Chapter 2
The setup of the model

2.1 A monetary market economy

All economic activity in the model is borne by decentralized actions of agents. These agents are categorized as households, firms, and banks each assuming the following economic functions. The households buy and consume goods, make investments, and provide labor to firms. The firms, on the other hand, hire labor and purchase capital goods in order to produce and sell goods. The banks, finally, act as the financial intermediaries between households and firms. That is, they manage transactions between non-bank agents, they offer saving contracts to households and loan contracts to firms, and they facilitate purchases of equity (Figure 2.1).

All these activities are modeled as market phenomena. That is, each type of good or service that exists in this model is traded in a separate market. Markets come into existence whenever agents offer a product or a service for sale. Thus, every market consists of a list of offers, each of which specifies the quantity offered by an individual offerer and the respective asked price. In each market the total quantity supplied is thus determined by the sum of the individual quantities. Formally, such a market can be described with the help of a diagram that measures offered quantity on the abscissa and unit price on the ordinate. In such a diagram every offer constitutes a horizontal supply-curve of a given length. By sorting these offers in ascending price order while cumulating over their quantity it is possible to construct an upward sloping supply curve (Figure 2.2). Such a supply curve, however, is not to be confounded with a Marshallian supply curve. It does not describe the hypothetical total supply given a hypothetical equilibrium price, but rather the price spectrum at which the marketable quantity is available. Thus, there is price

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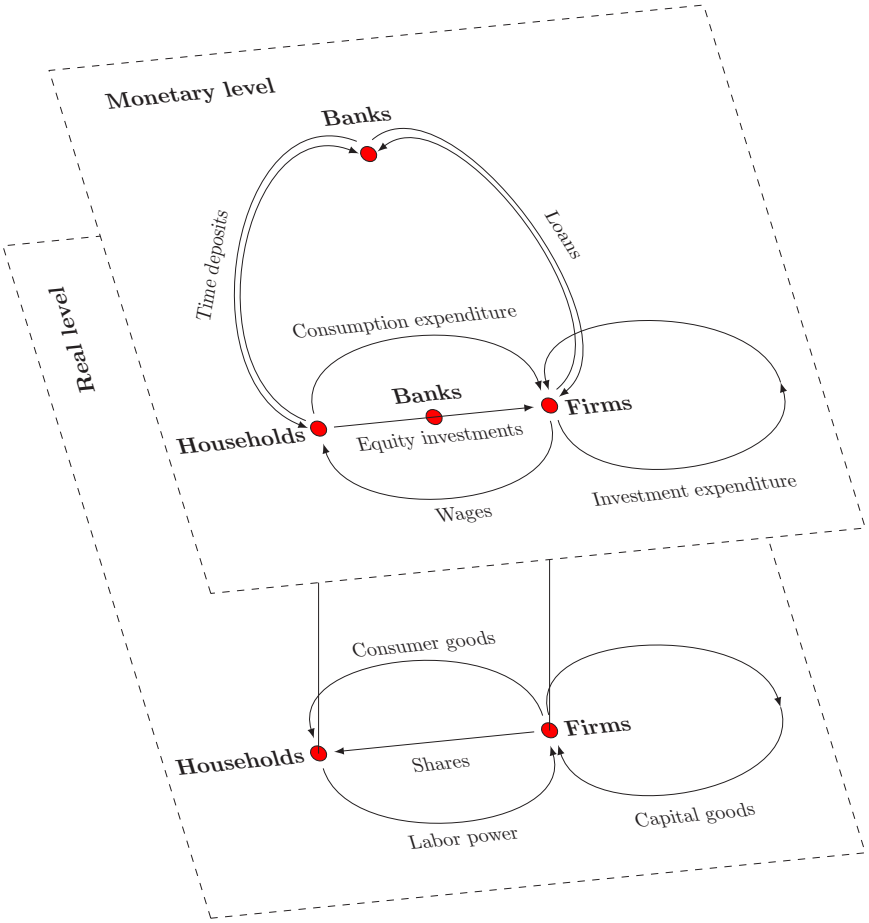

Fig. 2.1: In every market transaction a good is exchanged against money. The real level and the monetary level of the economy are thus complementary to each other. The figure illustrates the different market activities of the agents (dividend payments are not shown).

