Economic forecasting and policy analysis with an empirically estimated agent-based model for Austria

Sebastian Poledna\textsuperscript{1} \quad Michael Miess\textsuperscript{2}

\textsuperscript{1}International Institute for Advanced Systems Analysis (IIASA), Laxenburg
Institut für Höhere Studien (IHS), Wien

\textsuperscript{2}Environment Agency Austria (Umweltbundesamt), Wien
Institut für Höhere Studien (IHS), Wien
Institute for Ecological Economics, WU Wien

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Outline of presentation

1. Introduce into ABM
2. Focus on data sources for ABM
   ▶ National accounting data
   ▶ Add-in of Sabina data
3. Forecasting on different levels of granularity
4. Application of ABM to estimating the economic impacts of COVID-19 in Austria
Overarching ideas and research agenda for ABM

- Use **Data from national accounts** to *estimate* ABM to a national economy (Austria).
- Keep ABM simple – **no free parameters**.
- Use **Parameter-free adaptive learning** for expectation formation.
- Construct an ABM without an initial transient (*burn-in*) phase.
- **Validation:** Compare *forecasting performance* of ABM to that of standard models, e.g. (simple) times series models and a standard DSGE model.

**Outlook:** Can the construction of this type of empirically estimated ABMs be a way to **address the Lucas critique** from a new angle, i.e.

- Incorporate detailed *micro-foundations, forward looking behaviour + endogenous model dynamics* of economy as a complex system (emergence),
- Compensating for potential weaknesses of more standard approaches such as DSGE models, and satisfying the Lucas critique at the same time?
Economic forecasting: ABM for a small open economy

An empirical ABM that depicts the national economy of Austria.

- Incorporates all economic activities (producing and distributive transactions) as classified by the European system of accounts (ESA).
- Includes all economic entities: all juridical and natural persons are represented by agents.
- Integrates data from input-output tables (IOTs), national annual sector accounts (NASA), government statistics, census and business demography data, and business surveys.
- Behavioural equations used are standard in literature, e.g. [Delli Gatti et al., 2011, Assenza et al., 2015]
- Parameters are estimated rather than calibrated, no free parameters,
  - → No “burn-in” phase.
- **Empirical validation**: compare out-of-sample prediction performance of the ABM with that of autoregressive (AR), vector autoregressive (VAR) and DSGE models estimated on the same observable time series.
Agents & markets

Agents:
- Non-financial corporations (firm sector), limited companies and self-employed – ca. 600,000 firm agents.
- Financial corporations (banking sector), one representative bank.
- Households (individual persons) – ca. 8.2 million household agents:
  - Employed (active on labor market),
  - Unemployed (involuntarily idle),
  - Investor (own firms),
  - Inactive households (not active on labor market, receive social benefits).
- General government.

Markets: characterized by search & matching
- 64 different products according to sectoral structure as in IOT,
- These products can be used for consumption, or for investment/intermediate inputs (different markets),
- Additional markets: labour, credit and deposits.
Major Economic Agents and their Interactions
Agent behavior

▶ Each **firm** chooses its supply, prices, production and investment:
  ▶ Supply Choice according to expected demand (expected real economic growth),
  ▶ Pricing according to expected costs (expected inflation),
  ▶ Production by limitational (Leontief) production technology,
  ▶ Investment accounting for expected wear and tear of capital.
  ▶ Realized sales: minimum of supply choice, demand, and production possibilities (search & matching).

▶ Each **household** expects nominal disposable income $Y^e_h(t)$ depending on the *activity status* and expected inflation.
  ▶ spends a (fixed) fraction of this expected income on **consumption** and **investment**.

▶ The general government mainly acts as a consumer (**government consumption**) and as a ’redistributional’ entity.

▶ The **banking sector** takes deposits from firms and households, extends loans to firms, and receives advances from or deposits reserves at the central bank.

▶ **Interest rates** $r(t)$ are determined by means of a fixed risk premium $\mu$ over the policy rate $\bar{r}(t)$ set by the central bank according to a Taylor rule.
Expectations – parameter-free adaptive learning

**Parameter-free adaptive learning:** Agents (firms and households) act as econometricians who estimate the parameters of their model to make forecasts of key macroeconomic aggregates.

**Expectations:** formed according to an autoregressive model of lag order one (AR(1)).

**AR models:** Dependent variable $x(t)$ explained by its lag(s) up to order p, and an error term $\epsilon(t)$.

The expected real growth rate $\gamma^e(t)$ and the expected inflation rate $\pi^e(t)$ are inferred from agents’ predictions of (expected) gross domestic product (real GDP, in log levels) and inflation (the GDP deflator $DEFL$, 2010=100), lag order one:

$$GDP^e(t) = \alpha^{GDP} GDP(t - 1) + \epsilon^{GDP}(t) \quad (1)$$

$$DEFL^e(t) = \alpha^{DEFL} DEFL(t - 1) + \epsilon^{\pi}(t) \quad (2)$$

For both expectation formation and forecasting below, we used the AIC and BIC criterion to determine the optimal lag length for the AR model.
Firms: Supply Choice & Pricing (Adaptive Learning)

Supply choice/demand expectations:
Firms forms expectations about economic growth ($\gamma^e(t)$) according to AR(1) process, i.e. by parameter-free adaptive learning. Each firm $i$ adapts desired scale of activity ($Q_i^s(t)$) according to the previous period’s demand ($Q_i^d(t−1)$) and the assumptions about the development of the real growth rate ($\gamma^e(t)$)

$$Q_i^s(t) = Q_i^e(t) = Q_i^d(t−1)(1+\gamma^e(t))$$  \hspace{1cm} (3)

Pricing: according to expected inflation rate $\pi^e(t)$, cost-structure ('cost-push inflation'), unit target operating surplus:

$$P_i(t) = \frac{w_i(t)(1 + \tau^{SIF})\bar{P}_{HH}(t−1)(1+\pi^e(t))}{\alpha_i(t)} + \frac{1}{\beta_i} \sum_g a_{sg} \bar{P}_g(t−1)(1+\pi^e(t)) + \frac{\delta_i}{\kappa_i} \bar{P}^{CF}(t−1)(1+\pi^e(t))$$

$$+ \frac{\tau_i^Y P_i(t−1)(1+\pi^e(t))}{\kappa_i \omega} + \frac{\tau_i^K}{\kappa_i \omega} \bar{P}^{CF}(t−1)(1+\pi^e(t)) + \bar{\pi}_i P_i(t−1)(1+\pi^e(t))$$

