Wiener Studien zur Politischen Ökonomie

Band 23

Macroeconomics and Banking Networks

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Schriftenreihe herausgegeben von Univ.-Prof. Dr. Gerhard Hanappi

ISSN 2074-9880

Projekt 15299

Jubiläumsfonds der Österreichischen Nationalbank

An Investigation of Banking-Macroeconomics Networks

FINAL REPORT

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Vienna, 28.2.2018

Content

Introduction

This report consists of three major parts describing the scientific activities of the project. First methodology is discussed. A central topic of the project since we apply a new technique, agent-based modelling, to approach our research topic. In this part we also provide a first route to agent-based modelling of our research question – and a critique and further development of the agent-based modelling approach.

Then, in part 2, we provide an overview of European economics and involved institutions. They are at the centre of what we want to investigate with the new scientific methodology. The basic structure of our second model, called A-POEM, is presented and the empirical data with which it can be loaded is explained and prepared. A discussion of scope and modularity of our model concludes this part.

In part 3 the details of A-POEM are presented, and some selected explorations for the case of Austria are carried out. A concluding summary provides a guideline through our arguments along the whole project duration.

Scientific publications, keynotes given, conferences and workshops and other by-products of our research are mentioned in all parts of the text, many of them in part 1. They also have been documented in the interim reports provided during our project time.

It remains to thank the Austrian National Bank and its team for the patient and friendly support.

Vienna 28-2-2018, Hardy Hanappi

1. Methodology

Contemporary economic theory is characterized by a large gap between models focussing on isolated firm dynamics loosely connected by highly stylized market mechanisms (i.e. microeconomics) and systems of national aggregates based on statistics and estimated socio-psychological constants (i.e. macroeconomics). Considered under the first perspective banks are just another instance of a 'representative firm': Their goal variable is profit maximization under the usual constraints of factor cost minimization and a negatively sloped demand curve. Under the second perspective banking assumes a dramatically different character. On the level of national aggregates banking activities, in the recent decade often summarized as 'finance', is a necessary precondition for all sectors of the economy and not just one of these sectors, or just the productive activity of a particular firm. The double image of contemporary mainstream theory thus in this case becomes a stark contrast, a contradiction in frameworks.

This is the reason why a project on banking-macroeconomics networks necessarily is dominated by questions of methodology. As a most fruitful methodological starting point evolutionary economics, or more precisely evolutionary political economy was chosen. Though this field sometimes is categorized under the header of 'heterodox approaches', it actually is much older and more firmly rooted in classical economic theory than the current mainstream[1]. It actually dates back to Thomas Robert Malthus, Adam Smith and to the contemporaries of the father of evolutionary theory, Charles Darwin[2]. In short, classical political economy in the 19th century already had addressed the questions of unifying economic and political dynamics, though it had not at its disposal the technical tools and the empirically observed data, which we have at our fingertips today. The task of this project with respect to methodology therefore was to provide some foundations on how to bridge the gap between the necessary synthesis of the object of investigation, i.e. Europe's political economy, and the modern formal apparatus plus data, in particular represented by agent-based modelling as part of economic simulation. Additionally, the focus on banking also enforced a rethinking and reframing of the contradictions between micro- and macroeconomics. For such a formidable task it is mandatory – and indeed intimidating – to start with a survey on existing literature.

[1] The pejorative adjective 'heterodox' often is used by mainstream economists to boost the importance of the fashionable neoclassical approach and to give the false impression that it somehow is the only evolutionary survivor in the dynamics of the history of economic thought.

[2] See [Hanappi, 1994].

With respect to literature and the basic *theoretical foundations* of an evolutionary macroeconomic framework for the study of the Banking-Macroeconomics Network several research papers and book chapters have been produced and most of them have already been published. This task, of course, is a very ambitious one that cannot be limited to the duration of a specific research project. It builds on a large amount of work done before the start of the project and certainly will go on after the end of the project. It has to be emphasized that the starting point of the proposed evolutionary macroeconomic framework, our main theoretical motivation, first was to overcome the limits of standard Keynesian macroeconomic models – in particular with respect to international monetary stock-flow modelling and the framework of institutional actors. Moreover, our investigations take place amidst the most severe turmoil shaking the structure of our object of investigation since the end of World War 2. In a sense we were confronted with the opposite of ideal laboratory conditions. While this has heavy implications for the use of econometrics – some recent developments simply occur for the first time in history and therefore an econometric look in the past is useless – it also implies that all theoretical issues made carry the weight to be perceived as proposals for economic policy. In a situation of many years of deep crisis political decision-makers are desperately in need of welfare enhancing economic policy recipes. With respect to our research project this explains why in our publications the borderline between theoretical result and the application of this result often is blurred. There is no long-lasting stable framework from which we can draw a set of 'eternally' valid laws, which then can be applied to study their overall reaction on 'exogenous shocks'. In a situation like this quantitative analysis using simulation is limited to provide some insight into the set of possible future short-term scenarios that are implied by accounting identities, some assumed socio-psychological behavioural constants and some – partly newly invented – policy rules. To be more specific: the study of a return to an equilibrium path does not make sense if it is impossible to identify such a path given the current actual institutional actors and their rapidly changing behavioural relationships. Thus our work partly is forced to assume the character of a proposal for socioeconomic and political design – reflected in the topics dealt with in the publications accompanying the project.

The following activities can be listed to provide an overview of the project work in this first phase of the project:

- Our work has been presented at several *workshops and conferences*. In particular it has to be mentioned that at the international conference of the European Association of Evolutionary Political Economy (EAEPE) in Cyprus in November 2014

(http://eaepe.org/?page=events&side=annual_conference) papers of Dr. Scholz-Wäckerle and Dr. Hanappi were presented and well received. The conference volume with selected research papers (including our work) has been edited by Hanappi–Katsikides–Scholz-Wäckerle [Hanappi, Katzikides, Scholz-Wäckerle, 2015] and appeared with Routledge Publishers. At the EAEPE Conference in Genoa in September 2015 Hanappi and Scholz-Wäckerle presented the research paper '*Evolutionary Political Economy: Content and Method*'[3]. The international workshop '*Metamorphosis of Europe*', organized by Hardy Hanappi in Vienna in December 2013 has brought together some 20 leading scientists from all over Europe to discuss during 2 days the current problems of the EU as well as the methodological possibilities of economists to contribute to their solution. This workshop was highly appreciated and the follow-up, '*Metamorphosis of Europe – Step 2*', took place at the Austrian Chamber of Labour on December 10-12, 2015. A full-length video of it is available at http://www.econ.tuwien.ac.at/events/metamorphosis2015/ .

- Several other occasions where our ideas were presented could be added, e.g. at the University of London, at the University of Piraeus, at the Hungarian Academy of Sciences in December 2015[4], at the Complexity Science Workshop of the TU Vienna in January 2016, at the University of Tokyo or at the Executive Academy of the WU Vienna (both in June 2016), and invited lectures at the Summer School of the European Association for Evolutionary Political Economy in Rome (July 2016) and the University of Siena (November 2016).
- Two *keynotes* related to the project were given by Hardy Hanappi. One in Nicosia at the international conference of ICABE (http://www.icabe.gr/) with the title '*Can Europe survive? Ten Commandments for Europe's Next Ten Years*', and one at the Annual International Conference of the Mendel University in Brno (2014) with the title '*Contours of a post-crisis European production structure*'. Another keynote of Hardy Hanappi took place at the '5th International Conference on European Studies' in Tirana (Albania) with the title '*The Balkan States as part of Europe - The Political Economy of Subsidiarity*' at 6th of November 2015. Again several talks at less prominent occasions took place too.
- With respect to *publications in books* related to the project first of all Dr. Scholz-Wäckerle's book '*The Foundations of Evolutionary Institutional Economics: Generic Institutionalism*' [Wäckerle, 2014] has to be mentioned. In this book many of the fundamental ideas of this project are discussed. Two other book contributions by

[3] A previous version of this paper has been published in German, see [Hanappi and Wäckerle, 2014].
[4] "Networks, Complexity, and Economic Development" International Workshop - Budapest, Nov. 30 - Dec. 01. Contribution by Hardy Hanappi and Markus Rohringer: *Cooperation, Competition, and Innovation Heterogeneous-Agents-Based modelling perspectives* [20].

Hardy Hanappi are rather basic for our approach: In '*Money, Credit, Capital, and the State*' [Hanappi, 2013a] I explain why all economic theory has to be monetary economics and how the changing money forms accompany the evolution of capitalist states. The book chapter '*Can Europe Survive? Ten Commandments for Europe's Next Ten Years*' [Hanappi, 2013b] presents my take on the economic policy measures necessary to keep European unification on track. In one of the appendices a radical critique of the quantity theory of money is presented. A more methodological inclined foundation for evolutionary thought in economics is presented in '*Evolutionary Dynamics in Revolutionary Times*' [Hanappi, 2013c]. In [Hanappi, 2014a] a detailed description of evolutionary modelling and how it relates to other macroeconomic approaches is provided. In another book chapter titled '*Unemployment in Mediterranean EU Countries. Fighting Youth Unemployment*' [Hanappi, 2015a] a set of specific new and innovative policy measures to fight unemployment in Mediterranean EU countries is proposed. To study the possible success of such measures as well as how they can be financed is indeed one of the goals of applying an evolutionary simulation model to this question. In a similar vein the book chapter '*Shangri-La Governance. A Sketch of an Integral Solution for European Economic Policy based on a Synthesis of Europe's Problems*' [Hanappi, 2015b] lays emphasis on the strong interconnection between Europe's problems and sketches how their solutions could look like.

- Several *journal publications* related to the project can also be mentioned. Three papers, already published and one presented at an international conference, document the use of our first version of the agent-based model. In '*On the Bottom-up Foundations of the Banking-Macro Nexus*' [Wäckerle, 2013] Manuel Scholz-Wäckerle describes the basic methodological foundations of our simulation model. The actual structure then is depicted by Rengs and Wäckerle in '*A Computational Agent-Based Simulation of an Artificial Monetary Union for Dynamic Comparative Institutional Analysis*' [Rengs and Wäckerle, 2014]. The abstract of this paper gives an excellent overview:

  Abstract—We present a highly stylized agent-based computational model (ABM) of an artificial economic and monetary union. Contrary to other current macroeconomic ABMs, it focuses on the relations/consequences of credit financed, high-leveraged economies, conspicuous consumption within and across borders and a monetary and economic union of individual countries. The model includes a number of boundedly rational agents of the following types: a central bank, states & governments, banks, firms and households. In summary, it enables simulations of interacting political economies within a monetary union, entailing complex interactions and

interdependencies between centralized governments/central banks and decentralized markets for goods (regular and status), labor, loans as well as bonds from the bottom up. Through its modular structure, we are able to apply dynamic comparative institutional analysis by investigating medium and long-run economic effects.

The third of this set of simulation-related papers has the title '*Analyzing the co-evolution of central-bank policies and heterogeneous credit demand in an agent-based artificial monetary union*' [Rengs and Wäckerle, 2015] and has been presented at the Italian Economic Conference in Naples in November 2015. Two other journal publications related to the theoretical background of our work can be mentioned. In '*Evolutionary Political Economy in Crisis Mode*' [Hanappi, 2014b] the need for our new approach of evolutionary modelling is explained by the failure of mainstream approaches to come to grips with the current crisis. And finally in '*Schumpeter and Goodwin*' [Hanappi, 2015c] some important issues for modelling innovation in a macroeconomic context can be found. This was particularly important for the innovation module of economic sectors in A-POEM, see 3.2 below.

The best entry point to a better understanding of our approach in these first years of the project probably is a more concise look at what we now call the Rengs-Wäckerle-Hanappi Model. It is summarized in a short paper presented at a conference in Iceland reproduced here in 1.1. The main methodological idea was to build an economic simulation bottom-up, i.e. to develop simulated artificial economics analogous to the attempt to provide micro-foundations to macroeconomics in mainstream theory.

1.1 The Hanappi - Rengs - Wäckerle Modell

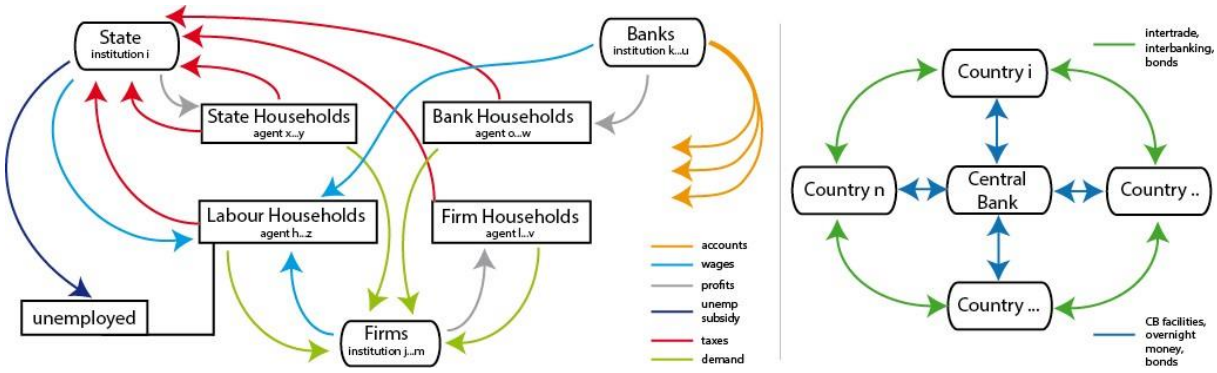
We present a mid-range computational agent-based model (currently ~5000 agents) of interconnected economies, where each economy is developed as a bottom-up macro-economic system. In this respect we follow the recently growing literature on heterogeneous and endogenous macroeconomics focussing on the economy as an evolving complex adaptive system. In particular, our model shares characteristics similar to Delli Gatti et al. (2005), Delli Gatti et al. (2010), Cincotti et al. (2010) or Raberto et al. (2012); for a recent overview compare Bargigli and Tedeschi (2012). This type of agent-based economic models highlights the incorporation of endogenous money in a full-fledged bottom-up economy, thereby following a Post-Keynesian approach, compare also Seppecher (2012) for instance. The fast growing literature and the increasing attention towards this modelling realm in the economic community speaks for the tremendous success of this approach in emphasizing the notion of systemic risk and vulnerability in credit networks between households, firms and banks. Economic stability reaches a new theoretical level beyond general equilibrium economics by synthesizing Post-Keynesian macroeconomics with bottom-up econophysics. Others such as Dosi et al. (2008) introduce Schumpeterian innovation into multi-agent models and look into the business cycles of artificial macroeconomies. Recently this approach got synthesized by the authors with the Keynesian agent-based interpretation for policy investigations between short- and long-run, compare Dosi et al. (2010). The agent-based approach with regards to macroeconomic modelling experiences a fresh spring and the current agendas are majorly given within the mentioned corridors. Open research questions and problems are still manifold from several aspects of non-general-equilibrium economics. A more elaborate paper will elaborate on aspects of agent-based macroeconomic models, which still represent niches in this approach. (1) We derive an interconnected multicountry system from the bottom up representing an artificial monetary union, addressing prototypic within and between interbanking as well as export/import relations. (2) We account for current conflicts within three capital ruling classes (firm-owners, bank-owners and state-owners) and between capital and labour. Insofar we highlight the different role models of agents in action in modern globalized political economies. (3) Our model emphasizes the interactive dimension of agent-based macroeconomic models, in particular the aspect of social learning in local neighbourhoods. Thereby our model is different from models employing micro-simulation techniques, compare Gilbert et al. (2005) or Gilbert (2007) for a disambiguation. In particular, we refer to modelling characteristics presented in Hanappi (2012)[1], as outlined in the following.

Topology, Agents and Institutions

The model connects real and monetary sector across a goods, labour and credit market. It exhibits a price and wage system in dependence of micro-founded production. Firms produce one good conditional on labour input and physical capital. They pay wages with respect to their local market situations, meaning in particular that each firm has its own local consumption community. Firms expect prices adaptively to the changing environment (price competition within the whole firm population), which are matched with households' reservations finally. Households currently buy one unit of good if their reservation price is below the firms' selling price in correspondence with their budget constraints. Banks issue loans to firms in order to recapitalize them (physical capital gets depreciated every round) if the firm's expected rate of profit is above a profitability threshold. Households are able to save their remaining income in bank deposits, visible on the liability side of the banks' balance

sheets. We focus on the bank as a financial intermediary of endogenous credit-money. Therefore, we are able to monitor economic activities in a consistent stock-flow framework, with focus on an integration of balance sheets and the transaction flow matrix, compare Godley and Lavoie (2012, p. 44). The basic monetary flows are given in Figure 1.

Figure 1: Basic Model Architecture – Monetary Flows



Source: flow diagram based on Hanappi (2012, Appendix 1)

Agents and institutions are represented as nodes on the network, where their stock variables (assets and liabilities) are encapsulated. They are connected via links representing the flows of the economy, in particular given by consumption payments (purchasing amount and paid price), wage flows, interest payments, tax and saving flows. Every agent's and institution's account is held by a particular bank. The basic declaration of institutions is given below

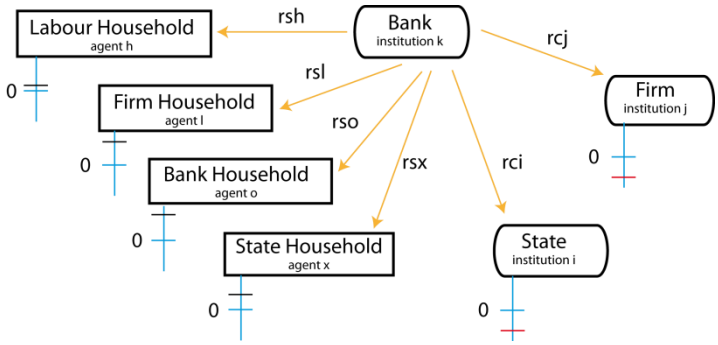
States $(\boldsymbol{i} \ldots \boldsymbol{n})$
States collect taxes on consumption goods, a corporate tax on firm profits, an income tax on worker/employee wages and a tax on bank profits. Major expenditures are currently assumed by the payment of unemployment subsidies, reflecting a basic public social infrastructure. Every country contains institutions (firms and banks) and households (firm-owner-, bank-owner-, state-owners and labour households).

Firms $(\boldsymbol{j} \ldots \boldsymbol{m})$
Firms are implemented as nodes on an institutional layer of the network. They produce and sell one single homogenous capital good with regards to their heterogeneous labour input and homogenous physical capital. Since labour households are randomly distributed, firms are also equipped with different initial labour input. Firms are able to hire and fire workers with regards to their production processes. Residuals stemming from the production and sales activities represent the profit of a firm which is fully transferred to the firm-owner at the end of each period.

Banks $(\boldsymbol{k} \ldots \boldsymbol{u})$
Banks are implemented in a similar way as firms, but produce financial capital respectively. We initialize banks in small and tightly connected oligopolistic interbank markets. Banks hold the accounts of all involved agents and institutions, accordingly they transform savings of one group into credit for another (Hanappi 2012). In our model banks charge different interest rates to the different heterogeneous groups of households of our model, as well as different rates for saving and investment, explained in section 3. Otherwise the central bank is

implemented to lend facilities to banks and to buy bonds already in exchange. Bank relations are monitored within a consistent accounting system, as illustrated in Figure 2.

Figure2: Bank Accounts and Interest Rates



Source: flow diagram based on Hanappi (2012, Appendix 1)

Households

We distinguish between four types of households: Labour households $(\boldsymbol{h} \ldots \boldsymbol{z})$ are engaged in a capitalist-worker relation, where the capitalist can either own a firm, bank or state. We allow for inter- and intra-class conflicts respectively. Bank $(\boldsymbol{o} \ldots \boldsymbol{w})$ and firm owners $(\boldsymbol{l} \ldots \boldsymbol{v})$ govern the processes of industrial and financial capital production and collect the full profits of firms and banks each period. State-owners $(\boldsymbol{x} \ldots \boldsymbol{y})$ respond to these two modes of capitalist production with corresponding endogenous policies. Labour households are randomly distributed across the firm population by initialization. Insofar we distinguish also between workers (producing an industrial good) employed in firms and employees (producing a financial capital good) employed in banks. Firms and banks may fire and hire workers/employees as explained in section 3. In consequence labour households may also be unemployed and involved in a state relation only thereafter. However, all households are free to choose their trading firm independent from their wage relation.

Activities and Dynamics

In our agent-based model time advances in discrete steps (round-based) and agents are updated semiasynchronously in different phases. In general we assume one time step in the model to be roughly equivalent to one month of real economic production and consumption. Thus 100 time periods in the model represent approximately 8 years of economic time respectively; reflecting the statistical time period of a Juglar cycle, compare Hagemann (2008, p. 234). Each turn agents are asked to do the following activities – the timing of events:

- produce (major firm activity)
- invest (firm-bank interaction)
- hire and fire (firm-labour household interaction)
- consume (household-firm interaction)
- save (household-bank interaction)
- pay interest (household-bank + firm-bank interaction)
- collect taxes (household-state + firm-state + bank-state interaction)
- pay unemployment subsidies (unemployed labour household-state interaction)

Production

Firms perform one whole production phase per simulated time step. The production process exhibits the core of this agent-based interconnected artificial monetary union. Although it refers to a fictional and highly simplified mechanism, it entails the basic decision problems for entrepreneurs. Every firm's output is constrained by a Cobb-Douglas production function of the following form:

$$Y_j = A_i * L_j^{\beta} * K_j^{\alpha} \quad (1)$$

The planned output (Y_j) of a firm (j) in a country (i) depends on labour input (L_j) and physical capital (K_j). In the current version of the model we have not yet incorporated any endogenous technical progress and keep the technological coefficient (A_i) constant and exogenously given. This will of course be a crucial parameter for a further empirical calibration and endogenization of Schumpeterian innovation. Labour input refers to the number of workers per firm in this simplified picture. Since the firm is not confronted with fixed costs, wages represent the only costs in this context. Physical capital is heterogeneously distributed over the population of firms. To start with a roughly meaningful value physical capital, K_j is chosen to be optimal for the average firm size, i.e. depending on the number of employees (L_i) for country (i)) and the number of firms (n_i) in country (i)), following from (1).

$$K_j = \frac{L_i}{n_i}\frac{\beta}{\alpha} \quad (2)$$

We plan to use the production coefficients as reasonable variations for the different political economies. Physical capital is depreciated every turn by δ (e.g. $\delta = 4\%$), meaning that every firm needs to constantly reinvest in their machines and equipment. It is assumed that firms do not have perfect information about consumer demand. They try to optimize their profits by firstly determining the expected sales in their consumption neighbourhood in the next time step. Expected sales quantity is derived by a simple mechanism, which leads to an individual price expectation for the following period.

$$p^e_{t_j} = p^e_{(t-1)_j} + \gamma(p_{(t-1)_i} - p^e_{t-1}) \quad (3)$$

The crucial point related to this adaptive expectation mechanism is given by the computed country price $(p_{(t-1)i})$ of the last period. This price represents the average price within a country i computed as the share of revenues and sold quantities. It is understood as a public ex-post price information available for each country in every time step. Firms use this as a reference point to calculate the expectation error from the last period; which is weighted by (γ) as an exogenous parameter for price anticipation. Lower values of (γ) refer to firms resistant to shortterm price changes in the whole market and follow just the trend. Firms with a higher value of (γ) take account of price changes to a high degree and expect the price for the next period more realistically. Future implementations may elaborate on endogenous anticipation weights, changing from within the evolving economy. Furthermore, it is assumed

that firm (j) will not produce below its marginal costs, i.e. the wage per worker. For the sake of simplicity, we currently assume that the firm has a rough expectation about the demand structure and adjusts its production to be a share of the projected sales:

$$q_{t_j}^e = \left(q_{top_i} - p_{t_j}^e * \left(\frac{q_{top_i}}{p_{top}} \right) \right) * \frac{L_j}{m_i} \tag{4}$$

Every firm sets its expected production stock with regards to the market size (q_{topi}) of country (i), which is given by the highest possible quantity of sale in the market (i.e. which is the result of every consumer buying the good).Firms currently a priori assume that the consumers behave very simplistic and thus calculate a fictitious demand curve $q_{top_i} - p_{t_j}^e * \left(\frac{q_{top_i}}{p_{top}} \right)$ for their home market. This expectation gets weighted with regards to the relative firm size in country (i); the share between the size of firm (j), i.e. the firm's labour input (L_j), and the amount of firms (m_i) in country (i). Quantities not sold to the market remain as inventories in the stock of the firm. That means in particular that firms may not need to produce with full capital utilization each round, since they may sell their stock from former periods in the given period. We compare the inventories with the above calculated expected stock every round to adapt production during the period. Since firms optimize their production process they may fire workers in this step if they can rely on a sufficient stock for further selling. Of course this becomes an apparent adaptation issue in the first periods of production (because of the naïve initial expectations which tend to overshoot), in the medium-run firms adopt an adequate production process by hiring and firing on behalf of their expected output. If their stocks can't cover the expected stocks fully, the production process needs to be adapted for the difference between available physical capital and additional physical capital, purchased to sustain production.

Investment

In this case firms may purchase credit-money from banks to recapitalize their physical capital; we assume a full monetarization of physical capital. In order to compute the expected firm profit rate for every firm j as a measure for credit evaluation and potential investment, we need to calculate expected firm profits in advance:

$$\rho_{t_j}^e = p_{t_j}^e * q_{t_j}^e - \sum_{a=1}^{L_{t_j}} w_{t_{j_a}} - (DB_{t-1_j} + DB_{t_j}^e) * (r_{c_j} + rep_c) \tag{5}$$

Expected profits for firm j are given by expected revenue $(p_{t_j} * q_{t_j}^e)$ minus current wages for all currently employed workers. In addition firms need to pay interest (r_{cj}) on previously accumulated credit debt $(DB_{(t-1)j})$ as well as credit repayments with a given repayment rate (rep_c) for the previously accumulated credit debt (currently a simplistic mechanism). $(DB_t{}^e{}_j)$ represents the expected purchase of additional credit for the following round, depending on the difference between available and additionally demanded physical capital to sustain production in our case. Endogenizations of the interest rates are of particular importance for further simulation experiments. Furthermore if profits are positive, then every firm profit (ρ_{tj}) is transferred to the firm owner at the end of the period. We refer to profits respectively (ρ_{tl}) for each firm household l. With computed firm profit expectations we may focus on the expected profit rate now.

$$\pi^e_{t_j} = \frac{\rho^e_{t_j}}{K_{t_j}} \tag{6}$$

With reference to Hanappi (2012) we define the expected profit rate as the ratio between expected profits $(\rho^e_{t_j})$ and physical capital stock (K_{tj}) of firm (j). Credit-money for re-investment in physical capital is purchased if the expected profit rate is above the interest rate on firm credits.

$$if\ \pi^e_{t_j} > r_{c_k}\ then\ invest \tag{7}$$

In case of (6) the firm's physical capital receives a reinvestment of (DB_{tj}), reflecting the current credit debt supplied by bank (k), which is added to the asset side of the bank and to the liability side of the firm in correspondence. We assume that every firm maintains credit relations with just a single bank at the moment. If (6) is not fulfilled, the firm cannot afford further reinvestment (credit-driven production) and needs to cool down production to a new output level. If there are still more than one worker employed in the firm, it is able to fire workers. In that case it firstly reduces the level of output (Y_j) with regards to given physical input and secondly labour input (L_j) aiming for the new output target. If this newly calculated labour input is above the actual amount of workers, we need to cool down production to the lowest level in this case, producing inefficiently thereafter. Otherwise the firm may still fire more workers, then the type of the labour household switches to unemployed.

Consumption

All households consume either one or no good per period depending on their reservation prices. Currently reservations are equally distributed across each household population with regards to a country-dependent maximum price. The labour household population represents the greatest share within households and is initialized with a fine granularity of reservation prices therefore. Firm, bank and state owners (still households) have higher reservation prices respectively with regards to the median. In the basic version of the model every consumer randomly chooses firm for trade and maintains this connection, thereby consumers do not vary between producing firms. If the reservation price is higher than the proposed price and firms still have quantities in stock, then one unit is traded. After all trades have been completed, average price for the whole market in country (i) is computed with respect to actualized revenues and traded quantities. This average country price represents the reference price for the new expectations in the following period. Then, realized assets and liabilities are computed for each firm. Afterwards we calculate the real profits made by firms and transfer them to the firm owners if they are positive.

Firm bankruptcy

With regards to the evaluations at the end of a consumption period, a firm may also end up with a negative account. Respectively the firm may go bankrupt if it exceeds a certain debt risk threshold determined by its bank. For that very reason we compute the debt ratio of every firm and compare the debt and the account with the remaining physical capital. Then it depends on the bank's heterogeneous risk aversion to either drop the firm or to keep it alive.

Risk aversion becomes a key parameter for further developments with regards to systemic risk in firm-bank networks and interbanking across the economies. In case of firm insolvency all customer relations are dissolved initializing search for a new selling firm randomly. In consequence the firm-owner gets unemployed.

Saving/Overdraft

Households save remaining money after trade. Banks assign interest rates on savings for labour households (r_{sh}), for firm- (r_{sl}) state owners (r_{sx}) and for bank owners (r_{so}). Every period banks update their assets and liabilities with regards to these interest payments. Households hold their saving account at their connected bank. We address interest on overdraft (r_o) in the same manner. With regards to interest payments and savings we assume that the ruling class receives a discount, since greater values of accumulated wealth are involved. In dependence on the bank's in- and outgoing interest payments we are able to calculate the bank's profit. The revenues (R_{tk}) of the bank contain all interest income on outstanding credit and current overdraft by its debtors. The costs (C_{tk}) of the bank refer correspondingly to the bank's interest payments on household savings and positive institutional accounts. Revenues are given by their difference conclusively:

$$R_{tk} = Liab_{tx} * r_{ox} + Liab_{ti} * r_{oi} + Liab_{to} * r_{oo} + \sum_{l=1}^{dk}(Liab_{tl} * r_{ol}) + \sum_{h=1}^{ek}(Liab_{th} * r_{oh}) + \sum_{j=1}^{fk}(Liab_{tj} * r_{oj}) + \sum_{j=1}^{fk}(DB_{tj} * r_{ck}) \quad (8)$$

…where (d_k) relates to the number of firm-owners connected to bank (k), i.e. their industrial capitalist customers; (e_k) relates to the number of labour households connected to bank (k); (f_k) relates to the number of firms connected to bank (k). The revenues of bank (k) depend on the sum of overdraft payments on liabilities of connected customers plus the accumulated debt of purchased credits of firms. At the moment there is just one or none state and state household connected to the bank, in consequence we don't need to accumulate in this case ($Liab_{tx} * r_{ox} + Liab_{ti} * r_{oi} +$).

Bank costs are described correspondingly with regards to interest payments on savings.

$$C_{t_k} = Asset_{t_x} * r_{s_x} + Asset_{t_i} * r_{s_i} + Asset_{t_o} * r_{s_o} + \sum_{l=1}^{d_k}(Asset_{t_l} * r_{s_l}) + \sum_{h=1}^{e_k}(Asset_{t_h} * r_{s_h}) + \sum_{j=1}^{f_k}(Asset_{t_j} * r_{s_j}) \quad (9)$$

Assets refer to the current savings of involved agents. In sum profits (ρ_{tk}) of bank (k) are given by revenues minus costs, as stated in (10).

$$\rho_{tk} = R_{tk} - C_{tk} \quad (10)$$

The profits of bank (k) are then transferred to the bank owner (o) if there are any, following the same logic as explained previously in context of firm profits.

Taxing and unemployment

Basically we implement taxes on value-added (t_{vati}), income (t_{inci}) and firm- $(t_{\rho i}j)$ bank- $(t_{\rho i}k)$ profits.

Collected taxes equip the state with purchasing power for infrastructure investments and periodical payments. At the moment the state maintains just one social infrastructure, i.e. unemployment subsidies. In the simulation we initialize unemployment at 10% of all labour households for state (i). States currently compensate 50% of the initial wage level for unemployed agents.

Outlook, and Experiments

We are looking forward to discuss preliminary simulation results with regards to the endogenous dynamics in the basic version of the model. Beyond this basic version's intra-country closed economy actions we are currently implementing inter-country actions for empirically calibrated country profiles for 3-5 economies. The latter refer to export/import transactions between firms and customers of two different countries, firm-bank interactions in multiple countries and in the future also firm-firm interactions with intermediate goods. In particular banks will be equipped with different generic credit-rules for bank lending on a cognitive, behavioural and social level in a prototypic way, as proposed in Wäckerle (2013) in the long run.

In future versions of the model we plan to use the simulation as a test bed for different sets of unconventional monetary policy by the central bank, e.g. lending facilities and quantitative easing.

Further simulation experiments of this agent-based artificial monetary union will focus on the political conflicts between the stated three different ruling classes. In this respect we are looking forward to discuss systemic vulnerability within an artificial monetary union as an emergent property of political processes involving different ruling classes in the evolution of capitalism.

References

Bargigli, L. and Tedeschi, G. (2012), 'Major trends in agent-based economics,' *Journal of Economic Interaction and Coordination*, DOI 10.1007/s11403-012-0105-6.

Cincotti, S., Raberto, M. and Teglio, A. (2010), 'Credit Money and Macroeconomic Instability in the Agent-Based Model and Simulator Eurace', *Economics: The Open-Access, Open-Assessment E-Journal*, Vol. 4: 2010-26. http://dx.doi.org/10.5018/economics-ejournal.ja.2010-26.

Delli Gatti, D., Di Guilmi, C., Gaffeo, E., Giulioni, G. Gallegati, M. and Palestrini, A. (2005), 'A new approach to business fluctuations: heterogeneous interacting agents, scaling laws and financial fragility', *Journal of Economic Behavior & Organization*, Vol. 56 (4): 489-512.

Delli Gatti, D., Gaffeo, E. and Gallegati, M. (2010), 'Complex agent-based macroeconomics: a manifesto for a new paradigm', *Journal of Economic Interaction and Coordination*, Vol. (5): 111-135.