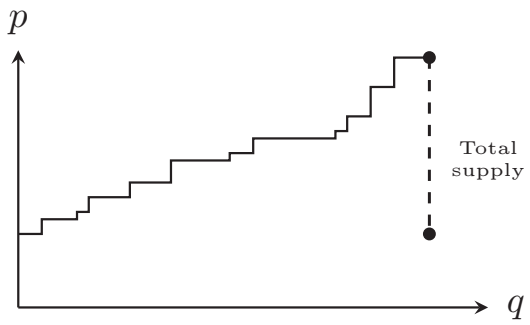

Fig. 2.2: A market is constituted by a list of offers. Each offer can be depicted as a horizontal supply curve of a given length. When combined, these supply curves describe the total quantity that is offered in the market and the price spectrum at which this quantity is offered.

dispersion in every market. In what follows the median of the prices of a given market is called the price level of that market.

Transactions occur in case agents on the demand side of a market respond to the offers in that market. In all transactions only one unit of a good is traded. In order to buy a unit of a good each potential buyer consults a fixed number of randomly selected offers and chooses the one with the lowest price. Subsequently, each potential customer evaluates whether a purchase of the chosen good would improve his economic situation. In the case of the households this evaluation is made on the basis of individual preference while in the case of firms and banks it is based on profitability. The result of this assessment is in any case the formation of a reservation price. If, according to this reservation price, it is rational for an agent to buy a unit of the selected offer he pays the required sum to the offering agent and receives the good in exchange. Otherwise, he declines the offer. All market transactions are thus two-sided affairs in which money and a good change hands, requiring a coincidence of wants. Also note that in the market search process all agents apply a principle of economizing. They generally prefer to buy low and to sell high which is corollary of human action under the conditions of market exchange (Mises, [1949] 2008, pp.241).

On an individual basis a market can thus be depicted by combining the supply curves of the consulted offers with the buyer's demand curve, which, in turn, displays the buyer's reservation price and the desired quantity, which is always one unit of the good (Figure 2.3). A transaction occurs if at least one supply curve intersects with the demand curve. In Misesian ([1949] 2008, pp.245) terms one can say that after every transaction the market reaches a plain state of rest because trad-

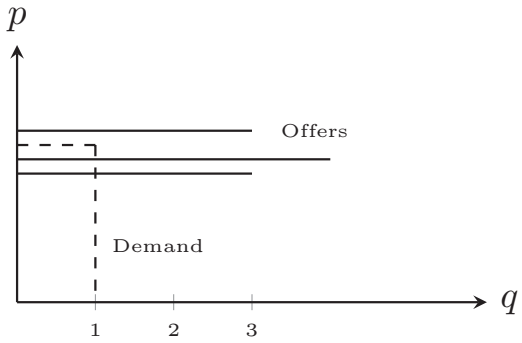

Fig. 2.3: A market from the perspective of a single customer. The horizontal supply curves are the offers found in the market ($\eta = 3$). The demand curve captures the customer's reservation price and the fact that purchasing decisions are marginal decisions. A transaction occurs if at least one supply curve intersects with the demand curve.[1]

ing comes to a halt. After a transaction the seller updates his offer by subtracting the sold quantity from the offered quantity. His supply curve thus becomes shorter and a new state of the market comes into being.

At the end of a time period each offerer is left with a certain number of unsold goods. Some firms may have sold all their offered goods while others may have sold none. In each market the firm that is able to sell goods at the highest transaction price can be called the marginal selling firm. A market has cleared if by the end of a time period all goods in the entire market are sold. There are also extreme cases in which there is either no demand for an offered good or no supply of a good that is desired by the customers. In these cases no transactions occur.

Due to the knowledge constraints of the market participants no market in this model is ever efficient. There is no mechanism which matches the higher priced offers to the buyers with high reservation prices. Rather, each buyer deals with the market situation from his own perspective and acts to his own advantage. Since the results of a market search are established stochastically a market looks different to every potential buyer. Moreover, the timing of a market activity matters for the search result since every market transaction changes the supply conditions in that market. Yet, the fact that the agents enter the market in a uniformly random

[1] If the market search is conducted by a seller, then the reservation price marks the lower bound of the prices that he is willing to accept. The horizontal curves then represent demand curves of which he selects the one with the highest price and his individual supply curve is upward sloping.

order and the fact that all offers in the market have an equal selection probability guarantee that no agent has a systematic advantage over others.

