Appendix A. Details of the agent-based model

Appendix A.1. Firms

Each firm i ($i = 1, 2, \dots, I = \sum_s I_s$) produces a principal product g ($g = 1, 2, \dots, G$) using labour, capital and intermediate inputs from other firms, and is part of an industry or sector s ($s = 1, 2, \dots, S$),[1] with a number of I_s firms in each industry. Demand for products of firm i is formed on markets for final consumption goods, capital goods as well as material or intermediate input goods. Firms face fundamental uncertainty regarding the main determinants of their individual success on the market: future sales, market prices, the availability of inputs for the production process (labour, capital, intermediate inputs), wages, cash flow, and their access to external finance, among others, are unknown. Consequently, each firm has to form expectations about the future that may not correspond to actual realizations.

Appendix A.1.1. Sales

Firms experience demand from other agents—be it a household h or a government entity j intending to consume, or a firm demanding capital or intermediate input goods–who act as consumers. Demand $Q^{\mathrm{d}}_i(t)$[2] will be determined by the consumers only after the firm has set its price and carried out production $Y_i(t)$. It is subject to the search-and-matching mechanism specifying the consumers of firm i:

$$Q^{\mathrm{d}}_i(t) \begin{cases} < Y_i(t) + S_i(t-1) & \text{if demand from consumers is smaller than supply from firm } i\text{, and} \\ = Y_i(t) + S_i(t-1) & \text{if demand from consumers exactly matches supply from firm } i\text{, and} \\ > Y_i(t) + S_i(t-1) & \text{if demand from consumers is larger than supply from firm } i\text{ ,} \end{cases} \tag{A.1}$$

where $S_i(t-1)$ is the inventory of finished goods. In this search-and-matching mechanism, every agent active on a market as a consumer—be it a household h or a government entity j intending to consume, or a firm demanding capital or intermediate input goods—searches for the best bargain, i.e. the lowest price, to satisfy its demand for each of products g it requires. The consumption and supply networks in the model are formed in every period of the model according to a search-and-matching process: in each period, consumers visit a number of randomly chosen foreign or domestic firms that sell the good g (see Online Appendix A.6.1 for details on foreign firms). The probability of a firm i being chosen is given (1) by the price charged by firm i according to an exponential distribution, where firms charging a lower price are more likely of being picked, and (2) by the relative size of the firm compared to other firms so that bigger firms have a higher probability to be picked. The total probability of firm i of being selected in this process is then the average of the latter two probabilities:

$$\begin{aligned} pr^{\mathrm{price}}_i(t) &= \frac{e^{-2P_i(t)}}{\sum_{i \in I_{s=g}} e^{-2P_i(t)}} \\ pr^{\mathrm{size}}_i(t) &= \frac{Y_i(t)}{\sum_{i \in I_{s=g}} Y_i(t)} \\ pr^{\mathrm{cum}}_i(t) &= \frac{pr^{\mathrm{price}}_i(t) + pr^{\mathrm{size}}_i(t)}{2} \end{aligned}$$

where $pr^{\mathrm{price}}_i(t)$ is the probability of firm i of being selected by a consumer due to its offering price, $pr^{\mathrm{size}}_i(t)$ the probability of being chosen due to its size, $pr^{\mathrm{cum}}_i(t)$ the cumulative average probability to be picked according to both of these factors, and $Y_i(t)$ is the production of goods by firm i, see Equation (A.13). If the most preferred firm is in short supply, the consumer resorts to the remaining firms, otherwise it satisfies all its demand with the first firm. If an agent does not succeed in satisfying its demand for a specific product g, it saves involuntarily.

[1] We suppose a one-to-one correspondence between the sets of industries s and products g, meaning that the n-th sector produces only the n-th good, and $S = G$; formally, the correspondence between goods g being produced in sector s would be represented by a unity matrix.

[2] In this manuscript subscripts are used for indices referring to an agent in the model, while superscripts generally indicate a behavioural relation for a variable. For example, a quantity X referring to a firm is denoted by X_i, expectations for a quantity X are written as X^{e}, or demand for a quantity X is indicated by X^{d}. Additionally, superscripts in capital letters are used to further distinguish related variables, e.g. $\bar{P}^{\mathrm{HH}}(t)$ denotes the consumer price index while $\bar{P}^{\mathrm{CF}}(t)$ is capital formation price index.

Thus sales are then the realized demand dependent on the supply available from firm i after the production process has taken place:

$$Q_i(t) = \min(Y_i(t) + S_i(t-1), Q_i^{\mathrm{d}}(t))\,. \tag{A.2}$$

The difference between production and sales is excess supply

$$\Delta S_i(t) = Y_i(t) - Q_i(t)\,, \tag{A.3}$$

which is a reflection of firms' expectation error concerning demand. This difference is stored as inventories,

$$S_i(t) = S_i(t-1) + \Delta S_i(t)\,, \tag{A.4}$$

until the next period, where they are supplied on the goods market together with newly produced goods. We do not assume any depreciation of this inventory of finished goods.

Appendix A.1.2. Price Setting and Supply

Firms set prices and determine supply based on the expectations for economic growth and inflation. The expectations regarding economic growth and inflation are formed using simple forecasting heuristics, namely parsimonious AR(1) rules.[3] The supply choice of firm i is thus made based on the expected rate of real economic growth ($\gamma^{\mathrm{e}}(t)$) and the previous period's demand for its product $Q_i^{\mathrm{d}}(t-1)$:

$$Q_i^{\mathrm{s}}(t) = Q_i^{\mathrm{d}}(t-1)(1 + \gamma^{\mathrm{e}}(t))\,. \tag{A.5}$$

Expectations regarding economic growth are formed using an autoregressive model with lag one (AR(1)):

$$\log(Y^{\mathrm{e}}(t)) = \alpha^{\mathrm{Y}}(t-1)\log\left(\sum_i Y_i(t-1)\right) + \beta^{\mathrm{Y}}(t-1) + \epsilon^{\mathrm{Y}}(t-1)\,, \tag{A.6}$$

where $\alpha^{\mathrm{Y}}(t-1)$ and $\beta^{\mathrm{Y}}(t-1)$ are re-estimated every period on the time series of aggregate output of firms $\sum_i Y_i(t')$ where $t' = -T', -T'+1, -T'+2, \ldots, 0, 1, 2, \ldots, t-1$. $\epsilon^{\mathrm{Y}}(t-1)$ is a random shock with zero mean and variance re-estimated every period from past observations over the last $T' + t - 1$ periods. Output is entered in log levels and the growth rate is calculated from the percentage change to the previous period:

$$\gamma^{\mathrm{e}}(t) = \frac{Y^{\mathrm{e}}(t)}{\sum_i Y_i(t-1)} - 1\,. \tag{A.7}$$

Given the impossibility of certain and accurate forecasts in an environment of fundamental uncertainty and imperfect information, firms' may choose forecasting methods that closely reflect their economic environment but fail to be a complete model of the economy with every detail according to the concept of procedural rationality (Gigerenzer, 2015). As we pointed out above, a forecasting method that meets these requirements is the AR(1) rule: this is a simple procedure for projecting past trends into the future while its forecasting capabilities are comparably high. With the AR(1) rule, adaptive learning leads to convergence to the BLE in the model economy, and gaps between expected and realized values of variables will be closed gradually.[4]

[3] Since the AR(1) learning process is slow and often near unit root (with AR(1) coefficients close to 1), our behavioural rule is close to the special case of $\alpha^Y(t) = 1$. There may be phases, however, where the learning process temporary deviates from a near-unit root process and, therefore, in our behavioural model, we use the more general and more flexible AR(1) rule with learning of its parameters rather than the special case. This is comparable to other adaptive mechanisms such as VAR expectations as used in the US Federal Reserve's FRB/US macroeconomic model (Brayton et al., 1997), or expectations according to an exponential moving average (EMA) model as in Assenza et al. (2015).

[4] Consider, for example, the case of excess demand (supply shortage), where growth expectations, in general, were lower than realized growth rates. Here, production is increased to a point where supply and demand will converge to equilibrium. The converse logic applies to excess supply (overproduction), where growth expectations and prices gradually move downwards. Should a smaller or larger shock—such as an (endogenous) bankruptcy of a firm, or an exogenous demand or supply shock (e.g. the COVID-19 pandemic, or an export shock)—pull the economy off the trend, path dependencies might ensue that change the long term BLE of this model economy. However, after the medium to long turn, adaptive learning will steer the model towards this new BLE, as can be observed in our applications to the economic effects COVID-19 pandemic (see Section 6).

Similarly, price setting by the firm evolves according to the expected rate of inflation ("built-in inflation") and the cost-structure faced by the firm ("cost-push inflation"):

$$P_i(t) = P_i(t-1) \cdot \underbrace{(1+\pi_i^c(t))}_{\substack{\text{Cost-Push}\\ \text{Inflation}}} \cdot \underbrace{(1+\pi^e(t))}_{\substack{\text{Built-In}\\ \text{Inflation}}}, \tag{A.8}$$

where

$$\pi_i^c(t) = \underbrace{\frac{(1+\tau^{SIF})\bar{w}_i}{\bar{\alpha}_i}\left(\frac{\bar{P}^{HH}(t-1)}{P_i(t-1)}-1\right)}_{\text{Increase of unit labour costs}} + \underbrace{\frac{1}{\beta_i}\left(\frac{\sum_g a_{sg}\bar{P}_g(t-1)}{P_i(t-1)}-1\right)}_{\text{Increase of unit material costs}} + \underbrace{\frac{\delta_i}{\kappa_i}\left(\frac{\bar{P}^{CF}(t-1)}{P_i(t-1)}-1\right)}_{\text{Increase of unit capital costs}} \quad \forall i \in I_s\,. \tag{A.9}$$

Here, $\bar{\alpha}_i$ indicates the average productivity of labour, $\bar{w}_i$ are average gross wages indexed by the consumer price index $\bar{P}^{HH}(t)$, and including employers' contribution to social insurance charged with a rate τ^{SIF}; $\frac{1}{\beta_i}\sum_g a_{sg}$ are unit expenditures (in real terms) on intermediate input by industry s on good g weighted by the average product price index for good g ($\bar{P}_g(t)$), δ_i/κ_i are unit capital costs due to depreciation (δ_i is the firm's capital depreciation rate and κ_i the productivity coefficient for capital), $\bar{P}^{CF}(t)$ is the average price of capital goods. Expectations on inflation are formed using an autoregressive model of lag order one (AR(1)):

$$\log(1+\pi^{\mathrm{e}}(t)) = \alpha^{\pi}(t-1)\pi(t-1) + \beta^{\pi}(t-1) + \epsilon^{\pi}(t-1)\,, \tag{A.10}$$

where $\alpha^{\pi}(t-1)$ and $\beta^{\pi}(t-1)$ are re-estimated every period on the time series of inflation $\pi(t')$ where $t' = -T', -T'+1, -T'+2, \ldots, 0, 1, 2, \ldots, t-1$. $\epsilon^{\pi}(t-1)$ is a random shock with zero mean and variance re-estimated every period from past observations over the last $T'+t-1$ periods. The inflation rate is calculated from the log difference of the producer price index (CPI):

$$\pi(t) = \log\left(\frac{\bar{P}(t)}{\bar{P}(t-1)}\right), \tag{A.11}$$

where the producer price index is defined as

$$\bar{P}(t) = \frac{\sum_i P_i(t)Q_i(t) + \sum_m P_m(t)Q_m(t)}{\sum_i Q_i(t) + \sum_m Q_m(t)}\,, \tag{A.12}$$

where $P_m(t)$ and $Q_m(t)$ are the price and sales from foreign producers m, for details see Online Appendix A.6.1. With our assumption for firm price setting, we simultaneously incorporate firms' current input cost structure as well as their expectations about future cost, inflation and profits. The latter avoids firm bankruptcies resulting from irrational pricing behaviour. Here adaptive learning will again gradually close expectation gaps in the model economy between the actual state of the economy and the BLE. In particular, if inflation is above its trend level, inflation expectations will decrease, lowering prices to the trend level, and vice versa.

Appendix A.1.3. Production

In each period t firm i (which is part of industry s) produces output ($Y_i(t)$, in real terms) in form of the principal product g by means of inputs of labour ($N_i(t)$, the number of persons employed), intermediate goods/services and raw materials ($M_i(t)$, in real terms), as well as capital ($K_i(t-1)$, in real terms). We assume a production function with Leontief technology and separate nests for intermediate goods, labour and capital, respectively—all of which represent upper limits to production:

$$Y_i(t) = \min\left(Q_i^{\mathrm{s}}(t), \beta_i M_i(t-1), \alpha_i(t)N_i(t), \kappa_i K_i(t-1)\right), \tag{A.13}$$

where $\alpha_i(t)$ is the productivity of labour of firm $i \in I_s$, see Equation (A.25), and β_i and κ_i are productivity coefficients for intermediate inputs and capital, respectively. Production by firm i may not equal the desired scale of activity ($Q_i^{\mathrm{s}}(t)$). Output could be limited by the amount of available labour force, the quantity of intermediate goods, or the availability of capital needed in the production process. In these cases, the firm has to scale down activity. As noted before, the assumption of a Leontief production technology—given the properties of our model—is consistent with the data and is in line with the literature (Assenza et al., 2015). Moreover, as our explicit aim was to derive the simplest possible ABM that has the features we desire, we relegate all further extensions of the model, such as assumptions on technological progress that change technology coefficients, to further research.

Appendix A.1.4. Investment

In each period the i-th firm has to decide how much to invest ($I_i^{\mathrm{d}}(t)$, in real terms). Investments allow the firm to adjust the real capital stock $K_i(t)$. Capital adjustment, however, is not immediate and time-consuming. New capital goods[5] bought at the time t will be part of the capital stock only in the next period $t+1$. This makes capital a durable and sticky input. The desired investment in capital stock in period t is

$$I_i^{\mathrm{d}}(t) = \frac{\delta_i}{\kappa_i} \min\left(Q_i^{\mathrm{s}}(t), \kappa_i K_i(t-1)\right), \tag{A.14}$$

where δ_i is the firm's capital depreciation rate. The economic rationale behind this equation is that firms adjust their investment demand to the expected wear and tear of capital and that only capital planned to be used in the production process is expected to depreciate and needs to be replaced by new investment. The latter in turn depends on the expected future demand by the firm according to past demand and the expected rate of economic growth. Also, in this case, the choice of our investment function is driven (1) by what we observe to be consistent with the data and (2) the desire to reach the simplest possible formulation of the behavioural equations in our ABM. Given the relations between excess demand or supply pointed out above, investments will tend to the approximate trend equilibrium path of this model economy due to the adaptive learning mechanism inherent to expectation formation. In particular, should realized growth rates surpass growth expectations, investment in subsequent periods will adapt to the approximate trend equilibrium level, and vice versa.

We assume a homogenous capital stock for all firms and thus fixed weights b_g^{CF}, namely, each firm i—irrespective of the sector s firm i is part of—demands $b_g^{\mathrm{CF}} I_i^{\mathrm{d}}(t)$ as its real investment from firms producing good g:

$$I_{ig}^{\mathrm{d}}(t) = b_g^{\mathrm{CF}} I_i^{\mathrm{d}}(t). \tag{A.15}$$

It may be the case that firms cannot obtain the requested investments goods on the capital goods market, or at an unexpectedly high price. The amount of realized investment, therefore, depends on the search-and-matching process on the capital goods market, see Online Appendix A.1.1:

$$I_i(t) \begin{cases} = \sum_g I_{ig}^{\mathrm{d}}(t) & \text{if the firm successfully realized the investment plan, and} \\ < \sum_g I_{ig}^{\mathrm{d}}(t) & \text{if all firms visited could not satisfy its demand} \end{cases} \tag{A.16}$$

In the case where firm i cannot realize its investment plan, it will have to scale down future activity, see Equation (A.13). The capital stock, as an aggregate of all goods g, evolves according to a depreciation and investment law of motion, where only the amount of capital actually used in the production process depreciates:

$$K_i(t) = K_i(t-1) - \frac{\delta_i}{\kappa_i} Y_i(t) + I_i(t). \tag{A.17}$$

Appendix A.1.5. Intermediate Inputs

Each firm needs intermediate input of goods for production. We assume that firm i holds a stock of input goods $M_i(t)$ (in real terms) for each type of good g. From this stock of intermediate input goods, firm i takes out materials for production as needed, and it keeps these goods in positive supply to avoid shortfalls of material input impeding production. Each period the i-th firm has to decide on the desired amount of intermediate goods and raw materials ($\Delta M_i^{\mathrm{d}}(t)$) that it intends to purchase in order to keep its stock in positive supply:

$$\Delta M_i^{\mathrm{d}}(t) = \frac{\min\left(Q_i^{\mathrm{s}}(t), \kappa_i K_i(t-1)\right)}{\beta_i}. \tag{A.18}$$

Firms thus try to keep their stock of material input goods within a certain relationship to $Q_i^{\mathrm{s}}(t)$ by accounting for planned material input use in this period. Here also, similar to Equation (A.13), firm i is part of industry s and consumes an intermediate input g according to sector-specific technology coefficients (a_{sg}). This is given by

$$\Delta M_{ig}^{\mathrm{d}}(t) = a_{sg} \Delta M_i^{\mathrm{d}}(t) \quad \forall i \in I_s. \tag{A.19}$$

[5] We assume no difference between investment (or capital) goods, consumption and intermediate-input goods in our model, but rather that each product g is used for all these demand components, according to production needs and consumer preferences.

In the intermediate goods market, too, the amount of realized purchases of intermediate goods depends on a search-and-matching process, see Online Appendix A.1.1:

$$\Delta M_i(t) \begin{cases} = \sum_g \Delta M^{\mathrm{d}}_{ig}(t) & \text{if the firm successfully realized its plan, and} \\ < \sum_g \Delta M^{\mathrm{d}}_{ig}(t) & \text{if all firms visited could not satisfy its demand.} \end{cases} \tag{A.20}$$

If firm i does not succeed in acquiring the materials it intended to purchase, it will be limited in its production possibilities. The stock of good g held by firm i evolves according to the material use in the production process necessary to achieve actual production ($Y_i(t)$) and realized new acquisitions of intermediate goods:

$$M_i(t) = M_i(t-1) - \frac{Y_i(t)}{\beta_i} + \Delta M_i(t)\,. \tag{A.21}$$

We assume a steady use by the firm of its raw materials in production, and hence that the material stock does not depreciate.

Appendix A.1.6. Employment

Each firm i uses employment $N_i(t)$ as labour input for production, which is the number of persons employed. The firm decides on the planned amount of employment $N^{\mathrm{d}}_i(t)$ in each period according to its desired scale of activity ($Q^{\mathrm{s}}_i(t)$) and its average labour productivity ($\bar{\alpha}_i$):

$$N^{\mathrm{d}}_i(t) = \max\left(1, \mathrm{round}\left(\frac{\min\left(Q^{\mathrm{s}}_i(t), \kappa_i K_i(t-1)\right)}{\bar{\alpha}_i}\right)\right). \tag{A.22}$$

Rounding to the nearest integer translates as follows: if the additional labour demand of firm i is less than a half-time position, labour demand is left unchanged. If the additional production needs of the firm i exceed a half-time occupation, a new employee is hired. If the operating workforce at the beginning of period t ($N_i(t-1)$), i.e. the number of persons employed in $t-1$, is higher than the desired workforce, the firm fires $N_i(t-1) - N^{\mathrm{d}}_i(t)$ randomly chosen employees (accounting for production constraints due possibly to a shortage of capital). If demand for labour to reach the desired scale of activity is greater than the operating workforce, the firm posts labour vacancies,

$$V_i(t) = N^{\mathrm{d}}_i(t) - N_i(t-1)\,, \tag{A.23}$$

which represent a demand for new labour. Whether vacancies are filled or not depends on the search-and-matching mechanism in the labour market (see Online Appendix A.2.1), thus

$$N_i(t) \begin{cases} = N^{\mathrm{d}}_i(t) & \text{if the firm successfully fills all vacancies, and} \\ < N^{\mathrm{d}}_i(t) & \text{if there are unfilled vacancies.} \end{cases} \tag{A.24}$$

As employees are either employed full-time, part-time, or work overtime, the actual productivity of labour $\alpha_i(t)$ of firm i reflects overtime or part-time employment:

$$\alpha_i(t) = \bar{\alpha}_i \min\left(1.5, \frac{\min\left(Q^{\mathrm{s}}_i(t), \beta_i M_i(t-1), \kappa_i K_i(t-1)\right)}{N_i(t)\bar{\alpha}_i}\right), \tag{A.25}$$

where the maximum work effort is 150 per cent of a full position (which is the maximum working time legally allowed in Austria for a limited duration). To remunerate increased or decreased work effort as compared to a full-time position, the average wage $\bar{w}_i$ of firm i is adapted accordingly:

$$w_i(t) = \bar{w}_i \min\left(1.5, \frac{\min\left(Q^{\mathrm{s}}_i(t), \beta_i M_i(t-1), \kappa_i K_i(t-1)\right)}{N_i(t)\bar{\alpha}_i}\right), \tag{A.26}$$

where $w_i(t)$ is the real wage paid by firm i. Nominal wage increases accounting for inflation are considered when money wages are paid out to households as part of their disposable income, see Online Appendix A.2.4.

Appendix A.1.7. External Finance

Firms may need external financial resources to finance current or future expenditures. Thus, each firm i forms an expectation on its future cash flow $\Delta D_i^{\mathrm{e}}(t)$, that is, the expected change of deposits $D_i(t)$:

$$\Delta D_i^{\mathrm{e}}(t) = \underbrace{\Pi_i^{\mathrm{e}}(t)}_{\text{Exp. profit}} - \underbrace{\theta L_i(t-1)}_{\text{Debt instalment}} - \underbrace{\tau^{\mathrm{FIRM}}\max(0, \Pi_i^{\mathrm{e}}(t))}_{\text{Corporate taxes}} - \underbrace{\theta^{\mathrm{DIV}}(1-\tau^{\mathrm{FIRM}})\max(0, \Pi_i^{\mathrm{e}}(t))}_{\text{Dividend payout}}, \tag{A.27}$$

where

$$\Pi_i^{\mathrm{e}}(t) = \Pi_i(t-1)(1+\gamma^{\mathrm{e}}(t))(1+\pi^{\mathrm{e}}(t)), \tag{A.28}$$

is the profit expected by firm i based on the profit in the previous period; θ is the rate of debt instalment on firm i's outstanding loans $L_i(t-1)$, τ^{FIRM} is the corporate tax rate, and θ^{DIV} is the dividend payout ratio. If the internal financial resources of a firm are not adequate to finance its expenditures, the firm will ask for a bank loan, i.e. new credit $\Delta L_i^{\mathrm{d}}(t)$, to cover its financing gap

$$\Delta L_i^{\mathrm{d}}(t) = \max(0, -\Delta D_i^{\mathrm{e}}(t) - D_i(t-1)). \tag{A.29}$$

The availability of credit depends on the capitalization of the banking sector and the arrival of firms to ask for a loan, see Online Appendix A.4.1 for details. If the firm cannot obtain a loan on the credit market, it might become credit constrained, see Equation (A.64). If the firm does not obtain the desired loan, it may become insolvent, see Online Appendix A.1.9.

Appendix A.1.8. Accounting

Firm profits $\Pi_i(t)$ are an accounting measure that is defined as revenues from sales plus changes in inventories minus expenditures on labour, material, depreciation, interest payments and taxes:

$$\begin{aligned}\Pi_i(t) = {} & \underbrace{P_i(t)Q_i(t)}_{\text{Sales}} + \underbrace{P_i(t)\Delta S_i(t)}_{\text{Inventory change}} - \underbrace{(1+\tau^{\mathrm{SIF}})w_i(t)N_i(t)\bar{P}^{\mathrm{HH}}(t)}_{\text{Labour costs}} \\ & - \underbrace{\frac{1}{\beta_i}\bar{P}_i(t)Y_i(t)}_{\text{Material costs}} - \underbrace{\frac{\delta_i}{\kappa_i}P_i^{\mathrm{CF}}(t)Y_i(t)}_{\text{Depreciation}} - \underbrace{\tau_i^{\mathrm{Y}}P_i(t)Y_i(t) - \tau_i^{\mathrm{K}}P_i(t)Y_i(t)}_{\text{Net taxes/subsidies on products/production}} \\ & - \underbrace{r(t)(L_i(t-1) + \max(0, -D_i(t-1)))}_{\text{Interest payments}} + \underbrace{\bar{r}(t)\max(0, D_i(t-1))}_{\text{Interest received}},\end{aligned} \tag{A.30}$$

where $r(t)$ is the interest rate paid on outstanding loans, see Equation (A.66). $\bar{P}_i(t)$ and $P_i^{\mathrm{CF}}(t)$ are the actual prices paid by firm i for intermediate goods and investment in capital goods, respectively, which both are an outcome of the search an matching process. $\bar{P}^{\mathrm{HH}}(t)$ is the consumer price index (CPI):

$$\bar{P}^{\mathrm{HH}}(t) = \sum_g b_g^{\mathrm{HH}}\bar{P}_g(t), \tag{A.31}$$

where b_g^{HH} is the household consumption coefficient for product g and $\bar{P}_g(t)$ is the producer price index for the principal good g:

$$\bar{P}_g(t) = \frac{\sum_{i\in I_{s=g}} P_i(t)Q_i(t) + P_{m=g}(t)Q_{m=g}(t)}{\sum_{i\in I_{s=g}} Q_i(t) + Q_{m=g}(t)}. \tag{A.32}$$

Firm net cash flow reflects the amount of liquidity moving in or out of its deposit account:

$$\begin{aligned}\Delta D_i(t) = {} & \underbrace{P_i(t)Q_i(t)}_{\text{Sales}} - \underbrace{(1+\tau^{\mathrm{SIF}})w_i(t)N_i(t)\bar{P}^{\mathrm{HH}}(t)}_{\text{Labour costs}} - \underbrace{\bar{P}_i(t)\Delta M_i(t)}_{\text{Material costs}} - \underbrace{\tau_i^{\mathrm{Y}}P_i(t)Y_i(t) - \tau_i^{\mathrm{K}}P_i(t)Y_i(t)}_{\text{Net taxes/subsidies on products and production}} \\ & - \underbrace{\tau^{\mathrm{FIRM}}\max(0, \Pi_i(t))}_{\text{Corporate tax payments}} - \underbrace{\theta^{\mathrm{DIV}}(1-\tau^{\mathrm{FIRM}})\max(0, \Pi_i(t))}_{\text{Dividend payments}} - \underbrace{r(t)(L_i(t-1) + \max(0, -D_i(t-1)))}_{\text{Interest payments}} \\ & + \underbrace{\bar{r}(t)\max(0, D_i(t-1))}_{\text{Interest received}} - \underbrace{P_i^{\mathrm{CF}}(t)I_i(t)}_{\text{Investment costs}} + \underbrace{\Delta L_i(t)}_{\text{New credit}} - \underbrace{\theta L_i(t-1)}_{\text{Debt instalment}}.\end{aligned} \tag{A.33}$$

Furthermore, firm i pays interest on outstanding loans and overdrafts on firm i's deposit account (in case $D_i(t) < 0$) at the same rate $r(t)$, which includes the bank's markup rate. In the opposite case when the firm holds (positive) deposits with the bank, i.e. $D_i(t) > 0$, the interest rate received is lower and corresponds to the policy rate set by the central bank, see Online Appendix A.4.

Firm deposits are then previous deposits plus net cash flow:

$$D_i(t) = D_i(t-1) + \Delta D_i(t)\,. \tag{A.34}$$

Similarly, overall debt is updated as follows:

$$L_i(t) = (1-\theta)L_i(t-1) + \Delta L_i(t)\,. \tag{A.35}$$

Finally, firm equity $E_i(t)$ evolves as the balancing item on the firm's balance sheet, where all stocks are accounted for mark-to-market:

$$E_i(t) = D_i(t) + \sum_g a_{sg}\bar{P}_g(t)M_i(t) + P_i(t)S_i(t) + \bar{P}^{\mathrm{CF}}(t)K_i(t) - L_i(t) \quad \forall i \in I_s\,. \tag{A.36}$$

$\bar{P}^{\mathrm{CF}}(t)$ is the capital goods price index (CGPI) defined as

$$\bar{P}^{\mathrm{CF}}(t) = \sum_g b_g^{\mathrm{CF}}\bar{P}_g(t)\,, \tag{A.37}$$

where b_g^{CF} is the capital formation coefficient for product g.

Appendix A.1.9. Insolvency

If a firm is cash-flow insolvent, i.e. $D_i(t) < 0$, and balance-sheet insolvent, i.e. $E_i(t) < 0$, at the same time, it goes bankrupt and is replaced by a firm that newly enters the market. We assume that the real capital stock of the bankrupt firm is left to the entrant firm at zero costs, but that the new firm has to take over a part of the bankrupt firm's liabilities. Therefore, a part of loans taken out by the bankrupt firm is written off so that the remaining liabilities of firm i amount to a fraction ζ^{b} of its real capital stock. After this partial debt cancellation, the remaining liabilities of the bankrupt firm are transferred to the balance sheet of the entrant firm. In the next period $(t+1)$ liabilities of firm i are initialized with

$$L_i(t+1) = \zeta^{\mathrm{b}}\bar{P}_i^{\mathrm{CF}}(t)K_i(t) \tag{A.38}$$

and firm deposits with

$$D_i(t+1) = 0\,. \tag{A.39}$$

Correspondingly, in the next period $(t+1)$ equity of the new firm i is initialized with

$$E_i(t+1) = E_i(t) + \left(L_i(t) - D_i(t) - \zeta^{\mathrm{b}}\bar{P}_i^{\mathrm{CF}}(t)K_i(t)\right). \tag{A.40}$$

Appendix A.2. Households

The household sector consists of a total number of H ($h = 1, 2, \ldots, H$) persons. Every person in the household sector has an *activity status*, that is, a type of economic activity from which she receives an income. Each person also participates in the consumption market as a consumer with a certain consumption budget. The activity status is categorized into H^{act} economically active and H^{inact} economically inactive persons. Economically active persons are H^W workers, and I investors (the number of investors equals the number of firms and is constant, see below). The set of workers consists of $H^{\mathrm{E}}(t)$ employed persons and $H^{\mathrm{U}}(t)$ unemployed persons that are actively looking for a job. $H^{\mathrm{E}}(t)$ and $H^{\mathrm{U}}(t)$ are endogenous since we assume that agents may switch between these two sets by being dismissed from their current job or by being hired for a new position. Economically inactive persons include, among others, persons below the age of 15, students, and retirees.