Target unit operating surplus

$$\text{(4)}$$
Firms: Output & Investment

**Output** $Y_i(t)$ produced via:
(1) intermediate inputs $M_i(t)$, (2) labor $N_i(t)$, (3) capital stock $K_i(t - 1)$, with a fixed coefficient (Leontief) technology, where the coefficients are obtained from IOTs:

$\alpha_i(t), \beta_i$ and $\kappa_i$ – productivity coefficients,

$a_{sg}$ – technologically determined input (“technology”) coefficients:

$$Y_i(t) = \min \left( Q_{s1}^i(t), \frac{\beta_i}{a_{s1}} M_{i1}(t - 1), \frac{\beta_i}{a_{s2}} M_{i2}(t - 1), \ldots, \frac{\beta_i}{a_{sg}} M_{ig}(t - 1), \alpha_i(t) N_i(t), \kappa_i K_i(t - 1) \right) \tag{5}$$

**Investment** – according to:
(1) depreciation rate of capital $\delta_i$, (2) productivity of capital $\kappa_i$, and (3) desired scale of activity $Q_{s1}^i(t)$ based on demand expectations,

$$I_i^d(t) = \frac{\delta_i}{\kappa_i} Q_{s1}^i(t) = \frac{\delta_i}{\kappa_i} Q_{ie}^i(t) = \frac{\delta_i}{\kappa_i} Q_{id}^i(t - 1) [1 + \gamma_e(t)] \tag{6}$$
Non-financial and Financial Corporations (Firms): Economic activities

- Output (P.1) → part of which results in realized sales:
  - + $P_i Q_i$ where $P_i$ is price charged, and $Q_i$ are realized sales of firm $i$
  - Intermediate consumption (P.2)
  - Capital consumption (P.51C)
  - Wages and salaries (D.11)
  - Employers’ social contributions (D.611)
  - Taxes on products (D.21)
  - Other taxes on production (D.29)
  - Subsidies on products (D.31)
  - Other subsidies on production (D.39)
  - = Operating surplus (B.2A3N)
  - Interest (D.41)
  - Taxes on income (D.51)
  - dividend payments (D.42)

1The ESA code is given in brackets.
Households - income: each household forms expectations on its expected nominal disposable income $Y^e_h(t)$ (i.e. expected net income after taxes and including social or unemployment benefits):

$$Y^e_h(t) = \begin{cases} 
(w_h(t) \left[ 1 - \tau^{SIW} - \tau^{INC} (1 - \tau^{SIW}) \right] + s^{other}) \bar{P}^{HH}(t-1)(1 + \pi^e(t)) & \text{if employed} \\
(w_h(t) + s^{other}) \bar{P}^{HH}(t-1)(1 + \pi^e(t)) & \text{if unemployed} \\
(s^{inact} + s^{other}) \bar{P}^{HH}(t-1)(1 + \pi^e(t)) & \text{if not economically active} \\
\theta^{DIV} (1 - \tau^{INC})(1 - \tau^{FIRM}) \max(0, \Pi^e_i(t)) + s^{other} \bar{P}^{HH}(t-1)(1 + \pi^e(t)) & \text{if an investor} \\
\theta^{DIV} (1 - \tau^{INC})(1 - \tau^{FIRM}) \max(0, \Pi^e_k(t)) + s^{other} \bar{P}^{HH}(t-1)(1 + \pi^e(t)) & \text{if a bank investor} 
\end{cases}$$

Here,

- $w_h(t)$ is wage income or unemployment benefits (which are a fixed fraction $\theta$ of the wage last earned before the unemployment) of household $h$,
- $\bar{P}^{HH}(t-1)$ is last period’s consumer price index,
- $\Pi^e_i(t)$ are expected profits of firm $i$, $\Pi^e_k(t)$ are expected bank profits,
- $s^{inact}$ are social benefits for inactive persons (mostly pension payments), $s^{other}$ social benefits distributed equally to all households
- $\tau^{INC}$ is the income tax rate, $\tau^{SIW}$ is the rate of social insurance contributions to be paid by the employee, $\theta^{DIV}$ is the dividend payout ratio, and $\tau^{FIRM}$ the corporate tax rate.
Households: Consumption, Investment & Savings

Households spend a fraction of their expected income on consumption:

\[ C^d_h(t) = \frac{\psi Y^e_h(t)}{1 + \tau^{VAT}} \]  

and on investment:

\[ I^d_h(t) = \frac{\psi^H Y^e_h(t)}{1 + \tau^{CF}} \]

where \( \psi, \psi^H \) are propensities to consume, invest out of expected income; \( \tau^{VAT}, \tau^{CF} \) are value added, investment tax rates. Total household consumption allocated to goods \( g \) according to fixed coefficients from IOTs, analogous to firm investment above.

Households’ consumption, investment plans need not be realized (fundamental uncertainty!): expectation mistakes, search and matching

Savings: difference between realized disposable income \( Y_h(t) \), realized consumption expenditure \( C_h(t) \), used to accumulate financial wealth:

\[ D_h(t) = D_h(t - 1) + Y_h(t) - [(1 + \tau^{VAT}) C_h(t) + (1 + \tau^{CF}) I_h(t)] \]
Households: Economic activities

- Wages and salaries (D.11)
- Property Income (D.4)
- Mixed Income from Self-Employment (B2A3N)
- Social benefits other than social transfers in kind (D.62)
- Other current transfers net (D7, D8, D.9)
- Final consumption expenditure (P.3)
- Taxes on products (D.21)
- Taxes on income (D.5)
- Employees’ social contributions (D.612, D.613, D.614)
- Capital formation (dwellings) (P.51)
General Government: Economic activities

Government mainly acts as a consumer (government consumption) and as a ‘redistributonal’ entity: consumes on the goods market to provide a public good, collects taxes, provides transfers.