2.2 Physical capital

There is a variety of different types of goods that can be produced in this modeled economy. This heterogeneity of physical capital is represented by a grid with each node representing one type of good (Figure 2.4). The horizontal layers of the grid are conceived as stages of production. That is, the top layer represents consumer goods and the lower layers describe goods of higher order, i.e. intermediate goods. The different nodes in each layer, which are labeled in alphabetical order, display the variety of goods within a certain stage. The columns of the grid can be understood as lines of production, i.e. each of these columns constitutes an isolated chain of suitable preliminary inputs.

Type-A goods are neither consumer goods nor intermediate goods but can be used to assemble machines. The difference between intermediate capital goods and machines lies in the fact that the former are fully used up in a production process while the latter wear out over time. The machines thus constitute the fixed capital of firms. The life span of machines is assumed to be identical for all machines and is labeled τ_k.

Goods, in general, are non-perishable and can be stored until sold. Also, the firms have no direct use for their products. They buy goods only for the purpose of production and they produce goods only for the purpose of selling. The households, in turn, only buy consumer goods for the purpose of near-term consumption. Furthermore, all goods of the same type are assumed to be of the same quality.

Each firm specializes in the production of one type of good. One can imagine this as each firm choosing one node where it will operate. Since the number of firms in the model is limited, this implies that not every type of good will always be produced. Only if firms choose to produce a certain good do goods of the respective type come into existence. It is possible that multiple firms produce the same good. All firms producing the same good use the same input factors. In general, goods can either be produced by the use of labor or by combining labor with capital goods. Firms producing type-A goods and firms operating at the highest stage of a production line use labor only. All other firms use labor, machines, and goods from the next higher stage of their own line of production as input factors (Figure 2.5).[2]

[2] The factor of land remains abstract in this model, but the use of land is implied in all processes of production, since firm owners can be considered as land owners. All dividends thus contain a rent component.

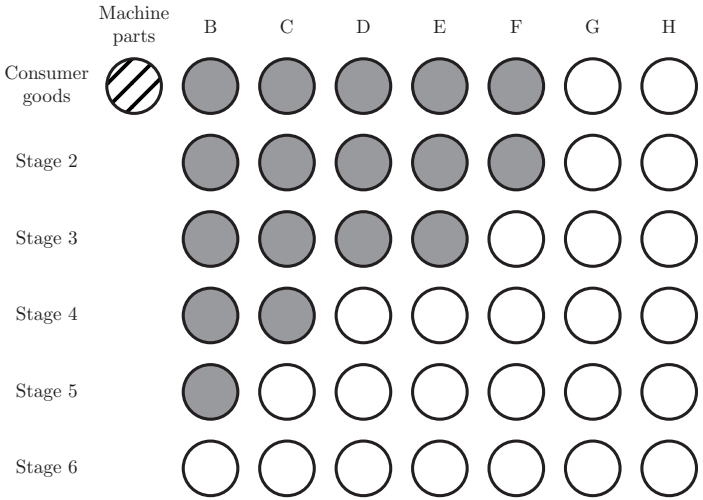

Fig. 2.4: The heterogeneity of capital: Stage-1 goods represent consumer goods and type-A goods represent machine parts. All other goods are intermediate goods. In each stage of production there is a variety of goods that can be produced. Only if firms operate at a node do goods of the respective type come into existence. Since not all nodes are always populated by firms, not all types of goods are always produced (white nodes).

The quantitative relation between input and output in this model is described by a production function that embodies the following principles. First of all, labor must be used in all production processes. That is, no output can be generated using capital alone. Each worker, when working without capital, can produce pr_l goods per time period (or pr_m goods in the case of type-A firms). The division of labor and the use of capital generally enhance the productivity and the processing capacity of labor. That is, when provided with an intermediate good a worker can produce pr_x goods per time period. Moreover, without the help of machines each worker can only process cap_l intermediate goods per time period, but the use of machinery enables a worker to process cap_k goods. Each machine can only be used by one worker and each worker can only handle one machine at the time. A single machine requires the input of μ_k machine parts, i.e. type-A goods.