Appendix A.2.1. Activity Status

The h-th worker ($h = 1, 2, \ldots, H^{\mathrm{W}}$) supplies labour to the extent of employment (part-time, full, or including overtime). If worker h works for firm i in period t, she receives wage $w_h(t) = w_i(t)$. If unemployed, the person looks for a job on the labour market from firms with open vacancies in random order and applies for a job (the *search-and-matching* process on the labour market). The unemployed person will accept a job from the first firm with open vacancies that she has the chance to visit. If she does not find a vacancy to fill, that is, when there are no open vacancies left in the economy, she remains unemployed. For simplicity's sake, we do not consider hiring or firing costs for firms, and fired employees become unemployed and start searching for a job in the same period. All unemployed persons receive unemployment benefits, which are a fraction of the labour income that was last received in the period when unemployment starts. In the event that an unemployed person finds a new job, she is remunerated with the wage of firm i that provides the new employment:

$$w_h(t) = \begin{cases} w_i(t) & \text{if employed by firm } i \\ w_h(t-1) & \text{otherwise, i.e. if unemployed.} \end{cases} \tag{A.41}$$

For simplicity's sake, we assume that each firm is owned by one investor, i.e. the number of investors matches that the number of firms overall. Each investor receives income in the form of dividends in the event that the firm she owns makes profits after interest and tax payments. We assume limited liability, i.e. in the case of bankruptcy, the associated losses are borne by the creditor and not the investor household, see Online Appendix A.1.9. An economically inactive person h receives social benefits $sb^{\mathrm{inact}}(t)$ and does not look for a job:

$$sb^{\mathrm{inact}}(t) = sb^{\mathrm{inact}}(t-1)(1+\gamma^{\mathrm{e}}(t)). \tag{A.42}$$

Additionally, each household receives additional social transfers $sb^{\mathrm{other}}(t)$ (related to family and children, sickness, etc.) from the government, which we assume to be constant and the same size for all households:

$$sb^{\mathrm{other}}(t) = sb^{\mathrm{other}}(t-1)(1+\gamma^{\mathrm{e}}(t)). \tag{A.43}$$

Appendix A.2.2. Consumption

In a bounded rationality setting, consumers' behaviour follows a rule of thumb (heuristic) where they plan to consume a fraction of their expected disposable net income including social benefits ($Y^{\mathrm{e}}_h(t)$). Expected disposable net income inclusive of social transfers is determined according to the household's activity status and the associated income from labour, expected profits or social benefits, as well as tax payments, the consumer index price index of the last period, and expectations of the rate of inflation $\pi^{\mathrm{e}}(t)$ formed using an AR(1) model (see Equation (A.10)):

$$Y^{\mathrm{e}}_h(t) = \begin{cases} \left(w_h(t)\left(1-\tau^{\mathrm{SIW}}-\tau^{\mathrm{INC}}(1-\tau^{\mathrm{SIW}})\right)+sb^{\mathrm{other}}(t)\right)\bar{P}^{\mathrm{HH}}(t-1)(1+\pi^{\mathrm{e}}(t)) & \text{if employed} \\ \left(\theta^{\mathrm{UB}}w_h(t)+sb^{\mathrm{other}}(t)\right)\bar{P}^{\mathrm{HH}}(t-1)(1+\pi^{\mathrm{e}}(t)) & \text{if unemployed} \\ \left(sb^{\mathrm{inact}}(t)+sb^{\mathrm{other}}(t)\right)\bar{P}^{\mathrm{HH}}(t-1)(1+\pi^{\mathrm{e}}(t)) & \text{if not economically active ,} \\ \theta^{\mathrm{DIV}}(1-\tau^{\mathrm{INC}})(1-\tau^{\mathrm{FIRM}})\max(0,\Pi^{\mathrm{e}}_i(t))+sb^{\mathrm{other}}(t)\bar{P}^{\mathrm{HH}}(t-1)(1+\pi^{\mathrm{e}}(t)) & \text{if investor in firm } i \\ \theta^{\mathrm{DIV}}(1-\tau^{\mathrm{INC}})(1-\tau^{\mathrm{FIRM}})\max(0,\Pi^{\mathrm{e}}_k(t))+sb^{\mathrm{other}}(t)\bar{P}^{\mathrm{HH}}(t-1)(1+\pi^{\mathrm{e}}(t)) & \text{if a bank investor} \end{cases} \tag{A.44}$$

where $\Pi^{\mathrm{e}}_i(t)$ (see Equation (A.28)) and

$$\Pi^{\mathrm{e}}_k(t) = \Pi_k(t-1)(1+\gamma^{\mathrm{e}}(t))(1+\pi^{\mathrm{e}}(t)) \tag{A.45}$$

is the expected profit based on the profit of the previous period of firm i and of the banking sector, respectively; τ^{INC} is the income tax rate, τ^{SIW} is the rate of social insurance contributions to be paid by the employee, θ^{DIV} is the dividend payout ratio, and τ^{FIRM} the corporate tax rate.

The consumption budget (net of VAT) of household h ($C^{\mathrm{d}}_h(t)$) is thus given by:

$$C^{\mathrm{d}}_h(t) = \frac{\psi Y^{\mathrm{e}}_h(t)}{1+\tau^{\mathrm{VAT}}}, \tag{A.46}$$

where $\psi \in (0,1)$ is the propensity to consume out of expected income and τ^{VAT} is a value added tax rate on consumption. Again, the choice of this simple formulation of the consumption function is motivated by the availability and structure of our data, as well as by the ABM literature, in particular following the model in Delli Gatti et al. (2011). Consumers then allocate their consumption budget to purchase different goods from firms. The consumption budget of the h-th household to purchase the g-th good is

$$C^{\text{d}}_{hg}(t) = \frac{b^{\text{HH}}_{g} \bar{P}_g(t-1)}{\bar{P}^{\text{HH}}(t-1)} C^{\text{d}}_h(t)\,, \tag{A.47}$$

where b^{HH}_g is the consumption coefficient for the g^{th} product of households.[6] Once they have determined their consumption budget, consumers visit firms in order to purchase goods according to the search-and-matching mechanism, see Online Appendix A.1.1 above. Whether the individual firm can accommodate demand depends (apart from aggregate economic conditions) on its production and inventory stock. Thus realized consumption of household h is another outcome of the search-and-matching process:

$$C_h(t) \begin{cases} = \sum_g C^{\text{d}}_{hg}(t) & \text{if the consumer successfully realized the consumption plan, and} \\ < \sum_g C^{\text{d}}_{hg}(t) & \text{if all firms visited could not satisfy the consumer's demand.} \end{cases} \tag{A.48}$$

Appendix A.2.3. Household Investment

To depict a simple housing market, households use part of their income to invest in dwellings and other durable investment goods. Similar to Equation (A.46) above, we assume household investment occurs according to a fixed rate ψ^{H} on expected disposable net income:

$$I^{\text{d}}_h(t) = \frac{\psi^{\text{H}} Y^{\text{e}}_h(t)}{1+\tau^{\text{CF}}}\,, \tag{A.49}$$

where τ^{CF} is the tax rate on investment goods. Investment demand by household h for product g net of taxes ($I^{\text{d}}_{hg}(t)$) is then determined by fixed weights b^{CFH}_g:

$$I^{\text{d}}_{hg}(t) = \frac{b^{\text{CFH}}_g \bar{P}_g(t-1)}{\sum_g b^{\text{CFH}}_g \bar{P}_g(t-1)} I^{\text{d}}_h(t)\,. \tag{A.50}$$

Again, realized sales of investment goods purchased by households are an outcome of the search-and-matching process on the capital goods market:

$$I_h(t) \begin{cases} = \sum_g I^{\text{d}}_{hg}(t) & \text{if the household successfully realized the investment plan, and} \\ < \sum_g I^{\text{d}}_{hg}(t) & \text{if all firms visited could not satisfy its demand.} \end{cases} \tag{A.51}$$

The capital stock of household h then follows:

$$K_h(t) = K_h(t-1) + I_h(t)\,. \tag{A.52}$$

Appendix A.2.4. Income

In each period t, all households receive income according to their activity status. Nominal disposable net income $Y_h(t)$ (i.e. realized income after taxes but including unemployment benefits and other social transfers) of the h-th household is different from expected income by the realized inflation in period t, which is represented by the current consumer price index, as well as the realized profits by firms and the bank:

$$Y_h(t) = \begin{cases} \left(w_h(t)\left(1-\tau^{\text{SIW}}-\tau^{\text{INC}}(1-\tau^{\text{SIW}})\right) + sb^{\text{other}}(t)\right)\bar{P}^{\text{HH}}(t) & \text{if employed} \\ \left(\theta^{\text{UB}} w_h(t) + sb^{\text{other}}(t)\right)\bar{P}^{\text{HH}}(t) & \text{if unemployed} \\ \left(sb^{\text{inact}}(t) + sb^{\text{other}}(t)\right)\bar{P}^{\text{HH}}(t) & \text{if not economically active} \\ \theta^{\text{DIV}}(1-\tau^{\text{INC}})(1-\tau^{\text{FIRM}})\max(0,\Pi_i(t)) + sb^{\text{other}}(t)\bar{P}^{\text{HH}}(t) & \text{if investor in firm } i \\ \theta^{\text{DIV}}(1-\tau^{\text{INC}})(1-\tau^{\text{FIRM}})\max(0,\Pi_k(t)) + sb^{\text{other}}(t)\bar{P}^{\text{HH}}(t) & \text{if a bank investor.} \end{cases} \tag{A.53}$$

[6]We assume all households to buy the same set of goods, independent of the amount they spend on consumption.

Appendix A.2.5. Savings

Savings is the difference between current disposable income $Y_h(t)$ and realized consumption expenditure $C_h(t)$ plus realized investment in housing $I_h(t)$, and is used to accumulate financial wealth:[7]

$$D_h(t) = D_h(t-1) + \underbrace{Y_h(t) - (1+\tau^{\mathrm{VAT}})C_h(t) - (1+\tau^{\mathrm{CF}})I_h(t)}_{\text{Savings}} + \underbrace{\bar{r}(t)\max(0, D_h(t-1))}_{\text{Interest received}} - \underbrace{r(t)\max(0, -D_h(t-1))}_{\text{Interest payments}} \quad \text{(A.54)}$$

Additionally, the stock of deposits is corrected for interest payments on overdrafts of the household's deposit account ($D_h(t-1) < 0$), and interest received on deposits held with the bank ($D_h(t-1) > 0$).[8]

Appendix A.3. The general government

In our model, the government takes two functions: as a consumer on the retail market (government consumption), and as a redistributive entity that levies taxes and social contributions to provide social services and benefits to its citizens. We assume that government consumption is exogenous and attributed to individual government entities. Government expenditures, revenues, the deficit and the public debt, however, are accounted for at the aggregate level (i.e. for the general government).

Appendix A.3.1. Government Consumption

Individual government entities j ($j = 1, 2, \ldots, J$) participate in the goods market as consumers. These entities represent the central government, state government, local governments and social security funds. Demand for real final consumption of the general government ($C^{\mathrm{G}}(t)$) is assumed to follow an autoregressive process of lag order one (AR(1)):

$$\log\left(C^{\mathrm{G}}(t)\right) = \alpha^{\mathrm{G}} \log\left(C^{\mathrm{G}}(t-1)\right) + \beta^{\mathrm{G}} + \epsilon^{\mathrm{G}}(t-1)\,, \quad \text{(A.55)}$$

where $\epsilon^{\mathrm{G}}(t-1)$ is a random shock with zero mean and variance $\left(\sigma^{\mathrm{G}}\right)^2$. The total nominal government consumption demand is then uniformly distributed to the J government entities and attributed to goods g:

$$C^{\mathrm{d}}_j(t) = \frac{C^{\mathrm{G}}(t)\sum_g c^{\mathrm{G}}_g \bar{P}_g(t-1)(1+\pi^{\mathrm{e}}(t))}{J}\,, \quad \text{(A.56)}$$

and the consumption budget of the j-th government entity to purchase the g-th good is given by

$$C^{\mathrm{d}}_{jg}(t) = \frac{c^{\mathrm{G}}_g \bar{P}_g(t-1)}{\sum_g c^{\mathrm{G}}_g \bar{P}_g(t-1)} C^{\mathrm{d}}_j(t)\,, \quad \text{(A.57)}$$

where c^{G}_g is the fraction of goods of type g demanded by the government. Realized government consumption is then another outcome of the search-and-matching process on the consumption goods market:

$$C_j(t) \begin{cases} = \sum_g C^{\mathrm{d}}_{jg}(t) & \text{if the government successfully realized the consumption plan, and} \\ < \sum_g C^{\mathrm{d}}_{jg}(t) & \text{if all firms visited could not satisfy its demand.} \end{cases} \quad \text{(A.58)}$$

Other expenditures of the general government include interest payments, social benefits other than social transfers in kind, and subsidies. Interest payments by the general government are made with a fixed average interest rate r^{G} on loans taken out by the government $L^{\mathrm{G}}(t-1)$. Social transfers by the government consist of social benefits for inactive households ($\sum_{h\in H^{\mathrm{inact}}} sb^{\mathrm{inact}}(t)$) such as pension payments or social exclusion benefits, social benefits for any household h ($\sum_h sb^{\mathrm{other}}(t)$) such as relating to family, sickness or housing, and unemployment benefits for unemployed households ($\sum_{h\in H^{\mathrm{U}}(t)} w_h(t)$). Subsidies are paid to firms with subsidy rates (uniform for each industry, but different across industries) on products and production, and are incorporated in the net tax rates on products (τ^{Y}_i) and production (τ^{K}_i), respectively.[9]

[7]Savings can also be negative in our model, in which case the respective person h would decumulate her financial wealth to finance her consumption needs.

[8]Here, we assume that these interest payments or receipts do not enter the household's consumption decision, and thus we abstract from wealth effects on consumption.

[9]The latter can therefore also have negative values if a sector receives more subsidies on products or production than it has to pay in taxes.

Appendix A.3.2. Government Revenues

Revenues of the general government are generated through taxes, social contributions and other transfers from all sectors.

$$
\begin{aligned}
Y^{\mathrm{G}}(t) = {} & \underbrace{(\tau^{\mathrm{SIF}} + \tau^{\mathrm{SIW}})\bar{P}^{\mathrm{HH}}(t) \sum_{h \in H^{\mathrm{E}}(t)} w_h(t)}_{\text{Social security contributions}} + \underbrace{\tau^{\mathrm{INC}}(1 - \tau^{\mathrm{SIW}})\bar{P}^{\mathrm{HH}}(t) \sum_{h \in H^{\mathrm{E}}(t)} w_h(t)}_{\text{Labour income taxes}} + \underbrace{\tau^{\mathrm{VAT}} \sum_h C_h(t)}_{\text{Value added taxes}} \\
& + \underbrace{\tau^{\mathrm{INC}}(1 - \tau^{\mathrm{FIRM}})\theta^{\mathrm{DIV}} \left(\sum_i \max(0, \Pi_i(t)) + \max(0, \Pi_k(t)) \right)}_{\text{Capital income taxes}} + \underbrace{\tau^{\mathrm{FIRM}} \left(\sum_i \max(0, \Pi_i(t)) + \max(0, \Pi_k(t)) \right)}_{\text{Corporate income taxes}} \\
& + \underbrace{\tau^{\mathrm{CF}} \sum_h I_h(t)}_{\text{Taxes on capital formation}} + \underbrace{\sum_i \tau_i^{\mathrm{Y}} P_i(t) Y_i(t)}_{\text{Net taxes/subsidies on products}} + \underbrace{\sum_i \tau_i^{\mathrm{K}} P_i(t) Y_i(t)}_{\text{Net taxes/subsidies on production}} + \underbrace{\tau^{\mathrm{EXPORT}} \sum_l C_l(t)}_{\text{Export taxes}} .
\end{aligned}
\tag{A.59}
$$

Appendix A.3.3. Government Deficit

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

$$
\begin{aligned}
\Pi^{\mathrm{G}}(t) = {} & \underbrace{\sum_{h \in H^{\mathrm{inact}}} \bar{P}^{\mathrm{HH}}(t) sb^{\mathrm{inact}}(t) + \sum_{h \in H^{\mathrm{U}}(t)} \bar{P}^{\mathrm{HH}}(t) \theta^{\mathrm{UB}} w_h(t) + \sum_h \bar{P}^{\mathrm{HH}}(t) sb^{\mathrm{other}}(t)}_{\text{Social benefits and transfers}} \\
& + \underbrace{\sum_j C_j(t)}_{\text{Government consumption}} + \underbrace{r^{\mathrm{G}} L^{\mathrm{G}}(t-1)}_{\text{Interest payments}} - \underbrace{Y^{\mathrm{G}}(t)}_{\text{Government revenues}} .
\end{aligned}
\tag{A.60}
$$

Appendix A.3.4. Government Debt

The government debt as a stock variable is determined by the year-to-year deficits/surpluses of the government sector:

$$
L^{\mathrm{G}}(t) = L^{\mathrm{G}}(t-1) + \Pi^{\mathrm{G}}(t) . \tag{A.61}
$$

For reasons of model parsimony, we assume that the government sells its debt contracts to the central bank, which we model as a "clearinghouse" for capital flows between the national economy and the Rest of the World. Thus, we implicitly assume that the purchase of government bonds is financed by inflows of foreign capital recorded on the liability side of the central bank's balance sheet.

Appendix A.4. The bank

For the sake of simplicity, we assume that there is one representative bank.[10] The bank takes deposits from firms and households, extends loans to firms, and receives advances from (or deposits reserves at) the central bank.

[10]This assumption of one representative bank is above all due to national accounting conventions. From national annual sector accounts, which determine the logic of financial flows between the aggregate sectors for our model (households, non-financial corporations, financial corporations, government and rest of the world), we obtain balance sheet positions (credit and debts), as well as interest payment flows between firms and the financial sector (banks) on an aggregate level. Since we do not have information on financial relations between individual firms (or industries) and banks for this model, we have no empirically based method to determine credit and debt relations, acquisition and provision of credit, as well as interest payments, between individual firms (or industries) and individual banks. Therefore, we account for credit relations and financial flows between individual firms and banks on an aggregate level for the banking sector, i.e. we assume a representative bank extending credit to individual firms according to the amount of firms' real capital stock, while we account for the value added generated by financial corporations in the real economy according to the logic of IOTs as separate industries within the firm sector.

Appendix A.4.1. Provision of Loans

The bank extends loans to firms according to a risk assessment of potential borrowers and is subject to minimum capital requirements imposed by the regulator. Thus, the bank can extend loans up to a multiple of its equity base or net worth. However, the bank—like any other agent—has no knowledge of the realized value of either its equity capital or loans extended to the individual firm i, due to fundamental uncertainty prevailing in the model economy. Therefore, the bank has to form expectations both for its equity capital ($E_k^{\mathrm{e}}(t)$) and for the sum of all loans extended to firms in the economy ($\sum_{i=1}^{I}(L_i^{\mathrm{e}}(t) + \Delta L_i(t))$):

$$\frac{E_k^{\mathrm{e}}(t)}{\sum_{i=1}^{I}(L_i^{\mathrm{e}}(t) + \Delta L_i(t))} = \frac{E_k(t-1)}{\sum_{i=1}^{I}((1-\theta)L_i(t-1) + \Delta L_i(t))} \geq \zeta, \tag{A.62}$$

where $0 < \zeta < 1$ can be interpreted as a minimum capital requirement coefficient. Hence, $1/\zeta$ is the maximum allowable leverage for the bank. $\Delta L_i(t)$ is the realized amount of new loans to firm i in period t, which is either the full amount of new credit demanded by firms ($\Delta L_i^{\mathrm{d}}(t)$, see Equation (A.29)) if the capital requirements for the banks have not been surpassed and the borrower's loan-to-value ratio is satisfied (see Equation (A.63) and Equation (A.64)). However, it is equal to zero if the bank does not have enough equity capital to provide the loan asked for by firm i.

Furthermore, the bank forms a risk assessment of a potential default on the part of firm i before extending a loan to it. This risk assessment is based on the borrower's leverage as measured by its loan-to-value ratio, i.e. the amount of loans over the market value of its capital stock. Thus, the bank will grant a loan to firm i only up to the point where the borrower's leverage (or loan-to-value) ratio after the loan (including overdrafts on deposit accounts), is below ζ^{LTV}, which is a constant. However, due to fundamental uncertainty, also in this case the bank has to form expectations on the value of firm i's capital stock ($K_i^{\mathrm{e}}(t)$):

$$\frac{L_i^{\mathrm{e}}(t) + \Delta L_i(t)}{K_i^{\mathrm{e}}(t)} = \frac{\overbrace{(1-\theta)L_i(t-1)}^{=L_i^{\mathrm{e}}(t)} + \Delta L_i(t)}{\underbrace{\bar{P}^{\mathrm{CF}}(t-1)\,(1+\pi^{\mathrm{e}}(t))\,K_i(t-1)}_{=K_i^{\mathrm{e}}(t)}} \leq \zeta^{\mathrm{LTV}}. \tag{A.63}$$

Here, $K_i^{\mathrm{e}}(t)$ denotes the amount of collateral the bank expects a certain firm i to hold at the moment when the firm asks for credit, while $L_i^{\mathrm{e}}(t)$ is the amount of debt already in the books of the firm. Given this debt-to-collateral ratio (inclusive of the amount of new loans $\Delta L_i(t)$ asked by firm i) is below the threshold loan-to-value ratio set by the bank, the bank will grant credit to firm i (conditional on the bank's own leverage ratio). Altogether, therefore, the amount of new credit extended to firm i by the bank ($\Delta L_i(t)$) is limited by the credit demanded by the firm, the bank's risk assessment regarding the default of its potential borrower, and the minimum capital requirements imposed by the regulator:

$$\Delta L_i(t) \begin{cases} = \Delta L_i^{\mathrm{d}}(t) & \text{if the borrower's loan-to-value ratio (eq. (A.63)) and capital requirements (eq. (A.62)) are satisfied} \\ < \Delta L_i^{\mathrm{d}}(t) & \text{otherwise.} \end{cases} \tag{A.64}$$

The order of arrival of firms at the bank is assumed to be random. A financially robust (low leverage) firm, which in principle deserves a large chunk of bank loans, may be denied credit if it arrives "too late" (i.e. after other less robust firms).

Appendix A.4.2. Accounting for Profits and Losses

The bank's profits are computed as the difference between revenues from interest payments payable on outstanding loans to firms, including overdrafts on deposit accounts incurred by firms and households ($D_{i,h}(t-1) < 0$), and costs due to interest payments on deposits held with the bank by firms and households ($D_{i,h}(t-1) > 0$):

$$\Pi_k(t) = \underbrace{r(t)\left(\sum_{i=1}^{I} L_i(t-1) + \max(0, -D_i(t-1)\right) + r(t)\sum_{h=1}^{H}\max(0, -D_h(t-1)) + \bar{r}(t)\max(0, D_k(t-1))}_{\text{Interest received}}$$
$$\underbrace{-\,\bar{r}(t)\sum_{i=1}^{I}\max(0, D_i(t-1)) - \bar{r}(t)\sum_{h=1}^{H}\max(0, D_h(t-1)) - \bar{r}(t)\max(0, -D_k(t-1))}_{\text{Interest payments}} \tag{A.65}$$

Deposits are remunerated at the policy rate $\bar{r}(t)$, which we assume to be set exogenously by the central bank. The interest rate $r(t)$ for bank credit to firms is then determined by a fixed markup μ over the policy rate $\bar{r}(t)$:

$$r(t) = \bar{r}(t) + \mu\,. \tag{A.66}$$

Bank equity grows or shrinks according to bank profits or losses, and is given by

$$E_k(t) = E_k(t-1) + \Pi_k(t) - \underbrace{\theta^{\mathrm{DIV}}(1-\tau^{\mathrm{FIRM}})\max(0, \Pi_k(t))}_{\text{Dividend payments}} - \underbrace{\tau^{\mathrm{FIRM}}\max(0, \Pi_k(t))}_{\text{Corporate taxes}} - \underbrace{\sum_{i \in I'}(L_i(t) - D_i(t) - \zeta^{\mathrm{b}}\bar{P}_i^{\mathrm{CF}}(t)K_i(t))}_{\text{Write-off of bad debt}}\,, \tag{A.67}$$

where I' is the set of insolvent borrowers, and we assume that outstanding overdraft of firm i's deposit account as well as a fraction $(1-\zeta^{\mathrm{b}})\bar{P}_i^{\mathrm{CF}}(t)K_i(t)$ of loans extended to firm i have to be written off from the bank's balance sheet. The residual and balancing item on the bank's balance sheet ($D_k(t)$),[11] after accounting for loans extended, deposits taken in and its equity capital, are (net) central bank reserves held ($D_k(t) > 0$) or advances obtained by the bank from the central bank ($D_k(t) < 0$).[12]

$$D_k(t) = \sum_{i=1}^{I} D_i(t) + \sum_{h=1}^{H} D_h(t) + E_k(t) - \sum_{i=1}^{I} L_i(t)\,. \tag{A.68}$$

Appendix A.5. The Central Bank

The central bank (CB) sets the policy rate $\bar{r}(t)$ based on implicit inflation and growth targets, provides liquidity to the banking system (advances to the bank), and takes deposits from the bank in the form of reserves deposited at the central bank. Furthermore, the central bank purchases external assets (government bonds) and thus acts as a creditor to the government.

Appendix A.5.1. Determination of Interest Rates

The policy rate is determined by a generalized Taylor rule (Taylor, 1993). Following Blattner and Margaritov (2010), we use a "growth" rule specification where the output gap does not enter the equation:[13]

$$\bar{r}(t) = \rho\bar{r}(t-1) + (1-\rho)\left(r^* + \pi^* + \xi^{\pi}\left(\pi^{\mathrm{EA}}(t) - \pi^*\right) + \xi^{\gamma}\gamma^{\mathrm{EA}}(t)\right), \tag{A.69}$$

where ρ is a measure for gradual adjustment of the policy rate, r^* is the real equilibrium interest rate, π^* is the inflation target by CB, ξ^{π} is the weight the CB puts on inflation targeting and ξ^{γ} the weight placed on economic

[11] Which also includes currency held by the bank.

[12] Note that this variable, if it takes a positive value ($D_k(t) > 0$), signifies that the bank holds positive net reserves, i.e. it holds more reserves than advances and is thus a net creditor to the central bank. On the other hand, in the opposite case of $D_k(t) < 0$, this means that the bank has taken out more central bank advances than it holds central bank reserves, i.e. it is a net debtor to the central bank. The possibility of an inequality of advances and reserves, or, for that matter, an inequality of loans and deposits, is due to the fact that we do not explicitly distinguish between deposits and reserves for reasons of model parsimony. Rather, we use the central bank as a "clearing house" for flows of reserves and deposits between the national economic and the RoW, see Equation (Appendix A.5.2).

[13] Here, we rely on empirical evidence and statements by leading central bankers reported in Blattner and Margaritov (2010) implying that the concept of an output gap does not seem to influence the behaviour of the European Central Bank (ECB) to a large extent.

growth, respectively. Inflation ($\pi^{\mathrm{EA}}(t)$) and economic growth ($\gamma^{\mathrm{EA}}(t)$) of the monetary union are assumed to follow an autoregressive process of lag order one (AR(1)):

$$\log\left(1+\pi^{\mathrm{EA}}(t)\right)=\alpha^{\pi^{\mathrm{EA}}}\log\left(1+\pi^{\mathrm{EA}}(t-1)\right)+\beta^{\pi^{\mathrm{EA}}}+\epsilon^{\pi^{\mathrm{EA}}}(t-1) \tag{A.70}$$

and

$$\log\left(Y^{\mathrm{EA}}(t)\right)=\alpha^{\mathrm{Y^{EA}}}\log\left(Y^{\mathrm{EA}}(t-1)\right)+\beta^{\mathrm{Y^{EA}}}+\epsilon^{\mathrm{Y^{EA}}}(t-1)\,, \tag{A.71}$$

where

$$\gamma^{\mathrm{EA}}(t)=\frac{Y^{\mathrm{EA}}(t)}{Y^{\mathrm{EA}}(t-1)}-1\,, \tag{A.72}$$

and $\epsilon^{\pi^{\mathrm{EA}}}(t-1)$ and $\epsilon^{\mathrm{Y^{EA}}}(t-1)$ are random shocks with zero mean. $\epsilon^{\pi^{\mathrm{EA}}}(t-1)$ has variance $\left(\sigma^{\pi^{\mathrm{EA}}}\right)^2$, and the variance of $\epsilon^{\mathrm{Y^{EA}}}(t-1)$ takes the extent to which the shocks are common to the economic growth of the monetary union and imports and exports, as reflected by the covariance matrix C, into account. Note that we assume here a small open economy as part of a monetary union with no influence on interest rates.[14]

Appendix A.5.2. Accounting for Profits and Losses

The central bank's profits $\Pi^{\mathrm{CB}}(t)$ are computed as the difference between revenues from interest payments on government debt, as well as revenues ($D_k(t)<0$) or costs ($D_k(t)>0$) due to the net position in advances/reserves vis-à-vis the banking system:

$$\Pi^{\mathrm{CB}}(t)=r^{\mathrm{G}}L^{\mathrm{G}}(t-1)-\bar{r}(t)D_k(t-1)\,. \tag{A.73}$$

The central bank's equity $E^{\mathrm{CB}}(t)$ evolves according to its profits or losses and its past equity and is given by

$$E^{\mathrm{CB}}(t)=E^{\mathrm{CB}}(t-1)+\Pi^{\mathrm{CB}}(t)\,. \tag{A.74}$$

The net creditor/debtor position of the national economy to the rest of the world ($D^{\mathrm{RoW}}(t)$)[15] evolves according to the following law of motion

$$D^{\mathrm{RoW}}(t)=D^{\mathrm{RoW}}(t-1)-\underbrace{(1+\tau^{\mathrm{EXPORT}})\sum_l C_l(t)}_{\text{Exports}}+\underbrace{\sum_m P_m(t)Q_m(t)}_{\text{Imports}}\,. \tag{A.75}$$

Here, for example, a balance of trade surplus (deficit) enters with a negative (positive) sign, since $D^{\mathrm{RoW}}(t)$ is on the liability side of the CB's balance sheet. Thus a trade surplus (deficit), i.e. an inflow (outflow) money into (out of) the national economy, would reduce (increase) national liabilities versus the RoW. Inherent stock-flow consistency relating to the accounting principles incorporated in our model implies that our financial system is closed via the accounting identity that connects the change in the amount of deposits in the banking system[16] to the government deficit (surplus)[17] and to the balance of trade:[18]

$$\begin{aligned}E^{\mathrm{CB}}(t)+D^{\mathrm{RoW}}(t)&=L^{\mathrm{G}}(t)-D_k(t)\\&=L^{\mathrm{G}}(t)-\sum_{i=1}^{I}D_i(t)-\sum_{h=1}^{H}D_h(t)-E_k(t)+\sum_{i=1}^{I}L_i(t)\,.\end{aligned}$$

[14]For example, Austria as part of the euro area contributes only about 3 per cent of the total GDP of the monetary union.

[15]If $D^{\mathrm{RoW}}(t)<0$, the national economy is a net creditor of the RoW, if $D^{\mathrm{RoW}}(t)>0$, the national economy is a net debtor to the RoW.

[16]These changes in the amount of deposits in the banking system directly correspond to changes in net central bank reserves $D_k(t)$, which in turn depend the private sector's surplus or deficit in relation to both the government and the RoW.

[17]Financial flows relating to a deficit (surplus) on the part of the government sector either accrue to (are paid by) the private sector (households and firms), or have to flow to (in from) the RoW, in the first case increasing (decreasing) deposits, in the second case increasing (decreasing) D^{ROW}.

