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An agent-based model

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Abstract

We develop an agent-based stock-flow consistent macroeconomic model with multiple industries and supply chains to analyse the propagation of sectoral shocks. The model features five industries with heterogeneous firms producing final goods, intermediate inputs, and capital goods. Key innovations are the distinction between homogeneous intermediate goods (produced on stock) and tailor-made capital goods (ordered in advance), reflecting differences in production processes and the usage of the Almost Ideal Demand System (AIDS) for modelling household consumption behaviour. Calibrated to Austrian data using Eurostat sources and neural posterior estimation, the model is used to analyse the economy's response to a sector-specific supply shock, illustrated through the example of a flooding event affecting the primary sector. Our results demonstrate that inventory levels critically determine economic resilience: a 100-year flood has limited impact regardless of the industry setup, but under a 1,000-year flood, low inventory ratios trigger a vicious circle in which supply shortages cascade across industries, preventing reconstruction and causing a prolonged GDP contraction. High inventory buffers, by contrast, enable rapid recovery. Hence, the structural decomposition into industries becomes decisive when inventories are low, revealing that interdependencies matter most during supply-constrained crises. These findings highlight the importance of explicitly modelling industry interdependencies and inventory dynamics for understanding shock propagation.

Keywords: agent-based model, supply chains, input-output analysis, inventories, shock propagation, climate change

JEL classification: C63, D57, E17, E37, Q54

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1 Introduction

The majority of currently used agent-based (AB) models use only two factors of production: labour and capital (e.g. Caiani et al., 2016, Dawid et al., 2016). However, recent events, such as the COVID-19 pandemic or the start of the full-scale war in Ukraine, have highlighted how economies can suddenly face a shortage of crucial production factors. In order to understand the disruptions that are associated with such shortages, it is important to include inter-industry relationships and the corresponding supply chains in macroeconomic models.

In this paper, we develop an agent-based stock-flow consistent model that features multiple industries (primary, manufacturing, construction, services, and energy) as well as different types of firms (producers of final consumption goods, intermediate goods, and capital goods). We parameterise the model to fit the Austrian economy, using various publicly available data sources, including data on employment (Eurostat, 2023a) and unemployment (Eurostat, 2023f), demographic data (Eurostat, 2023d, 2024a, 2024c), income data (Eurostat, 2025a), data on public expenditure and revenues (Eurostat, 2023b, 2023c), data on financial assets and liabilities (Eurostat, 2025b) and consumption data (Eurostat, 2025c). For the calibration of the flow of goods between sectors, we use input-output tables (Eurostat, 2023e). One innovation of our model is that we take into account that intermediate and capital goods differ from each other in terms of homogeneity: while intermediate goods are usually quite homogeneous, capital goods (e.g. manufacturing facilities) tend to be more tailor-made. Hence, we assume that intermediate goods are produced on stock and later sold on a market, while capital goods have to be ordered in advance and are delivered to the customers once finished.

To illustrate the model's ability to capture sectoral shock propagation, we subject it to a targeted shock in a single industry. As an illustrative application, drawing on damage estimates by Bachner et al. (2024), we simulate a flooding event that destroys part of the capital stock, input inventory, and output inventory of affected firms.

Our results show that the size of intermediate input inventories is a key determinant of the economy's ability to absorb a supply-side shock. For a disruption in the form of a 100-year flood, the decline in real GDP is limited and the single- and multiple-industry setups behave similarly regardless of inventory levels. Under a severe shock of a 1,000-year flood, however, low inventories trigger a supply-chain crisis in which shortages cascade across industries, leading to a GDP drop of over 30% with no full recovery. High inventories, by contrast, provide a buffer for a rapid rebound. These findings demonstrate that modelling industry interdependencies and inventory dynamics is essential for understanding the propagation of large, non-uniform shocks.

The paper is structured as follows: Section 2 provides a survey of the existing literature, while Section 3 gives an outline of the model. The calibration process is described in Section 4. Section 5 provides the model simulations, comparing baseline and shock scenarios as well as illustrating the sensitivity of the model to parameter changes. The final section concludes.

2 Literature Review

The model presented here builds on and generalises various strands in the literature. There are only a few papers in the AB macroeconomic literature that include multiple industries. The model by Seppecher et al. (2018) is closely related to what we intend to do: it includes an intermediate goods sector whose products are assembled by the consumption goods industry to yield a final product, which is then sold to consumers. The primary objective of Seppecher et al. (2018) is to analyse the endogenous formation of markups. In particular, the authors concentrate on how firms decide on markups as well as on how markups evolve when industries are dependent on the products and prices of other industries. It is to this end that they include an intermediate-goods-producing industry sector. Pettena and Raberto (2022) use world-level input-output data to calibrate an agent-based model including six industries and a capital goods sector. They employ the model to analyse different green transition scenarios. In their model, intermediate and capital goods are ordered one period in advance, while production of final goods is based on demand expectations. If the supply of intermediate and capital goods falls short of demand due to supply constraints, final sales to households are rationed. They abstract from inventories by assuming that any unsold goods perish within one period.

Reissl et al. (2022) propose an agent-based model calibrated by using Italian input-output data to analyse the impact of COVID-19-related lockdowns. They highlight the importance of desired inventory ratios, pointing out that low inventory ratios would increase the impact of a supply shock, whereas high inventory ratios may lead to hardly any shock impact, as firms would hold sufficient inventories. In order to estimate sector-specific inventory rates, they use an algorithm based on the method of simulated moments.

The role of inventories in shock propagation is also studied in the broader macroeconomic literature. Kahn (1987) shows that inventory investment amplifies production volatility relative to sales, a result that Bils and Kahn (2000) extend by demonstrating that the cyclical behaviour of inventories reveals the nature of underlying demand and supply shocks. Alessandria et al. (2010) document that import delivery lags and inventory-carrying costs create significant frictions in international trade, causing import volumes to collapse sharply after large devaluations, while Alessandria et al. (2013) show that trade wedges (i.e. the persistent deviations of trade flows from standard model predictions) are largely attributable to importers' inventory-management decisions. More recently, Otto et al. (2017) show that supply chain disruptions can be efficiently mitigated by warehousing and idle capacities – a finding that our model reproduces in the context of a sectoral supply shock – and that the interaction of inventory levels and industry structure determines the conditions under which such mitigation is effective. Our model connects these previously separate literatures by modelling inventories as an explicit buffer stock within a multi-industry production network, allowing us to study how the interaction of inventory levels and industry structure shapes the propagation of shocks.

Another interesting direction can be found in Mellacher, 2021, who models the endogenous formation of industries. Given a 'potential product space' (Mellacher, 2021, p. 16), entrepreneurs can try to radically innovate and invent a new product/industry. Other entrepreneurs can then try to imitate this new product in order to capture a part of the new market. However, the production process

includes only labour, but does not feature capital or intermediate products.
Poledna et al., 2023 also develop an AB model involving multiple industries. They use coefficients from input-output tables to base their model of the Austrian economy on empirical data. However, they deviate in some important respects from the AB perspective, such as by assuming that all firms have the same expectations for the future. The main application of their model is to show the quality of the forecasts that the AB model is able to produce.
The model by Wiese et al. (2024) is based on the model by Poledna et al. (2023) but adds several extensions that should increase its accuracy of prediction, including a housing market, synthetic populations with income, wealth and consumption heterogeneity, and an improved credit market. They also use a state-of-the-art approximate Bayesian inference method to calibrate their model to 38 OECD countries and show that their model produces more accurate predictions as the model by Poledna et al. (2023) or an AR(1) process.
Our model of production also relates to the 'snakes and spiders' terminology used in Baldwin and Venables (2013): while the production technology in the model cannot be seen as either a 'snake' or a 'spider', it does have elements of both. In order for final goods to be produced, intermediate input and capital goods have to be used; thus, it has a sequential nature and resembles a snake. The production of final, intermediate, and capital goods always needs intermediate inputs from all industries (as well as labour and capital inputs); in this regard, the mode of production resembles a spider.
The input-output structure of our model also directly relates to the growing literature on production networks as a propagation mechanism for sectoral shocks. Acemoglu et al. (2012) show that, in the presence of input-output linkages, microeconomic shocks propagate through the network and do not cancel out in the aggregate. The degree to which they do so depends on the asymmetry of sectors' roles as suppliers. Carvalho (2014) demonstrates that input-output networks transform idiosyncratic firm-level disturbances into aggregate fluctuations, with the network's structure (not just its size) determining the macro response. Building on this result, Carvalho and Tahbaz-Salehi (2019) review how production networks act as a shock amplifier, particularly through input bottlenecks and cascading failures. Baqaee and Farhi (2019, 2021) show that once production networks are explicitly modelled, Hulten's Theorem (which states that, within a general equilibrium model, the macroeconomic impact of a shock to a certain industry is a simple function of the industry's sales share) no longer holds. Our model contributes to this literature by organising firm production in multiple, intertwined industries, thus creating a production network in an AB stock-flow consistent framework, and by showing that the interaction of inventory buffers and network structure becomes economically decisive when inventories are low.

3 Model description

In each period of the simulation, the following order of events takes place:

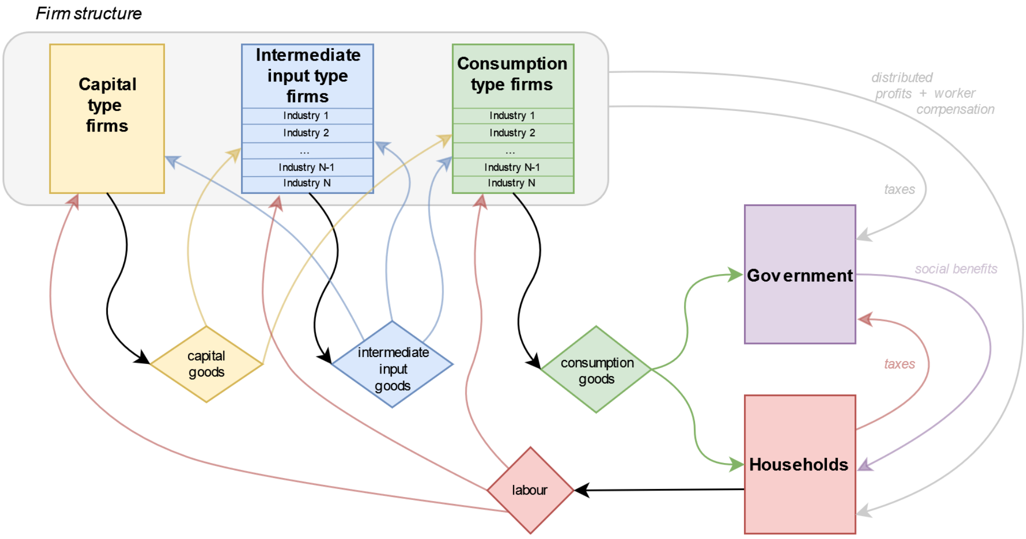
1. Firms update their production plans as well as their demand for labour, capital, and intermediate inputs. Markups and wages are updated, too.

2. Firms assess their credit demand. Banks evaluate firms' loan applications and supply credit accordingly. If firms are credit-constrained, they adjust

their demand for labour, capital, and intermediate inputs to the available financial means.

3. Workers revise their reservation wages, and employed workers decide whether to look at job offers of other firms.
4. Labour market: unemployed and employed workers looking for a new job interact with firms with vacancies on the labour market.
5. Workers receive wages and pay taxes.
6. The government pays unemployment benefits and social benefits.
7. Production of firm output takes place. Firms calculate unit costs and update prices.
8. Markets are cleared: first, firms purchase intermediate goods; next, firms order or purchase capital goods; and, finally, individuals and the government purchase consumption goods on the final goods market.
9. Interest, bonds, and loans repayments are processed.
10. The banking sector, the central bank, and firms calculate profits and distribute them to their owners (in the case of the central bank: the government).
11. The government collects taxes from firms and banks as well as their respective owners, and then it issues bonds, which banks buy.
12. The central bank accommodates reserve requests by banks.

Figure 1: Model structure



Source: Own elaboration.

3.1 General model setup

We model the firm sector of the economy as consisting of $K = 3$ types of firms: final goods producers (whose goods are used for consumption purposes), intermediate input producers (whose goods are used in the production process in all other firms), and capital goods producers (who produce a capital good that must be ordered one period in advance).

The final-goods and intermediate-input producers are furthermore separated into industries. Each industry is comprised of a certain number of firms. All firms within an industry produce the same good (but may offer it at different prices); thus, household agents wanting to consume a good j can buy such a good j from any firm in industry j.

Every firm has the same set of properties, though the values of these properties can either differ between industries (e.g. intermediate input coefficients: these are different for each industry but the same for all firms *within* an industry) or firms (e.g. planned production levels). Within an industry, firms differ in size, with size following a lognormal distribution.

The next sections describe the behaviour of the agents in more detail. We use the following notation: Given x_t is the realisation of a variable (e.g. the value of real sales that a certain firm has achieved in period t), we define x_t^e as the expectation of a given agent of variable x (before its exact value is known). Similarly, x_t^d defines an agent's desired level of variable x. In the following equations, we drop the agent index, firm type index (k), or industry index (i or j) where it is not necessary.

3.2 Household agents

Household agents[1] in our model are either active labour market participants (i.e. workers, employed or unemployed), inactive individuals (e.g. pensioneers or under working age), or firm or bank owners. Firm owners contribute to the production of their firm (i.e. the labour input available to a firm consists of the number of hired workers plus the owner). While employees receive a wage, the owner's income consists of the earned profit of the firm.

If an individual is employed at a firm, they will provide their labour to the firm in exchange for a wage. Active but unemployed households receive unemployment benefits, which consist of a share of previous net wage income (ϵ^{uebr}) during the first two periods of unemployment. After these two periods, the agent is no longer eligible and unemployment benefits are reduced to zero.

Individuals interact with firms looking for additional workers through a job board, where firms post their vacancies. Unemployed agents always look at job offers, whereas employed agents only do so with a certain probability (Pr^{search}). Unemployed workers write $n^{app,u}$ number of job applications, while employed workers select $n^{app,e}$ job applications and only apply to offers exceeding their current wage. Individuals who have become unemployed in the current period are still looking for jobs that offer a wage at least as high as their previous wage. Individuals who have already received unemployment benefits will accept any job that pays more than the benefits they currently receive. Inactive individuals receive social benefits (consisting of the Classification of Functions of Government

[1]Note that while we call these agents 'households' and 'household agents', we use individual-level data to calibrate the data for these agents. Thus, we are thinking of 'individuals' (with each having their own household) rather than 'households' (a group of individuals living together.)

[COFOG] categories: old age, sickness and disability, survivors, and family and children).