Dosi, G., Fagiolo, G. and Roventini, A. (2008), 'The microfoundations of business cycles: an evolutionary, multiagent model', *Journal of Evolutionary Economics*, Vol. 18 (3): 413-432.

Dosi, G., Fagiolo, G. and Roventini, A. (2010), 'Schumpeter meeting Keynes: A policy-friendly model of endogenous growth and business cycles', *Journal of Economic Dynamics and Control*, Vol. 34 (9): 1748-1767.

Gilbert, N., Troitzsch, K. G. (2005), *Simulation for the social scientist*, 2nd edition, Open University Press, Berkshire, UK

Gilbert, N. (2007), *Agent-Based Models (Quantitative Applications in the Social Sciences)*, Sage Publications London, London, UK

Godley, W. and Lavoie, M. (2012), *Monetary Economics. An integrated Approach to Credit, Money, Income, Production and Wealth*, 2nd edition, Palgrave MacMillan.

Hagemann, H. (2008), 'Schumpeter on development', in Shionoya, Y. and Nishizawa, T. (eds.) (2008): *Marshall and Schumpeter on Evolution: Economic Sociology of Capitalist Development*, 225-243, Edward Elgar Publishing, Cheltenham, UK.

Hanappi, H. (2012), 'Can Europe Survive? Ten Commandments for Europe's Next Ten Years', *Papers in Evolutionary Political Economy* Nr.9.

Raberto, M., Teglio, A. and Cincotti, S. (2012), 'Debt Deleveraging and Business Cycles. An Agent-Based Perspective', *Economics: The Open-Access, Open-Assessment E-Journal*, Vol. 6: 2012-27. http://dx.doi.org/10.5018/economics-ejournal.ja.2012-27.

Seppecher, P. (2012), 'Flexibility of Wages and Macroeconomic Instability in an Agent-Based Computational Model with Endogenous Money', *Macroeconomic Dynamics*, Cambridge University Press, Vol. 16 (s2): 284297.

Wäckerle, M. (2013), 'On the bottom-up foundations of the banking-macro nexus', *Economics Discussion Papers*, No 2013-5, Kiel Institute for the World Economy. http://www.economicsejournal.org/economics/discussionpapers/2013-5

Several other papers by Manuel Scholz-Wäckerle and Bernhard Rengs more or less followed the approach described in the Hanappi-Rengs-Wäckerle Model, see [Wäckerle, 2013], [Rengs and Scholz-Wäckerle, 2017], and [Rengs and Scholz-Wäckerle, 2018]. Till today, most research in economic modelling that uses agent-based approaches still adapts microeconomic assumptions and uses them to derive issues that emerge at the macro-level by combining the simulated consequences – mostly co-ordinated by assumed, specific market mechanisms. These simulations clearly provide more adequate results than those that are derived with the much stronger and simpler assumptions that the analytical apparatus of difference-differential equation systems forces upon mainstream macroeconomics. It can therefore be expected that work in this area will be gain ground as a valuable tool for economic policy consulting.

Nevertheless, our methodological aspirations pointed beyond this type of mimicking the task of microeconomic foundation building, of a better equipped computational microeconomics. The doubts on the prevailing methodological starting points are highlighted in the next chapter. They prepare the ground for the second phase of the methodological framework we arrived at towards the end of the project.

1.2 Agent-based approaches in simulation modelling

When Markus Rohringer joined the project, substituting Manuel Scholz-Wäckerle who took on a job as senior lecturer at WU Vienna, he already had a rich experience with agent-based models. In particular, he had been working on the simulation of innovation activities of firms and its impact on market structures. In this chapter he provides his view on agent-based methodologies and highlights its relationship to pragmatism.

1.2.1 Agent-based approaches in simulation modelling

The dissatisfaction with neoclassical economics has many reasons. Among others, one of the biggest targets for critique is the empirical plausibility and the plausibility and validation of the results.

In terms of a general paradigm, agent-based modelling in economics is often related to the school of evolutionary economics. While this is such a heterogeneous stream of economic thoughts that it is impossible to give a clear-cut definition, looking at several authors in the field reveals certain tendencies and common characteristics, which automatically come with a critique of standard economics.

Evolutionary Economics as Foundation and Critique of the Mainstream

In some way, all of the authors begin with a critique of the standard economics. However, I want to point out Arthur (2006), Dopfer (2003) and Potts (2000). Arthur interestingly enough never speaks explicitly about evolutionary economics, but rather about out-of-equilibrium economics. He clearly comes from the side of agent-based modelling, but is in my opinion right in saying that all the economic branches like complexity economics, agent-based modelling or adaptive economics are nothing more than different manifestations of one new economic path, only with different specialties and nuances. We would call that path evolutionary economics; he prefers out-of-equilibrium economics, simply to point out the differences to equilibrium economics, which he heavily criticizes. Nevertheless, he states that “evolution emerges naturally from the very construction of such modelling” (Arthur [2006]). The key element of his proposed approach is perpetual novelty. Here he states, not surprisingly, that standard economics cannot produce perpetual novelty with its equilibria, but an evolutionary approach can.

However, it gets more interesting when he points out two more concrete problems of standard economics and how they could be solved with the new approach. The first one is the problem of multiple equilibria. Standard economics can be used to identify different consistent patterns, but cannot tell us how one is chosen – there is an indeterminacy. Arthur proposes therefore to see the problem not as the selection of one of several god-given

equilibria, but as one of constant equilibrium formation. It then becomes a dynamic process with random events, where different equilibria can emerge under the same conditions.

The second problem is similar, it is about expectational indeterminacy. To put it short, Arthur describes his famous El Farol bar problem, where rational expectations wouldn't work at all (the outcome they predict could never be realized). But with an agent-based formation of expectations (internal model building of the agents), this problem can be solved. In summary, Arthur sees this out-of-equilibrium theory not in competition to equilibrium economics, but rather the latter as a special case of the first. This is of course a clever way to put the new theory ahead of the old one.

Dopfer on the other hand uses a more epistemological, but to us even more enlightening approach to describe the foundations of evolutionary economics. He speaks in terms of paradigms (unquestioned believes that determine the way of building theories) and compares the standard economic paradigm (he calls it a mechanistic, neo-classic economic paradigm) to the new evolutionary one. He compares the ontological assumptions of these paradigms and describes the evolutionary one as histonomic, in contrast to the nomological program. Histonomic means that there is a local repeatability of phenomena, but there is also a historical context, which makes global repeatability impossible (at some point, there is a change). He then describes three different mechanistic axioms and compares them with their evolutionary pendant.

The first axiom says that every matter-energy actualizes itself, and it is doing this in one specific way. The evolutionary paradigm agrees on the first part, but doesn't believe in one specific way, which could be called some universal law. Instead, not only are there multiple ways for actualization for a given point in time, but the set of those different ways also changes for every point in time. In a mechanistic paradigm all single particles of matter-energy follow the same path (trajectory). As the law of this trajectory is invariant, for a given starting condition, there is no variety in the actualization. Following the thought of Epikur and his clinamen, some of the particles "at times quite uncertain and at uncertain places, (...) swerve a little form their course, just so much, that you might call it a change of direction".

The second axiom says that all particles are isolated. This is based on Newtons mechanics, where every particle follows its own laws. There is no feedback between micro- and macrobehaviour. Dopfer doesn't really declare the evolutionary counterpart to this, but it's obviously the complete opposite, so that there is feedback, the consequences of the actions of particle recoil to itself.

The third axiom then states that particles are continuous. The classical model describes only continuity, not discontinuity of movements. In Newtons mechanics, there is no causality, no

reason given for the beginning and the ending of a movement. Of the three phases "origination", "continuation" and "termination", only the middle one is described endogenous, the other two are exogenous. It is no big surprise that in the evolutionary paradigm, all three are endogenous.

A somewhat similar, because also ontological attempt to unify the view on evolutionary economics comes from Potts. In his book "The New Evolutionary Microeconomics" Potts not only criticizes standard economics, or, how he calls it, neowalrasian economic theory. In the course of his critique he also tries to unify the perspective of all 'heterodox schools', by saying that they in fact all criticize the same main issue of the 'orthodox school', but are either not really aware of it, or just come from so different starting points, that they look at the same topic from too different angles. This is a rather brave attempt, as Potts includes in these heterodox schools among others the Evolutionary, Realist, Behavioral, Institutional and even Austrian and Post- Keynesian school.

So, even as it is obvious that all these schools criticize certain aspects of standard economics, it is at first glance hard to believe that all their critique can be unified into one fusion. So what is this mystical key aspect underlying the neowalrasian economic theory that is the target of this unified critique? According to Potts it is the concept of the field.

The neowalrasian economic theory is built on a real field Rn. There hasn't been much critique to this concept, as it was very successful in mathematics (foundation of integral and differential calculus), and therefore it is also the underlying principle of modern science - natural sciences especially. This tremendous success made obviously a huge impression on economists, who ever since tried to make economics more 'scientific' and adopted this concept. But what is the problem then and why shouldn't the field concept be as successful in economics as it is in physics? Potts argues that the main problem with this concept is, that it does not recognize connections as own elements. Rather in a field it is automatically assumed, that all elements are connected with each other, or as we can see in general equilibrium theory, "that everything is a function of everything else must be understood to be literally true" (Potts [2000]).

For Potts, in physics this is no problem, as in a gravitational field indeed everything affects everything. But for economics it seems rather unrealistic to assume this universality. As soon as it can be shown that not everything is connected with everything, there exists no legitimation for the concept of a field anymore. Rather should the focus lie on specific connections, which become elements themselves and can have their own properties, because otherwise

> Interactions, knowledge and structure are specific connections between points in space and therefore the very existence of these concepts is excluded by the assumption that all points relate, a priori, to all other points directly; that is, with a single mathematical operation... In a field, 'interaction' does not mean anything because there is no example of non-interaction - everything interacts with everything else.
>
> (Potts [2000])

But what is then the answer to this problem? How can you give these connections meaning? According to Potts there is only one way to realize this, and that is by the usage of graph theory and complex systems. Therefore, he suggests that there are only two hard-core propositions which build the ontological backbone of evolutionary economics:

- Evolutionary-HC1: There exists a set of elements.
- Evolutionary-HC2: There exists a set of connections.

(Potts [2000])

While this seems rather trivial and the first proposition doesn't differ from what we already know from standard economics, the implications of the second one should not be underestimated. It sets the connections on the same level of importance as the elements. This is especially important regarding innovation, because combination and recombination of elements is strongly dependent on the connections of these elements. We can observe in reality that novelty is only very seldom created by the introduction of completely new elements. It is most of the time even not about which elements are combined, but rather how they are combined - for example in which order, with which manufacturing process, and so on.

Features of Agent-based Models

Agent-based Models try to overcome the fallacies of equilibrium-based models in the spirit of evolutionary economics. A short definition is given by Caiani (2015):

> Agent Based Models (ABM) in Economics conceive the economic system as a **complex adaptive system** composed of **heterogeneous, adaptive** economic actors intertwined through an **evolving network** of **local interactions** taking place within a well-structured space.
>
> These interactions concur in shaping the **emergent properties** of the system. Continuous feedbacks between micro and macro levels.

We can find a similar definition by Epstein (2006), one of the founding fathers of ABM. According to him, the most common features are:

- Heterogeneity
- Autonomy
- Space and Local Interactions
- Bounded/Procedural Rationality
- Focus on Out-of-Equilibrium Dynamics
- Non-Linearities

Let's have a look at these features in more detail.

Heterogeneity

In Agent-based models, every agent is explicitly modelled. Typically, we have different classes of agents that can differ from each other in terms of preferences, heuristic behavior and so on. Realistically within each of these classes we have a certain homogeneity, often especially regarding their behavioral rules. In theory though, we could model each agent separately.

Additionally, there are stochastic influences, for example the initial placement of the agent within the simulation space or a random social network that connects each agent with other agents (more on that later on). So even within an alleged homogenous population there can emerge heterogeneous developments because of previous (stochastic) conditions, since we usually have path-dependency.

Autonomy

While usually agents are given a rather limited set of behavioral rules on which they can act on, their actual decision making is autonomous at execution time. Often their perceived environment is crucial in this decision process. Therefore, while looking at a single agent decision, the result of this single decision should not come as a surprise to the modeler if she knows all parameters. However, since each other agent is constantly changing the environment with their own decisions, the development of this agent might come as a surprise – as well as the emerging macro-results of the simulation as a whole.

While most agent-based models are still based on simple heuristics, we could have more complex degrees of learning. The agents might be able to adapt their own behavioral rules based on their perception. Again, these meta-rules have to be defined by the modeler, but it should be easy to imagine that this adds a whole new layer of complexity. Examples for more complex algorithms would be neural networks or genetic algorithms.

Space and Local Interactions

Most agent-based models possess some sort of spatial structure. There is no limit to the abstractness of this space. It can be a physical map, maybe even based on real geodata or maybe a more simplified artificial space that represents the distribution of resources, interactive objects and of course agents. Often the agents are able to move within this space and, like it is often the case in reality, only interact with other objects or agents if they are in their vicinity and not with the whole population. The concepts of "local" and "neighborhood" are therefore often quite important in these models.

However, we can also realize space in a less physical way. For example, we could model a social network, where the closeness between two agents is characterized by the distance of their links or how many common nodes (for example common friends) they have. Often, the behavior of agents is adaptive to some extend or at least influenced by their (social) neighbors, which means that we might be able to observe the emergence of behavioral cliques.

Bounded Rationality

One of the biggest targets for critique on mainstream economics is the hyper rational agent with perfect information. Experimental and behavioral economics has shown however, that people in reality never act like that. Instead, they usually follow simple heuristics. Often, these simple rules are formed by a process of trial and error and are therefore adaptive. On the one hand, these heuristics are necessary because people have bounded computational ability (or the effort of actually "computing" the problem would excess the probable benefit) or, related to that, limited time in ad-hoc decisions.

On the other hand, they often simply do not have perfect information. They are most likely not experts in all areas that would influence their decision or they simply lack the access to all the relevant data. Often there is also a cognitive bias and a certain difficulty in dealing with uncertainty. This can be shown by experiments regarding problem framing. Depending on how information is presented, people might react in different ways, even though the facts are the same and there is no lying involved.

Out-of-Equilibrium Dynamics

This topic targets another point of critique regarding neoclassical economics: The general equilibrium. In agent-based models, equilibria are of no initial concern. Behavioral rules on the agent level are defined as well as initial conditions. Then, after the simulation is running for some time, macro-phenomena emerge. This however does not exclude equilibria per se. They might occur, but as in reality, often they are only temporary. Often there is a certain tipping point at which local stability ends and another era of instability begins.

We can have all sorts of developments. There can be a tipping point in the other direction where the system locks in a equilibrium and does not change significantly anymore. There might also be a cyclic development where different stages follow each other repeatedly. The system might also get completely out of control and could "explode" (for example exponential growth of the population) or "die" (for example, all agents disappear and there is no possibility for recovery). The latter obviously could be seen as some sort of equilibrium as well. In very complex system, we might not be able to observe any regularity at all, but we could find upper and lower bounds for certain variables.

Either way, in agent-based modelling the focus is clearly put on the process rather than on the final state (which might not even exist). So, even if there is no equilibrium, we can still analyse the results of the model and draw conclusions. This requires different methods of economic analysis (for example the Monte Carlo method) but at the same time can provide a more comprehensive analysis.

Non-Linearities

Agent-based models, or maybe computational economic simulations in general, are usually non-linear. As we already said, there exists path dependency, because of the interactions between the agents itself and the results of their action for their environment. We have

multiple feedback loops between different tiers of the model. Additionally, every time we start the simulation with different starting conditions, we follow a different path.

Only very simple models that lack any stochastic influence might produce the same result over and over again. Usually at least some of the starting conditions are always stochastic, for example the placement of the agents and their connections. This volatility is also one of the biggest weak points of agent-based models and one of the reasons why we need certain analytical tools (like the Monte Carlo method to compensate for the volatility) and the possibility of empirical validation.

1.2.2 A plea for pluralism: Truth and Knowledge in Economic Modeling in the Light of Pragmatism

In the course of this work, the lines between different modelling and implementation techniques have blurred. While we might call our model an agent-based one, it is different from typical micro-based ABM by implementing representative agents and ideas from game theory while at the same time using equation-based frameworks and econometric estimations. In this chapter, we will take an epistemological excurse with a focus on the pragmatic school of Dewey to show why such a pluralism with focus on the solution rather than terminology is necessary. The new heterodox approaches enrich the economic landscape towards a more pragmatic direction.

Introduction

The matters of truth, knowledge and methodology have always been substantial issues in the self-reflection of economics as a science. This is motivated by the very question itself: “What actually makes economics a scientific and not merely an engineering discipline?” Faced by this constant doubt - from within and without - it is not very surprising that neoclassical economists in the 20th century felt the urge to become, or at least appear more scientific by trying to copy the methodology and language of natural sciences. This was not only characterized by a turn towards the increasing use of mathematics, but also by incorporating the views of logical positivism. Even then, it seemed to be already characteristic for economics to lag substantially behind its role models: While physicists had surpassed the Newtonian mechanistic paradigm of linear systems long ago, economists only started to discover it for themselves.

In an idealistic - from today’s view maybe naive - way, they attempted to find the universal laws of economics. One heavily influential publication was “The Methodology of Positive Economics” by Friedman in 1953. His line of arguments defines positivism primarily in the contrast to normativism and reduces it to a difference between descriptive and prescriptive economics, while being heavily in favor of the former. This implies a questionable possibility of full objectivism and the neglect of any values contained within the theories. Even then, it

would be a whole argument on its own if there could be any descriptive results that do not imply prescriptive consequences in social sciences. However, the bigger issue here is, that his work among others legitimated an epistemological approach of "as-if" modeling, describing an ideal state rather than what can be found in daily experience, culminating in a theoretical general equilibrium that is only disturbed by stochastic shocks.

Even though the discipline has distanced itself from the positivistic attempt of finding universal laws and general equilibrium theory in its classical sense, some of the basic assumptions and habits still run deep. The homo economicus - a representative agent with perfect rationality - is still there, as well as the highly stylized mathematical models. These models led to the economists' reputation of being mere puzzle solvers - puzzles that would not exist in the first place without them and their methodology. However, we also see a strong shift towards more pluralism, caused by different economic heterodox schools, whose growing influence was even further accelerated by the recent economic crisis. There is also a tendency towards empiricism. Instead of universal laws, rather small and local questions are tried to be answered by econometric analysis. Inductive reasoning, carried out via sophisticated variable generation and statistical techniques, grows more important than sticking to a certain theory; it can even be perceived as a "de-emphasis of theory" (Milberg, 2004).

Given these developments and the special position of economics - being a social science that acts like a natural science - it is interesting to look at the epistemological and methodological aspects that we now only briefly touched from a philosophical point of view. It is our belief that economic modeling turns unconsciously towards a pragmatist methodology. The aim of this chapter is to find this connection with an emphasis on Dewey, the third of the three founding fathers of pragmatism, and there especially on his theory of inquiry. The chapter is therefore structured the following way: In the next section, we will further elaborate the points already introduced briefly, examine the basic issues in terms of truth and knowledge in economics, why they provided critics with such a big target and what is changing right now. The third part will introduce some key ideas of Dewey's pragmatism and investigate the meaning of these concepts for social sciences. In the fourth section, Hands' identification of four pragmatic features in contemporary science theory is presented and linked with the state of arts in economic modeling. The paper will conclude with collecting the actual implications of the previous insights on economic methodology, by other authors as well as in our own view, which will argue in favour of pluralism and heterodox approaches.

The Struggle with Truth and Knowledge

If we want to boil them down to their core message, all concerns that gave rise to critique can be summarized by the two statements:

- Economics tries to substantiate its claim to be a proper science by imitating natural sciences through universal, mathematical laws.
- Economics is completely out of touch with reality and solves self-created puzzles instead of trying to explain real economic phenomena.

Interestingly enough, on a first glance these two views seem to contradict each other. How can a discipline at the same time be out of touch with reality and claim to provide universal laws for exactly that reality? We will see however, that these problems are highly connected and stem from a deductivism that is innate to the nature of economics and is hard to overcome. In this chapter, we will try to combine the views of different authors that come from different starting points with different terminology, but it is easy to realize that they are talking about the same issues.

Mill's Methodology

A good introduction to this topic is delivered by Viskovatoff (2004). According to him, mainstream economics still follows Mill's methodology, which starts by dividing sciences into experimental and deductive. In his view, every science starts out as experimental and only with collecting empirical knowledge can transform into a deductive one, when the laws of the domain of interest are understood well enough.

> Economics is exceptional in that it starts by being a deductive science. The reason for this is that experiments are very difficult in economics [...]. The fact that from its origins economics has avoided the experimental method does not compromise it empirically, for two main reasons. First, in the economic domain, it is not difficult, simply by means of "casual empiricism", to determine what the important cause that should be looked at is: it is people's desire to increase their wealth. [...] Second, even though one develops the theory deductively, this does not mean that the science as a whole does not maintain an empirical contact. This is because when the theory is applied, one does aim to verify its conclusions. (Viskovatoff, 2004, p. 272)

While Viskovatoff criticizes both claims himself, he seems to be of the opinion, that they are still part of contemporary economic modeling. Over ten years have passed since his writing and we would slightly disagree on both. The hyper-rational utility-maximizing agent is a constant target of critique, even in mainstream economics. The second claim is still true to some extent, but as we will cover later, there is a strong shift from theory-driven models to data-driven econometric analysis.

Viskovatoff takes an interesting turn in his treatment of the topic by focusing on Hausman (1992) who calls economics an "inexact and separate science". It is separate because it ignores the empirical evidence that speaks against rational choice and "one confronts theory with observation when one *applies* it for practical purposes, not when one is 'developing' it." (Viskovatoff, 2004, p. 273) It is inexact because there are no "exact" economic laws, but "inexact" ones.

Heterodox Critique

Unsurprisingly, a lot of critique of mainstream economic modeling comes from the side of heterodox schools of economics. Often the critique is on an ontological and methodological level, but Dopfer (2003) also provides an epistemological one. He speaks in terms of paradigms and compares the standard economic paradigm (he calls it a mechanistic, neoclassic economic paradigm) to the new evolutionary one. He compares the assumptions of these paradigms and describes the evolutionary one as histonomic, which means that there is a local repeatability of phenomena, but there is also a historical context, which makes global repeatability impossible (at some point, there is a change). In contrast, mainstream economics is nomological, which again refers to general laws that are always deterministic.

Another line of critique, that is more on an ontological level, comes from Potts (2000), who also uses it to promote the research program of evolutionary economics. The argument, however, is interesting on its own, as it puts another complexion on the problem of mathematical models. According to Potts, the source of the problem is the concept of the field. The mainstream economic theory is built on a real field R^n. There has not been much critique to this concept, as it was very successful in mathematics (foundation of integral and differential calculus), and therefore it is the underlying principle of modern science - natural sciences especially. What is the issue then and why should the field-concept not be as successful in economics as it is in physics?

Potts argues that the main problem with this concept is that it does not recognize connections as distinct elements. Rather in a field it is automatically assumed, that all elements are connected with each other, or as we can see in general equilibrium theory, “that everything is a function of everything else - must be understood to be literally true” (Potts, 2000, p. 12). For Potts, in physics this is no problem, as in a gravitational field indeed everything affects everything. However, for economics it seems rather unrealistic to assume this universality. As soon as it can be shown that not everything is connected with everything, there exists no legitimation for the concept of a field anymore. Rather should the focus lie on specific connections, which become elements themselves and can have their own properties. According to Potts, the way to realize this is by the usage of graph theory and complex systems.

Disentanglement from Reality

By now, the reader might be already able to picture how the standard approach could lead to a disentanglement of theory from economic reality. If there are no exact laws, but economists struggle to postulate them nevertheless, how can we expect any predictive power? However,

the deductive approach found a reinforced legitimation by Friedman's (among others) "as-if" argument with the famous billiard analogy:

> Consider the problem of predicting the shots made by an expert billiard player. It seems not at all unreasonable that excellent predictions would be yielded by the hypothesis that the billiard player made his shots as if he knew the complicated mathematical formulas that would give the optimum directions of travel, could estimate accurately by eye the angles, etc., describing the location of the balls, could make lightning calculations from the formulas, and could then make the balls travel in the direction indicated by the formulas. Our confidence in this hypothesis is not based on the belief that billiard players, even expert ones, can or do go through the process described; it derives rather from the belief that, unless in some way or other they were capable of reaching essentially the same result, they would not in fact be expert billiard players. (Friedman, 1953, p. 21)

In the meantime, other influential economists, for example Paul Krugman, have heavily criticized this analogy. The basic line of argument is that even expert players deviate from the perfect shot, and that only this imperfection makes the sport interesting. The same is true for economics. Often the smallest deviations are the true reason for the dynamics that we observe. However, the historic influence of this stance cannot be underestimated and is lasting until today. Of course, economic modeling has developed since then and many extensions have been made to tackle the targets of critique. Still, many artifacts that are rooted in this "as-if" methodology survived until today in one form or another, among them (general) equilibria, representative agents, rationality and so on.

If there is one thing that is easy to find in the literature, then it is critique of the disentanglement of economics from reality - often formulated rather bluntly. One such strong critique, chosen just representatively for many others, comes from Boettke et al. (2004). They quote the American cynic Will Rogers by describing "an economist as someone who can tell you what will happen under any given circumstances and his guess is liable to be as good as anyone else's." While the question, if economic modeling should actually aim to be prescriptive - we argue that you can't build a predictive model without implying a prescription for an ideal policy - is still to be answered, it seems to be true, that "economics falls into disrepute because economics discusses matters which touch on everyday life, yet it seems that economists are talking about something so remote from the world within which we dwell in our everyday life." (Boettke et al., 2004, pp. 327-328).

Development over Time

One could argue that such a fatalistic view neglects recent developments in economics. A more differentiated picture is provided by Milberg (2004), who divides the history of economic modeling in three eras. According to him, all the criticism towards deductivism only truly applies to the first and longest era, the one of general equilibrium analysis that dates back to the 1870s. However, according to him, it is not the "mathematization" per se, that characterized this era, but rather a particular mathematics, based on the dominance of axioms.

He distinguishes the general equilibrium paradigm from what followed in the late 1970s, a movement that he calls the "New Economics". The reason for this change that he provides does not lack a certain cynicism: "Poor predictive power has never led to the demise of a dominant paradigm in economics, and the reason for the professional decline in status of general equilibrium analysis must be found elsewhere. The answer seems to be at a stage

prior to prediction that of hypothesis generation itself - that is, in the 'context of discovery' as opposed to the 'context of justification'." (Milberg, 2004, p. 361)

Features of these new approaches were imperfect market competition, asymmetric information, increasing returns to scale and so on. According to him, even more important was a methodological move away from hypothetico-deductivisim towards a creeping inductivism. However, with increasing flexibility, these models soon were faced with the critique of "ad hocery" and that they basically could predict any outcome, based on the implemented assumptions. They were even more stylized mathematical models and a change in a single assumption could lead to complete different results - therefore they lacked the robustness that was so much pursued in the general equilibrium tradition. This robustness was replaced by mathematical traceableness as "criterion for the choice of functional form".

Milberg continues his argument by stating that the creeping inductivism in combination with the legitimacy crisis of the New Economics opened the door for a move towards empiricism. "International economists, for example, may now ask simple, open-ended, experientially relevant questions, and apply sophisticated statistical techniques to answer them." (Milberg, 2004, p. 366) These works do not necessarily provide answers that "test" a particular theory. Instead, "hypotheses are often rooted in simple economic logic, intuition, or current events, and emphasis is placed instead on the sophistication of the measurement of variables and the techniques used to show correlations between and among variables." The question that he poses is whether this new trend is a turn in a truly pragmatist sense or simply naive falsificationism?

Dewey's Pragmatism and Social Sciences

Before we can try to answer this question in the next section, we first have to dive into pragmatism, even if only in a very cursory way. Pragmatism suffered - and still suffers - heavily from the over-simplified caricature to which it is reduced by its critiques, according which it asks only about "what works" and sets utility equal to truth.

James' "Cash-Value"

This mostly stems from some of James' (the other big advocate of classical pragmatism, next to Peirce and Dewey) rather controversial statements, for example:

> Where our ideas [do] not copy definitely their object, what does agreement with that object mean? [...] Pragmatism asks its usual question. "Grant an idea or belief to be true," it says, "what concrete difference will its being true make in any one's actual life? What experiences [may] be different from those, which would obtain if the belief were false? How will the truth be realized? What, in short, is the truth's cash-value in experiential terms?" The moment pragmatism asks this question, it sees the answer. True ideas are those that we can assimilate, validate, corroborate, and verify. False ideas are those we cannot. That is the practical difference it makes to us to have true ideas; that therefore is the meaning of truth, for it is all that truth is known as. (James, 1909, Preface, pp. v-vii)

It can be imagined that especially the notion of "cash-value" encountered hard opposition and gave rise to this sort of caricature. While this is partly caused by James' provocative writing style, other pragmatists, even though expressing themselves much more carefully, met similar resistance. Dewey had to fight against the claim that he believes that everything that gives

satisfaction is true. Critique also came from within: Even Peirce (1908), the founding father of pragmatism, considers James' form of relativistic truth - as the "seeds of death" that infected pragmatism.

However, putting aside the relativistic aspect, the notion of the "cash-value" is of interest for economic modeling. As Rorty (1998) argued, it might have helped James to use the term "justified" instead of "true". As soon as we accept that we are not able to find universal laws in economics, we might benefit from exchanging the concept of truth with justification as the highest aim that is realistically achievable. We will come to this argument in more detail in the next section. For now, it is enough to state, that while the practical implications of a theory are a main and shared concern in pragmatism, the reduction of truth to utility is not.

Dewey's Experience and Inquiry

Besides the differences between its own advocates (Peirce even renamed his own philosophy to pragmaticism to distance himself from other pragmatists), one reason why pragmatism is so hard to grasp is its lack of easy answers. Following the treatise by Morgan (2014) "pragmatism as a philosophy goes beyond problem solving" (p. 1046) even though "the fundamental principles of pragmatism are indeed well suited for the analysis of problem solving". Regarding the application of pragmatism for social sciences, he quotes Denzin:

> Classic pragmatism is not a methodology per se. It is a doctrine of meaning, a theory of truth. It rests on the argument that the meaning of an event cannot be given in advance of experience. The focus is on the consequences and meanings of an action or event in a social situation. This concern goes beyond any given methodology or any problem-solving activity. (Denzin, 2012, p. 81)

When we are talking about inquiry, this does not necessary include only research. Inquiry can also occur in everyday life. There is no sharp distinction, but rather a gradual one, "just as a decision about buying a car demands more attention than what to order for lunch". Morgan then presents a structured list of five steps for Dewey's systematic approach to inquiry:

1. Recognizing a situation as problematic;
2. Considering the difference it makes to define the problem one way rather than another;
3. Developing a possible line of action as a response to the problem;
4. Evaluating potential actions in terms of their likely consequences;
5. Taking actions that are felt to be likely to address the problematic situation.

(Morgan, 2014, p. 1047)

This process of inquiry is then connected with the cyclical exchange of beliefs and actions and is therefore everything but linear. For example, our beliefs influence which research topic we pursue and which method we apply. If there is any clear message that can be taken away from Dewey's work on its own (which is usually hard, as his writings are artfully crafted, complex and interwoven constructs), then it is his attempt to "break down the dualism between realism and idealism. [...] Within Dewey's pragmatism and its emphasis on experience, ontological arguments about either the nature of the outside world or the world of our conceptions are just discussion about two sides of the same coin." (Morgan, 2014, p. 1048) To put it in Dewey's own words:

> [I]t is not thought as idealism defines thought which exercises the reconstructive function. Only action, interaction, can change or remake objects. The analogy of the skilled artist still holds. His intelligence is a factor in forming new objects which mark a fulfillment. But this is because intelligence is incarnate in overt action, using things as means to affect other things. (Dewey, 1958 (1925, p. 158)

Pragmatic Features for Economic Modeling

These strong words might already raise certain ideas in the reader's imagination and should highlight how relevant and fitting pragmatism is for social sciences in general, but especially for economics. To this conclusion came also Hands (2004), whose approach was to identify four common features in contemporary science theory and connect them with the ideas of pragmatism. We will then look specifically into the meaning of all four of them for economics. These features are:

1. Science is fundamentally social and must be understood in social terms.
2. The actual practice of science is essential for understanding scientific knowledge.
3. There is an inclination towards pluralism.
4. There is an emphasis on naturalism (but this is controversial).

(Hands, 2004, pp. 255-264)

Sociality

According to Hands, there is a heated discussion over what it actually means for science to be social. This is home ground for pragmatism, as it clearly propagated from the very beginning that scientific knowledge was fundamentally social.

Economics has been heavily criticized for investigating a social construct and at the same time ignoring the social aspects, for both its subjects of investigation and as the creation of knowledge. Regarding the subject matter, with the assumptions of perfect rationality and representative agents, the social networks of individuals were completely irrelevant and

therefore ignored. At the same time, a social construct - real world economics - was treated in a mechanistic way. Only when the search for universal laws was abandoned, it was possible to see how our knowledge base is socially constructed. We now have an era of multiple heterodox schools; even the mainstream is not unified. Such a scientific landscape automatically includes the awareness that each claim of picturing reality better than the others has a social background. Our beliefs are formed by our social networks and are heavily influenced by our peers, mentors and scientific origin. The other way around, science has a responsibility towards society as well.

Scientific Practice and Innovation

The second aspect is a consensus that the actual practice of science is necessary for understanding scientific knowledge. Again, this also converges with pragmatism. One of the aims of pragmatism was to provide a philosophy, which results from "an analysis of what takes place in the experimental inquiry of natural science" (Dewey, 1929, p. 161).