[18]A positive (negative) balance of trade will either increase (decrease) deposits held by the private sector, or reduce (increase) the amount of government debt by, e.g. reducing (increasing) the amount of government deficit.

Appendix A.6. Imports and Exports

To depict trade with the RoW, we include a set of agents that are based abroad and trade with the domestic economy. For simplicity's sake, a representative foreign firm for each sector supplies goods on domestic markets for intermediate, capital and consumption goods (imports), while foreign consumers demand products on these domestic markets (exports). As a further simplifying assumption, we assume a small open economy setting where we suppose the demand for exports and the supply of imports to be exogenously given. This implies that imports to the domestic economy are subject to a supply constraint. However, demand for imports is endogenous, as is the supply of exports.

Appendix A.6.1. Imports

Following this approach, the total supply of imports $Y^{\mathrm{I}}(t)$ (in real terms) is assumed to follow an autoregressive process of lag order one (AR(1)):

$$\log\left(Y^{\mathrm{I}}(t)\right) = \alpha^{\mathrm{I}} \log\left(Y^{\mathrm{I}}(t-1)\right) + \beta^{\mathrm{I}} + \epsilon^{\mathrm{I}}(t-1)\,, \tag{A.76}$$

where $\epsilon^{\mathrm{I}}(t-1)$ is a random shock with zero mean and variance that takes the extent to which the shocks are common to the economic growth of the monetary union and imports and exports, as reflected by the covariance matrix C, into account. A representative foreign firm for each sector imports goods from the RoW and supplies them to domestic markets. Thus the m-th, ($m = 1, 2, \ldots, S$), foreign firm representing an industry s imports the principal product g:[19]

$$Y_m(t) = c^{\mathrm{I}}_{g=s} Y^{\mathrm{I}}(t)\,, \tag{A.77}$$

where c^{I}_g is the fraction of imported goods of type g as part of total imports. The prices for these import goods are assumed to develop in line with the average sectoral domestic price level. The foreign firm thus sells its products at the inflation-adjusted average sectoral domestic price level. Consequently,

$$P_m(t) = \bar{P}_g(t-1)(1 + \pi^{\mathrm{e}}(t))\,, \tag{A.78}$$

where m produces the principal product g. This corresponds to the assumption of a fixed relation between the domestic and international price level, i.e. the same inflation rate at home and abroad. Sales of imports are then the realized demand as an outcome of the search-and-matching process on the goods markets (see Online Appendix A.1.1):

$$Q_m(t) = \min(Y_m(t), Q^{\mathrm{d}}_m(t))\,, \tag{A.79}$$

where $Q^{\mathrm{d}}_m(t)$ is subject to the search-and-matching mechanism specifying the demand by consumers from foreign firm m:

$$Q^{\mathrm{d}}_m(t) \begin{cases} < Y_m(t) & \text{if demand from consumers is smaller than supply from foreign firm } m\text{, and} \\ = Y_m(t) & \text{if demand from consumers exactly matches supply from foreign firm } m\text{, and} \\ > Y_m(t) & \text{if demand from consumers is larger than supply from foreign firm } m. \end{cases} \tag{A.80}$$

Appendix A.6.2. Exports

The l-th ($l = 1, 2, \ldots, L$) foreign consumer, be it a foreign firm, household, or government entity, participates in the domestic goods market as a consumer. Total sales to these foreign consumers on domestic markets represent exports to the rest of the world. Analogous to imports, the total demand for exports ($C^{\mathrm{E}}(t)$) is assumed to follow an autoregressive process of lag order one (AR(1)):

$$\log\left(C^{\mathrm{E}}(t)\right) = \alpha^{\mathrm{E}} \log\left(C^{\mathrm{E}}(t-1)\right) + \beta^{\mathrm{E}} + \epsilon^{\mathrm{E}}(t-1)\,, \tag{A.81}$$

where $\epsilon^{\mathrm{E}}(t-1)$ is a random shock with zero mean and variance that takes the extent to which the shocks are common to the economic growth of the monetary union and imports and exports, as reflected by the covariance matrix C, into

[19]As for domestic firms, we assume that there is a one-to-one correspondence between the sets of industries s and products g, meaning that the n-th sector produces only the n-th good, and $S = G$.

account. The total demand for exports is then uniformly distributed to the L foreign consumers and attributed to goods g:

$$C_l^{\mathrm{d}}(t) = \frac{C^{\mathrm{E}}(t)\sum_g c_g^{\mathrm{E}}\bar{P}_g(t-1)(1+\pi^{\mathrm{e}}(t))}{L}\,, \tag{A.82}$$

and the demand for exported goods by the l-th foreign consumer to purchase the g-th good is given by

$$C_{lg}^{\mathrm{d}}(t) = \frac{c_g^{\mathrm{E}}\bar{P}_g(t-1)}{\sum_g c_g^{\mathrm{E}}\bar{P}_g(t-1)}C_l^{\mathrm{d}}(t)\,, \tag{A.83}$$

where c_g^{E} is the fraction of exports of goods of type g. Realized consumption by foreign consumers is then an outcome of the search-and-matching process on goods markets (see Online Appendix A.1.1):

$$C_l(t)\begin{cases} = \sum_g C_{lg}^{\mathrm{d}}(t) & \text{if the foreign consumer successfully realized the consumption plan, and} \\ < \sum_g C_{lg}^{\mathrm{d}}(t) & \text{if all firms visited could not satisfy its demand.} \end{cases} \tag{A.84}$$

Appendix A.7. Macroeconomic aggregates

Finally, GDP in our model can be calculated by aggregating the value of all final goods and services produced and purchased by agents in the model in a given period. The nominal GDP and its components of each period t can be defined by the production, expenditure, and income approach:

$$\begin{aligned}
GDP(t) = & \underbrace{\sum_i \tau_i^{\mathrm{Y}} P_i(t)Y_i(t) + \sum_h \tau^{\mathrm{VAT}} C_h(t) + \sum_h \tau^{\mathrm{CF}} I_h(t) + \sum_j \tau^{\mathrm{G}} C_j(t) + \sum_l \tau^{\mathrm{EXPORT}} C_l(t)}_{\text{Taxes on products}} \\
& + \underbrace{\sum_i (1-\tau_i^{\mathrm{Y}})P_i(t)Y_i(t)}_{\text{Total sales of goods and services}} - \underbrace{\sum_i \frac{1}{\beta_i}\bar{P}_i(t)Y_i(t)}_{\text{Intermediate inputs}} \quad \text{(Production approach)} \\
= & \underbrace{\sum_h (1+\tau^{\mathrm{VAT}})C_h(t)}_{\text{Household consumption}} + \underbrace{\sum_j (1+\tau^{\mathrm{G}})C_j(t)}_{\text{Government consumption}} + \underbrace{\sum_h (1+\tau^{\mathrm{CF}})I_h(t) + \sum_i P_i^{\mathrm{CF}}(t)I_i(t)}_{\text{Gross fixed capital formation}} \\
& + \underbrace{\sum_i P_i(t)\Delta S_i(t) + \bar{P}_i(t)\left(\Delta M_i(t) - \frac{1}{\beta_i}Y_i(t)\right)}_{\text{Changes in inventories}} + \underbrace{\sum_l (1+\tau^{\mathrm{EXPORT}})C_l(t)}_{\text{Exports}} \\
& - \underbrace{\sum_m P_m(t)Q_m(t))}_{\text{Imports}} \quad \text{(Expenditure approach)} \\
= & \underbrace{\sum_i \tau_i^{\mathrm{Y}} P_i(t)Y_i(t) + \sum_h \tau^{\mathrm{VAT}} C_h(t) + \sum_h \tau^{\mathrm{CF}} I_h(t) + \sum_j \tau^{\mathrm{G}} C_j(t) + \sum_l \tau^{\mathrm{EXPORT}} C_l(t)}_{\text{Taxes on products}} \\
& + \underbrace{\sum_i P_i(t)Q_i(t) + P_i(t)\Delta S_i(t) - (1+\tau^{\mathrm{SIF}})\bar{P}^{\mathrm{HH}}(t)N_i(t)w_i(t) - \frac{1}{\beta_i}\bar{P}_i(t)Y_i(t) - \tau_i^{\mathrm{Y}}P_i(t)Y_i(t) - \tau_i^{\mathrm{K}}P_i(t)Y_i(t)}_{\text{Gross operating surplus and mixed income}} \\
& + \underbrace{\sum_i (1+\tau^{\mathrm{SIF}})\bar{P}^{\mathrm{HH}}(t)N_i(t)w_i(t)}_{\text{Compensation of employees}} + \underbrace{\sum_i \tau_i^{\mathrm{K}}P_i(t)Y_i(t)}_{\text{Net taxes on production}} \quad \text{(Income approach)}
\end{aligned}$$

Similarly, inflation, which is measured by the GDP deflator, is the economy-wide average price of all goods and services produced and sold, where again all individual prices and sales are determined on the agent level by our search and matching mechanism. In our model, the GDP deflator is defined as nominal GDP divided by real GDP:

$$\begin{aligned}&\textit{GDP deflator}(t)\\&=\frac{\sum_i \tau_i^{\mathrm{Y}} P_i(t)Y_i(t) + \sum_h \tau^{\mathrm{VAT}} C_h(t) + \sum_h \tau^{\mathrm{CF}} I_h(t) + \sum_j \tau^{\mathrm{G}} C_j(t) + \sum_l \tau^{\mathrm{EXPORT}} C_l(t) + \sum_i (1-\tau_i^{\mathrm{Y}}) P_i(t)Y_i(t) - \sum_i \frac{1}{\beta_i} \bar{P}_i(t) Y_i(t)}{\sum_i \tau_i^{\mathrm{Y}} Y_i(t) + \sum_h \tau^{\mathrm{VAT}} \frac{C_h(t)}{\bar{P}_h(t)} + \sum_h \tau^{\mathrm{CF}} \frac{I_h(t)}{\bar{P}_h^{\mathrm{CF}}(t)} + \sum_j \tau^{\mathrm{G}} \frac{C_j(t)}{\bar{P}_j(t)} + \sum_l \tau^{\mathrm{EXPORT}} \frac{C_l(t)}{\bar{P}_l(t)} + \sum_i (1-\tau_i^{\mathrm{Y}}) Y_i(t) - \sum_i \frac{1}{\beta_i} Y_i(t)}\,.\end{aligned}$$

Appendix B. Conditional forecasts with the agent-based model

We generate forecasts conditional on exogenous paths for imports, exports and government consumption, corresponding to a small open economy setting and exogenous policy decisions. In this setup, we assume that imports and exports, as well as government consumption, are exogenously given from data. Thus, in this setup, we replace Equations (A.76), (A.81), and (A.55) and set imports, exports and government consumption according to observed data.

Furthermore, in this setup, we assume that agents' forecasts take into account expectations on imports, exports and government consumption. Thus, we replace Equations (A.6) and (A.10) and assume expectations on economic growth and inflation to be formed using an autoregressive model with exogenous predictors and lag order one (ARX(1)). Thus, in this setup expectations on economic growth are formed according to an ARX(1) rule:

$$\log(Y^{\mathrm{e}}(t)) = \alpha^{\mathrm{Y}}(t)\log\left(\sum_i Y_i(t-1)\right) + \gamma^{\mathrm{I}}(t)\log(Y^{\mathrm{I}}(t)) + \gamma^{\mathrm{G}}(t)\log(C^{\mathrm{G}}(t)) + \gamma^{\mathrm{E}}(t)\log(C^{\mathrm{E}}(t)) + \beta^{\mathrm{Y}}(t) + \epsilon^{\mathrm{Y}}(t)\,, \quad \text{(B.1)}$$

where $\alpha^{\mathrm{Y}}(t)$, $\gamma^{\mathrm{I}}(t)$, $\gamma^{\mathrm{E}}(t)$, $\gamma^{\mathrm{G}}(t)$, $\beta^{\mathrm{Y}}(t)$, and $\epsilon^{\mathrm{Y}}(t)$ are re-estimated every period on the time series of aggregate output of firms $\sum_i Y_i(t')$ and the exogenous predictors imports $Y^{\mathrm{I}}(t')$, exports $C^{\mathrm{E}}(t')$ as well as government consumption $C^{\mathrm{G}}(t')$, where $t' = -T', -T'+1, -T'+2, \ldots, 0, 1, 2, \ldots, t-1$. Output, imports and exports as well as government consumption are entered in log levels.

Similarly, in this setup expectations on inflation are formed using an autoregressive model with exogenous predictors and lag order one (ARX(1)):

$$\log(1+\pi^{\mathrm{e}}(t)) = \alpha^{\pi}(t)\pi(t-1) + \gamma^{\mathrm{I}}(t)\log(Y^{\mathrm{I}}(t)) + \gamma^{\mathrm{G}}(t)\log(C^{\mathrm{G}}(t)) + \gamma^{\mathrm{E}}(t)\log(C^{\mathrm{E}}(t)) + \beta^{\pi}(t) + \epsilon^{\pi}(t)\,, \quad \text{(B.2)}$$

where $\alpha^{\pi}(t)$, $\gamma^{\mathrm{I}}(t)$, $\gamma^{\mathrm{E}}(t)$, $\gamma^{\mathrm{G}}(t)$, $\beta^{\pi}(t)$, and $\epsilon^{\pi}(t)$ are re-estimated every period on the time series of inflation $\pi(t')$, and the exogenous predictors are imports $Y^{\mathrm{I}}(t')$, exports $C^{\mathrm{E}}(t')$ and government consumption $C^{\mathrm{G}}(t')$, where $t' = -T', -T'+1, -T'+2, \ldots, 0, 1, 2, \ldots, t-1$. Again, imports and exports as well as government consumption are entered in log levels.

Appendix C. Modifications to the agent-based model to assess the economic effects of the COVID-19 pandemic

To implement the COVID-19 related shocks in the model, we made four modifications with respect to the model presented in Online Appendix A. Specifically, we model the COVID-19 pandemic by (1) a domestic supply shock caused by the restrictions of economic activities due to the lockdown measures; (2) an export demand shock; (3) a supply shock from a decrease in imports; and (4) we implement a short-time work policy instrument. To account for the effects of the COVID-19 pandemic in the RoW, we replace Equations (A.76) and (A.81) and set imports and exports to the March 2020 Coronavirus pandemic scenario projected by Oxford Economics.[20]

Implementation of the domestic supply shock involves modifying Equation (A.5), which is replaced by

$$Q_i^{\mathrm{s}}(t) = Q_i^{\mathrm{d}}(t-1)(1+\gamma_i^{\mathrm{X}}(t))(1+\gamma^{\mathrm{e}}(t))\,, \tag{C.1}$$

where $\gamma_i^{\mathrm{X}}(t)$ is the domestic supply shock to firm i at time t caused by the restrictions of economic activities due to the lockdown measures. Thus, the supply choice of firm i is reduced by a factor that represents the duration and extent of lockdown to the firm. To calibrate the domestic supply shock, we use AMS data on the net inflow of unemployed persons by sector as of March 2020 and assume that approximately 65 per cent of companies would use the short-time work policy instrument.

To implement the short-time work policy instrument, Equations (A.41) and (A.60), as well as the search-and-matching mechanism in the labour market are modified. Equation (A.41) is replaced by

$$w_h(t) = \begin{cases} \max(0.9\bar{w}_i(t), w_i(t)) & \text{if on short-time work at firm } i \\ w_i(t) & \text{if employed by firm } i \\ w_h(t-1) & \text{otherwise, i.e. if unemployed.} \end{cases} \tag{C.2}$$

Thus if firm i makes use of the short-time work policy instrument, employees always receive at least 90 per cent of the average wage ($\bar{w}_i$) equivalent to a full-time position at firm i. To account for short-time work in the government expenditures, Equation (A.60) is replaced by

$$\begin{aligned} \Pi^{\mathrm{G}}(t) = {} & \underbrace{\sum_{h\in H^{\mathrm{inact}}} \bar{P}^{\mathrm{HH}}(t) sb^{\mathrm{inact}}(t) + \sum_{h\in H^{\mathrm{U}}(t)} \bar{P}^{\mathrm{HH}}(t)\theta^{\mathrm{UB}} w_h(t) + \sum_h \bar{P}^{\mathrm{HH}}(t) sb^{\mathrm{other}}(t)}_{\text{Social benefits and transfers}} + \underbrace{\sum_j C_j(t)}_{\text{Government consumption}} \\ & + \underbrace{r^{\mathrm{G}} L^{\mathrm{G}}(t-1)}_{\text{Interest payments}} + \underbrace{\sum_i (1+\tau^{\mathrm{SIF}}) \max(0, 0.9\bar{w}_i(t) - w_i(t)) N_i(t) \bar{P}^{\mathrm{HH}}(t)}_{\text{Short-time work}} - \underbrace{Y^{\mathrm{G}}(t)}_{\text{Government revenues}} \,. \end{aligned} \tag{C.3}$$

Therefore the government pays the difference between the reduced salary ($w_i(t)$) and the equivalent of 90 per cent of the wage of a full-time position ($\bar{w}_i$). The search-and-matching mechanism in the labour market is modified to give firms the option to use short-time work instead of laying off employees, for which we assume a probability of two thirds. Moreover, we assume the short-time work policy instrument can be used by firms until the end of the second quarter of 2021, i.e. for up to 6 simulation periods.

[20]For details see `https://www.oxfordeconomics.com/country-economic-forecasts`.

Appendix D. Parameters of the ABM for the Austrian economy

This section presents more details on our parameter calibration procedure, see Section 4 in the main text for a short overview. To calibrate the model presented in Online Appendix A in the main text to the Austrian economy, we use data from Eurostat. Parameters of the model are calibrated so that a period t is one quarter and each agent in the model represents a natural person or legal entity, such as a corporation, a government entity, or any other institution, in Austria. Austria is a typical example of an advanced small open economy with about 8.8 million inhabitants and more than half a million registered businesses.[21] It is closely integrated into the European economy by extensive trade: the export quota, i.e. the share of exports in GDP, is slightly more than 52 per cent, the import quota is about 48 per cent. Austria's well-developed service sector constitutes about 71 per cent of total GDP, while the industry sector takes a smaller share with about 28 per cent in GDP, and the agricultural sector contributes much less (about 1.5 per cent of GDP). Austria has a well-developed social and welfare system, primarily based on social security contributions, as well as taxation of income and consumption. Correspondingly, the ratio of public spending to GDP is about 52 per cent, while the overall tax burden, that is, the ratio of total taxes and social security contributions to GDP, reaches 43 per cent.

Table D.1: Eurostat data tables

Name	Code
Population by current activity status, NACE Rev. 2 activity and NUTS 2 region	cens_11an_r2
Business demography by legal form (from 2004 onwards, NACE Rev. 2)	bd_9ac_l_form_r2
Symmetric input-output table at basic prices (product by product)	naio_10_cp1700
Cross-classification of fixed assets by industry and by asset (stocks)	nama_10_nfa_st
Government revenue, expenditure and main aggregates	gov_10a_main
General government expenditure by function (COFOG)	gov_10a_exp
Quarterly non-financial accounts for general government	gov_10q_ggnfa
Quarterly government debt	gov_10q_ggdebt
Financial balance sheets	nasq_10_f_bs
Non-financial transactions (annually)	nasa_10_nf_tr
Non-financial transactions (quarterly)	nasq_10_nf_tr
GDP and main components (output, expenditure and income)	namq_10_gdp
Money market interest rates - quarterly data	irt_st_q

Note: The codes under which the respective datasets are available from Eurostat (such as, e.g. naio_10_cp1700) are shown in the second column.

Data sources and the respective Eurostat data tables are collected in Table D.1.[22] Parameters of the ABM are always calibrated to one reference quarter. For the forecasting exercise in Section 5 in the main text, parameters were calibrated to *28* different reference quarters from the first quarter of 2010 to the last quarter of 2016. Here we show, as an example, parameter values for 2010:Q4.

Appendix D.1. Firms

Parameters that specify the number of firms are taken directly (or derived from) business demography data. Annual business demography data shows the characteristics and demography of the business population. The data is drawn from business registers and depicts (1) the population of active enterprises, (2) the number of enterprise births and deaths, and (3) related variables on employment. Specifically, we use data from business demography by legal form

[21] For facts and figures about the Austrian economy see, e.g. the Austrian Statistical Agency, `http://statistik.at/web_en/statistics/index.html` (Last accessed November 30^{th}, 2018).

[22] Data are obtained from the Eurostat bulk download facility where it is freely available, see `http://ec.europa.eu/eurostat/estat-navtree-portlet-prod/BulkDownloadListing?sort=1&dir=data` (Last accessed November 30^{th}, 2018). The codes under which the respective datasets are available from Eurostat (such as, e.g. naio_10_cp1700) at this download facility are given in brackets in the description below.

Table D.2: Model parameters

Parameter	Description	Value	Source
G/S	Number of products/industries	62	census data, business demography data
H^{act}	Number of economically active persons	4729215	
H^{inact}	Number of economically inactive persons	4130385	
J	Number of government entities	152820	
L	Number of foreign consumers	305639	
I_s	Number of firms/investors in the s^{th} industry	see Table D.3	
$\bar{\alpha}_i$	Average productivity of labour of the i^{th} firm	see Online Appendix D.1	input-output tables
κ_i	Productivity of capital of the i^{th} firm	see Online Appendix D.1	
β_i	Productivity of intermediate consumption of the i^{th} firm	see Online Appendix D.1	
δ_i	Depreciation rate for capital of the i^{th} firm	see Online Appendix D.1	
$\bar{w}_i$	Average wage rate of firm i	see Online Appendix D.1	
a_{sg}	Technology coefficient of the g^{th} product in the s^{th} industry	see Online Appendix D.1	
b_g^{CF}	Capital formation coefficient of the g^{th} product (firm investment)	Table D.3	
b_g^{CFH}	Household investment coefficient of the g^{th} product	Table D.3	
b_g^{HH}	Consumption coefficient of the g^{th} product of households	Table D.3	
c_g^{G}	Consumption of the g^{th} product of the government in mln. Euro	Table D.3	
c_g^{E}	Exports of the g^{th} product in mln. Euro	Table D.3	
c_g^{I}	Imports of the g^{th} product in mln. Euro	Table D.3	
τ_i^{Y}	Net tax rate on products of the i^{th} firm	Online Appendix D.3	
τ_i^{K}	Net tax rate on production of the i^{th} firm	Online Appendix D.3	
τ^{INC}	Income tax rate	0.2134	government statistics, sector accounts
τ^{FIRM}	Corporate tax rate	0.0762	
τ^{VAT}	Value-added tax rate	0.1529	
τ^{SIF}	Social insurance rate (employers' contributions)	0.2122	
τ^{SIW}	Social insurance rate (employees' contributions)	0.1711	
τ^{EXPORT}	Export tax rate	0.0029	
τ^{CF}	Tax rate on capital formation	0.0876	
τ^{G}	Tax rate on government consumption	0.0091	
r^{G}	Interest rate on government bonds	0.0091	
μ	Risk premium on policy rate	0.0293	
ψ	Fraction of income devoted to consumption	0.9394	
ψ^{H}	Fraction of income devoted to investment in housing	0.0736	
θ^{DIV}	Dividend payout ratio	0.7768	
θ^{UB}	Unemployment benefit replacement rate	0.3586	Basel III, ECB statutes, banking practices, literature
θ	Rate of instalment on debt	0.05	
ζ	Banks' capital ratio	0.03	
ζ^{LTV}	Loan-to-value (LTV) ratio	0.6	
ζ^{b}	Loan-to-capital ratio for new firms after bankruptcy	0.5	
π^*	Inflation target of the monetary authority	0.005	
α^{G}	Autoregressive coefficient for government consumption	0.9845	national accounts (exogenously estimated)
β^{G}	Scalar constant for government consumption	0.1515	
σ^{G}	Standard deviation of government consumption	0.0112	
α^{E}	Autoregressive coefficient for exports	0.9693	
β^{E}	Scalar constant for exports	0.3261	
α^{I}	Autoregressive coefficient for imports	0.974	
β^{I}	Scalar constant for imports	0.2762	
$\alpha^{\text{Y}^{\text{EA}}}$	Autoregressive coefficient for euro area GDP	0.9673	
$\beta^{\text{Y}^{\text{EA}}}$	Scalar constant for euro area GDP	0.4817	
$\alpha^{\pi^{\text{EA}}}$	Autoregressive coefficient for euro area inflation	0.3834	
$\beta^{\pi^{\text{EA}}}$	Scalar constant for euro area inflation	0.0026	
$\sigma^{\pi^{\text{EA}}}$	Standard deviation of euro area inflation	0.0025	
ρ	Adjustment coefficient of the policy rate	0.9263	
r^*	Real equilibrium interest rate	-0.0034	
ξ^{π}	Weight of the inflation target	0.3214	
ξ^{γ}	Weight of economic growth	1.2994	
C	Covariance matrix of euro area GDP and imports and exports		

Note: Model parameters for the reference quarter 2010:Q4. Exogenous autoregressive coefficients and parameters of the Taylor rule are estimated over the sample 1997:Q1 to 2010:Q4.

Table D.3: Sectoral parameters

	I_s	N_s	α_s	β_s	κ_s	δ_s	w_s	τ_s^{Y}	τ_s^{K}	b_g^{CF}	b_g^{CFH}	b_g^{HH}	c_g^{G}	c_g^{E}	c_g^{I}
A01	47901	123068	0.0113	1.6632	0.0445	0.0115	0.0003	0.0095	-0.2611	0.0033	0.0006	0.0113	0	0.0051	0.0168
A02	1867	18107	0.031	1.9507	0.2071	0.0132	0.0023	0.0088	-0.0398	0	0	0.002	0	0.0006	0.0041
A03	234	283	0.0384	1.5277	0.0339	0.0076	0.0019	0.023	0.0036	0	0	0.0003	0	0	0.0004
B	448	6395	0.0709	1.8244	0.193	0.0282	0.0078	0.0124	-0.0073	0.0008	0.0044	0.0003	0	0.0073	0.0582
C10-12	4842	79431	0.0533	1.3946	0.5036	0.0253	0.0059	0.002	-0.0112	0	0	0.0631	0	0.0543	0.049
C13-15	2254	21660	0.034	1.5409	0.3781	0.0203	0.0058	0.0042	-0.0035	0.0033	0	0.0307	0	0.0214	0.0469
C16	3802	34971	0.0502	1.3227	0.441	0.0172	0.0058	0.0047	0.0033	0.0031	0.0671	0.0004	0	0.0239	0.0101
C17	1019	18789	0.0781	1.3819	0.4154	0.0248	0.009	0.0035	-0.0017	0	0	0.002	0	0.028	0.0161
C18	463	12444	0.0536	1.5943	0.3241	0.0269	0.009	0.003	0.0056	0	0	0	0	0.0059	0.0004
C19	7	1544	0.6485	1.0612	0.8349	0.0332	0.0142	0.0091	-0.0027	0	0	0.0191	0	0.0119	0.041
C20	459	16812	0.1849	1.1085	0.8021	0.0192	0.0075	0.0021	0.0005	0	0.0017	0.0077	0	0.0764	0.0873
C21	104	10505	0.0673	1.8145	0.218	0.0243	0.0075	0.0033	0.0054	0	0	0.0054	0.0236	0.0212	0.03
C22	679	27163	0.0465	1.5616	0.436	0.0265	0.0079	0.004	0.0085	0.0028	0.0103	0.0034	0	0.0269	0.0302
C23	1697	33127	0.0414	1.6122	0.2644	0.0215	0.0079	0.0091	0.0087	0.0026	0.026	0.0011	0	0.015	0.0131
C24	2639	37414	0.0872	1.3083	0.5346	0.0265	0.008	0.0071	0.0042	0.0053	0	0	0	0.0686	0.0572
C25	2127	65597	0.0401	1.5823	0.4047	0.0238	0.008	0.0037	0.0054	0.0132	0.0116	0.0021	0	0.0381	0.0328
C26	461	21164	0.0496	1.7646	0.1922	0.0378	0.0073	0.0023	0.0013	0.046	0	0.0106	0.0005	0.0384	0.0611
C27	838	41492	0.0459	1.8096	0.3563	0.0296	0.0073	0.0014	0.002	0.0209	0	0.0068	0	0.0506	0.04
C28	1519	69049	0.0545	1.4923	0.5705	0.029	0.0085	0.002	0.0076	0.1155	0.0022	0.0008	0	0.0994	0.0901
C29	365	26418	0.1023	1.2977	0.4101	0.0298	0.0085	0.0016	0.0029	0.071	0	0.0193	0	0.0789	0.0845
C30	115	9932	0.0858	1.3929	0.9631	0.0501	0.0085	0.0019	0.0058	0.0155	0	0.0018	0.0002	0.0196	0.0126
C31_32	6147	48442	0.0325	1.5459	0.4844	0.0201	0.0057	0.0081	0.0109	0.031	0	0.0205	0.0039	0.0294	0.0293
C33	2219	24758	0.0737	1.7116	1.9881	0.001	0.0167	0.0027	0.0125	0.042	0	0	0	0.0068	0.0054
D	2923	29577	0.193	1.2803	0.2504	0.0195	0.0114	0.0044	0.0076	0	0	0.0265	0	0.013	0.0065
E36	319	1860	0.0999	2.5568	0.0404	0.0096	0.0131	0.0071	0.0266	0	0	0	0	0	0
E37-39	2660	13748	0.1128	1.8111	0.0706	0.0127	0.0131	0.0133	0.0082	0	0	0.0005	0	0.0064	0.0117
F	40541	289349	0.0392	1.6356	0.4121	0.0132	0.0072	0.0045	0.0117	0.2993	0.7263	0.0096	0	0.0046	0.0092
G45	12773	79935	0.0228	2.0223	0.4418	0.0133	0.0061	0.0048	0.0182	0.0135	0	0.0257	0	0.0039	0.0004
G46	35476	211081	0.0374	2.4179	0.4638	0.0227	0.0087	0.0051	0.013	0.0391	0.0127	0.0405	0.0088	0.0675	0.0024
G47	54533	367771	0.0136	2.9497	0.3571	0.0161	0.0041	0.0085	0.0188	0.0041	0.0458	0.1216	0.009	0.0013	0
H49	15527	130956	0.0275	2.0273	0.1609	0.019	0.0062	0.0255	0.019	0.0015	0.0017	0.0261	0.0307	0.0352	0.0273
H50	194	650	0.0361	1.2564	0.167	0.053	0.004	0.0018	0.006	0	0.0001	0.0002	0	0.0029	0.0083
H51	315	8345	0.095	1.2358	0.429	0.0555	0.0113	0.0043	0.0084	0	0	0.0089	0	0.007	0.0069
H52	1681	51360	0.0407	2.7059	0.0473	0.0114	0.0096	0.0054	0.0206	0.0008	0.0006	0.0049	0.0259	0.0133	0.0121
H53	681	27422	0.0222	2.1974	1.0301	0.0263	0.0077	0.014	0.0255	0	0	0.0019	0	0.0027	0.0015
I	58156	297890	0.0179	2.7159	0.2657	0.0104	0.0041	0.0161	0.0049	0	0	0.1177	0.0002	0.0163	0.0122
J58	1635	13604	0.0607	1.5737	1.5975	0.0597	0.0107	0.0017	0.0009	0.0074	0	0.0076	0.0009	0.0064	0.0116
J59_60	3754	13894	0.0389	1.5732	0.5533	0.0527	0.0077	0.0033	-0.0297	0.0027	0	0.0063	0	0.0019	0.0048
J61	407	11480	0.143	1.7194	0.1393	0.0323	0.0154	0.003	0.0087	0	0	0.017	0	0.0051	0.0046
J62_63	20232	61985	0.0433	2.0445	1.1161	0.0922	0.0118	0.0031	0.0183	0.0865	0	0	0	0.014	0.0118
K64	2242	80368	0.0447	2.5271	0.2861	0.0219	0.0142	0.0385	0.0165	0	0	0.0172	0.0001	0.0131	0.0076
K65	451	30324	0.048	1.7555	0.5365	0.0167	0.0122	0.0464	0.0216	0	0	0.024	0	0.0065	0.0036
K66	11338	24314	0.03	1.551	2.2166	0.0433	0.0049	0.0252	0.0121	0	0	0.002	0	0.0007	0.0007
L68A	12043	29579	0.3427	3.1659	0.0817	0.0254	0.0111	0.0138	0.0111	0.0046	0.0053	0.1743	0.0006	0.0009	0.0006
M69_70	42306	127617	0.0316	1.9971	0.9906	0.0101	0.0082	0.0051	0.0169	0.0008	0.0013	0.0025	0	0.0112	0.0091
M71	21944	65354	0.0304	2.1107	0.4426	0.0255	0.0072	0.0031	0.0165	0.0213	0.0783	0	0.0019	0.0087	0.0017
M72	2351	14252	0.1489	3.7771	1.4908	0.1989	0.055	0.0136	0.0018	0.138	0	0	0.0022	0.0116	0.0069
M73	14055	36513	0.0372	1.3863	1.5151	0.0331	0.0043	0.0106	0.0076	0	0	0	0.0002	0.0055	0.0065
M74_75	14077	21981	0.0245	2.1126	0.7966	0.0338	0.0036	0.0082	0.0051	0	0	0.0022	0.0002	0.001	0.0004
N77	3578	12244	0.1545	3.2182	0.0896	0.0601	0.0064	0.0051	0.0034	0	0	0.0076	0.0014	0.0058	0.0063
N78	1437	82828	0.0131	8.2178	5.9849	0.047	0.0084	0.0009	0.0453	0	0	0	0	0.0005	0.0007
N79	2692	14603	0.038	1.2591	0.9922	0.0209	0.0048	0.0073	0.0073	0	0	0.0126	0.0018	0.0003	0.0004
N80-82	14290	113132	0.0146	2.7553	0.6147	0.0179	0.0044	0.0059	0.0223	0.0018	0.0042	0.0056	0.0086	0.0015	0.0018
O	10000	251139	0.0213	3.3616	0.1017	0.0118	0.0092	0.043	0.0182	0	0	0.0004	0.3324	0.0009	0.0004
P	12573	115507	0.0351	7.5534	0.1476	0.017	0.0206	0.0258	0.0267	0	0	0.0144	0.2207	0.0001	0.0003
Q86	40749	166917	0.0304	3.484	0.2036	0.0133	0.0121	0.0449	0.0125	0	0	0.0351	0.2371	0.001	0.0007
Q87_88	20452	138958	0.0111	3.3889	0.2328	0.0122	0.0057	0.0306	-0.0348	0	0	0.0249	0.0478	0	0.0029
R90-92	16239	35610	0.0231	3.4512	0.2376	0.0239	0.008	0.0211	-0.0063	0.0023	0	0.0133	0.0129	0.0013	0.0013
R93	6525	22679	0.0192	2.7801	0.067	0.009	0.0041	0.0165	0.0022	0	0	0.0097	0.0047	0.0001	0.0001
S94	7182	57121	0.0142	2.6605	0.1527	0.0089	0.0057	0.0659	0.0316	0	0	0.0111	0.0218	0	0
S95	1979	4947	0.0515	2.3755	2.3548	0.1389	0.0117	0.0193	0.0149	0	0	0.0021	0	0	0
S96	18762	60330	0.0124	3.476	0.1854	0.0129	0.0027	0.0104	0.0134	0	0	0.0172	0.002	0	0.0002

Note: Sectoral parameters are shown for 2010:Q4.