3.2.1 Consumption demand and budget allocation

Nominal consumption spending depends on an autonomous part (c_0), the marginal propensity to consume for income exceeding the autonomous part (c_1), and the propensity to consume out of net wealth (c_2):

$$C = \min\left(\max(c_0 + c_1 \cdot (Y - c_0) + c_2 \cdot W, c_0), W\right) \tag{1}$$

where Y denotes disposable income and W financial net wealth. The inner max operator ensures that consumption never falls below the autonomous level c_0, while the outer min restricts total spending to available deposits, reflecting the absence of consumer credit in the model.
Since our model includes multiple industries, where every industry produces a different good, individuals must decide on how to allocate this consumption budget. We use the established Almost Ideal Demand System (AIDS), proposed by Deaton and Muellbauer (1980), to achieve this.
Particularly, every individual in our model computes their budget shares b_j of expenditures (where indices j and k both represent goods from industries) based on the following equation:

$$b_j = \kappa_j + \sum_k \gamma_{kj} \log(p_k) + \beta_j \log(M/\tilde{P}) \tag{2}$$

where M is the household's total nominal consumption budget and price index $\tilde{P}$ is defined as

$$\log \tilde{P} = \kappa_0 + \sum_j \kappa_j \log p_j + 1/2 \sum_j \sum_k \gamma_{jk} \log p_j \log p_k \tag{3}$$

All households observe average final good prices p_j from the current period, and κ_0, κ_j, β_j, and γ_{jk} are exogenous parameters calibrated to match Austrian consumer behaviour.
The advantage of this specification is that it can easily replicate important properties of consumer behaviour. The β_j parameter can be interpreted as income elasticity: $\beta_j \leq 0$ means good j is a normal good (i.e. its budget share decreases with increasing income), while $\beta_j > 0$ means it is a luxury good (i.e. its budget share increases with increasing income). Similarly, the γ_{jk} parameters are cross price elasticities (i.e. they measure how the share of good j changes when the price of good k increases).
After households have received their income (as wages, profits, or social benefits) and allocated their consumption budget to the final consumption goods, they go to the final goods market, where they interact with the final goods producers.

3.3 Firms

3.3.1 Production planning: labour, capital, intermediate inputs

At the beginning of each period, all final-good and intermediate-input firms use adaptive expectations to decide on their production level for this period, meaning that their sales expectations are formed as follows (see Caiani et al., 2016):

$$S_t^e = S_{t-1}^e + \lambda \cdot (S_{t-1} - S_{t-1}^e) \tag{4}$$

where S are real sales and λ is the 'expectation reaction parameter' governing the strength with which the expectations are updated.

Based on this real sales expectation, firms calculate their desired output inventory ($INV^{d,Q}$; a buffer stock, calculated as a ratio of the expected real sales) and their desired production level (Q_t^d):

$$Q_t^d = S_t^e + (INV_t^{d,Q} - INV_{t-1}^Q) \tag{5}$$

$$INV_t^{d,Q} = \nu^{d,Q} \cdot S_t^e \tag{6}$$

where $\nu^{d,Q}$ denotes the desired output inventory ratio and INV^Q the actual current output inventory stock.

Capital firms do not produce on stock, but instead take orders, which takes place on the market for capital goods. This reflects the fact that intermediate and capital goods differ from each other in terms of homogeneity: while intermediate goods are usually quite homogenous, capital goods (e.g. manufacturing facilities) tend to be more tailor-made. In the case of capital firms, desired output then becomes equal to the number of orders (O_t) net of any unintended inventory left over from the previous period (i.e. goods that could not be delivered due to a customer's inability to pay)[2]:

$$Q_{c,t}^d = O_t - INV_t^Q \tag{7}$$

Based on this desired production level, the firm decides on whether to hire or fire workers. Furthermore, it checks whether the currently available intermediate input inventories and capital stock are large enough for the desired production level. If not, the firm scales down its possible production level to the maximum output level possible.

Specifically, the demand for capital goods (i.e. investment demand I^d) is given by the difference between the expected desired capital stock in the delivery period $t+1$ (K_{t+1}^d) and the capital stock that the firm expects to actually have in that delivery period (K_{t+1}^e):

$$I_t^d = max\{K_{t+1}^{e,d} - K_{t+1}^e, 0\} \tag{8}$$

The expected desired capital stock is determined by the expected desired production in the delivery period ($Q_{t+2}^{d,e}$), the capital input coefficient (α^K), and the capital stock buffer factor (ψ^c), as firms always want to hold some excess capacity to be sufficiently flexible in their production decision:

$$K_{t+1}^{e,d} = \left\lceil Q_{t+1}^{d,e} \cdot \alpha^K \cdot (1 + \psi^c) \right\rceil \tag{9}$$

Expected desired production in the period when the capital goods are delivered (which is $t+2$, since orders in period t are produced in $t+1$ and will hence be available in $t+2$) is equal to the expected sales in the delivery period:

$$Q_{t+2}^d = S_{t+2}^e \tag{10}$$

[2]For the sake of simplicity, we assume that the unintended inventory can be reused for new orders in the next periods.

where sales expectations in the delivery period are formed by projecting the previous trend in the evolution of sales expectations two steps (i.e. periods) into the future:

$$S^e_{t+2} = S^e_t + \lambda \cdot (S^e_t - S^e_{t-1}) \cdot 2 \tag{11}$$

In the case of capital firms, desired output is equal to expected orders in the delivery period. The expected orders are updated analogously to equations (10) and (11). Capital firms refuse to take any further orders once a certain maximum (O^{max}) is reached, since they do not want production falling short of accepted orders. This maximum is hence determined by full capacity output as determined by the capital stock (K_t):

$$O^{max}_t = \frac{K_{t+1}}{\alpha^K} \tag{12}$$

If firms nevertheless fail to deliver their respective orders, these orders become invalid after two periods without any payment happening between the firm and its client. Firms that fail to deliver their orders bear a disadvantage on the market, as potential clients take this into account when making their decisions (see equation 29).

Using the economy-wide inflation rate from last period, firms adjust the wages (W) of their employees for inflation (π) according to

$$W_t = W_{t-1} \cdot \{1 + \mu \cdot max(\pi, 0)\} \tag{13}$$

where μ denotes the inflation adjustment parameter ($0 \leq \mu \leq 1$). The firm then estimates production costs for the current period. A value of μ smaller than one means that firms do not fully adjust wages to inflation.

3.3.2 Credit market interaction

Once a firm knows about its real demand for production factors, it estimates its financial needs based on prices in the previous period adjusted for inflation. The resulting estimate is then multiplied by a financial buffer factor ($\psi^{finance} > 1$) to avoid liquidity problems.

Prices (P) are set as unit costs (UC) plus a markup (m):

$$P = (1 + m) \cdot UC \tag{14}$$

Unit costs include intermediate inputs used up in production, the labour costs multiplied by the degree of utilisation of the workforce, and capital depreciation multiplied by the degree of utilisation of the capital stock (including the desired capital buffer stock).[3] This adjustment serves the purpose to only consider actual production costs (and not costs for unused capacities, which would lead to prices fluctuating as production levels go up and down). Furthermore, unit costs also contain an imputed labour cost for the firm owner, set equal to the wage rate paid to the firm's employees (including any overtime premium). This virtual wage is

[3] The degree of utilisation of the workforce (u_L) is calculated as $u_L = \frac{y}{(L+1)/\alpha^L}$, where y denotes actual output, α^L the labour input coefficient, and L the number of employed workers. We add 1 to the labour force to account for the production input of the firm owner. Similarly, the utilisation of the capital stock (u_K) is given by actual output divided by the capital stock (K) divided by the capital input coefficient (α^K): $u_K = \frac{y}{K/\alpha^K}$.

calculatory: without it, one-person firms would have zero wage costs and thus unrealistically low unit costs. The virtual wage is deducted from the production tax base (see Section 3.5), since the owner ultimately receives the firm's profit rather than this virtual wage.

As in Caiani et al. (2016), firms decrease the markup (by a given fixed percentage χ^{markup}) if they sold less than expected in the previous period (i.e. if their actual output inventory higher than their desired output inventory level). Conversely, they increase the markup (with percentage χ^{markup}) if real sales in the previous period were higher than or equal to what was expected.

$$m_t = \begin{cases} m_{t-1} \cdot (1 - \chi^{markup}), & inv_t > inv_t^d \\ m_{t-1} \cdot (1 + \chi^{markup}), & inv_t \leq inv_t^d \end{cases} \tag{15}$$

Before the firm goes to the labour market to hire additional workers (if necessary), it will assess its financial needs for the current period. It estimates the financial means it needs to pay for wages (of the current employees and possible new hires), intermediate input purchases, and capital goods. Since this period's prices of intermediate and capital goods are not yet known to the firm (as firms set prices once goods have been produced), they take prices from last period and add the commodity-specific inflation rate observed in that period.

If the financial needs exceed the available funds, the firm will apply for a loan from the banking sector. If a loan application is only partially granted or not granted at all, the firm will reduce its output level such that the production costs of the current period remain within its financial possibilities and any upcoming debt payments can be serviced in full.

3.3.3 Labour market interaction

If a firm chooses to hire additional workers, it will post one job ad for every vacant position to the economy-wide job board. To increase the chances of being able to hire the number of workers it needs, the firm sets the offered wage (W^o) in the job ad to the average wage of the firm's current employees ($\overline{W}$) multiplied by one plus a random number (ϵ) drawn from a folded normal distribution $N(0, \sigma^{folded})$:

$$W_t^o = \overline{W_t} \cdot (1 + \pi) \cdot (1 + \epsilon) \tag{16}$$

This markup is only applied when the firm is actively seeking additional workers (i.e. when current employment falls short of required employment). The wage offer is also updated for inflation (π) before the hiring-specific markup is applied.

All employees then receive their wage. Taxes on wages are paid to the government. In addition, firm owners pay taxes on their income (i.e. distributed profits). As profits are calculated and transferred to the owners at the end of the period, they can only be spent during the next period, whereas wages are paid at the beginning and hence form the basis of current period's consumption decisions. Consumption decisions of firm owners therefore rely on the previous period's distributed net profits.

3.3.4 Insolvency and bankruptcy

When a firm cannot meet its debt payments, it is first declared overdue, its missed debt payments are added to the loan, and the payments are postponed for a period. If it still cannot pay its debt in the next period, it is declared insolvent (see Section 3.4 for more details). Insolvent firms are liquidated, which means that the bank is selling the firm to recoup part of its funds. In order to maintain a constant number of firm agents in an easy and reasonable way, we assume that the firm is re-purchased by its initial owner, with the purchasing price being equal to the value of the firm's assets or, if the owner cannot afford that, to the funds available to the owner.[4] Any loans that cannot be repaid by the selling price have to be cancelled at the bank's expense.

3.3.5 Production and market clearing

Firms produce according to a Leontief-type production function:

$$Q = \min\left\{\frac{K}{\alpha_K}, \frac{E+1}{\alpha_E}, \frac{INV_1}{\alpha_1}, ..., \frac{INV_n}{\alpha_n}\right\} \tag{17}$$

where Q is the firm's real output, K is its capital stock, E is employed workers, and INV_j refers to the inventory of the j-th intermediate input (each of these intermediate inputs j is produced by a firm in industry j). α_j is the input coefficient for production factor j: the higher this coefficient, the more of input j is needed to produce a given quantity of output Q. These input coefficients are calculated from input-output tables and are the same for all firms in an industry. We add 1 to the labour input because we assume that the owner also contributes in the production process. Furthermore, workers are allowed to work overtime if a labour shortage emerges, where maximum overtime per worker is set to 50% of regular time (Poledna et al., 2019).
The desired amount of inventory for intermediate input j is a function of current desired output (Q^d), the corresponding production coefficient (α_j), and the desired intermediate input inventory factor ($\nu^{d,iin}$):

$$INV_{jt}^{d,\text{input}} = \frac{Q_t^d}{\alpha_j} \cdot \nu^{d,iin} \tag{18}$$

Since market clearing takes place after production, firms have to produce with the inventories they acquired in the previous period. Hence, intermediate input inventories only react to changes in desired production levels with a time lag.
Once market interactions[5] have taken place, firms make debt payments and assess gross profits (Π^G):

$$\Pi^G = Q \cdot P^{net} + (I^D - T^D) - PC \tag{19}$$

where gross profits are calculated as sales revenue ($Q \cdot P^{net}$) plus interest on deposits minus tax on this interest income ($I^D - T^D$) and minus production costs PC. Total production costs are the sum of wages, capital depreciation, intermediate input purchases, interest on loans, social security payments, and production taxes.
If gross profits are greater than zero, firms retain a share ρ^f and distribute the rest to the respective owners, subject to available liquidity:

$$\Pi^{dist} = \min\big((1-\rho^f) \cdot \Pi^G,\ \max(D_t - U_t, 0)\big) \tag{20}$$

[4] See on this also the bail-in by households used in Caiani et al., 2016.
[5] The procedure for how markets are cleared is described in greater detail in Section 3.6.

for $\Pi^G > 0$ and $\Pi^{dist} = 0$ otherwise, where D_t denotes the firm's current deposits and U_t its upcoming expenses (e.g. for outstanding capital orders). If the firm's liquidity is insufficient to fully pay the intended dividends, only the available funds net of upcoming obligations are distributed.
Finally, all machines (i.e. capital goods) age by one period. Machines that have reached their maximum age are removed from the firm's capital stock.

3.4 Banking sector and central bank

The banking sector provides financial funds to firms (via bank loans) and the government (by purchasing government bonds). When firms apply for loans based on their estimated financial needs, banks assess the maximum size of the loan (L^{max}) they would provide to this firm. Doing so, they assess the maximum loan amount they would provide based on available collateral (L^c) and expected servicing ability (L^a).

$$L^{max} = \max\left(L^c, L^a\right) \tag{21}$$

L^c is simply the net value of the firm's assets (total assets net of total pre-existing debt) multiplied by credit supply factor σ^c:

$$L^c = \sigma^c \cdot \left[\sum A - \sum L\right] \tag{22}$$

L^a is calculated by multiplying the mean net profits (Π^{net}) over the past Φ periods by credit supply factor (σ^a), which gives the maximum annuity payment (Γ^{max}) that the bank would trust the firm with:

$$\Gamma^{max} = \sigma^a \cdot \sum_{i=1}^{\Phi} \Pi_{t-i}/\Phi \tag{23}$$

The amount of credit associated with this annuity can be calculated by

$$L^a = \Gamma^{max} \cdot \frac{(1+i^L)^{\Xi^{b,L}} - 1}{(1+i^L)^{\Xi^{b,L}} \cdot i^L} \tag{24}$$

where $\Xi^{b,L}$ denotes the maturity of the loan and i^L the interest rate. If L^{max} is greater than zero, this is the loan that the bank is willing to grant to the firm. Loan repayments follow an annuity schedule, with equal periodic installments covering both principal and interest. In the final installment, any remaining principal is settled as a bullet payment to avoid rounding residuals. If a firm cannot meet its full installment, the unpaid amount is capitalised back into the loan, the installment is recalculated for the remaining duration, and the loan is marked as overdue. If the loan was already overdue and the firm still cannot pay, an insolvency procedure is initiated.
In order to keep the model simple, we assume that the banking sector always purchases any amount of bonds issued by the government. Besides loans to firms and government bonds, the bank assets also include central bank deposits. Here, we assume that banks manage reserves such that the bank deposits-to-reserve ratio (rr^B) remains constant.
The central bank supplies these reserves to the banking sector by providing central bank loans or purchasing government bonds from the banking sector. Here, we assume that the central bank uses both instruments such that the proportion of

given loans and purchased bonds remains constant. Any profits earned by the central bank (consisting of the interest earned on bonds and central bank loans minus the interest on central bank deposits) is directly forwarded to the government.