For Dewey, the connection between experimental reasoning and industrial revolution and economic progress was obvious. Technological and scientific advance go hand in hand. Industrial applications of innovations provide new questions that then again lead to further progress as well as they deliver new means for experimental reasoning. Wealth that is produced in the industry is infused at least partially into science, and even the social life itself is revolutionized by innovations, which then again influences how we approach scientific knowledge. This is a very organic view on how scientific knowledge emerges; very different to the "Received View" where economists simply follow the rules laid out by some philosophers and the only remaining question being whether these rules are fulfilled and if the approach is therefore scientific enough. "With pragmatism there is no such caricature; knowledge evolves through its associated doing, and doing is what economic life is all about." (Hands, 2004, p. 264)

While this is true about economic life, economics itself has neglected this relation for a long time. It is ironic how the economy itself is transformed perpetually by innovations and at the same time, the science that should handle this phenomenon is talking about equilibria and handling growth as something that "unfortunately" cannot be argued away completely, but is pushed aside as far as possible. The entrepreneur (defined by Schumpeter (1911 (1964)), some individual or collective that takes an economic risk to realize an innovation, does not fit into the neoclassical economic view, because their behavior is considered irrational. It is about time for economics to dig deeper into the emergence of novelty, as it has economic as well as epistemological relevance.

Pluralism

The third feature is an inclination towards pluralism. While the first two aspects were already rather easy to connect with pragmatism, this is one of its key agendas (only Peirce seems to

be somewhat controversial). To put it as general as possible, according to Hands there is a recognition in contemporary science that there is not one single way to insight. For Dewey, it was possible to separate the scientific method from the various subject matters. The inclusion of social sciences, however, stems not only from his pluralism. As we have already seen before, Dewey focused especially on the social aspects of science. It was his goal that experimental reasoning should be applied to other aspects of human social life.

Turning towards economics, this should not be confused with "the 'economic imperialism' that has emerged since the 1960s where the economic method is exported to the fields of politics, sociology and even philosophy." (Boettke et al., 2004, p. 327) The framework of inquiry and experimental reasoning is rather a specific epistemological mindset than a strict method. Economics is in a phase of change right now. At the latest with the financial crisis, it became clear, that the old tools are not able to capture what is going on in the economic world. In the search for new approaches that try to operate on a smaller, less universal but more empirical basis - each in very different ways - we need pluralism to explore these different paths and gain collective knowledge about how to advance.

Naturalism

The last feature will be treated only briefly here, because to us it is better placed in a discussion about science theory, not how to apply it to actual science, or to be more precise, its applied relevance is already covered with the second feature that goes in a similar direction. The argument is that the scientific approach should be used for investigating scientific knowledge, which means that epistemological questions should be tackled like scientific ones. One could use for example evolutionary models to study how scientific believes are changing.

Sketching a Pragmatic Methodology for Economics

By now, we have discussed the epistemological issues in economics and we have tried to demonstrate, what pragmatism has to offer for economic modeling and why it is a good fit. Now we are turning towards a question that has been only brushed slightly in the previous section: What should a pragmatic methodology for economics look like? Literature on the connection between pragmatism and economics is scarce; therefore, it is not by accident, that many of the sources used here are from the same collection (Khalil, 2004). If there is any literature to be found, it usually does not consider the philosophic implications but rather applies it on a much lower level - for example to model pragmatic individuals in terms of choice, rationality, instinct and habit (Barbalet, 2008). Alternatively, it even considers pragmatism as some sort of social and ethic paradigm (Kolodko, 2014). Pragmatism in general is not a cookbook paradigm that gives clear and easy instructions how to build a methodology. Therefore, the ideas presented here are only rough sketches. We will go briefly into three different views regarding this topic before coming to our own conclusions.

Viskovatoff (2004, p. 285) criticizes both in mainstream economics: The belief in "laws" as well as "taking empirical inquiry to involve the collection of statistical data which have little relation to actual human concerns[.]" For him, both are aspects of the same problem, which is the assumption that there is some natural order in the economy. While we agree with the former, we do not follow the second point. Does he criticize the empirical inquiry itself? Personally, we would say it is what has come closest to pragmatism in economics so far. More likely, it is the scale and the data used in these attempts that he is criticizing. That once again, globally valid connections are searched for instead of focusing on interactions on a smaller scale that we can actually observe in the real world.

Then, however, his presented solution is not a big step forward. He argues that we should learn about the economy by acting in the world and observe the outcome, only to state in the next sentence what we all know - in economics, we cannot conduct experiments, as our only one-time experiment is history. His idea for a proxy solution stems from physics once again. In astronomy, he says, we also cannot conduct experiments with the planets but only observe them. Therefore, in his idea, the only form of "experiment" we have are different political or social regimes in different countries.

While he puts a lot of effort into stating how this is different to universal laws, as it is only about tendencies, we personally do not see that fine line. Further, it also seems to still imply a nomological paradigm. To recall the critique from Dopfer (2003), he on the other hand said, that we should follow a histonomic approach: There is a local repeatability of phenomena, but there is also a historical context, which makes global repeatability impossible. To believe that the fact that a specific regime in year X in country Y produced a certain outcome gives us implications for the application in other countries does not seem too different to us from the existing empirical inquiry that he criticizes.

He presents another line of argument that shall be summarized only briefly here. According to him, contemporary economic methodology is rather descriptive than normative. In his view, this would have disappointed Dewey, because philosophy should be criticism and therefore a proper economic methodology has to be normative. Obviously, by proposing a new methodology, one cannot avoid criticizing the current economic practice, but we are not sure if that automatically makes it normative. It just shows one possible (and probably even vague) direction.

Speaking of vague, another treatise (Boettke, Lavoie, and Storr, 2004, p. 351) tries to connect pragmatism with the Austrian economic school and subjectivism. It focuses on Dewey's process of inquiry and boils down to the message that we should "begin with our experience-in-the-world and to test our theories by returning there." To go a little bit more into detail, they argue that according to Dewey, inquiry always aims at answering questions that arise in

the world. However, this experience-in-the-world tends to be confused, obscure and conflicting. At first glance, it seems to be hard to follow inquiry in such a world.

According to the authors, the first step of inquiry is the realization that a situation actually requires inquiry, that it is problematic. If you can identify the problem well enough, you have already half of the answer. Therefore, it is crucial that it arises out of experience-in-the-world, because mere thought experiments and puzzle solving are leading you on a wasteful course.

After we have proposed our hypothesis, we have to test it. First, we check if it is consistent with our picture of the world, then we verify it in the world - which means usually by empiric data. The following quote describes this test beautifully and it is remarkable that once again, there is no notion of truth, but a description of justification:

> Does it end in conclusion which, when they are referred back to ordinary life-experiences and their predicaments, render them more significant, more luminous to us, and make our dealings with them more fruitful? Or does it terminate in rendering the things of ordinary experience more opaque than they were before, and in depriving them of having in "reality" even the significance they had previously seemed to have? Does it yield the enrichment and increase of power of ordinary things which the results of physical science afford when applied in everyday affairs? Or does it become a mystery that these ordinary things should be what they are; and are philosophic concepts left to dwell in separation in some technical realm of their own? (Dewey, 1958 (1925, p. 7)

Basically, the whole argument was an ode to empirical induction. While we wholeheartedly agree, it raises the question whether this is all that we can take away from a pragmatic approach, as it is not something especially original. As Milberg (2004) has pointed out, there is already a trend in economics towards empiricism. We are now coming back to the attempt of answering the question that was stated already in section 2: Is this just "measurement without theory", a naive falsification or a real methodological turn towards pragmatism?

His answer is a classical "both". For him, to call current economic research truly pragmatic, it would have to involve an even deeper inductivism. However, empirical research and computing techniques have massively increased over the last century and there is a stronger awareness of the limitations of regression analysis. On the other side, there still is the problem of "data mining", where only selective variables are chosen and results are presented. All issues aside, this new movement has at least incorporated the pragmatists' principle of putting observation in the center of hypothesis formation.

According to Milberg, it comes as no surprise that even in mainstream economics there is this - maybe unconscious - move towards pragmatism. Several other schools of thoughts claim in contrast quite openly to incorporate pragmatism as their philosophical foundation, among them monetarists as well as institutionalists, feminist economists and complexity scientists. For Milberg at that time the question was still open whether any of these pragmatist tendencies will dominate economic research or if there simply will be an era of pluralism.

More than ten years later, we argue strongly in favor of the emergence of pluralism. At the latest, the financial crisis has demonstrated that mainstream economics lacks significant answers to real problems. We do not proclaim that new approaches will allow us to pursue again the quest for ultimate "truth". Instead, we want to come back to the questions posed

at the very beginning: How can we define truth in a social science if there are no general laws? How do we accumulate knowledge and what actually counts as knowledge? We propose to completely abandon the concept of "truth" in economic modeling and replace it with "justification". That probably sounds much more radical than it actually is, because no serious economic modeler will ever be convinced to have covered the truth. Nevertheless, they still might have the idea in the back of their mind to come as close as possible.

In a histonomic paradigm, that allows for ever-changing evolution and revolution, which is exactly what we experience in the world. This does no good. As Dewey (1958 (1925, p. 7) stated it, the criterion instead has to be whether our results "render [life-experiences] more significant, more luminous to us, and make our dealings with them more fruitful". This, however, is not the same as "what works", because ultimately the goal has to be real empirical inquiry which is not pure empiricism without any theory, but a fusion of both. Theory has to be based on experience-in-the-world and verified against it, but theory itself cannot be omitted.

We pledge for more pluralism in the accumulation of knowledge as well. Statistical data is equally important for social networks, individual relations and behavior. Very insightful knowledge about individual behavior might be collected in behavioral economics and psychological studies but is only tolerated as long as it remains within its own realm and does not bother the mainstream too much. This is because these results about rationality, altruism, influence of social peers, etc. contradict completely what many mainstream models still incorporate for mathematical elegance.

However, ignorance cannot be the solution. Instead, these results have to be taken seriously, as they are an equal part of our experience-in-the-world as big statistical data. Of course, it is unrealistic to expect every model to incorporate all different kinds of knowledge and data. There has to be abstraction, otherwise it would not be a model. At the same time, as Dewey said, the whole process has to start in the world and only if we can describe the problem in the context of experiences we can ask the right questions and choose the right methods.

Methodical pluralism will help in coming closer to this goal, because there are only benefits in tearing down the walls between the different economic schools. It might indeed make sense to incorporate certain macroeconomic aspects of a mathematical model in an agent-based simulation, which at the same time uses empiric results from behavioral economics on the micro-level. There is also no single prescription for the scale of such models. It might be very enlightening to use the results from econometric analysis and implement them in an agent-based toy model that only highlights the general dynamics that result out of these findings and therefore has an instructive purpose for implications in the real world without immediately giving you real-world figures and explicit policy implications.

Conclusion

To conclude, while pragmatism does not give us a clear set of instructions how to formulate a proper economic methodology, it at least provides a guiding hand towards a certain direction. Economists have already walked this direction to some extent, after the realization that neither, the quest for universal laws, nor over-stylized mathematical puzzle solving is in touch with the actual economic world.

We have tried to show why Dewey in particular is a good fit for this new path with his concepts of experience and inquiry, not only for recent developments in science theory in general, but specifically for economics. Pragmatism does not only help us with its requirement that inquiry

has to start with experience-in-the-world and end there, by being tested against it, but it also puts an emphasis on pluralism. This is much needed in economic modeling, both in what is regarded as useful knowledge as well as which methods should be applied.

Further, we have proposed to abandon the concept of "truth" as a validation criterion and instead replace it with a concept of "justification". Again, this is not the same as "what works" or "cash-value" in the caricatured sense. Instead, it is just an acknowledgment that economics is after all a social science with a subject matter that is ever changing. This does not diminish its status as "proper" science; on the contrary, it only legitimates it. That is the path that we wanted to walk in our model.

References

B. W. Arthur. Out-of-equilibrium economics and agent-based modelling. In Kenneth L. Judd and Tesfatsion Leigh, editors, *Handbook of Computational Economics, Vol. 2: Agent-Based Computational Economics*, pages 1551 – 1563. North-Holland, 2006.

J. Barbalet. Pragmatism and economics: William james' contribution. *Cambridge Journal of Economics*, 32(5):797, 2008.

J. Baumgartner, F. Breuss, and S. Kaniovski. WIFO-Macromod - An Econometric Model of the Austrian Economy, 2004.

P. J. Boettke, D. Lavoie, and V. H. Storr. The subjectivist methodology of austrian economics, and dewey's theory of inquiry. In E. L. Khalil, editor, *Dewey, pragmatism, and economic methodology*, Routledge INEM advances in economic methodology. Routledge, 1. publ. edition, 2004.

T. A. Boylan and P. F. O'Gorman. Pragmatism in economic methodology: The duhem-quine thesis revisited. *Foundations of Science*, 8(1):3–21, 2003.

N. K. Denzin. Triangulation 2.0. *Journal of Mixed Methods Research*, 6(2):80–88, 2012.

J. Dewey. *The Public and its Problems: An Essay in Political Inquiry*. H. Holt and Company, 1927.

J. Dewey. *The Quest for Certainty: A Study of the Relation of Knowledge and Action*. New York: Putnam, 1929.

J. Dewey. *Experience and Nature*. Dover Books on Western Philosophy. Dover Publications, 1958 (1925).

K. Dopfer. The evolutionary paradigm of economics. Originally supposed to be the Introduction of the collection 'Evolutionary Foundations of Economics', 2003.

L. Friedman. The methodology of positive economics. In M. Friedman, editor, *Essays in Positive Economics*, pages 3–43. University of Chicago Press, 1953.

H. Hanappi. Austria 1 - Ein Simulationsmodell der österreichischen Wirtschaft. In H. Hanappi, editor, *Wiener Studien zur Politischen Ökonomie*, volume 2. 1983.

D. W. Hands. Pragmatism, knowledge and economic science. In E. L. Khalil, editor, *Dewey, pragmatism, and economic methodology*, Routledge INEM advances in economic methodology. Routledge, 1. publ. edition, 2004.

D. M. Hausman. *The Inexact and Separate Science of Economics*. Cambridge University Press, 1992.

W. James. *The Meaning of Truth*. Dover Publications, 1909.

E. Khalil. *Dewey, Pragmatism and Economic Methodology*. Routledge INEM Advances in Eco- nomic Methodology. Taylor & Francis, 2004.

G. Kolodko. The new pragmatism, or economics and policy for the future. *Acta Oeconomica*, 64 (2):139–160, 2014.

M. S. Lawlor. Dewey and economic reality. In E. L. Khalil, editor, *Dewey, pragmatism, and economic methodology*, Routledge INEM advances in economic methodology. Routledge, 1. publ. edition, 2004.

W. Milberg. After the "new economics", pragmatist turn? In E. L. Khalil, editor, *Dewey, pragmatism, and economic methodology*, Routledge INEM advances in economic methodology. Routledge, 1. publ. edition, 2004.

D. L. Morgan. Pragmatism as a paradigm for social research. *Qualitative Inquiry*, 20(8):1045– 1053, 2014.

C. S. Peirce. A neglected argument for the reality of god. *Hibbert Journal*, 7:90, 1908.

D. Pissarenko. Basics of input-output analysis. 2003.

J. Potts. *The New Evolutionary Microeconomics*. Edward Elgar Publishing, Cheltenham, Eng- land and Northampton, MA, USA, 1 edition, 2000.

S. J. Ralston. Can pragmatists be institutionalists? john dewey joins the non-ideal/ideal theory debate. *Human Studies*, 33(1):65–84, 2010.

R. Rorty. *Truth and Progress: Philosophical Papers*. Cambridge University Press, 1998.

I. Sanderson. Intelligent policy making for a complex world: Pragmatism, evidence and learning. *Political Studies*, 57(4):699–719, 2009.

J. Schumpeter. *Theorie der wirtschaftlichen Entwicklung*. Duncker und Humblot, Berlin, Ger- many, 6 edition, 1911 (1964).

M. P. Timmer, E. Dietzenbacher, B. Los, R. Stehrer, and G. J. de Vries. The World Input-Output Database: Content, Concepts and Applications, 2014.

A. Viskovatoff. A deweyan economic methodology. In E. L. Khalil, editor, *Dewey, pragmatism, and economic methodology*, Routledge INEM advances in economic methodology. Routledge,
1. publ. edition, 2004.

1.3 Critique and limitations of Agent-based models

As already mentioned further above the methodological aspirations of the project were reaching beyond the methodological foundations of many of current attempts of the large teams that today produce agent-based models for economists. The previous chapter showed that the questions involved reach deeply into the philosophical underpinnings of science itself. It is clear that a more detailed treatment of the enormous amount of knowledge that has been produced in this area goes far beyond the scope of this project. Instead, what follows is a very specific but concise proposal of what we use as a pragmatic starting point for agent-based modelling. This is the background of what has been produced and what is described in the remaining parts of this report. The following text has recently been published in an economic journal, see [Hanappi, 2018], and can be considered as a further sign that agent-based modelling techniques are finally getting accepted by the scientific community of economists. It should be read as a complement to the previous chapter, as an attempt to stretch the capability of the new technical possibilities to their epistemological limits.

Introduction

In many areas of the social sciences the technique of agent-based modelling (ABM) becomes more and more popular. For many researchers not specialized in computer simulation this catchy term seems to provide a way between Scylla and Charybdis, between the arcane dream worlds of mainstream, general equilibrium economists and the jungle of sociological singularities that leaves us in a forest of contradictory case studies. Of course, the former - due to their mathematical language and despite their mostly trivial content – are much harder to read; but the mass of the latter has the disadvantage to become even more boring soon. Once it is decided to construct an ABM, this immediately implies that at least a vague idea of what an ABM looks like has to exist. As in most other areas, this idea usually is based on imitation: Take a look at what others did. This is what happened in the last twenty years, and as could have been expected a large set of quite different types of software applications and corresponding customers emerged. Today, still a clear picture of what is characteristic for ABM remains controversial[5].

This paper is just another brief attempt to contribute to the understanding of this not so new approach. It starts with some selected historical steps in the emergence of agent-based modelling. There exist much more comprehensive treatments, which include many details that here due to the needed brevity of the argument are omitted. But by these omissions my argument highlights what I consider to be important.

[5] E.g. compare the views of Nigel Gilbert [Gilbert, 2008] and Chen and Wang[Chen and Wang, 2010].

What follows is a concise sketch of the essence of ABM for novices and those unsatisfied with many of the more restrictive definitions of the field. The part ends with a recipe for building an ABM.

The last part discusses the future of ABM. It is organized along the lines of the three aspects of a language: syntactic, semantic, and pragmatic evolution. This part on the future necessarily contains several more speculative elements, it should be read as a collection of possible visions.

History of ABM

Agent-based modelling is only a fashionable new name for the use of computer simulations in economics, which exists almost as long as computers. When in the fifties and sixties large US universities installed computer centres to support researchers in the natural sciences, there soon were also economists showing up, eager to transfer tedious calculations to the new machinery.
Before that, large amounts of data as well as larger difference equation systems built on the then new analytical technique of input-output tables were using up a lot of intellectual effort that now could be delegated to computers. The advent of computer simulation therefore can be considered as the appearance of 'an economist's little helper', a calculating machine.

Then came a shift of focus that was initiated by the computer firms acting in an oligopoly, and that quickly was taken up by the scientific interpreters of the new machines. The growth of demand for computers coming from military and other state institutions was starting to slow down, and to revive it in the 'age of high mass consumption' [Rostow, 1960] made smaller and more flexible devices necessary. Small firms and households did not need extreme calculation power, like research in theoretical high-energy physics. What they would buy was a small machine that offered a large diversity of different uses, from simple household accounting via writing letters to computer games for children and idle employees. In the early eighties, the personal computer was born, and as an educational add-on the teaching of informatics in schools was introduced. Scientists like Alan Newell and Herbert Simon quickly saw that with this diversity of uses the old calculator had become a 'symbol manipulating device', see [Newell and Simon, 1972]. Indeed, whatever one can consider as a symbol can easily be translated in a bit stream and then can be manipulated in many more ways than just adding and subtracting[6].At that time another fashionable term was invented to attract research money: 'artificial intelligence'. Its success was built on the surprise of computer illiterates about the speed of machines searching in databases. This looked 'intelligent', though it had little to do with the traditional meaning of the word[7]. Till today 'artificial intelligence' haunts software applications, including economic simulations.

The early fields of application quite naturally followed the divide of economics into microeconomics and macroeconomics. On the one hand, simple oligopolistic markets were mirrored, while on the other hand early Keynesian macroeconomic models were simulated. Of course, contrary to abstract general form models of economists these models first had to be econometrically estimated to fill in parameter values into the behavioural equations.

[6] Quite to the contrary, it is somewhat complicated to perform adding with the processes most elementary to computers, e.g. 'copying', compare [Hanappi, 1992].

[7] See [Hanappi and Egger, 1993] for some thoughts on artificial intelligence.

Without using the word 'agent' such a behavioural equation already was meant to capture the behaviour of an economic entity, of economic agents. In microeconomics they were firms, households, or individuals, in macroeconomics they were more abstract aggregates of 'all households' (e.g. consumption function), 'all firms' (e.g. investment function), or 'several state institutions' (e.g. tax function). With the increasing technical abilities of hard- and software soon there emerged first attempts to combine micro- and macroeconomic computer simulations, a task paralleling the more conventional efforts of mainstream economic theory to provide a microfoundation for macroeconomics. In the late eighties, it more or less became clear that the latter task had failed since it needed very implausible restrictions on the micro-level to allow for aggregation at all. Moreover, the convenient trick only to consider stable equilibria, or equilibrium paths, became less and less useful in a world that was governed by amplifying disequilibria, e.g. in the labour market. But the human capital stock of academic economists built up by this type of research was already too large to be easily given away. The alternative to use computer simulations would have needed too much investment in learning the new techniques for the established community; it became a territory for mavericks only[8].

Outside standard economic theory, economic simulation got a ***first boost from*** a completely different side. In ***biology*** mathematical modelling, in particular game theoretic models were applied with increasing success, see e.g. [Maynard-Smith, 1980]. Darwin's idea of evolutionary dynamics was simulated by computer programs and the results were compared to the developments in actual biological populations. This inspired two economists, Sidney Winter and Richard Nelson, to use computer simulation to mirror market dynamics. Their 'animals' were firms and instead of Darwinian traits they were characterized by a set of 'routines' they used. And then a simulation of market dynamics was used to study how the worst 'routines' were weeded out by some kind of 'survival of the fittest'. This type of dynamics, now a simulation exercise, of economic processes never coming to rest in an equilibrium had been described by Joseph Schumpeter 70 years earlier [Schumpeter, 1911]. Richard Nelson in his early life indeed had been a famous representative of standard microeconomics and always had longed for an inclusion of Schumpeterean thought in economic theory. With their book, which they called 'Evolutionary Economics', Nelson and Winter started an economic school of the same name [Nelson and Winter, 1982]. And this school still heavily relies on the techniques of computer simulation, today under the label of agent-based simulation.

A whole group of scientists then tried to find new foundations for the social sciences with the help of computer sciences. The 'New Foundations'-movement spread out over a wide disciplinary range, starting on the more formal end already in 1959 with Stephen Wolfram's 'A New Kind of Science' and reaching into the most prestigious research journal of economists, the 'American Economic Review', where Robert Axtell and Joshua Epstein published an article on 'Artificial Life', see [Wolfram, 2002], [Axtell and Epstein, 1996], [Axtell et al., 2012]. Models of the 'artificial life'-variety usually had homogenous small agents that resembled ants: They commanded only very few instruments (e.g. moving and eating) and very few goals (e.g. food consumption), but a huge number of them (e.g. ten thousand) were positioned on a common landscape and the simulation then started. The result waited for was a specific, reproducible pattern of aggregate outcome of the enormous amount of interactions on the micro-level. These artificial ants' worlds still followed the quest to derive emerging patterns on the macro-level from the simple, archaic behaviour of micro-agents – now, of course, with the help of

[8] The Scottish economist Brian Arthur, the modeller of the famous 'Inductive Reasoning and Bounded Rationality. The El Farol Bar Problem', is such a case [Arthur, 1994].

simulations. So it basically was still the old research program of methodological individualism now dressed up as the fancy new fashion 'artificial life'. To break this spell ABM had to move on heterogeneous agents and the ability of their internal models to allow for more or less sophisticated forecasts. Only then communication processes could bring about some countervailing macro-foundation[9] of micro-behaviour, and finally the more adequate possibility to dissolve the unhealthy opposition between micro and macro in a simulation with full interaction between all levels.

The ***second important external boost*** to economic theory building that was almost completely ignored by mainstream economists came ***from the study of complex systems*** with the help of ***network theory***. Its roots can be traced back to the scientific revolution in theoretical physics that led to quantum theory. With this new knowledge of basic rules that govern physical processes at the smallest scale the validity of the older Newtonian mechanics could be understood as a special case that can describe behaviour if one looks at statistical averages occurring if an enormous mass of small units interact. The mathematician and physicist Erwin Schrödinger, who gave this theory the analytical waveform, arguing from this new perspective in 1943 asked a surprising old question: What is Life[10]? This took the natural sciences to the next level. The old atomism of ancient Greek philosophy had assumed a mass of homogenous atoms, the new quantum theory had discovered a diversity of ever smaller heterogeneous particles interacting in strange looking ways. Asking now how these processes could be formally described stretched the analytical capabilities to their limits[11].

Applying the new finite diversity ideas to the human species meant to depart from the image of a unique homo economicus. Even with the old analytical apparatus of mathematics, heterogeneity could be envisaged, compare [Casti, 1989]. The transdisciplinary genius John von Neumann, who after a talk with the eminent economist Nicolas Kaldor had produced an elegant economic growth model, realized that a deep change in formalisation techniques was inevitable. To support new analytical techniques he revived the old concepts of Charles Babbage and Ada Lovelace, and together with some, outstanding US engineers invented the modern computer. As it turned out, this device was able to accommodate heterogeneity to a previously unimaginable extent. In a daring attempt to imagine the future abilities of this 'new combination' of theory and technical support – note the importance of Schumpeter's characterisation of innovation - Doyne Farmer and Aletta Belin early on tried to grasp the implications, see [Doyne and Belin, 1990].

And then, in 1944, John von Neumann even proposed to invent a new mathematical language for social processes – game theory, see [Neumann, 1944]. It took 40 years until his ideas arrived at least in biology, when Maynard-Smith successfully applied it to animal systems. But already in 1962 a researcher in the area of weather forecasting, played around on his computer with the parameters of simple dynamic systems and discovered that these

[9] An intermediate step thus was to construct computer simulations of the interaction of macroeconomic agents, compare [Hanappi, 1995]. The next logical step then is to open up the 'black boxes' of lower level agents and turn them into simulated 'white boxes' in the sense of Norbert Wiener, see [Hanappi and Hanappi-Egger, 1998].

[10] See [Schrödinger, 1943].

[11] In an attempt to describe network evolution as a learning process Stuart Kaufmann started to apply Boolean networks early on too, see [Kauffman, 1993]. The idea to use networks seemed to be in the air and quickly led to the emergence of another fancy term: Complexity. It turned out to be at the centre of the research program of the most creative research institute in the field, the **Santa Fe Institute**. This institute was also the place where the agent-based modelling simulation package SWARM was developed and applied by Robert Langton and his team. In a sense, the worldwide success story of ABM started there.

deterministic systems were able to produce time series that could not be distinguished from random series, e.g. from white noise. The methodological impact was severe: Once a historical time series is given and looks like an economic law heavily disturbed by exogenous shocks, it might as well be completely deterministic. A new set of methods to deal with that question had to be developed, and since it soon was found out that the probability of these 'deterministic chaos systems' rises with the size of the system it was evidently necessary to use simulation methods. Strict mathematical arguments often start by assuming to opposite extreme situations. In the case of many endogenous variables one extreme can easily by fixed: assume that everything depends on everything. An opposite extreme would be that the dynamics allow to derive the second variable from the first only, the third from the second only, and so on until the first variable then depends on the last only. The Hungarian mathematician Paul Erdös saw that these two extremes have a geometrical representation as graphs, the nodes are variables and the links are dynamic equations. While the first extreme thus displayed a graph with direct links between all nodes, the second extreme is ring with two links at each node only. Erdös' own innovation was to assume that links might sequentially emerge between variables, following a random process that can be described by well-known stochastic processes. Erdös' random graph theory was just the beginning of the boom of network theories. In the 90-ties Laszlo Barabasi and his team discovered that in a surprising number of living system a special structure could be found empirically – the so-called 'small world'-structure, compare [Barabasi, 2014],[Watts, 1999]. How a sequence of link emergences can be algorithmically specified to lead to such an empirically found structure since then is a vivid field of scientific research. One such procedure is built on the assumption of preferential attachment, i.e. the probability of a node to be part of the next link that is dropped on the network is proportional to the number of links that it already has. It is evident that nodes could also be interpreted as agents, and this is exactly what is assumed in so-called 'games played on networks'. Strategic decisions of agents using their internal models of other agents (in the sense of Neumann's game theory) then lead to actions, which are the links between nodes[12]. It is clear that the size and content of internal models as well as the number of links that an agent can perceive and deal with is crucial. The limits of these modelling elements determine how adequate a network can mirror an object of investigation.

The agent-based models developed in the last decade therefore collect innovative developments in the recent history of sciences and provide a transdisciplinary focus[13]. The next part will sketch how ABM deviates from mainstream economic modelling and what is needed to produce an agent-based model.

Essential features of ABM

The basic idea of ABM is that agents, living entities using internal model-building, are mimicked by computer programs. Immediate consequences of this starting point are that

a) An agent's structure has to be described by a program that is sophisticated enough to allow for the sequence (i) perception – (ii) embedding in an internal model – (iii) choice of an action (including the action 'communicate');

[12] Note that actions can either be in the world of information, i.e. communication, or physical processes outside language.

[13] Compare [Hanappi, 2014] for an embedding of the new approach in history of traditional economic modelling.

b) Agents and the programs representing them will typically different, i.e. the standard case of ABM typically will be heterogeneous ABM.
c) There has to be a main program, which is not an agent, and which provides a description of the environment in which the agents can perceive and influence this environments dynamics by their actions.

By disentangling the material world outside the internal consciousness of an agent from what goes on within its internal information processing ABM can describe model-driven behaviour of agents that use models, which differ markedly from the actual dynamics of their environment. The most important task in this respect is to explore how the selection of *what* is observed, *how* it is embedded in an internal model, and *how* finally actions are *recognized* and *chosen*, how this whole process is developing over time. Again it must be emphasized that for each agent this perpetually repeated process can and will be different.

The scientist constructing an agent-based model evidently has to know a lot about the empirically observed agents that shall be described by the ABM. Contrary to most of mainstream economic model building there is not the same necessity to simplify agents' behaviour according to the technical requirements of analytical methods. In particular assumptions that some processes can be ignored because they are so fast that it is sufficient to include only the result of their convergence in the form of *equilibrium equations are superfluous*. There is also not the same need to simplify matters by assuming that the heterogeneity of agents shall be ignored and a common representative type of agent, the *homo economicus* or the '*representative firm*', is good enough for an adequate picture of reality. Moreover, the somewhat metaphysical assumption that agents are born with *innate preference orders* - which in more advanced versions of mainstream economic models might allow for slow modification – that guide their choice of instrument variables, this 'heroic' assumption can be replaced by an answer to the underlying question: Where do incentives for actions come from? The answer of ABM is less simple. Incentives are a mixture of signals sent directly from the body of the agent (e.g. 'feeling hungry', 'low revenues', 'political instability', etc.) and of the interpretation of perceptions with the help of the internal model that produces indirect signals.

Perception thus means that impressions are routed to the internal model that structures them into a vector of need levels. With the increased influence of internal models, the focus on communication processes, i.e. the exchange of models between agents, is strengthened.

The ***shift of methodology*** also concerns the ***choice of the scope of models***. When after the marginalist turn of economic theory - initiated by Walras, Menger, and Jevons in 1874 – mathematical methods started to dominate economics, it seemed to be immediately evident that (following theoretical physics) one had to start with the smallest and easiest unit to model economic dynamics. This unit was assumed to be the physical human individual and the

approach was labelled methodological individualism. Later, including micro-units of the production sphere that conceptually were socially neutralized (being called 'firms' rather than 'firm owners') the entire discipline was dubbed microeconomics. Though the mathematical model for a single unit was strikingly simple, copying natural science formalisms and adding some psychological hypothesis was good enough, it proved to be much more difficult to combine them to derive a kind of aggregate 'social thermodynamics'. From Léon Walras to the Arrow-Hahn model of 1967 this effort proved to be manageable only with an increasing amount of implausible additional assumptions. Keynes work in the interwar period had been the theoretical answer to the impotence of marginalist theory in the face of the Great Depression of the 30-ties. Marginalism simply could not explain how such self-amplifying disequilibria in all markets could can happen, and as a consequence it could not propose any remedies. Keynes success thus was built on the methodological innovation to bring aggregates back into the picture that constituted economics. Aggregates, like total consumption of a nation or total labour demand of all firms of a nation, were combined in an accounting framework mirroring national aggregates, this is the essence of macroeconomics. Of course, this accounting framework nevertheless needs agents that drive it. On the one hand these 'aggregate agents' were constructed using socio-psychological constants characterising average microeconomic behaviour, e.g. a propensity to consume of individuals or a propensity to invest of firms, on the other hand some aggregates important for national accounting asked for the re-introduction of an agent that was neglected in marginalism: the state. With this latter methodological innovation, a second improvement of standard theory was possible. The exogenously determined agent 'state' could be used to prescribe remedies for the apparent, welfare-decreasing disequilibria. But the methodological gap between marginalist microeconomics and Keynes' macroeconomics could hardly be deeper. While the former claimed that general equilibrium ruled in the long-run and re-established itself quickly if non-economic events disturbed it, the latter focussed on the short-run and emphasized the need of state intervention, of an exogenously added political agent necessary to stabilize capitalism, to fight self-amplifying, endogenous disequilibrium processes. The restriction to consider only the short-run was due to the obvious variations of the aggregate agents' socio-psychological 'constants' across different nations and across time. The disparate methodology between micro- and macroeconomics produced different sets of mathematical toolboxes used by the two sub-disciplines. While microeconomics still followed calculus as it was developed for physics by Isaac Newton, substituting 'economic principles of man' for the laws of physics, macroeconomics typically fell prey to the use of simple linear models developed by early followers of Keynes. This inconsistency of methodology obviously was a challenge for mathematically inclined economists like Paul Samuelson. His so-called 'neo-classical synthesis' – a dramatic misnomer – aimed at providing a set of mathematical links smoothening the jump

from microeconomics to macroeconomics. In retrospect these efforts were not too successful. Most of them needed even stronger restrictions on the functional forms to be used and ever more implausible assumptions on expectation processes performed by microeconomic units[14]. With the focus of economics, which in the meantime had become microeconomics *plus* macroeconomics, shifting to questions of consistency and losing any responsibility for being adequate with respect to the world outside of their models, the scope of the science was redefined: It became dominated by mathematical requirements of elegance and solvability, i.e. the syntax of the formal apparatus.