Formally, this production function is a fixed-proportions production function $y : \mathbb{N}^3 \mapsto \mathbb{N}_0$. This function holds no matter where on the grid a firm operates and is given as

$$y(l,x,k) = pr_x \cdot \min\{cap(l,k),x\} + pr_l \cdot \max\{l-x,0\} \ , \tag{2.1}$$

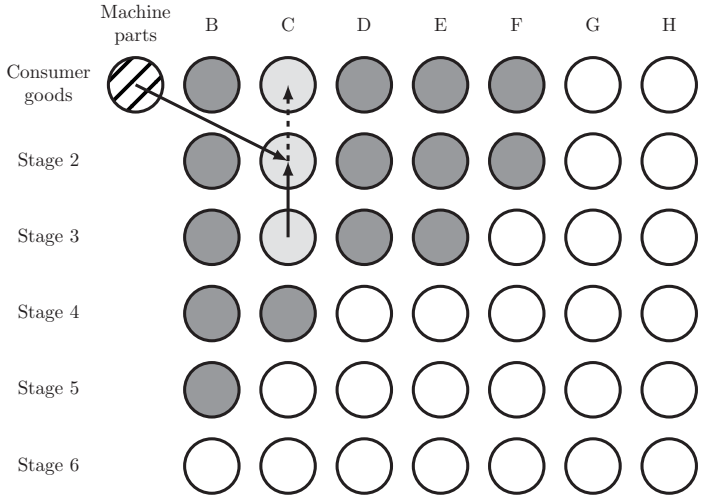

Fig. 2.5: The complementarity of capital: The production of a good requires specific input factors. For any firm, only the capital goods from the next higher stage are suitable preliminary inputs. Fixed-capital goods, in contrast, can be put to multiple uses.

where y denotes the number of goods produced and k, x, and l are units of fixed capital, intermediate goods, and labor, respectively. The function $cap : \mathbb{N}^2 \mapsto \mathbb{N}_0$ describes the number of intermediate goods that a firm can process with a given number of workers and machines. It is defined as

$$cap(l,k) = cap_k \cdot k + cap_l \cdot (l-k) \; . \tag{2.1a}$$

For firms of type A, which cannot use capital, the production function simplifies to

$$y(l) = pr_m \cdot l \; .$$

The parameters pr_x, pr_l, and cap_l describe the gains in productivity that can be reaped from the division of labor while the parameters cap_k, μ_k, pr_m, and τ_k describe the productivity enhancements of capital accumulation. Together, these parameters represent the level of technology that is available in the economy. In order for these productivity gains to be positive, the technology parameters need to respect the following relations[3]

[3] All technology parameters are $\in \mathbb{N}$.

$$\begin{aligned} pr_x &\geq 3 \cdot pr_l \\ cap_k &> cap_l \\ \frac{cap_k - cap_l}{cap_l} \cdot \tau_k &> \frac{\mu_k}{pr_m} > 1 \,. \end{aligned} \tag{2.2}$$

Overall, the way physical capital is modeled here is an interpretation of the exposition of Lachmann ([1956] 2007, Ch.1). Moreover, the production function (2.1) is in agreement with the law of returns. When keeping the input of two of the production factors constant then there exists an optimal input level for the third factor. If one deviates from this level in either direction the average productivity of the factors falls (cf. Mises, [1949] 2008, pp.127). Moreover, Equation (2.1) exhibits constant returns to scale. The setup furthermore implies that fixed capital requires to be continually supported by circulating capital. No fixed capital can yield any revenue but by means of circulating capital. The fact that production takes time is captured by the fact that goods that were produced in one time period can only be sold in the following time period. Finally, one should note that firms at the highest stage of production will always produce without capital. Hence, there is always a possibility to raise the productivity of these firms by providing capital goods to them.

2.3 The financial system

2.3.1 Accounting

Money is the universal medium of exchange in this modeled economy. The quantity of money that circulates in this economy is fixed and it is backed by some assumed physical commodity. Every non-bank agent has its physical money safeguarded by a certain, randomly selected bank. Thus, physical money is generally held by banks. This safeguarded money is, however, at the depositors' disposal at all times and the banks do not lend these deposits to third parties. Moreover, these deposits do not bear interest. The safeguarded money can be transferred to the account of a different agent upon the initiative of the depositor. Thus, these deposits are sight deposits and serve as money substitutes (cf. Mises, [1949] 2008, pp.429). They are henceforth also referred to as money.