- Taxes on income (D.5, D.91)
- Taxes on products and production (D.2)
- Property Income (D.4)
- Social contributions (D.61)
- Final consumption (P.3)
- Subsidies (D.3)
- Interest payments (D.41)
- Social benefits other than social transfers in kind (D.62)
- Other current expenditures (D.7, D.8, D.9)
Exports, Imports, Government Consumption

According to the **small open economy (SoE)** assumption as appropriate for the Austrian economy and exogenous policy decisions, these economic aggregates are either assumed to be

- exogenously given from data (conditional forecasts),
- or to follow autoregressive (AR) processes according to the SoE setting for Austria.

Thus, imports $Y^I(t)$, exports $C^E(t)$ and government consumption $C^G(t)$ (all real and in log levels) either follow AR(1) processes (unconditional forecasting setup):

\[
Y^I(t) = \alpha^I Y^I(t - 1) + \epsilon^I \quad (11)
\]
\[
C^E(t) = \alpha^E C^E(t - 1) + \epsilon^E \quad (12)
\]
\[
C^G(t) = \alpha^G C^G(t - 1) + \epsilon^G, \quad (13)
\]

or are given exogenously in the conditional forecasting setup.
Data sources - national accounting data
\[ \text{GDP} = \sum_{i=1}^{611278} (1 - \tau_i^Y) P_i(t) Y_i(t) - \sum_{g,s,i \in I_s} \bar{P}_g(t) a_{sg} \frac{Y_i(t)}{\beta_i} \] (Production approach)

\[ \begin{align*}
\text{Household consumption} & = \sum_{h=1}^{8248321} C_h(t) \\
\text{Government consumption} & = \sum_{j} C_j(t) \\
\text{Gross fixed capital formation} & = \sum_{h=1}^{8248321} I_h(t) + \sum_{i=1}^{611278} \bar{P}^{CF}(t) l_i(t) \\
\end{align*} \]

\[ \begin{align*}
\text{Changes in inventories} & = \sum_{i=1}^{611278} P_i(t) \Delta S_i(t) + \sum_{g,s,i \in I_s} \bar{P}_g(t) \left( \Delta M_{ig}(t) - a_{sg} \frac{Y_i(t)}{\beta_i} \right) + \sum_{i} (C_i(t)) \\
\text{Exports} & = \sum_{i} \left( \Pi_i(t) + r(t) L_i(t) + \bar{P}^{CF}(t) \frac{\delta_i}{\kappa_i} Y_i(t) \right) \\
\text{Imports} & = \sum_{m} P_m(t) Q_m(t) - \sum_{i} \tau_i^Y P_i(t) Y_i(t) \quad \text{(Expenditure approach)} \\
\text{Net taxes on products} & = \sum_{h=1}^{8248321} w_h(t) + \sum_{i=1}^{611278} \left( \Pi_i(t) + r(t) L_i(t) + \bar{P}^{CF}(t) \frac{\delta_i}{\kappa_i} Y_i(t) \right) \\
\text{Compensation of employees} & = \sum_{i} \tau_i^K P_i(t) Y_i(t) \quad \text{(Income approach)} \\
\text{Gross operating surplus and mixed income} & = \sum_{i} \tau_i^K P_i(t) Y_i(t) \quad \text{(Income approach)} \\
\end{align*} \]
Parameter setting: European System of Accounts

- Input-output tables (IOTs)
- National annual sector accounts (NASA)
- Government statistics
- Demographic statistics and census data
- Business surveys
<table>
<thead>
<tr>
<th>Name</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP and main components - output, expenditure and income (quarterly time series)</td>
<td>namq_10_gdp</td>
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<tr>
<td>Symmetric input-output table (IOT) at basic prices (product by product)</td>
<td>naio_10_cp1700</td>
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<tr>
<td>Cross-classification of fixed assets by industry and by asset (stocks)</td>
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<td>Balance sheets for financial assets</td>
<td>nasa_10_f_bs</td>
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<td>Non-financial transactions</td>
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<td>Business demography by legal form (from 2004 onwards, NACE Rev. 2)</td>
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<td>Government revenue, expenditure and main aggregates</td>
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<tr>
<td>Government deficit/surplus, debt and associated data</td>
<td>gov_10dd_edpt1</td>
</tr>
<tr>
<td>Government expenditure by function - COFOG</td>
<td>gov_10a_exp</td>
</tr>
<tr>
<td>Population by current activity status, NACE Rev. 2 activity and NUTS 2 region</td>
<td>cens_11an_r2</td>
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<tr>
<td>Money market interest rates - annual data</td>
<td>irt_st_a</td>
</tr>
<tr>
<td>Money market interest rates - quarterly data</td>
<td>irt_st_q</td>
</tr>
</tbody>
</table>
Challenges with national accounting data

- Harmonize IO tables with government statistics
- Harmonize IO tables and time series data
- Inconsistencies between datasets are most problematic issue:
  - Time series data are updated, IO data are not
  - No cross-classification tables IO and NASA data (financial variables)
  - etc.
**Figure**: Parameter setting: Initial Output/Cost Structure
**Figure:** Parameter setting: Initial number of firms/employees

The graph illustrates the distribution of the initial number of firms and employees across different sectors. The x-axis represents the sectors, and the y-axes represent the number of firms and employees. Each sector is color-coded to differentiate between firms and employees. The graph shows a wide variation in the number of firms and employees across the sectors.
Figure: Firm Size distribution
General Government: Revenues $Y^G(t)$

$$
Y^G(t) = (\tau^{SIF} + \tau^{SIW}) \bar{P}^{HH}(t) \sum_{h \in H^E(t)} w_h(t) + \tau^{INC} (1 - \tau^{SIW}) \bar{P}^{HH}(t) \sum_{h \in H^E(t)} w_h(t)
$$