Parallel to these changes in economic methodology computers had been developed. First, they were used in many rather profane domains, like administrative counting procedures and calculating gun fire directions on warships. In mathematical economics of the after-war period they made their appearance as little helpers for problems still formulated by standard mathematical modelling of the type described above, in particular providing approximations in some econometric areas. But in the late 60-ties finally proper simulation models of economic interactions were emerging. Their goal rarely was to check consistency, or to provide the most simple, 'heroic', assumption that still can be solved analytically; they typically tried to come as close as possible to the actual dynamics of the physical economic process of the process they tried to imitate, the process outside the domain of their own language, the singular process in the material, physical world. In short, instead of being syntax-driven, they were semantics-driven. The scope of ABM therefore relies on the observation of specific economic processes that can be good enough covered by observations, and can be good enough isolated from their respective environment. Whenever these requirements are met the algorithmic language is almost unrestricted in its ability to mimic a scientifically suggested essential dynamics. It is not syntax that drives this process, but the attention that the scientific community of ABM modellers gives to events happening outside the world of the language they use. It is thus this scope that makes ABM particularly interesting for practical questions, coming from economic policy or any other field. Unfortunately, there also is a downside of this astonishing flexibility implicitly included in the scope of ABM: Once an object of investigation is chosen and its essential features are pinned down by the model builder, there is no way to prove that simulation runs prove *semantically* correct results. In a sense an ABM is just another way to tell the model builder's story in a different language, it is formal story telling producing narratives[15]. The critique that multiple, partially contradicting narratives of the same object of investigation can be told therefore also applies to agent based models.

[14] An outstanding example is the rational expectations hypothesis, compare [Sargent, 1979].

[15] If formalization is syntax driven, it is always possible to check if a theorem is syntactically true or false. But here the disadvantage is that the distance to the object of investigation can easily produce the illusion that the derived truth concerns areas outside the language.

Nevertheless, it is possible to compare the relative adequacy of different agent-based models. The standard procedures to do so can be borrowed from econometrics applied to a comparison between simulation runs and observed data in an ex-post simulation. So there is no 'everything goes' freedom of different models but a 'something is more adequate than something else' that governs progress in ABM.

Finally, the phenomenon of ***emergence*** of patterns of aggregate behaviour often is mentioned as a particular feature of agent-based modelling, and deserves indeed some attention. In these questions there is a deep issue at stake. Finding a pattern in observations of repeated behaviour lies at the heart of every cognitive process, it is a major building block of internal model-building of all living systems and indeed – applied to the agent's own history – constitutes self-consciousness. In the first instance pattern recognition clearly is not an act that takes place in the solitude of an individual member of a species. Thanks to Charles Darwin we know that knowledge can be accumulated in a species by evolutionary processes that work with a combination of (slightly disturbed, i.e. mutated) copying of behavioural traits and weeding out of some of them by forces of the environment [Darwin, 1859]. The agent, which is the subject of the pattern recognition process, of knowledge accumulation, therefore is the species, at least from a biological perspective. A special property of the human species - for many scientists its characteristic property– is its ability to distribute the knowledge of the species across its members. This process needs several preconditions. First, individuals need a brain that allows to communicate, i.e. to translate physical processes into symbol systems that can be stored, reactivated and re-translated into physical utterances. Second, there must be a physical medium of exchange between individuals that carries the symbols, transports them from one brain to the next, e.g. air for voices, papyrus for written text. Besides several other preconditions for the somewhat illusionary impression of individual pattern recognition it also needed the special catalyst called recursion to initiate the particular human process: Recursion means that a sequence of copies, each one called by its predecessor, can produce the experience of time. More precisely, this primal experience is the contradiction between the constancy of reappearing copies, of consciousness, and its opposition of a permanently changing environment. With this feature knowledge accumulation in human societies in principal is freed from learning appropriate behavioural answers to changing environments the hard way: It is not necessary that the part of the population that acts inappropriate dies to allow for the survival of the fittest. The French Enlightenment had already anticipated and proclaimed this goal when Darwin worked on its biological roots.

Some two hundred years earlier René Descartes had specified some rules for the scientific method that the part of society specialized in discovering the patterns that govern the world, i.e. the scientists, should use [Descartes, 1637]. For him the task to discover scientific laws had

to start with the observation of a problem at an aggregate level, and then to proceed by taking the big question apart in ever smaller problems that can be solved easier. According to Descartes this is the essence of analysis in its original sense. What emerges in the end of this process are the atoms, which once they are revealed provide the emergence of their synthesis, this is what Descartes calls the scientific method. The parallelism to the actual discoveries of the natural sciences in his time is evident. Analytical investigation of ever smaller sub-problems necessarily involves an increasing amount of division of labour between different sub-disciplines, and this clearly makes the moment of synthesis, of the emergence of an overarching understanding of a larger phenomenon more difficult and demanding. It simply will happen less often. Today we command an overwhelming amount of highly specialized knowledge in a similarly overwhelming diversity of different sub-disciplines. The latent force of synthesizing this knowledge is enormous, but the intellectual capacity needed to do so, to transfer it from latent knowledge of the species to a manifest emergence, is enormous as well.

With the technique of agent-based modelling there seems to be the possibility to invert Descartes' traditional methodology. The scientist starts with a set of simply modelled micro-agents and works bottom-up by letting them interact on what is called an (interaction-) landscape. Since this interaction is just computer simulation it is easy to experiment with different sets of axiomatic micro-agents. Eventually then aggregate results of these interactions after some time can produce simple patterns in aggregated variables that surprise the scientist. This is the moment of emergence of knowledge for ABM research – at least according to the advocates of this argument. The argument certainly touches on an important methodological point but still falls short of its force as long as it neglects the following consideration: Assumptions on micro-agents that play the role of axioms from which the aggregate patterns are derived need not – and indeed never should – be the end of ABM research. A first move from bottom upwards is just the starting point for deriving better assumptions on a modified set of heterogeneous micro-agents, and a next simulation run. ABM research is a never-ending cycle of repetitive, adapted derivations alternating between running bottom up and running top-down. Moreover, this oscillating movement supports the formalization of three extremely important elements of political economy: ***expectations***, ***power***, and ***institutions***. On the way from bottom upwards, micro-agents use internal models that include expected future values of variables that emerge on the top-level only, e.g. unemployment rates, inflation rates, budget deficits. This process links the two levels from below. On the other hand, political power on the top level restricts the action space of the micro-agents and thus acts as a link from above. Power can be exerted in two formats: either as directly coercive physical power or as information-power that distorts the expectation process of micro-agents. If the social reproduction is taking place over a longer time-period, this interplay between the two levels resembles a repeated strategic game played by the

scientific community of ABM researchers. To solve the conflict between the opposing forces of expectation modelling and power modelling certain conventions will develop, instituted views what to assume. A typical auxiliary mediator in models of market mechanisms would be an auctioneer managing a tâtonnement process. A more refined example would be social partnership oriented state committee guiding the development of wage structures. It is typical for the channelling of conflicts into institutions that these institutions over time become new intermediate levels between the micro-agents and the top-level political entity. Computer simulation, of course, can and should mimic all essential intermediate levels, i.e. institutions, which are run through by the oscillatory process. Creating models for the interaction between expectation-building of agents, exertion of power by higher-level agents and the resulting institutional solutions of conflicts therefor mirrors what goes within the methodological process of ABM itself. It leads the researcher directly into the dynamics of its object of investigation. This indeed is a particular strength of agent-based modelling. Note that from this perspective a sudden emergence of knowledge not only happens when a one-shot bottom up modelling is reaching the aggregate view, ***emergence of knowledge can happen at all levels and at any time of the repetitive modelling process***.

Though from this point of view, knowledge accumulation as the central project of the human species is unlimited a single ABM research project always has a finite time horizon. And again, computer programs representing agents can as easily be equipped with finite expectation horizons, shortened memory capacities and finite anticipation depth in game-theoretic settings, just as the modelling scientist can and will regulate the effort that is spent on the different details of the project given a hard deadline for project accomplishment. It thus makes sense to provide a short recipe on how cook an exemplary heterogeneous agent-based model:

Step 1: ***Choose a topic*** that is closed enough with respect to its environment to allow for an independent consideration of its internal dynamics. There shall be links between the topic and its environment but the force from outside, from exogenous variables into the model, should be much stronger than the influence of the model on its environment. This can be difficult in the beginning if too many things seem to be fully interdependent. The art of the scientist consists to a large extent in the choice of neglecting less important elements and keep the essential ones. Additionally, the time frame of the model, see above, has to be fixed. The result of step 1 is the scope of the model.

Step 2: ***Identify the major agents*** in your model. Agents at every level within the scope of the model can be considered. Each agent has at least one goal variable and at least one instrument variable, which define its embedding within the model. The set of variables of the ABM therefore consists of four types of variables: goal variables, instrument variables, auxiliary variables, and exogenous variables. The first three types are called endogenous variables,

auxiliary variables are all those variables that help to formulate relationships either in material processes or in internal models and which are neither goals nor instruments. The result of step 2 are two linked lists, one with agents and one with all variables.

Step 3: ***Construct the internal models*** of the agents. A minimal internal model of an agent has to consist of a suggested relationship between its single instrument and its single goal variable. Of course, most mental models are more sophisticated and include conflicting goals, multiple instruments, and auxiliary variables. At this stage a close inspection of the empirically observed physical agent is mandatory leading almost necessarily to a heterogeneous set of agents. As an important part of this step it has to be suggested which variables the agent does ***perceive*** and in which way they are perceived – and used in the internal model. A central part of perception concerns information coming from other agents, i.e. the endogenous instrument variables (communication elements[16]) set by other agents. The result of step 3 is a non-quantified logical blueprint of the model that contains all agents, all variables, and links showing which ones are related.

Step 4: ***Empirical data*** for all used variables has to be found. Since important parts of ABM concern internal model building processes, which are rarely covered by official statistics, this can be a tedious task; in some cases, some crude assumptions will be the only possibility. The result of step 4 is a table with historically observed values of all variables.

Step 5: ***Econometric estimation*** of the suggested relationships. The quality of these estimations will vary according to the quality of the available data, in extreme cases just guesses of some parameters will have to be used. The result is a quantitatively specified blueprint of the ABM.

Step 6: ***Software implementation*** of the model. There is a broad range of simulation tools, from the use of procedural computer languages to highly specialized simulation packages. Since the first implementation of a new model usually is considered as a preliminary toy model that can be iteratively used to improve steps 1 to 6, it is very important that this model can be easily handled. A simple software tool with some graphic capabilities therefore should be the result of step 6.

Step 7: ***Systematic result generation*** by a large number of steadily improved simulation runs. Since the repeated improvement process of step 1 to step 6 after some time has to reach an end – either because improvements are becoming arbitrarily small, or because the deadline

[16] A communication element can be a whole model, which an agent posts in the hope to influence the actions of other agents in a way that furthers its own goal achievement.

of the research project is approaching – some time before this endpoint the overall emerged new knowledge has to be collected and interpreted and condensed in a report.

3 - Future perspectives of ABM

The perspectives of ABM will be discussed along three dimensions: syntax, semantics, and pragmatics.

The ***syntax of ABM*** certainly is still waiting for some substantial structural improvements, not to speak of standardisation. The variety of software support of ABM will certainly persist in the future, and this is to be welcomed[17]. But nevertheless some particularly important features will be identified (e.g. support graphic capabilities), while others will peter out (e.g. too rigid syntactical restrictions). One important improvement will concern reproducibility of results of simulation runs: The same ABM implemented with different software shall produce the same simulation results. As a precondition for this future task transparency of what happens inside software packages is an immediate imperative.

A more daring goal is the development of a new arrangement of the set of operations that are in the action set of agents. Assigning values to variables and copying/imitating are certainly operations at least as basic as adding and subtracting. Moreover, actions in the area of perception, which to a large extent relies on pattern recognition combining external sensors with memory, will experience some special treatment as fundamental elements of syntax. Even more challenging is a type of behaviour observed in real cognitive processes that performs switching between a seemingly stable background and movements in front of this background: If a sensitivity border is reached, sometimes it is only the feeling to be bored, then the moving foreground is taken as stable and the focus is redirected to the dynamics of the background. This switch in the mode of perception occurs more often than commonly understood and adds a new dimension to perceptions. In the moment there exists no syntax element that supports it in ABM[18].

The future challenges of the ***semantics of ABM*** are straightforward extensions of the characteristics provided in the previous part of this paper. The semantic relations are the links between language elements and the elements outside language to which they refer. ABM, the language, in the future will probably change along the lines of its object of investigation. Since – as explained above – the scope of its application is adjusted to a well-defined object, better ABM will mean that there will be a diversity of tailored languages for different areas. An evolutionary economics approach asking for the simultaneous treatment of micro-, meso-, and macro-processes will be supported by a very special type of ABM. In another area dealing with communication processes the features of ABM that concern manipulations of internal models will be particularly well supported to support ideas of learning and manipulating across agents. In a third example market processes of information commodities with high fixed cost and zero variable cost can be supported with software allowing for more sophisticated arrangements of public-private production and more refined preference modelling – fashion effects and communication are essential. This broadening of ABM language into different jargons at first sight looks like a counter-movement to the streamlining effects of syntactic innovations. But how far this

[17] Software development since the times of SWARM has been tremendous with respect to the amount of the available packages, though rather modest with respect to their fundamental capabilities. Currently most popular packages include Anylogic, Repast, NetLogo, and Python; for system dynamics a survey can be found at https://dsweb.siam.org/Software.

[18] In everyday language this process typically is reflected as an exchange of the roles of verb and noun, or of adjective and noun; a procedure typical for the dialectical textsof the German philosopher Hegel.

diversification produces feedbacks on syntax innovation on a higher ground – both working in the same direction – remains an open question.

It is evident that an argument analogous to domain specification can be made with respect to agent specification. For agents specific forms of perception could be the starting point, or characteristic sets of instrument variables. Another dimension along which the object of investigation of ABM could frame its form will be the respective environment, which surrounds it. Modelling agents acting within a market regulated environment will look different to modelling a free-wheeling bargaining process outside market institutions. In all these cases innovations of the ABM language will come from a close inspection of its respective object of investigation.

The most interesting future prospects of ABM become visible if one looks at the ***pragmatic aspect***. In their simplest form future agent-based models can be used as ***extensions of the 'brain' of an agent***. Anticipation of future interactions between multiple agents, e.g. as modelled in game theory, easily go beyond the information processing capabilities of the agent. In that case an appropriate ABM can help.

Consider another pragmatic example, the conflict between actions optimizing short-run goals and those being necessary for long-run goal achievement. Information processing constrains usually make it more difficult to anticipate long-run implications than advantages in the short-run. With the help of ABM an old goal of enlightenment can be realized: Decisions that in the short-run appear as sacrifice can be made incentive compatible because long-run implications are better understood. This clearly concerns the whole area of global environmental questions.In many cases short-run profit maximization of micro-units, e.g. firms, contradicts the long-run survival of the landscape within which they operate.

This idea leads straight into the most interesting pragmatic aspect of agent-based modelling, the study for intervention into large scale social evolution. It is the limited extent of landscapes, the predictable borderlines of possible extensions, of extensive growth, of globalisation, which necessitates considerations of deep re-structuring of prevailing dynamics[19]. Since dynamic forces in the mixture of national and continental human populations are driven not only by the respective governance systems – the different ruling classes –but also are characterized by the spread of culture-specific internal mental models that form partially contradicting class forces, it becomes mandatory to gain some insight into this highly complicated process with the help of ABM; hopefully this will be possible in the future. The build-up and vanishing of classes, on national as well as on a global level badly needs a scientific investigation combining the study of economic, political and ideological (mental model oriented) forces. By and large overall welfare increase that also avoids exploding inequality and is to take place in a limited environment can only emerge if the rules of interaction between the different parts of human society that were tailored to conditions prevailing 200 years ago, are changed. There are probably only a handful of feasible new combinations, of new rule sets, i.e. global/local democracy mechanisms, new information sphere governance, modes of organization of production, which could be envisaged. To produce visions of them, to detect them, and to find ways to transform the current setting to the most preferable vision is certainly the most ambitious, but also the noblest goal to which agent-based models can contribute.

References

Arthur B., 1994,**Inductive Reasoning and Bounded Rationality**, American Economic Review (Papers and Proceedings). 84: 406–411.

[19] Compare[Hanappi, 2016].

Axtell and Epstein, 1996, **Growing Artificial Societies. Social Science from the Bottom Up**, MIT Press.

Axtell et al., 2012, **Getting at Systemic Risk via an Agent-Based Model of the Housing Market**, AER, 102(3): 53-58.

Barabasi L., 2014, **Linked: How Everything Is Connected to Everything Else and What It Means for Business, Science, and Everyday Life**, Basic Books.

Casti J., 1989, **Alternate Realities: Mathematical Models of Nature and Man**. New York: John Wiley & Sons.

Chen Shu-Hengand Wang Shu G., 2010,**Emergent Complexity in agent-based computational economics**, Journal of Economic Surveys, Blackwell Publishing.

Darwin Ch., 1859, **On the Origin of Species**.

Descartes R., 1637, **Discours de la méthode pour bien conduire sa raison, et chercher la vérité dans les sciences**.

Farmer D. and Belin A., 1990, **Artificial Life: The Coming Evolution**, Proceedings in Celebration of Murray Gell-Man's 60th Birthday. Cambridge University Press.

Gilbert N., 2008, **Agent-based Models**, SAGE Publishers.

Hanappi H., 1992, **Evolutionism in Natural Sciences and Social Sciences. On Basic Concepts of Evolutionary Economics**, Methodus 92/1.

Hanappi, H., 1995, **Perspectives of Gaming**, in " Macroeconomic Policy Games", Physica-Verlag, Heidelberg.

Hanappi H., 2014, **Bridges to Babylon. Critical Economic Policy: From Keynesian Macroeconomics to Evolutionary Macroeconomic Simulation Models**, in 'Economic Policy and the Financial Crisis' edited by Lukasz Mamica and Pasquale Tridico (Routledge).

Hanappi H., 2016, **Capital after Capitalism. The evolution of the concept of capital in the light of long-run sustainable reproduction of the species**. Invited Paper at the International Conference of the 'Financialisation, Economy, Society and Sustainable Development' (FESSUD) research project in Siena, 11th of November 2016. Published as MPRA 77161.

Hanappi H. and Egger E., 1993,**Intelligent Design versus Solving of Artificial Problems. Artificial Intelligence Research at the Crossroads**, proceedings of the IEEE region 10 International Conference on "Computers, Communication and Automation", October 19-21, Bejing, China.

Hanappi H. & Hanappi-Egger E., **Norbert Wiener's Cybernetic Critique of the Information Society - An Update**. Innternational Conference Cybernetics 99, Gran Canaria, Spain, February 8-12, 1998, Proceedings, Springer.

Kauffman S., 1993, **The Origin of Life**, Oxford University Press.

Maynard-Smith J., 1982, **Evolution and the Theory of Games**, Cambridge University Press.

Nelson R. and Winter S., 1982, **Evolutionary Economics**, Belknap Press.

Neumann J. v., 1944, **Theory of Games and Economic Behaviour**, Princeton University Press.

Newell A. und Simon H. A.,1972,**Human problem solving**, Englewood Cliffs, N.J., Prentice-Hall.

Rostow W.W., 1960, **The Stages of Economic Growth: A Non-Communist Manifesto**.

Sargent Th., 1979, **Macroeconomic Theory**, Emerald Group Publishing, UK.

Schrödinger E., 1943, **What is Life? : The Physical Aspect of the Living Cell**.

Schumpeter J.A., 1911, **Theorie der wirtschaftlichen Entwicklung**.

Watts A., 1999, **Small Worlds: The Dynamics of Networks between Order and Randomness**, Princeton University Press.

Wolfram S., 2002, **A New Kind of Science**, Wolfram Publishers.

2. Modelling European Economics and Institutions

A basic fact that usually is not made explicit in scientific research is the interdependence between the object of investigation and the scientific language used. In one direction of the argument it is evident that social science – in particular the language of scientific political economy – has been developed by human societies as just another intellectual tool to understand and to improve its working. Scientific language, e.g. agent-based modelling of political economy, therefore to some extent carries the marks of its object of investigation. In the opposite direction of the argument it is also clear that any successfully applied tool sooner or later will change the object that it was designed to work on. In the social science successful theories in the end are produced to act either as self-fulfilling or as self-destroying prophecies; even if the first step of scientific work typically is carried out with the pure intent to understand how the social system works.

In the project at hand this interdependence implies that not only the characteristics of the agent-based modelling approach have to brought on the table, but that also the empirical facts concerning the object of investigation have to be made explicit. Only then the appropriate modelling style can be developed – in ABM there is no 'one size fits it all'. In this part of the project, which took on shape as phase 2 of our work, this influence of the political economy of Europe is the focus. It starts in 2.1 with a brief synopsis that presents a specific view on Europe's economic history and underlines what our research considers as essential dynamics and which traits and events are thought to be negligible. Two important features stand out: (1) The experience of the last 300 years is characterized by an ever more complicated interdependence between steadily growing economic and political entities, and (2) there is an enormous and steady increase of new goods and new production techniques. These two basic trends often are summarized as ***globalisation*** and ***technical progress***. The first trend implies the emergence of additional organizational levels of social interaction, what usually is called an ***institutional framework***. But this is only a necessary condition that comes only stepwise into being - consider the emergence of the European Union, of OECD, or of the United Nations. The corresponding sufficient condition is the rising welfare increase that is made possible by advances in the ***global division of labour***. Division of labour, this basic property of the progress human societies, is also visible in the second trend, technical progress. Specialized groups of entities take care of ***social and economic innovation***. In chapter 2.2 our solution to identify these entities, to sort them out into three levels of agents, is presented. A remarkable implication of the importance of innovation is the need to consider the production sphere in more detail, i.e. to describe single sectors of the economy, because

it is there where innovation takes place. But a sectoral model implies agents that represent sectors, a theoretical innovation not to be found in standard macroeconomics[20].

Note also that it is also the feature of increasing division of labour, which is responsible for the emergence of ever new forms of money and finance. Since for every productive entity surplus produced in one sphere of production involves scarcity in all the products and services that are not produced, a means of exchange, a carrier medium of (institutionally averaged) social value is needed. And advances in production technology as well as the exploration of new utility dimensions (see the second trend) ask for non-traditional behaviour that has to be equipped social value withdrawn from the usual circuit of money. This is what today is summarized as 'finance'. The agent carrying out finance is simply dubbed 'bank', and only in a more detailed specification the typical distinctions - e.g. investment banking, central banking, savings bank, etc. – have to be filled in.

As this brief overview shows a strict divide between a real and a monetary side of an economy leads nowhere, both sides are so interwoven that they can only be understood as one interacting system. The continuing emergence of new forms of carriers of social value, of new money forms, comes with the emergence of new institutions of political economy. The challenge of theories of evolutionary political economy is to understand this process – and eventually to guide decision-making entities in their attempts to improve welfare.

The study of the banking-macroeconomics network can also be considered from the point of view of pure network theory[21]: The nodes of such a network would be the institutions, the agents, which are thought to be relevant, and the edges would be the activities that link these agents. Another type of nodes could be used to describe institutionalized automatic handling of activities, e.g. market mechanics, that are manifest expressions of certain constellations of agents. To develop such a concise network, the framework that we are providing in part 3 of this report can be used. In an extension of the current project the exciting results of modern network theory might enable valuable additional insight.

References

Newman M., 2010, **Networks: An Introduction**, Oxford University Press.

Barabási L., 2016, **Network Science**, Cambridge University Press.

[20] It is well-established input-output analysis, which can help out – and is used in this project.
[21] Compare [Newman, 2010] and [Barabási, 2016].

2.1 Synopsis of European Evolution[22]

British classical political economists of the 19th century experienced and identified the world in which they lived as being different from societies of the Middle Ages. Since the most obvious change had taken place in production methods and the way production had become a consequence of spending money for the means of production, they summarized their diagnosis in the statement: Capitalism is a mode of production. There are two approaches to understand what makes capitalism a particular type of a mode of production[23].

One possibility is to study economic history, the observed development of human societies. In a famous statement of the classics this approach was praised by saying that 'all knowledge in the end reduces to knowledge about our history'. Today this approach often is called the *diachronic approach*, investigating a phenomenon along the time line of its emergence.

Another possibility to understand a phenomenon is to investigate its current essential variables and their relations. The logic found in the contemporary processes then might reveal a general property of our society. This approach usually is called the *synchronic approach* to a phenomenon, since it develops its abstraction by generalizing properties of synchronizing processes today, occurring in the most advanced societies.

Proper social science combines both approaches, switching between the two and using suggestions from the one to improve investigations in the other domain. A brief application of both research streams for the concept 'capitalism' is sketched below.

A diachronic synopsis to position capitalism

A possible structure for historical development of human societies has already been presented in [Hanappi, 1986]. In the very long-run only '***early social forms***' and '***commodity producing societies***' are distinguished. While in the first tribes of hunters and gatherers the production of surplus output for the explicit purpose of exchange was not a common characteristic, we now still live in a commodity producing society[24]. Concentrating on commodity producing societies Karl Marx - following the mainstream of serious historians of his time – suggested to distinguish three stages of commodity producing societies: the ***slavery*** mode of production, ***feudalism***, and ***capitalism***. It is intriguing to study how such different types of agents and their relationships, each of them more or less stable for many generations, did emerge in a relatively short time period out of the breakdown of its predecessor. I have dubbed these deep structural breaks in commodity producing societies: metamorphosis. In the relatively short process of a metamorphosis (the correlate in physics is called phase transition) the basics for the longer run of the next stage are laid.

[22] An extended version of this text with the title 'Capital after Capitalism' is forthcoming in the Journal 'World Review of Political Economy' (Pluto Journals, London UK) later in 2018.

[23] This distinction of approaches follows Ronald Meek's description of the 'logical-historical' approach, see [Meek, 1979, pp. 299-318].

[24] I apologize to all anthropologists for this much too rough summary of more than 80.000 years of development.

[3] See [Gramsci, 1930] for the link from social functions to the switch of ruling classes. While the ruling class in feudalism goes back to families particularly successful as military leaders, in capitalism the drivers are those particularly apt to exploit and to re-invest in productivity increasing techniques (and eventually new products).

Metamorphosis clearly is an open process, there always exists a certain finite set of possible fits of the remaining and newly emerging pieces – agents, institutions, etc. – with which a new mode of production is built. The study of the history of political economy can discover how metamorphosis actually has worked.

The step from feudalism to capitalism typically could be traced backed to a general difficulty of feudal classes to finance their territorial aspirations. In times of mainly agricultural production growth of surplus and power was bound to take place as war for new territory. But soldiers and mercenaries cost money, therefore finance started to play the dominant role for social development[3].

Money had already emerged before that break; it was a central feature of all commodity producing societies. Making exchange processes independent of the mutual coincidence of the needs of the exchanging parties, of loosening time and space restrictions, it was an omnipresent add-on to the essential processes in earlier commodity producing societies. But in capitalism it woke-up to become the central category, to be its own raison d'être. In previous societies it was just a non-commodity (not consumable) enabling better exchange processes of commodities, now the commodities became the less important accessories of the self-amplifying process of growing money property. Money accumulation being the prime motor of social dynamics, with commodity production becoming the dependent variable, led to a fascinating evolution of money forms, compare [Hanappi, 2013]. And since a sign system of social value, i.e. money, can only work if signs are understood and accepted – if necessary enforced by police – money forms were paralleled by an evolution of governance forms, of state forms. This in turn surfaced as a further, more fine-grained sequence of stages of capitalism.

In a first stage ***merchant capitalism*** increased productivity by exploiting the difference between cultures, between their products (e.g. spices and tea), between their socio-political structures (e.g. buying slaves in Africa), and between their different technological advantages (e.g. large cotton fields in America). Combining these differences in trade activity, e.g. the Western trade triangle[25], allowed to increase average global productivity. For the single merchant this increase materialized as profit, as a sum of money that could be added to the money advanced to enable the trade activity. The ships of a colonial empire were both, instruments of trade and military units to secure political dominance of a hegemonic state. The prime nation of merchant capitalism were the Dutch, their state, de facto Amsterdam, was the first hegemon of capitalism. On the financial side the Amsterdam Bourse exemplified a new institutional rule set that could handle global exchange of social values[26].

With the metamorphosis from merchant capitalism to ***industrial capitalism*** the hegemonic role was transferred from the Netherlands to England. The triggers for a metamorphosis can be found by looking at the limits, the bottlenecks encountered by the temporarily stable previous stage. In the case of merchant capitalism, a serious limit consisted in the almost constant output of merchandise, of stagnating productivity, in the advanced colonial

[25] Compare [Frank, 1978].

[26] Compare [Braudel, 1979, chapter 3].

hegemonic states. The second largest merchant capitalist power, namely England, was faster in overcoming this limit by introducing systematic increase of productivity in manufacturing – what today is praised as technical innovation. This new dimension of the characteristic feature of capitalism, i.e. productivity increase, has to be considered as an overlay on the still existing network of merchant capitalist relations. An even more sophisticated arrangement between the political power of still feudal circles and the new drivers of the wealth of the nation[27], i.e. the capitalist class described by classical political economists, was emerging. Class, a central concept for the understanding of 19th century industrial capitalism, became visible to classical political economists because poverty of masses of people occurred in front of their windows, in England[28]. Politics were visibly national class politics, the strong ties across nations that Europe's nobility had maintained during feudalism were loosened. At the height of the hegemonic power of the British empire its culture[29], above all its restless thrive to penetrate the whole colonial world with its economic style, laid the foundation of what till today can be considered as the core algorithm of capitalism.

From a financial point of view London – like Amsterdam a large port, showing that trade till today mainly is sea trade – accomplished and extended the art of contractual arrangements that merchant capitalism had produced. Money needed by innovative entrepreneurs or merchants was not lent from a rich uncle anymore, organizations facilitating the flow of money quickly were institutionalized. It was already during industrial capitalism that a first split between entrepreneurial activity and the financial support it needed appeared[30]. While technical innovation needed time and usually was stuck within a well-defined production process or product line, finance was a highly flexible and rapid instrument that could easily jump from one production sphere to the next. There certainly were contractual measures trying to fix the gaps between the two speeds, another source of the growth of the law system and accompanying professions, but as national finance developed into international finance the bridge between the two factions of the national capitalist class started to wobble. Today this divide still is a main source of concern.

The rupture to the third stage of capitalism, the metamorphosis that started with World War 1, had been triggered by a coincidence of events that suddenly transformed latent political contradictions into a full-fledged global war. A major ingredient of these contradictions was a relatively new phenomenon in the superstructure of advanced capitalist countries:

[27] In his classic book Adam Smith emphasizes only the welfare increasing benefits of division of labour on all levels to explain the superior role of Britain, see [Smith, 1776]. The downside of the processes constituting industrial capitalism, like the deepening of the contradiction between the British ruling class on the one side and slavery in Africa and the working class in England on the other side, are neglected.

[28] For David Ricardo a main topic was to distinguish two groups within the ruling class: old-style rentiers and progressive industrial capitalists [Ricardo, 1817 (1973)]. Karl Marx focussed on the conflict between industrial capitalists and the newly emerging working class. Framing history as a history of class struggles and despite his taking side for the proletariat as the next ruling class, he also acknowledges that the ruling class of capitalists fulfils a necessary historical mission, namely to increase labour productivity [Marx, 1848]. After capitalism less labour time will be necessary to produce the commodities and services for basic needs of mankind, for its primary biological metabolism.

[29] Compare [Hobsbawm, 1975].

[30] Early observers of this process typically interpreted it from a socialist political perspective, see [Lenin, 1914 (1999)] and [Hilferding, 1908 (1968)]. Both had read John Hobson [Hobson, 1902].

nationalism[31]. After the most disastrous catastrophe of WW1 the interwar period can be interpreted as the difficult transfer of hegemony from England to the USA, from the reign of the Pound Sterling to the era of the US Dollar. The third stage of capitalism that emerged can be called '***integrated capitalism***' (compare fig. 1).