3.5 Government

The government charges a uniform tax rate on wage income, capital income (interest and distributed profits), and taxable social benefits (pensions). Furthermore, it collects an industry-specific net production tax rate (production-related taxes minus subsidies[6]) and a value added tax (VAT) on final goods.

The base for the production tax are the production costs. When computing this tax base, the implicit wage of the firm owner (set equal to the average employee wage; see Section 3.3) is deducted. This position is merely calculatory: it ensures that one-person firms incorporate a wage cost in their unit costs, but does not represent an actual expense subject to production taxation. The owner receives the firm's profit, not this virtual wage.

On the expenditure side, the government distributes unemployment benefits to eligible agents, social benefits to inactive (out of the labour market) agents, and general social benefits that accrue to all individuals equally. All these benefits are calculated relative to the economy-wide mean wage and are thus implicitly indexed to inflation.

The government also purchases final goods. While spending on benefits and transfers adjusts automatically based on the number of eligible recipients, the amount that is spent on goods is adjusted in order to meet budgetary requirements. Here, we assume that the government wants to stick to a certain government deficit-to-GDP ratio, with speed of adjustment determined by χ^{br}. Furthermore, the government also reacts to deviations from what is considered to be a normal rate of unemployment ($\bar{u}$):

$$C_t^G = \max\Big(C_{t-1}^G + \chi^{br} \cdot \left(NS_{t-1}^G - s^G \cdot Y_{t-1}\right) \tag{25}$$

$$+ \chi^u \cdot (u_t - \bar{u}) \cdot C_{t-1}^G, 0\Big) \cdot (1 + \pi_t) \tag{26}$$

where NS_{t-1}^G denotes last period's net saving by the government (i.e. the budget balance), s^G the desired net saving rate, Y_{t-1} the last period's nominal GDP, χ^{br} the speed of budget adjustment parameter, χ^u the unemployment reaction parameter, and π_t the current period's inflation rate. The $\max(\cdot, 0)$ operator ensures that nominal government consumption demand remains non-negative. The resulting value is adjusted for inflation $(1 + \pi_t)$ to maintain the intended real spending level in the upcoming period.[7] We compute the expenditure shares of the different industry sectors based on the AIDS framework that was already used for

[6] In the case of the primary sector, the calibrated tax rate is negative, as subsidies exceed taxes.

[7] Modelling of governments in other agent-based models is done similarly, though often even in a more parsimonious way. Caiani et al. (2016) model a government without consumption demand that spends money through unemployment benefits, hiring households as public servants, collecting taxes, and issuing bonds. Poledna et al. (2023) model government expenditure based on an AR(1) process (with an AR-parameter of 0.9845, reflecting a close-to-unit-root process). The AR(1) equation can also be interpreted such that the constant term reflects $g0$ and the autocorrelated term equals $g1$, plus an additional shock-term being drawn from $N \sim \left(0, \sigma^2\right)$. In Gräbner-Radkowitsch

Table 1: Markets and their participants

Markets	**Buyers**	**Sellers**
Final goods	Consumers	Final good producers
Intermediate inputs	Final, intermediate input, and capital firms	Intermediate firms
Capital goods	Final, intermediate input, and capital firms	Capital firms

modelling the consumption patterns of households, though with different parameters.

3.6 Goods market clearing

The clearing of the goods markets (final, intermediate input, and capital goods market) happens very similarly, with only the buyer and seller roles being different in each (see Table 1).
At the beginning of the market clearing, a list of buyers and a list of sellers are constructed. Buyers are only included if they have a non-zero demand, and sellers are only included if they have a non-zero inventory to sell.
When buying intermediate goods, firms are drawn in random order. The randomly drawn firm will then randomly select an industry j to buy inputs from, where the weight of an industry (Ω_j) is based on which industry's input would increase the firm's production the most (i.e. the input that currently restricts its production the most). Particularly, the weight is calculated as the difference between the production level possible with the current level of inventories (INV_j) and the production level possible with one additional unit of input (j: $INV_j + 1$). The bigger the production increase of an industry j is, the higher its probability of being chosen is:

$$\Omega_j = y(\ldots, INV_j + 1, \ldots) - y(\ldots, INV_j, \ldots) \tag{27}$$

where $y()$ the Leontief production function.
Generally, we assume that purchasing firms only satiate a fraction of their demand in each visit to an industry in order to avoid a situation in which the firms entering the market last leave empty-handed when aggregate supply does not live up to aggregate demand. Specifically, in the v-th visit to a given industry, a firm may purchase at most $v/n^{f,visits}$ of its remaining demand for that industry's product, where $n^{f,visits}$ is the maximum number of visits per industry. From the chosen industry, the buyer randomly selects a seller, where the probability weight of each selling firm i (Ω_i) is based on its price (P_i) and size, measured by output inventory at the start of the period (INV_i):[8]

et al. (2022), government acts through provisioning of unemployment benefits and an externally fixed value of government consumption. Caiani et al. (2018) model government spending with a simple lump-sum amount that is given out to households to strengthen their purchasing power. In other agent-based models, the government sector mostly acts via hiring of public servants, payment of unemployment benefits, tax collection, and minimum wage regulation, but without actual government consumption (Caiani et al., 2018; Dosi et al., 2021; Mellacher & Scheuer, 2020).

[8] This approach is also used by Poledna et al., 2023.

$$\Omega_i = \frac{\Omega_i^{price} + \Omega_i^{size}}{2} \tag{28}$$

where $\Omega_i^{price} = \frac{1}{P_i} / \sum_{f=1}^{F} \frac{1}{P_f}$ and $\Omega_i^{size} = INV_i / \sum_{f=1}^{F} INV_f$ are the respective price and size weights and F refers to the total number of firms in the respective industry. For intermediate goods, the price used in the seller weight is the net price (excluding VAT), reflecting the fact that VAT payments are transferred to the government rather than constituting revenue for the selling firm.
Capital market clearing works similarly to how it does in the intermediate input market, except that firms do not purchase the goods directly (as the capital goods have yet to be produced) but place orders, with goods delivered in the following period. Firms are included as sellers if their maximum amount of orders exceeds zero. Another difference is that the capital market does not have different supplying industries; hence, industry selection on the side of buyers does not play a role. Furthermore, the price that is used for the price weights in equation (28) is adjusted with a penalty term for undelivered orders (O^u) in order to reflect that firms with undelivered orders are seen as less reliable:

$$P^{adj} = (1 - \zeta) \cdot \frac{P}{\overline{P}} + \zeta \cdot \frac{1 + UOR}{1 + \overline{UOR}} \tag{29}$$

where ζ is a weighting parameter and UOR denotes the firms undelivered order ratio ($UOR = O^u/y$) and $\overline{P}$ and $\overline{UOR}$ the respective industry averages.
In the final goods market, consumers select industries in a random order. After choosing an industry, they draw a random shortlist of firms based on the seller selection weights (see equation 28). Final consumers split their purchases among the firms on the shortlist according to their selection weights, where the share of demand that goes to firm i (η_i) is equal to the share of its weight (Ω_i) in the sum of weights of the shortlist:

$$\eta_i = \frac{\Omega_i}{\sum_{s=1}^{n^{hh,visit}} \Omega_s} \tag{30}$$

where $n^{hh,visit}$ denotes the number of firms on the shortlist.
While all agents go to the market only once, the government splits its purchase into 50 rounds, where the order in which individuals and the government can go to the market follows a random order.

3.7 Implementation

The model is implemented in the Julia programming language, which offers significant advantages for building agent-based simulation models. Julia's high-performance capabilities, achieved through just-in-time (JIT) compilation, ensure that computationally intensive simulations run efficiently. This is particularly beneficial for macroeconomic simulation models involving complex interactions (e.g. final good market clearance) and large-scale data processing (e.g. when each households calculates its expenditures shares).
The language's syntax is designed to be intuitive and similar to mathematical notation, which facilitates the translation of theoretical models into code. This makes Julia an accessible yet powerful tool for researchers who require both computational efficiency and ease of implementation.

4 Calibration

4.1 Empirical calibration

Empirical calibration is an essential feature when it comes to economic modelling. Only through the integration of empirical data does it become possible to derive conclusions from the model that also can inform policy makers and researchers with regard to the dimension and relevance of effects for economic realities.
In order to allow for flexibility with respect to applying the model to possible other countries, the model principally uses data from Eurostat. Table 2 lists the detailed datasheets that form the foundation of the empirical calibration.

Table 2: Data sources for empirical calibration

Name	**Full description**	**Abbreviation**	**Source**
Economic agents and demographic data			
NACE employment table	Employment by NACE Rev. 2 activity, age, and European socioeconomic group	lfsa_esegn2	Eurostat (2023a)
Number of firms data	Business demography by legal form and NACE Rev. 2 activity (2004-2020)	bd_9AC_l_form_r2	Eurostat (2024a)
Number of firms in agriculture	Main farm indicators by organic farming, utilised agricultural area, economic size, farm type of agricultural holding, and NUTS 2	ef_m_org	Eurostat (2024c)
Industry wage rates	Annual net earnings of a full-time single worker without children earning an average wage	earn_nt_netft	Eurostat (2025a)
Population data	Population on 1 January by age and sex	demo_pjan	Eurostat (2023d)
Unemployment data	Unemployment by sex and age – annual data	une_rt_a	Eurostat (2023f)
Government data			
Government spending data	General government expenditure by function (COFOG)	gov_10a_exp	Eurostat (2023b)
Government revenue data	Government revenue, expenditure, and main aggregates	gov_10a_main	Eurostat (2023c)
Financial data			
Financial stocks (Eurostat)	Financial balance sheets – quarterly data	nasq_10_f_bs	Eurostat (2025b)
ECB deposit facility rate	Deposit facility rate (overnight)	DFR	ECB (2025d)
ECB main refinancing rate	Main refinancing operations rate	MRR	ECB (2025e)
ECB MFI interest rates	Bank interest rates on outstanding deposits and loans	MIR	ECB (2025b), ECB (2025c)
ECB government bond yields	Maastricht government bond yields (secondary market)	GFS	ECB (2025a)
ECB central bank loans	Central bank loans to euro area credit institutions	ILM	ECB (2025e)
Input-output data			
IO table	Symmetric input-output table at basic prices (product by product)	naio_10_cp1700	Eurostat (2023e)
Other reference data			
Depreciation information	Taxation law on depreciation [Abschreibung]	Abschreibung	Unternehmensservice Portal (2024)
Max unemployment benefit	Current values on social insurance [Aktuelle Werte]	Beitragsrechtliche Werte 2016	Österreichische Sozialversicherung (2023)
Consumption data	Household final consumption expenditure by purpose (COICOP 1999)	nama_10_co3_p3	Eurostat (2025c)

We calibrate our model for Austria for the first quarter of 2019. The calibration process is inspired by Caiani et al. (2016), as we match aggregate empirical values

to aggregate values of our model. Details on the computation can be found in Appendix A.2.
We assume that firm sizes follow a Pareto distribution and distribute various indicators (e.g. number of employees, total debt, and deposits) according to this distribution such that the aggregates match the empirical counterparts.
Households that participate in the labour market are initially randomly matched to a firm, which in turn determines their initial wage, deposits, etc. Again, this is done in such a way that the individual values sum up to the total informed by the empirical calibration.
The calibration process is structured in such a way to allow for a flexible aggregation of the available industries into J groups, where, in our case, $J = 5$ is the default value. In addition to the typical sectoral structure consisting of 'primary' (agriculture and mining industries), 'manufacturing', and 'services', the energy sector is often of specific interest and should therefore be modelled as a separate industry. The construction and utilities industries are also much more capital-intensive than the rest of the service sector and should arguably be taken as a separate sector. Hence, we aggregate the 64 NACE Rev.2 industries available from IO tables into five industries ('primary', 'manufacturing', 'energy', 'construction and utilities', and 'services'), which then also constitute the five intermediate inputs needed for production. Labour and capital complete the set of input factors.
For the scenario comparison, we apply the same calibration procedure with $J = 1$, thus aggregating all industries into one general 'industry', for which we will later use the term 'economy'.

4.2 Algorithmic calibration

One major challenge that has hindered the widespread adoption of agent-based models in real-world modelling and decision-making scenarios is the difficulty of performing parameter estimation. Unlike traditional models, agent-based simulation models often lack a tractable likelihood function, which makes it challenging to apply standard statistical inference techniques.

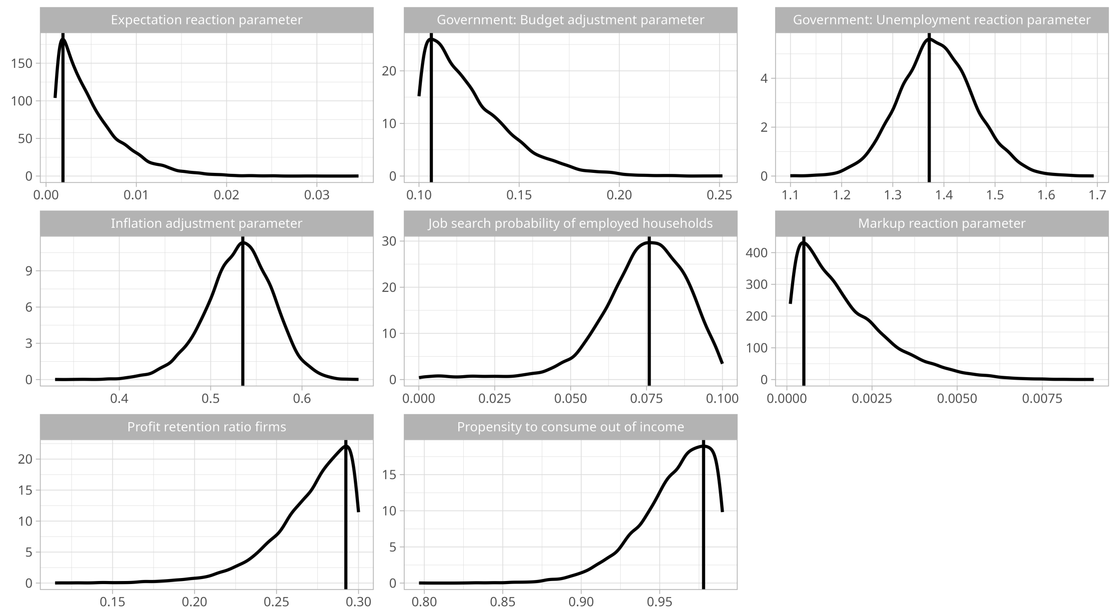
Table 3: Parameters used in the algorithmic calibration, their bounds, and the value found in calibration

Description	**Bounds**	**Calibrated value**
Expectation reaction parameter λ	[0.001, 0.3]	0.0019
Propensity to consume out of income c_1	[0.40, 0.99]	0.9780
Inflation adjustment parameter μ	[0.25, 0.9]	0.5352
Markup reaction parameter χ^{markup}	[0.0001, 0.02]	0.0005
Job search probability of employed households Pr^{search}	[0.0, 0.1]	0.0759
Profit retention ratio of firms ρ^f	[0.0, 0.3]	0.2923
Government: Budget adjustment parameter χ^{br}	[0.1, 0.5]	0.1062
Government: Unemployment reaction parameter χ^u	[0.75, 2.0]	1.3713

To address this issue, Dyer et al. (2024) explore the efficacy of two classes of black-box approximate Bayesian inference methods: neural posterior estimation and neural density ratio estimation. These methods have recently drawn

significant attention within the probabilistic machine learning community and offer promising solutions for parameter inference in economic simulation models.
Neural posterior estimation involves using neural networks to approximate the posterior distribution of the model parameters given observed data. The key idea is to train a neural network to map the observed data to the parameters of the model. This approach leverages the expressive power of neural networks to capture the complex relationships between the data and the parameters.
This method is compatible with multivariate time-series data, which is a crucial issue for our economic application. Dyer et al. (2024) show that this algorithm does not require hundreds of thousands of simulations, making it a suitable option for large-scale economic simulations like ours.
Preliminary simulations with our model have shown that there are eight parameters that have a significant impact on the simulation outcome (although they cannot be empirically estimated). These parameters are given in Table 3. The bounds are given either by 'natural' limits (e.g. a zero lower bound on the probability that employed households wil look for another, better-paid job) or by experience gained while working with the model (e.g. with an expectation reaction parameter greater than 0.3, the simulation becomes so volatile that the economy crashes too often).