All monetary transactions are conducted via checks, which transfer claims to physical money from one party to another. A summary of the different types of transactions that occur in the model is shown in Table 2.1. Since money, when

	Households	**Firms**	**Banks**	Sum
Consumption expenditure	$-$	$+$		0
Wage payments	$+$	$-$		0
Investment in capital goods		$+/-$		0
Saving and new loans	$-$	$+$	$+/-$	0
Redemption	$+$	$-$	$+/-$	0
Equity investment	$-$	$+$	$+/-$	0
Interest payments	$+$	$-$	$+/-$	0
Dividend payments	$+$	$-$	$-$	0

Table 2.1: Representative cash flow statements for the different types of agents. The exact figures vary for each agent. Money inflows are represented by a $+$ and outflows by a $-$ sign.

being transferred, always runs from one agent to another the sum across each row in that table amounts to zero. The monetary system of the economy is thus closed. Money is neither created nor destroyed and at all times it is held by a certain agent. The banks facilitate all money transactions free of charge. A transaction that takes place between parties who are clients of different banks implies that commodity money is physically transferred from one bank to another. Furthermore, the sums over the columns in Table 2.1, when taken for a certain time period, equal the total cash flow of an agent or sector in that time period. Whenever the cash flow in a particular entry is non-zero this is accounted for by a change in the balance sheet of the respective agent or sector.

Table 2.2 shows a representation of the balance sheets of the different types of agents. The assets of banks consist of their (physical) money holdings and the book value of their outstanding loans. The money holdings are subdivided in four different categories, namely sight deposits, loanable funds, reserves and escrow money. On the liabilities side the balance sheet of a bank shows the checking and time deposits of its customers and the bank's equity. The assets of firms comprise fixed capital and inventories as well as money while the financing of the firms' activities happens via loans and equity. The value of equity is determined by the excess of assets over liabilities. The equity values constitute liabilities for firms and banks and assets for households. Thus, the entire net worth of the economy lies with the households and the property distribution in this model is at all times defined.

All transactions between the agents are subject to standard accounting rules (in particular IAS 1, 2, 16, and 30). When a firm produces goods these goods are acti-

Households	
M^h	Net Worth
T	
E^f	
E^b	

Firms	
M^f	D
In	E^f
K	

Banks	
M^h, M^f	M^h, M^f
Lf	T
Rs	E^b
Es	
D	

Table 2.2: Representative balance sheets for the different types of agents. The exact figures vary for each agent.

vated at historical costs in the firm's balance sheet.[4] Thus, since the model abstracts from non-investive costs, the book value of any produced bundle of goods equals the amount of money that was spent on the labor and the intermediate goods that were used in its production. The book value of a single good therefore equals the total of these operating expenses divided by the size of the bundle. The book value of a good is written off when the good is sold and is recorded in the income statement of the selling firm as a cost of goods sold (Table 2.3). Goods are generally sold in the order in which they were produced. In contrast to intermediate goods, the purchase and use of a machine is not attributable to the production of certain goods. Hence, fixed-capital investments entail fixed costs for the firms. When machines are bought they are activated at their purchasing price and then written off according to a linear depreciation plan whose length is given by τ_k. The profit and loss statement of firms is thus determined by revenue, variable costs, and fixed costs. The latter also include the firm's financing costs (Table 2.3).

Time deposits come into existence when households transfer money from their checking account to a savings account. Such time deposits always have a contracted duration and interest rate. The interest payment is the difference between the amount of money deposited and the amount of money returned by the bank. When making a time deposit the households thus buy future money and they do so at a discount. In the model all saving contracts are standardized to amounts of T_0 monetary units redemption payment. With an interest rate r_s, the price of T_0 units of future money receivable in τ time periods is thus given as

$$p = \frac{T_{0,t+\tau}}{(1+r_s)^\tau} \ .$$

Each household may keep several savings accounts, including with banks that do not manage his sight deposits.

[4] Historical-cost accounting is here mainly chosen for ease of exposition, since mark-to-market valuations would require a continuous updating of the balance sheets of the agents. Historical-cost accounting also bears the advantage that all cost measures are fully objective.