Social security contributions

Labour income taxes

Value added taxes

Capital income taxes

Corporate income taxes

Taxes on capital formation

Net taxes/subsidies on products

Net taxes/subsidies on production

Export taxes

$$
+ \tau^{VAT} \sum_h C_h(t) + \tau^{INC} (1 - \tau^{FIRM}) \theta^{DIV} \left( \sum_i \max(0, \Pi_i(t)) + \max(0, \Pi_k(t)) \right)
$$

$$
+ \tau^{FIRM} \left( \sum_i \max(0, \Pi_i(t)) + \max(0, \Pi_k(t)) \right) + \tau^{CF} \sum_h l_h(t)
$$

$$
+ \sum_{s,i \in I_s} \tau^{Y}_i P_i(t) Y_i(t) + \bar{P}^{CF}(t) \sum_i \tau^K_i K_i(t) + \tau^{EXPORT} \sum_l C_l(t).
$$
General Government: Deficit & Debt

The **government deficit** (or surplus) resulting from its redistributive activities is

\[
\Pi^G(t) = \underbrace{Y^G(t)}_{\text{Government revenues}} - \sum_j C_j(t) - \underbrace{r^G L^G(t)}_{\text{Interest payments}} - \sum_{h \in H^{\text{inact}}} \tilde{P}^{HH}(t)_{sb}^{\text{inact}} + \sum_{h \in H^{U}(t)} \tilde{P}^{HH}(t) w_h(t) + \sum_{h} \tilde{P}^{HH}(t)_{sb}^{\text{other}} \tag{15}
\]

Social benefits and transfers

The **government debt** is determined by the year-to-year deficits/surpluses of the government sector:

\[
L^G(t) = L^G(t - 1) + \Pi^G(t) \tag{16}
\]
Forecasts using national accounting data
### Table: Unconditional forecasting performance

<table>
<thead>
<tr>
<th></th>
<th>GDP growth</th>
<th>GDP deflator growth</th>
<th>Household consumption</th>
<th>Investment</th>
<th>Euribor</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR(1)</td>
<td>RMSE-statistic for different forecast horizons</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1q</td>
<td>0.62</td>
<td>0.37</td>
<td>0.66</td>
<td>1.4</td>
<td>0.05</td>
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<td>2q</td>
<td>0.89</td>
<td>0.36</td>
<td>0.93</td>
<td>2.21</td>
<td>0.1</td>
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<tr>
<td>4q</td>
<td>1.33</td>
<td>0.34</td>
<td>1.32</td>
<td>3.5</td>
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<td>8q</td>
<td>1.48</td>
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<tr>
<td>12q</td>
<td>1.31</td>
<td>0.33</td>
<td>2</td>
<td>6.09</td>
<td>0.26</td>
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<tr>
<td>ABM</td>
<td>Percentage gains (+) or losses (-) relative to AR(1) model</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1q</td>
<td>-1.7 (0.02)</td>
<td>0 (0.96)</td>
<td>0.5 (0.94)</td>
<td>8.9 (0.13)</td>
<td>-235.7 (0.00)</td>
</tr>
<tr>
<td>2q</td>
<td>-1.8 (0.30)</td>
<td>-1.2 (0.29)</td>
<td>0.5 (0.96)</td>
<td>10.2 (0.20)</td>
<td>-90.3 (0.19)</td>
</tr>
<tr>
<td>4q</td>
<td>0.2 (0.93)</td>
<td>1.1 (0.14)</td>
<td>7.1 (0.62)</td>
<td>9.2 (0.28)</td>
<td>-15.9 (0.78)</td>
</tr>
<tr>
<td>8q</td>
<td>5.9 (0.13)</td>
<td>0.4 (0.78)</td>
<td>21.6 (0.04)</td>
<td>29.8 (0.00)</td>
<td>58 (0.00)</td>
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<tr>
<td>12q</td>
<td>4.6 (0.54)</td>
<td>-0.3 (0.10)</td>
<td>29.8 (0.00)</td>
<td>39.6 (0.00)</td>
<td>79.6 (0.00)</td>
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<td>DSGE</td>
<td>Percentage gains (+) or losses (-) relative to AR(1) model</td>
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<td></td>
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<td>1q</td>
<td>-5.7 (0.62)</td>
<td>5.3 (0.59)</td>
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<td>22.1 (0.24)</td>
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<tr>
<td>2q</td>
<td>-3.4 (0.80)</td>
<td>-20 (0.17)</td>
<td>7.2 (0.43)</td>
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<td>4q</td>
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<td>8q</td>
<td>39 (0.08)</td>
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<tr>
<td>12q</td>
<td>28.5 (0.00)</td>
<td>-4.3 (0.63)</td>
<td>7.1 (0.37)</td>
<td>50.8 (0.00)</td>
<td>-139.2 (0.00)</td>
</tr>
</tbody>
</table>

Table: RMSE-statistic for different forecast horizons from 2010:Q2-2016:Q4 of ABM in comparison to AR(1) and DSGE models (unconditional forecasts). Values in brackets indicate p-values of the [Diebold and Mariano, 1995] test on predictive accuracy.
### Table: Conditional forecasting (exogenous predictors)

<table>
<thead>
<tr>
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<td>0.38</td>
<td>0.58</td>
<td>1.11</td>
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<td>2q</td>
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<td>4q</td>
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<td>0.96</td>
<td>1.25</td>
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<td>8q</td>
<td>0.53</td>
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<tr>
<td>12q</td>
<td>0.58</td>
<td>0.41</td>
<td>1.43</td>
<td>1.35</td>
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</table>