Figure 2: Histogram of the parameter estimates of the sbi4abm algorithm



Source: Authors' calculations.

The implementation of the algorithm is publicly available[9] and can be instructed to use any simulation model for calibration. We let the calibration algorithm run our macroeconomic agent-based model 5,000 times (with uniform random draws of the eight parameters given in Table 3)[10]. The neural net algorithm uses six empirical quarterly time series for Austria to calibrate the simulation to: real GDP

[9]See https://github.com/joelnmdyer/sbi4abm

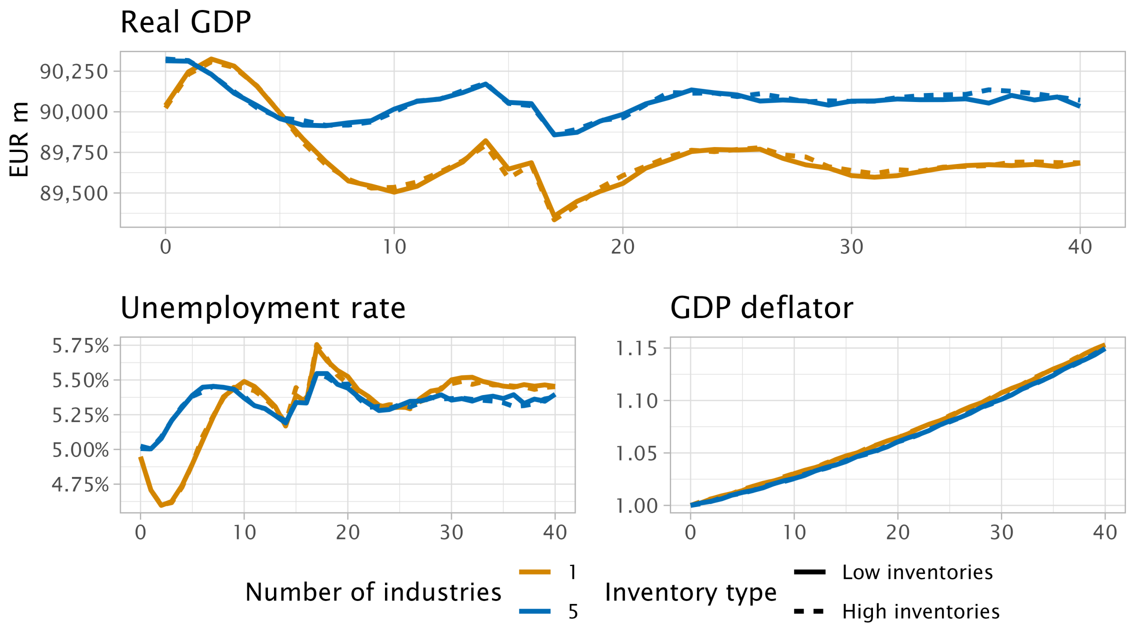
[10]We use the model with five industries and 'low' inventories (i.e. the desired intermediate-input inventory factor is set to 1.18) in this calibration, as it is the most complex setup. All calibrated parameter values can be used 'as is' for the case with only one industry.

growth, the inflation rate, the unemployment rate, growth of aggregate real public consumption expenditure, growth of aggregate real private consumption expenditure, and gross fixed capital formation growth. Due to technological progress, all growth rates have an average greater than 0. As our model does not yet include technological progress, we subtract the average of these growth rates so that their mean becomes 0.

4.2.1 Results of the algorithmic calibration

Figure 2 shows the histogram of 10,000 draws from the posterior distribution estimated by the neural net algorithm described in the previous section. The parameter distributions tell us the parameter values with which the model simulation produces time series that 'behave' like the empirical time series. We can see that all parameter distributions are unimodal and have a clear 'peak'. For our simulation exercises, we will continue by using the modes of the respective parameter distributions. The exact values for each parameter are also shown in Table 3.

Figure 3: Average real GDP for different simulation configurations



Source: Authors' calculations.

Figure 3 shows the average real GDP, unemployment rate, and GDP deflator of 100 'baseline' model replications.[11] Note that our calibration achieves a very good fit with the empirical data: our models produce real GDP values of around 90,000, which is just a 5.7% deviation from the empirical value of Austria in the first quarter of 2019. Unemployment fluctuates between 5% and 5.5% for most of the time, which is also very much in line with empirically observed values from Austria at that time (5.1%). The general price level increases by about 15% over a timespan of 40 periods (10 years), which is close to the total increase in the price level in the decade prior to 2019 (18%; see World Bank, 2025; own calculations).

[11] The figures do not include the first 20 periods, since we regard them to be a burn-in phase.

5 Model simulations: A supply-side shock

To demonstrate the model's ability to capture shock propagation across industries, we compare different model configurations under a common sector-specific shock. These configurations differ in their level of industry disaggregation, starting with the most aggregated version ($J = 1$), where the economy produces only one good, and the default industry setup ($J = 5$), splitting production into primary, energy, manufacturing, construction, and services.
Furthermore, to investigate whether the magnitude of impact depends on inventory levels, we report both scenarios for different intermediate input inventory ratios. The high inventory scenario uses a ratio of 2.16, based on Humphreys et al. (2001)[12]; the low inventory scenario uses a ratio of 1.18, following Poledna et al. (2023). A factor of 2.16 implies that firms hold enough intermediate inputs to sustain production for roughly two quarters even if no new deliveries arrive, while a factor of 1.18 provides a buffer of only about one quarter.
Combining these two dimensions, we obtain four model configurations: one industry / low inventories, one industry / high inventories, five industries / low inventories, and five industries / high inventories.

Table 4: Shock magnitudes expressed as a percentage of GDP

Scenario	**Damage in % GDP**
100-year flood	2.26
1,000-year flood	5.07

Source: Based on damage estimates for flooding events in Bachner et al. (2024); own calculations.

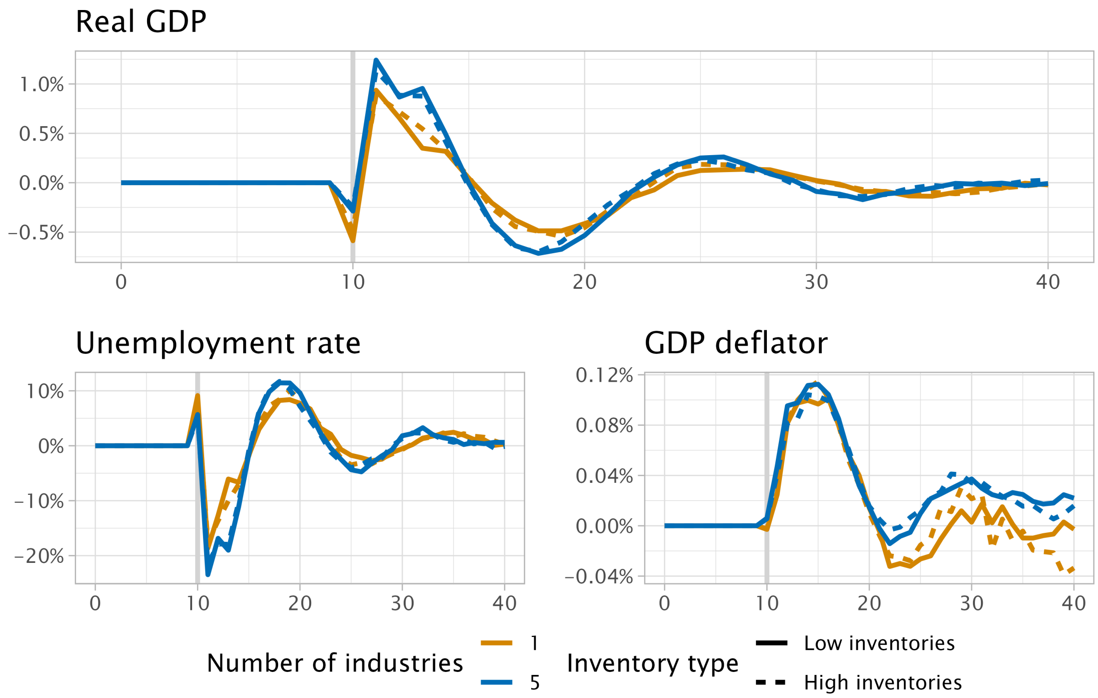
As an illustrative application, we will expose each model configuration to the same shock. We calibrate the shock magnitudes using damage estimates for flood events from Bachner et al. (2024). In each shock scenario, we randomly draw firms and destroy up to 75% of their capital stock and up to 100% of their input and output inventories, stopping once the aggregate-damage target is reached.
In the five-industry configurations, the shock is directed solely at the primary industry, reflecting a sector-specific disruption. We assume that the shock takes place in a primarily agricultural region and that agriculture is most vulnerable to this kind of event (Di Noia et al., 2025; Sun et al., 2022). In the aggregated setup, firms are drawn from the entire population, as this configuration does not distinguish between industries.
We report the percentage deviation of the shock scenario from the baseline without a shock.

5.1 100-year flood

In our first scenario, we look at the impact of a supply shock in the form of 100-year flood associated with an immediate damage equal to 2.26% of GDP. What we see first of all when we look at the impact on real GDP (upper panel in

[12]In their study, Humphreys et al. (2001) report a value of 1.11 for the input inventory-to-sales ratio. Multiplying that with real output and dividing by the total use of intermediate inputs (see Eurostat, 2023e) yields an implied input inventory ratio of 2.16.

Figure 4: Implications of a 100-year flood on real GDP, unemployment rate, and GDP deflator



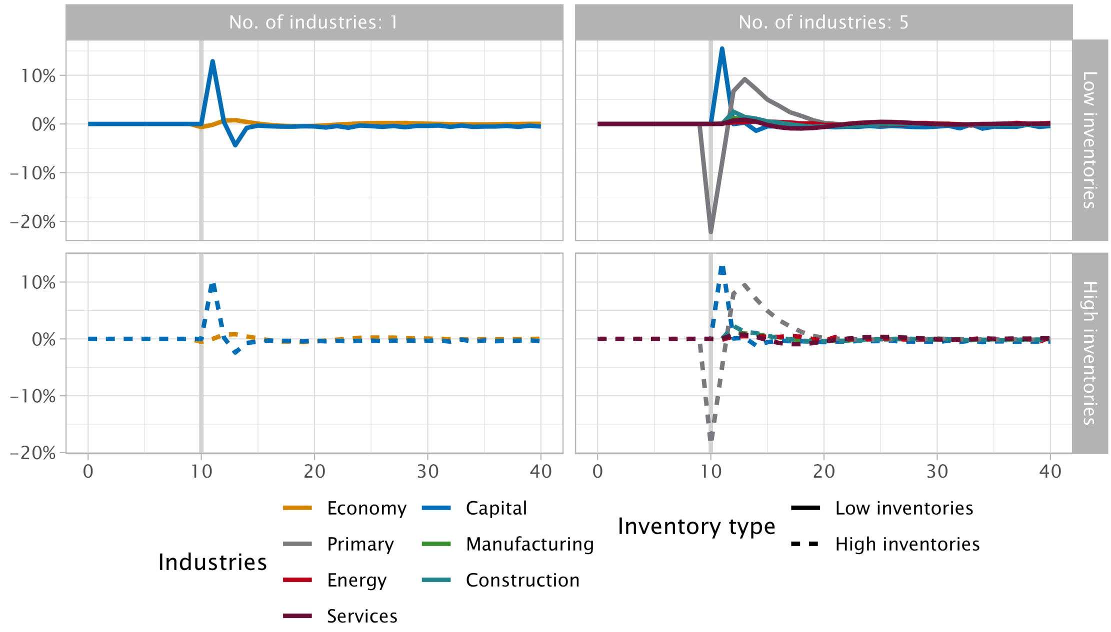
Source: Authors' calculations.

Figure 4) is that the immediate impact of the shock is smaller in the five-industry case compared to the single-industry case. That is because, in the five-industry case, destruction is only applied to the capital stock and inventory of firms in the primary sector, whereas it is applied to firms in the general 'economy' industry in the single-industry case. Since firms in the primary industry tend to be less productive than an average firm, damage caused to a primary firm has less impact on total production than the same amount of damage caused to a firm in the 'economy' industry.

However, we also see that the fluctuations caused in the resulting upswing (as affected firms rebuild their capital stock and inventories) and the subsequent downswing tend to be larger in the five-industry case (despite the initially smaller impact of the shock). Hence, accounting for multiple industries seems to be associated with slightly higher fluctuations in the recovery phase. When we look at the unemployment rate (lower left panel in Figure 4), we see a similar picture: the oscillations are more extreme for the five-industry case. High and low inventories do not seem to make much of a difference. The lower right panel of Figure 4 shows the GDP deflator, where the inflationary effect tends to be greater in the five-industry scenario.

Figure 5 shows individual industry developments. When we model the economy to consist of only one industry (see the left part of the figure), we see a small relative drop in value added in the 'economy' industry in the shock period. The capital industry (which we consider as separate and not part of the 'economy' industry) is not affected in the shock period, but it does see a large rise in value added in the subsequent period because (i) shocked firms want to rebuild their capital stock and (ii) unaffected firms saw demand for their products increase in the shock period

Figure 5: Implications on real GDP on industry level, 100-year flood



Source: Authors' calculations.