(from 2004 onwards, NACE Rev. 2) (bd_9ac_l_form_r2) to set the number of firms in industries (I_s) according to the

Table D.4: Statistical classification of economic activities in the European Community (NACE Rev. 2)

NACE	Description
A01	Crop and animal production, hunting and related service activities
A02	Forestry and logging
A03	Fishing and aquaculture
B	Mining and quarrying
C10-12	Manufacture of food products, beverages and tobacco products
C13-15	Manufacture of textiles, wearing apparel and leather products
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
C17	Manufacture of paper and paper products
C18	Printing and reproduction of recorded media
C19	Manufacture of coke and refined petroleum products
C20	Manufacture of chemicals and chemical products
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
C22	Manufacture of rubber and plastic products
C23	Manufacture of other non-metallic mineral products
C24	Manufacture of basic metals
C25	Manufacture of fabricated metal products, except machinery and equipment
C26	Manufacture of computer, electronic and optical products
C27	Manufacture of electrical equipment
C28	Manufacture of machinery and equipment n.e.c.
C29	Manufacture of motor vehicles, trailers and semi-trailers
C30	Manufacture of other transport equipment
C31_32	Manufacture of furniture; other manufacturing
C33	Repair and installation of machinery and equipment
D35	Electricity, gas, steam and air conditioning supply
E36	Water collection, treatment and supply
E37-39	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services
F	Construction
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles
G46	Wholesale trade, except of motor vehicles and motorcycles
G47	Retail trade, except of motor vehicles and motorcycles
H49	Land transport and transport via pipelines
H50	Water transport
H51	Air transport
H52	Warehousing and support activities for transportation
H53	Postal and courier activities
I	Accommodation and food service activities
J58	Publishing activities
J59_60	Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities
J61	Telecommuni-cations
J62_63	Computer programming, consultancy and related activities; information service activities
K64	Financial service activities, except insurance and pension funding
K65	Insurance, reinsurance and pension funding, except compulsory social security
K66	Activities auxiliary to financial services and insurance activities
L68B	Real estate activities excluding imputed rents
M69_70	Legal and accounting activities; activities of head offices; management consultancy activities
M71	Architectural and engineering activities; technical testing and analysis
M72	Scientific research and development
M73	Advertising and market research
M74_75	Other professional, scientific and technical activities; veterinary activities
N77	Rental and leasing activities
N78	Employment activities
N79	Travel agency, tour operator reservation service and related activities
N80-82	Security and investigation activities; services to buildings and landscape activities; office administrative, office support and other business support activities
O84	Public administration and defence; compulsory social security
P85	Education
Q86	Human health activities
Q87_88	Social work activities
R90-92	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities
R93	Sports activities and amusement and recreation activities
S94	Activities of membership organisations
S95	Repair of computers and personal and household goods
S96	Other personal service activities

population of active enterprises in t (V.11910). Business demography tables do not include the agriculture, forestry and fishing sector (A01-A03), or the public administration, defense, and compulsory social security sector (O64).

Table D.5: Statistical classification of economic activities in the European Community (NACE Rev. 2)

NACE	Description
A	Agriculture, forestry and fishing
B, C, D and E	Industry (except construction)
F	Construction
G, H and I	Wholesale and retail trade, transport, accomodation and food service activities
J	Information and communication
K	Financial and insurance activities
L	Real estate activities
M and N	Professional, scientific and technical activities; administrative and support service activities
O, P and Q	Public administration, defence, education, human health and social work activities
R and S	Arts, entertainment and recreation; other service activities; activities of household and extra-territorial organizations and bodies

The number of firms in industries A01-A03 is set according to the *"Grüner Bericht"*,[23] and the number of firms in industry O64 (i.e. generic administrative government units) is set at $10,000$. The amount L of foreign firms that import and export goods is not available from business demography data. As a first simplifying assumption, this number is assumed to be 50 per cent of domestically producing firms, which approximately corresponds to the share of exports in total value added. For the classification of industries (s), we use the statistical classification of economic activities in the European Community (NACE). Products (g) are classified according to the classification of products by activity (CPA), which is fully aligned with NACE. Several consolidated tables including input-output tables, demographic data and cross-classification tables are compiled for the euro area and European Union with a breakdown of 64 activities/products (NACE*64, CPA*64). We, therefore, set the number of industries (S) and the number of products (G) to 62 ($S = 62, G = 62$).[24]

Several model parameters concerning the firm agents are directly taken from input-output tables (IOTs) or are derived from them. The input-output framework of the ESA consists of supply and use tables in current prices and the prices of the previous year. Supply and use tables are matrices describing the values of transactions in products for the national economy categorized by product type and industry; see (Eurostat, 2013). We use the symmetric input-output table at basic prices (product by product) (naio_10_cp1700) to set the technology, consumption and capital formation coefficients (a_{sg}, b_g^{HH}, b_g^{CF}, c_g^{G}, c_g^{E} and c_g^{I}). Specifically, we use intermediate consumption (P.2)[25] of 64 (CPA*64) products for the technology coefficient of the g^{th} product in the s^{th} industry a_{sg}. To obtain the technology coefficient, the entries are normalized column-wise. Real estate services (CPA_L68) also include imputed rents. Entries of "services of households as employers, undifferentiated goods and services produced by households for own use" (CPA_T) and "Services provided by extraterritorial organizations and bodies" (CPA_U) contain zeros only and are excluded. The capital formation coefficient of the g^{th} product b_g^{CF} is set according to the gross fixed capital formation (P.51G) as given in the symmetric input-output table. The consumption coefficient of the g^{th} product of households b_g^{HH} is set according to final consumption expenditure by households (P.3) plus final consumption expenditure by non-profit organizations serving households (NPISH). Again, entries are normalized to obtain capital formation and consumption coefficients. The consumption of the g^{th} product of the government c_g^{G}, imports of the g^{th} product c_g^{I} and exports of the g^{th} product (c_g^{E}) are taken directly from the symmetric input-output table by using the final consumption expenditure by the government (P.3), as well as total exports (P.6) and imports (P.7).

[23]In English the *Green report*, which is a yearly report on agricultural development in Austria, as well as on the social and economic situation of Austrian farmers and forest workers. For further reference, see `http://www.awi.bmlfuw.gv.at/index.php?id=gruenerbericht` (Last accessed November 30th, 2018).

[24]We do not include the sectors *"Services of households as employers and services produced by households for own use"* (T), as well as, *"Services provided by extraterritorial organisations and bodies"* (U) in the model.

[25]The accounting code of the European System of Accounts (ESA) data source is given in brackets. In this coding system, the capital letter D represents a figure from the distributive transactions account, while a P indicates data from the transactions in products and non-produced asset account. The letter B generally stands for a balancing item, i.e. the subtraction of one side of an account from the other. Balancing items carry much of the most vital information in these data. For example, operating surplus/mixed income (B.2A3N) is obtained by subtracting the cost factors compensation of employees and taxes on products from value added. The capital letter F indicates a financial asset/liability for financial balance sheets, e.g. F.2 indicates currency and deposits. The numbers after the letters indicate the type of transaction/balancing item/asset class, in a similar coding system as IO classification with increasing amount of detail in the classification as the amount of digits increases. This means that, e.g. D.41 (interest payments) is a sub-category of D4 (property income).

For some parameters, we need to combine the logic of annual sectoral accounts and IOTs. The information by institutional sector in the sector accounts and the information by industry or product in the supply and use tables can be linked by cross-classification tables. We use the cross-classification tables and structural business statistics (business demography) to complement symmetric IOTs. Specifically, we are using business demography data (bd_9ac_l_form_r2) to set the average productivity of labour for firm i ($\bar{\alpha}_i$), which is assumed to be equal across firms in each industry s, but different between industries ($\bar{\alpha}_i = \alpha_s \quad \forall i \in I_s$). It is defined by output (P.1) in the industry divided by the number of persons employed in the population of active enterprises in t (V.16910) in the industry.[26] The average wage that employees receive from firm i ($\bar{w}_i = \frac{w_s}{N_s} \quad \forall i \in I_s$) (which is industry-specific) is defined by wages and salaries (D.11) in the industry divided by the number of persons employed in the population of active enterprises in t (V.16910) in the industry. The average productivity of capital in the i^{th} firm (κ_i) is set using cross-classification of fixed assets by industry and by asset (stocks) (nama_10_nfa_st) and is again assumed to be equal across firms by industries ($\kappa_i = \kappa_s \quad \forall i \in I_s$) and different across industries s. It is defined by output (P.1) in the industry divided by total fixed assets (net) (N11N)[27] in the industry multiplied by the desired capacity utilization rate (ω, see Online Appendix E.1). An exception is the sector L68 (real estate services), where the stock of household dwellings ($K_h(0)$) is included that has no productive use in the economy regarding the output of goods and services on markets, and thus has to be treated differently. We remove the stock of dwellings from sector L68 and attribute it to the household sector, see Online Appendix E.2. The productivity of intermediate consumption goods of firm i (β_i) is again the same for each firm in industry s, but differs across industries ($\beta_i = \beta_s \quad \forall i \in I_s$). It is defined by output (P.1) in the industry divided by total intermediate consumption (P.2) of the industry from symmetric input-output tables. The average depreciation of capital in the i^{th} firm (δ_i) is again heterogeneous across industries and homogenous across firms by industry ($\delta_i = \delta_s \quad \forall i \in I_s$). It is defined by the of fixed capital (P.51C1) in the industry divided by total fixed assets (net) (N11N) in the industry multiplied by the desired capacity utilization rate.

Firms' dividend payout ratio θ^{DIV} is set to match interest and dividend receipts (D.4 received) plus mixed income (B.2A3N)[28] by the household sector in sector accounts (non-financial transactions (nasa_nf_tr)) in relation to total net operating surplus and mixed income (B.2A3N) as obtained from IOTs. As these payments also include interest payments to the household sector, the dividend payout ratio can be seen as the total return property rights ownership in non-financial and financial firms by the household sector and is set accordingly for each individual firm.

Appendix D.2. Households

Parameters that specify the number of households (persons) are taken directly (or derived from) census data. A population census provides a numerical picture of the structure of the population, households and families in a country. We use the register-based census and the register-based labour market statistics in Austria conducted by Statistik Austria and supplied via Eurostat. Specifically, we are using statistics on population by current activity status, NACE Rev. 2 activity and NUTS 2 region (cens_11an_r2) to set the constant number of inactive persons (H^{inact}). The total number of economically active persons (H^{act}) is set to the total number of persons employed in the population of active enterprises in t (V16910) plus the total number of unemployed and one investor for each firm. The total number of unemployed (plus the labour reserve) is taken from the European Labour Force Survey (LFS).[29]

[26]The Labour force survey (LFS) defines an employee as an individual who works for a public or private employer and who in return receives compensation in the form of wages, salaries, fees, gratuities, payment by results or payment in kind. Professional military staff are also included (`http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Employee_-_LFS`). In the context of the Labour Force Survey (LFS), an employed person is a person aged 15 and over (or 16 and over in Iceland and Norway) who, during the reference week, performed work—even if just for one hour a week—for pay, profit or family gain. For further information, see `http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Employed_person_-_LFS` (Last accessed November 30^{th}, 2018).

[27]We use total fixed assets (net) because the gross capital stock includes the values of the accumulated consumption of fixed capital. Most fixed assets can be recorded in balance sheets at current purchasers' prices reduced for the accumulated consumption of fixed capital; this is known as the written-down replacement cost. The sum of the reduced values of all fixed assets still in use is described as the net capital stock. The gross capital stock includes the values of the accumulated consumption of fixed capital.

[28]In the logic of IOTs, the self-employed are attributed to firm sectors. Thus, operating surplus of IO sectors includes mixed income, which directly flows to households in the depiction of our model and is thus treated as dividend income.

[29]The number of unemployed and employed persons extracted from the Labour Force Survey (LFS) complies with the ILO definition. According to the ILO definition, unemployed persons are defined as persons who are without work during the reference week, are currently available to work and have either actively been seeking work during the past four weeks or have already found a job to start within the next three months. The LFS

Households' marginal propensity to consume out of initial disposable income (ψ) is chosen such that consumption out of disposable income ($\psi Y_h(0)$) equals actual household and NPISH consumption in IOTs (P.3 in sectors S.14, S.15). The parameter ψ^{H} capturing the fraction of household expected disposable income $Y_h(0)$ which is invested gross of taxes every period is set according to IOTs. We set ψ^{H} and the household investment coefficients b_g^{CFH} such that investment in dwellings as obtained from IOTs for Austria provided by Statistik Austria[30] is consistent. The replacement rate for unemployment benefits θ^{UB} is chosen according to the statutory replacement rate of 55 per cent of the net income, which amounts to a replacement rate on the gross income of $\theta^{\mathrm{UB}} = 0.55(1 - \tau^{\mathrm{INC}})(1 - \tau^{\mathrm{SIW}})$.

Appendix D.3. The general government

The number of government entities (J) is set to 25 per cent of domestically producing firms, which roughly equals the share of government consumption in total value added. This corresponds to a realistic depiction of public entities comprising municipalities, public schools, social insurance carriers, and districts, among others, in Austria according to their participation in the Austrian economy.

Tax and subsidy rates are set such that these rates approximate the actual financial flows observed in sector accounts, i.e. non-financial transactions (nasa_10_nf_tr), as well as government revenue, expenditure and main aggregates (gov_10a_main). In the context of the model, we define an average tax rate as the aggregate tax flow paid by an institutional sector (firms in CPA classification, households, etc.) divided by the corresponding aggregate monetary flow that serves as the base for the tax and that is received by the same institutional sector (such as income, profit, output, fixed assets, etc.). This average tax rate obtained from macroeconomic aggregates is then applied to every individual unit/person in our model in the corresponding economic context. The income tax rate τ^{INC} on income from both labour and capital is particularly chosen such that tax payments on wages received by employees and taxes on dividends received by investors add up to total income tax payments by the household sector taken from government expenditure data (gov_10a_main, D.5REC and D.91REC).[31] For reasons of model parsimony, we abstract from the progressivity of the Austrian tax system (e.g. regarding income taxes) and secondly from other tax regulations (deductions, exemptions, etc.) relevant for some agents due to specific features of the Austrian tax code.

Firm profit taxes τ^{FIRM} are specified by the ratio of total corporate tax flows (D.51, paid by sectors S.11 and S.12), which are obtained from sector accounts (non-financial transactions (nasa_nf_tr)), to total operating surplus and mixed income (sum over all firm sectors), which we directly take from IOTs (B.2A3N). Value added tax rates τ^{VAT} are specified as total value added taxes net of subsidies (D.21X31) from IOTs divided by consumption by households and NPISH (P.3 in sectors S.14 and S.15). Rates for social security contributions both for employers (τ^{SIF}) and employees (τ^{SIW}) are levied on the gross wage income of households (D.11) as given in IOTs. Employers' social security contributions are taken from IOTs by subtracting total gross wage income (D.11) from the total compensation of employees (D.1). Employees' social contributions include actual social security contributions (D.613) as well as social security supplements to be paid by employees (D.614) and are obtained by subtracting employers' social contributions from total social contributions received by the government according to government statistics (gov_10a_main, D.61REC). Finally, sector-specific net rates for other taxes and subsidies on products ($\tau_i^{\mathrm{Y}} = \tau_s^{\mathrm{Y}} \quad \forall i \in I_s$) as well as on production ($\tau_i^{\mathrm{K}} = \tau_s^{\mathrm{K}} \quad \forall i \in I_s$) are taken from IOTs: sectoral product tax (D.21X31) and production tax (D.29X39) payments. Tax rates on exports (τ^{EXPORT}), which are levied on total firms' exports as in IOTs (P.6 total) as a uniform tax rate according to total net export tax flows in IOTs (D.21X31 for final use export, P.6). Taxes on capital formation (τ^{CF}) payable on firm investments are determined by dividing tax flows on investments in dwellings by total investments in dwellings (obtained from IOTs provided by Statistik Austria, see Footnote 30). The interest rate on government debt (r^{G}) is obtained from government statistics (gov_10q_ggdebt, gov_10q_ggnfa) and is calibrated to the interest due per quarter by the general government as a proportion of the total government debt.

also provides information on persons who do not meet the ILO criteria for unemployment but who are willing and available to work within short notice (labour reserve).

[30] See `https://www.statistik.at/web_en/statistics/Economy/national_accounts/input_output_statistics/index.html` (Last accessed November 30th, 2018) for more information on IOTs provided by Statistik Austria. More detailed IOTs for Austria, which include a breakdown of investment into different investment purposes (dwellings, other buildings and structures, machinery, transport equipment, cultivated assets, and intangible fixed assets), can be purchased. This is the only case where we do not rely on publicly and freely available data from the Eurostat bulk download facility.

[31] From national accounting data alone, it is not possible to distinguish between the amount of income taxes due to incomes from labour and capital, respectively. For this distinction, it would be necessary to resort to the Austrian tax code and household surveys.

Appendix D.4. The Bank

Banks' capital requirement coefficient (ζ) is set at 3 per cent. A capital requirement of 3 per cent corresponds to the maximum leverage ratio (tier 1 capital in relation to total exposure) as recommended in the Basel III framework. The rate of debt instalment (θ) is set such that firms repay 5 per cent of their total outstanding debt every quarter. The risk premium (μ) paid on firms' outstanding debt is obtained from sector accounts. It is calibrated such that total interest payments in our model financial market, where firm debt constitutes the only financial asset held by the banking sector, matches empirically observed interest payments (D.41) paid by non-financial (S.11) and financial corporations (S.12) in the sector accounts (non-financial transactions (nasq_10_nf_tr)). Therefore, the risk premium (μ) is calculated by the difference between the 3-month Euribor interest rate obtained from money market interest rates (irt_st_q) and the observed interest payments (D.41) divided by the liabilities of non-financial corporations (S.11), which is obtained from sector accounts (financial balance sheets (nasq_10_f_bs)).

The bank's maximum loan-to-value (LTV) ratio (ζ^{LTV}) is set to 60 per cent. LTV is one of the most common ratios considered for secured loans, and loans with an LTV ratio below 60 per cent are typically considered as low- or medium-risk loans. Finally, the loan-to-value ratio for a new firm replacing a bankrupt firm ζ^{b} is set to be equal to 0.5.

Appendix E. Initial conditions of the ABM for the Austrian economy

This section presents details on the initial conditions for the model presented in Online Appendix A in the main text. Initial conditions for the ABM are always set to one reference quarter representing the Austrian economy. For the forecasting exercise in Section 5 in the main text, initial conditions were set to represent *28* different reference quarters from the first quarter of 2010 to the last quarter of 2016. Here in Table E.1, we show, as an example, initial conditions for 2010:Q4.

Table E.1: Initial conditions

Initial condition	Description	Value
$P_i(0)$	Initial price of the i^{th} firm	see Online Appendix E.1
$Y_i(0)/Q_i^{\text{d}}(0)$	Initial production/demand of the i^{th} firm (in mln. Euro)	see Online Appendix E.1
$K_i(0)$	Initial capital of the i^{th} firm (in mln. Euro)	see Online Appendix E.1
$M_i(0)$	Initial stocks of raw materials, consumables, supplies of the i^{th} firm (in mln. Euro)	see Online Appendix E.1
$S_i(0)$	Initial stocks of finished goods of the i^{th} firm (in mln. Euro)	see Online Appendix E.1
$N_i(0)$	Initial number of employees of the i^{th} firm	see Online Appendix E.1
$D_i(0)$	Initial liquidity (deposits) of the i^{th} firm (in mln. Euro)	see Online Appendix E.1
$L_i(0)$	Initial debt of the i^{th} firm (in mln. Euro)	see Online Appendix E.1
$\Pi_i(0)$	Initial profits of the i^{th} firm (in mln. Euro)	see Online Appendix E.1
$D_h(0)$	Initial personal assets (deposits) of the h^{th} household (in mln. Euro)	see Online Appendix E.2
$K_h(0)$	Initial household capital (in mln. Euro)	see Online Appendix E.2
$w_h(0)$	Initial wage of the h^{th} household (in mln. Euro)	see Online Appendix E.2
$sb^{\text{inact}}(0)$	Initial pension/social benefits in mln. Euro	0.0023
$sb^{\text{other}}(0)$	Initial social benefits received by all households in mln. Euro	0.0005
$L^{\text{G}}(0)$	Initial government debt (in mln. Euro)	244696.8
$\Pi_k(0)$	Initial banks' profits (in mln. Euro)	see Online Appendix E.4
$E_k(0)$	Initial banks' equity (in mln. Euro)	106948
$E^{\text{CB}}(0)$	Initial central banks' equity (in mln. Euro)	107627.8
$D^{\text{RoW}}(0)$	Initial net creditor/debtor position of the national economy to RoW (in mln. Euro)	0

Note: Initial conditions are shown for 2010:Q4.

Table E.2: Initial conditions for the institutional sectors

Initial condition	Description	Value
D^{I}	Initial liquidity (deposits) of the firm sector (in mln. Euro)	52141
L^{I}	Initial debt of the firm sector (in mln. Euro)	244953
ω	Desired capacity utilization rate	0.85
w^{UB}	Initial unemployment benefits (in mln. Euro)	0.0042
D^{H}	Initial personal assets (deposits) of the household sector (in mln. Euro)	222933
K^{H}	Initial capital (dwellings) of the household sector (in mln. Euro)	405376.9

Note: Initial conditions are shown for 2010:Q4.

Appendix E.1. Firms

The distribution of firm sizes in industrial countries is well-known to be highly skewed, with large numbers of small firms coexisting with small numbers of large firms (Ijiri and Simon, 1977; Axtell, 2001). Initial employment of firm i ($N_i(0) \quad \forall i \in I_s$) is therefore drawn from a power law distribution with exponent -2 (where $\sum_{i \in I_s} N_i(0) = N_s$ and $N_i(0) > 0$), which approximately corresponds to firm size distribution in Austria.[32] To determine initial production

[32] The firm size distribution is obtained from the SABINA database.

$Y_i(0)$ of the i th firm, we use the initial employment by firm $N_i(0)$, and compute the corresponding amount of production by the productivity of labour per unit of output $\bar{\alpha}_i$:

$$Y_i(0) = Q_i^{\mathrm{d}}(0) = \bar{\alpha}_i N_i(0) \,.$$

The initial capital of firm i, $K_i(0)$, (i is part of industry s) is then obtained by dividing firm i's initial level of production $Y_i(0)$ by the productivity of capital κ_i and the desired rate of capacity utilization ω.

$$K_i(0) = \frac{Y_i(0)}{\kappa_i \omega} \,.$$

Thus, it is the share of the capital of the i th firm in sector s as measured by production, accounting for the reserve capacity of its capital stock targeted by firm i. The initial stocks of raw materials, consumables, supplies, and spare parts (i.e. intermediate inputs) of the i^{th} firm ($M_i(0)$) are set such that—given the initial level of production by firm i, the productivity of intermediate inputs β_i and a buffer stock of material inputs $1/\omega$—firms hold enough intermediate inputs to be able to provide for the expected use of these inputs as well as accounting for their desired buffer stock:

$$M_i(0) = \frac{Y_i(0)}{\omega \beta_i} \,.$$

Regarding financial and current assets cross-classification tables are not available. Correspondingly, a breakdown of financial and current assets for the 64 economic activities (NACE*64) is not available in macroeconomic data. Thus, we apportion initial debt $L_i(0)$ to the i^{th} individual firm by disaggregating total firm debts according to the share of the firms' capital stock $K_i(0)$ in the total capital stock $\sum_i K_i(0)$:

$$L_i(0) = L^{\mathrm{I}} \frac{K_i(0)}{\sum_i K_i(0)} \,,$$

where the total amount of firm debt L^{I} is obtained from national accounting data (financial balance sheets (nasa_10_f_bs), loans (F.4) of non-financial corporations (S.11), non-consolidated liability position). The total initial liquidity (deposits) of all firms as an aggregate, D^{I}, is set according to national accounting data (financial balance sheets (nasa_10_f_bs), non-consolidated deposits (F.2) held by the non-financial corporations (S.11)). This aggregate is broken down onto single firms by the share of firm i's operating surplus in the overall operating surplus, where we assume that firm liquidity (deposits) moves in line with its production as a liquid form of working capital used for current expenditures:

$$D_i(0) = D^{\mathrm{I}} \frac{\max(\bar{\pi}_i Y_i(0), 0)}{\sum_i \max(\bar{\pi}_i Y_i(0), 0)} \,,$$

where $\bar{\pi}_i = 1 - \left(1 + \tau^{\mathrm{SIF}}\right) \frac{\bar{w}_i}{\bar{\alpha}_i} - \frac{\delta_i}{\kappa_i} - \frac{1}{\beta_i} - \tau_i^{\mathrm{K}} - \tau_i^{\mathrm{Y}}$ is the operating margin. Initial profit of the i^{th} firm is given by the initial operating surplus and the initial income from interest less interest payments:

$$\Pi_i(0) = \bar{\pi}_i Y_i(0) - r(0) L_i(0) + \bar{r}(0) D_i(0) \,.$$

The initial inventories of finished goods $S_i(t)$ of firm i is assumed to be equal to zero due to a lack of reliable data sources. The initial price of the i^{th} firm $P_i(0)$ is set to one.

Appendix E.2. Households

Initial personal assets (deposits) of the h^{th} household ($D_h(0)$) are obtained from national accounting data (financial balance sheets (nasa_10_f_bs), F.2, currency and deposits held by the household and NPISH sectors, S14_S15, non-consolidated asset position), which is disaggregated onto the individual level according to the share of each household's income in total income as a proxy for the household's wealth:

$$D_h(0) = D^{\mathrm{H}} \frac{Y_h(0)}{\sum_h Y_h(0)} \,,$$

where D^{H} are the initial personal assets (deposits) of the household sector and $Y_h(0)$ is determined according to Equation (A.53) in the main text. Initial capital (dwellings) of the h^{th} household ($K_h(0)$) is set to match dwellings

(N111N) as obtained from balance sheets for non-financial assets (nama_10_nfa_st) and is again disaggregated onto the individual level according to the share of each household's income in total income as a proxy for the household's wealth:

$$K_h(0) = K^{\mathrm{H}} \frac{Y_h(0)}{\sum_h Y_h(0)} ,$$

where K^{H} is the initial capital (dwellings) of the household sector.