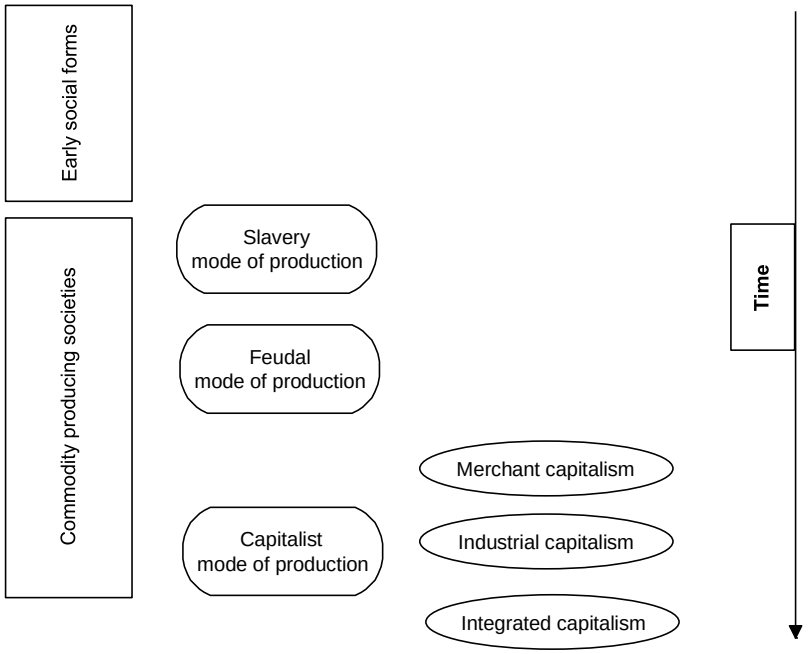


Figure 1: The historic position of Capitalism

Under the lead of the USA it set out to integrate the deep contradictions that broke up in WW1 into a new form of the core capitalist algorithm. A central difficulty had been the exploding conflict with the national working classes that in Russia had even culminated in the founding of the USSR. As a consequence, Western democracies enabled integration via participation of working class representatives in national governments. This was only possible if feudal political leadership was abolished, and this should have solved another contradiction, namely how to overcome the conflicting territorial aspirations linked to feudal governance. Unfortunately, political entrepreneurship in the form of Fascist movements was able to surprise the world with a fall back to authoritarian dictatorship in Germany and Italy[32]. Its rise to power to a considerable extent was owed to its capacity to provide an answer to the question of unemployment that became extremely urgent during the Great Recession of the 30-ties. The German answer to the sharp economic downturn of the world economy was the same as in other advanced economies: a stronger state should intervene and should provide employment and effective demand. But in Germany the NSDAP played on the stirring-up of

[31] It was not just the motivation for the assassin of heir apparent Franz Ferdinand, Gavrilo Princip, it also was a general attitude of large parts of the population in many European states. In the Austrian-Hungarian and the Osman empires nationalism within the empires pushed towards their fall, while German nationalism turned outside, against the large colonial powers England and France to fight for global leadership.

[32] A thorough discussion of Fascism goes beyond the scope of this text, for a still valid characterization compare [Kalecki, 1943]. A decisive role certainly was played by the newly available technical devices, like broadcasting, which enabled 'micro-politics': The transfer of the leader's voice into each living room and each brain at any time of the day.

nationalism and specified this public employment as the recruitment of soldiers. Economic activity was commanded by the newly installed institutions of the NAZI-regime; it concentrated on the build-up of weapon industries. As it turned out, the fascist variant of 'capitalism' that rests on military conquered territory and state terrorism is not a sustainable form of governance[33]. The 1000 years dream broke down after 7 years, which brought the human species close to the edge of extinction.

The same general feature of integrated capitalism, namely stronger involvement of the nation state to eliminate emerging contradictions stemming from the working of the core capitalist algorithm, had been applied in the USA in a completely different form. Anticipating in practice what Keynes prescribed later in his 'General Theory', see [Keynes, 1936], Fordism and 'blockbuster' Roosevelt's 'New Deal' tried to eliminate troubles of lacking effective demand and oligopolistic inefficiencies.

What these measures incorporated and anticipated from a financial perspective is most interesting. In a sense it is only in integrated capitalism of the American variety after the defeat of Fascism that the concept of capital comes to its full flourishing. In the practice of economic policy of the 25 years after WW2 Keynes ideas most visibly proved that capitalism, in its third stage of integrated capitalism, can fulfill its historical mission. It led to dramatic welfare increases, though only in the developed countries of Europe and North America[34]. It is remarkable that towards the end of this period economic theory started to stroll away from its former commitment to provide models that can explain actually observed phenomena.

Since the mid 70-ties integrated capitalism is on the retreat. The monetary mechanisms that had allowed to realize profits, i.e. to sell goods and services, by letting consumers and states going into debt, these mechanisms are successively called into question. A worldwide rollback of Keynesian policies, like fixed exchange rate regimes or a pro-capitalist role of state intervention in markets, is taking place. In the mid-run this conservative revival in a few areas could successfully iron out bureaucratic excess of state administrations; but the general judgement certainly can only be that the force of integrated capitalism was inverted. Since 25 years integrated capitalism now is disintegrating.

Disintegration also meant that financial power now was rapidly centralizing and concentrating in the USA. Hand in hand with this development ever more superior military might and a top position in research could be developed there[35].

In 1990 another external shock[36], the political breakdown of the USSR and their satellite states, was giving this process a severe twist. Without a global military challenge, the weapon

[33] An insightful study of the internal economic processes of fascist Germany was provided by Sohn-Rethel, compare [Sohn-Rethel, 1973 (1987)].

[34] In [Vercelli, 2017] this first phase of financialisation is called 1st financialisation.

[35] The European intellectuals and scientists that fled from the fascists in WW2 had already prepared the ground for this advantageous spurt of research in the USA.

[36] Seen in a wider context this shock was not external. It was the coincidence of a late success of Western propaganda via TV and an even more delayed effect of Stalin's misconception of 'socialism in one country' - held together by army and police. Both sources might be well described endogenously in a more extended elaboration.

industries and related political cadres seemed to have lost their reason of existence. But after a short period of confusion these sectors and their promoters recovered and formed a new globally acting force. To a considerable extent, NATO today is shaping world policy again; see [Hanappi, 2017] for a more detailed treatment.

An even more remarkable turn has been taken by international finance. Alessandro Vercelli describes it as 2nd financialisation, see [Vercelli, 2017]. Indeed, the dynamics of integrated capitalism since the end of the Soviet Block in 1990 has to be understood in the context of the global political economy.

The conservative roll-back in economic policy that had started ten years earlier, in 1980, was characterized by a continuous flow of capital towards the USA; mainly due to higher interest rates and the promise of higher profits rates that in the Reagan era were stimulated by save state public investments in the military-industrial complex of the USA[37]. In Europe this outflow of capital led to an economic downturn as interest rates started to rise too and capital cost increased. While many SMEs went bankrupt and Europe's big unemployment problem started, the group of European transnational companies organized counteraction – they pushed for a powerful political representation of their needs, something that could build a counterweight to the government of the USA. These efforts resulted in the strengthening of the European Union in the mid 80-ties. But contrary to the USA, several European countries were characterized by relatively strong positions of labor movement institutions, unions, social-democratic governments, chambers of labor, and the like. As a consequence, purchasing power did decrease moderately only - households and governments went into debt - and Europe became the largest consumer worldwide. Across the Atlantic capital was amassed, blue collar workers' wages could fall to the level of the 60-ties and the inequality in income and wealth started to explode.

Then, in 1990, it seemed that the world now had become capitalist, that the system of integrated capitalism finally had reached its natural destiny. In Europe, this euphoric misinterpretation led to a short boom that broke down in 1993. Since capitalism certainly is not the final natural state into which human societies quickly return as soon as misbehaving labor movement institutions (including Stalinist aberrations) are eliminated, 'capitalism in 100 days' (Jeffrey Sachs) did not happen. In fact, only little happened in the newly opened territory, the capitalist machinery could not take hold of the deeply ingrained local behavioural rule sets. In the long-run the most successive local political entrepreneur turned out to be Vladimir Putin, who is playing exactly on the backward cultural traits of Russia that held back the core capitalist algorithm. US money was more successful in finding fertile grounds in China. The two most important developments that hold integrated capitalism alive till today are the excessive use of ***exchange rate exploitation***[38] and the emergence of ***global***

[37] Investment in war equipment is one of the few investments that does not need effective demand of consumers with purchasing power. It is eventually 'consumed' by military action and paid from the state. It is thus no surprise that a hegemonic state, which is in control of the worldwide used currency, can build-up military superiority. The amounts needed can partly be financed by increasing the money supply. The remaining effect on money markets then results in a rise of domestic interest rates.

[38] Put simply, exchange rate exploitation is based on a continuous decrease of wages (in terms of the world currency) in producer countries due to a continuous devaluation of their local currency vis-à-vis the world

value chains constructed on basis of the former. In both respects China is a pivotal global player. China's arrangements with international finance controlled mainly in the USA are a key explanatory element for the dynamics of global political economy. As the tremendous economic upswing of China shows, its government successfully managed to position itself as a middle-man, a managing entity, in between the urgent needs for further profit promising global opportunities that large US-based finance expresses and the possible local production possibilities in the poor producer countries, being itself for the most part still one of them.

Integrated capitalism thus to a large extent has achieved the integration of global production. In doing so it also has undermined the motor of its historical mission, namely to increase average global labor productivity. This mission had the tricky feature that the private vice of profit maximization of firms (from a catholic point of view) implied the public benefit of rising labor productivity – in the long-run less labor time and more leisure time for all would be possible if workers would fight successfully for an adequate distribution of these benefits. Since average global productivity growth since 1980 approaches zero and the move to a more adequate distribution is necessarily (exchange rate exploitation!) politically blocked, the historical capitalist mission has run out of steam. After 1990: Enter 2nd financialisation.

In the desperate search where to place the enormous amounts of money that have been amassed in large financial pools new financial techniques cut almost all links to physical economic property. Assets are ascribed a certain value not because they refer to a factory producing products that are thought to represent a certain social value, they are rather priced according to their expected selling price in an ever shorter future – without too much reference for which 'physical entity of last resort' they stand. The move from savings of households – that in Europe now rather are going into debt – to assets held by the small group of very rich investors is symptomatic. Expectation based bubbles in financial markets are an immediate and necessary consequence. The ICT bubble in 2001 was a first warning, the great financial crisis of 2008 might have been the deadly blow for integrated capitalism. Since then the turmoil of chaotic piecemeal engineering in economic policy and finance is not ending, and is not successful either. Substantial economic growth, i.e. capital accumulation, is not returning. What comes next?

A synchronic description of the core capitalist algorithm

The diachronic positioning of capitalism has not been possible without some recurring references to the logic of the ***core capitalist algorithm***, which in turn is itself a concept derived from the study of history. It entails what the diachronic approach reveals as essential characteristic and translates it into a more abstract and more general model. Since it should cover all three stages of capitalism it has to be independent of the different money forms by which these stages differ. On the other hand, it must entail the above mentioned historic mission of capitalism, which distinguishes this type of commodity producing society from

currency, i.e. the US Dollar. This mechanism uses local customs and political regimes in producer countries to ensure persistent low consumption levels of the local population. It is essentially a modernized form of one of the above mentioned elements of merchant capitalism.

other such societies, like feudalism. As the previous chapter already made plausible this core property consists of the capitalist algorithm shown in figure 2.