The banks, in turn, can use the saved money to make loans to firms.[5] When a loan contract is signed money is transferred from the originating bank to the checking account of the firm that took the loan. In this model there are two types of loans, to wit, short-term operating loans, which are used to finance the operations of firms and have no definite duration, as well as investment loans, which are used to finance fixed-capital investments. Operating loans are automatically renewed by the banks, conditional upon the firm being able to effectuate the interest payments. Moreover, they can be redeemed upon the initiative of the firm at any time. For these loans interest always has to be paid on the volume that the loan had at the end of the previous time period. Investment loans, in contrast, are installment credits with equal periodic redemption payments. The first installment is due in the same time period that the contract was signed and interest is to be paid on the volume of the loan prior to the repayment. With every installment that a firm pays the outstanding amount is reduced by the redemption content of that installment. Hence, the interest payments for an investment loan are relatively high at the beginning of the contracted time period and they become smaller toward the end. In general, for a loan D, which is signed in the time period t_0, which has a face value of D_0, a duration of τ, and an interest rate of r_d, the required interest payment due in time period t can be written as

$$Int_t(D) = \begin{cases} r_d \cdot D_0 \cdot (1 - \frac{t-t_0}{\tau}) & \text{for investment loans} \\ r_d \cdot D_{t-1} & \text{for operating loans,} \end{cases}$$

while the obligatory redemption payments are

$$Red_t(D) = \begin{cases} \frac{D_0}{\tau} & \text{for investment loans} \\ 0 & \text{for operating loans.} \end{cases}$$

Banks earn profits by lending at a rate that is higher than the rate at which they borrow. The profit of a bank can thus be calculated as the difference between the received and the effectuated interest payments while controlling for the write-downs of loans that have not been paid back (Table 2.3).

2.3.2 Firm creation, equity requirements, bankruptcy

The creation of firms and banks is organized by a single investment bank. The investment bank integrates two distinct economic functions. First, it transfers the eq-

[5] By assumption, the banks do not lend to households.

Firms	**Banks**
Revenue ($= p_t \cdot s_t$)	Interest income
./. Costs of goods sold (In_t^s)	./. Interest expense
./. Depreciation ($\tau_K \cdot (K_{t-1} + I_t)$)	
Gross profit	Net interest income
./. Financing costs (Int_t)	./. Provision for loan losses
Net profit	Net profit

Table 2.3: Representative income statements for firms and banks. The exact figures vary for each agent.

uity investments of the households to start-up firms, and, second, it decides where on the production grid it finances new entrepreneurial projects. To this end, the investment bank monitors all markets and determines the various relations between firms and workers as well as the different price levels. The next firm is always created in that market in which the number of employers is lowest relative to the number of employees.

Moreover, for each firm created the investment bank decides over the number of workers and preliminary inputs that the new firm shall employ. This decision is made according to whether the transacted volume in the market in which the firm shall be created is higher or lower than the parameter Q. If above, then the number of required workers is set to l_0^{ext} and if below it is l_0^{min}. In addition, requirements for intermediate goods are considered if a market for preliminary inputs exists at the position where the firm is to be created. The number of required intermediate goods is always set equal to the number of envisaged employees. Independent thereof, with a probability of ϕ and under the conditions that, for one, the number of firms that operate at the highest stage of a randomly selected production line is greater than f^{min}, and second, that their accumulated sales exceed q^{min}, the investment bank decides to create a new firm outside the current production structure, namely at the next higher stage of the selected line of production. In this case the labor requirement for a new firm is l_0^{min}.

Based on the calculated input requirements and on the observed market prices the investment bank calculates the funding requirement for each new firm. The funding requirement for banks is always M^0. The investment bank acquires funds via sales in the market for equity. The price of one share is fixed to the amount T_0. Once the bank has collected sufficient funds for a new firm or bank, it creates a new agent by transferring money to a newly created checking account. The creation of firms and banks always happens in the order in which the respective bankruptcies occurred. The numbers of firms and banks that operate in the economy are limited to N_f and N_b, respectively. If that number is reached then no additional firms or banks can be created, but, depending on the preferences of the households the

number of active firms and banks may be lower than those values. The investment bank provides all its services free of charge. Money that cannot be immediately allocated to a new venture is kept in an escrow account.

Every firm or bank, when it is created, is equipped with the money that has been provided by its equity investors. The relative share by which the investors provide start-up capital equals the relative share of the dividends that each investor is entitled to. Moreover, the start-up capital of firms and banks constitutes their subscribed capital and, by assumption, this money cannot be distributed to the shareholders. That is, the equity of a firm or bank may never fall below the value of its subscribed capital unless it is due to losses. Since there is no secondary market for equity, the equity investment decisions of households are final and their claims only expire if the respective firm or bank goes bankrupt.