The initial wage of the h^{th} household ($w_h(0)$) is equal to the initial wage paid by firm i ($\bar{w}_i$), if i is the employer of household h; or it is equal to the initial unemployment benefits w^{UB}, if the household is unemployed. Initial unemployment benefits are set by dividing the total flow of unemployment payments (GF.1005), as obtained from the Eurostat data set government expenditure by function (gov_10a_exp), by the number of unemployed persons (wstatus=UNE), which is determined according to the statistics on population by current activity status, NACE Rev. 2 activity and NUTS 2 region (cens_11an_r2). Thus, $w_h(0)$ is determined as follows:

$$w_h(0) = \begin{cases} \bar{w}_i & \text{if employed by firm } i \\ \frac{w^{\mathrm{UB}}}{\theta^{\mathrm{UB}}} & \text{if unemployed} \end{cases} .$$

Transfers other than consumption, savings, taxes and subsidies[33] are netted out for the government and household sectors and treated as a net transfer from the government to the household sector. Government transfers to households in the form of social benefits (D.62) are attributed to the different household (consumer) types according to their employment status. The data are taken from national accounting statistics on general government expenditures by function (COFOG classification, Eurostat table gov_10a_exp), which are used to allocate the total flow of the different social benefits ($sb^{\mathrm{inact}}(0)$, $sb^{\mathrm{other}}(0)$) from the government to persons to whom this transfer applies. To break the overall economic flows of social benefits down onto an individual household level, we follow the following procedure: all social benefits are given in equal proportion to the different household types such that the sum of individual flows adds up to total macroeconomic flows.

Appendix E.3. The general government

Initial government debt ($L^{\mathrm{G}}(0)$) is set according to the Austrian government's (sector S.13) consolidated gross debt (GD) as obtained from the Eurostat data set government deficit/surplus, debt and associated data (gov_10dd_edpt1).

Appendix E.4. The Bank

Initial bank's equity ($E_k(0)$) is obtained from national accounting data (financial balance sheets (nasa_10_f_bs), F.5 and BF.90, non-consolidated equity and financial net worth of monetary financial institutions other than the central bank (S122_S123)). Initial bank's profits are given by the initial income from interest less interest payments:

$$\Pi_k(0) \; = \mu \sum_i L_i(0) + \bar{r}(0) E_k(0) ,$$

where initial advances from the central bank ($D_k(0)$) are set according to Equation (A.68) in the main text.

Appendix E.5. The Central Bank

Initial central bank's equity ($E^{\mathrm{CB}}(0)$) is the residual on the central bank's passive side, obtained by deducting initial bank reserves held ($D_k(0)$) and the initial net creditor/debtor position with the rest of the world ($D^{\mathrm{RoW}}(0)$) from the central bank's assets (initial government debt ($L^{\mathrm{G}}(0)$)). Thus, the initial central bank's equity ($E^{\mathrm{CB}}(0)$) is set according to Equation (Appendix A.5.2) in the main text where the initial balance of trade with the rest of the world ($D^{\mathrm{RoW}}(0)$) is assumed to be zero and the initial bank reserves held ($D_k(0)$) are set according to Equation (A.68) in the main text.

[33] In particular property and interest income (D.4) in the government sector, other current transfers (D.7), adjustments for changes in pension entitlements (D.8), as well as capital transfers other than capital taxes (D.9 - D.91)

Appendix F. DSGE model used for out-of-sample forecasting

Appendix F.1. DSGE model: Short description

The DSGE model used for out-of-sample forecasting is a two-country New Keynesian New Open Economy macro model of the Austrian economy (home) and the euro area (foreign), constructed tightly along the lines of Smets and Wouters (2007). It is a modified version of the two-country DSGE model as put forth in Breuss and Rabitsch (2009). Specifically, this model was modified to achieve comparability with the Smets and Wouters (2007) model through the rescaling of several shocks and estimating the model to growth rates, both of which stabilized the Bayesian estimation procedure.

The two-country economy is normalized to one, where the size of the home economy equals n, the size of the foreign economy equals $(1 - n)$. Firms in each region produce goods using capital and labour according to a Cobb-Douglas production function. Each of the two countries specializes in the production of one region-specific good, i.e. there are both domestic and foreign tradable goods. These domestic and foreign tradable goods come in several varieties, over which producers have some degree of power in price-setting. Investment is assumed to be a constant elasticity of substitution (CES) index over domestic and foreign investment goods. Financial markets are assumed to be complete, that is, a full set of Arrow-Debreu securities is assumed to exist. Households receive utility from consumption and disutility from working. They also own the economy's capital stock, which they rent to firms as means of production, and supply a variety of differentiated labour services, over which they have some degree of power in wage-setting. Furthermore, household consumption is assumed to be a CES index over domestic and foreign consumption goods, which is possibly different from the CES investment index. In line with recent literature on DSGE models, a number of both real and nominal frictions is assumed. First, costs for capital adjustment and habit formation are imposed. Second, some degree of stickiness for both prices set by firms and wages demanded by households is assumed according to Calvo (Calvo, 1983) staggered price and wage-setting mechanisms. Both prices and wages are partially indexed, that is, they are to some degree inflation-adjusted in the event that price or wage changes are not possible. The DSGE model is estimated using Bayesian methods on a quarterly basis and on the same data set as the time series models.

Below, the model equations for the home economy are set out, assuming that the foreign economy is described by an analogous set of equations unless this is explicitly stated otherwise. All foreign variables are denoted with an asterisk (*).

Appendix F.2. Consumption

Appendix F.2.1. Households' intertemporal optimization

The domestic economy is assumed to be populated by a continuum of household agents over the interval [0,n), foreign household agents are populated over (n,1]. Each household is indicated by the index j. Household j intends to maximize her discounted expected lifetime utility, which is assumed to be separable in consumption and leisure. Household j derives utility from consumption $C_t(j)$ in relation to a habit level H_t, and disutility from providing a differentiated type of labour $L_t(j)$:

$$\underset{C_t(j),l_t(j),B_{t+1}(j),K_{t+1}(j)}{max} E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \left(\frac{(C_t(j) - H_t)^{1-\sigma_c}}{1-\sigma_c} \right) \exp\left(\frac{-(1-\sigma_c)}{1+\sigma_l} L_t(j)^{1+\sigma_l} \right) \right\} \tag{F.1}$$

where β is the discount factor, σ_c is the coefficient of relative risk aversion (the inverse of the intertemporal elasticity of substitution), and σ_l is the inverse of the elasticity of work effort with respect to the real wage.

The habit level H_t is assumed to be proportional to aggregate past consumption:

$$H_t = hC_{t-1}.$$

The (domestic) household budget constraint is determined by total household income from different sources, and by nominal expenditures for consumption ($P_tC_t(j)$) and investment ($P_t^X X_t(j)$), where P_t and P_t^X are the price indices for consumption and investment goods, respectively, which may differ from each other. Sources of income for household j are wages received ($W_t^{hh,nom}(h, j)L_t(j)dh$), income from the rental of capital to firms for production purposes ($R_t^{k,nom}u_t(j)\overline{K}_{t-1}$), dividend payments from firm ownership ($\frac{1}{n}\int_0^n Div(h, j)dh$), and net government transfers

$T_t(j)$. Under the assumption of *complete markets*, each individual household has access to a full set of state-contingent (Arrow-Debreu) securities. In the following, we denote the price of one unit of domestic currency available in period $t+1$ contingent on the state of nature at $t+1$ being s_{t+1} by $Q(s_{t+1}|s_t)$. Assuming complete markets, $Q(s_{t+1}|s_t)$ is the same for all individual households. If now $B_{H,t}(j, s_{t+1})$ represents the claim to $B_{H,t}$ units of domestic currency at time $t+1$ for the state of nature s_{t+1}, which a household j can buy at time t and carry over into time $t+1$. $Q^*(s_{t+1}|s_t)$ and $B_{F,t}(j, s_{t+1})$ are defined analogously in terms of foreign currency. Nominal interest rates can thus be expressed by $R_t = 1/(\sum_{s_{t+1}} Q(s_{t+1}|s_t))$ and $R_t^* = 1/(\sum_{s_{t+1}} Q^*(s_{t+1}|s_t))$. Now let S_t denote the nominal exchange rate of domestic currency per unit of foreign currency.

The household budget constraint, which is subject to a risk shock ε_t^b, is thus given by:

$$\sum_{s_{t+1}} Q(s_{t+1}|s_t)\varepsilon_t^b B_{H,t}(j, s_{t+1}) + \sum_{s_{t+1}} Q^*(s_{t+1}|s_t)\varepsilon_t^b S_t B_{F,t}(j, s_{t+1}) =$$

$$\left[\begin{array}{c} B_{H,t-1}(j, s_t) + S_t B_{F,t-1}(j, s_t) + \\ W_t^{hh,nom}(h, j)L_t(j)dh + R_t^{k,nom}u_t(j)\overline{K}_{t-1}(j) + a\left(u_t(j)\overline{K}_{t-1}(j)\right)P_t \\ +\frac{1}{n}\int\limits_0^n Div(h, j)dh + T_t(j) - P_t^X X_t(j) - P_t C_t(j) \end{array}\right], \tag{F.2}$$

where $R_t^{k,nom}$ is the nominal return rate to physical capital, $u_t(j)$ is the capital utilization rate as chosen by the household agent and $\overline{K}_{t-1}$ is the previous period's physical capital stock.

Since households choose the utilization rate of capital, the amount of effective capital that households rent to firms is:

$$K_t(j) = u_t(j)\overline{K}_{t-1}(j).$$

Furthermore, $a\left(u_t(j)\overline{K}_{t-1}(j)\right)$ are costs for the utilization of capital that depend on the real return rate on capital, the utilization rate of capital and a fixed parameter ϕ_a as follows:

$$a\left(u_t(j)\overline{K}_{t-1}(j)\right) = \left[\overline{r}^k (u_t(j) - 1) + \frac{\phi_a}{2}(u_t(j) - 1)^2\right]\overline{K}_{t-1}(j), \tag{F.3}$$

where $\overline{r}^k$ denotes the real rate of return on capital in the steady state ($\overline{r}^k = \frac{\overline{R}^{k,nom}}{\overline{P}}$). The law of motion for capital reads as follows:

$$\overline{K}_t(j) = (1-\delta)\overline{K}_{t-1}(j) + \varepsilon_t^X\left[1 - \frac{\phi_K}{2}\left(\frac{X_t(j)}{X_{t-1}(j)} - \gamma\right)^2\right]X_t(j), \tag{F.4}$$

where δ is the depreciation rate of physical capital, and $\left[1 - \frac{\phi_K}{2}\left(\frac{X_t(j)}{X_{t-1}(j)} - \gamma\right)^2\right]$ is a function that transforms investment into physical capital stock including adjustment costs for investment, where, similar to the utilization of capital above, investment above the steady state growth rate γ bears additional costs. Furthermore, ϕ_K represents a fixed parameter for investment adjustment costs, γ is the trend growth rate in the steady state of the exogenous productivity factor, and ε_t^X is an exogenous shock to investment. The shocks to household bond holdings and investment follow autoregressive processes with coefficients ρ_b, ρ_X and i.i.d. error terms η_t^b, η_t^X with variances σ_B, σ_X:

$$\ln\varepsilon_t^b = \rho_b \ln\varepsilon_{t-1}^b + \eta_t^b, \eta_t^b \sim N(0, \sigma_B)$$
$$\ln\varepsilon_t^X = \rho_X \ln\varepsilon_{t-1}^X + \eta_t^X, \eta_t^X \sim N(0, \sigma_X)$$

Households maximize utility, Equation (F.1) subject to the demand for labour, Equation (F.39) as defined below, the budget constraint, Equation (F.2), and the capital law of motion, Equation (F.4). If one denotes the Lagrange multiplier of the household budget constraint by $\Lambda_t(j)$, and the household constraint regarding the capital law of motion by $Q_t(j)$, one can derive the respective first-order conditions listed as follows.

Consumption C_t^j:

$$\Lambda_t(j) = (C_t(j) - hC_{t-1})^{-\sigma_c} \exp\left(\frac{-(1-\sigma_c)}{1+\sigma_l} L_t(j)^{1+\sigma_l}\right) \tag{F.5}$$

Labour supply L_t^j:

$$\left[\frac{(C_t(j) - hC_{t-1})^{1-\sigma_c}}{1-\sigma_c}\right] \exp\left(\frac{-(1-\sigma_c)}{1+\sigma_l} L_t(j)^{1+\sigma_l}\right)(\sigma_c - 1) L_t(j)^{\sigma_l} = -\Lambda_t(j) \frac{W_t^{hh,nom}(h,j)}{P_t} \tag{F.6}$$

Domestic and foreign Arrow-Debreu securities holdings, $B_{H,t}^j$ and $B_{F,t}^j$:

$$\Lambda_t(j) \sum_{s_{t+1}} Q(s_{t+1}|s_t)\varepsilon_t^b = \beta E_t\left\{\Lambda_{t+1}(j) \frac{P_t}{P_{t+1}}\right\} \tag{F.7}$$

$$\Lambda_t(j) \sum_{s_{t+1}} Q^*(s_{t+1}|s_t)\varepsilon_t^b S_t = \beta E_t\left\{\Lambda_{t+1}(j) \frac{S_{t+1}}{S_t}\frac{P_t}{P_{t+1}}\right\} \tag{F.8}$$

where S_t denotes the nominal exchange rate of domestic currency per unit of foreign currency.
Investment X_t^j:

$$\begin{aligned}\Lambda_t(j)\frac{P_t^X}{P_t} &= Q_t(j)\Lambda_t(j)\frac{P_t^X}{P_t}\left\{\begin{array}{c}\varepsilon_t^X\left[1 - \frac{\phi_K}{2}\left(\frac{X_t(j)}{X_{t-1}(j)} - \gamma\right)^2\right] \\ -\varepsilon_t^X \phi_K\left(\frac{X_t(j)}{X_{t-1}(j)} - \gamma\right)\frac{X_t(j)}{X_{t-1}(j)}\end{array}\right\} \\ &\quad + \beta Q_{t+1}(j)\Lambda_{t+1}(j)\frac{P_{t+1}^X}{P_{t+1}}\varepsilon_{t+1}^X\left[\phi_K\left(\frac{X_{t+1}(j)}{X_t(j)} - \gamma\right)\right]\left(\frac{X_{t+1}(j)}{X_t(j)}\right)^2\end{aligned} \tag{F.9}$$

Capital stock $\overline{K}_t^j$:

$$Q_t(j)\Lambda_t(j)\frac{P_t^X}{P_t} = \left\{\begin{array}{c}\beta E_t Q_{t+1}(j)\Lambda_{t+1}(j)\frac{P_{t+1}^X}{P_{t+1}}(1-\delta) + \\ \beta E_t \Lambda_{t+1}(j)\left[\frac{R_{t+1}^{k\ nom}}{P_{t+1}} u_{t+1}(j) - \left[\overline{r}^k (u_{t+1}(j) - 1) + \frac{\phi_a}{2}(u_{t+1}(j) - 1)^2\right]\right]\end{array}\right\} \tag{F.10}$$

Capacity utilization u_t^j:

$$\frac{R_t^{k,nom}}{P_t} = \left(\overline{r}^k + \phi_a(u_t(j) - 1)\right) \tag{F.11}$$

Appendix F.2.2. Households' intratemporal optimization

Consumption. Each consumer j's overall consumption, $C_t(j)$, is composed of a bundle of domestic and foreign consumption goods indexed by H and F, which are subject to a constant elasticity of substitution (CES):

$$C_t(j) = \left[\gamma_c^{\frac{1}{\epsilon}} C_{H,t}^{\frac{\epsilon-1}{\epsilon}}(j) + (1-\gamma_c)^{\frac{1}{\epsilon}} C_{F,t}^{\frac{\epsilon-1}{\epsilon}}(j)\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{F.12}$$

where ϵ denotes the elasticity of substitution between the bundles of domestic and foreign goods, and γ_c is the share parameter in the CES consumption function. Domestic (foreign) consumption $C_{H,t}$ ($C_{F,t}$) again are CES bundles over many varieties of domestic (foreign) goods ($c_t(h,j), c_t(f,j)$), according to a constant elasticity of substitution θ:

$$C_{H,t}(j) = \left[\left(\frac{1}{n}\right)^{\frac{1}{\theta}} \int_0^n c_t(h,j)^{\frac{\theta-1}{\theta}} dh\right]^{\frac{\theta}{\theta-1}} \tag{F.13}$$

$$C_{F,t}(j) = \left[\left(\frac{1}{1-n}\right)^{\frac{1}{\theta}} \int_n^1 c_t(f,j)^{\frac{\theta-1}{\theta}} df\right]^{\frac{\theta}{\theta-1}} \tag{F.14}$$

In each period, the consumer allocates her consumption of domestic varieties by minimizing expenditure: $\min_{c_t(h)} \int_0^n p_t(h)c_t(h,j)dh - P_{H,t}C_{H,t}(j)$. By inserting Equation (F.13) and minimizing with respect to $c_t(h,j)$, one obtains the optimal demand function as follows:

$$c_t(h,j) = \frac{1}{n}\left(\frac{p_t(h)}{P_{H,t}}\right)^{-\theta} C_{H,t}(j). \tag{F.15}$$

One can derive the optimal domestic CES price index $P_{H,t}$ by inserting the demand function for the h good, Equation (F.15), into the CES consumption bundle, Equation (F.13), to obtain:

$$P_{H,t} = \left[\frac{1}{n}\int_0^n p_t(h)^{1-\theta}dh\right]^{\frac{1}{1-\theta}} \tag{F.16}$$

Solving the analogous problem for the consumption of varieties of foreign goods,

$$\min_{c_t(f)}\left(\int_n^1 p_t(f)\,c_t(f,j)\,df - P_{F,t}\left[\left(\frac{1}{1-n}\right)^{\frac{1}{\theta}}\int_n^1 c_t(f,j)^{\frac{\theta-1}{\theta}}df\right]^{\frac{\theta}{\theta-1}}\right),$$

yields the optimal demand functions and price indices for varieties of foreign goods:

$$c_t(f,j) = \frac{1}{1-n}\left(\frac{p_t(f)}{P_{F,t}}\right)^{-\theta} C_{F,t}(j) \tag{F.17}$$

$$P_{F,t} = \left[\frac{1}{1-n}\int_n^1 p_t(f)^{1-\theta}df\right]^{\frac{1}{1-\theta}}. \tag{F.18}$$

Using Equation (F.12), and minimizing with respect to $C_{H,t}(j)$ and $C_{F,t}(j)$, one can derive optimal demand functions for bundles of home and foreign goods:

$$C_{H,t}(j) = \gamma_c\left(\frac{P_{H,t}}{P_t}\right)^{-\epsilon} C_t(j) \tag{F.19}$$

$$C_{F,t}(j) = (1-\gamma_c)\left(\frac{P_{F,t}}{P_t}\right)^{-\epsilon} C_t(j). \tag{F.20}$$

By inserting the input demand functions, equations (F.19) and (F.20), into the aggregate CES bundle of home and foreign goods, equation (F.12), one obtains the optimal price index P_t as:

$$P_t = \left[\gamma_c P_{H,t}^{1-\epsilon} + (1-\gamma_c)\,P_{F,t}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}$$

Investment. Investment by household j ($X_t(j)$) is modelled in a fashion similar to that of consumption, that is, as CES indices over domestic and foreign (varieties of) investment goods $x_t(h,j)$, with the same elasticity of substitution ϵ, but a different share parameter γ_x. Investment demand functions and prices are thus given by:

$$x_t(h,j) = \frac{1}{n}\left(\frac{p_t(h)}{P_{H,t}}\right)^{-\theta} X_{H,t}(j) = \frac{1}{n}\left(\frac{p_t(h)}{P_{H,t}}\right)^{-\theta}\left[\gamma_x\left(\frac{P_{H,t}}{P_t^X}\right)^{-\epsilon} X_t(j)\right] \tag{F.21}$$

$$x_t(f,j) = \frac{1}{1-n}\left(\frac{p_t(f)}{P_{F,t}}\right)^{-\theta} X_{F,t}(j) = \frac{1}{1-n}\left(\frac{p_t(f)}{P_{F,t}}\right)^{-\theta}\left[(1-\gamma_X)\left(\frac{P_{F,t}}{P_t^X}\right)^{-\epsilon} X_t(j)\right] \tag{F.22}$$

$$P_t^X = \left[\gamma_X P_{H,t}^{1-\epsilon} + (1-\gamma_X) P_{F,t}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \tag{F.23}$$

Appendix F.2.3. Government purchases

Public consumption of government agent j, $G_t(j)$, is modelled in a fashion similar to that for private consumption, that is, as CES indices over domestic and foreign varieties of goods. Analogously to above, one can derive demand functions and prices for the government as follows:

$$g_t(h,j) = \frac{1}{n}\left(\frac{p_t(h)}{P_{H,t}}\right)^{-\theta} G_{H,t}(j) = \frac{1}{n}\left(\frac{p_t(h)}{P_{H,t}}\right)^{-\theta}\left[\gamma_G\left(\frac{P_{H,t}}{P_t^G}\right)^{-\epsilon} G_t(j)\right] \tag{F.24}$$

$$g_t(f,j) = \frac{1}{1-n}\left(\frac{p_t(f)}{P_{F,t}}\right)^{-\theta} G_{F,t}(j) = \frac{1}{1-n}\left(\frac{p_t(f)}{P_{F,t}}\right)^{-\theta}\left[(1-\gamma_G)\left(\frac{P_{F,t}}{P_t^G}\right)^{-\epsilon} G_t(j)\right] \tag{F.25}$$

$$P_t^G = \left[\gamma_G P_{H,t}^{1-\epsilon} + (1-\gamma_G) P_{F,t}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \tag{F.26}$$

Appendix F.3. Intermediate labour union sector and wage-setting

Following Smets and Wouters (2007), households supply their homogenous labour to an intermediate labour union, which differentiates the labour services from labour varieties of type l and sets wages in a Calvo fashion, selling the labour varieties of type l to labour packers. Labour used by the producer of intermediate goods of variety h, $L_t(h)$—henceforth for reasons of simplicity referred to as L_t—is then a Dixit-Stiglitz composite of varieties of labour l:

$$L_t = \left[\int_0^n L_t(l)^{\frac{1}{1+\lambda_w}}\, dl\right]^{1+\lambda_w} \tag{F.27}$$

(or, more precisely, $L_t(h) = \left[\int_0^n l_t(l,h)^{\frac{1}{1+\lambda_w}}\, dl\right]^{1+\lambda_w}$),

where λ_w is the elasticity of substitution among differentiated labour types. There are labour packers who buy the labour from the unions, package L_t (or $L_t(h)$ to be precise) and resell it to intermediate goods producing firms. Labour packers maximize profits in a perfectly competitive environment. From the optimization problem of labour packers ($W_t^{nom} L_t - \int_0^n W_t^{nom}(l)\, l_t(l) dl$), one can derive labour input demand of variety l. The corresponding aggregate wage index is given by:

$$L_t(l) = \frac{1}{n}\left(\frac{W_t^{nom}(l)}{W_t^{nom}}\right)^{-\frac{1+\lambda_w}{\lambda_w}} L_t \tag{F.28}$$

$$W_t^{nom} = \left[\frac{1}{n}\int_0^n W_t^{nom}(l)^{\frac{1}{\lambda_w}}\, dl\right]^{\lambda_w} \tag{F.29}$$

or, in more precise notation:[34]

[34] In the following, the h index of the h-variety firm will be abstracted from to simplify notation.

$L_t(h,l) = \frac{1}{n}\left(\frac{W_t^{nom}(h,l)}{W_t^{nom}}\right)^{-\frac{1+\lambda_w}{\lambda_w}} L_t(h)$

$W_t^{nom} = \left[\frac{1}{n}\int_0^n W_t^{nom}(h,l)^{\frac{1}{\lambda_w}} dl\right]^{\lambda_w}$

Labour unions take the households' marginal rate of substitution as the cost of the labour services in their negotiations with labour packers. The (nominal) household's marginal rate of substitution is given by equation (F.6), rearranging this equation yields the nominal wage level for households that unions take to wage negotiations $W_t^{hh,nom}$:

$$W_t^{hh,nom} = \frac{P_t\left[\frac{(C_t-hC_{t-1})^{1-\sigma_c}}{1-\sigma_c}\right]\exp\left(\frac{-(1-\sigma_c)}{1+\sigma_l}L_t(l)^{1+\sigma_l}\right)(\sigma_c-1)L_t(l)^{\sigma_l}}{-\Lambda_t}. \tag{F.30}$$

The markup above the marginal disutility of labour is distributed back to households. In setting the wage rate for labour of type l, the union is subject to nominal rigidities à la Calvo. In particular, the union can reset the wage in the current period with probability $1-\xi_w$. Where the wage rate cannot be reset, the wage rate $W_t^{nom}(l)$ increases with the deterministic GDP trend growth rate γ, a weighted average of the steady state inflation, π, and last period's inflation, π_{t-1}. The wage-setting problem of the labour union is then described as:

$$\max_{W_t^{nom}(l)} E_t\sum_{k=0}^{\infty}(\beta\xi_w)^k\frac{\Lambda_{t+k}}{\Lambda_t}\frac{P_t}{P_{t+k}}\left\{W_{t+k}^{nom,ind}(l)-W_{t+k}^{hh,nom}\right\}L_{t+k}(l) \tag{F.31}$$

subject to

$$L_{t+k}(l) = \frac{1}{n}\left(\frac{W_{t+k}^{nom,ind}(l)}{W_{t+k}^{nom}}\right)^{-\frac{1+\lambda_w}{\lambda_w}} L_{t+k} \tag{F.32}$$

$$W_{t+k}^{nom,ind}(l) = W_t^{nom}(l)\,Ind_{t,k}^{w}$$

$$W_{t+k}^{hh,nom} = \frac{P_{t+k}\left[\frac{(C_{t+k}-hC_{t+k-1})^{1-\sigma_c}}{1-\sigma_c}\right]\exp\left(\frac{-(1-\sigma_c)}{1+\sigma_l}L_{t+k}(l)^{1+\sigma_l}\right)(\sigma_c-1)L_{t+k}(l)^{\sigma_l}}{-\Lambda_{t+k}}. \tag{F.33}$$

Here, $Ind_{t,k}^{w}$ denotes the rule for wage indexation, which is given by:

$$Ind_{t,k}^{w} = \left\{\begin{array}{c} 1 \text{ for } k=0 \\ \left(\Pi_{l=1}^{k}\gamma\pi_{t+l-1}^{\iota_w}\pi^{1-\iota_w}\right) \text{ for } k=1,...,\infty \end{array}\right\}, \tag{F.34}$$

and where ι_w is a parameter governing the degree of this wage indexation.

Solving this maximization problem, one arrives at the following markup equation for the optimal nominal wage $W_t^{o,nom}$:

$$W_t^{o,nom}(l) = (1+\lambda_w)\frac{E_t\sum_{k=0}^{\infty}(\beta\xi_w)^k\frac{\Lambda_{t+k}}{\Lambda_t}\frac{P_t}{P_{t+k}}W_{t+k}^{hh,nom}\left[\frac{1}{n}\left(\frac{Ind_{t,k}^{w}}{W_{t+k}^{nom}}\right)^{-\frac{1+\lambda_w}{\lambda_w}}L_{t+k}\right]}{E_t\sum_{k=0}^{\infty}(\beta\xi_w)^k\frac{\Lambda_{t+k}}{\Lambda_t}\frac{P_t}{P_{t+k}}\left[\begin{array}{c} Ind_{t,k}^{w} \\ \left[\frac{1}{n}\left(\frac{Ind_{t,k}^{w}}{W_{t+k}^{nom}}\right)^{-\frac{1+\lambda_w}{\lambda_w}}L_{t+k}\right]\end{array}\right]}. \tag{F.35}$$

Households' wages that could not be chosen optimally due to the Calvo pricing mechanism (those which could not adapt their wages according to the Calvo probability of rigid wages ξ_w) are subject to a standard wage indexing related to the development of the general price level in the economy and the trend GDP growth rate. The wage index of these households evolves according to:

$$(W_t^{nom})^{-\frac{1}{\lambda_w}} = \xi_w\left(W_{t-1}^{nom}\gamma\pi_{t-1}^{\iota_w}\pi^{1-\iota_w}\right)^{-\frac{1}{\lambda_w}} + (1-\xi_w)\left(W_t^{nom,o}(l)\right)^{-\frac{1}{\lambda_w}} \tag{F.36}$$

Finally, λ_w is not a fixed parameter but follows the exogenous ARMA process with an AR coefficient ρ_w, an MA coefficient θ_w, and an i.i.d. error term $\epsilon_{w,t}$ with variance σ_w:

$$\ln \lambda_{w,t} = (1-\rho_w)\lambda_w + \rho_w \ln \lambda_{w,t-1} - \theta_w \epsilon_{w,t-1} + \epsilon_{w,t}, \epsilon_w \sim N(0,\sigma_w) \tag{F.37}$$

Appendix F.4. Production

Appendix F.4.1. Domestic good producers

The domestic consumption goods come in many varieties. Each domestic firm h specializes in one variety of goods, producing according to a Cobb-Douglas production function:

$$Y_t(h) = F(K_t(h), L_t(h)) = A_t K_t(h)^{\alpha} [Z_t L_t(h)]^{1-\alpha} - \Phi Z_t, \tag{F.38}$$

where $K_t(h)$ denotes the physical capital stock used by firm h for production, $L_t(h)$ is an index of different types of labour services, A_t denotes total factor productivity, Z_t is a long-run labour-augmenting productivity factor that grows with the exogenous rate (γ), and Φ is a constant parameter indicating fixed costs of production in relation to the exogenous productivity factor. Each firm behaves as a monopolistic competitor, setting prices $p_t(h)$ and $p_t^*(h)$ in the local and foreign market to maximize profits, taking as given the households' and government's demand for that good, $c_t(h,j)$, $x_t(h,j)$, $c_t^*(h,j^*)$, $x_t^*(h,j^*)$, $g_t(h,j)$, $g_t^*(h,j^*)$. The firm's problem can be decomposed into a cost minimization problem and a profit maximization problem as set out in the following.

Appendix F.4.2. Producer as a cost minimizer

Cost minimization by the firm provides information on the optimal capital-labour ratio. The minimization problem of an individual firm h is given by

$$\min_{L_t(h),K_t(h)} \left\{ \begin{array}{c} W_t^{nom} L_t(h) + R_t^{k,nom} K_t(h) + \\ MC_t^{nom}(h)\left[Y_t(h) - A_t K_t(h)^{\alpha} [Z_t L_t(h)]^{1-\alpha} - \Phi Z_t\right] \end{array} \right\},$$

which yields first-order conditions for firm h described in the following.