The entity that applies this algorithm can be a merchant, a firm owner, a transnational company, a financial entity, or – as the recent ideologues of privatization try to stipulate – a government or even each single human individual. It is evident that depending on the entity chosen the names used in the labels of figure 2 have to be slightly modified. Note that an essential part of this algorithm consists of producing and using a set of visions. These visions are different internal models maintained by a social entity, which usually are easily transferred (at least partly) in communication processes. This not only explains Schumpeter's empirical observation of swarming of innovations, see [Schumpeter, 1939], it points quite generally to the utmost importance of communication processes.

```
For each member of the set of currently possible visions do ('vision loop')
        Produce a vision of specific entrepreneurial activity
        Check expected wage cost
        Check expected interest on credit-money (vulgo 'capital cost')
        Check expected effective demand
        Compute expected growth rate of capital
        Estimate the probability to achieve that growth rate
End of vision loop
Choose the vision yielding the highest utility of a mean-variance utility function
Check if the selected vision's utility exceeds the expected utility of a supplier of credit-money
If the lender's utility is higher, then perform the chosen project,
                                    else become a supplier of credit-money.
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Figure 2: The core capitalist algorithm Source:
[Hanappi, 2013, p. 262]

At this point of the argument it is fruitful to return to the latest developments in economic history: With the recent surge of information technology worldwide communication processes made a quantum jump. Media today can often frame the interpretation schemes of the population stronger than local direct experience or face-to-face communication can do. As mentioned in the previous chapter, the use of broadcasting to disseminate fascist interpretation schemes has been an early warning signal of the force of centralized media power. After WW2 financial bubbles are another obvious example. The spread of the core capitalist algorithm as a general feature of human nature to be applied to states and single persons has been the central assault of information power masterminded by politicians of the conservative roll-back; there it went under the name of 'privatization'. Its final task would be human individuals that in their self-perception are just singular carriers of business plans, of internal models looking like the core capitalist algorithm.

In many OECD countries this vision of conservative ideologues has already reached considerable shares of the population. But since it is built on the use of technology, hardware and software, which is open to other manipulating power groups too - e.g. religious organizations, neo-fascist groups, nationalists, environmentalists and the like – several

competitors for the minds and hearts of the global audience appeared on the stage. In the last years this not only has contributed to the rise of Islam and the migration wave to Europe when war and Islamic repressions hit Arab populations, in the sequel it also is fuelling state control of information flows within the advanced countries – in the name of anti-terrorism and security.

Any vision of the next mode of production has to take into account this qualitatively new mode of communication structure the next generation will live in, compare [Hanappi and Egger, 1993]. The eminent importance of this issue can be expressed by stating that we are entering an **age of alienation**, where the primary metabolism of the human species can and will be pushed in the background and interaction can and will predominately take place in the information sphere, using symbolic objects that are alien to primary needs. A closer look at current developments, e.g. BREXIT and the election of Donald Trump as president of the USA, reveals that we have already entered this new age.

The core capitalist algorithm, these days more than 500 years old, since 2008 by and large proves to be an inadequate model for the new century. Not only is it inapplicable for the huge majority of the world population and its social institutions (including production units), in the mid-run it is even forcing zero growth on its most optimistic proponents, the transnational corporations.

To get some ideas which features of the old mode of production will survive, and which will disappear, the best advice can be found by looking at the most dramatic break lines, the major contradictions of todays integrated capitalism.

Rupture Lines and Order Parameters

In theoretical physics the phenomenon of phase transition has been extensively studied and today is pretty well understood. If water starts to boil, there is a small range of temperature within which several properties of water experience a dramatic qualitative change; e.g. in the colder state water cannot be compressed, while in the hotter state it can. The phase transition thus eliminates some essentials (a 1st set of variables) and creates a set of new essentials (a 2nd set of variables). Moreover, it takes place along a continuous change of a third set of variables, e.g. temperature. Physicists therefore define phase transition as a discontinuity of the derivative of some dependent variables as the third type of variables, the so-called order parameters, change[39].

As explained in more detail in [Hanappi and Scholz-Wäckerle, 2017] phase transitions in nonliving systems are a very instructive metaphor for metamorphosis in political economy. The old set of properties described by entities and their relations falls apart, at least a substantial part of it ceases to exist. During the relatively short time of rearrangement, in societies usually only a few decades, a small, in any case finite set of possible new arrangements for the next temporarily stable arrangement is available. Several groups,

[39] Second order phase transition discovered by Landau, [Landau, 1937], takes place if the second derivative experiences a jump. In this case transition is smooth, but variables can emerge and disappear.

classical political economy called them classes, struggle, build coalitions, propose possible visions, are eventually recombining and invent new institutions until a winning coalition is able to dominate the others[40]. Given the current potential of means of mass destruction, survival of the species at no point of metamorphosis is guaranteed. Returning to the concept of order parameters, the corresponding index in evolutionary political economy should represent two highly significant tendencies in the evolution of human societies: First, ***the tendency towards ever larger area and population***, which a political entity commands. From small tribes, to medieval cities, to nation states, to continents, to the global society. Second, the ***increasing political participation*** of larger parts of the population in the political process, ***i.e. democratization***. While the first trend is an important element contributing to the division of labor, which in turn frees us from necessary labor, the second tendency is the challenge to use increasing leisure time for the rising importance and difficulty of self-governance. An index, indeed a measure of progress, thus also is an index of consciousness of the human society. Under the extensive perspective of the first trend, consciousness proceeds from an individual's consciousness, to family consciousness, to tribe consciousness, to class consciousness, to a nation's consciousness, to a continental unit's consciousness, to conscious humanism. The second trend then outlines temporary difficulties and emerging successes, i.e. the pulsation, of the efforts to ***bridge the contradictions between the ever larger political entities***. Conscious intensions of the different political entities are partly contradicting and have to be reconciled. As temporary arrangements, safeguarded by ever more centralized police- and law-systems, institutions are providing longer periods of a peaceful working of a political entity, in capitalism they have been dubbed 'social structures of accumulation' by David Gordon [Gordon, 1980]. But during such stages contradictions slowly take on new forms asking for new solutions, which then – in a metamorphosis – lead to an eruptive restructuring, a revolution.

In capitalism the essential political agent that drives its historical mission, that increases productivity by pushing towards new forms of exploitation, is the ***entrepreneur***, the character mask of merchant capital, industrial capital, and integrating capital. The capitalist algorithm performed by all of them already shows an implicit contradiction that is related to the concepts of '***social value***' and '***exploitation***', a contradiction that did not disappear but was continuously deepening. At the beginning of an accumulation step the acquired inputs have to be bought, and since the labor time bought must be cheaper than the revenues achieved after a successful sale of output to allow for a profit, it follows that what is rewarded to the owners of labor power can buy less social value than the social value represented by the revenues. This simple fact of accounting is called exploitation. Of course, also non-labor inputs have to be bought from other owners of means of production, contributing to their revenues, which then leads to a repeated reshuffling of profits within the capitalist class depending on price structure dynamics. But the core principle to ***extract social value from labor time*** remains valid. How this is done distinguishes the different stages of capitalism, and since

[40] Note that standard mainstream economics, i.e. neoclassical economics, has never touched these most crucial nodes of social evolution; despite its adherence to the simple Newtonian mechanics it uses. This reveals its implicit mission, namely to describe the stability of capitalism, and *only* the stability.

social value appears in the physical world as money, the different stages did breed a sequence of money forms, compare again [Hanappi, 2013].

Capitalism can therefore be considered as the mode of production that lets money forms change, from a simple physical carrier of social value, a symbol, to the form of credit, and finally to its appearance as capital[41]. Earlier forms of commodity production already used simple money, but only in capitalism this inner evolution of money forms was possible. Hand in hand with this stepwise evolution a sequence of regulatory accumulation regimes took place. What was regulated and policed by the institutions of the respective ruling class were the flows of social values that the relevant exploitation processes and their correlated distribution channels produced. The concepts of 'finance', 'distribution', 'social justice', and the like thus all are derived from the concept of social value and a specified set of prevailing exploitation[42]. In each stage the typical entrepreneur added new features to its behavioural setup: A new, innovative mode to bridge the opposition between private vice (profit making) and public benefit (overall productivity increase) emerged. In the last two decades of integrated capitalism this mysterious entity 'entrepreneur' materialized as the ***transnational company*** (TNC). It has been able to globalize productivity increases and positive profit rates by the introduction of ***global value chains***. The independence from the fetters of single nation states not only circumvents all local achievements of labor movements by the use of exchange rate exploitation, it also leads to a new form business governance. Capital not only became independent from a specific economic sector, now it considers itself to be independent from any political interference[43]. In a sense this global reach of business governance can be viewed as a prelude – though mirror-inverted – of democratic, political global governance. What now proves to be impossible for TNCs alone, for global business governance, is to reconcile the saved profit rates with sustainable mechanisms of social value transfers. In this last phase of integrated capitalism, which aimed at incorporating global class contradictions in a framework of social value transfers, vulgo money streams, this task evidently reached certain new frontiers.

On the one hand the seemingly tranquilized class contradictions brought about an underground movement of dissatisfied, confused and angry citizens in several advanced countries. Indeed, in retrospect, the fascist movements of the 20th century can be understood much better in this perspective. The force of these movements – today as well as in the past – can be channelled into a takeover of authoritarian regimes by gifted 'political entrepreneurs'; a major tool being the ***technological media world*** outside democratic control. With respect to the introduction of a new mechanism for social value streams, in mainstream economics called 'finance', these authoritarian regimes typically are ultra-

[41] This process has been described as the trend of increasing financialisation by Alessandro Vercelli [Vercelli, 2017].

[42] It is important to distinguish the dominant exploitation form from still co-existing older exploitation forms. E.g. in merchant capitalism the dominant capitalist merchant acts in an environment where older exploitation forms in other continents play an important role.

[43] Political leaders – Ronald Reagan was an earlier example – are considered to be actors selling the goals of strong groups of TNCs to a nation-wide public that actually has no influence on global dynamics.

orthodox[44] in amassing public debt to build-up police states and military, what in fashionable terms is called 'security'. The contradictions they were promising to solve thus are quickly transferred to exploding political contradictions between nation states, finally leading to wars. On the global scale at which a 3rd World War certainly will take place, this is synonymous to the extinction of the species.

On the other hand, the welfare enhancing side of capitalism, spreading productivity increases throughout the global population finally got stuck; indeed, it always has been a slow and cumbersome process enforced by the world-wide labor movements. Process innovation as well as product innovation have always had a political bias, though mainstream economists stubbornly exclude it from their analysis. Their central task to reduce cost in the production process typically goes hand in hand with technological unemployment, while the introduction of new products, of new utility dimensions, always has to anticipate customers rich enough to buy these commodities; in contradiction to the wages of employees, see the first task. With these difficulties global innovation practices based on single firm profit-maximization became a problem. To allow 'non-effective demand'[45] to build-up large-scale debt means only to postpone the harvest of profits by a class-internal transfer to banks and tax authorities. This latter faction of the ruling class, i.e. finance ministers, have to take the heat. With the technology induced speed-up of all financial processes such a Keynesian short-term orientation necessarily results in a speed-up of ever larger financial bubbles. The global financial bubbles of 2001 (ICT bubble) and 2008 were the first signs of the sclerosis of innovation under the dictate of the capitalist algorithm.

In the light of this narrative the central question of this paper is if and how the capitalist algorithm will survive the metamorphosis. This question cannot be answered by a simple 'yes' or 'no'. As explained above, its survival is only feasible if a deep change within the algorithm takes place. Its major goal variable, namely accumulation ('growth') of the mysterious variable 'capital' will have to be substituted. A simple substitution by growth of the equally mysterious variable (aggregate) 'utility', i.e. 'welfare', will not shed further light on the question. The only more instructive investigation could be the study of the currently most pressing problems of the existing mode of production. In the phase of metamorphosis several coalitions of political classes will try to gain hegemonic power, and the promise how to bridge these visible contradictions, these gaps, will probably be an essential element of the struggle. Still a well-received promise can nevertheless lead to disaster, e.g. Hitler in the mid-thirties, promised correctly to restore employment and national pride – in the short-run. Today, a positive vision

[44] Ultra-orthodox in this context means that the authoritarian leaders dress their national myths in a pseudo-feudal mode of class-rule, simply disregarding already existing global financial mechanisms, and therefore sacrifice their exploding public debt at the altar of 'autonomy'. Aggression against neighbouring states, i.e. war, is the typical result of such a development.

[45] Keynes' concept of 'effective demand' is a subtle hint that workers might need something but only those who have the money to buy it can be considered as demand. The adjective 'effective' suggests that effects are only those elements that play a role in the mind of the selling firm owner.

for solutions of global problems has to be scientifically grounded and long-run oriented[46]. This has to be kept in mind when studying the limits of the current state of integrated capitalism.

A **first limit**, a breaking point, clearly is **global finance**. Reflecting a very special form of social value as it is extracted from the global population and redistributed towards multi-layered global classes, it is the central piece of the mosaic to be re-framed. In this respect a feature of the sequence of capitalist phases comes into play that has not been mentioned so far: In the course of time the political entities involved have become larger; from regions, to states, to continents, to the whole globe. Finance capital today, like the global value chains it entertains, is a global phenomenon. But the political counterpart that could control it, that could provide its democratic legitimacy, does not exist yet. The non-existence of global governance vis-à-vis global finance and TNCs, above summarized as business governance, thus is a contradiction that must be eliminated. Many more fine-grained measures of democratic control will have to be implemented too. The general thrust, more empathetically spoken the general truth, has to be that that finance and its institutions are political elements, and not just profit maximizing firms. In Europe the latest change of the role of Central Banks and the ECB already signal that this transformation is on its way.

The **second important limit** comes from the set of problems summarized as **environmental problems**. Again, most of these problems ask for coordinated interventions on a global level, thus implicitly hinge on the existence of global governance. As for finance, some preliminary moves in the right direction are already appearing, e.g. the new energy policy of Germany. But for most global environmental limits, e.g. scarce water resources, the non-existence of global governance implies non-action. The disastrous growth imperative of existing integrated capitalism drives itself to the edge. As recent developments in the USA show, re-orientation towards accelerated profit growth in the name of an ideology of national greatness usually is directly linked to environmental ignorance.

The **third important** limit concerns **political governance** itself, namely its **feasibility in** the above mentioned **age of alienation**. The danger of new, ever more dangerous wars between nations streamlined along centrally implanted dogmas is just the other side of the coin that could point towards the implementation of a democratic global governance. The coin is flipped in the air by modern information and communication technologies, and ICT are here to stay. To get from here to there, that is to arrive at global governance as it is needed for overcoming the first two limits, the age of alienation has to be mastered. In that sense this third problem is the hardest and the most urgent. In certain aspects it resembles the French enlightenment and indeed several small bonfires lit by scientists worldwide are already announcing the possibility of a second renaissance, see [Hanappi, 2015]. To unify these first attempts a common vision of the approaching next mode of production will be a pivotal element.

[46] The adjective 'sustainable' is not used in this paper, since the concept of 'sustainability' plays a more restricted role than usual. Here 'sustainable' only refers to the property of a program to perform correctly during the next, temporarily stable mode of production. It therefore is replaced by the loose expression 'in the long-run', which avoids the misleading connotation of being valid for eternity.

The Return of Time and Space

From a more general perspective the limits reached are limits of time and space[47].

First consider ***time***. As noted by classical political economy all economics in the end boils down to the economics of time. Social value, as it finally appears in the form of financial power, originated in the production of commodities that consumed labor time. Partly this labor time is applied in combining it with frozen labor time spent earlier, i.e. with means of production, capital goods. Additionally, in some processes natural resources are used, some of them are not renewable. The human population itself is finite, and so is its total supply of labor time. But the problem today is not the finiteness of total supply of labor time but rather the facts that (i) redistribution of the produced social value follows a successful sale of one's labor time to the owners[48] of frozen labor time (means of production), that (ii) frozen labor is so productive that only a small part of more specialist workers can be profitably employed, and that (iii) it is necessary to sell all commodities to receive a surplus in cash. Some financial instruments today help to ameliorate the difficulties arising from the **divergence between unused labor time and private accumulation of social value**, e.g. transfers to support the primary metabolism of the unemployed or the build-up of debt to solve problem (iii). This avoids revolts and postpones the realization of already contracted fruits of exploitation to a later date – when debt has to be paid back[49]. But none of the existing instruments is designed to eliminate the basic contradiction mentioned above that is the source of reappearing conflict after each step of piecemeal engineering. A ***new type of time and value organization*** therefore is the ***main task*** of ***future global finance***, it only can work with a move back, from private to public decision-making. The mechanism of global business governance sketched above is the highest form of privatization, and it is dramatically failing to protect the species from political and environmental disaster. The ***role of markets***[50] should be cut back to the tasks they are assigned to in the dream world of mainstream economics: as a ***system of sensors for the taste of consumers***, tailored to specific goods and services. This too would be a ***secondary function*** of future global finance – the relation between life time and labor time thus could return to the command of the population, via a new type of political global finance.

The reduced average labor time for the needs of the primary metabolism of the species that capitalism has brought about will have to be re-arranged in both spheres, in global production

[47] It looks like a joke, but the neglect of the limits of time and space is a mirror image of Kant's early emphasis on the utmost importance of time and space for human thought, see [Kant, 1781 (1998)]. Kant, of course, was one of the promoters of the ideas of French enlightenment in Germany.

[48] As Ann Davis recently showed, the evolution of property relations is a fundamental entry point to the understanding of class relations [Davis, 2015].

[49] This simple consideration already reveals why austerity policy is a proposal that leads to a breakdown head-on. It destroys demand.

[50] A common tool in ideological warfare is to elevate 'the market' to the status of an independent economic agent. Markets are not setting prices and quantities, they only provide rules that the actual market participants, sellers and buyers, have to observe. To be able to enforce these rules there must be a third party, usually a political entity like the state, which possesses more coercive power than the participants. With this constellation a large diversity of market mechanisms, of rule sets, can be designed. To pretend that markets are deciding something only serves to obscure the actual roles of participants and political entities.

as well as in global consumption. The link within and between both spheres, of course, is the social value attributed to labor time units and consumption units. In its most biological dimension the feasibility condition of the primary metabolism consists of the assignment of a vector of labor time units (for different types of labor at specified dates in different parts of the world) to a vector of quantitative consumption (goods and services at specified dates in different parts of the world). If the available time of the population is larger than this minimum reproduction level, then the distribution of the available total leisure time has to be decided on. It is at this stage where communication, bargaining, new voting procedures and new institutional solutions will enter the scene. Making time, competencies, and needs explicit is not a task that lends itself to a central planning office, it is a multi-directional communication process. What has to emerge is the correlate to the central nerve system of a biological entity. The language used for these global communication processes will have to supersede contemporary languages in several ways to master the enormous amount of information, data and programs, involved in bargaining; and the classes[51] involved in the process will have to learn how to work with new combinations of natural languages and algorithmic tools. Language shapes consciousness. The time concept of the species transcends the very limited time concept of its single individuals, with a new communication form, including self-communication on all levels, consciousness itself has to turn to the long-run perspective of a species. This is the deeper meaning of humanism, call it ***vision 1***.

Now consider ***space***. The world is a finite area and the option to expand accumulation to unknown territories has vanished long ago. Today, physical space by most people is experienced as local space, only the electronic world provides an expansion of space. But the latter expansion is limited by those who provide access and content of the internet. In the age of alienation, as described above, this seemingly expanding space actually could be a narrowing down of views. Enlarging the experienced space clearly is a main task for ***global education policy***. Since education is part of infrastructure it has to be financed by taxes, and will have to result in large transfers that redistribute taxes collected in rich countries to parts of the world where education is most backward. A similar argument has to be made for non-renewable resources: for the scarcest of them strongest restrictions on consumption and highest efforts on technological improvements that substitute them have to be made. If this is carried out consistently physical restrictions probably can be brought in accordance with human needs, call this ***vision 2***.

But before this is possible and space can return to the agenda of the human species as a manageable task, it is one of the most endangered elements of the current metamorphosis – similar to the threat coming from alienation. If a majority of the ruling class of contemporary capitalism transforms itself into an atavistic authoritarian dictatorship – Fascism in the 20th century can be interpreted as just a first, failed attempt in this direction – then it will concentrate its core military power in a geographically well defended area, a specified space on the globe. The USA is a prime candidate for this role. Nevertheless, this core will need strong links to the rest of the world to maintain its necessary exploitation processes. And for

[51] It would be naïve to assume that classes will disappear. But they certainly will not be aligned along the private possession of means of production. There might be other demarcation lines stemming from positions in production or consumption, or from geography.

this scenario a different type of communication structure would be substantial: At one level ideological influence flowing from the central space to the periphery is needed (ideological dominance), while on a second level information on all activities of individuals outside the core has to be collected to avoid insurgencies (secret service activities). If successful, this organization of communication, of the 'central nervous system', produces a split of humanity, of two parts with two different types of consciousness. The consequence of this vision is the anticipation of a superior part within the human species, a superior 'race' exploiting the less valuable races. Space, i.e. geographically and intellectually understood territory, will be split into two asymmetric parts. It will not be returned to the democratically controlled sphere of the whole human species. This vision, ***vision 3***, too poses high demands on innovation, though on completely different forms of new artefacts.

Visions 1 and 2 point to a new type of innovation activity, in [Hanappi, 2010] it was called ***reproductive innovation***, while vision 3 rather sounds like what is currently happening to keep alive old style capitalism. The first type of reproductive innovation concerns social innovations that enable to overcome time restrictions including the invention of democratic mechanisms. They also should step forward to provide new dimensions of utility compatible with the new regime. The second type of reproductive innovations will be traditional technical innovations that adjust living circumstances in different parts of the world and take care of environmental limits.

This type of reproductive innovations stimulated in the first two scenarios (wining over scenario 3) then will be carried out by global governance institutions that then inherit the historical mission of capital[52]. This feature of a new form of society would be 'capital' after capitalism. Time and space would have returned.

Capital after Capitalism

As a matter of fact, it necessarily must remain a highly speculative enterprise to formulate ideas on what happens after capitalism. The metamorphosis of a mode of production is an extremely volatile process. The disappearing elements might reappear in a completely different form, democratic decision making in this new technological environment will often exceed information processing capacities of single human individuals. The age of alienation is waiting for us with a most astonishing menagerie of artefacts – if the process of metamorphosis comes to a positive end for mankind at all. The biological record shows that the end of a species usually can be understood as a metamorphosis that has not been mastered.

If it is indeed the end of capitalism that is approaching and not just the beginning of its next stage – and this seems to be the case – then the new mode of production will centre around a new historical mission. Growth of productivity will slide to the periphery. Its major engine, the innovative entrepreneur, will become an element dependent on the new core mission. As

[52] Immediate projects to be launched would concern large global infrastructure improvements for the poorest parts of the world.

far as we can see today this new core mission will have to be the mastering of living with limits reached by the human species (in time and space), and to be able to become an organic community along these limits. The central nervous system of this global organism already started to exist, to exist electronically in the form of the internet. From this perspective it today is just the necessary hardware for a conscious handling of the human species. From the same set of technological achievements comes a stupefying ability to support and substitute many of the management activities of humans related to their primary metabolism. From this perspective the 'second machine age' (see [Brynjolfsson and McAfee, 2016]) is a blessing and not a danger for employment. Given these foundations what remains for the new mode of production is to organize political, economic and cultural power in a way that secures reproduction of the species without losing the force of a vibrating pulse, i.e. reproductive innovation. Joseph Schumpeter saw that the end of capitalism is inevitable, he honestly regretted this, and predicted a gray and boring future of large scale administrative handling of affairs by bureaucrats[53]. Exactly 500 years ago, in 1516, Sir Thomas More (Morus) published his classic 'Utopia'[33], where at the beginning of capitalism he sketched a place that is not here – the literal translation of 'utopia'. His dream of a faraway island on which most of the hardships of the primary metabolism have been eliminated – by 500 years of 'neither just nor beautiful' capitalism (Keynes) – remained alive and today gains power because many technical preconditions have been reached. Now, the place 'no place' (utopia) could be here. Not on an unknown island out in the sea, but globally spanning around the whole globe. And this is exactly the core mission of the next mode of production, to enable utopia on a geographically limited globe and with a population that needs conscious global government in time.

References

Braudel F., 1979, *Civilisation materiélle, économie et capitalism, XV^e^-XVIII^e^ siècle. Le temps du monde*, Librairie Armand Colin, Paris.

Brynjolfsson E. and McAfee A., 2016, *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*, W.W. Norton, New York.

Buenstorf G. et al. (eds.), *The Two Sides of Innovation. Economic Complexity and Evolution*, Springer, New York.

Davis A. E., 2015, *The Evolution of the Property Relation*, Palgrave Macmillan, New York.

Frank A. G., 1978, *World Accumulation 1492-1789*, Macmillan Press, London.

[53] See [Schumpeter, 1943 (2003)].

[33] See [Morus, 1516 (1995)].

Gordon D. M., 1980, *Stages of accumulation and long economic cycles*. In Processes of the World-System (ed. T. Hopkins and I. Wallerstein). Beverly Hills, CA: Sage Publications, pp. 9-45.

Gramsci, A. 1930 (1999). *Prison Notebooks*. In: Further Selections from the Prison Notebooks, London: Electric Book Company.

Hanappi H., 1986, *The Stages of Industrial Capitalism*. Invited Paper on the International Workshop "Technological and Social Factors in Long Term Fluctuations", University of Siena December 1986. Published by Springer publ., editor: A. Vercelli et al.

Hanappi H., 2010, From Growth to Innovative Reproduction. A Roadmap for a European Model of Evolution, paper presented at the EAEPE Conference 2010, October 28-30 in Bordeaux. Published as MPRA Paper No. 29062. On the web: https://mpra.ub.uni-muenchen.de/29062/1/MPRA_paper_29062.pdf

Hanappi H., 2013, *Money, Credit, Capital, and the State, On the evolution of money and institutions*, in: [Buenstorf G. et al. (eds), pp. 255-282].

Hanappi H., 2015, *From Political Crisis to Europe's Second Renaissance? An interpretation of recent events and some ideas for the future.* Policy brief published as working paper MPRA 67922. On the web: https://mpra.ub.uni-muenchen.de/67922/1/MPRA_paper_67922.pdf

Hanappi H., 2017, *NATO Expansion versus Consolidation of the EU. Intra- and interclass Dynamics in the context of the Next Cold War*, in: [Hanappi, Katsikides, Scholz-Wäckerle (eds.), 2017].

Hanappi H. and Egger E., 1993, *Information Age - Deformation Age - Reformation Age. An Assessment of the Information Technology Kondratieff*, proceedings of the EAEPE 1993 Conference 'The Economy of the Future – Ecology : Technology : Institutions', Barcelona, 4-6 Nov. 1993.

Hanappi H., Katsikides S., Scholz-Wäckerle M., 2017, *Evolutionary Political Economy in Action. A Cyprus Symposium*, Routledge Publ., London.

Hanappi H. and Scholz-Wäckerle M., 2017, *Evolutionary Political Economy: Content and Methods*, Forum for Social Economics, special issue, (forthcoming). On the web: http://www.econ.tuwien.ac.at/hanappi/Papers/Hanappi-Wäckerle_2015b_final.pdf

Hilferding R., 1908 (1968), *Das Finanzkapital*, Europäische Verlagsanstalt, Frankfurt a. M.

Hobsbawm E., 1975, *The Age of Capital 1848-1875*, Weidenfeld & Nicolson, London.

Hobson J. A., 1902, *Imperialism. A Study*, James Pott & Co., New York.

Kalecki M., 1943, *Political aspects of full employment*, Political Quarterly, vol. 14, pp. 322-331.

Kant I., 1781 (1998), *Critique of Pure Reason*, translated and edited by Paul Guyer and Allen W. Wood, Cambridge University Press.

Keynes J.M., 1936 (2007), *The General Theory of Employment, Interest and Money*, Palgrave Macmillan, New York.

Landau L., 1937 (1969), *On the theory of phase transitions*, translated and reprinted from Landau L.D. "Collected Papers" (Nauka, Moscow, 1969), vol. 1, pp. 234–252. Originally published in Zh. Eksp. Teor. Fiz. 7, pp. 19–32.

Lenin I. W., 1914 (1999), *Imperialism. The Highest Stage of Capitalism*, Resistance Books, Sidney.

Marx K., 1848 (2004), *Manifesto of the Communist Party*, proofed English Edition by Andy Blunden, Marxists Internet Archive (marxists.org).

Meek R., 1973, *Studies in the Labour Theory of Value*, Lawrence & Wishart, London.

More T. (Morus), 1516 (1995), *Utopia*, translated and edited by George M. Logan, Robert M. Adams, and Clarence H. Miller, Cambridge University Press.

Ricardo D., 1817 (1973), *The Principles of Political Economy and Taxation*, Everyman's Library, London.

Schumpeter J.A., 1939, *Business Cycles. A Theoretical, Historical and Statistical Analysis of the Capitalist Process*, McGraw-Hill, New York.

Schumpeter J.A., 1943 (2003), *Capitalism, Socialism & Democracy*, Taylor & Francis e-Library. On the web: http://cnqzu.com/library/Economics/marxian%20economics/Schumpeter,%20Joeseph-Capitalism,%20Socialism%20and%20Democracy.pdf

Smith A., 1776, *An Inquiry into the Nature and Causes of the Wealth of Nations*, Edwin Cannan, London.

Sohn-Rethel A., 1973 (1987), *The Economy and Class Structure of German Fascism*, translated by Martin Sohn-Rethel, Free Association Books, London.

Vercelli A., 2017, *Crisis and Sustainability. The Delusion of Free Markets*, Palgrave Macmillan, London.

2.2 Three Levels of Agents

The need to grasp some essential dynamics of a large and complicated network like the European political economy in this second phase of the project made it clear that some major refinements and reformulations of our approach were necessary. To learn how to tackle new challenges it is advisable to study what other scientists propose.

Obviously there are other projects that have similar goals as we do. The idea to have some sort of policy tool/simulation for the European economy is, of course, an attractive one. And the usage of agent-based modelling has experienced a huge uplift - at the latest since the crisis, when conventional models failed, but even already before.

One particular project that stands out is the Eurace@Unbi Model [3], which was originally finished in 2009, but has been extended since then. It is a typical bottom-up agent-based model that basically tries to cover all aspects of the European economy. From an agent-based perspective, this is an obvious obvious approach. A description and results can be found at Dawid et al. [10].

Other similar projects that are going on right now are Project Symphony [5], coordinated by Prof. Silvano Cincotti and ISIGrowth [4]. To our knowledge, both projects have not delivered a complete model yet, but only published papers to isolated topics, like Popyan et al. [14].

However, the scope (in terms of duration, number of involved facilities and researchers and computational power needed) of these and similar projects shows what is necessary in terms of resources for such a holistic bottom-up approach. Therefore, it became clear rather quickly for us, that our approach should follow a somewhat scaled down framework – which can turn out to be an advantage: Being forced to concentrate on the essential features and to clearly specify the levels of granularity of the model can avoid the danger of being unable to understand the overall working of multi-causal dynamics. This, together with our sectoral perspective, gives our approach a more macro-based game-theoretic flavour, where we don't have micro-agents, but representatives' agents for each sector in each country and a multi-level structure with government and central banking.

The lowest level, the most detail revealing granularity, has to consider innovation activities as essential element of European dynamics. Though with respect to detail it would be preferable to study innovation at the factory floor of single innovative production units, such an approach is not only beyond the scope of this project, the diversity of the many interesting findings evidently also endangers an overarching evaluation of what can be generalized. To use the sectors of a national economy as they are empirically covered by input-output statistics as the smallest units of political economy entities, as agents, seemed to be the best

choice for our framework. We therefore called this most detailed level our **level 3**. Input-output theory has experienced a remarkable revival in the last two decades. While it was impossible to get yearly IO-data for most OECD countries on a regular basis 30 years ago, the large WIOT project ('World Input-Output Tables') now provides exactly that. The data needed for our level 1 thus is available and will be kept accurate in the foreseeable future too.

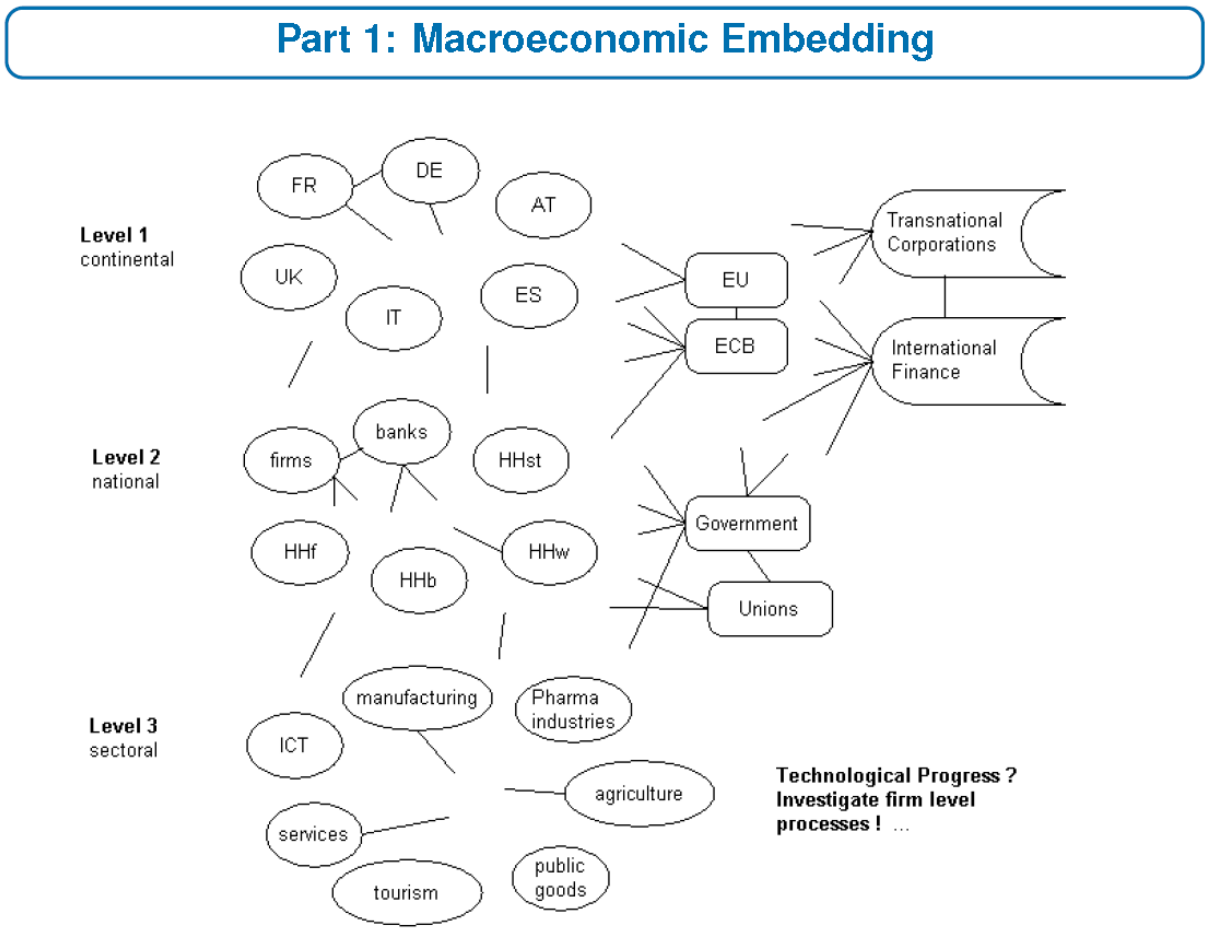
The next higher level, **level 2**, evidently is the level of national agents. This is the level where John Maynard Keynes had re-introduced[54] macroeconomic dynamics in the interwar period. For Keynes purposes, namely to highlight the importance of state intervention to stabilize capitalism, it was sufficient to introduce just two agents: a fiscal authority controlling taxes and government expenditure, and a monetary authority that could influence the price-wage system[55]. In our view such a narrowing down of the set of national agents misses many of the relevant and important dynamics that we experience daily. The minimal set needed should include a national agent taking care of the agenda of all firms, an agent that does the same job for workers ('unions'), four agents that represent segments of the set of households, an agent representing government (including also the fiscal authority in Keynes model), and one agent representing banking. The four types of households are necessary to distinguish between the different types of employers, which provide household income: firm owners (HHf), banks (HHb), workers (HHw), and state employees (HHst). Note that the banking sector is on level 2; it is an agent that evolved out of the division of commodity production and only partially needed service activities (elements of level 3). The emergence of more aggregated agents is a rather complicated process again. In the case of banking, as in the case of government or labour movement institutions, one 'national agent' always consists of a network of smaller, mostly co-operating units. The emerging existence of an aggregated agent therefore can be interpreted as the stepwise constitution, of a tightening of certain network properties and the building of a membrane which shelters the new agent from destructive outside interventions, but allows for perception and communication. Though it is tempting to study entry and exit of aggregate agents from an agent-based modelling perspective, in the context of this project the above mentioned assumptions must suffice.

At **level 1**, the continental level, the building of aggregated agents has proceeded a further step: countries have built the European Union, national banking systems have joined forces in the European Central Bank. For the sake of treatability our project does not go into the details of level 2 and level 3 in countries other than Austria, and thus the actions of these

[54] It was only 'forgotten' in 1874, when the marginalist revolution of economic theory gave up political economy.
[55] While many modern Keynesian models still work with the money supply as the relevant instrument variable, Keynes originally thought on the regulation of the credit volume as the more adequate transmission variable. Since in his writings he left a rather broad room for different interpretations – and never provided a rigid mathematical formulation - different schools are still fighting over what Keynes really meant.

countries appear only at level 1, comparable to actions of the other European agents. What should not be forgotten is that globalisation does not stop on the European level. Two further large and global entities are absolutely crucial for the dynamics on all levels: transnational corporations and international finance.

In the figure below this framework is summarized.



We thus distinguish three interconnected levels of granularity: the continent, the country, the sector. At level 1 connections between countries as well as those with international players are dealt with. Which countries will be included can be chosen. At level 2, which could be specified for each country, we depict important national players. In different countries this set of players will differ too. The different HH- are households belonging to different employee groups, at least their relative size will differ in different countries. Finally, at level 3 a few major sectors of the respective national economy are considered. Here the interaction with the newly constructed ICT sector, and more generally innovation processes, are of particular interest. Note that in the graph only a few connections are displayed, they shall indicate the general interdependence. Technological progress is only considered per sector, not on the firm level. This approach to innovation thus rests on a consideration of the evolution of the technical coefficients as specified in the I-O-framework.

The agent ‘sector i in country j’ typically takes the decision on a new combination of intermediate inputs simultaneously with the employment decision and the investment and finance decision. And it bases these decisions on events it perceives and interprets with the help of its internal model. This is the core assumption of agent-based evolutionary modelling: **entities act on what they see and then interpret with the use of their internal model**. And even this internal model – on a slower time-scale – eventually will be subject to evolution. We have successfully developed some internal sector models for Austria to provide an example.

Some global routines can determine the evolution of the general economic environment, based on actual forecasts. Higher level agents then can perceive the parts of these forecasts they need, and can decide to which extent they believe in them. It is clear however that we do not replicate whole macroeconomic models within our own model, so what is presented is a simplified framework to be filled with data and estimated behavioural equations.

References

[1] Ameco Online. URL http://ec.europa.eu/economy_finance/db_indicators/ameco/index_en.htm.

[2] EU KLEMS. URL http://euklems.net/.

[3] The Eurace@Unibi Model. URL http://www.wiwi.uni-bielefeld.de/lehrbereiche/vwl/etace/Eurace_Unibi/.

[4] ISIGrowth. URL http://www.isigrowth.eu/.

[5] Project Symphony. URL http://projectsymphony.eu/.

[6] World Economic Outlook Database. URL http://www.imf.org/external/pubs/ft/weo/2016/01/weodata/index.aspx.

[7] World Input-Output Tables. URL http://www.wiod.org/new_site/database/wiots.htm.

[8] P. Andrade, A. M. V. Monteiro, and G. C´amara. From Input-Output Matrixes to Agent-Based Models: A Case Study on Carbon Credits in a Local Economy. In *Social Simulation (BWSS), 2010 Second Brazilian Workshop*, pages 58 – 65, 2010. doi: 10.1109/BWSS.2010.16.

[9] J. Baumgartner, F. Breuss, and S. Kaniovski. WIFO-Macromod - An Econometric Model of the Austrian Economy, 2004.

[10] H. Dawid, S. Gemkow, P. Harting, S. van der Hoog, and M. Neugart. Agent-Based Macroeconomic Modeling and Policy Analysis: The Eurace@Unibi Model, 2014.

[11] M. Gelman, A. Jochem, and S. Reitz. Transmission of global financial shocks to EMU member states: The role of monetary policy and national factors, 2016.

[12] H. Hanappi. Austria 1 - Ein Simulationsmodell der ¨osterreichischen Wirtschaft. In H. Hanappi, editor, *Wiener Studien zur Politischen Okonomie¨* , volume 2. 1983.

[13] D. Pissarenko. Basics of input-output analysis. 2003.

[14] L. Popyan, M. Napoletano, and A. Roventini. Taming Macroeconomic Instability: Monetary and Macro Prudential Policy Interactions in an Agent-Based Model, 2015.

[15] M. P. Timmer, E. Dietzenbacher, B. Los, R. Stehrer, and G. J. de Vries. The World Input-Output Database: Content, Concepts and Applications, 2014.

[16] Hanappi H., 2015a, Unemployment in Mediterranean EU Countries. Fighting Youth Unemployment, in SOCIETIES IN TRANSITION. The Social Implications of Economic, Political and Security Transformations., edited by S. Katsikides and P. I. Koktsidis, Springer. http://link.springer.com/book/10.1007/978-3-319-13814-5

[17] Hanappi H., 2016, *Shangri-La Governance. A Sketch of an Integral Solution for European Economic Policy based on a Synthesis of Europe's Problems*, in: Katsikides S. and Hanappi H. (eds.), 2015, Society and Economics in Europe. Disparity versus Convergence? Book forthcoming with Springer publishers. http://www.springer.com/gp/book/9783319214306

[18] Hanappi H., 2015c, *Schumpeter and Goodwin*, Journal of Evolutionary Economics, vol.25/no 1.

[19] Hanappi, Katzikides, Scholz-Wäckerle, 2016, (eds.), 2015, *Evolutionary Political Economy in Action. A Cyprus Symposium*. Book forthcoming with Routledge publishers.

[20] Hanappi H. and Rohringer M., 2015, *Cooperation, Competition, and Innovation. Heterogeneous-Agents-Based modelling perspectives*, contribution to the International Workshop “Networks, Complexity, and Economic Development”, Budapest, Nov. 30 - Dec. 01.

2.3 Empirical Underpinnings: Data

Every serious modelling approach in political economy has to keep an eye on the availability of empirically observed data that can render the proposed model as being a plausible interpretation of reality. In the last decades modern information technologies have transformed the traditional scarcity of economic data into the problem of an excess of numbers, an unsurmountable avalanche of so-called 'big data'. This becomes a difficulty because the usefulness of the selection of certain time series in this case is the essential art of the model-builder, a wrong choice of data treated with a sophistically looking statistical apparatus can give the work a nimbus of high-quality research that is completely mistaken. In the case of evolutionary political economy (including dynamic institutional elements) the problem is further complicated by the fact that typical macroeconomic datasets still are collected along the theoretical needs of standard Keynesian, or better Hicksian, models. Of course, large data providers like OECD try to catch up to the needs of innovative model-builders and some smaller providers like the DICE database at LMU in Munich try to systematize institutional data, but the availability of such data usually is more than one step behind the needs of model-builders.

For the modelling framework we developed, we call it A-POEM (**A P**olitical **E**conomy **M**odel), we used whatever we could get from standard databases like WIOT, National Accounts' data, KLEMS, or special national data of Statistics Austria. Though we tried to use all these sources as consistently as possible it quickly became clear that arriving at a fully consistent data set that would fit our aspirations would exceed our human resources by far. Thus our framework is certainly not based on data that enables us to say that forecasts made with it are particularly precise. In that respect the last word is not spoken yet. The purpose of A-POEM therefore is to show how a useful model should look like and in which directions future empirical research should try to collect data and gain an understanding of the internal models and variables used by agents.

What follows is description of our different data sources.

From Input-Output Tables to Agent-Based Models[56]

Perhaps the biggest challenge in this approach is to combine the Input-Output Data with an agent-based modelling perspective, as we have macroeconomic data on the one hand and a modelling school with a strong microeconomic focus on the other hand. The attempt to

[56] For all references in this chapter, written by Markus Rohringer, please use the reference list of chapter 1.2.

find literature to this sort of crossover turned out to be rather difficult. A relevant paper, which is a small and rather specific conference paper is Andrade et al. [8].

This paper is still an interesting finding, as the suggested approach there is to treat each column (industry sector) in the input-output table as an agent. This coincides in its general idea very much with our own thoughts and therefore is a small confirmation for our approach. Nevertheless, the paper remains on the level of general considerations and will not be of much help when dealing with the specific challenges that will inevitably come along with the attempt to mix these concepts.

Data Analysis and Transformation with Stata

The WIOD [7] is available both in Excel files for each year and as a whole database in the Stata format. Using Stata, we started to analyse the data. Among other things we looked which sectors are the most important ones, how they developed over time and the constellation of international and domestic trade based on the sectoral division.

We also compared the data with another database, EU KLEMS [2], which does not cover intersectoral or international input-output data, but does have the domestic data (like gross output) for each country on the same sectoral level. The comparison has shown that the data is far from being consistent. While the general ratios and scales are similar, in absolute numbers there are huge differences. Therefore, mixing the data would have to be done extremely carefully.

We decided to use the 15 main industry sectors (denoted as letters in ISIC, while the subsectors are divided in numbers) and summarize the data accordingly. For a start we also decided to focus only on the Austrian data, as we have the most experience with it and can interpret data easier - also it is simpler for us to align the data with the agent-based model (internal model building of the actors, general economic forecast and so on).

As already mentioned, one big issue is that the ICT sector is missing in ISIC rev.3. There is no indicator in the WIOT data how to extract it. However, as a rough approximation we are using the ICT capital compensation from EU KLEMS. This is a ratio value that indicates how much of the capital compensation flows into ICT for each sector. We then multiply this ratio with the output of the sector from the WIOT and subtract this amount from the respective sector and add it to the ICT sector. This has to be done for the input side as well as the output side and also the ICT to ICT trades have to be estimated this way.

There is however the issue, that EU KLEMS changed the ISIC Revision at some point, as rev.4 is the newer version (and actually has a dedicated ICT sector). The data for rev.3 therefore exists only until 2007. This means that the values for 2008 to 2011 had to be forecasted by us - we used a simple linear regression, as this is anyway only an approximation.

Creating an Overview for Austria from 2005 to 2011

For further investigation the data had to be summarized and presented in a comprehensive way. We kept focusing on Austria and zoomed in to the years 2005 to 2011, which are not only the most recent years that we have data from, but the most interesting, as they show the development of the crisis and the reaction to it - both especially interesting for us, as we do not intend to follow the classical general equilibrium theory. We extracted the domestic intermediary input and output for each sector to put it in contrast to imports and exports as well as the final demand of domestic goods. Further it pictures the total output, the total consumption and the taxes and value added, see figure 1.

This view will be used to analyse the reaction to the crisis and extract behavioural patterns for the development of the division of the production factors - for example it can be shown, that as a reaction to the crisis, the foreign trade is reduced and more inputs from the own sector are used. A long run analysis of the whole data (not only from 2005) could further be used to describe innovation in terms of the shift of production factors.

Austria 2010

	Industry / Category	AtB AGRICULTURE	C MINING AND	D TOTAL MANU	E ELECTRICITY,	F CONSTRUCTI	G WHOLESALE	H HOTELS AND	I TRANSPORT	J FINANCIAL IN	K REAL ESTATE,	L PUBLIC ADMI	M EDUCATION	N HEALTH AND	O OTHER COMM	P PRIVATE HOU	ICT ICT	**Sum Domestic Intermediary Output**	Final Demand of Domestic Goods	Export	**Total Output**
		Industries Input																			
Industries Output	AtB	2.040,64	0,90	4.186,42	13,02	54,45	46,98	350,04	15,20	2,74	21,39	8,22	8,11	32,93	5,66	0,00	456,24	**7.242,95**	3.110,69	1.390,72	**11.744,35**
	C	9,41	44,51	465,24	9,98	426,03	31,02	8,66	38,90	4,69	47,56	33,71	3,70	6,46	12,92	0,00	82,03	**1.224,82**	483,77	1.278,99	**2.987,58**
	D	727,86	120,43	24.775,53	647,43	6.733,68	2.083,28	2.082,77	706,91	479,05	2.800,30	601,60	297,32	961,62	526,36	0,00	3.368,09	**46.912,23**	25.883,42	115.155,32	**187.950,96**
	E	160,24	95,35	3.302,69	21.094,93	289,62	620,09	430,07	565,76	121,78	1.126,62	416,87	393,67	625,57	541,92	0,00	1.658,13	**31.443,31**	6.225,71	3.092,73	**40.761,76**
	F	158,95	91,00	2.362,71	402,33	5.734,98	754,58	591,79	1.152,28	220,39	5.197,25	617,43	368,24	414,05	531,42	0,00	1.597,60	**20.194,98**	31.324,19	1.870,57	**53.389,74**
	G	884,03	124,35	15.936,93	498,83	2.892,57	3.073,90	1.021,45	1.223,11	288,30	1.929,35	515,80	214,97	1.352,50	440,36	0,00	2.686,91	**33.083,36**	30.648,38	5.242,51	**68.974,25**
	H	14,51	4,05	352,25	29,05	69,75	217,55	154,11	774,94	88,97	149,89	63,63	33,61	55,78	47,43	0,00	432,61	**2.488,15**	18.813,89	3.922,00	**25.224,03**
	I	60,20	73,21	2.751,08	217,62	484,11	1.723,94	140,68	3.363,07	392,09	747,87	289,96	71,31	199,25	263,45	0,00	1.902,71	**12.680,56**	11.243,24	11.032,53	**34.956,32**
	J	66,18	28,08	1.718,27	238,94	383,92	1.193,82	241,08	382,63	3.191,14	1.421,13	418,94	84,46	196,33	257,64	0,00	1.635,40	**11.457,97**	6.334,76	5.534,21	**23.326,93**
	K	216,84	187,82	8.067,78	647,85	3.126,78	7.654,68	1.614,95	2.804,11	2.399,85	15.352,62	2.396,57	733,92	1.804,40	1.905,02	0,00	5.383,53	**54.296,72**	38.763,82	11.595,90	**104.656,45**
	L	5,39	2,52	158,29	11,80	50,63	110,97	17,65	52,19	44,41	236,30	265,04	9,91	25,47	41,14	0,00	121,11	**1.152,81**	25.030,13	454,86	**26.637,81**
	M	7,15	5,77	160,21	26,06	26,31	68,82	5,76	39,48	53,73	98,19	247,25	65,95	51,79	15,33	0,00	109,76	**981,55**	18.792,79	244,06	**20.018,41**
	N	130,30	1,25	67,12	2,94	11,26	20,08	7,63	13,96	5,05	20,27	36,22	9,32	565,27	3,47	0,00	69,76	**963,88**	29.087,50	208,53	**30.259,90**
	O	13,72	14,21	1.207,53	75,79	145,69	491,54	247,38	152,64	223,65	2.558,79	122,23	41,90	275,69	1.649,18	0,00	665,06	**7.885,00**	13.226,39	560,67	**21.672,05**
	P	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**0,00**	79,75	0,00	**79,75**
	ICT	347,24	86,20	6.820,30	1.111,06	1.645,07	2.380,60	629,74	2.333,41	1.759,35	2.834,96	692,43	209,72	637,78	641,40	0,00	2.173,21	**24.302,48**	26.968,76	17.947,44	**69.218,68**
Sum Domestic Intermediary Input		**4.842,66**	**879,64**	**72.332,35**	**25.027,63**	**22.074,86**	**20.471,86**	**7.543,76**	**13.618,58**	**9.275,21**	**34.542,50**	**6.725,90**	**2.546,10**	**7.204,89**	**6.882,69**	**0,00**	**22.342,15**	**256.310,77**	286.017,17	179.531,02	**721.858,97**
Imports f. Production		1.471,80	398,38	53.122,70	5.661,35	7.638,47	6.491,14	1.315,24	5.876,98	1.315,64	5.817,12	1.650,36	548,18	3.149,53	1.540,12	0,00	8.817,50	**104.814,52**			
Total intermediate consumption		**6.314,47**	**1.278,02**	**125.455,05**	**30.688,98**	**29.713,32**	**26.963,00**	**8.859,00**	**19.495,57**	**10.590,84**	**40.359,62**	**8.376,25**	**3.094,28**	**10.354,42**	**8.422,81**	**0,00**	**31.159,65**	**361.125,29**			
Taxes less Subsidies (including foreign goods)		347,68	81,07	5.036,69	1.573,01	1.241,57	1.301,11	673,07	1.626,12	554,98	1.723,71	463,12	244,70	600,75	537,36	0,00	1.848,35	**17.853,29**	18.140,69		
Value Added	Labor Compensation	7.860,00	476,85	35.890,62	3.014,87	14.168,30	24.474,27	7.412,91	9.374,04	8.853,21	5.799,13	14.843,88	15.569,73	17.393,41	10.296,73	79,75	24.656,24	**200.163,96**			
	Capital Compensation	-2.826,17	1.140,81	20.086,53	5.332,89	7.985,32	16.329,35	8.272,14	5.153,57	3.715,79	56.883,02	2.966,24	1.115,30	1.834,47	2.439,34	0,00	8.526,87	**138.955,45**			

Figure1: ScreenshotfromtheAustriaOverviewfor2010

As it turned out after having finished our work of transforming and preparing our data till 2011, the WIOT database issued new data, now reaching till 2014. We therefore had to re-do all the data transformations to include the new data sets.

World Input Output Database

After reconsidering the future focus of the project, it was established that we want to put a special emphasis on the economic links within the European Union, but also to a few important external players. The question how to realize this proved to be more difficult though. An inclusion of the World Input Output Database (WIOD) was determined to be ideal, as a big amount of real world data could be used as a foundation for the model.

The World Input Output Database (WIOD) is a database that contains all flows between the different sectors of numerous countries. It basically takes the concept of a national input-output table and expands it to international trade - the result is a WIOT (World Input Output Table). A description of the content and construction of the WIOD can be found at Timmer et al. (2014).

Classical input-output tables consist of four quadrants: Intermediate demand, final demand, primary inputs to industries and primary inputs to direct consumption. For a general explanation of input-output tables please find Pissarenko (2003). However, the WIOT somewhat differs from this structure, as there are no primary inputs, because we look at several countries at the same time. Therefore, all trades except final demand can be regarded as intermediate demand, just between different countries. Then, as our rows we have the output sectors for each country and as columns there are the input sectors together with the final demand.

The WIOD is available both in Excel files for each year and as a whole database in the Stata format. While getting acquainted with Stata, we started to analyse the data. Among other things it has been investigated which sectors are the most important ones, how they developed over time and the constellation of international and domestic trade based on the sectoral division. Further, the data was compared with another database, EU KLEMS, which does not cover intersectoral or international input-output data, but does have the domestic

data (like gross output) for each country on the same sectoral level. The comparison has shown that the data is far from identical. While the general ratios and scales are similar, in absolute numbers there are huge differences. Therefore, mixing the data would have to be done extremely carefully. Fortunately, with the change of the WIOD from Rev. 3 to 4 this was not necessary anymore.

The sectors in the WIOT are divided according the ISIC (International Standard Industrial Classification. The original data that we started to work with was only available for the years until 2011 and was structured according to the ISIC Rev. 3 classification. This was less detailed than the current Rev. 4 and contained no dedicated ICT sector. A lot of work was put into aggregation of the data and to combine it with the EU KLEMS data, to use the ICT capital compensation from there to roughly extract the ICT share of each sector.

Obviously, especially considering the financial crisis, which might give the most interesting insights for policy analysis, the fact that the data was available only until 2011,

when the crisis just started, was unsatisfactory. Therefore, it was good news when WIOD 2016 was released in November 2016. This new data covers the years from 2000 to 2014 and is based on ISIC Rev. 4. This had several implications for us – good ones and bad ones. The advantage was, besides covering the more interesting years, that with the new rev. 4 structure, the data was more detailed and big parts of the ICT sector were already explicit, so our rough extract was not necessary anymore. However, this made the new data incompatible with the old one. Therefore, our previous transformations and estimations were not usable anymore and had to be done for a second time.

The data of the sectors was summarized to its 21 main sectors. With the data of these trading streams between the sectors of each country, the technical coefficients could be worked out on this granularity. The new structure of the aggregated sectors can be found in the following table:

Sector	Description
A	Agriculture, forestry and fishing
B	Mining and quarrying
C	Manufacturing
D	Electricity, gas, steam and air conditioning supply
E	Water supply; sewerage, waste management and remediation activities
F	Construction
G	Wholesale and retail trade; repair of motor vehicles and motorcycles
H	Transportation and storage
I	Accommodation and food service activities
J	Information and communication
K	Financial and insurance activities
L	Real estate activities
M	Professional, scientific and technical activities
N	Administrative and support service activities
O	Public administration and defense; compulsory social security
P	Education
Q	Human health and social work activities
S	Other service activities
T	Activities of households as employers; undifferentiated goods- and services-producing
U	Activities of extraterritorial organizations and bodies
ICT	ICT

Table 1:ISIC Rev. 4 (with addition of ICT)

Macroeconomic Data

As we will explain later on in detail, our simulation contains a global routine that estimates the general economic situation for each country at the beginning of each year. This internal forecast will be used by the agents as a base for their decisions. To be able to do this, first the simplified equations for the forecast of the total demand had to be defined. This includes private consumption, public consumption, exports and imports. These equations are a simplified version of actual forecast models like those that are used for example by WIFO in Austria (see Baumgartner et al. [2004] and Hanappi [1983]).

The main source of economic data is Ameco Online (Annual macro-economic data) from the European Commission. For forecasts that go further into the future, also the World Economic Outlook is used. With this data, the estimation of parameters was done in EViews. These parameters were then used in the agent-based simulation. A specialty of this estimation is, that it also takes into account the individual influence of the biggest economic sectors on the total demand.

2.4 Scope and Modularity

As explained in chapter 1.3 on methodology every modelling framework first of all is characterized by its scope, i.e. what is the borderline of the object of investigation that is to be simulated. The simple answer is that for A-POET this scope is Europe. The banking-macroeconomics framework of Austria would be much too small to provide more than just the hint that most important variables are set from outside and cannot be determined as endogenous variables of a model of Austria. This is different for the case of Europe. There indeed is a very specific network of interactions between real economies of European countries and banking activities (including central banks as well as the ECB) on national and continental level – the so-called ***European Social Model***. It makes sense to determine essential economic variables as endogenous variables of this model; even if some global variables – like the oil price, or US interest rates – exert exogenous influences. As long as the feedback of Europe on these exogenous forces is small enough (so that no strong amplification loops could happen) these exogenous variables can be included in the form of exogenously given scenarios.

A more interesting case is the existence of **global players**, of agents that can choose places inside and outside Europe for their activities. We have introduced two such global agents, an agent called '**transnational companies**' and a second one called '**international finance**'. The extremely high aggregation level of these two agents makes it severely speculative to describe which variables they perceive and how they react using their internal model. Nevertheless, the practices of profit maximization of transnational companies – price discrimination, choice of production country and value chain, tax evasion, etc. – are already well studied and at least a rough image of their physiognomy is possible. In particular, it has to be kept in mind that only those actions that concern Europe have to be specified. The case of international finance is not too different, though for financial activities a much higher speed and thus a tremendously higher fragility has to be assumed. International finance commands enormous amounts of money, which in its electronic form can be moved almost instantaneously. Moreover, the internal model of this agent is full of relationships that include very speculative expectation processes, avalanches of broken down expectations are the daily business of stock exchanges. It is no surprise that the routines of ironing out small bubbles at global stock exchanges, while being the standard money machine for big traders, from time to time gets out of hand and produces a global crisis. But again, this is not the focus of this project. For A-POET it is good enough to have an agent that displays the standard behaviour of 'international finance' – and this needs not a very sophisticated internal model.

The geographic borders of Europe are currently assumed to be the borders of the European Union. But here already the second concept, namely **modularity**, comes into play:

Each country is a module at level 1 and can be added or excluded for certain simulation exercises. It thus shall be possible to study further enlargements of the EU as well as its shrinking, e.g. the implications of BREXIT. To design a country at level 1 is not an easy task and cannot rely too much on a common scheme. First, the countries place in the global division of production and consumption makes a difference, and second its historical and cultural background will have shaped its institutional structure. Data from national accounts and other sources can help, but even for small country models design with skill and deep knowledge is mandatory. It goes without saying that we were not able to build country models for the 28 EU member countries, we only provide the framework to plug them in.

Inside the country, at level 2, the national institutional setting has to be kept small too. Up to 10 agents seems to be a manageable size, remember that for 28 EU members this would mean designing 280 institutions!

Things are getting worse if we consider level 3. We managed to collapse the original number of economic sectors provided by WIOT to have only 20 sectors. But in an IO framework this still would imply that we would have to design 400 market mechanisms in each country – in total 11200 market mechanisms - to get the full picture of what is going on, just on markets only. This tells us something on the importance of modularity.

Modularity is not only a nice feature that allows to tailor the framework to a specific question; the overwhelming richness in detail of our object of investigation makes it absolutely necessary to keep the number of modules involved as small as possible. If possible, only the most important sectors in only the most closely connected countries with just the most important national agents should be present in a specific simulation.

Finally, the specific **role of banking** in this context has to be emphasized. Finance appears at all three levels. For the sectors of a country it enters their internal model as a determining capital cost, and as a consequence not just the possibilities for innovation but also as influencing the size of a sector – via different conditions for bankruptcies and start-ups in different sectors. Even more important can be the influence of finance on import and export conditions of different sectors – e.g. via exchange rates influencing input factors and tourism.

At the second level finance not only sits in the background of the old Keynesian theme of demand constraints. It also is present as an element determining the vulnerability of state institutions via government debt, which is always at risk with respect to interest rate hikes. This immediately links finance to level 1, i.e. finance in other countries or international finance. The agent ‘banking’ at level 2 therefore is of utmost importance, it has been extremely farsighted by Rudolf Hilferding to call the current stage of capitalism ‘finance capitalism’.

3. The Agent-Based Political Economy Model A-POEM

The framework for simulation A-POEM elaborated in the last phase of the project is a conceptual proposal. It has been fully prepared to be implemented in an appropriate programming language. First tests with the programming language APL, an interpreter, show that it should be easy to use this framework. In principle, any procedural programming language, as long as its restrictions for certain applications are not too narrow, could be used.

Most work will have to be spent on the specification of the internal models of agents. In the following chapters we provide examples of agent specification, in particular for agents at level 3. Of course, agents can interact across levels, though the number of such links should be kept small. The interaction dynamics of a simulation run are hard to follow anyway.

A typical experiment could ask to what extent and in which way car production in Germany – the largest production sector in Germany, and of eminent importance for Austrian exports – influences European wage levels and interest rates. To study this the researchers will have to zoom in to the sectors that are most linked in the input-output matrix. They also would have to take a close look on a correct specification of global conditions, since car production is a global business. The regulatory framework (see 3.1) in Germany and perhaps in some other large importing countries will have to be considered. Parallel to these considerations it might also be helpful to identify which parts of A-POEM can easily be ignored. At the end of this specification process the user will already have learned a lot about the question to be answered. Finally, the remaining loose ends can then be explored by the use of simulation runs.

Burning questions of financing the integration of migrants, in particular enabling their employment in the diverse sectors of the economies of different countries can be discussed in a much more informed way with the use of A-POEM.

The major pre-condition for all these promising applications is a team of at least 5 researchers that keep the used datasets as well as the other parts of the application (estimates, programs, extensions to cover new and important topics) alive. And this, again, is a question of finance.

3.1 Model structure

For each year the main program runs first the agents at level 1, i.e. calls the respective programs, whose decisions mirror the general global economic climate. This is represented by a set of global economic variables, like expected GDP growth, expected inflation, expected interest rate development, and the like. Their decisions and communicated instrument variables are stored in a so-called media cube. Each level has its own media cube that is an n-dimensional data structure where all information that the agents of this level produce or acquire is stored. What data they write to and read from the media cube is specified in the agent's program where perception (acquire data) and communicate instrument variables (write data) are determined.

An interesting feature of A-POEM is that it takes communicative competence of agents serious. In a first round the decisions on prices, quantities, employment, wages, investment, innovation (structural changes), and finance of economic sector agents are only published as proposals in media cube 3. In a second round each sector can respond on the proposals it reads – we take advantage of available input output data – and can revise its decision[57]. A similar use of media cubes takes place on all three levels. Once all sectors have made their decisions a program mirroring different market mechanisms takes their decisions and enforces consistency. Instead of a market clearing algorithm that with the help of hypothetical demand-supply functions changes prices until demand equals supply, a simple disequilibrium mechanism, e.g. 'the shorter side of the market determines the quantity' is used. Eventually excess supply builds up inventory or excess demand is remembered by households (in the media cube). Reactions of agents changing prices and quantities do not take place in the anonymous market mechanism programs but are part of the decision process of agents. Sector agents also have the option to change their input structure (process innovation) or to add risky offers to the final demand components (product innovation). To make their decision they build expectations on future additional profits and their likeliness. This, of course, is influenced by the additional capital cost set by level 2 agent 'banks', and by expected demand as published in media cube 2. The stagnation of investment demand by firms observed in the years after 2008 in this context simply is the dominance of the second constraint: It does not matter how cheap investment is as long as it cannot be expected that the product can be sold. Only when small replacement investment has driven down the quality of the capital stock long enough, say till 2018, investment is restarted again.

Next come the respective national institutions. Firms can try to set wages and employment, but the agent 'workers' has some power to limit their choices. The quantitative

[57] In the current version we only allow for one round of revisions, but this could be easily increased.

extent to which this is possible is regulated in the bargaining game played by the level 2 entities ‘firm owners’, ‘banking’, ‘state’, and ‘workers’. Again one round of communication with media cube 2 is allowed for. The same is true for the price setting of economic sectors, in this case restricted by the demand of the different types of households. Note that this interaction takes place across level 3 (sectors) and level 2 (household aggregates). The actions of level 2 agents are executed given the decisions of economic sectors. To assure consistency, the ruling regulation set (e.g. tax rates, subsidies, etc.) is applied – a political pendant to the market mechanisms at level 3.

An interesting feature is implemented at level 1, the continental level. It is at this level at which the regulation set just mentioned in the last paragraph is determined. The idea behind is that the periodically occurring political elections (all 4 or 5 years) can – in a crude way - be endogenized. In a political election voters coming from the specified household types are on the one hand characterized by traditional voting behaviour, but to an increasing extent are also motivated by the individual advantage they expect from a change in the regulation set. Since employment offers of economic sectors (damped by union power) determine the wandering of households between household types, the relative weights of the different types will change. Governments then will make policy offers in media cube 1 to attract voters, represented as households at level 2. Of course, there also is an influence of level 2 agents ‘banks’, ‘firm owners’ and ‘workers’ on the voting process. We have not yet experimented with that feature, but we expect interesting results.

3.2 The case of Austria

At the sectoral level 3 the Austrian economy has been used as an example to demonstrate with the help of three sectors how agent design can proceed. What these three examples show is first of all that economic sectors are indeed behaving qualitatively very different. The failure of a microfoundation of macroeconomics with the help of the theoretical construct of a representative firm is no surprise at all. A second lesson is that relatively simple relationships seem to be sufficient to describe the essential characteristics of a sector. Firms evidently do not build the highly sophisticated, expectation augmented internal models, which general equilibrium models with rational expectations suggest. They seem to follow rather simple-minded heuristics – and probably even these heuristics are rather diverse. Nevertheless, the large amount of diverse heuristics clearly allows for a typical behaviour of the whole sector. This simple rule learned from Newtonian physics confronted with quantum chaos at the micro-level seems to be valid for political economy too. A third conclusion concerns innovation. As the development of technical coefficients shows, innovation at the sectoral level 3 is painstakingly slow. Decisions by and large follow traditional patterns and even information and communication technologies are still introduced very cautiously to the traditional production processes. Finance seems to act neither as a break nor as a stimulus for production and investment. Perhaps many of these findings are owed to the high share of SMEs in the Austrian economy, innovation as well as financial disaster (2008) tends to be 'imported'.

Take a closer look at the following three sectors.

Agriculture

In APL the core of the internal model of Austrian agriculture looks like this:

```
⍝ Interpret with internal model

⍝ Instrument Variables


AUTq[T+1;1]←AUTq[T;1] ⍝ OUTPUT

BELIEVE1←0.978334×MEDIA3[T;(T+1);1;1;1] ⍝ Adjust believe in nominal global gdp growth forecast

Gagr←2.61+(0.9175×BELIEVE1)-0.261×MEDIA1[T;T-2;1;1;1] ⍝ Impact on agricultural nominal output growth

Z[1]←AUTq[T+1;1]←AUTq[T;1]×1+0.01×Gagr ⍝ Compute output


AUTp[T+1;1]←AUTp[T;1] ⍝ PRICE

BELIEVE2←*0.28554509731+0.5821×⍟MEDIA3[T;(T+1);1;2;1] ⍝ Adjust believe in nominal global inflation forecast

Pagr←¯0.7702371533×Gagr ⍝ Output impact on agricultural prices

Z[2]←AUTp[T+1;1]←AUTp[T;1]×1+0.01×Pagr+BELIEVE2 ⍝ Compute price level
```

```
AUTe[T+1;1]←AUTe[T;1] ⍝ EMPLOYMENT

Eagr←-3.81852264437+0.995985006545×AUTe[T;1] ⍝ Substitution of labour by capital in a shrinking sector

Wpower←MEDIA2[T;T+1;4;1]←MEDIA2[T;T+1;4;1] ⍝ Workers' power index

Z[3]←AUTe[T+1;1]←AUTe[T+1;1]×ELASe[T;1]×Wpower ⍝ ELASe: Sector specific elasticity of employment (Union Power)


AUTv[T+1;1]←AUTv[T;1] ⍝ GROSS INVESTMENT

Z[4]←AUTv[T+1;1]←0.873931578296×AUTv[T;1]+0.126297152002×AUTv[T;1]-AUTvn[T;1] ⍝ Replacement investment


AUTvn[T+1;1]←AUTvn[T;1] ⍝ NET INVESTMENT

Z[5]←AUTvn[T+1;1]←AUTvn[T;1]+0.229907953107-0.136161784261×AUTv[T;1] ⍝ If last investment was high depreciation will be low


⍝ STRUCTURAL CHANGES


MEDIA1[T+1;T+1;1;1;6]←MEDIA1[T;T;1;1;6] ⍝ MACHINERY SHARE IN INVESTMENT

MEDIA1[T+1;T+1;1;1;6]←(AGRINVM←0.00979×(2000+T)+0.45564455374×AUTv[T+1;1])÷AUTv[T+1;1] ⍝ Share of machinery in investment
grows


MEDIA1[T+1;T+1;1;1;7]←MEDIA1[T;T;1;1;7] ⍝ CONSTRUCTION SHARE IN INVESTMENT

MEDIA1[T+1;T+1;1;1;7]←(AGRINVC←0.0065376×(2000+T)+0.4255×AUTv[T+1;1])÷AUTv[T+1;1] ⍝ Share of construction in investment
grows


MEDIA1[T+1;T+1;1;1;8]←MEDIA1[T;T;1;1;8] ⍝ OWN USE SHARE IN INPUTS

MEDIA1[T+1;T+1;1;1;8]←MEDIA1[T;T;1;1;8]×1.6042077×(1-MEDIA1[T;T;1;1;8]) ⍝ Own use in inputs follows logistic function


MEDIA1[T+1;T+1;1;1;9]←MEDIA1[T;T;1;1;9] ⍝ IMPORTED MACHINERY SHARE IN INVESTMENT

MEDIA1[T+1;T+1;1;1;9]←*1.375551-0.99153×⍟(1-MEDIA1[T;T;1;1;9]) ⍝ Share of imported machinery in machinery investment grows


AUTw[T+1;1]←AUTw[T;1] ⍝ WAGE

MEDIA1[T+1;T+1;1;1;10]←*6.47175863537+1.17545511×⍟MEDIA1[T;T;1;1;6] ⍝ Development of wage index due to past machinery
investment

MEDIA1[T+1;T+1;1;1;10]←MEDIA1[T+1;T+1;1;1;10]←×ELASw[T;1]×Wpower ⍝ ELASw: Sector specific elasticity of wages