<table>
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<tr>
<th>“ABMX” (cond. fc.)</th>
<th>Percentage gains (+) or losses (-) relative to ARX(1) model</th>
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<tbody>
<tr>
<td>1q</td>
<td>3.3 (0.12) -0.9 (0.21) -22.1 (0.19) -1.8 (0.94)</td>
</tr>
<tr>
<td>2q</td>
<td>-0.9 (0.90) -1.1 (0.34) -8.4 (0.62) -11.8 (0.74)</td>
</tr>
<tr>
<td>4q</td>
<td>-23.1 (0.51) 0.8 (0.51) -12.8 (0.55) -107.1 (0.10)</td>
</tr>
<tr>
<td>8q</td>
<td>-1 (0.94) -1 (0.00) 18.8 (0.05) -142.3 (0.03)</td>
</tr>
<tr>
<td>12q</td>
<td>18.5 (0.00) -1.6 (0.00) 6.6 (0.33) -120.5 (0.06)</td>
</tr>
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<table>
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<th>“DSGEX” (cond. fc.)</th>
<th>Percentage gains (+) or losses (-) relative to ARX(1) model</th>
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<tbody>
<tr>
<td>1q</td>
<td>-60.7 (0.05) 1.4 (0.91) -200.3 (0.08) -1.1 (0.96)</td>
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<tr>
<td>2q</td>
<td>-105.8 (0.00) -17.1 (0.28) -196.7 (0.09) -3.5 (0.90)</td>
</tr>
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<td>4q</td>
<td>-105.4 (0.00) -12.4 (0.59) -242.2 (0.12) -86.2 (0.00)</td>
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<td>8q</td>
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<td>-160.2 (0.00) -33.9 (0.00) -354 (0.00) -71.9 (0.00)</td>
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</table>

**Table:** RMSE-statistic for different forecast horizons from 2010:Q2-2016:Q4 of ABM with 6 predictors in comparison to ARX(1) with the same predictors, as well as to a DSGE model with conditional forecasts. Values in brackets indicate p-values of the [Diebold and Mariano, 1995] test on predictive accuracy.
Conditional Prediction Performance, Quarterly levels: 2010:Q4 - 2013:Q4

**GDP (quarterly)**

- DATA
- AR(1)
- DSGE
- ABM

**Consumption (quarterly)**

**Investment (quarterly)**

**Government (quarterly)**

**Exports (quarterly)**

**Imports (quarterly)**

**Figure:** ABM (black), AR(1) (blue), DSGE (red), Eurostat data (dashed); horizon 12q
Conditional Prediction Performance, Growth: 2010:Q4 - 2013:Q4

**Figure:** ABM (black), AR(1) (blue), DSGE (red), Eurostat data (dashed); horizon 12q
Table: Out-of-sample forecast performance of sectoral gross value added (GVA)

<table>
<thead>
<tr>
<th></th>
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<td><strong>AR(1)</strong></td>
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<tr>
<td>1q</td>
<td>10.97</td>
<td>1.29</td>
<td>1.39</td>
<td>0.98</td>
<td>2.37</td>
<td>3.95</td>
<td>0.37</td>
<td>1.68</td>
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<td>2q</td>
<td>14.29</td>
<td>1.75</td>
<td>1.81</td>
<td>1.48</td>
<td>2.93</td>
<td>4.94</td>
<td>0.61</td>
<td>1.94</td>
<td>0.71</td>
<td>0.58</td>
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<td>4q</td>
<td>14.13</td>
<td>2.62</td>
<td>2.74</td>
<td>2.46</td>
<td>4.77</td>
<td>6.79</td>
<td>1</td>
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<td>1.01</td>
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<tr>
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<td>12.95</td>
<td>3.46</td>
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<td>3.69</td>
<td>7.03</td>
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<td>2.81</td>
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<td>1.75</td>
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<td>9.6</td>
<td>3.5</td>
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<td>3.47</td>
<td>10.01</td>
<td>11.57</td>
<td>1.98</td>
<td>2.77</td>
<td>2.06</td>
<td>2.63</td>
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<tr>
<td><strong>ABM</strong></td>
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<tr>
<td><strong>Percentage gains (+) or losses (-) relative to AR(1) model</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1q</td>
<td>0 (1.00)</td>
<td>4.5 (0.41)</td>
<td>5.2 (0.55)</td>
<td>-6.9 (0.15)</td>
<td>4.4 (0.17)</td>
<td>0.8 (0.92)</td>
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<td>-6 (0.52)</td>
<td>10 (0.31)</td>
<td>-1.5 (0.92)</td>
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<tr>
<td>2q</td>
<td>-5.6 (0.65)</td>
<td>12.7 (0.22)</td>
<td>15.8 (0.11)</td>
<td>-3.9 (0.67)</td>
<td>13 (0.06)</td>
<td>2 (0.90)</td>
<td>-95.5 (0.00)</td>
<td>-16.2 (0.30)</td>
<td>20.7 (0.12)</td>
<td>6.9 (0.83)</td>
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<tr>
<td>4q</td>
<td>-10.2 (0.44)</td>
<td>19.8 (0.26)</td>
<td>34.5 (0.00)</td>
<td>2.2 (0.88)</td>
<td>17.9 (0.00)</td>
<td>14.2 (0.52)</td>
<td>-132.2 (0.00)</td>
<td>-40.1 (0.23)</td>
<td>29.8 (0.20)</td>
<td>19.2 (0.60)</td>
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<tr>
<td>8q</td>
<td>-10.5 (0.76)</td>
<td>31.3 (0.24)</td>
<td>64.7 (0.00)</td>
<td>13.9 (0.13)</td>
<td>32.2 (0.00)</td>
<td>41.9 (0.09)</td>
<td>-194.2 (0.00)</td>
<td>-68.3 (0.02)</td>
<td>3.9 (0.92)</td>
<td>25.5 (0.45)</td>
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<tr>
<td>12q</td>
<td>-79.3 (0.00)</td>
<td>41.8 (0.07)</td>
<td>65.7 (0.00)</td>
<td>26.2 (0.00)</td>
<td>37.5 (0.00)</td>
<td>53.7 (0.00)</td>
<td>-215.4 (0.00)</td>
<td>-116.3 (0.00)</td>
<td>-20.9 (0.59)</td>
<td>42 (0.00)</td>
</tr>
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</table>

Sectors shown: Forestry and fishing (A); Industry (except construction) (B, C, D and E); Manufacturing (C); Construction (F); Wholesale and retail trade, transport, accommodation and food service activities (G, H and I); Information and communication (J); Financial and insurance activities (K); Real estate activities (L); Professional, scientific and technical activities, as well as administrative and support service activities (M and N); Public administration, defence, education, human health and social work activities (O, P and Q); Arts, entertainment, and recreation, as well as other service activities (R and S). The forecast period is 2010:Q2 to 2016:Q4. All models are re-estimated each quarter. ABM results are obtained as an average over 500 Monte Carlo simulations. The values in brackets indicate the p-values of [Diebold and Mariano, 1995] tests.
National accounting