Labour demand $L_t(h)$:

$$W_t^{nom} = MC_t^{nom}(h)(1-\alpha) A_t K_t(h)^{\alpha} L_t(h)^{-\alpha} Z_t{}^{1-\alpha},$$

or rewriting it as the labour demand function:

$$L_t(h) = (1-\alpha)\left(\frac{W_t^{nom}}{MC_t^{nom}}\right)^{-1} Y_t(h). \tag{F.39}$$

Capital demand $K_t(h)$:

$$R_t^{k,nom} = MC_t^{nom} \alpha A_t K_t(h)^{\alpha-1} [Z_t L_t(h)]^{1-\alpha},$$

or rewriting it as the capital demand function:

$$K_t(h) = \alpha \left(\frac{R_t^{k,nom}}{MC_t^{nom}}\right)^{-1} Y_t(h). \tag{F.40}$$

If the labour demand function, Equation (F.39), is joined with the capital demand function, Equation (F.40), the optimal capital-labour ratio is obtained. This optimal ratio will be the same for all domestic intermediate goods producers, and thus concurs with the economy-wide capital-labour ratio:

$$\frac{1-\alpha}{\alpha} = \frac{W_t^{nom} L_t(h)}{R_t^{k,nom} K_t(h)}. \tag{F.41}$$

By inserting the labour and capital demand functions into the production function, Equation (F.38), one can derive the following expression for nominal marginal costs, which is the same for all firms, i.e. $MC_t^{nom}(h) = MC_t^{nom}$, as it only depends on aggregate prices:

$$MC_t^{nom} = \frac{1}{A_t} \frac{\left(R_t^{k,nom}\right)^{\alpha} \left(W_t^{nom}\right)^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}} \frac{1}{Z_t^{1-\alpha}}. \tag{F.42}$$

Appendix F.4.3. Producer as a profit maximizer

According to the Calvo price-setting mechanism, firms may not be allowed to change their price every period. Rather, it is assumed that they cannot change their price unless they receive a price-change signal. The probability that a given price can be re-optimized at period t is assumed to be constant and equal to ξ_P. Furthermore, it is assumed that each firm h has market power in the market for the good it produces, and maximizes expected profit according to a discount rate (from period t to period $t+k$). Define by $\Omega_{t,t+k} = \beta \frac{\Lambda_{t,t+k}}{\Lambda_t} \frac{P_t}{P_{t+k}}$ the households' stochastic discount factor from period t to period $t+k$. Under sticky prices according to the Calvo mechanism, with partial indexation to producer prices ($Ind_{t,k}^p$), and assuming producer currency price-setting, the firm maximization problem is given by:

$$\max_{p_t^o(h), S_t p_t^*(h)} E_t \sum_{k=0}^{\infty} \xi_P^k \Omega_{t,t+k} \left\{ \begin{array}{c} \left[p_t(h) Ind_{t,k}^p - MC_t^{nom}(h)\right] \left[\frac{1}{n}\left(\frac{p_t(h)}{P_{H,t+k}} Ind_{t,k}^p\right)^{-\theta} \left(A_{H,t+k}\right)\right] + \\ \left[S_t p_t^*(h) - MC_{t+k}^{nom}(h)\right] \left[\frac{1}{n}\left(\frac{S_t p_t^*(h)}{S_{t+k} P_{H,t+k}^*} Ind_{t,k}^p\right)^{-\theta} \left(A_{H,t+k}^*\right)\right] \end{array} \right\}, \tag{F.43}$$

where the producer price indexation rule $Ind_{t,k}^p$, similarly to the case for wages above, is given by

$$Ind_{t,k}^p = \left\{ \begin{array}{c} 1 \text{ for } k=0 \\ \left(\Pi_{l=1}^k \pi_{H,t+l-1}^{\iota_p} \pi_H^{1-\iota_p}\right) \text{ for } k=1,...,\infty \end{array} \right\}. \tag{F.44}$$

The parameter ι_p indicates the degree of price indexation.

Solving this maximization problem with respect to the price charged by firm h, $p_t(h)$, yields the following optimal price for firm h, $p_t^o(h)$:

$$\frac{p_t^o(h)}{P_{H,t}} = \frac{\left(\frac{\theta}{\theta-1}\right) E_t \sum_{k=0}^{\infty} (\beta\xi_P)^k \frac{\Lambda_{t+k}}{\Lambda_t} \left\{\frac{MC_{t+k}^{nom}(h)}{P_{t+k}} \left[\left(\frac{P_{H,t}}{P_{H,t+k}} Ind_{t,k}^p\right)^{-\theta} \left(A_{H,t+k} + A_{H,t+k}^*\right)\right]\right\} \frac{1}{Z_t}}{E_t \sum_{k=0}^{\infty} (\beta\xi_P)^k \frac{\Lambda_{t+k}}{\Lambda_t} \frac{P_{H,t+k}}{P_{t+k}} \left\{\left[\left(\frac{P_{H,t}}{P_{H,t+k}} Ind_{t,k}^p\right)^{1-\theta} \left(A_{H,t+k} + A_{H,t+k}^*\right)\right]\right\} \frac{1}{Z_t}}. \tag{F.45}$$

Under the assumption of producer currency price-setting, the law of one price holds at the level of individual goods, and the price level of firm h in the foreign economy, $p_t^*(h)$, is given by:

$$S_t p_t^*(h) = p_t^o(h).$$ [35]

From these equilibrium price indices and the optimal price-setting relation, one can derive how prices evolve over time (with indexation):

$$1 = \xi_P \left(\frac{P_{H,t-1}}{P_{H,t}} \pi_{H,t-1}^{\iota_p} \pi_H^{1-\iota_p}\right)^{1-\theta} + (1-\xi_P) \left(\frac{p_t^o(h)}{P_{H,t}}\right)^{1-\theta}, \tag{F.47}$$

where $\pi_{H,t} = \frac{P_{H,t}}{P_{H,t-1}}$.

[35] Note that when prices are not sticky, Equation (F.45)) reduces to the standard expression:

$$p_t(h) = \frac{\theta}{1-\theta} MC_t^{nom}(h) \tag{F.46}$$

Appendix F.4.4. Good Market Clearing

According to the optimality conditions described above, the goods market clearing condition is then given as follows:

$$Y_t(h) = A_t K_t^{\alpha} [Z_t L_t]^{1-\alpha} - \Phi Z_t = \begin{bmatrix} \left[\gamma_c \left(\frac{P_{H,t}}{P_t}\right)^{-\epsilon} C_t + \gamma_x \left(\frac{P_{H,t}}{P_t^X}\right)^{-\epsilon} X_t + G_t\right] + \\ \frac{1-n}{n}\left[\gamma_c^* \left(\frac{P_{H,t}^*}{P_t^*}\right)^{-\epsilon} C_t^* + \gamma_x^* \left(\frac{P_{H,t}^*}{P_t^{X*}}\right)^{-\epsilon} X_t^*\right] \end{bmatrix}. \tag{F.48}$$

Appendix F.5. Fiscal Authority

The role of fiscal policy in the model is highly simplified. Government spending is assumed to be financed by lump-sum taxes (T_t below denotes net transfers, that is, total government transfers minus taxes). The government is not allowed to run budget deficits, and its budget constraint therefore is:

$$G_t + T_t = 0$$

Appendix F.6. Monetary Authority

The monetary authority is assumed to apply a standard interest-feedback rule. The interest rate targets inflation as well as the output gap, and is set according to a Taylor rule:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\left(\frac{\pi_t}{\overline{\pi}}\right)^{\rho_\pi} \left(\frac{y_t}{\overline{y}}\right)^{\rho_Y}\right]^{1-\rho_R} \varepsilon_t^R,$$

where R_t is the short term money market interest rate (policy rate) set exogenously by the central bank (and thus also the interest rate on bond holdings by households as in the household budget constraint, see Equation (F.2)), R is the policy rate in the steady state, π_t is inflation at time t, $\overline{\pi}$ is the inflation target set by the central bank, y_t is output at time t, $\overline{y}$ is the output target by the central bank, ρ^R is the degree of interest rate smoothing by the central bank, ρ^π denotes the weight the central bank places on inflation targeting, ρ^Y is the weight the central bank places on the output gap, and ε_t^R is an exogenous shock to monetary policy.

Appendix F.7. Additional Equilibrium Conditions

Arrow-Debreu securities are in zero net supply (the only security traded internationally is the F-bond; the H-security is traded only domestically):

$$\int_0^n B_{H,t}(j, s_{t+1}) dj = 0 \tag{F.49}$$

$$\int_0^n B_{F,t}(j, s_{t+1}) dj + \int_n^1 B_{F,t}^*(j^*, s_{t+1}) dj^* = 0 \tag{F.50}$$

Equilibrium in the factor markets requires:

$$L_t = \int_0^n L_t(h)\, dh = \int_0^n \int_0^n l_t(h, j)\, dh dj$$

$$L_t^* = \int_n^1 L_t^*(f)\, df = \int_n^1 \int_n^1 l_t^*(f, j^*)\, dh dj^*$$

$$K_t = \int_0^n K_t(h)\, dh$$

$$K_t^* = \int_n^1 K_t^*(f)\, df$$

Appendix F.8. Exogenous shock processes

Model dynamics are decisively driven by altogether 13 exogenous processes (shocks), i.e. 6 shocks each in the domestic (Austrian) and foreign (euro area) economy, and a monetary policy shock common to both areas due to the monetary union. In all of the shocks below, ρ signifies an autoregressive component of the shock process, while u_t and η_t are normally distributed white noise processes with a variance σ. The following equations denote these exogenous shocks:

Technology shock—here A_{SS} denotes the steady state level of the technology shock, which is used to rescale the shock to better match the data:

$\boxed{A_t}$ $\quad A_t = \rho_A A_{t-1} + (1-\rho_A)\ln A_{SS} + u_{A,t}, u^{A,t} \sim N(0, \sigma_A)$

Government spending shock—here g_{SS} again is the steady state level of the shock for rescaling purposes, and c_{gy} signifies a cross-correlation coefficient between technology and government spending shocks:

$\boxed{g_t}$ $\quad g_t = \rho_G g_{t-1} + (1-\rho_G)\ln g_{SS} + c_{gy} u_{A,t} + u^{G,t}, u^{G,t} \sim N(0, \sigma_G)$

Shock to bond holdings by households:

$\boxed{\varepsilon_t^b}$ $\quad \ln \varepsilon_t^b = \rho_b \ln \varepsilon_{t-1}^b + \eta_t^b, \eta_t^b \sim N(0, \sigma_B)$

Shock to investment demand:

$\boxed{\varepsilon_t^X}$ $\quad \ln \varepsilon_t^X = \rho_X \ln \varepsilon_{t-1}^X + \eta_t^X, \eta_t^X \sim N(0, \sigma_X)$

Shock to monetary policy (only one shock due to common monetary union):

$\boxed{\varepsilon_t^R}$ $\quad \ln \varepsilon_t^R = \rho_R \ln \varepsilon_{t-1}^R + \eta_t^R, \eta_t^R \sim N(0, \sigma_R)$

Shock to elasticity of substitution among differentiated labour types—here a moving average (MA) θ_w term is also included in the shock process:

$\boxed{\lambda_{w,t}}$ $\quad \ln \lambda_{w,t} = (1-\rho_w)\lambda_w + \rho_w \ln \lambda_{w,t-1} - \theta_w \epsilon_{w,t-1} + \epsilon_{w,t}, \epsilon_w \sim N(0, \sigma_w)$

Shock to price-setting by firms—again with an additional MA term θ_p:

$\boxed{\lambda_{p,t}}$ $\quad \ln \lambda_{p,t} = \left(1-\rho_p\right)\lambda_p + \rho_p \ln \lambda_{p,t-1} - \theta_p \epsilon_{p,t-1} + \epsilon_{p,t}, \epsilon_p \sim N\left(0, \sigma_p\right)$

Appendix F.9. Deflating, detrending and model solution

To solve the model, we transform all first-order conditions that are in nominal terms and growing in terms of stationary, deflated quantities. All quantity variables are detrended by the exogenous productivity rate Z_t, Z_t^*, while all price variables are deflated by the price level P_t, P_t^* for the home and foreign economies, respectively.

These detrended, deflated variables are given by the following expressions:

$$c_t = \frac{C_t}{Z_t}, c_{H,t} = \frac{C_{H,t}}{Z_t}, c_{F,t} = \frac{C_{F,t}}{Z_t}, x_{H,t} = \frac{X_{H,t}}{Z_t}, x_{F,t} = \frac{X_{F,t}}{Z_t}, g_{H,t} = \frac{G_{H,t}}{Z_t}, g_{F,t} = \frac{G_{F,t}}{Z_t}, x_t = \frac{X_t}{Z_t}, c_t^* = \frac{C_t^*}{Z_t}, c_{H,t}^* = \frac{C_{H,t}^*}{Z_t}, c_{F,t}^* = \frac{C_{F,t}^*}{Z_t}, x_{H,t}^* = \frac{X_{H,t}^*}{Z_t}, x_{F,t}^* = \frac{X_{F,t}^*}{Z_t}, g_{H,t}^* = \frac{G_{H,t}^*}{Z_t}, g_{F,t}^* = \frac{G_{F,t}^*}{Z_t}, \widetilde{w}_t = \frac{W_t^{o,nom}(l)}{Z_t P_t}, w_t = \frac{W_t^{nom}}{Z_t P_t}, \widetilde{w}_t^* = \frac{W_t^{*o,nom}(l)}{Z_t P_t^*}, w_t^* = \frac{W_t^{*nom}}{Z_t P_t^*}, \overline{k}_t = \frac{\overline{K}_t}{Z_t}, k_t = \frac{K_t}{Z_t}, x_t = \frac{X_t}{Z_t}, w_t^{hh} = \frac{W_t^{hh,nom}}{P_t Z_t}, y_t = \frac{Y_t}{Z_t}, p_t^X = \frac{P_t^X}{P_t}, r_t^k = \frac{R_t^{k,nom}}{P_t}, \pi_t = \frac{P_t}{P_{t-1}}, \pi_t^* = \frac{P_t^*}{P_{t-1}^*}, RER_t = \frac{S_t P_t^*}{P_t}, TOT_t = \frac{P_{F,t}}{S_t P_{H,t}^*}, p_{H,t} = \frac{P_{H,t}}{P_t}, p_{F,t} = \frac{P_{F,t}}{P_t}, p_t^X = \frac{P_t^X}{P_t}, p_t^G = \frac{P_t^G}{P_t}, p_{H,t}^* = \frac{P_{H,t}^*}{P_t^*}, p_{F,t}^* = \frac{P_{F,t}^*}{P_t^*}, p_t^{X*} = \frac{P_t^{X*}}{P_t^*}, p_t^{G*} = \frac{P_t^{G*}}{P_t^*},$$

where RER_t is the real exchange rate, and TOT_t are the terms of trade.

Appendix F.10. Data sources and model estimation

Appendix F.10.1. Data sources

We use quarterly data from 1997:Q1-2019:Q3 from the following data sources available from the Eurostat bulk download facility, all seasonally and calendar adjusted:

1. GDP and main components - output, expenditure and income (quarterly time series) (**namq_10_gdp**)
2. Population and employment (quarterly time series) (**namq_10_pe**)
3. Money market interest rates - quarterly data (**irt_st_q**)

In particular, to take the DSGE to the data, the following time series from Eurostat data are used (all from namq_10_gdp):

- Gross domestic product at market prices, chain linked volumes (2010) (B1GQ),
- Final consumption expenditure, chain linked volumes (2010) (P3),
- Gross fixed capital formation, chain linked volumes (2010) (P5G),
- Compensation of employees, current prices, million euro (D1),
- inflation (GDP deflator: Gross domestic product at current prices divided by chain linked volumes GDP measure).

Furthermore, to determine the amount of employment, we use the variable employment in thousand persons according to the domestic concept (EMP_DC, from namq_10_pe), a proxy for aggregate hours worked, as these data are not available for Austria or the euro area on a quarterly basis.[36] The nominal interest rate is represented by the three-month Euribor, i.e. short term money market interest rates (variable name MAT_M03 from irt_st_q).

Appendix F.10.2. Measurement Equations: Growth rates used for estimations

As is standard in the current DSGE literature, the model is estimated on growth rates. The measurement equations to estimate the model need at least the same amount of shocks as observable time series to allow for model estimation. Since we have 13 shocks in our model, we choose 13 observable time series to estimate the DSGE model. The time series used to estimate the log-linearized version of the model for both Austria and the euro area are growth rates (in real terms) for GDP (dY^{obs}, dY^{obs*}), consumption (dC^{obs}, dC^{obs*}—consumption of domestic and foreign goods in the respective country as a CES bundle), investment (dX^{obs}, dX^{obs*}—again as a home-foreign goods CES bundle), employment ($EMPL^{obs}, EMPL^{obs*}$—where a linear trend was removed to make the time series stationary), wages (dW^{obs}, dW^{obs*}), as well as inflation (Π^{obs}, Π^{obs*}). Furthermore, one time series of interest rates (R^{obs}) common to both areas is added. Summing up, the vector of observable variables is linked to DSGE model variables as follows (where hat variables denotes variables in percentage deviations from steady state, e.g. $\widehat{y_t} = \log(y_t/\overline{y})$):

$$\begin{bmatrix} dY^{obs} \\ dC^{obs} \\ dX^{obs} \\ dW^{obs} \\ EMPL^{obs} \\ \Pi^{obs} \\ dY^{obs*} \\ dC^{obs*} \\ dX^{obs*} \\ dW^{obs*} \\ EMPL^{obs*} \\ \Pi^{obs*} \\ R^{obs} \end{bmatrix} = \begin{bmatrix} \gamma^{obs} + \widehat{y}_t - \widehat{y}_{t-1} \\ \gamma^{obs} + \widehat{c}_t - \widehat{c}_{t-1} \\ \gamma^{obs} + \widehat{x}_t - \widehat{x}_{t-1} \\ \gamma^{obs} + \widehat{w}_t - \widehat{w}_{t-1} \\ l^{obs} + \widehat{l}_t \\ \pi^{obs} + \widehat{\pi}_t \\ \gamma^{*obs} + \widehat{y}^*_t - \widehat{y}^*_{t-1} \\ \gamma^{*obs} + \widehat{c}^*_t - \widehat{c}^*_{t-1} \\ \gamma^{*obs} + \widehat{x}^*_t - \widehat{x}^*_{t-1} \\ \gamma^{*obs} + \widehat{w}^*_t - \widehat{w}^*_{t-1} \\ l^{*obs} + \widehat{l}^*_t \\ \pi^{*obs} + \widehat{\pi}^*_t \\ r^{obs} + \widehat{R}_t \end{bmatrix} \tag{F.51}$$

[36] As is also noted in Breuss and Rabitsch (2009).

Appendix F.10.3. Bayesian estimation

For reasons of parsimony, we refrain from a detailed repetition of the principles of Bayesian estimation. The interested reader is referred to the excellent reviews that can be found in Fernandez-Villaverde (2010); An and Schorfheide (2007); Schorfheide (2011), or the short expositions in Breuss and Rabitsch (2009); Smets and Wouters (2003), among others. The method used in this paper is quite standard in the literature and largely follows the procedure in Breuss and Rabitsch (2009): from the state space representation of the DSGE model solution, the log-likelihood over the sample period 1997:Q1 - 2010:Q1 is estimated. For the forecast, the DSGE model is then re-estimated every quarter until 2019:Q3. The thereby obtained posterior distribution is maximized to compute the mode of the estimated parameters. The significance of the parameters can be examined by deriving the standard errors of these parameters estimated from the inverse Hessian matrix. After the mode of the posterior is calculated by this procedure, the mode is used as a starting point for a sampling algorithm in order to generate a large sample of MCMC (Markov-Chain Monte Carlo) draws to approximate the shape of the posterior parameter distribution. For this purpose, the Metropolis-Hastings algorithm is used, which is standard in the literature.

Appendix F.10.4. Calibrated parameters

Unless explicitly mentioned otherwise, the parameters described below are set equally for the home and foreign economy. Some parameters are not estimated but calibrated for this model, closely adhering to standard values that have been well-tested by a large body of DSGE literature. The depreciation rate δ is set to 2.5 per cent to correspond to the sample mean of the labour-output and investment-output ratios. The capital share in production, the Cobb-Douglas production function parameter α, is set to about 19 per cent. The weight of domestic and foreign consumption goods in their respective overall aggregate net consumption index are reflected in the parameters γ_C and γ_C^*, which are calibrated by using the measures of imports in private consumption from the GTAP database along the lines of Breuss and Rabitsch (2009). This implies a weight of $\gamma_C = 0.8964$ on domestically produced consumption goods in Austria. For the euro area this translates into a weight of goods produced in the euro area without Austria of $(1-\gamma_C^*) = 0.9974$, where for simplicity's sake it is assumed that the weights in the respective CES indices do not differ from each other. The country share n of Austria in the total model economy in comparison to euro area is set to 0.031, which approximately corresponds to the share of Austrian GDP in the euro area within the calibration period (2010:Q1-2019:Q3). This implies a size of the euro area economy (1-n) of 0.969. We calibrate the parameters pinning down the effective discount factor that appears in the model's Euler equations, unlike in the original contribution of Smets and Wouters (2007). In particular, we choose a net quarterly growth rate $\gamma^{const} = 0.5\%$, a net steady state inflation rate of $\pi^{const} = 0.5$, and (following Smets and Wouters (2007)) a coefficient $\beta^{const} = 0.16$. This, together with the estimated value of σ_{C^*}, gives rise to an effective discount factor that approximately implies a quarterly real interest of 0.75 per cent.[37,38]

Appendix F.10.5. Prior and posterior distributions for estimated parameters

Tables F.1 and F.2 show information about the prior and posterior distributions of the Bayesian estimation after the MCMC sampling procedure. For all parameter estimates used for simulations, part of which is shown below, the number of Metropolis-Hastings draws has been set to 250,000.

[37] In particular, the Euler equation reads $\lambda_t = \frac{\beta}{\gamma^{\sigma_c}} E_t \left\{ \lambda_{t+1} \varepsilon_t^b R_t \frac{1}{\pi_{t+1}} \right\}$, with effective discount factor $\frac{\beta}{\gamma^{\sigma_c}}$. This also means that the constant terms appearing in the model's observable equations (γ^{obs}, γ^{*obs} , etc.) are estimated freely and independently so as to best match the data, and are not treated as functions of estimated structural parameters. Even though this estimation strategy deviates from Smets and Wouters (2007), it yields a superior forecasting performance over the alternative.

[38] In particular, the logic of the original paper of Smets and Wouters (2007) is as follows. There, the net steady state inflation rate in per cent, π^{const}, the net quarterly growth rate, γ^{const}, and parameter β^{const} are the *estimated* structural parameters. From these, the (nominal) effective discount factor term that appears in the model's Euler equations is updated at each parameter draw as $\overline{\beta^c}/\overline{\pi}$, where $\overline{pi}$=$\pi^{const}/100 + 1$ is the steady state gross inflation rate, and $\overline{\beta^c}$=$(\beta/\gamma^{\sigma_c}$, with γ=$\gamma^{const}/100+1$, and $\beta = 100/(\beta^{const} + 100)$. Similarly, the various constant terms in the definitions for observables are updated at each parameter draw: in that case, γ^{const} would be the constant term in the observables for the growth rates of output, consumption, investment and wages, π^{const} the term in the observables for inflation, and r^{const}=$(cr - 1)100$ with cr=$(\beta/\gamma^{sigmac}$ the term in the equation for the interest rate-observable. We explored adopting this estimation strategy extensively, but it did not yield better forecasting performance compared to the calibration strategy reported in the main text.

Table F.1: Results from Metropolis-Hastings (parameters) for 1997:Q1 - 2010:Q1

	Prior			Posterior			
	Dist.	Mean	Stdev.	Mean	Stdev.	HPD inf	HPD sup
ρ_A^*	beta	0.5	0.2	0.967	0.0244	0.9374	0.9953
ρ_A	beta	0.5	0.2	0.972	0.0163	0.9486	0.9948
ρ_B^*	beta	0.5	0.2	0.263	0.1377	0.0484	0.4638
ρ_B	beta	0.5	0.2	0.144	0.0751	0.0257	0.2565
ρ_G^*	beta	0.5	0.2	0.962	0.0179	0.9359	0.9873
ρ_G	beta	0.5	0.2	0.798	0.0734	0.6838	0.9199
ρ_X^*	beta	0.5	0.2	0.454	0.0895	0.3098	0.6052
ρ_X	beta	0.5	0.2	0.339	0.1352	0.1144	0.5533
ρ_R^*	beta	0.5	0.2	0.467	0.0755	0.344	0.5901
ρ_p^*	beta	0.5	0.2	0.89	0.1184	0.8318	0.9874
ρ_p	beta	0.5	0.2	0.567	0.1781	0.282	0.8510
ρ_w^*	beta	0.5	0.2	0.835	0.0889	0.6997	0.9554
ρ_w	beta	0.5	0.2	0.549	0.1341	0.3265	0.7664
θ_p^*	beta	0.5	0.2	0.386	0.1519	0.1298	0.6275
θ_p	beta	0.5	0.2	0.925	0.0419	0.8647	0.9891
θ_w^*	beta	0.5	0.2	0.472	0.1478	0.2268	0.7126
θ_w	beta	0.5	0.2	0.341	0.1538	0.0894	0.5825
ϕ_X^*	norm	4	1.5	3.732	1.1002	2.0005	5.2677
ϕ_X	norm	4	1.5	5.339	1.2807	3.1532	7.3868
ξ_p^*	beta	0.5	0.1	0.743	0.0577	0.636	0.8351
ξ_p	beta	0.5	0.1	0.794	0.0298	0.746	0.8440
ξ_W^*	beta	0.5	0.1	0.715	0.0549	0.6264	0.8056
ξ_W	beta	0.5	0.1	0.766	0.0332	0.7125	0.8207
ι_W^*	beta	0.5	0.15	0.282	0.1073	0.1083	0.4514
ι_W	beta	0.5	0.15	0.393	0.1136	0.2043	0.5744
ι_p^*	beta	0.5	0.15	0.195	0.0917	0.0552	0.3304
ι_p	beta	0.5	0.15	0.487	0.1342	0.2658	0.7069
ϕ_a^*	beta	0.5	0.15	0.521	0.1433	0.2891	0.7612
ϕ_a	beta	0.5	0.15	0.493	0.1527	0.24	0.7442
σ_C^*	norm	1.5	0.25	1.294	0.0906	1.1469	1.4435
h^*	beta	0.7	0.1	0.591	0.063	0.4874	0.6942
h	beta	0.7	0.1	0.762	0.0509	0.6768	0.8439
σ_L^*	norm	2	0.5	0.773	0.3617	0.2184	1.3495
σ_L	norm	2	0.5	1.93	0.4141	1.2455	2.6120
ρ_π^*	norm	1.5	0.25	1.103	0.0408	1.0421	1.1657
ρ_r^*	beta	0.75	0.1	0.679	0.0437	0.6083	0.7500
ρ_Y^*	norm	0.125	0.05	0.005	0.0043	0.001	0.0104
ρ_{DY}^*	norm	0.125	0.05	0.252	0.0442	0.1814	0.3250
π_*obs	gamm	0.625	0.1	0.489	0.0595	0.3919	0.5860
π_{obs}	gamm	0.625	0.1	0.605	0.0649	0.4984	0.7118
r_{obs}	gamm	0.5	0.1	0.685	0.0905	0.5398	0.8370
γ^{*obs}	norm	0.4	0.1	0.251	0.0364	0.1924	0.3067
γ^{obs}	norm	0.4	0.1	0.221	0.0396	0.1563	0.2860
c_{gy}^*	norm	0.5	0.25	0.358	0.1112	0.1757	0.5397
c_{gy}	norm	0.5	0.25	0.188	0.1146	0.01	0.3471
α^*	norm	0.3	0.05	0.336	0.0295	0.2889	0.3858
α	norm	0.3	0.05	0.218	0.0388	0.1534	0.2807
$(1+\Phi)^*$	norm	1.25	0.125	1.276	0.1051	1.1002	1.4461
$1+\Phi$	norm	1.25	0.125	1.564	0.0962	1.4025	1.7166
ξ_{empl}	beta	0.7	0.2	0.566	0.0485	0.4863	0.6439
ξ_{empl}^*	beta	0.7	0.2	0.752	0.0291	0.705	0.7995
ϵ_s	invg	2.5	1	1.91	0.1885	1.5994	2.2161
ϵ_s^*	invg	2.5	1	2.004	0.3796	1.3836	2.6408

Appendix F.11. Variance Decomposition

A forecast error variance decomposition reveals which shocks drive different macro variables in the model economy by determining the extent to which the forecast error variance of each of these variables can be explained by the

Table F.2: Results from Metropolis-Hastings (standard deviation of structural shocks) for 1997:Q1 - 2010:Q1

	Prior			Posterior			
	Dist.	Mean	Stdev.	Mean	Stdev.	HPD inf	HPD sup
σ_A^*	invg	0.1	2	0.444	0.071	0.3319	0.5580
σ_A	invg	0.1	2	0.621	0.1016	0.4597	0.7770
σ_B^*	invg	0.1	2	0.165	0.0236	0.1269	0.2027
σ_B	invg	0.1	2	0.3	0.0316	0.2487	0.3509
σ_G^*	invg	0.1	2	0.314	0.0327	0.2613	0.3672
σ_G	invg	0.1	2	0.589	0.061	0.4901	0.6885
σ_X^*	invg	0.1	2	0.396	0.0663	0.2888	0.5015
σ_X	invg	0.1	2	0.844	0.1415	0.6125	1.0759
σ_R^*	invg	0.1	2	0.115	0.0141	0.0925	0.1377
σ_p^*	invg	0.1	2	0.142	0.0273	0.0989	0.1859
σ_p	invg	0.1	2	0.426	0.0523	0.3405	0.5083
σ_w^*	invg	0.1	2	0.129	0.0214	0.0942	0.1635
σ_w	invg	0.1	2	0.176	0.0283	0.1317	0.2231

different exogenous shocks. For the exposition, the unconditional variance decompositions (i.e. at horizon infinity) and the conditional variance decompositions (i.e. at the forecast horizon of 12 quarters) are shown for the first year to which the model is estimated (2010:Q1), as well as for the last year of model estimation (2019:Q3).

Appendix F.11.1. 2010:Q1

At first glance, the unconditional variance decomposition depicted in Table F.3 reveals some noteworthy results and valuable insights for the conditional forecast conducted in Section 5.3 in the main text. This is especially so for the growth rates of consumption and investment, which are the variables that have to be partly controlled exogenously for the conditional forecast, as further laid out in Online Appendix F.12 below.[39] Consumption growth in Austria (dC^{obs}), as to be expected, is mostly determined by the risk shock to household bond holdings (η_t^b, which in essence corresponds to a "consumption shock"), all other influences seem to be relatively minor. This picture is somewhat different for the euro area, even though the consumption shock (η_t^{b*}) there also plays the most important role in determining changes in euro area consumption (dC^{obs*}). However, the importance of technology shocks, for consumption seems especially, to be higher in the euro area. Investment growth both in Austria (dX^{obs}) and the euro area (dX^{obs*}), as would be expected according to economic intuition, are primarily determined by the shock to investment demand.

The conditional variance decomposition shown in Table F.4 below demonstrates that for the forecast horizon of 12 quarters (q), the decisive features of the unconditional variance decomposition remain unchanged. However, the importance of some shocks diminishes, while the influence of other shocks rises. Especially, in the short term, the degree of influence of the technology shock in the euro area on employment and inflation is more than halved as compared to the long-run variance decomposition. Compared to these noteworthy changes in the variance decompositions for the euro area, it seems that for the Austrian economy the influences of shocks remain much more stable from the short to the long term, potentially related to the fact that economic developments in Austria are more subject to other exogenous influences such as exports or imports.

Appendix F.11.2. 2019:Q3

The unconditional and conditional variance decompositions for the model estimated for 2019:Q3 qualitatively show a very similar picture as for 2010:Q1, with only minor differences in the quantitative degree of the various

[39]The particular variance decompositions most relevant for the conditional forecasts are highlighted by red-colored cells in Tables F.3, F.4, F.5 and F.6 below.