Z[6]←AUTw[T+1;1]←AUTw[T;1]×MEDIA1[T+1;T+1;1;1;10]÷MEDIA1[T;T;1;1;10] ⍝ Compute nominal wage
```

If the reader happens to be no APL programmer, this condensed view of a sectors behaviour can be easily interpreted.

First the planned **output** for the next year is determined. To do so, the general GDP forecast for Austria of ECFIN (the economics and finance unit of the EU) is looked up in the

relevant media cube. But the farmers do not believe in this forecast since they have observed that it has been systematically to stable, compare fig. 1.

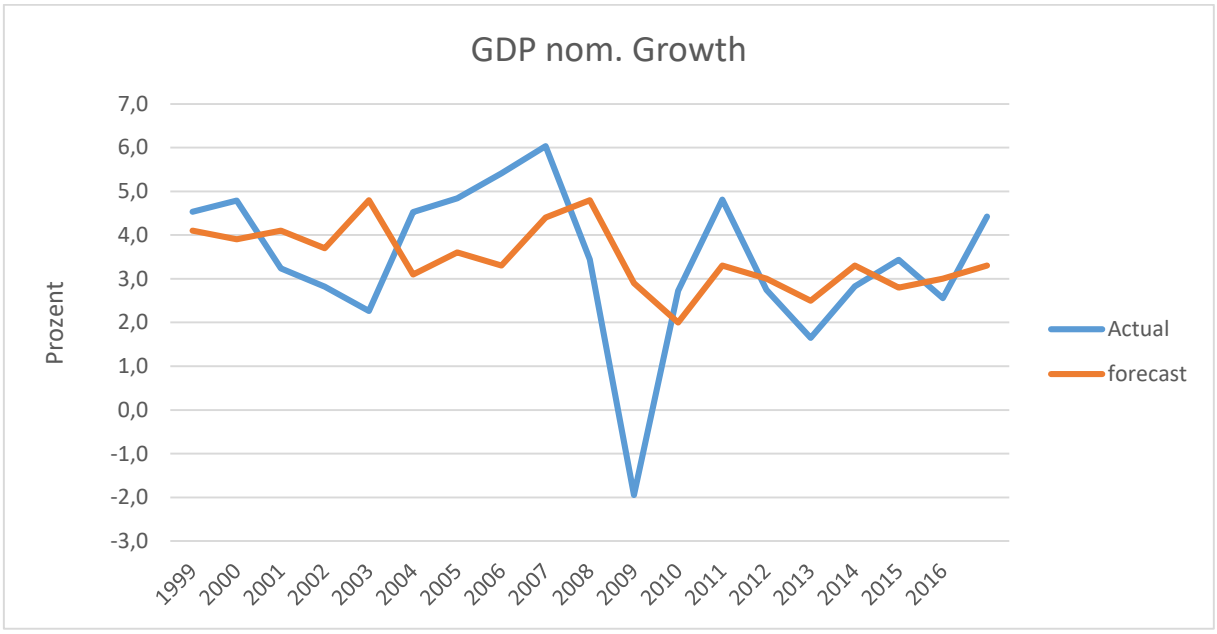


Figure 1: Forecasting bias of GDP growth
Source: ECFIN

Next the impact of general GDP growth on the growth of the agricultural sector is considered, see fig.2. This gives the output proposal of agriculture.

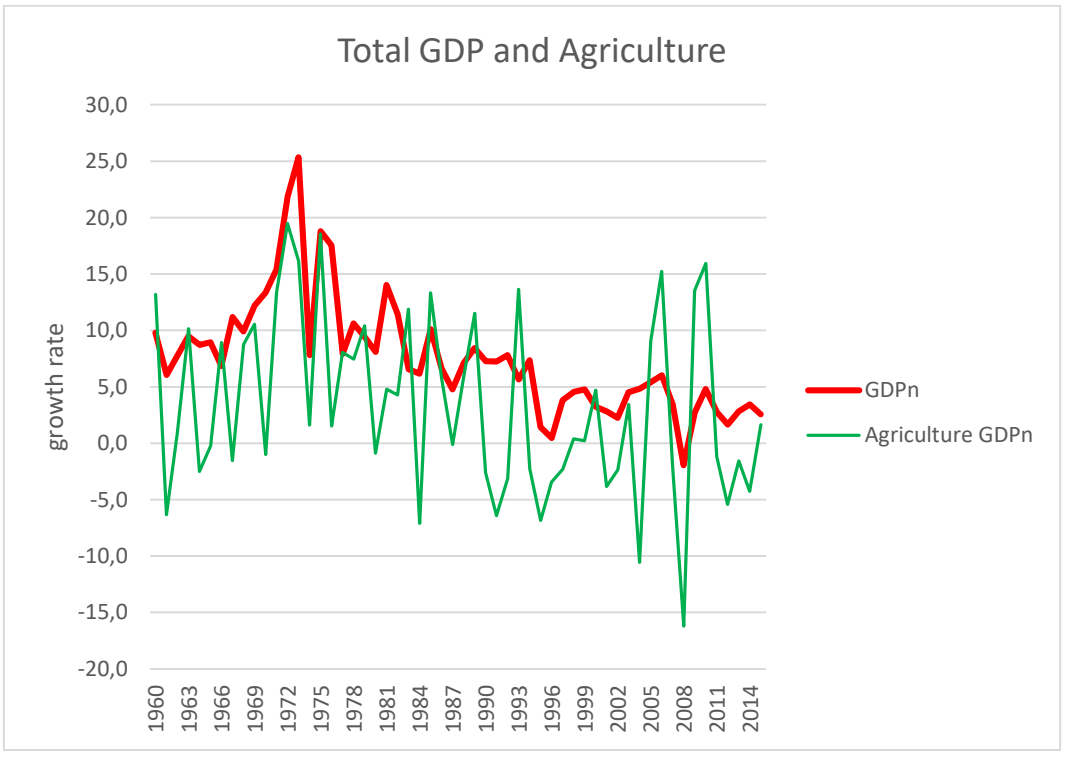


Figure 2: Total GDP and GDP in agriculture
Source: WIOT and AMECO

Note also that nominal agricultural GDP oscillates much stronger than nominal GDP.

Then the price level is determined. Again the general forecast is not fully believed in, compare fig. 3.

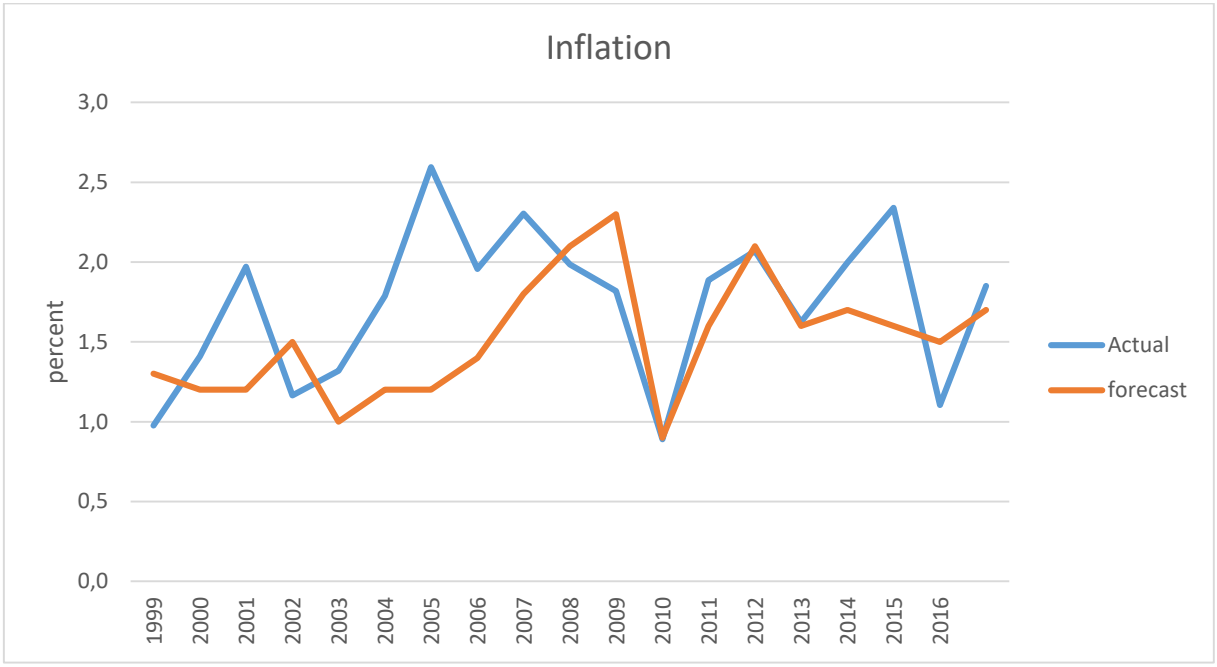


Figure 3: Forecasting bias of inflation rate
Source: ECFIN

But to determine agricultural price levels it turns out that here larger output indeed depresses the price level, very much the result that economists would like to see, compare fig.4.

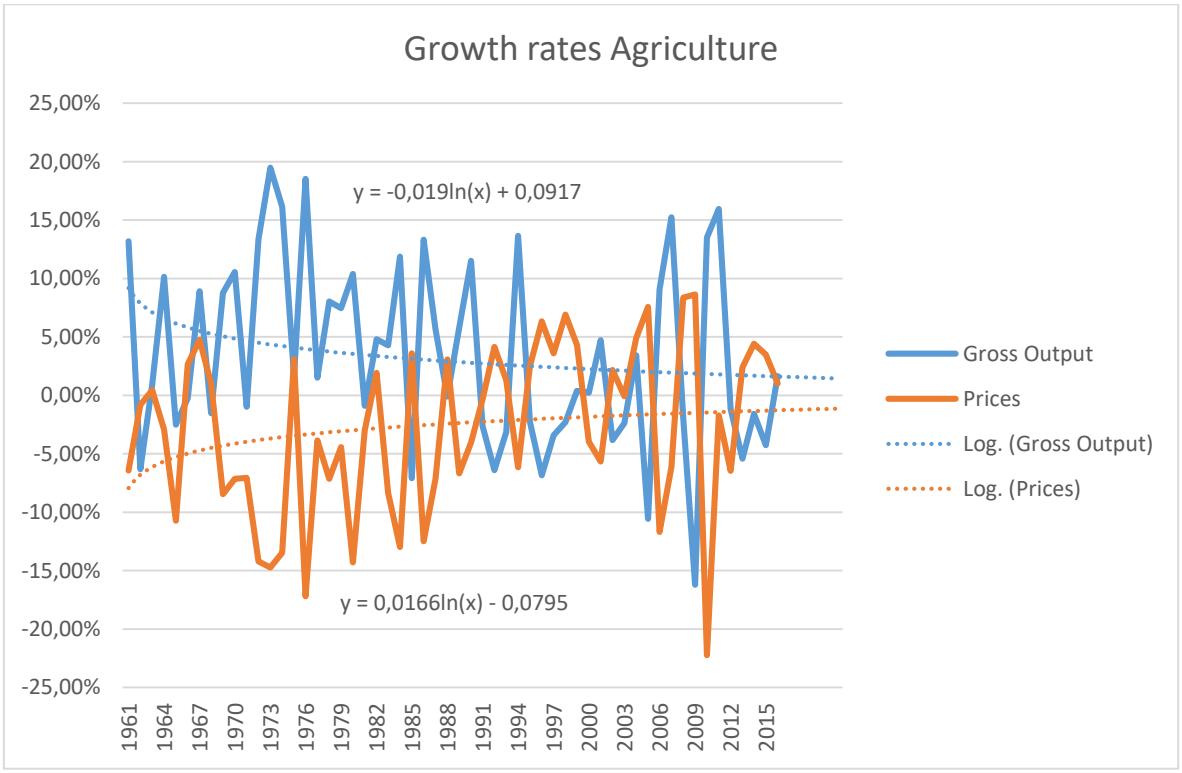


Figure 4: Prices and GDP in agriculture
Source: AMECO

Together with the corrected general inflation forecast this provides the price proposal of agriculture.

Then employment in agriculture is considered. Everyone is used to a steady long-run decrease and this exactly what in fig. 5 is shown for the time since 1976. It also shows that this decrease more recently has been accompanied by an increase of real wages.

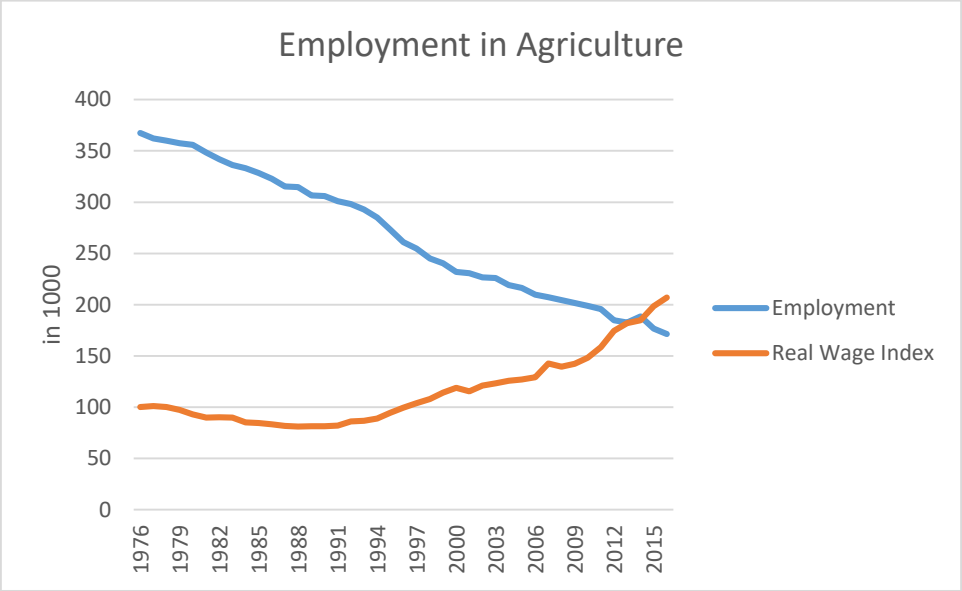


Figure 5: Employment in agriculture
Source: AMECO

The steady loss in employment can eventually be modified by changes in the power of unions, though this did not play a strong role in the past.

Since the 90-ties net investment seems to approach zero, that is gross investment follows the depreciation of the capital stock; in other words, investment mostly can be considered as replacement investment, fig.6. This unimpressive dynamics of investment is also used to set the proposal.

Besides the downward trend in employment a more significant feature of this sector is revealed by a look at its input structure. There evidently a long-run increase of machinery inputs can be seen, fig.7. The process of less workers and more machinery inputs in agriculture is just the classical substitution process between labour and capital. Additional demand for domestic machinery implies more sales for the machinery sector, as to a lesser extent is the case for the construction sector. But as fig. 8 reveals this machinery is also more and more imported. Imported machinery inputs grow even stronger than domestic inputs in machinery. Besides capital-labour substitution the other overwhelming trend towards increased division of labour between countries, i.e. rising trade, is also taking place in agriculture.

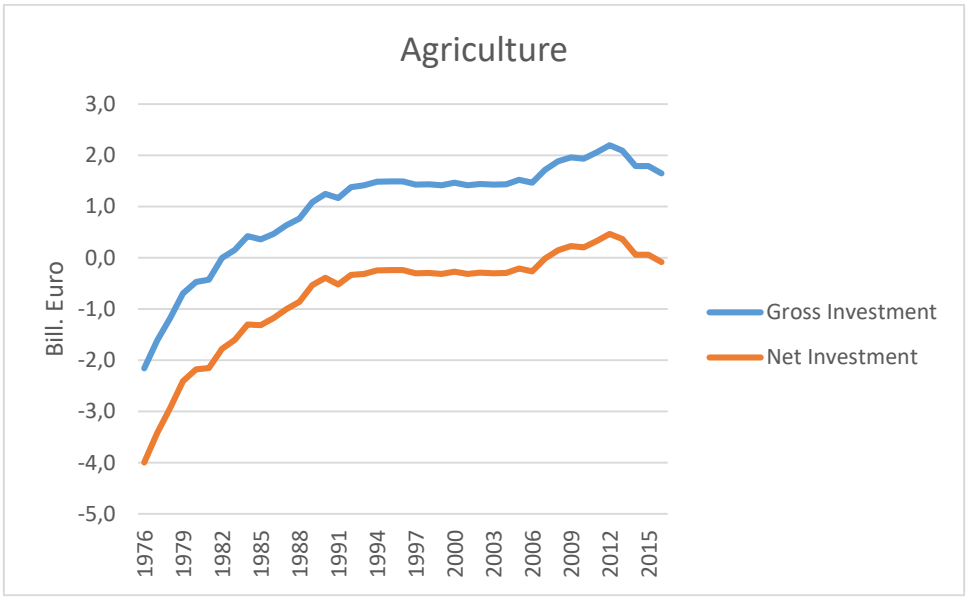


Figure 6: Investment in agriculture
Source: AMECO

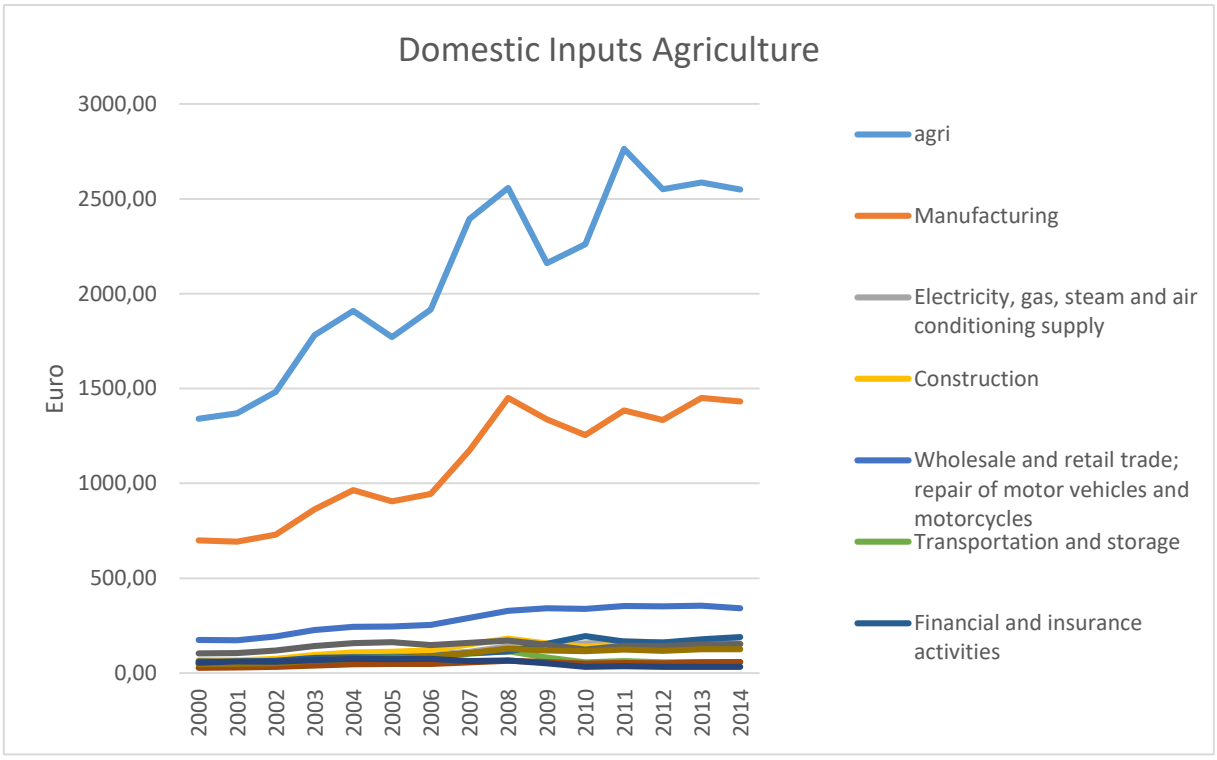


Figure 7: Intermediate domestic inputs in agriculture
Source: WIOT

Another structural trend concerns the rise of own use within the agricultural sector, a simple logistic function seems to fit best to describe this process.

Turning to the development of wages the increase in machinery in the following year leads to higher wages, which is plausible since more advanced machinery needs better trained and more expensive workers, while the wage sum can be kept low by less employment. Since

agriculture is such a small sector its interplay with finance is not made explicit within the agent. Investment can always be easily financed.

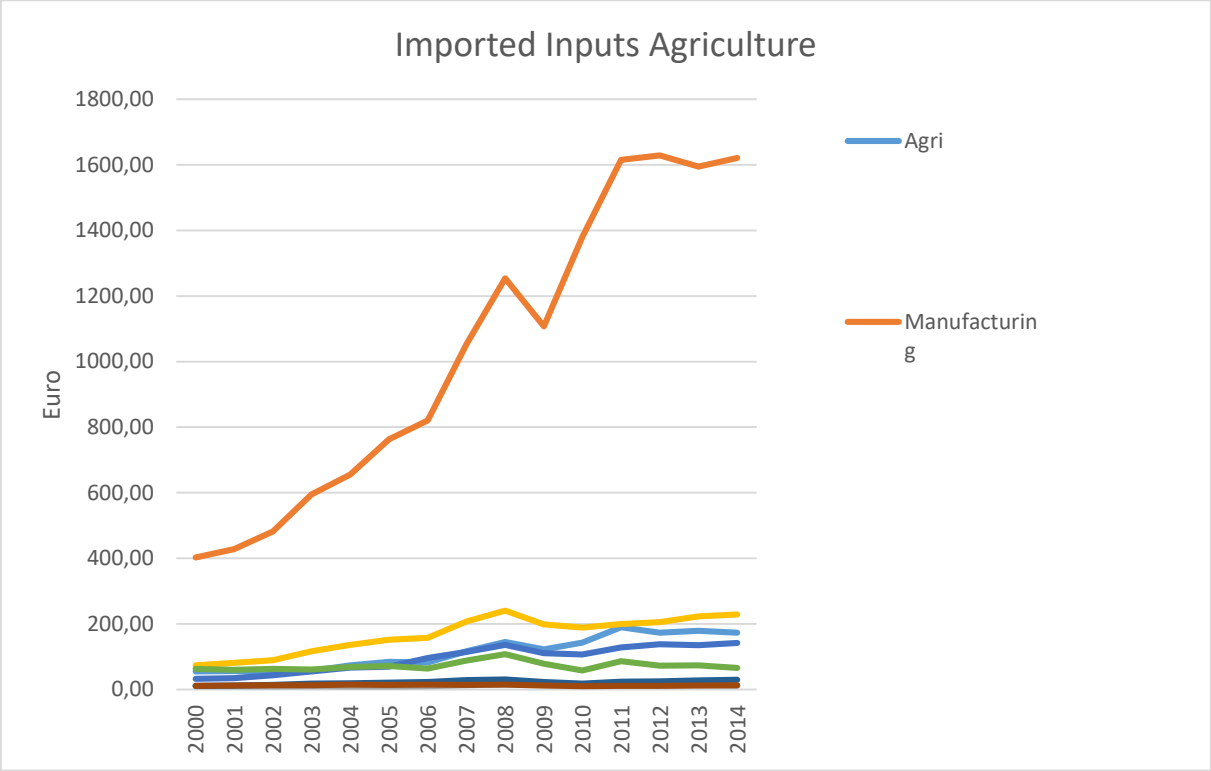


Figure 8: Intermediate foreign inputs in agriculture
Source: WIOT

As this little narrative of the behaviour of the agricultural sector shows it needs a lot empirical knowledge and diagrams to come up with a convincing story. Of course, this is not the only possible story and we certainly miss some important detail. Moreover, it is not a 'rational' story starting with profit maximization under well-known constraints. But returning to the recipe of agent-based modelling presented in 1.3 we have to remember that the only task is to construct an internal model, which is adequate to what goes on in the mind of the average farmer – nothing else. And this task seems to have been reached.

Mining and Quarrying

The agent of the sector of mining and quarrying in many respects resembles agriculture though since 2003 employment seems to stabilize, see fig. 9. Also investment seems to be nominally constant influencing employment slightly positively. Even wage development follows a flat path mildly influenced by a so far unspectacular wage influence of the national 'workers' agent. Note that there is a different elasticity from workers' power (the agent

'workers') to wages in every sector since this influence varies considerably. How strong this agent is decided mainly at national elections, but unemployment also plays a weakening role.

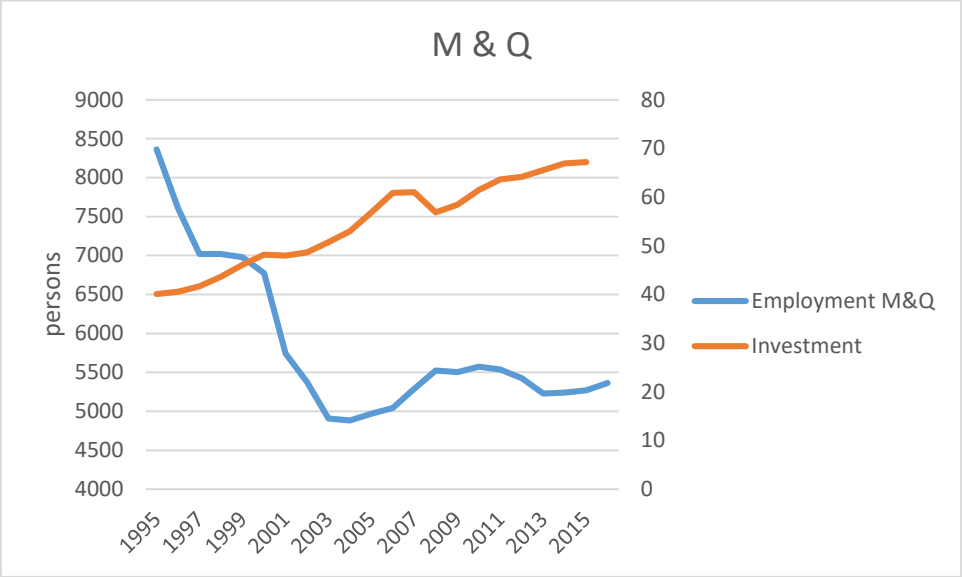


Figure 8: Employment and Investment in Mining and Quarrying
Source: AMECO

The quiet development of this sector has been the same in the 80-ties as a graph taken from an older study, [Hanappi, 1997], shows, see fig. 9. It is remarkable that even in times of greater changes of interest rates investment in M & Q is not influenced.

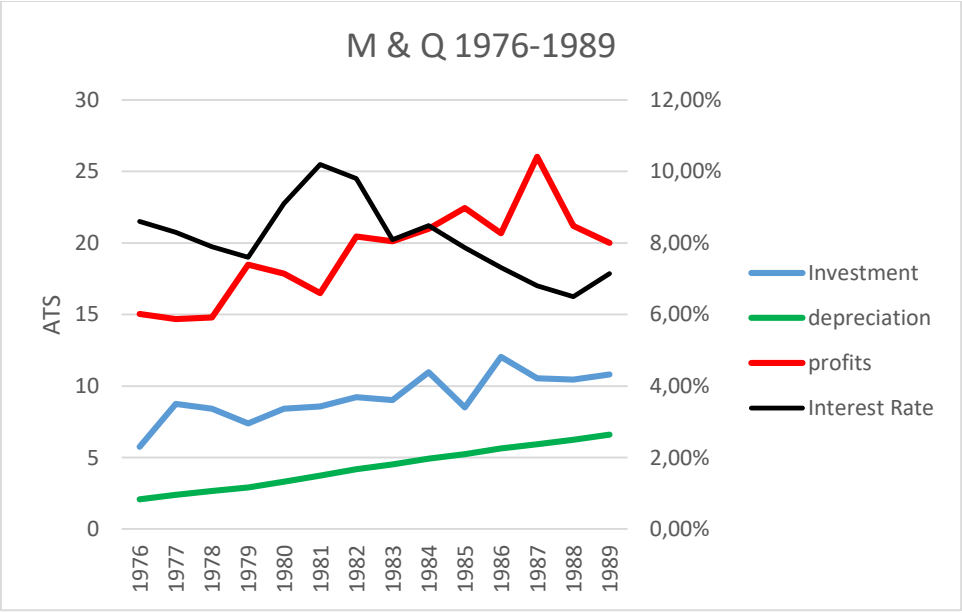


Figure 9: Historic time series in Mining and Quarrying
Source: [Hanappi, 1997]

But two other aspects of specific structural change in M & Q are characteristic and could only be detected by input output data.

First, there is a marked shift away from output produced for final demand to output produced for intermediate demand, see fig. 10.

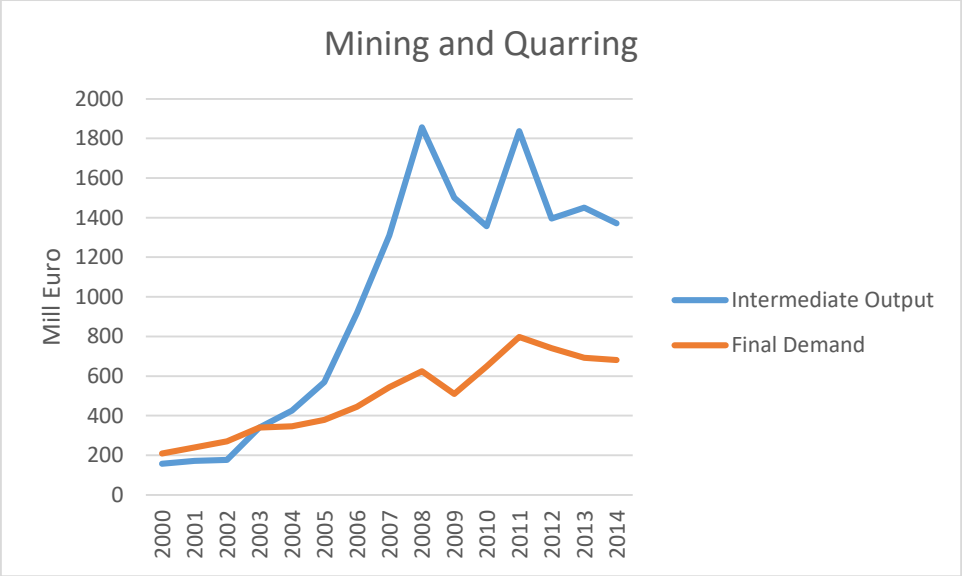


Figure 10: A shift in output structure of M & Q
Source: WIOT

Second, on the input side this is accompanied by a strong increase of intermediate imports, while imports for final demand stagnate, see fig. 11.

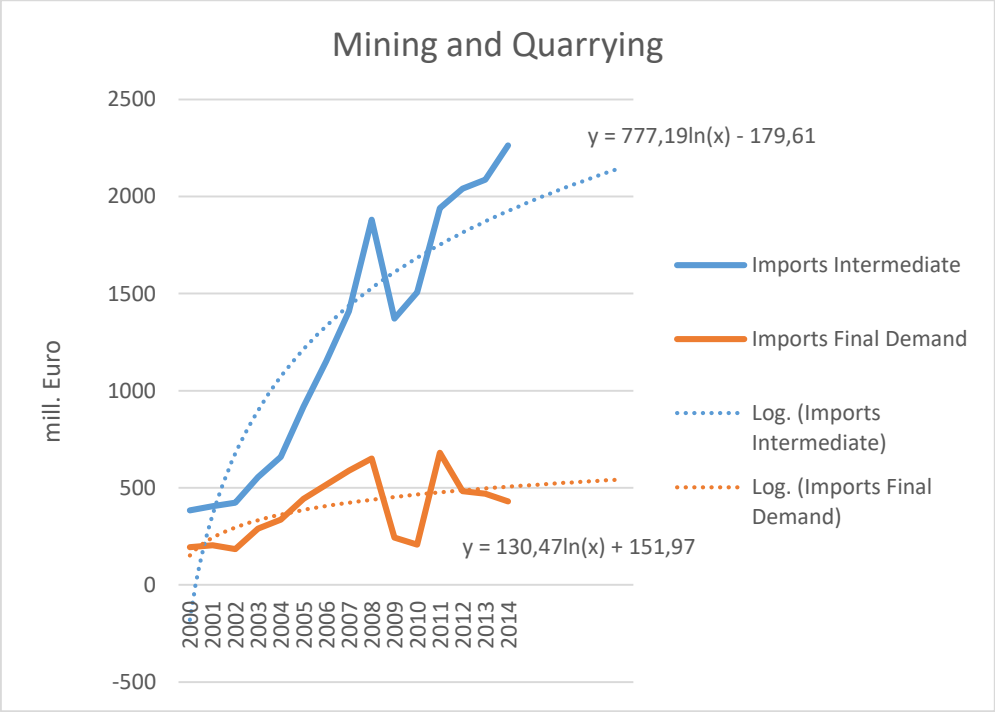


Figure 11: A boom in intermediate inputs of M & Q
Source: WIOT

Both characteristics hint at a specific behaviour of the agent representing the sector and therefore were included its program. In particular, the repercussion on total Austrian imports play a role for other agents.

Manufacturing

Manufacturing is a very large sector, compare fig. 12 showing gross outputs.

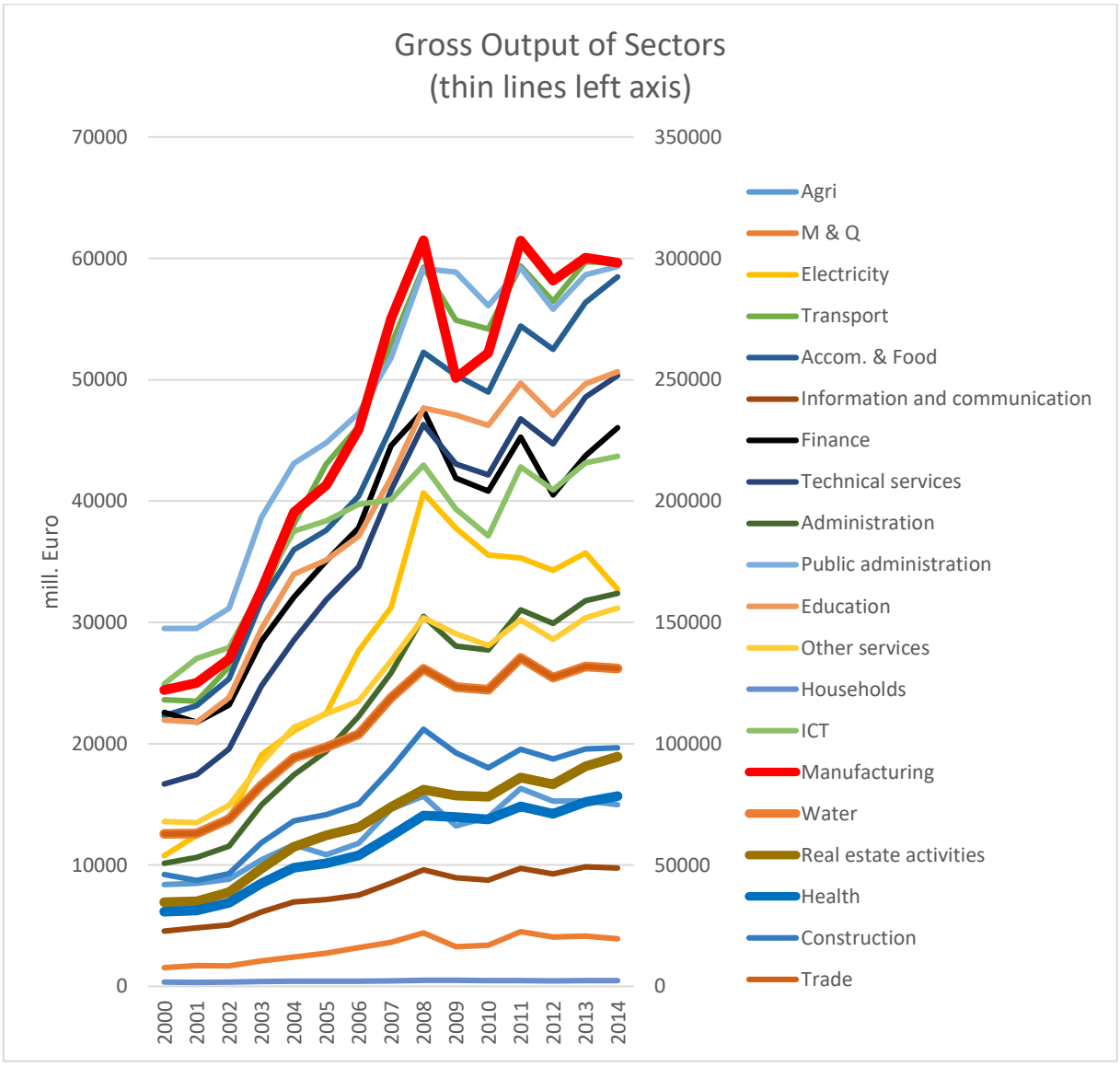


Figure 12: Gross Output of all sectors
Source: WIOT

It therefore plays a decisive role in the development of GDP and its declining growth rates since the mid 70-ties, see fig. 13. It is remarkable how close both lines in fig. 13 are, and that they indicate that the long-term trend points to a very low growth asymptote around 2%. Since these are nominal growth rates and the long-run inflation goal of the ECB is also 2%, this implies a zero growth rate in real terms.

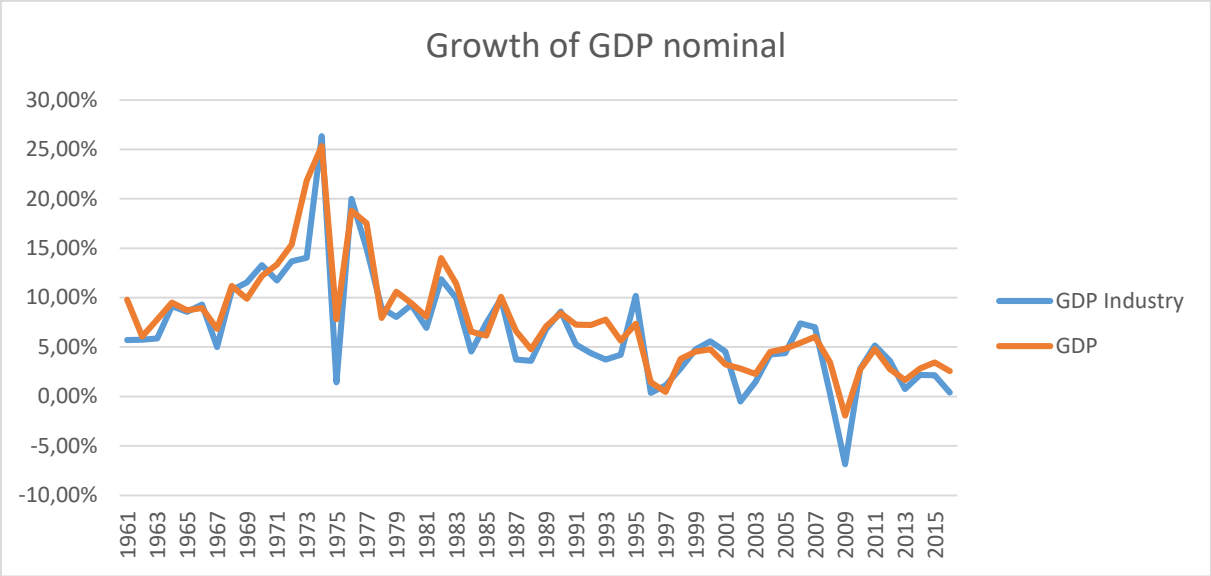


Figure 13: Growth rates of nominal GDP, total and industry
Source: AMECO

Price development of manufacturing shows that the traditional decrease now started to oscillate around a stable level, as the overall inflation rate (damped by industry prices) also does, see fig. 14.

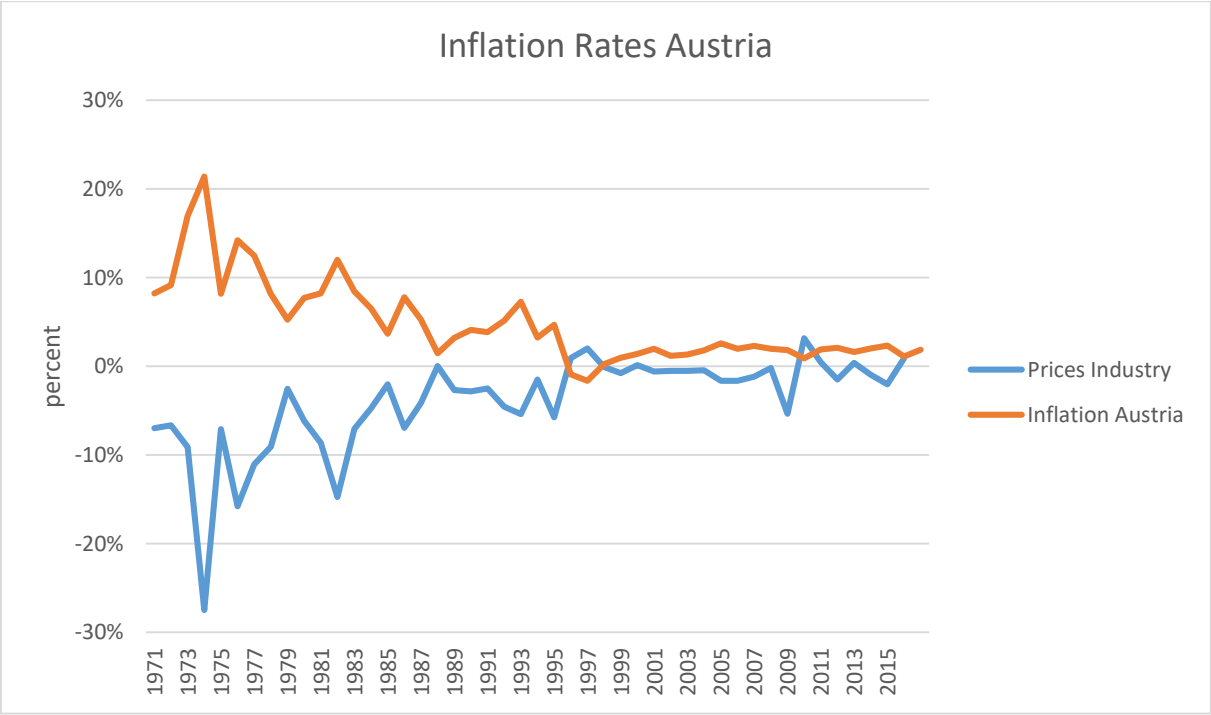


Figure 14: Inflation rates
Source: AMECO

The agent's long-run behaviour with respect to prices therefore could be explained as a sluggish reaction on the downward trend lower output growth; a quite reasonable argument from an economic perspective.

A more puzzling behaviour was found with respect to the employment decision of the agent. As shown in fig. 15 there clearly is a downward trend in employment accompanied by increasing investment. This is the well-known substitution process between capital and labour. Moreover, the figure also shows that around 80% of this investment is in machinery (boosting of course the own use of this sector). But estimating these relationships econometrically gave three different, rather good results. So which one should we plug into the agent's internal model? We decided to use all three of them, weighing together the different results! This can be interpreted as different 'minds' inhabiting the agent's 'brain'. The weight structure could be context dependent, determining how important a certain argument is at the moment[58]. This type of modelling possibility is one of the advantages of agent-based modelling, which is not present in standard mathematical models in economics.

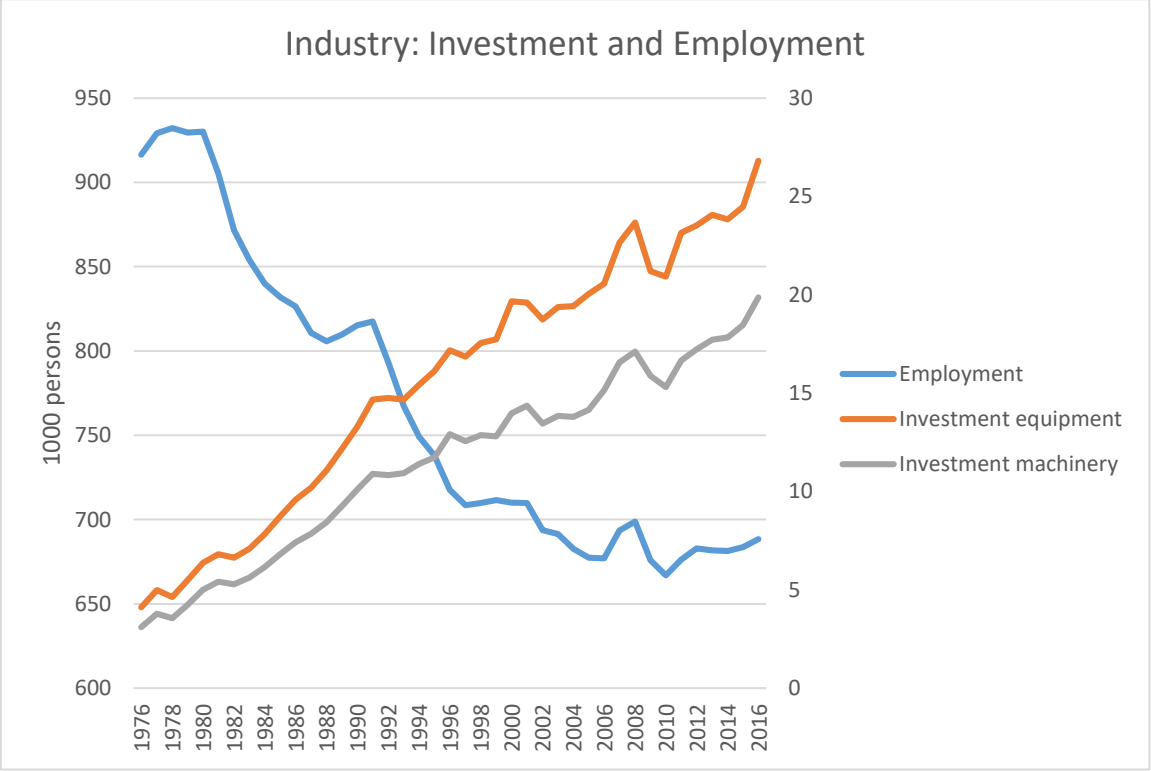


Figure 15: Employment and investment in industry
Source: AMECO

Wages in industry are rising rather smoothly, in the long run following an autoregressive process, despite the recently stagnating labour productivity, see fig. 16. This points at the fact that a reduced number of workers still is experiencing wage increases, which actually are achieved by rising capital productivity, see the high investment in machinery. Such narratives fit well to the physiognomy of this agent.

[58] Compare [Aydinonat, 2018] for similar ideas.

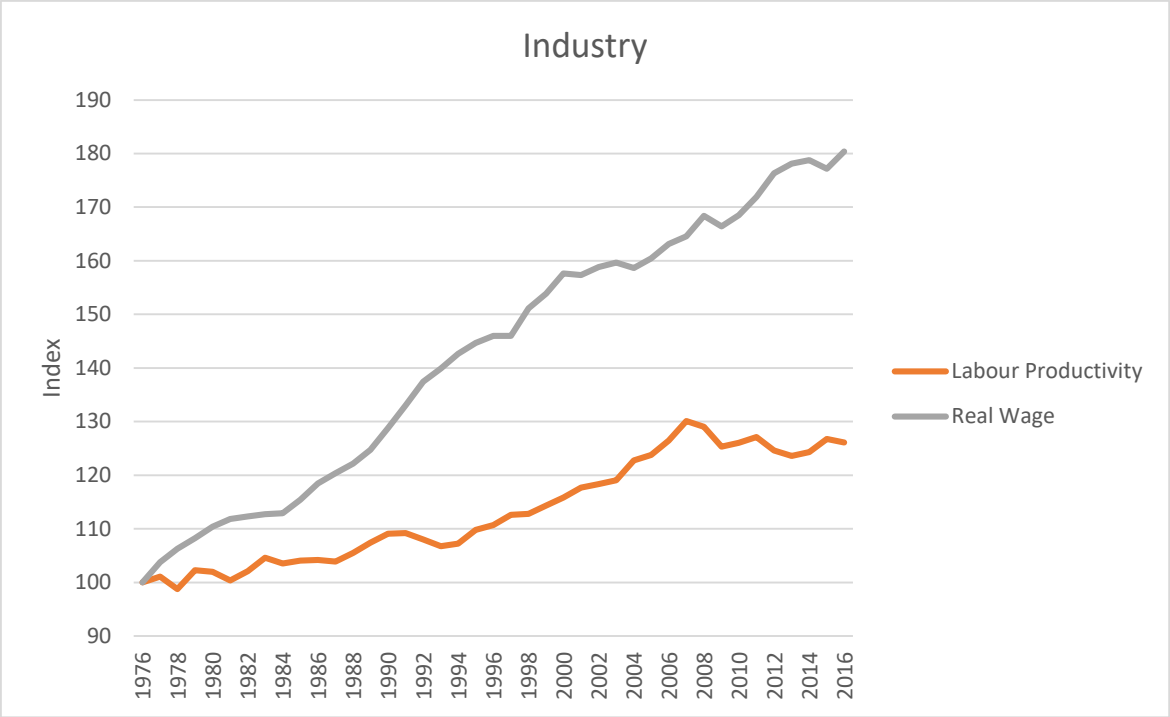


Figure 16: Wage and labour productivity
Source: AMECO

In the light of this heavy investment in machinery manufacturing plays an important role for finance. Therefore, level 2 of Austria has been augmented by a further agent called 'Industriellenvereinigung' (association of industrialists), which concentrates the needs of sector 3 (plus some other sectoral agents at level 3) to interact directly at level 2 with the agent 'bank'.

References

Aydinonat N.E., 2018, **The Diversity of Models as a Means to Better Explanations in Economics**, Department of Political and Economic Studies University of Helsinki, Finland.

Hanappi H., 1997, **Der Informationssektor in Österreich**, Wiener Studien zur Politischen Ökonomie, Band14. Web: http://www.econ.tuwien.ac.at/hanappi/Wispo/wispo_9.pdf

4. Summary

Over the years the project 'An Investigation of Banking-Macroeconomics Networks' has produced an extremely rich and diverse spectrum of scientific results. It has proceeded in two phases, partially forced by the change of collaborator – Dr. Scholz-Wäckerle was replaced by Mag. Rohringer – but partially also due to the logic of scientific work itself. In the first phase we explored the standard approaches in agent-based modelling to study our object of investigation. We produced research papers, book contributions, workshops and conferences, and our own computer models to do so. We took the close interplay between the so-called 'real side economy' and the monetary side of banking serious and were confronted with the need not include more and more aspects to provide an adequate picture of our topic.

Therefore, in phase 2 we had to decide how to go on. If we would remain in the sphere of standard agent-based models trying to graft dynamics on standard microeconomic concepts (the bottom-up approach), then we would have needed a large team, economists and programmers, to collect and combine the vastly grown area to be covered. Due to finance and scope of the project this was not feasible. What we decided in phase 2 therefore was to use what we have learned in phase 1 and to dare a new and unconventional start with an enhanced methodological understanding of agent-based modelling. The main new element being the insistence that we want to model the **actually used internal models** of **relevant entities in political economy**. The **models** we had to look for therefore were preliminary logical constructs derived from the perceptions of entities with limited model-building capacity (see chapter 1.3). This goes far beyond Herbert Simon's idea of bounded rationality; it allows for wrong and twisted perceptions, manipulation by communication, even the emergence of manifest new physical facts out of some follies in the communication sphere – all this is just the often neglected other side of the coin, of the 'rationally and learning entity'. The nice thing with agent-based modelling is that we can model this other side as easily as the front side. The second methodological innovation, **relevant agents**, is as important as the first one. It is a direct assault on methodological individualism. We understand entities in political economy always as a collection of smaller elements, starting with the smallest reproducible agent, the family (consisting of several physical individuals), and ending with the human species. This conception of an agent as a group with internal communication immediately implies the existence of a shared language with which an internal understanding, implies the existence of an internal model of how to interpret new incoming perceptions. This leads directly to the question: What are relevant groups in society? Of course, banks and macroeconomic decision-makers are to be considered due to the topic of the project. But they clearly are embedded in a broader setting. From below the basic economic production sphere

has to be brought into the picture – we chose input-output analysis as a starting point. From above we decided to draw the borderline of Europe (with two exceptions, transnational companies and international finance). This is why we came up with a structure of three levels. One more overarching element of relevance had to be included: technical progress. Since this typically starts at specific economic sectors we included it as an input structure decision at our lowest level. Everything else we ignored, but the task still remained much too grand to be satisfactory accomplished in the remaining project time. So what we did was to produce at least the framework of such an agent-based model. We called it A-POEM to remind us of the narrative character that we implanted in the internal models of our agents. For some parts of the modelling we showed how to proceed: The preparation of input-output data for Austria only was very time consuming – but also revealing a lot knowledge hidden by macroeconomic aggregates. Several sector agents of Austria's level 3 were studied and their internal models could be sketched with the help of a larger amount of econometric and modelling work. The basic ideas of the physiognomy of other agents were provided. In the end the framework of A-POEM now is ready to be filled with the results of empirical investigation. This marks the end of our project work. As always is the case with scientific work, it is also the start for further work that can build on its results.