down. The decline is from the beginning caused by the adjustment of desired consumption to decreasing incomes, and after some period influenced by the increased marginal utility of consumption to savings. Decreasing of savings finally helps to stabilize the economy again and allows to turn it into the growth anew.

The idea was presented on the very simple model with a lot of simplified assumptions. The reason of that was to present the clear cyclical movement, without the side effects of other macroeconomic variables. Additional variables could mess up the driving force of the cyclical behavior in the economy, making the model more realistic but the cyclical movement less traceable. Incorporating the technol-

ogy growth into the model could further lead to the permanent growth of potential economic activity and the cyclical movement along the growing function. The relaxation of all these assumptions, as well as deeper sensibility analysis, based on various types of lattices are all possible developments of this idea in future work.[g]

The simple idea of possible endogenous cyclical movement in the economy explained in this paper should not be understood as the unique source of business cycle movement, but rather as a one of more procyclical sources from the complex bunch of factors influencing the economy. We believe that incorporating this idea into more complex models could help to explain some cyclical movements and could be contributory in searching the way how to revive the descended economic activity.

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[g]The expanded versions of the model were already used for comparing various monetary policies in Závacká [2015a], investigating the consumption-income ratio within different labor tier workers in Závacká [2015b] and measuring the income inequality in Závacká [2015c].

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