Table F.3: Posterior mean unconditional variance decomposition (in per cent) for model parameter estimation to 2010:Q1

	$u_{A,t}$	$u^*_{A,t}$	$u_{G,t}$	$u^*_{G,t}$	η^b_t	η^{b*}_t	η^X_t	η^{X*}_t	η^R_t	ϵ_w	ϵ^*_w	$\epsilon_{p,t}$	$\epsilon^*_{p,t}$
dY^{obs}	11.6	0.13	40.46	0.03	7.87	0.01	11.99	6.43	5.31	0.58	0.04	15.13	0.43
dC^{obs}	7.62	1.62	2.25	0.72	73.37	0.01	0.89	0.45	6.84	0.48	0.06	5.51	0.2
dX^{obs}	2.97	0.25	0.29	0.19	0.05	0	92.33	0.26	1.58	0.19	0.03	1.63	0.24
$EMPL^{obs}$	26.87	10.58	12	1.79	2.9	0.03	7.71	8.57	9.62	3.85	0.24	13.32	2.52
Π^{obs}	16.48	23.68	1.26	5.79	0.21	0.06	0.98	5.61	8.14	0.62	0.84	30.14	6.18
dW^{obs}	9.23	1.44	5.41	0.42	0.61	0.01	3.47	2.06	5.48	25.56	0.09	45.54	0.68
dY^{obs*}	0.01	21.86	0	18.78	0.01	4.23	0.01	26.55	11.76	0	2.45	0.05	14.27
dC^{obs*}	0.04	13	0	1.59	0	34.43	0	2.41	29.53	0	4.22	0.01	14.76
dX^{obs*}	0.03	7.9	0	0.37	0	0.03	0.01	66.66	6.63	0	1.89	0.01	16.45
$EMPL^{obs*}$	0.21	12.48	0	17.75	0	0.24	0.01	7.16	4.5	0	11.82	0	45.83
Π^{obs*}	0.22	42.55	0.01	11.51	0	0.23	0.02	9.32	14.92	0	3.18	0	18.01
dW^{obs*}	0.01	15.7	0	0.41	0	0.1	0	3.69	7.21	0	22.91	0	49.96
R^{obs}	0.32	49.36	0.01	16.46	0.01	0.32	0.03	13.14	3.56	0	2.47	0.01	14.3

Table F.4: Posterior mean conditional variance decomposition (in per cent) for model parameter estimation to 2010:Q1

	$u_{A,t}$	$u^*_{A,t}$	$u_{G,t}$	$u^*_{G,t}$	η^b_t	η^{b*}_t	η^X_t	η^{X*}_t	η^R_t	ϵ_w	ϵ^*_w	$\epsilon_{p,t}$	$\epsilon^*_{p,t}$
dY^{obs}	5.84	0.08	51.67	0.02	10.01	0.01	13.17	6.92	4.39	0.16	0.02	7.3	0.41
dC^{obs}	2.28	0.95	1.84	0.58	87.29	0	0.52	0.2	4.76	0.03	0.03	1.41	0.11
dX^{obs}	0.15	0.14	0.02	0.14	0	0	97.97	0.06	1.26	0.04	0.01	0.18	0.01
$EMPL^{obs}$	46.1	0.12	25.53	0.03	5.57	0.01	8.41	6.57	5.57	0.67	0.04	1.08	0.28
Π^{obs}	21.31	0.17	1.54	0.25	0.21	0.03	0.25	2.39	5.11	0.91	0.07	67.59	0.17
dW^{obs}	4.84	2	8.62	0.67	0.3	0	3.83	2.15	6.13	48.37	0.13	21.67	1.28
dY^{obs*}	0	18.58	0	25.85	0.01	6.09	0.01	29.47	10.46	0	0.86	0.04	8.63
dC^{obs*}	0.05	3.27	0	0.67	0	54.11	0	2.09	29.37	0	1.42	0	9.02
dX^{obs*}	0.01	3.03	0	0.12	0	0.02	0	79.03	6.26	0	0.77	0	10.76
$EMPL^{obs*}$	0.01	7.08	0	16.93	0.01	2.52	0.01	23.33	12.13	0	6.01	0.01	31.97
Π^{obs*}	0	20.42	0	5.75	0	0.54	0.01	9.39	17.81	0	4.99	0	41.07
dW^{obs*}	0.01	8.44	0	0.3	0	0.06	0	2.68	5.93	0	28.92	0	53.67
R^{obs}	0.01	4.99	0.04	17.43	0.03	2.76	0.05	24.21	30.63	0	2.47	0.08	17.3

shocks determining the development of macroeconomic aggregates in the model. This shows that, over the forecast horizon, the model behaviour is not expected to change qualitatively to a high degree.

Appendix F.12. Conditional Forecasts with the DSGE Model: Method

To replicate a setup of time series models with contemporaneous exogenous predictors for exports and imports[40,41] (as in the ARMAX and VARX models above) within a DSGE model, we run so-called *conditional forecasts* in the DSGE model. For this purpose, we have to compute forecasts for a given constrained path of an endogenous variable.[42] While for the time series models these exogenous data directly enter the parameter estimation procedure, in the DSGE model—following Leeper and Zha (2003) or Smets and Wouters (2004) (where this conditional forecasting procedure

[40] Since government consumption in the DSGE model is represented by a stochastic exogenous shock, we do not consider government consumption as an exogenous predictor for the DSGE mode.

[41] For all analyses below and according to the logic of the DSGE model, exports from Austria to the euro area (imports of euro area from Austria) are represented by consumption (C^*_H) and investment (X^*_H) of Austrian goods in the euro area, while imports of Austria from the euro area (exports of euro area to Austria) are represented by the domestic (Austrian) use of goods produces in the euro area for consumption (C_F) and investment (X_F), respectively.

[42] See the Dynare Manual, pp. 97-100 for additional information on conditional forecasts.

Table F.5: Posterior mean unconditional variance decomposition for model parameter estimation to 2019:Q3

	$u_{A,t}$	$u^*_{A,t}$	$u_{G,t}$	$u^*_{G,t}$	η^b_t	η^{b*}_t	η^X_t	η^{X*}_t	η^R_t	ϵ_w	ϵ^*_w	$\epsilon_{p,t}$	$\epsilon^*_{p,t}$
dY^{obs}	16.7	0.06	36.83	0.04	8.07	0	10.67	9.66	2.12	4.33	0.02	11.31	0.19
dC^{obs}	4.67	0.27	3.74	1.16	70.22	0.01	1.07	0.82	4.31	5.92	0.16	7.5	0.16
dX^{obs}	4.58	0.25	0.52	0.36	0.16	0.01	83.18	0.47	1.3	2.09	0.1	6.36	0.63
$EMPL^{obs}$	3.58	0.52	21.55	2.71	1.35	0.01	2.3	1.81	1.96	36.05	0.66	26.33	1.16
Π^{obs}	17.35	8.25	9.56	14.03	0.62	0.22	1.54	3.5	9.89	4.49	3.53	19.81	7.23
dW^{obs}	7.7	0.34	3.26	0.49	0.37	0.01	1.53	0.69	1.33	16.39	0.16	67.36	0.38
dY^{obs*}	0.01	11.34	0	30.45	0	7.36	0.01	27.18	7.36	0	4	0.02	12.27
dC^{obs*}	0.01	5.22	0.02	1.93	0	42.28	0	3.98	19.63	0	10.43	0	16.5
dX^{obs*}	0.02	3.2	0.02	0.13	0	0.04	0.01	80.25	2.6	0.01	1.51	0	12.21
$EMPL^{obs*}$	0.02	1.32	0.02	18.35	0	0.3	0	1.21	1.94	0	37.04	0	39.79
Π^{obs*}	0.1	22.7	0.1	28.3	0	0.72	0.02	3.35	14.6	0	9.48	0.01	20.6
dW^{obs*}	0	6.15	0	0.68	0	0.33	0	3.5	6.21	0	19.66	0	63.46
R^{obs}	0.15	22.19	0.16	40.94	0.01	0.83	0.02	5.31	3.48	0.01	9.32	0.02	17.55

Table F.6: Posterior mean conditional variance decomposition (in per cent) for model parameter estimation to 2019:Q3

	$u_{A,t}$	$u^*_{A,t}$	$u_{G,t}$	$u^*_{G,t}$	η^b_t	η^{b*}_t	η^X_t	η^{X*}_t	η^R_t	ϵ_w	ϵ^*_w	$\epsilon_{p,t}$	$\epsilon^*_{p,t}$
dY^{obs}	13.72	0.03	43.43	0.02	8.87	0	10.7	9.82	1.63	1.16	0.01	10.53	0.09
dC^{obs}	1.36	0.14	2.41	0.84	87.98	0	0.75	0.68	3.02	0.29	0.08	2.39	0.06
dX^{obs}	1.22	0.12	0.16	0.27	0.03	0	92.63	0.13	1.07	0.53	0.03	3.78	0.04
$EMPL^{obs}$	16.52	0.07	34.96	0.04	6.32	0.01	7.94	7.05	2.74	5.89	0.02	18.34	0.09
Π^{obs}	25.72	0.31	9.75	0.17	0.58	0.06	0.87	2.12	6.41	4.74	0.07	49.04	0.17
dW^{obs}	3.71	0.27	2.85	0.42	0.03	0	1.03	0.54	0.88	16.59	0.09	73.22	0.37
dY^{obs*}	0.01	11	0	39.25	0	8.75	0.01	31	5.12	0	0.54	0.02	4.29
dC^{obs*}	0.01	0.55	0.02	0.27	0	69.5	0	4.49	18.61	0	1.57	0	4.97
dX^{obs*}	0.01	0.86	0	0.02	0	0.01	0	91.21	1.95	0	0.28	0	5.67
$EMPL^{obs*}$	0.01	9.93	0	28.71	0	4.56	0.01	14.32	9.55	0	6.63	0.01	26.26
Π^{obs*}	0.01	24.41	0	9.67	0	0.97	0.01	2.45	15.1	0	6.16	0	41.22
dW^{obs*}	0	2.74	0	0.56	0	0.08	0	3.28	4.96	0	23.94	0	64.44
R^{obs}	0.04	5.43	0.08	25.43	0.02	4.12	0.04	13.85	33.74	0.01	2.38	0.08	14.78

is applied to interest rate paths)—it is necessary to control certain exogenous shocks. These exogenous shocks are unanticipated by the optimizing agent in the DSGE model and are chosen so as to match the corresponding values of the exogenous predictors, which are the conditioning information, that is, in our case Austria's exports to and imports from the euro area. In particular, the reduced-form, first-order, state-space representation is used to find the structural shocks that are needed to match the restricted, exogenous paths. When these controlled shocks are used, the state-space representation can be applied to forecasting. According to the variance decomposition conducted in Online Appendix F.11 above, we use the consumption shocks at home and abroad as the controlled exogenous shocks, which account for the large bulk of Austria's exports—namely, foreign consumption of goods produced at home—and imports, namely, consumption in Austria of goods produced abroad. Intensive testing of the DSGE model revealed that including additional controlled shocks for the conditional forecasts worsened the forecast performance. This also pertains to shocks to investment, which account for a minority of trade between Austria and the euro area. For these reasons, and in line with the results from the variance decomposition, we restricted the number of controlled shocks to consumption shocks.

Appendix F.13. Forecast performance: the DSGE model and a VAR(1) in comparison

Appendix F.13.1. Unconditional forecasts

As a simple validation exercise for the DSGE model, Tables F.7 and F.8 compare the out-of-sample forecast performance of the DSGE model to that of an unconstrained VAR(1) model according to a traditional root mean squared error (RMSE) measure of fit, analogous to Section 5 in the main text. The unconstrained VAR(1) is a natural benchmark model for forecasting accuracy and is, for example, the benchmark adopted in Smets and Wouters (2007). For this exercise, the VAR(1) and the DSGE model are initially estimated on the same time series (1997:Q1 - 2010:Q1) and are then re-estimated every quarter for the calibration period (2010:Q2-2019:Q3). Each quarter of the calibration period is then used as a starting point to conduct forecasts for horizons of one quarter (q), 2q, 4q, 8q and 12q. The forecasts are compared for GDP and its main components, consumption (CONS) and investment (INV), for the wage level (Wage), for inflation as measured by the GDP deflator (dP), and hours worked (Hours). Additionally, for the euro area, interest rates set by the central bank (Euribor) are considered for the forecast.

The unconditional forecasting results for Austria shown in Table F.7 clearly indicate that the DSGE model outperforms the VAR(1) model, especially for medium to long term horizons. DSGE forecasts for GDP improve on VAR(1) predictions by a considerable margin for a horizon up to 12q, while the VAR model has some advantages for shorter horizons of 1q and 2q. Moreover, the additional economic structure embedded in the theory-driven DSGE model seems to increase its forecasting performance over the VAR model for all other variables and also for shorter horizons. Accordingly, the DSGE model outperforms the VAR(1) for almost all horizons—sometimes by a margin over 50 per cent for longer horizons—for output, inflation, hours worked, and consumption.

Table F.7: RMSE-statistic of Austrian variables for different forecast horizons of DSGE in comparison to a VAR(1) model.

	GDP	dP	Hours	Wage	CONS	INV
VAR(1)	*RMSE-statistic for different forecast horizons*					
1q	0.53	0.40	0.21	0.52	0.67	1.42
2q	0.87	0.35	0.31	0.72	0.89	1.96
4q	1.88	0.33	0.49	1.17	1.34	2.81
8q	4.08	0.32	0.81	2.35	2.25	3.59
12q	5.68	0.30	1.01	3.26	3.09	4.71
DSGE	*Percentage improvements (+) or losses (-) relative to VAR(1) model*					
1q	3.78	15.57	31.14	-2.81	27.27	15.89
2q	5.62	13.34	29.87	-24.76	28.30	11.29
4q	27.77	5.94	20.01	-50.57	40.93	-14.35
8q	46.92	12.30	15.93	-37.88	47.23	-41.57
12q	51.07	4.46	24.92	-27.72	54.67	-26.87

The unconditional forecasting results for the euro area, depicted in Table F.8, show a similar picture to the results for Austria, but with slight variations. The DSGE model outperforms the VAR(1) model for all horizons in GDP, hours, wages and consumption, with improvement in inflation and investment for some forecasting horizons. Only for interest rate forecasts, the DSGE model performs worse throughout.[43] DSGE model forecasts of consumption in the euro area are worse in relation to the VAR model compared with Austria. However, this deterioration in the forecast performance of the DSGE model for the euro area in comparison with Austria is due to the performance of the VAR model, as the VAR model seems to forecast euro area consumption better.

[43] Note that even in the original paper by Smets and Wouters (2007), interest rate forecasts were the (only) variable for which the DSGE model could not outperform their VAR(1) benchmark at all horizons. This limited performance of the DSGE model with regards to interest rate forecasts appears to have worsened due to the time period we are focusing on, where policy rates set by the ECB and growth rates were especially downward trending. What could also be noteworthy is that the Taylor rule embedded in the DSGE model tends to capture interest rates better at longer than at shorter horizons in comparison with the VAR model (similar to Smets and Wouters (2007)).

Table F.8: RMSE-statistic of euro area variables for different forecast horizons of DSGE in comparison to a VAR(1).

	GDP	dP	Euribor	Hours	Wage	CONS	INV
VAR(1)	*RMSE-statistic for different forecast horizons*						
1q	0.47	0.20	0.06	0.14	0.32	0.37	2.06
2q	0.81	0.19	0.10	0.30	0.58	0.66	2.15
4q	1.91	0.18	0.18	0.76	1.26	1.44	3.95
8q	4.08	0.17	0.40	1.76	2.86	2.88	6.76
12q	5.17	0.18	0.52	2.38	4.02	3.71	7.71
DSGE	*Percentage improvements (+) or losses (-) relative to VAR(1) model*						
1q	27.76	12.98	-33.60	23.15	16.91	10.93	-21.14
2q	30.18	5.40	-87.24	20.27	18.88	5.88	-6.72
4q	44.80	2.99	-87.74	26.50	20.50	13.86	20.10
8q	50.70	-16.03	-21.86	29.10	19.67	17.39	27.85
12q	48.08	-31.34	-8.83	28.63	15.30	16.61	17.24

Appendix F.13.2. Conditional forecasts

Table F.9 shows the forecast performance of the DSGE model in a conditional forecasting setup for Austria according to the methodology briefly described in Online Appendix F.12 above. As noted there, for this procedure, consumption shocks are controlled to match the exogenously given paths of exports and imports in the DSGE model. Overall, the DSGE model delivers a fairly reasonable forecast performance in comparison to the VARX(1) model, which includes the same exogenous predictors. However, the DSGE model forecast performance deteriorates for some variables with respect to the unconditional case. This becomes most clearly visible when the DSGE forecast performance is looked at for consumption, which obviously decreases due to the controlling of consumption shocks to match the exogenous predictors. With this method, even though the overall forecast performance of the DSGE model increases with respect to the unconditional case, a price has to be paid with the distortion of the general equilibrium framework underlying the DSGE model that decreases its forecast performance. This is less so for Austria than for the euro area, as the additional information of exogenously given exports and imports seems to largely outweigh the distortion of the endogenous variables in the model in the small open economy setting. Accordingly, except for consumption, DSGE model forecasts of Austrian variables do not deteriorate to a large degree with respect to the unconditional case, sometimes even improving slightly, such as in the short horizon (1q, 2q) for inflation forecasts and more pronounced and for almost all horizons for GDP and investment forecasts, where the VAR(1) forecasts deteriorate with respect to the unconditional case.

Table F.9: RMSE-statistic for conditional forecasts of Austrian variables for different forecast horizons of DSGE in comparison to a VARX(1) model.

	GDP	dP	Hours	Wage	CONS	INV
VARX(1)	*RMSE-statistic for different forecast horizons*					
1q	0.44	0.40	0.21	0.47	0.69	1.60
2q	0.59	0.35	0.33	0.67	0.87	2.38
4q	0.92	0.32	0.60	1.09	1.30	3.99
8q	1.39	0.33	1.12	2.20	2.45	7.26
12q	1.88	0.35	1.72	3.34	4.23	12.67
DSGE (conditional forecasts)	*Percentage improvements (+) or losses (-) relative to VARX(1) model*					
1q	-22.68	8.03	1.85	-11.07	-103.10	23.79
2q	-2.50	2.72	2.21	-30.93	-110.61	23.49
4q	15.38	-16.75	4.29	-55.27	-141.66	11.25
8q	28.92	-43.09	5.45	-37.22	-121.06	14.28
12q	48.27	-98.26	17.17	-16.65	-79.56	35.02

Table F.10: RMSE-statistic for conditional forecasts of euro area variables for different forecast horizons of DSGE in comparison to a VARX(1) model.

	GDP	dP	Euribor	Hours	Wage	CONS	INV
VARX(1)	*RMSE-statistic for different forecast horizons*						
1q	0.36	0.20	0.07	0.16	0.30	0.37	2.08
2q	0.49	0.19	0.11	0.33	0.51	0.63	2.14
4q	0.87	0.20	0.22	0.79	1.02	1.33	3.41
8q	1.71	0.24	0.50	1.95	2.32	2.85	4.70
12q	2.74	0.37	0.99	3.67	4.20	4.60	6.86
DSGE (conditional forecasts)	*Percentage improvements (+) or losses (-) relative to VARX(1) model*						
1q	-89.09	-6.51	-100.82	-6.11	11.66	-269.35	-19.88
2q	-125.94	-42.36	-142.31	-4.28	11.96	-244.50	-6.12
4q	-86.75	-91.44	-130.87	1.79	12.82	-160.84	8.12
8q	-34.37	-110.94	-69.90	17.95	12.57	-85.55	-10.10
12q	-0.40	-82.10	-10.44	39.41	27.98	-54.10	-5.43

The conditional forecasting comparison between the DSGE and VARX models for the euro area is depicted in Table F.10. Here, consumption forecasts by the DSGE model further deteriorate with respect to the VARX(1) model. Additionally, the DSGE model is now outperformed by the VARX model for GDP and inflation forecasts, for all forecast horizons, and for investment, for some horizons. The additional distortion resulting from the controlled consumption shocks restrains the forecasting capabilities of the DSGE model more severely in the case of the much larger and less open euro area economy. Here, the additional information on exports and imports between Austria and the euro area, which only accounts for a very small amount of economic activity in the euro area, does not suffice to counter-balance the distortion introduced by the controlled shocks within the DSGE model.

Appendix F.14. DSGE model estimated on the Wu and Xia (2016) shadow rate

Table F.11: RMSE-statistic of Austrian variables for different forecast horizons of the DSGE estimated on the shadow rate of Wu and Xia (2016) in comparison to a VAR(1) model.

	GDP	dP	Hours	Wage	CONS	INV
VAR(1)	*RMSE-statistic for different forecast horizons*					
1q	0.53	0.41	0.20	0.52	0.67	1.44
2q	0.87	0.37	0.30	0.73	0.92	2.02
4q	1.87	0.35	0.48	1.18	1.44	2.85
8q	4.03	0.34	0.84	2.40	2.54	3.32
12q	5.59	0.32	1.12	3.46	3.43	4.33
DSGE	*Percentage improvements (+) or losses (-) relative to VAR(1) model*					
1q	7.33	19.54	29.22	3.52	29.21	16.25
2q	9.65	1.45	26.53	-17.73	34.37	7.30
4q	32.02	-18.66	18.38	-41.58	38.35	-27.53
8q	50.00	6.25	23.27	-23.26	50.65	-74.97
12q	52.23	-0.01	30.56	-11.42	53.65	-54.82

Section 5.2 of the main text and Online Appendix F.13 documented that the DSGE's success in terms of its interest rate forecasting performance is limited. Section 5.2 emphasized that this is partly due to the AR(1) being a particularly tough benchmark to beat. Instead, Online Appendix F.13 documented that, relative to a VAR(1), the overall forecasting performance of the DSGE is not substantially worse compared to Smets and Wouters (2007), despite the fact that our forecasting horizon includes the substantially more challenging period after the financial crisis of 2007-2008. Also, while true that, in comparison to other variables, the forecasting performance for the interest rate is poorer, this appears

Table F.12: RMSE-statistic of euro area variables for different forecast horizons of the DSGE estimated on the shadow rate of Wu and Xia (2016) in comparison to a VAR(1).

	GDP	dP	Euribor	Hours	Wage	CONS	INV
VAR(1)	*RMSE-statistic for different forecast horizons*						
1q	0.48	0.22	0.12	0.15	0.32	0.38	2.12
2q	0.78	0.21	0.20	0.31	0.57	0.69	2.12
4q	1.80	0.20	0.37	0.79	1.22	1.54	3.87
8q	3.85	0.22	0.72	1.98	2.85	3.19	6.53
12q	4.91	0.24	1.04	2.79	4.15	4.18	7.52
DSGE	*Percentage improvements (+) or losses (-) relative to VAR(1) model*						
1q	27.56	19.38	-122.58	21.74	10.89	-3.41	-20.18
2q	26.21	14.51	-182.35	18.08	5.89	-12.76	-11.96
4q	38.71	0.29	-168.51	26.53	7.60	-0.30	20.86
8q	47.81	-17.35	-92.08	37.28	16.50	17.08	29.60
12q	46.26	-36.79	-54.40	40.14	19.21	21.14	13.28

Table F.13: RMSE-statistic for conditional forecasts of Austrian variables for different forecast horizons of the DSGE estimated on the shadow rate of Wu and Xia (2016) in comparison to a VARX(1) model.

	GDP	dP	Hours	Wage	CONS	INV
VARX(1)	*RMSE-statistic for different forecast horizons*					
1q	0.44	0.41	0.20	0.47	0.70	1.59
2q	0.59	0.36	0.29	0.66	0.91	2.36
4q	0.96	0.34	0.50	0.99	1.42	3.77
8q	1.55	0.35	0.83	1.84	2.67	6.31
12q	2.18	0.34	1.19	2.74	4.23	10.05
DSGE (conditional forecasts)	*Percentage improvements (+) or losses (-) relative to VARX(1) model*					
1q	-19.86	12.39	-1.48	-8.52	-107.04	18.53
2q	-1.11	4.60	-8.21	-28.44	-115.11	10.49
4q	21.03	-6.54	-9.42	-58.74	-144.77	-14.16
8q	40.58	-27.49	-18.84	-46.60	-121.44	-18.43
12q	54.29	-112.01	-12.94	-28.82	-92.04	5.17

to be a more general result—not necessarily related to the zero lower bound (ZLB): on the one hand, based on our model, the same picture arises when considering estimation and forecasting periods that end prior to the financial crisis of 2007-2008 (i.e. when the data is not plagued by potential ZLB problems); on the other hand, even in the original Smets and Wouters (2007) model (estimated on a closed economy model on US data and on a time period that ends significantly before the onset of the financial crisis), the forecasts for the nominal interest rate performed worst, and, at short horizons, do not outperform their VAR(1) benchmark.[44]

Nonetheless, it can be argued that the only mediocre performance of interest rate forecasts of the DSGE model could be a result of the fact that the DSGE model does not explicitly adopt the modelling of a (potentially binding) ZLB on the nominal interest rate over some part of the estimation or forecasting horizon. The ZLB can be consequential as, typically, the nominal interest rate, if governed by the logic of a standard Taylor rule, would decrease in response to the low values of inflation and output observed in the aftermath of the financial crisis of 2007-2008 and would thus help to contain and stabilize the drop in output and inflation. Without the possibility of nominal interest rates falling further (below zero), the resulting effects on output and inflation may be that they fall more strongly when the policy

[44]We explain this finding by the estimated strong mean reversion in the nominal interest rate (related to, particularly, the estimated interest rate smoothing coefficient of the Taylor rule). The low estimated coefficient for the degree of interest rate smoothing may not be helpful in terms of the interest rate forecasts but does appear to help in explaining some of the other variables of the total of 13 observables in the DSGE model.

Table F.14: RMSE-statistic for conditional forecasts of euro area variables for different forecast horizons of the DSGE estimated on the shadow rate of Wu and Xia (2016) in comparison to a VARX(1) model.

	GDP	dP	Euribor	Hours	Wage	CONS	INV
VARX(1)	*RMSE-statistic for different forecast horizons*						
1q	0.37	0.21	0.13	0.16	0.30	0.38	2.14
2q	0.51	0.20	0.17	0.35	0.52	0.68	2.16
4q	0.92	0.22	0.27	0.84	1.03	1.44	3.50
8q	1.87	0.27	0.46	2.11	2.35	3.10	5.04
12q	2.96	0.39	0.68	3.72	4.18	4.64	7.41
DSGE (conditional forecasts)	*Percentage improvements (+) or losses (-) relative to VARX(1) model*						
1q	-68.21	-19.60	-183.65	-20.62	6.50	-234.51	-18.39
2q	-88.01	-43.37	-294.94	-4.83	0.78	-195.47	-8.96
4q	-50.29	-71.84	-330.22	8.25	-1.54	-117.16	11.72
8q	-14.36	-93.11	-276.37	27.16	6.14	-55.04	3.70
12q	9.54	-94.66	-208.83	43.55	26.39	-39.47	3.29

rate is implicitly pegged at/around zero, as in this case, the real rate may increase. Also, agents arguably understand this policy setting and incorporate it in their forming of expectations and in their behaviour. It can thus be argued that a model that ignores the ZLB may lead to inaccurate forecasts, calling into question linear estimation methods that ignore the constraint.

The economic literature has responded to these new challenges dictated by ZLB times by exploring various solution methods that can handle occasionally binding constraints and by developing estimation methods for such cases. For small scale models, global solution methods can yield accurate approximations of the true model solutions, and estimation via a nonlinear (particle) filter may be feasible (see, e.g. Gust et al. (2017), Plante et al. (2017), and Richter and Throckmorton (2016)). However, for larger models with many state variables, this approach quickly becomes infeasible, and methods that make some compromise in accuracy but at a gain in speed may need to be applied. These often comprise piecewise-linear approximations, estimated using an inversion-filter or a regime-switching approach. A non-exhaustive list of references in this literature includes Guerrieri and Iacoviello (2017), Atkinson et al. (2020), Hirose and Sunakawa (2016), Hirose and Inoue (2016), Cuba-Borda et al. (2019), Aruoba et al. (2021), Kulish et al. (2017), and Linde et al. (2017). A lot of these contributions are methods focused and evaluate (solution and) estimation accuracy or are applied to small-scaled example models. An exception is, e.g. Linde et al. (2017), who estimate a regime-switching version of Smets-Wouters (2007) model with a ZLB regime. They do find that accounting for the ZLB leads to gains in the log marginal likelihood, but the gains of doing so are much smaller compared to adding other important model features such as financial frictions or time-varying volatility. Fratto and Uhlig (2020), on the other hand, argue that the ZLB is largely irrelevant to understand the behaviour of the U.S. economy in the workhorse Smets and Wouters (2007) model.

In summary, while quite some work in the direction of estimating medium-scale models with a ZLB has been done, the degree of benefits of doing so is still under discussion. Also, we are not aware of applications of estimated DSGE models with a ZLB of the size we employ in our paper—a two-region extension of a Smets-Wouters style model. In order to, nonetheless, account for the possible effects of a ZLB on our estimation and forecast results, we follow a different strategy.[45] That is, the issue can possibly be addressed *without* explicitly estimating a model version with an occasionally binding ZLB by replacing the (constrained) observed interest rate (the 3m-Euribor) with, e.g. the estimate of the euro area shadow rate of Wu and Xia (2016). Shadow rates are fictional short term rates that are constructed from the observed yield curve and are therefore not restricted by the effective lower bound. By using such a policy rate as a proxy for the central bank's policy stance, one can assess the effect of monetary policy without introducing non-linearity to the model (Wu and Xia, 2016). In addition, the advantage is that t also reflects the further monetary loosening that comes from unconventional monetary policy actions—which have been taking place in the real world on a large scale and are not explicitly modelled.

[45]We thank an anonymous referee for suggesting this approach.

Tables F.11 and F.12 document the forecast performance from a version of the DSGE model estimated on the Wu-Xia shadow rate, benchmarked against a VAR(1) that also includes the shadow rate. As can be seen, for almost all variables (output, inflation, consumption, investment, wages), the forecast performance of the version estimated on data including the shadow rate is not substantially different from the version where the included interest rate measure is the 3m-Euribor. The only significant difference arises for interest rate forecasts themselves, in which case the forecasting performance actually deteriorates in the model version estimated on the Wu-Xia shadow rate. Finally, Table F.13 and Table F.14 document similar results when considering conditional forecasts.

Appendix G. Additional tables

Table G.1: Optimized log-likelihood of VAR models of different lag orders

Order of the VAR	Log-likelihood
VAR(1)	3038.27
VAR(2)	2997.90
VAR(3)	2959.07

Note: All models are estimated using the period 1997:Q1 to 2019:Q3.