**Figure:** GDP: production, income, and expenditure approaches, ABM (solid) vs. data (dashed)
**Figure:** Sectoral decomposition: ABM simulations (solid), observed data (dashed) without Sabina data
Revenue forecasts for Austrian firms using Sabina data
Revenue forecasts for Austrian firms

Based on the SABINA database from Bureau van Dijk

- Company financials, in a detailed format, with up to 10 years of history for 175,000 companies in Austria
- Directors, shareholders and subsidiaries
- Activity codes and trade descriptions
- Stock data for listed companies
- Detailed corporate structures and the corporate family
- Business and company-related news
- M&A deals and rumors
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Source</th>
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</thead>
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<tr>
<td>$G/S$</td>
<td>Number of products/industries</td>
<td>62</td>
<td>literature</td>
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<tr>
<td>$\mu_{\text{econ}}$</td>
<td>Number of economically active persons</td>
<td>47,9215</td>
<td>census, business, demographics data</td>
</tr>
<tr>
<td>$\mu_{\text{inactive}}$</td>
<td>Number of economically inactive persons</td>
<td>413,0385</td>
<td>census, business, demographics data</td>
</tr>
<tr>
<td>$J$</td>
<td>Number of government entities</td>
<td>152,820</td>
<td>government statistics, national accounts</td>
</tr>
<tr>
<td>$L$</td>
<td>Number of foreign consumers</td>
<td>306,639</td>
<td>government statistics, national accounts</td>
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<tr>
<td>$i_t$</td>
<td>Number of firms in the $i$th industry</td>
<td></td>
<td>firm level, ORBS/SAIDNA, input-output tables, sector accounts</td>
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<tr>
<td>$\bar{\alpha}_i$</td>
<td>Average productivity of labor of the $i$th firm</td>
<td></td>
<td>firm level, ORBS/SAIDNA, input-output tables, sector accounts</td>
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<tr>
<td>$\kappa_i$</td>
<td>Productivity of capital of the $i$th firm</td>
<td></td>
<td>firm level, ORBS/SAIDNA, input-output tables, sector accounts</td>
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<td>$\beta_i$</td>
<td>Productivity of intermediate consumption of the $i$th firm</td>
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<td>firm level, ORBS/SAIDNA, input-output tables, sector accounts</td>
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<td>$\delta_i$</td>
<td>Depreciation rate for capital of the $i$th firm</td>
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<td>$\bar{w}_i$</td>
<td>Average wage rate of firm $i$</td>
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<td>firm level, ORBS/SAIDNA, input-output tables, sector accounts</td>
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<td>$\kappa_g$</td>
<td>Technology coefficient of the $g$th product in the $s$th industry</td>
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<td>firm level, ORBS/SAIDNA, input-output tables, sector accounts</td>
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<td>$\mu_{\text{TH}}$</td>
<td>Capital formation coefficient of the $g$th product (firm investment)</td>
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<td>firm level, ORBS/SAIDNA, input-output tables, sector accounts</td>
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<td>$\mu_{\text{HH}}$</td>
<td>Household investment coefficient of the $g$th product</td>
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<td>firm level, ORBS/SAIDNA, input-output tables, sector accounts</td>
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<td>$\mu_{\text{CH}}$</td>
<td>Consumption coefficient of the $g$th product of households</td>
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<td>government statistics, national accounts, sector accounts</td>
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<td>$\mu_{\text{CG}}$</td>
<td>Consumption of the $g$th product of the government in mln. Euro</td>
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<td>government statistics, national accounts, sector accounts</td>
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<tr>
<td>$\mu_{\text{H}}$</td>
<td>Exports of the $g$th product in mln. Euro</td>
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<td>government statistics, national accounts, sector accounts</td>
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<td>$\mu_{\text{W}}$</td>
<td>Imports of the $g$th product in mln. Euro</td>
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<td>government statistics, national accounts, sector accounts</td>
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<td>$\gamma_i$</td>
<td>Net tax rate on products of the $i$th firm</td>
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<td>government statistics, national accounts, sector accounts</td>
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<td>$\gamma^X_i$</td>
<td>Net tax rate on production of the $i$th firm</td>
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<td>government statistics, national accounts, sector accounts</td>
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<td>$\mu_{\text{IT}}$</td>
<td>Income tax rate</td>
<td>0.2134</td>
<td>government statistics, national accounts, sector accounts</td>
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<tr>
<td>$\mu_{\text{CFT}}$</td>
<td>Corporate tax rate</td>
<td>0.0779</td>
<td>government statistics, national accounts, sector accounts</td>
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<td>$\mu_{\text{VAT}}$</td>
<td>Value-added tax rate</td>
<td>0.1529</td>
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<td>$\mu_{\text{SIF}}$</td>
<td>Social insurance rate (employers' contributions)</td>
<td>0.2122</td>
<td>government statistics, national accounts, sector accounts</td>
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<td>$\mu_{\text{SIW}}$</td>
<td>Social insurance rate (employees' contributions)</td>
<td>0.1711</td>
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<td>$\mu_{\text{EXPORT}}$</td>
<td>Export tax rate</td>
<td>0.003</td>
<td>government statistics, national accounts, sector accounts</td>
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<td>$\mu_{\text{CP}}$</td>
<td>Tax rate on capital formation</td>
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<td>government statistics, national accounts, sector accounts</td>
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<td>$\mu_{\text{CG}}$</td>
<td>Tax rate on government consumption</td>
<td>0.0091</td>
<td>government statistics, national accounts, sector accounts</td>
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<td>$\mu_{\text{I}}$</td>
<td>Interest rate on government bonds</td>
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<td>government statistics, national accounts, sector accounts</td>
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<tr>
<td>$\mu_{\text{P}}$</td>
<td>Risk premium on policy rate</td>
<td>0.0256</td>
<td>government statistics, national accounts, sector accounts</td>
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<tr>
<td>$\psi$</td>
<td>Fraction of income devoted to consumption</td>
<td>0.9079</td>
<td>government statistics, national accounts, sector accounts</td>
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<tr>
<td>$\mu_{\text{H}}$</td>
<td>Fraction of income devoted to investment in housing</td>
<td>0.0819</td>
<td>government statistics, national accounts, sector accounts</td>
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<tr>
<td>$\theta_{\text{UB}}$</td>
<td>Unemployment benefit replacement rate</td>
<td>0.3586</td>
<td>government statistics, national accounts, sector accounts</td>
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<td>$\theta_{\text{XXV}}$</td>
<td>Dividend payout ratio</td>
<td>0.7953</td>
<td>government statistics, national accounts, sector accounts</td>
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<tr>
<td>$\theta$</td>
<td>Rate of installment on debt</td>
<td>0.05</td>
<td>national accounts, sector accounts, estimated</td>
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<tr>
<td>$\zeta$</td>
<td>Banks' capital requirement coefficient</td>
<td>0.03</td>
<td>national accounts, sector accounts, estimated</td>
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<td>$\zeta_{\text{LTV}}$</td>
<td>Loan-to-value (LTV) ratio</td>
<td>0.6</td>
<td>national accounts, sector accounts, estimated</td>
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<td>$\zeta_0$</td>
<td>Loan-to-capital ratio for new firms after bankruptcy</td>
<td>0.5</td>
<td>national accounts, sector accounts, estimated</td>
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<td>$\pi^*$</td>
<td>Inflation target of the monetary authority</td>
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<td>$\alpha^C$</td>
<td>Autoregressive coefficient for government consumption</td>
<td>0.9832</td>
<td>national accounts, sector accounts, estimated</td>
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<td>$\beta^C$</td>
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<td>national accounts, sector accounts, estimated</td>
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<td>$\alpha^E$</td>
<td>Autoregressive coefficient for exports</td>
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<td>$\beta^E$</td>
<td>Scalar constant for exports</td>
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<td>national accounts, sector accounts, estimated</td>
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# Initial conditions