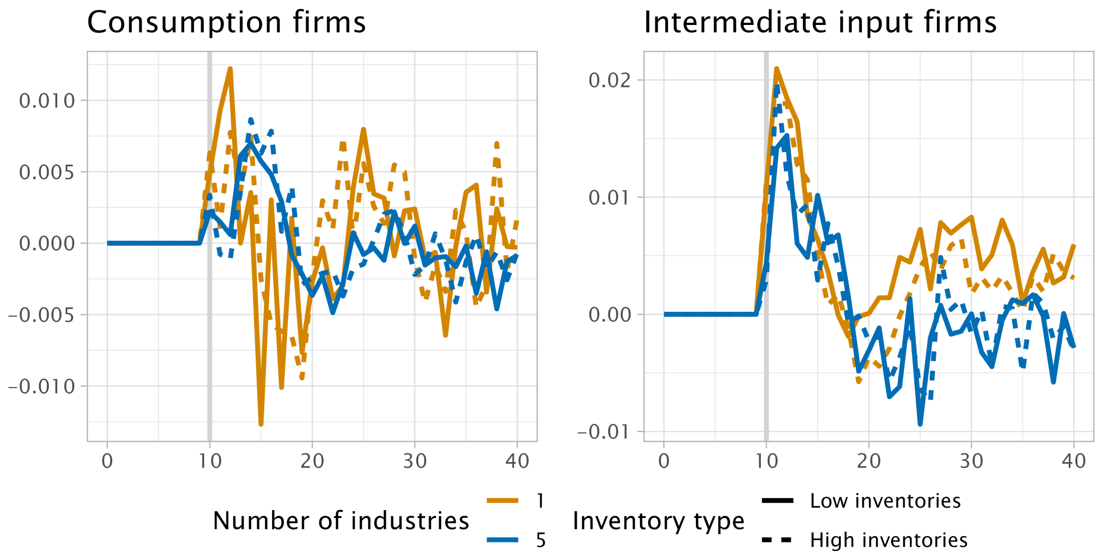
and adjusted production plans – and, thus, also their capital demand – upwards. This pattern holds for both low and high inventories.

In the case where we disaggregate the economy into five industries plus a capital industry, we see, in essence, a similar picture: since all shocked firms are in the primary sector, this is also the sector that sees the biggest negative outcome in the shock period. The industry rebounds, and we see a prolonged upswing following the shock. The capital industry behaves as in the one-industry case, experiencing no difference in the shock period but a sudden uptick in activity in the post-shock period because of the increased demand for capital goods following the capital destruction in the shock period. For the other industries (i.e. energy, manufacturing, construction, and services), we only see smaller fluctuations, which are obviously caused by the fall in primary output in the shock period and a shortcoming of primary intermediate inputs in the subsequent periods.

Figure 6 depicts the Hirschman-Herfindahl index as a measure of market concentration for consumption and intermediate input firms. A 100-year flood does not produce a long-lasting change in concentration, indicating that the damage is too minor to drive firms out of business or to permanently alter market shares. What is notable, however, is the lack of a discernible impact on market concentration in the consumption-firm sector, while we do see a large temporary (for approximately 15 periods) spike in concentration in the intermediate-inputs market.

The reason for this is that, in the final goods market, consumers (households) are rationed in their consumption of primary goods until production has recovered (i.e. they buy what is offered on the market), but they do not 'make up' for unsatisfied demand from earlier periods. In the intermediate-inputs market, however, the buyer firms keep track of their inventories and want to refill their inventory stocks of primary goods. This process needs several periods, during which the bigger firms in the primary industry (who can increase their production more easily) sell larger

Figure 6: Implications on Hirschman-Herfindahl index, 100-year flood



Source: Authors' calculations.

volumes of their goods, resulting in substantially higher market shares. The higher Hirschman-Herfindahl index in the intermediate inputs primary industry drives the spike in the Hirschman-Herfindahl index for the intermediate input firms.

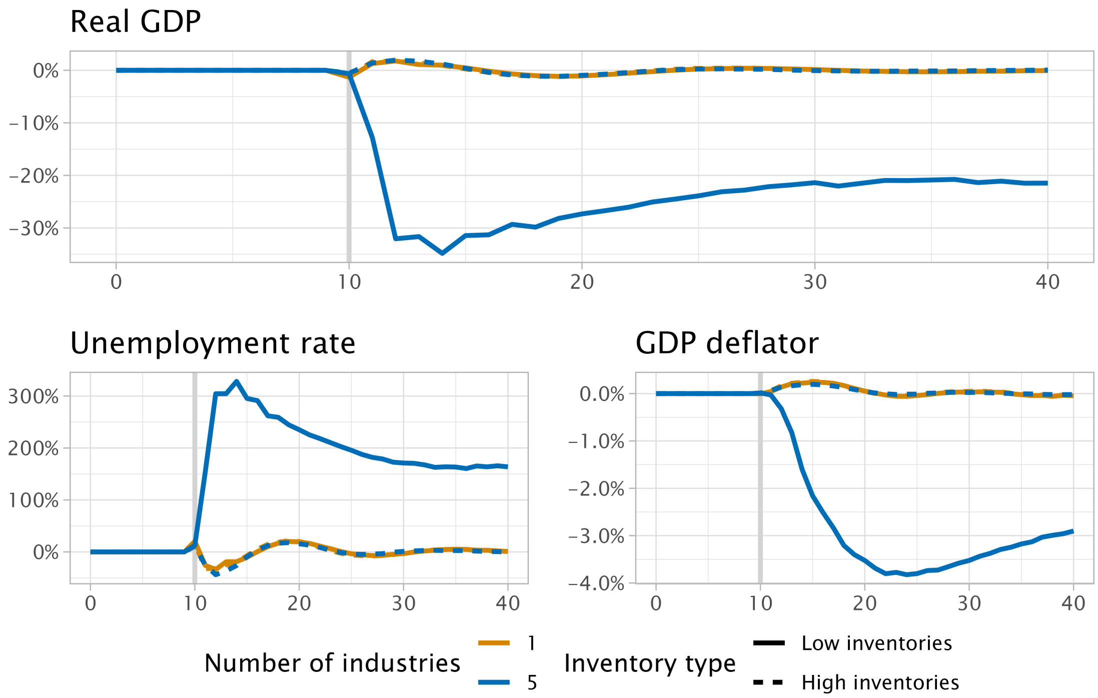
5.2 1,000-year flood

While we could observe some differences between scenarios, these differences tended to be small. However, this changes once we increase the magnitude of the shock by assuming that a 1,000-year flood hits our model economy. Bachner et al. (2024) associate a 1,000-year flood with an immediate damage of 5.07% of GDP. In this case, the model configuration matters a lot (see Figure 7): while with high inventories, a short drop in output is associated with a rapid recovery (for both setups with $J = 1$ and $J = 5$), the low-inventories scenario with five industries faces a drop in real GDP of more than 30% compared to the baseline scenario and never fully recovers.

The underlying reason for this development is that, given the magnitude of the damage concentrated in a single industry, the other industries run out of inventories before the reconstruction of that industry is finished. After initially enduring a recession in the immediate aftermath, the economy enters a vicious cycle in which producers of capital and other intermediate goods (that are supposed to replace destroyed machines and empty intermediate good inventories) cannot produce and deliver their products since they have run out of inputs from the primary industry. That, in turn, worsens the shortage of primary inputs, and so on. This is associated with a tripling of the unemployment rate. In terms of the general price level (lower-right panel in Figure 7), the short-lived recessions are accompanied by periods of inflation, whereas this existential crisis is accompanied by a prolonged deflationary period in the five-industry, low-inventories setup.

We can again take a look beneath the surface by switching to an industry-level perspective (Figure 8). While for the high-inventory case, the results look similar to the 100-year flood (i.e. seeing an initial decline in the affected industry and a

Figure 7: Implications of a 1,000-year flood on real GDP, unemployment rate, and GDP deflator



Source: Author's calculations.

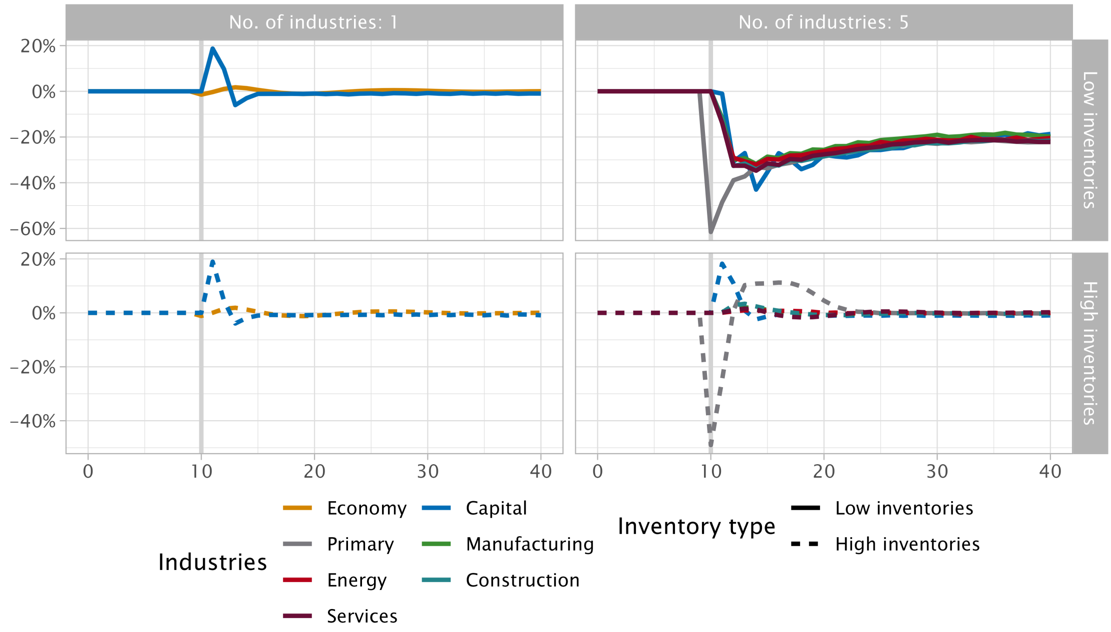
boom in the capital industry), results look different for the low-inventories scenario – but only for the five-industry case. In the latter, we observe not only the initial decline in the affected (primary) industry, but also a delayed decline in all other industries (including the capital industry) due to a critical shortage of supply from the primary industry. Hence, at low input-to-inventory ratios, modelling the structural interdependence of industries makes a remarkable difference, as it shows how a shock is working its way through industries and compounding to a substantial economy-wide impact.

The 1,000-year flood shock shows a persistent increase in concentration particularly in the affected primary industry, as shown in Figure 9. The more severe destruction of capital and inventories forces weaker firms into insolvency, opening the opportunity for bigger firms to attract more consumers and increase their market shares.

To further strengthen this argument, we vary inventory ratios in steps of 0.1 (Figure 10), which illustrates quite clearly the negative correlation between the inventory ratio and both the depth of the corresponding slump and the duration of the necessary recovery period.

These results highlight that the macroeconomic impact of a sector-specific supply shock depends not only on the magnitude of physical damage itself, but also on the resilience of supply chains – a factor that is easily overlooked in models that abstract from industry interdependencies.

Figure 8: Implications on real GDP on industry level, 1000-year flood



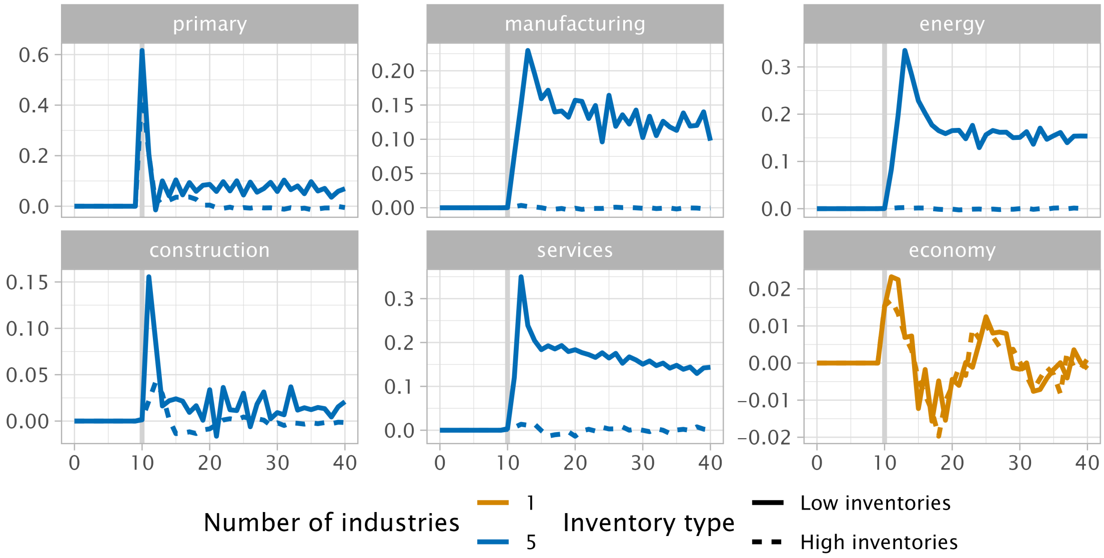
Source: Authors' calculations.

6 Summary and conclusions

In this paper, we developed an agent-based stock-flow consistent model featuring multiple industries and supply chains in addition to illustrating its usefulness by analysing the propagation of a sector-specific supply shock. We find that the level of inventories has a large influence on the results: while differences in the impact of a shock between the single-industry and the multiple-industry scenario are relatively small in the high-inventories case, differences can be quite dramatic in the low-inventories case. The reason behind this is that the lower the inventory levels, the higher the probability that an actual supply shortage emerges. Once shortage of a particular input arise, the economy enters a vicious cycle in which other industries fail to provide goods, making it even harder for the initially affected industry to recover and close the initial supply gap.

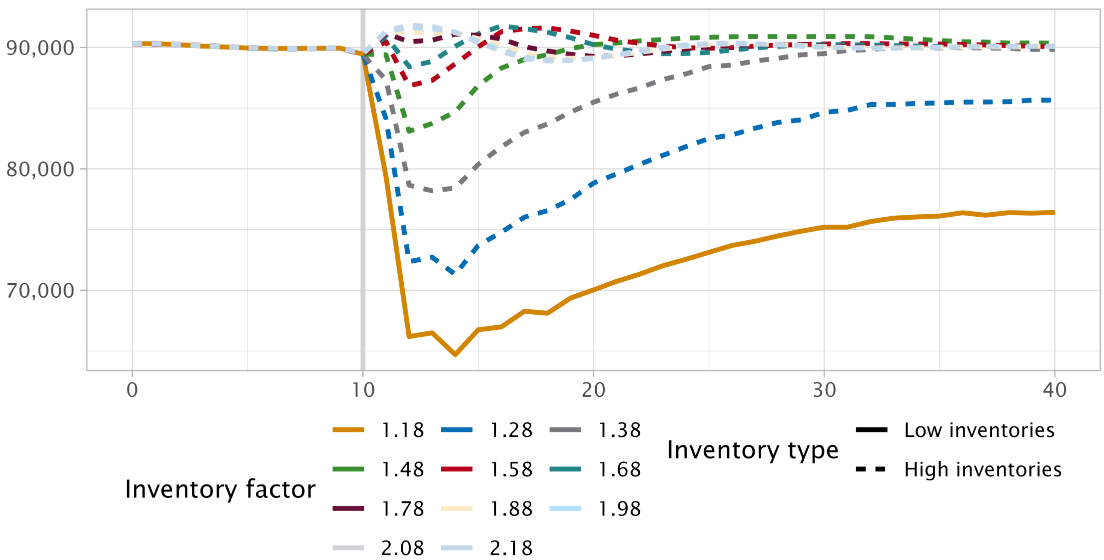
Our results demonstrate the value of explicitly modelling industry structures and supply chains when analysing shock propagation. Conventional single-sector models risk underestimating the macroeconomic consequences of large, sector-specific disruptions, as they abstract from the cascading shortages that can arise when inventories are low. The model's ability to capture these non-linear dynamics makes it a useful tool for studying a wide range of policy-relevant questions (e.g. on climate adaptation and supply-chain resilience) where the sectoral composition of shocks matters.