Table G.2: Out-of-sample forecast performance of VAR models of different lag orders

	GDP	Inflation	Government consumption	Exports	Imports	GDP EA	Inflation EA	Euribor
VAR(1)	*RMSE-statistic for different forecast horizons*							
1q	0.45	0.33	0.66	1.53	1.66	0.41	0.17	0.05
2q	0.82	0.3	0.67	2.83	2.66	0.79	0.15	0.08
4q	1.78	0.28	1	6.18	5.67	1.85	0.16	0.18
8q	4.06	0.28	1.61	13.46	11.96	4.08	0.18	0.42
12q	5.83	0.25	2.1	18.93	16.08	5.36	0.19	0.57
VAR(2)	*Percentage improvements (+) or losses (-) relative to VAR(1) model*							
1q	-2.6 (0.74)	-0.5 (0.96)	-9.1 (0.26)	-5.4 (0.56)	-4.8 (0.45)	-15.5 (0.26)	-14.2 (0.09*)	-3.3 (0.80)
2q	0.3 (0.96)	-0.9 (0.91)	-7.6 (0.30)	-7.2 (0.56)	-8.2 (0.38)	-10 (0.45)	-23.9 (0.04**)	-14.2 (0.22)
4q	6.5 (0.41)	-6.1 (0.41)	-12.1 (0.42)	-4 (0.78)	-2.6 (0.81)	-1.7 (0.90)	-6.2 (0.19)	-26.2 (0.17)
8q	15.6 (0.21)	0.2 (0.97)	-8.4 (0.78)	13.3 (0.14)	12.6 (0.06*)	11.1 (0.26)	-10.3 (0.09*)	-16.4 (0.23)
12q	25.8 (0.23)	-0.5 (0.94)	-13.4 (0.76)	27.8 (0.11)	25.9 (0.11)	25.3 (0.36)	-0.9 (0.72)	2.2 (0.58)
VAR(3)	*Percentage improvements (+) or losses (-) relative to VAR(1) model*							
1q	-7.5 (0.60)	-12.9 (0.27)	-26.5 (0.04**)	-4.3 (0.69)	-2.4 (0.81)	-32.8 (0.21)	-23.2 (0.04**)	-27.5 (0.13)
2q	1.4 (0.90)	-32.9 (0.06*)	-24.2 (0.13)	1.6 (0.87)	-2.3 (0.74)	-15.3 (0.25)	-40.6 (0.01**)	-23.4 (0.12)
4q	23.1 (0.15)	-17.1 (0.22)	-12 (0.34)	7.6 (0.56)	5.8 (0.59)	8.5 (0.66)	-15.1 (0.28)	-12 (0.19)
8q	37.9 (0.22)	-7.5 (0.34)	1.6 (0.83)	26.3 (0.14)	24 (0.08*)	22.8 (0.33)	-13.2 (0.12)	7.9 (0.07*)
12q	47.6 (0.25)	-10 (0.40)	-7.7 (0.48)	42 (0.08*)	35.9 (0.05**)	29.5 (0.42)	-2.6 (0.69)	25.8 (0.01**)

Note: The forecast period is 2010:Q2 to 2019:Q4. The VAR models are estimated starting in 1997:Q1 and are re-estimated each quarter. In parentheses, we show *p*-values of (modified) Diebold-Mariano tests (Harvey et al., 1997), where we test whether forecasts are significantly different in accuracy than the VAR(1) (the null hypothesis of the test is that the VAR(2) and the VAR(3) are less accurate than the VAR(1)). *, **, and *** denotes significance at the 10 per cent, 5 per cent, and 1 per cent levels, respectively.

Table G.3: Mean biases of ABM in comparison to VAR model

	GDP	Inflation	Government consumption	Exports	Imports	GDP EA	Inflation EA	Euribor
VAR(1)	*Mean biases for different forecast horizons*							
1q	0.0018 (0.04**)	0.0001 (0.00***)	-0.0007 (0.58)	0.0081 (0.00***)	0.0078 (0.01***)	0.0018 (0.02**)	-0.0002 (0.00***)	0.0001 (0.33)
2q	0.005 (0.00***)	-0.0002 (0.00***)	-0.0017 (0.24)	0.0213 (0.00***)	0.02 (0.00***)	0.0048 (0.00***)	0 (0.01**)	0.0004 (0.00***)
4q	0.0136 (0.00***)	-0.0001 (0.29)	-0.0035 (0.10*)	0.0544 (0.00***)	0.05 (0.00***)	0.0129 (0.00***)	0.0004 (0.00***)	0.0015 (0.00***)
8q	0.0334 (0.00***)	-0.0001 (0.17)	-0.0056 (0.15)	0.1236 (0.00***)	0.1104 (0.00***)	0.0303 (0.00***)	0.0009 (0.00***)	0.004 (0.00***)
12q	0.0489 (0.00***)	0.0001 (0.87)	-0.0057 (0.19)	0.1775 (0.00***)	0.1515 (0.00***)	0.0402 (0.00***)	0.001 (0.00***)	0.0055 (0.00***)
VECM	*Mean biases for different forecast horizons*							
1q	-0.0006 (0.20)	0.0007 (0.02**)	0.0026 (0.04**)	-0.0011 (0.03**)	-0.0011 (0.10)	-0.0003 (0.78)	-0.0007 (0.00***)	0 (0.06*)
2q	-0.0006 (0.43)	0.0003 (0.00***)	0.0049 (0.00***)	-0.0001 (0.05*)	-0.001 (0.14)	-0.0005 (0.86)	-0.0006 (0.00***)	-0.0001 (0.03**)
4q	0.0001 (1.00)	0.0003 (0.00***)	0.0091 (0.00***)	0.0038 (0.10*)	0 (0.31)	-0.0004 (0.97)	-0.0008 (0.00***)	-0.0003 (0.00***)
8q	0.0032 (0.10)	0.0004 (0.00***)	0.0167 (0.00***)	0.0146 (0.04**)	0.0039 (0.69)	0.0002 (1.00)	-0.0011 (0.00***)	-0.0004 (0.00***)
12q	0.006 (0.06*)	0.0007 (0.05**)	0.0237 (0.00***)	0.0247 (0.02**)	0.0054 (0.74)	-0.0021 (0.75)	-0.0013 (0.00***)	-0.0006 (0.00***)
ABM	*Mean biases for different forecast horizons*							
1q	-0.0023 (0.01**)	-0.0004 (0.12)	-0.0032 (0.03**)	-0.0084 (0.00***)	-0.0087 (0.00***)	-0.0022 (0.00***)	0.0006 (0.01***)	0.0001 (0.05**)
2q	-0.004 (0.01***)	-0.0008 (0.04**)	-0.0029 (0.05*)	-0.0136 (0.00***)	-0.0154 (0.00***)	-0.0044 (0.00***)	0.0007 (0.00***)	0.0003 (0.02**)
4q	-0.0068 (0.00***)	-0.0007 (0.28)	-0.0029 (0.12)	-0.0231 (0.00***)	-0.0277 (0.00***)	-0.0087 (0.00***)	0.0009 (0.00***)	0.0006 (0.00***)
8q	-0.0107 (0.00***)	-0.0007 (0.33)	-0.0047 (0.06*)	-0.0415 (0.00***)	-0.0507 (0.00***)	-0.0176 (0.00***)	0.0008 (0.00***)	0.0014 (0.00***)
12q	-0.0145 (0.00***)	-0.0004 (0.67)	-0.0082 (0.04**)	-0.0596 (0.00***)	-0.0743 (0.00***)	-0.029 (0.00***)	0.0009 (0.00***)	0.0019 (0.00***)

Note: The forecast period is 2010:Q2 to 2019:Q4. The VAR(1) and the VECM are estimated starting in 1997:Q1 and are re-estimated each quarter. The ABM is calibrated to 39 different reference quarters from 2010:Q1 to 2019:Q3. ABM results are obtained as an average of 500 Monte Carlo simulations. In parentheses, we show p-values of Mincer and Zarnowitz (1969) tests, where we test whether the bias is significant. *, **, and *** denotes significance at the 10 per cent, 5 per cent, and 1 per cent levels, respectively.

Table G.4: Optimized log-likelihood of AR models of different lag orders

Order of the AR	GDP	Inflation	Household consumption	Investment	Euribor
AR(1)	344.93	377.51	346.09	248.04	514.39
AR(2)	335.37	372.03	334.79	239.32	513.29
AR(3)	323.30	362.60	326.56	230.50	495.16

Note: All models are estimated using the period 1997:Q1 to 2019:Q3.

Table G.5: Out-of-sample forecast performance of AR models of different lag order

	GDP	Inflation	Household consumption	Investment	Euribor
AR(1)	*RMSE-statistic for different forecast horizons*				
1q	0.52	0.3	0.52	1.18	0.03
2q	0.77	0.28	0.73	1.78	0.06
4q	1.26	0.28	1.14	2.91	0.11
8q	2.12	0.29	1.93	4.26	0.16
12q	2.89	0.25	2.74	6.01	0.2
AR(2)	*Percentage improvements (+) or losses (-) relative to AR(1) model*				
1q	3.9 (0.25)	-0.2 (0.81)	-2.4 (0.40)	1 (0.51)	-9.9 (0.39)
2q	4.9 (0.14)	0 (0.97)	-2.5 (0.49)	0.7 (0.75)	-40.2 (0.02**)
4q	1.8 (0.64)	0 (0.78)	-0.7 (0.51)	-0.2 (0.89)	-89.6 (0.01***)
8q	-0.1 (0.98)	-0.1 (0.50)	-0.7 (0.34)	0.1 (0.95)	-175.5 (0.02**)
12q	-1.5 (0.63)	-0.1 (0.20)	-0.8 (0.07*)	-0.3 (0.72)	-179.8 (0.01***)
AR(3)	*Percentage improvements (+) or losses (-) relative to AR(1) model*				
1q	3 (0.46)	-0.2 (0.91)	-2.3 (0.62)	-2.3 (0.49)	-7 (0.55)
2q	4.3 (0.16)	-0.2 (0.92)	-4.2 (0.37)	-3 (0.58)	-36.9 (0.03**)
4q	1.8 (0.62)	-0.8 (0.43)	1 (0.77)	-3.9 (0.46)	-84.3 (0.01**)
8q	0.9 (0.85)	0.2 (0.25)	1.3 (0.71)	-2.3 (0.68)	-164.9 (0.05**)
12q	-0.8 (0.79)	0.3 (0.37)	2.4 (0.00***)	-2.7 (0.49)	-167.7 (0.03**)

Note: The forecast period is 2010:Q2 to 2019:Q4. The AR models are estimated starting in 1997:Q1 and are re-estimated each quarter. In parentheses, we show p-values of (modified) Diebold-Mariano tests (Harvey et al., 1997), where we test whether forecasts are significantly different in accuracy than the AR(1) (the null hypothesis of the test is that the AR(2) and the AR(3) are less accurate than the AR(1)). *, **, and *** denotes significance at the 10 per cent, 5 per cent, and 1 per cent levels, respectively.

Table G.6: Mean biases of ABM in comparison to DSGE model

	GDP	Inflation	Household consumption	Investment	Euribor
AR(1)	*Mean biases for different forecast horizons*				
1q	0.0002 (0.54)	-0.0005 (0.14)	0.0014 (0.24)	-0.0045 (0.03**)	0.0001 (0.14)
2q	0.0009 (0.52)	-0.0008 (0.04**)	0.0026 (0.09*)	-0.0086 (0.00***)	0.0002 (0.04**)
4q	0.0027 (0.43)	-0.0007 (0.08*)	0.0055 (0.01***)	-0.018 (0.00***)	0.0004 (0.00***)
8q	0.0078 (0.08*)	-0.0007 (0.09*)	0.0125 (0.00***)	-0.0323 (0.00***)	0.0011 (0.00***)
12q	0.0132 (0.02**)	-0.0004 (0.72)	0.0199 (0.00***)	-0.0475 (0.00***)	0.0016 (0.00***)
DSGE	*Mean biases for different forecast horizons*				
1q	-0.0026 (0.00***)	0.0003 (0.00***)	0.0012 (0.09*)	-0.0027 (0.13)	0.0008 (0.00***)
2q	-0.0049 (0.00***)	-0.0002 (0.00***)	0.0018 (0.02**)	-0.006 (0.00***)	0.0017 (0.00***)
4q	-0.0094 (0.00***)	-0.0008 (0.01***)	0.0021 (0.12)	-0.0143 (0.00***)	0.0032 (0.00***)
8q	-0.0159 (0.00***)	-0.0007 (0.32)	0.0037 (0.22)	-0.0237 (0.00***)	0.0048 (0.00***)
12q	-0.0221 (0.00***)	0.0005 (0.01***)	0.0061 (0.02**)	-0.0315 (0.00***)	0.0056 (0.00***)
ABM	*Mean biases for different forecast horizons*				
1q	-0.0023 (0.01**)	-0.0004 (0.12)	-0.0035 (0.00***)	-0.0059 (0.01***)	0.0001 (0.05**)
2q	-0.004 (0.01***)	-0.0008 (0.04**)	-0.0048 (0.00***)	-0.0108 (0.00***)	0.0003 (0.02**)
4q	-0.0068 (0.00***)	-0.0007 (0.28)	-0.0063 (0.00***)	-0.0208 (0.00***)	0.0006 (0.00***)
8q	-0.0107 (0.00***)	-0.0007 (0.33)	-0.0078 (0.03**)	-0.0352 (0.00***)	0.0014 (0.00***)
12q	-0.0145 (0.00***)	-0.0004 (0.67)	-0.0083 (0.14)	-0.0495 (0.00***)	0.0019 (0.00***)

Note: The forecast period is 2010:Q2 to 2019:Q4. The AR(1) and the DSGE model are estimated starting in 1997:Q1 and are re-estimated each quarter. The ABM is calibrated to 39 different reference quarters from 2010:Q1 to 2019:Q3. ABM results are obtained as an average of 500 Monte Carlo simulations. In parentheses, we show p-values of Mincer and Zarnowitz (1969) tests, where we test whether the bias is significant. *, **, and *** denotes significance at the 10 per cent, 5 per cent, and 1 per cent levels, respectively.

Table G.7: Optimized log-likelihood of VARX models of different lag orders

Order of the VARX	Log-likelihood
VARX(1)	748.36
VARX(2)	733.17
VARX(3)	715.12

Note: All models are estimated using the period 1997:Q1 to 2019:Q3.

Table G.8: Conditional forecast performance of VARX models of different lag orders

	GDP	Inflation
VARX(1)	*RMSE-statistic for different forecast horizons*	
1q	0.45	0.31
2q	0.55	0.3
4q	0.83	0.3
8q	1.2	0.31
12q	1.44	0.28
VARX(2)	*Percentage improvements (+) or losses (-) relative to VARX(1) model*	
1q	1.9 (0.70)	-7.5 (0.07*)
2q	1.6 (0.62)	-2.9 (0.18)
4q	2.5 (0.04**)	-2 (0.18)
8q	3.6 (0.16)	-1.9 (0.25)
12q	4.8 (0.24)	-4 (0.34)
VARX(3)	*Percentage improvements (+) or losses (-) relative to VARX(1) model*	
1q	2.1 (0.69)	-3.3 (0.41)
2q	1 (0.78)	-1.9 (0.39)
4q	1.7 (0.32)	-1.4 (0.48)
8q	2.2 (0.67)	0.6 (0.80)
12q	3.1 (0.67)	0.9 (0.71)

Note: The forecast period is 2010:Q2 to 2019:Q4. The VARX models are estimated starting in 1997:Q1 and are re-estimated each quarter. In parentheses, we show *p*-values of (modified) Diebold-Mariano tests (Harvey et al., 1997), where we test whether forecasts are significantly different in accuracy than the VARX(1) (the null hypothesis of the test is that the VARX(2) and the VARX(3) are less accurate than the VARX(1)). *, **, and *** denotes significance at the 10 per cent, 5 per cent, and 1 per cent levels, respectively.

Table G.9: Mean biases of ABM in comparison to VARX model

	GDP	Inflation
VARX(1)	*Mean biases for different forecast horizons*	
1q	-0.0004 (0.67)	-0.0005 (0.06*)
2q	-0.0007 (0.69)	-0.0007 (0.01***)
4q	-0.0012 (0.69)	-0.0007 (0.01**)
8q	-0.0014 (0.22)	-0.0006 (0.01***)
12q	-0.0018 (0.01**)	-0.0003 (0.02**)
VECMX	*Mean biases for different forecast horizons*	
1q	-0.0009 (0.00***)	0.0007 (0.02**)
2q	-0.0015 (0.00***)	0.0006 (0.37)
4q	-0.0024 (0.00***)	0.0008 (0.23)
8q	-0.0031 (0.00***)	0.001 (0.11)
12q	-0.0037 (0.00***)	0.0016 (0.01**)
ABM	*Mean biases for different forecast horizons*	
1q	-0.0011 (0.00***)	0.0008 (0.08*)
2q	-0.0017 (0.00***)	0.0006 (0.37)
4q	-0.003 (0.00***)	0.0008 (0.23)
8q	-0.0043 (0.00***)	0.001 (0.12)
12q	-0.0056 (0.00***)	0.0016 (0.01***)

Note: The forecast period is 2010:Q2 to 2019:Q4. The VARX(1) and the VECMX are estimated starting in 1997:Q1 and are re-estimated each quarter. The ABM is calibrated to 39 different reference quarters from 2010:Q1 to 2019:Q3. ABM results are obtained as an average of 500 Monte Carlo simulations. In parentheses, we show *p*-values of Mincer and Zarnowitz (1969) tests, where we test whether the bias is significant. *, **, and *** denotes significance at the 10 per cent, 5 per cent, and 1 per cent levels, respectively.

Table G.10: Optimized log-likelihood of ARX models of different lag orders

Order of the AR	GDP	Inflation	Household consumption	Investment
ARX(1)	366.77	381.30	352.49	264.68
ARX(2)	356.79	375.83	342.05	255.87
ARX(3)	345.61	367.22	332.16	246.24

Note: All models are estimated using the period 1997:Q1 to 2019:Q3.

Table G.11: Conditional forecast performance or ARX models of different lag orders

	GDP	Inflation	Household consumption	Investment
ARX(1)	*RMSE-statistic for different forecast horizons*			
1q	0.44	0.31	0.49	1.19
2q	0.54	0.3	0.64	1.57
4q	0.82	0.3	0.98	2.5
8q	1.19	0.31	1.54	3.98
12q	1.44	0.28	2.19	5.59
ARX(2)	*Percentage improvements (+) or losses (-) relative to ARX(1) model*			
1q	2.9 (0.47)	-1.1 (0.32)	-3.2 (0.34)	0.4 (0.58)
2q	4 (0.25)	-0.9 (0.46)	-2.9 (0.49)	0.5 (0.60)
4q	3.3 (0.04**)	-0.9 (0.29)	-1.6 (0.42)	1.1 (0.17)
8q	3.5 (0.38)	-1 (0.17)	-2 (0.37)	1.2 (0.18)
12q	4.1 (0.46)	-1.8 (0.24)	-2.3 (0.18)	0.9 (0.16)
ARX(3)	*Percentage improvements (+) or losses (-) relative to ARX(1) model*			
1q	3.8 (0.37)	-2.1 (0.37)	-3 (0.57)	-1.8 (0.42)
2q	4.3 (0.26)	-2.3 (0.31)	-5.3 (0.34)	-1.6 (0.59)
4q	3.3 (0.04**)	-2.2 (0.15)	0 (1.00)	-0.8 (0.73)
8q	3.4 (0.52)	-0.5 (0.37)	2.3 (0.57)	0 (1.00)
12q	3.6 (0.59)	-1.1 (0.31)	4.8 (0.26)	-1.1 (0.72)

Note: The forecast period is 2010:Q2 to 2019:Q4. The ARX models are estimated starting in 1997:Q1 and are re-estimated each quarter. In parentheses, we show *p*-values of (modified) Diebold-Mariano tests (Harvey et al., 1997), where we test whether forecasts are significantly different in accuracy than the ARX(1) (the null hypothesis of the test is that the ARX(2) and the ARX(3) are less accurate than the ARX(1)). *, **, and *** denotes significance at the 10 per cent, 5 per cent, and 1 per cent levels, respectively.

Table G.12: Mean biases of ABM in comparison to DSGE model (conditional forecasts)

	GDP	Inflation	Household consumption	Investment
ARX(1)	*Mean biases for different forecast horizons*			
1q	-0.0005 (0.64)	-0.0005 (0.06*)	0.001 (0.43)	-0.0041 (0.09*)
2q	-0.0007 (0.67)	-0.0007 (0.00***)	0.0018 (0.22)	-0.0082 (0.00***)
4q	-0.0012 (0.66)	-0.0006 (0.01***)	0.0039 (0.04**)	-0.0177 (0.00***)
8q	-0.0015 (0.19)	-0.0006 (0.00***)	0.0091 (0.00***)	-0.0328 (0.00***)
12q	-0.0019 (0.01***)	-0.0002 (0.02**)	0.015 (0.00***)	-0.0481 (0.00***)
DSGE	*Mean biases for different forecast horizons*			
1q	-0.0007 (0.61)	0.0007 (0.00***)	0.0053 (0.01**)	-0.0031 (0.12)
2q	-0.0007 (0.61)	0.0008 (0.00***)	0.0109 (0.00***)	-0.0069 (0.00***)
4q	-0.0005 (0.87)	0.0013 (0.00***)	0.0236 (0.00***)	-0.0178 (0.00***)
8q	0.0001 (0.88)	0.0031 (0.00***)	0.0489 (0.00***)	-0.0356 (0.00***)
12q	-0.0007 (0.06*)	0.0058 (0.00***)	0.0717 (0.00***)	-0.0527 (0.00***)
ABM	*Mean biases for different forecast horizons*			
1q	-0.0011 (0.00***)	0.0008 (0.08*)	-0.0021 (0.01***)	-0.0047 (0.02**)
2q	-0.0017 (0.00***)	0.0006 (0.37)	-0.0019 (0.01***)	-0.0085 (0.00***)
4q	-0.003 (0.00***)	0.0008 (0.23)	-0.002 (0.04**)	-0.017 (0.00***)
8q	-0.0043 (0.00***)	0.001 (0.12)	-0.0009 (0.02**)	-0.0289 (0.00***)
12q	-0.0056 (0.00***)	0.0016 (0.01***)	0.0008 (0.01***)	-0.0412 (0.00***)

Note: The forecast period is 2010:Q2 to 2019:Q4. The ARX(1) and the DSGE model are estimated starting in 1997:Q1 and are re-estimated each quarter. The ABM is calibrated to 39 different reference quarters from 2010:Q1 to 2019:Q3. ABM results are obtained as an average of 500 Monte Carlo simulations. In parentheses, we show *p*-values of Mincer and Zarnowitz (1969) tests, where we test whether the bias is significant. *, **, and *** denotes significance at the 10 per cent, 5 per cent, and 1 per cent levels, respectively.

Table G.13: Optimized log-likelihood of sectoral VAR models of different lag orders

Order of the VAR	Log-likelihood
VAR(1)	2679.21
VAR(2)	2687.73
VAR(3)	2701.47

Note: All models are estimated using the period 1997:Q1 to 2019:Q3.

Table G.14: Out-of-sample forecast performance of sectoral gross value added (GVA)

	A	B, C, D and E	F	G, H and I	J	K	L	M and N	O, P and Q	R and S
VAR(1)	*RMSE-statistic for different forecast horizons*									
1q	5.25	1.2	1.49	0.8	1.66	3.29	0.41	1.17	0.46	0.62
2q	7.32	1.71	1.93	1.15	2.01	3.63	0.6	1.57	0.61	0.83
4q	9.9	2.24	3.35	1.83	2.96	5.03	0.9	2.28	0.88	1.19
8q	10.76	2.83	5.99	2.96	2.75	4.58	1.22	3.75	1.46	1.86
12q	13.67	3.31	8.06	3.79	3.63	4.45	1.72	5.04	1.94	2.63
VAR(2)	*Percentage improvements (+) or losses (-) relative to VAR(1) model*									
1q	-5.7 (0.18)	-3.7 (0.66)	-27.2 (0.13)	-19.9 (0.01***)	-13.1 (0.03**)	-8.7 (0.33)	-61 (0.03**)	-20.3 (0.18)	-6.5 (0.12)	-29.2 (0.04**)
2q	-2.8 (0.36)	2.3 (0.72)	-26.8 (0.02**)	-2.8 (0.65)	-7.6 (0.14)	-20.4 (0.06*)	-27.3 (0.07*)	3.6 (0.49)	-7.4 (0.20)	-25.8 (0.02**)
4q	3.6 (0.48)	4.5 (0.70)	-6.4 (0.16)	-0.4 (0.96)	-4.8 (0.31)	0.8 (0.92)	-16.2 (0.22)	-1.6 (0.78)	5.4 (0.44)	-22.4 (0.01**)
8q	1.1 (0.81)	-6.2 (0.68)	-1.2 (0.52)	0.7 (0.69)	-5.9 (0.22)	-13.6 (0.01**)	-18.1 (0.00***)	-1 (0.83)	4.7 (0.24)	-13 (0.01**)
12q	3.5 (0.40)	-6.2 (0.38)	-0.3 (0.88)	0 (1.00)	0 (1.00)	-3.3 (0.63)	-3.3 (0.77)	-3.9 (0.60)	-2.6 (0.61)	-7.1 (0.34)
VAR(3)	*Percentage improvements (+) or losses (-) relative to VAR(1) model*									
1q	-25.8 (0.18)	-7.3 (0.66)	-37.6 (0.02**)	-51.6 (0.03**)	-18.8 (0.25)	-27.1 (0.03**)	-78.3 (0.01***)	-26.4 (0.12)	-20.9 (0.01**)	-51.5 (0.02**)
2q	-14.4 (0.21)	-8.3 (0.56)	-22.7 (0.19)	-25.6 (0.11)	-21.4 (0.03**)	-29.9 (0.05*)	-76.7 (0.00***)	-3.4 (0.70)	-6.3 (0.44)	-43.4 (0.00***)
4q	1.9 (0.85)	-2 (0.84)	2 (0.89)	-27.4 (0.01***)	-4.6 (0.39)	-6 (0.68)	-94.2 (0.00***)	-9.5 (0.44)	1.4 (0.80)	-39.9 (0.00***)
8q	5.7 (0.71)	-19.6 (0.27)	8.4 (0.43)	-5.4 (0.37)	-14.2 (0.29)	-16.1 (0.23)	-96.2 (0.09*)	-5.3 (0.59)	-5.2 (0.46)	-30.9 (0.00***)
12q	11.5 (0.16)	-13.8 (0.33)	4.3 (0.29)	2.5 (0.77)	-2.3 (0.89)	-4.2 (0.72)	-75.6 (0.06*)	-10.1 (0.15)	-2.3 (0.59)	-25.7 (0.00***)

Note: GVA is shown for the sectors Agriculture, 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). All models are estimated starting in 1997:Q1. The forecast period is 2010:Q2 to 2019:Q4. The VAR models are estimated starting in 1997:Q1 and are re-estimated each quarter. In parentheses, we show p-values of (modified) Diebold-Mariano tests (Harvey et al., 1997), where we test whether forecasts are significantly different in accuracy than the VAR(1) (the null hypothesis of the test is that the VAR(2) and the VAR(3) are less accurate than the VAR(1)). *, **, and *** denotes significance at the 10 per cent, 5 per cent, and 1 per cent levels, respectively.

Table G.15: Mean biases of ABM in comparison to VAR(1) for sectoral gross value added (GVA)

	A	B, C, D and E	F	G, H and I	J	K	L	M and N	O, P and Q	R and S
VAR(1)	*Mean biases for different forecast horizons*									
1q	-0.0039 (0.02**)	-0.0003 (0.61)	-0.0058 (0.02**)	0.0017 (0.37)	-0.0036 (0.30)	-0.0023 (0.11)	0.0011 (0.22)	0.0046 (0.02**)	0.0005 (0.56)	0.0023 (0.06*)
2q	-0.0093 (0.00***)	-0.0012 (0.32)	-0.0104 (0.00***)	0.003 (0.28)	-0.0041 (0.15)	-0.0004 (0.13)	0.0019 (0.12)	0.0068 (0.01***)	0.0008 (0.27)	0.004 (0.01***)
4q	-0.0093 (0.00***)	-0.0025 (0.44)	-0.0209 (0.00***)	0.007 (0.06*)	-0.0076 (0.03**)	-0.0001 (0.01***)	0.0036 (0.04**)	0.0141 (0.00***)	0.0015 (0.02**)	0.0078 (0.00***)
8q	-0.0067 (0.00***)	-0.0048 (0.65)	-0.0418 (0.00***)	0.0173 (0.00***)	-0.0122 (0.00***)	0.0083 (0.04**)	0.0078 (0.00***)	0.0296 (0.00***)	0.0023 (0.02**)	0.0166 (0.00***)
12q	-0.0069 (0.00***)	-0.0065 (0.31)	-0.0597 (0.00***)	0.0299 (0.00***)	-0.0215 (0.00***)	0.0067 (0.01***)	0.0114 (0.00***)	0.0441 (0.00***)	0.0028 (0.01***)	0.0241 (0.00***)
ABM	*Mean biases for different forecast horizons*									
1q	-0.0006 (0.05**)	-0.0024 (0.14)	-0.0037 (0.01***)	-0.0018 (0.40)	-0.0054 (0.07*)	0.0015 (0.38)	-0.0048 (0.00***)	-0.006 (0.01***)	-0.0015 (0.05*)	-0.0009 (0.59)
2q	-0.0052 (0.00***)	-0.0027 (0.13)	-0.0078 (0.00***)	-0.0037 (0.18)	-0.0106 (0.00***)	0.0024 (0.22)	-0.0104 (0.00***)	-0.0121 (0.00***)	-0.0037 (0.00***)	-0.0025 (0.11)
4q	-0.001 (0.00***)	-0.003 (0.42)	-0.0168 (0.00***)	-0.006 (0.17)	-0.0204 (0.00***)	0.0047 (0.01**)	-0.0216 (0.00***)	-0.0229 (0.00***)	-0.0081 (0.00***)	-0.0059 (0.00***)
8q	0.0165 (0.00***)	-0.0037 (0.65)	-0.033 (0.00***)	-0.0081 (0.03**)	-0.0365 (0.00***)	0.0174 (0.03**)	-0.0423 (0.00***)	-0.0425 (0.00***)	-0.0176 (0.00***)	-0.0108 (0.00***)
12q	0.031 (0.00***)	-0.0049 (0.20)	-0.0451 (0.00***)	-0.0086 (0.00***)	-0.0566 (0.00***)	0.0201 (0.00***)	-0.063 (0.00***)	-0.0631 (0.00***)	-0.0276 (0.00***)	-0.0169 (0.00***)

Note: Bias is shown for the sectors Agriculture, 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 2019:Q4. The VAR(1) model is estimated starting in 1997:Q1 and is re-estimated each quarter. The ABM is calibrated to 39 different reference quarters from 2010:Q1 to 2019:Q3. ABM results are obtained as an average of 500 Monte Carlo simulations. In parentheses, we show p-values of Mincer and Zarnowitz (1969) tests, where we test whether the bias is significant. *, **, and *** denotes significance at the 10 per cent, 5 per cent, and 1 per cent levels, respectively.

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