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<th>Initial condition</th>
<th>Description</th>
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<td>$P_i(0)$</td>
<td>Initial price of the $i^{th}$ firm</td>
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<td>firm level, ORBIS/SABINA</td>
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<tr>
<td>$Y_i(0)/Q^d_i(0)$</td>
<td>Initial production/demand of the $i^{th}$ firm (in mln. Euro)</td>
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<td>$K_i(0)$</td>
<td>Initial capital of the $i^{th}$ firm (in mln. Euro)</td>
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<td></td>
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<tr>
<td>$M_i(0)$</td>
<td>Initial stocks of raw materials, consumables, supplies of the $i^{th}$ firm (in mln. Euro)</td>
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<td>$S_i(0)$</td>
<td>Initial stocks of finished goods of the $i^{th}$ firm (in mln. Euro)</td>
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<tr>
<td>$N_i(0)$</td>
<td>Initial number of employees of the $i^{th}$ firm</td>
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<tr>
<td>$D_i(0)$</td>
<td>Initial liquidity (deposits) of the $i^{th}$ firm (in mln. Euro)</td>
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<td>$L_i(0)$</td>
<td>Initial debt of the $i^{th}$ firm (in mln. Euro)</td>
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<tr>
<td>$\Pi_i(0)$</td>
<td>Initial profits of the $i^{th}$ firm (in mln. Euro)</td>
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<td>$D_h(0)$</td>
<td>Initial personal assets (deposits) of the $h^{th}$ household (in mln. Euro)</td>
<td>micro-data?</td>
<td></td>
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<tr>
<td>$K_h(0)$</td>
<td>Initial household capital (in mln. Euro)</td>
<td>micro-data?</td>
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<td>$w_h(0)$</td>
<td>Initial wage of the $h^{th}$ household (in mln. Euro)</td>
<td>micro-data?</td>
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<td>$sb^{\text{inact}}(0)$</td>
<td>Initial pension/social benefits in mln. Euro</td>
<td>0.0022</td>
<td>sector accounts, government statistics</td>
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<td>$sb^{\text{other}}(0)$</td>
<td>Initial social benefits received by all households in mln. Euro</td>
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<td>$L^G(0)$</td>
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<td>243871.1</td>
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<tr>
<td>$\Pi_k(0)$</td>
<td>Initial banks’ profits (in mln. Euro)</td>
<td>6516.2</td>
<td></td>
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<tr>
<td>$E_k(0)$</td>
<td>Initial banks’ equity (in mln. Euro)</td>
<td>97802.3</td>
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<td>$E^{\text{CB}}(0)$</td>
<td>Initial central banks’ equity (in mln. Euro)</td>
<td>115947.6</td>
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<td>$D^{\text{RoW}}(0)$</td>
<td>Initial net creditor/debtor position of the national economy to RoW (in mln. Euro)</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
Figure: Revenue forecasts for Austrian firms in comparison to observed data from SABINA
Forecasts for Austria using firm level data

**Figure:** Forecasts of the ABM (black), AR(1) (blue), DSGE (red), and observed Eurostat data.
Forecasts for Austria using firm level data

**Figure:** Forecasts of the ABM (black), AR(1) (blue), DSGE (red), and observed Eurostat data.
Forecasts for Austria using firm level data

**GDP (quarterly)**

- **DATA**
- **AR(1)**
- **DSGE**
- **ABM**

**Consumption (quarterly)**

**Investment (quarterly)**

**Government (quarterly)**

**Exports (quarterly)**

**Imports (quarterly)**

**Figure:** Forecasts of the ABM (black), AR(1) (blue), DSGE (red), and observed Eurostat data.
Calibration for the flash projections in the COVID crisis

- Parameters of the model are calibrated with Austrian data (as of 2019Q4): national accounts, census, firm-level data, input-output tables

- The COVID-19 shock is calibrated using labor market data (AMS), assumption on the use of short-time work and forecasts by Oxford Economics (imports / exports):
  - AMS data for March 2020 (by sector) + assumption that approx. 65% of companies use short-time work
  - April 2020 forecasts for Austrian imports and exports (Oxford Economics)
Projektions vs. Benchmark