Figure 9: Implications on Hirschman-Herfindahl index, by industries, 1,000-year flood



Source: Authors' calculations.

Figure 10: Comparisons of real GDP effects for different inventory factors in a 1,000-year flood



Source: Authors' calculations.

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A Appendix

A.1 Parameters and starting values

Tables A.1 and A.2 provide an overview of the parameters used in the model. Parameters in Table A.1 are based on statistical data or taken from the literature, while values in Table A.2 have been determined within the calibration process (see Section 4.2). Note that parameters depicted in Table A.1 have been adjusted to the model size (i.e. the model population has been downscaled to correspond to 1% of the actual population) as well as the time framing (i.e. one period corresponds to one quarter).[13]

Table A.1: Model parameters taken from data and literature

Parameter	Value	Description	Source
τ^{VAT}_{con}	14.3%	VAT rate consumption goods	Eurostat (2023e), own calc.
τ^{VAT}_{gov}	1.0%	VAT rate government purchases	Eurostat (2023e), own calc.
τ^{inc}	37.7%	income and social contribution tax rate	Eurostat (2023c), own calc.
$D^{init,F}$	€0.7bn	total initial deposits firms	Eurostat (2025b), own calc.
$D^{init,HH}$	€2.4bn	total initial deposits households	Eurostat (2025b), own calc.
$D^{init,B}$	€2.4bn	initial equity deposit banks	Eurostat (2025b), own calc.
$L^{init,F}$	€3.2bn	total initial loans firms	Eurostat (2025b), own calc.
B^{init}	€3.0bn	total initial government debt	Eurostat (2025b), own calc.
$B^{init,B}$	€2.3bn	total bonds initially held by banks	Eurostat (2025b), own calc.
$B^{init,CB}$	€0.8bn	total bonds initially held by the CB	Eurostat (2025b), own calc.
i^D	0.02%	interest rate deposits	ECB (2025b), own calc.
i^L	0.4%	interest rate on loans	ECB (2025b), own calc.
i^B	0.2%	interest rate government bonds	ECB (2025a), own calc.
$i^{D,CB}$	-0.1%	interest rate CB deposits	ECB (2025d), own calc.
$i^{L,CB}$	0.0%	interest rate CB loans	ECB (2025e), own calc.
$R^{init,B}$	€1.0bn	initial reserve deposits banks	ECB (2019), Eurostat (2025b), own calc.
$L^{init,B,CB}$	€0.2bn	initial CB loans to banks	ECB (2019), own calc.
rr^B	17.6%	desired reserve ratio banks	ECB (2019), Eurostat (2025b), own calc.
br^B	78.9%	CB bond purchase ratio	ECB (2019), Eurostat (2025b), own calc.

Continued on next page

[13]Industry-specific data, such as input coefficients and AIDS parameters, can be obtained from the authors upon request.

Parameter	Value	Description	Source
N^{HH}	88,588	number of household agents	Eurostat (2023d)
$n^{labourforce}$	45.0%	proportion of households in the labour force	Eurostat (2023d, 2024a, 2024c), own calc.
N^{inact}	48,706	number of inactive household agents	Eurostat (2024a, 2024c), own calc.
ψ^c	0.18	capital stock buffer factor	(Eurostat, 2023e), own calc.
$\bar{u}$	6.3%	unemployment rate considered normal by the government	
Y^{init}	1.7bn	initial total real output	(Eurostat, 2023e), own calc.
$\nu^{d,iin}$	2.16	desired intermediate inputs inventory factor	Humphreys et al. (2001), Eurostat (2023e), own calc.
$\nu^{d,Q}$	0.54	desired output inventory ratio	Humphreys et al. (2001, table 1)
$\epsilon^{SB^{old}/w}$	18.8%	ratio individual social benefits (taxable) to the average gross wage	Eurostat (2023b, 2023e), own calc.
$\epsilon^{SB^{oth}/w}$	10.6%	ratio individual social benefits (non-taxable) to the average gross wage	Eurostat (2023b, 2023e), own calc.
$\epsilon^{SB^{gen}/w}$	1.5%	ratio general individual social benefits to average net wage	Eurostat (2023b, 2023e), own calc.
ϵ^{uebr}	55%	unemployment benefit rate	Austrian Federal Chancellary (2025)
$\epsilon^{Y^{min}/w}$	31.2%	ratio of minimum legal income to average net wage	Vienna Online (2019), Eurostat (2023e), own calc.
$\epsilon^{ueb/w,max}$	70.2%	ratio of maximum unemployment benefits to average net wage	Austrian Federal Chancellary (2025), Österreichische Sozialversicherung (2023), Austrian Chamber of Labour (2023), (Eurostat, 2025a), own calc.
$(1-\tau^{inc}) \cdot \Pi^{dist,bank}$	€9.3m	initial net profit income bank owner	own calc. based on bank balance sheets and interest rates
$C^{init,gov}$	€193.2m	initial nominal government spending on goods and services	Eurostat (2023e), own calc.
s^G	-5.1%	desired net saving rate government	own calc. based on spending, tax rates and income levels

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Parameter	Value	Description	Source
u^d	0.85	firms' desired utilisation rate of the capital stock	Poledna et al. (2019), Eurostat (2024b)
c_2	0.0075	household agent consumption propensity out of wealth	Paiella (2007)
Φ^K	32	lifespan of capital stock	Unternehmensservice Portal (2024)
σ^{folded}	0.0094	standard deviation from folded normal distribution	Caiani et al. (2016)

Table A.2: Other model parameters

Parameter	Value	Description
$\psi^{finance}$	1.1	firms financial needs buffer factor
$n^{app,u}$	20	number of job applications when unemployed
$n^{app,e}$	5	number of job applications when employed and looking for a new job
$\Xi^{b,L}$	20	duration of bank loans
$\Xi^{cb,loan}$	1	duration of central bank loan
Ξ^{bond}	40	duration of government bond
σ^c	2.0	credit supply factor collateral
σ^a	2.0	credit supply factor servicing ability
$n^{hh,visit}$	3	number of consumption firms that households buy from each period
$n^{f,visit}$	30	number of intermediate firms that firms buy from each period
$n^{gov,visit}$	50	number of times the government enters the goods market
ζ	0.25	undelivered-orders penalty weight
ρ^b	0.1	profit retention ratio banks
Φ	8	net profits history length

A.2 Stock and flow tables

Table A.3 provides an overview of the financial and real stocks included in the model, while Table A.4 shows the involved financial flows. Note that, for model consistency, the sum of all financial assets in Table A.3 as well as the sum of all financial transactions in A.4 have to be equal to zero (see Godley & Lavoie, 2006).

Table A.3: Stock matrix

	HH	**Firms**	**Gov.**	**Banks**	**CB**	$\sum$
Deposits	D_{HH}	D_F	D_G	$D_B - D$		0
Loans		$-L_F$		L_F		0
Bonds			$-B$	B_B	B_{CB}	0
CB deposits				R_B	$-R_B$	0
CB loans				$-L_{CB}$	L_{CB}	0
Capital		K				K
Net worth	$-V_{HH}$	$-V_F$	$-V_G$	$-V_B$	$-V_{CB}$	$-K$
$\sum$	0	0	0	0	0	0

Notes: Note that $D = D_{HH} + D_F + D_G + D_B$ and $B = B_B + B_{CB}$. Subtracting net worth assures that columns and rows add up to zero. The only row not adding up to zero relates to capital stock, which is the only asset that is not also a liability at the same time (see Godley & Lavoie, 2006). Note that intermediate-input and output inventories (which are also only assets) are conventionally left out for reasons of exposition.

Table A.4: Flow matrix

	Households		**Firms**		**Government**		**Banks**		**CB**		
	Current	Capital	Current	Capital	Current	Capital	Current	Capital	Current	Capital	$\sum$
Consumption	$-C$		$+C$								0
Investment			$+I$	$-I$							0
IIN goods			$+IIN$	$-IIN$							0
[Production]			Y								
Wages	$+W$		$-W$								0
Income tax	$-T^I$				$+T^I$						0
Production tax			$-T^Y$		$+T^Y$						0
VAT			$-T^{VA}$		$+T^{VA}$						0
Unemployment benefits	B^u				$-B^u$						0
Social benefits	B^s				-B^s						0
Interest deposits	Int^D_{HH}		Int^D_F				$-Int^D$				0
Interest loans			$-Int^L$				Int^L				0
Interest bonds					$-Int^B$		Int^B_B		Int^B_{CB}		0
Interest CB loans							$-Int^{CBL}$		Int^{CBL}		0
Interest CB deposits							Int^{CBD}		$-Int^{CBD}$		0
Insolvency payments	$-Insolv$				$Insolv$						0
Debt cancellation					$Canc$		$-Canc$				0
Distributed firm profits	Π^d_F		$-\Pi^d_F$							0	
Distributed bank profits	Π^d_B						$-\Pi^d_B$				0
Distributed CB profits					Π_{CB}				$-\Pi_{CB}$		0
Net saving	$-S_{HH}$	$+S_{HH}$	$-S_F$	S_F	$-S_G$	S_G	$-S_B$	S_B			0
Δ deposits		$-\Delta D_{HH}$		$-\Delta D_F$		$-\Delta D_G$		$\Delta D - \Delta D_B$			0
Δ loans				ΔL				$-\Delta L$			0
Δ bonds						ΔB		$-\Delta B_B$		$-\Delta B_{CB}$	0
Δ CB deposits								$-\Delta R$		ΔR	0
Δ CB loans								ΔL^{CB}		$-\Delta L^{CB}$	0
$\sum$	0	0	0	0	0	0	0	0	0	0	0

Notes: Note that $\Delta D = \Delta D_{HH} + \Delta D_F + \Delta D_G + \Delta D_B$, $Int^D = Int^D_{HH} + Int^D_F$, $Int^B = Int^B_B + Int^B_{CB}$ and $\Delta B = \Delta B_B + \Delta B_{CB}$. All rows and columns add up to zero, assuring the model's stock-flow consistency. See Godley and Lavoie (2006) for further details.

B Appendix: Details of the empirical calibration

In the following sections, index k refers to the three firm types 'consumption' (abbreviated as 'con'), 'intermediate input' ('iin') and 'capital' ('cap'). Furthermore, index j refers to industries.

B.1 Number of agents

Numbers of 'persons in employment' are taken from a NACE-based employment table (Eurostat, 2023a) and summed up according to the model sectors. Persons in employment (N^{inemp}) are, according to the methodology of the EU Labour Force Survey (EU-LFS), persons aged 15 years and above who are either active as employees, self-employed, or family workers, and the count is 4.35 million persons.[14] The number of firms (N^{firms}) is based on farm data by NACE Rev. 2 (Eurostat, 2024c) for the primary sector and on Eurostat data on business demography by NACE Rev. 2 activity (Eurostat, 2024a) for the other industries. In order to avoid instability problems that result from having too many small firms within a sector, we assume that the average number of workers per firm in each sector is at least five and adjust the number of firms accordingly. In our case, this means a reduction in the number of firms in the primary sector. Furthermore, we assume that each firm is owned by one individual. Hence, in order to get to the number of employees (N^{emp}), we deduct the implied number of firm owners ($N^{firmowner}$) from persons in employment (N^{inemp}). Subsequently, we use the number of employees and firms as well as total output per sector from the IO table to calculate the average number of employees per firm as well as the average real production per firm in each sector ($\bar{y}_k$).
In a final step, the market-equilibrium-determined output levels are used to compute the initial number of firms and workers of each firm type and industry in the model. The number of firms follows from the equilibrium real output (Y_k^{real}) divided by the average real production per firm:

$$N_{j,k}^{firms} = \frac{Y_{j,k}^{real}}{\bar{y}_k} \tag{B.1}$$

Similarly, the total number of workers is $N_{j,k}^{workers} = N_{j,k}^{firms} \cdot \bar{n}_k$, where $\bar{n}_k = N_k^{emp}/N_k^{firms}$ is the average number of workers per firm. Since the resulting firm counts are generally not integers, they are rounded to whole numbers, and the per-firm values for real sales and workers are adjusted proportionally to preserve total output and employment.
The number of people being unemployed (N^{unemp}) refers to persons between the ages of 15 and 74 in Austria who were not employed, currently available for work, and actively seeking a job at the time of the survey reference week. In total, this was 220,000 persons (Eurostat, 2023f).
Finally, the total number of inactive agents (i.e. individuals out of the labour force) is calculated as a residual from the total population (N^{HH}, which was 8.68 million in Austria in 2019; Eurostat, 2023d), total employees, owners of firms,

[14] The Eurostat definition of 'persons in employment' is (Eurostat, 2023a): 'Employed persons comprise persons aged 15 years and more who were in one of the following categories: (a) persons who during the reference week worked for at least one hour for pay or profit or family gain, and (b) persons who were not at work during the reference week but had a job or business from which they were temporarily absent.'

Table B.1: Composition of firm output, gross valued added, and production costs

No.	Description	Variable	NACE Rev. 2 code
(1)	Gross nominal intermediate inputs	$IIN_{i,j}$	(for i inputs, and j industries)
(2)	Product taxes less subsidies	$T_j^{product}$	(D21X31)
(3)	Net operating surplus (NOS)	Π_j^{net}	(B2A3N)
(4)	Consumption of fixed capital (capital depreciation)	δK_j	(P51C)
(5)	Gross nominal compensation of employees	W_j	(D1)
(6)	Production taxes less subsidies	$T_j^{production}$	(D29X39)
(7a)	*Net nominal output*	Y_j^{net}	*(P1)*
(7b)	*Gross nominal output*	$Y_j = Y_j^{net}(1 + \tau^{VAT})$	

Source: Own calculation based on Eurostat (2023e).

banks (see below) and the unemployed. In other words, $N^{inact} = N^{HH} - N^{emp} - N^{firmown} - N^{bankown} - N^{unemp}$, which is used to calculate the ratio of household agents that are part of the labour force: $n^{labourforce} = (N^{HH} - N^{inact})/N^{HH}$.
The IO table provides specific numbers for different industries (e.g. agriculture, fishery, manufacturing, etc.) without explicitly differentiating different firm types (i.e. for types k). However, the IO table does include numbers on final consumption expenditures (P3), total intermediate good sales (P2), and gross fixed capital formation (P51G; values on new capital investment). Assuming a constant sales share for each firm of each firm type, it follows that the share of final consumption expenditures ($Z_{con} = Z_{con}^{HH} + Z_{con}^{gov}$) in total use ($TU; Z^{tot}$)[15] proxies the share of consumption firms of total firms ($N_{con}^{firms}/N^{firms}$). Accordingly, total intermediate-good sales (Z^{iin}) and gross fixed capital formation (Z^{cap}) as a share of total output (Z^{tot}) can be used as proxies for the share of intermediate-input firms and capital-producing firms, respectively:

$$\phi_{firms}^{j} = \frac{N_j^{firms}}{N^{firms}} = \frac{Z_j}{Z^{tot}} \tag{B.2}$$

B.2 Firms and production

B.2.1 Defining output components

The IO table from Eurostat firm output for each industry j is composed of several elements (see B.1). Since final consumers are paying VAT on top, we further differentiate between net and gross nominal output. Our model does not consider foreign trade and only looks at the domestic economy; total supply equals output. In line with the literature (see e.g. Poledna et al., 2023), the initial price level is assumed to be one (i.e. $P(0) = 1$). This means that the real output produced

[15]Total use Z^{tot} in the IO table is actually composed of total final use ($Z_{con} = Z_{con}^{HH} + Z_{con}^{gov}$, total intermediate use (Z_{iin}), and exports. Since our model is based on a domestic setting without foreign trade, we exclude exports from total use, such that $Z^{tot} = Z_{con} + Z_{cap} + Z_{iin}$

($Y_{i,j}^{real}$) is computed by dividing the net nominal output by the price level (equally for the real amount of intermediates needed):

$$Y_j^{real} = \frac{Y_j^{net}}{P} \tag{B.3}$$

$$IIN_{i,j}^{real} = \frac{IIN_{i,j}^{net}}{P} \tag{B.4}$$

Other statistics, such as gross value added (GVA) or production costs (PC), can be computed by adding together different accounting positions.
Next, we compute product tax rates on a per-industry basis. The total production taxes per industry (T_j^{prod}) are taken as the sum of 'Taxes less subsidies on products' (D21X31) and 'Other taxes less subsidies on production' (D29X39). Dividing these by the sum of production inputs (i.e. intermediate inputs IIN_j, compensation of employees W_j, and consumption of fixed capital δK_j) yields industry-specific production tax rates (τ_j^{prod}):

$$\tau_j^{prod} = \frac{T_j^{prod}}{\sum IIN_j + W_j + \delta K_j} \tag{B.5}$$

These tax rates enter the model's production accounting as an additional per-unit cost component on top of intermediate, labour, and capital input costs.

B.2.2 Computing input coefficients

The intermediate input coefficient of input i for industry j, ($\alpha_{i,j}$), based on intermediate inputs ($IIN_{i,j}^{net}$) relative to net nominal output Y_j^{net}, is computed as:

$$\alpha_{i,j} = \frac{IIN_{i,j}^{net}}{Y_j^{net}} \tag{B.6}$$

These industry-specific intermediate input coefficients are the basis of intermediate inputs for consumption and intermediate input firms.
Besides intermediate inputs, the firm production function also requires labour and capital to produce goods (i.e. $y = f(K, E, IIN)$). Based on gross workers compensation (e.g. Table B.1), the labour input coefficients can be computed based on the IO table information:

$$\alpha_{E,j} = \frac{\frac{W_j}{w_j} + N_j^{owners}}{Y_j^{net}} \tag{B.7}$$

where W_j denotes total worker compensation, w_j the wage rate, and N_j^{owners} the number of firm owners (since owners also contribute to production) in industry j.
Production coefficients for capital can be computed from reported capital depreciation ('consumption of fixed capital') reported in the IO table. As a uniform depreciation rate of capital, we assume a mid-sized piece of machinery (e.g. a car), which has, according to Austrian tax legislation, an average useful life of machinery (Φ^K) of eight years, or 32 quarters (Unternehmensservice Portal, 2024). We further assume a linear depreciation rate over the average useful life of capital for all firms, which defines a uniform depreciation rate ($\delta = \bar{\delta}$).[16]

[16] This yields a depreciation rate of 3.125%, which is a bit higher than other values in the literature, though of the same dimension; e.g. compared to 1.25% (Ciola et al., 2023).

The depreciation rate and the amount of quarterly capital investment to maintain a constant stock of capital are therefore considered to be:

$$\delta = \bar{\delta} = \frac{1}{\Phi^K} \tag{B.8}$$

$$I = \delta K \tag{B.9}$$

Assuming a linear depreciation of owned capital (regardless of its usage), we can calculate the amount of initial capital stock per industry and firm type K_j proportional to the depreciated capital, which equals the gross fixed capital formation in our data (I_j):

$$K_j = \frac{I_j}{\delta} \tag{B.10}$$

Furthermore, under normal conditions of operations, firms do not always run at maximum capacity utilisation but are assumed to have a certain degree of excess capacity, meaning capital utilisation is smaller than 1: $u < 1$. In line with data on capacity utilisation of Austrian firms over the past 25 years (Eurostat, 2024b), we assume that firms have a desired capacity utilisation of about 85%, $u^d = 0.85$. Based on notation of Post-Keynesian textbook conventions (Blecker and Setterfield, 2019), we consider real output under normal capacity conditions as $Y^{real} = Y^{real,n} = f(u^d \cdot K)$; for full capacity output ($Y^{real,K}$), it holds that $Y^{real,K} = \frac{1}{u^d} Y^{real,n} = \frac{1}{u^d} f(u^d \cdot K)$. Therefore, we can define a full-capacity output-to-capital ratio ($Y_j^{real,K}/K$) disaggregated by industries j and firm types k that will act as the maximum output which can be produced based on the available capital.
The inverse of the full capacity output-to-capital ratio represents the capital input coefficient $\alpha_{K,j}$ for industry j of firm type k:

$$\alpha_{K,j} = \frac{K}{Y_j^{real,K}} \tag{B.11}$$

Besides the input coefficients, two additional accounting quantities are computed from the IO table for use in the calibration. The production taxes share of output ($\tau_j^{prod\_share}$) is defined as the cumulative sum of intermediate, capital, and labour input coefficients multiplied by the industry-specific production tax rate:

$$\tau_j^{prod\_share} = \left(\sum_i \alpha_{i,j} + \alpha_{K,j} + \alpha_{E,j} \right) \cdot \tau_j^{prod} \tag{B.12}$$

The share of total production costs in output (ψ_j^{PC}) is the sum of all input coefficients plus the production taxes share:

$$\psi_j^{PC} = \sum_i \alpha_{i,j} + \alpha_{K,j} + \alpha_{E,j} + \tau_j^{prod\_share} \tag{B.13}$$

These serve as the basis for computing the industry markups:

$$m_j = \frac{1 - \psi_j^{PC}}{\psi_j^{PC}} = \frac{\Pi_j^{net}}{Y_j^{net}} / \psi_j^{PC} \tag{B.14}$$

For the model, we further adjust the markup to account for the fact that firm owners are assumed to receive implicit wage payments at the sectoral wage rate w_j. These implicit owner wages ($w_j \cdot N_j^{firms}$) are subtracted from net operating surplus and added to production costs, yielding the virtual-wage markup:

$$m_j^{vw} = \frac{\Pi_j^{net} - w_j \cdot N_j^{firms}}{PC_j + w_j \cdot N_j^{firms}} \tag{B.15}$$

B.2.3 Capital sector

We assume that each industry produces its own distinguishable final and intermediate goods. Hence, the production coefficients for the respective industries can be directly calculated from the information provided in the respective columns in the IO table. This is different for capital: each industry delivers capital goods for final use, which is recorded as gross fixed capital formation (P51G, I_j). However, since we follow the common convention in economics to treat capital as a homogenous good, we have to create a synthetic capital-producing sector. To do so, we compute the input coefficient of this industry as a weighted average of all industries, where the industries' shares of capital sales in total capital sales are used as weights w_j^{css}:

$$\alpha_{K,cap} = \sum_j \alpha_{K,j} \cdot w_j^{css} \text{ and } \alpha_{E,cap} = \sum_j \alpha_{E,j} \cdot w_j^{css} \tag{B.16}$$

While not needed for the production process, other shares of output can also be computed the same way (i.e. the profit share of output as $\Pi^{cap}/Y^{net,cap}$ or the production tax share of output as $T^{cap}/Y^{net,cap}$).

B.3 Household agent income and consumption

Household agents earn income through work, firm dividends, or social benefits from the government (e.g. unemployment benefits or payments to inactive households, such as via pensions). From the IO table, we obtain workers' gross income (W), which is based on gross compensation paid ($D1$), and capitalists' gross income, which is based on net operating surplus (B2A3N), as it is assumed to be distributed as income to the firm-owning households (Π^{dist}). Since the IO table does not include information on social benefits, we use information from the COFOG database on government spending and revenue (Eurostat, 2023b). Social benefits include unemployment benefits (SB^{ue}), old-age pension payments (SB^{old}), and other payments to inactive households (SB^{oth}).[17] Additionally, we consider general payments that are paid out to all household agents (SB^{gen}), since there are two more or less specific *social protection* accounting positions (i.e. housing and social exclusion) with a small size (together about 1.6% of total *social protection*), and also because the trade surplus is small (about 1.5% of GDP). We include this additional social transfer with the size of the actual trade surplus in order to take into account income that is available to households and used for living, which would remain unaccounted otherwise (since we do not model imports and exports). In the case of households that are part of the labour force but become unemployed, the government provides unemployment benefits. These benefits amount to 55% (ϵ^{uebr}) of the previous net wage (see Austrian Federal Chancellary,

[17] The subsumed payments under the category 'other social benefits' include payments regarding survivors, family and children, and sickness and disability.

2025) in the first two periods of unemployment. After that, agents are classified as long-term unemployed and cease to be entitled to unemployment benefits.[18]

B.3.1 Computing household income rates

The industry-specific wage rate for workers (w_j) is calculated as the total sum of gross compensation (W_j) divided by the number of workers ($N_j^{workers}$) per industry:

$$w_j = \frac{W_j}{N_j} \tag{B.17}$$

Earnings of firm owners are based on the industry-specific markup rates (m_j); see equations (B.14) and (B.15). Costs of production already account for depreciation of capital (δK). Assuming that in a stationary state, firm investment is equal to depreciation (i.e. firms keep their capital stock constant), the amount of total profits (Π_k^G) is equivalent to the amount of profits that could be distributed to firm-owning households. However, if we assume that firms retain a certain rate (ρ^f) within the firm, distributed profits (Π_j^{dist}) are equal to:

$$\Pi_j^{dist} = (1 - \rho^f) \cdot \Pi_j^G \tag{B.18}$$

Wages and distributed profits are subject to a uniform income tax rate and constitute a major part of government revenues (see below).
As inflation occurs in the model, social benefits paid by the state need to be adjusted for these price changes, and we need to express them in relative terms such that they do not lose their purchasing power. A straightforward solution to this problem is to link the social benefits to the compensation rates paid to workers. As old-age pension payments (SB^{old}) are subject to income taxation while other social benefits are not (SB^{gen}, SB^{oth}), we relate taxable social benefits to the average gross compensation rate ($\bar{w}$) and non-taxable social benefits to the average net compensation rate ($\bar{w^{net}}$):

$$\epsilon^{SB^{old}/w} = \frac{SB^{old}}{\overline{w}} \tag{B.19}$$

$$\epsilon^{SB^{oth}/w} = \frac{SB^{oth}}{\overline{w^{net}}} \tag{B.20}$$

$$\epsilon^{SB^{gen}/w} = \frac{SB^{gen}}{\overline{w^{net}}} \tag{B.21}$$

[18] In addition, unemployment benefit payments also have a ceiling in the benefit year (maximum amount of unemployment benefits, ueb^{max}), which is 55% of the net value of the social insurance maximum contribution basis of the base year. Dividing this value by the monthly average net wage ($w^{net,2019}$) of 2019 (Eurostat, 2025a) yields the net wage ratio $\epsilon_{ueb/w}^{max} = ueb^{max}/w^{net,2019}$. The labour law in Austria has changed in the meantime, but here is an example that is in line with the year 2019, where our model is situated: For someone who became unemployed in 2019 (benefit year), the according value of unemployment benefits generally amounted to 55% of the previous monthly net wage income, or a maximum of 55% of monthly net maximum contribution basis ('Höchstbeitragsgrundlage der Sozialversicherung') of three years ago (base year). According to official data for 2016, the monthly maximum contribution basis back then amounted to EUR 4,860 (Österreichische Sozialversicherung, 2023), translating to a monthly net amount of EUR 1,669.8, according the online calculator provided by the Austrian Chamber of Labour (Austrian Chamber of Labour, 2023).

B.3.2 Autonomous household consumption

Individuals buy goods for consumption purposes. The sectoral allocation of household consumption demand can be taken from the IO table (P3). Since the IO table separates final consumption of households from non-profit organisations serving households (NPISH), we add final consumption values of the NPISH (P3_S15) to final household consumption (P3_S13), as its size is much smaller than that one from households (around 4.8% of net household consumption). In this way, our model does not miss any consumption flows.
As a benchmark for autonomous consumption (c_0), we use the legal minimum income provisions (Y^{min}), which was EUR 863 per month in the reference year (see Vienna Online, 2019). Similar to government benefits, autonomous consumption is linked to mean income in order to automatically update for inflation.

$$c_0 = \overline{w^{net}} \cdot \epsilon^{Y^{min}/w} \tag{B.22}$$

where the minimum income to mean net wage ratio ($\epsilon^{Y^{min}/w}$) is calculated as

$$\epsilon^{Y^{min}/w} = \frac{Y^{min}}{\overline{w^{net}}} \tag{B.23}$$

B.3.3 Almost Ideal Demand System (AIDS) estimation

Values for the AIDS parameters are obtained from a LA-AIDS (Linear Approximate Almost Ideal Demand System; Deaton and Muellbauer, 1980) estimation using the *micEconAids* package, based on the Stone price index. Note that we only do the AIDS estimation when the number of industries J in the model is greater than one. With only one industry, estimation of AIDS parameters is not possible. The estimation proceeds in the following steps:

Step 1: Bridging COICOP to model industries. A bridging matrix from Cai and Vandyck (2020) maps individual COICOP consumption categories to statistical classification of products by activities (CPA) product categories. These CPA codes are then aggregated to the five model industries using an industry mapping.

Step 2: Aggregating consumption expenditure data. Consumption expenditure data from Eurostat (nama_10_co3_p3, CP_MEUR unit) by COICOP category are aggregated to the five model industries via multiplication with the industry-aggregated bridging shares matrix from step 1, yielding industry-level consumption expenditure time series and corresponding expenditure shares.

Step 3: Mapping expenditure to IO shares. IO-table household consumption data (P3_S14 + P3_S15) by CPA category are aggregated to the five model industries. For each industry, a linear regression maps the COICOP-based expenditure shares to the IO-based consumption shares, ensuring that the predicted shares are consistent with the structure of the IO table used elsewhere in the calibration.

Step 4: Constructing industry-specific price indices. COICOP-level price deflator data (PD15_EUR) are aggregated to industry-level price indices using the same industry-aggregated bridging shares, yielding a set of industry price indices consistent with the consumption categories.

Step 5: Rescaling to model units. Prices are normalised to the reference year 2019, and total expenditure is scaled to the per-household gross consumption level C^{net} in model units: $X^{cal} = C^{net} \cdot (1 + \tau^{VAT}) \cdot s/(f \cdot N^{HH})$, where s is the scaling factor (currently set to 1/100), f is the annual-to-quarterly conversion factor, and N^{HH} is the total number of households.

Step 6: LA-AIDS estimation and post-hoc kappa adjustment. The LA-AIDS model is estimated on the scaled dataset. The estimated kappa vector is then *post-hoc* adjusted such that, when combined with the estimated beta and gamma parameters, the AIDS demand system exactly reproduces the IO-observed consumption shares at the 2019 calibration baseline. All price and income elasticities (beta, gamma) are preserved by this adjustment.