Macroeconomic variables under different shutdown scenarios

GDP [real, EUR]

Government debt as % of GDP [%]

Unemployment rate [%]

Impact of shutdown scenarios on macroeconomic variables with respect to baseline scenario

GDP-growth rate [pp]

Government debt as % of GDP [pp]

Unemployment rate [pp]
Projektions vs. Benchmark

Contribution of industries to GDP-growth with shutdown until mid-May with respect to baseline scenario [pp]
Projektions vs. Benchmark

Contribution of income components to GDP-growth with shutdown until mid-May with respect to baseline scenario [pp]
Projektions vs. Benchmark

Contribution of expenditure components to GDP-growth with shutdown until mid-May with respect to baseline scenario [pp]
Conclusions

• Model simulations project a reduction of GDP of approx. 7% compared to the benchmark scenario for 2020
• Economic output at the end of the forecast period (end of 2022) is still below the pre-crisis growth path
• Asymmetric effects in sectors: strong effects in construction (F), wholesale and retail (G), transport (H), accommodation and hospitality (I) as well as in art, entertainment and recreation (R, S)
• Modeling the COVID crisis with an agent-based model leads to projections that are consistent with existing assessments (WIFO, IHS, IMF) and can be used as the basis for an evidence-based economic policy
• Next steps: projections of intersectoral spillover effects and insolvencies
References


An estimated dynamic stochastic general equilibrium model of the euro area.
Appendix

Thank you for your attention!

Further details on the agent-based model are included below.
Limitations

The following limitations apply for our work:

- Model takes a **short- to medium term perspective** due omission of some drivers of long-term economic growth:
  - no demographic change (population growth)
  - no productivity growth of labor due to increased skills and competences (education)
  - no effect on government financing conditions (e.g. interest rates) due to increased government debt and deficit levels

- some **structural features of labor market** not incorporated:
  - no skill mismatches and other structurally determined labor market frictions
  - no migration from workers active on labor market (employed and unemployed) to inactive persons and vice versa (no depiction of 'hidden labor force')

- **no structural differences** between firms producing for **domestic market** and exporting firms (though empirical evidence suggests the contrary)

- **no correlation** assumed between structural **features of firms** (e.g. size) and **technological parameters** derived from IOTs (e.g. no economies of scale)

These issues will be **addressed** in the ongoing **further development** of the model.
The Banking Sector

The bank takes deposits from firms and households, and extends a total amount of loans $L^{tot}(t) = \sum_{i=1}^{I} L_i(t)$

The bank will grant a loan to firm $i$ up to the point where the borrower’s leverage (or loan-to-value) ratio after the loan,

$$\frac{L_i(t)}{\bar{P}CF(t)K_i(t)} \leq \zeta^{LTV}$$

is below $\zeta^{LTV}$, which is a constant.

Furthermore, the bank is subject to minimum capital requirements, i.e. it can only extend total loans up to a maximum multiple of its equity base or net worth $E^B(t)$.

The interest rate $r(t)$ for bank credit to firms is determined by means of a fixed risk premium $\mu$ over the policy rate $\bar{r}(t)$ set by the central bank according to a Taylor rule:

$$r(t) = \bar{r}(t) + \mu$$
Firms: Demand & sales - search and matching

**Demand:** each firm $i$ experiences demand $Q_i^d(t)$ from consumers. The level of demand: determined by consumers after the firm has set its price and carried out production $Y_i(t)$, → and is subject to the search and matching mechanism specifying the visiting consumers of firm $i$:

$$
Q_i^d(t) = \begin{cases} 
< S_i(t-1) + Y_i(t) & \text{if demand from visiting consumers is smaller than supply} \\
= S_i(t-1) + Y_i(t) & \text{if demand from visiting consumers exactly matches supply} \\
> S_i(t-1) + Y_i(t) & \text{if demand from visiting consumers is larger than supply from } i,
\end{cases}
$$

where $S_i(t-1)$ is the inventory of finished goods.

**Sales** are then the realized demand dependent on the supply available from firm $i$ after the production process has taken place:

$$
Q_i(t) = \min(S_i(t-1) + Y_i(t), Q_i^d(t)).
$$

(17)
DSGE Model

As a comparison, we employ the two-country model of [Breuss and Rabitsch, 2009], which is based on [Smets and Wouters, 2003]:

- Two countries: Home (Austria), Foreign (Euro Area),
- Domestic and foreign tradable goods, i.e. countries specialize in production of one good; consumption and investment are an index over home and foreign goods subject to constant elasticity of substitution,
- Firms produce using capital and labor services (Cobb-Douglas)
- Households receive disutility from working and utility from consumption, own the capital stock which they rent to firms for production,
- Sticky prices and wages according to Calvo price setting mechanism, some degree of power by firms and households to set prices and wages,
- Complete financial markets,
- Capital adjustment costs.

The DSGE model is estimated using Bayesian methods on a set of 13 variables for the same time period as the ABM (1997:Q1-2010:Q1).
Figure: IO Sectors - NACE Rev. 2 Classification

<table>
<thead>
<tr>
<th>NACE Rev. 2</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 A</td>
<td>Agriculture, forestry and fishing</td>
</tr>
<tr>
<td>2 B, C, D and E</td>
<td>Manufacturing, mining and quarrying and other industry</td>
</tr>
<tr>
<td>3 F</td>
<td>Construction</td>
</tr>
<tr>
<td>4 G, H and I</td>
<td>Wholesale and retail trade, transportation and storage, accommodation and food service activities</td>
</tr>
<tr>
<td>5 J</td>
<td>Information and communication</td>
</tr>
<tr>
<td>6 K</td>
<td>Financial and insurance activities</td>
</tr>
<tr>
<td>7 L</td>
<td>Real estate activities*</td>
</tr>
<tr>
<td>8 M and N</td>
<td>Professional, scientific, technical, administration and support service activities</td>
</tr>
<tr>
<td>9 O, P and Q</td>
<td>Public administration, defence, education, human health and social work activities</td>
</tr>
<tr>
<td>10 R, S, T and U</td>
<td>Other services</td>
</tr>
</tbody>
</table>