Table B.2: Household AIDS demand system parameters

Industry	κ_j	β_j
Primary	0.013	0.001
Energy	0.046	-0.013
Manufacturing	0.267	-0.047
Construction	0.001	0.002
Services	0.673	0.057

Price coefficient matrix γ_{jk}

Industry j	**Industry k**				
	Primary	Energy	Manufacturing	Construction	Services
Primary	-0.003	-0.005	0.003	0.001	0.006
Energy	-0.005	0.016	-0.001	-0.002	-0.008
Manufacturing	0.003	-0.001	0.036	0.002	-0.040
Construction	0.001	-0.002	0.002	-0.002	0.001
Services	0.006	-0.008	-0.040	0.001	0.042

Source: Own LA-AIDS estimation based on Eurostat data

B.4 Government (income) taxation and spending

Based on information on paid taxes, we compute tax rates for key fields of government income (i.e. VAT and income tax rates). Information on VATs is taken from the IO table (Eurostat, 2023e), but since the IO table only features gross incomes, information on income taxes is taken from government revenue data (Eurostat, 2023c).

Since information on taxation in IO data is only given on an aggregate but not on an industry level, we calculate tax amounts in proportion to the sales. In this way, we compute taxes paid for final consumption by individuals (i.e. also considered as the more general VAT, $\tau^{VAT}_{con} = \tau^{VAT}$) as well as by the government:

$$\tau^{VAT}_{con} = \frac{T^{VAT}_{con}}{Z^{net,HH}_{con}} = \frac{T^{VAT}_{con}}{C^{net}} \tag{B.24}$$

$$\tau^{VAT}_{gov} = \frac{T^{VAT}_{gov}}{Z^{net,gov}_{con}} = \frac{T^{VAT}_{gov}}{G^{net}} \tag{B.25}$$

As Eurostat does not provide data separated by worker and profit income taxes, but only collective accounting information regarding taxes on all sorts of income and wealth ('Current taxes on income, wealth, etc., receivable'), we calibrate a uniform income tax rate (τ^{inc}) based on total taxable income (Y^{HH}), which is composed of worker's income (W), distributed profits to firm-owning individuals (Π^{dist}), and taxable income of the inactive population, which are basically old-age social benefits (SB^{old}) in the form of pensions. Furthermore, this tax rate also covers social insurance contributions ('Net social contributions, receivable'). While worker gross compensation (W) and distributed profits can be taken from the IO data, information on old-age social benefits is taken from government expenditure data (Eurostat, 2023b). Further elements of individual income are interest income on deposits (resulting from bank deposits D^{HH}) and bank profits ($\Pi^{dist,bank}$). This leads to the following income tax rate τ^{inc}:

$$\tau^{inc} = \frac{T^{inc} + T^{soc}}{Y^{HH}} = \frac{T^{inc} + T^{soc}}{wN + \Pi^{dist} + SB^{old} + \Pi^{dist,bank} + i^D \cdot D^{HH}} \tag{B.26}$$

In the model, taxable social benefits (i.e. pension payments) are set relative to the mean gross compensation rate. Hence, we calculate the corresponding benefits rate ($\epsilon^{SB^{old}/w}$) by dividing old-age benefits (Eurostat, 2023b) by the total number of inactive agents to get per capita benefits and then divide the result by the initial average rate of gross compensation. The benefit rate for other (non-taxable) social benefits to the inactive population ($\epsilon^{SB^{oth}/w}$) are calculated similarly by taking the sum of survivors, family and children, and sickness and disability payments (Eurostat, 2023b), dividing it by the total number of inactive agents, and then dividing the result by the initial average net compensation rate (i.e. the gross compensation rate reduced by the income tax rate). Finally, the rate of general transfers (received by all individual agents) to the net average compensation ($\epsilon^{SB^{gen}/w}$) is calculated by taking the sum of payments for housing, social inclusion, and the trade surplus (because this income would otherwise be missing in total household income; Eurostat, 2023b), divide it by the total number of individuals, and then divide the result by the net average compensation rate. Government consumption by industry (G_j) is taken from the IO data (P3_S13) and not further adjusted in the market clearing stage. The industry shares of government spending on products j (g_j) relative to total government spending (G) can be computed accordingly:

$$g_j = \frac{G_j}{G} \tag{B.27}$$

B.5 Financial sector parameters and stocks

Data on initial financial stocks are taken from financial balance sheets data (Eurostat, 2025b), and data for the central bank from ECB (2019). Since the

model does not feature household loans, initial loans of households are assumed to be zero. Initial government deposits are also assumed to be zero. For reasons of model consistency, total bank deposits are subsequently adjusted such that they are equal to total debt (which is the sum of bank loans and government bonds). Total household deposits are initially distributed among households proportionately to their share in total household income. For firms, total firm deposits are initially distributed among firms based on their share in total output. Data on central bank interest rates are taken from ECB (2025d) and ECB (2025e). Bank interest rates are available at ECB (2025b) and ECB (2025c), while bond interest rates are taken from ECB (2025a). All interest rates are calculated as yearly averages for the reference year.
The desired reserve ratio of banks (rr^B) is calculated as:

$$rr^B = \frac{R^{init,B}}{D^{init,HH} + D^{init,F} + D^{init,B} + D^{init,G}} \tag{B.28}$$

where $R^{init,B}$, $D^{init,HH}$, $D^{init,F}$, $D^{init,B}$, and $D^{init,G}$ refer to the initial reserve deposits of banks, as well as initial bank deposits ([F2] Currency and Deposits) of individual agents ([S14_S15] Households; non-profit institutions serving households), firms ([S11] Non-financial corporations), banks ([S121_S122_S123] Monetary financial institutions), and the government, respectively.[19]
Initial loans provided by banks are equal to loans ([F3] Debt Securities) owed by firms ($L^{init,F}$).[20] Total government debt (B^{init}) is split into bonds ([F3] Debt Securities) held by the central bank ($B^{init,CB}$) and the banking sector ($B^{init,B}$), where the latter is calculated as the residual from the former ($B^{init,B} = B^{init} - B^{init,CB}$). Accordingly, the central bank bond purchase ratio (br^B) is calculated as:

$$br^B = \frac{B^{init,CB}}{B^{init,CB} + L^{init,CB,B}} \tag{B.29}$$

Initial reserve deposits held by banks at the central bank (R) are equal to the sum of central bank loans given to banks (Lending to euro area credit institutions related to monetary policy operations denominated in euro) and government bonds held by the central bank ($R = L^{init,CB,B} + B^{init,CB}$).[21]
All monetary values (i.e. output, income, financial stocks) are converted from annual to quarterly model periods by dividing by a year scaling factor (f, typically 4). Interest rates are correspondingly divided by f to express them as quarterly rates. The scaling factor is further combined with a general model scaling factor (s) and a conversion from millions to single units ($\times 1,000$) to match the scale of the ABM.

B.6 Iterated market clearing

In order to start our model under stable conditions, we derive the conditions under which the model specification with the calibrated IO data clears the markets (i.e. where supply and demand dimensions in the (I) final consumption good, (II) intermediate good, and (III) capital good market balance out). We will go through

[19] For the government, we assume that bank deposits are initially zero.

[20] In accordance with the model assumptions, we assume that loans given to individual agents are equal to zero.

[21] This assures that the central bank's asset and liability sides add up to zero.

the market clearing in the three firm types according to the chronological order in which we introduced them.

Ad (I): We define the market clearing starting point as the state where gross nominal output of consumption firms (Y_j^{con}) has to meet the sum of gross final goods consumption of households (C_j) and government (G_j) for each industry j:

$$Y_j^{*con} \equiv C_j + G_j \tag{B.30}$$

Ad (II) and (III): Due to the complex nature of the model with various input sources, we solve the clearing of the intermediate and capital goods markets by iteration until the deviation between supply of and demand for intermediate and capital goods becomes practically zero.
Since production in the consumption goods sector has to meet the gross final goods consumption of households (C_j) and government (G_j) for each industry j, the output of the consumption goods firms is taken as given. From this follows that the demand of final goods-producing firms for intermediate inputs i ($Z_{iin,i}^{(1)con}$) and capital ($Z_{cap}^{(1)con}$) is also already determined.[22]

$$Z_{iin,i}^{(1)con} = Z_{iin,i}^{*con} \tag{B.31}$$
$$Z_{cap}^{(1)con} = Z_{cap}^{*con} \tag{B.32}$$

This demand has to be matched by intermediate and capital good firms. Hence, the first iteration of the intermediate and capital goods market ends with production of the intermediate good firms of each industry j ($Y_j^{(1)iin}$) being equal to the requirements of consumption good firms. The same applies to the output of capital good firms ($Y^{(1)cap}$). Computing the total demand for intermediate input good i of all consumption good firms requires taking the dot product of the intermediate input coefficient vector and the market clearing net output of consumption firms in each sector:

$$Y_j^{(1)iin} = Z_{iin,i}^{*con} = IIN_i^{*con} = \boldsymbol{\alpha}_{\boldsymbol{i}}^{\mathbf{con}'} \cdot \mathbf{Y}^{*\mathbf{net,con}} \tag{B.33}$$

Similarly, we can compute the respective output for capital type firms ($Y^{(1)cap}$), which needs to fulfil the demand for replacing depreciated capital of consumption type firms of all industries ($I^{*con} = \sum_j \delta K_j^{*con}$) based on the required capital input coefficients:

$$Y^{(1)cap} = Z_{cap}^{*con} = I^{*con} = \boldsymbol{\alpha}_{\boldsymbol{K}}^{\mathbf{con}'} \cdot \mathbf{Y}^{*\mathbf{net,con}} \tag{B.34}$$

The production of intermediate and capital goods firms creates additional demand for intermediate and capital goods. Hence, in the second round, we require intermediate input firms to produce the amount of goods that were demanded by consumption-, intermediate-, and capital-type firms in the previous round. The same applies to capital good firms. This means that the current gross intermediate good output of each industry j ($Y_j^{(2)iin}$) is based on the demand regarding product

[22] The parenthesis expression '(1)' refers to the first round of iterations. Accordingly, '(2)' refers to the second round, and '(n)' to the n-th round. Values that were already determined before the market clearing are marked with a superscript asterisk *.

i of the equivalent intermediate input sector j (i.e., $i = j$) of firms of all firm types ($\sum_k Z_{iin,i}^{(1)k}$). Computing the total demand for intermediate input good i of all consumption good firms ($Z_{iin,i}^{*con}$) as well as intermediate input type firms ($Z_{iin,i}^{(1)iin}$) requires taking the dot product of the intermediate input coefficient vector and the respective net outputs in each sector; the intermediate input demand for capital type firms is a simple multiplication:

$$Y_j^{(2)iin} = \sum_k Z_{iin,i}^{(1)k} = Z_{iin,i}^{*con} + Z_{iin,i}^{(1)iin} + Z_{iin,i}^{(1)cap} = \tag{B.35}$$

$$= \boldsymbol{\alpha_i^{\mathbf{con}'}} \cdot \mathbf{Y^{*net,con}} + \boldsymbol{\alpha_i^{\mathbf{iin}'}} \cdot \mathbf{Y^{(1)net,iin}} + \alpha_i^{cap} \cdot \mathrm{Y}^{(1)\mathrm{net,cap}} \tag{B.36}$$

Similarly to the first round, we can then compute the output of capital type firms:

$$Y^{(2)cap} = Z_{cap}^{*con} + Z_{cap}^{(2)iin} + Z_{cap}^{(1)cap} = I^{*con} + I^{(2)iin} + I^{(1)cap} = \tag{B.37}$$

$$= \boldsymbol{\alpha_K^{\mathbf{con}'}} \cdot \mathbf{Y^{*net,con}} + \boldsymbol{\alpha_K^{\mathbf{iin}'}} \cdot \mathbf{Y^{(2)net,iin}} + \alpha_K{}^{cap} \cdot \mathrm{Y}^{(1)\mathrm{net,cap}} \tag{B.38}$$

From now on, all consecutive iterations take the same form as this second round. Hence, in a more general form, we go through iterations and compute gross intermediate good output of industry j:

$$Y_j^{(x)iin} = Z_{iin,i}^{(x-1)} = \sum_k Z_{iin,i}^{(x-1)k} = Z_{iin,i}^{*con} + Z_{iin,i}^{(x-1)iin} + Z_{iin,i}^{(x-1)cap} = \tag{B.39}$$

$$= \boldsymbol{\alpha}_i^{\mathbf{con}'} \cdot \mathbf{Y^{*net,con}} + \boldsymbol{\alpha_i^{\mathbf{iin}'}} \cdot \mathbf{Y^{(x-1)net,iin}} + \alpha_i^{cap} \cdot \mathrm{Y}^{(\mathrm{x\ -\ 1})\mathrm{net,cap}} \tag{B.40}$$

and capital good output

$$Y^{(x)cap} = Z_{cap}^{*con} + Z_{cap}^{(x)iin} + Z_{cap}^{(x-1)cap} = I^{*con} + I^{(x)iin} + I^{(x-1)cap} = \tag{B.41}$$

$$= \boldsymbol{\alpha_K^{\mathbf{con}'}} \cdot \mathbf{Y^{*net,con}} + \boldsymbol{\alpha_K^{\mathbf{iin}'}} \cdot \mathbf{Y^{(x)net,iin}} + \alpha_K^{cap} \cdot \mathrm{Y}^{(\mathrm{x\text{-}1})\mathrm{net,cap}} \tag{B.42}$$

until the relative distance between supply and demand in each market becomes reasonably small (i.e. for each intermediate input industry j):

$$\left| Y_j^{(x)iin} - \sum_i Z_{iin,i}^{(x-1)} \right| \approx 0 \tag{B.43}$$

$$\left| Y^{(x)cap} - \sum_i Z_{cap,i}^{(x-1)} \right| \approx 0 \tag{B.44}$$

In order to account for desired intermediate input inventories ($INV^{d,iin}$), we compute a desired intermediate input inventory factor ($\nu^{d,iin}$). First, the implied intermediate inventory level follows from the input inventory sales ratio ($\nu^{iin} = 1.11$) reported in Humphreys et al. (2001) multiplied by total real output ($Y^{real,tot}$):

$$INV^{d,iin} = \nu^{iin} \cdot Y^{real,tot} \tag{B.45}$$

The desired intermediate input inventory factor is then the ratio of this implied inventory level to aggregate intermediate goods demand (IIN^{tot}):

$$\nu^{d,iin} = \frac{INV^{d,iin}}{IIN^{tot}} = \frac{\nu^{iin} \cdot Y^{real,tot}}{IIN^{tot}} \tag{B.46}$$

In the AB model, initial stocks of intermediate inputs are scaled by this factor to ensure that firms hold the desired level of input inventories relative to their production.

Based on the market equilibrium, we are also able to calculate the corresponding initial government budget deficit. We do so by taking the sum of total government spending on goods, total transfers given, and interest payments and then subtracting total government income (consisting of income tax paid on wage, profit, and interest income; VAT; and distributed central bank profits), where all tax calculations are based on incomes derived from the initial market equilibrium (i.e. initial sales, initial employment, etc.). The resulting government deficit-to-GDP ratio is used as desired government saving rate (s^G).

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