Bankruptcy happens via several stages. If at some point a firm is unable to serve its debt then it has to declare illiquidity. Once a firm is illiquid it cannot get new credit from any bank. Yet, the crediting banks, in general, concede to the firm to defer its debt obligations by a maximum of τ_1 time periods. Any money that an illiquid firm earns during this time has to be paid out to the creditors. In case such repayments are only partial the creditors receive money in proportion to their outstanding claims. Moreover, when the repayments are partial only the payment in excess of the required interest is treated as a redemption. If within the allowed time the firm can meet its obligations then it regains its old debtor status and can continue its operations. Otherwise, it has to file for bankruptcy. In that case all physical assets of the firm, which cannot or have not be sold at this point, are lost.

A second reason for firms to file for bankruptcy is if they are unable to sell goods at all. If a firm has not made sales in more than τ_2 time periods the firm withdraws from the market. The physical assets are thus written off and the bankrupt's money is distributed among its creditors in proportion to their creditor share, while debentures take priority over equity.

Banks, in the case of the illiquidity, suspend their operations entirely. That is, while being illiquid banks do not take on new time deposits nor do they issue new loans. They rather wait until all their outstanding loans have either been paid back or written off. Any income that a bank receives during this phase is distributed to the savers according to a scheme that respects the relative quantities of the claims. When there are no more outstanding loans and the bank's equity is positive it resumes its operations. Otherwise it goes bankrupt.

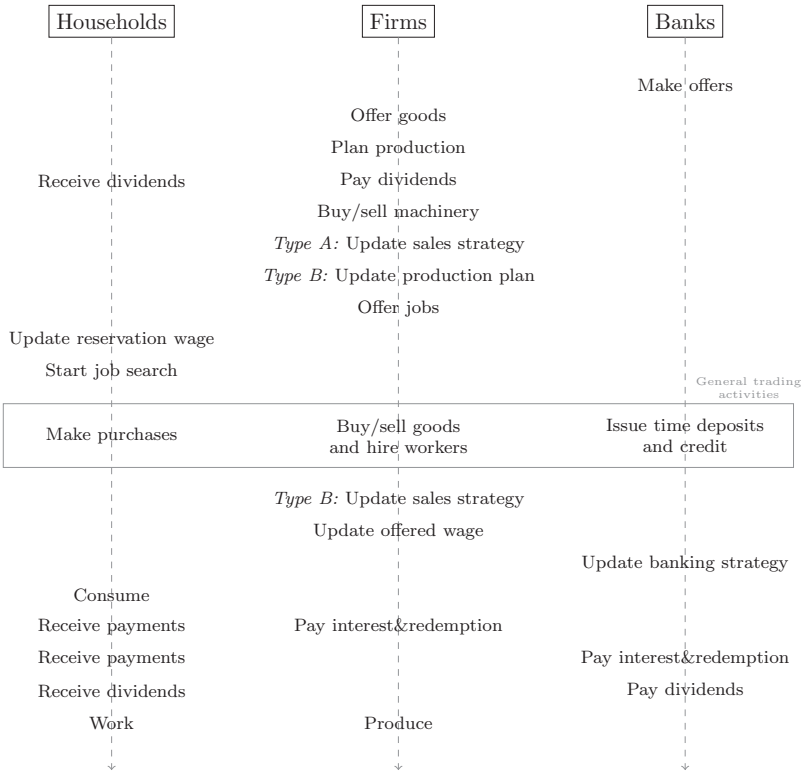

Fig. 2.6: The order of events within a time period. Firms that do not produce goods of type A are here labeled as type B. The rectangle marks the general trading activities.

2.4 Time periods

Each time period consists of a multitude of time points at which the various actions take place. No two actions in this model ever happen at once. The number of time steps within one time period thus corresponds to the number of performed actions. Those points in time, which lie somewhere within a time period, are labeled by t^* while the label t refers to entire time periods. If the value of a variable indexed by t changes in the course of a time period the index t refers to the end of the time period.

The order in which different types of actions take place is shown in Figure 2.6. The specific actions are explained in more detail in the following chapters. At the beginning of each time period all firms make offers in the various goods markets and the banks make offers in the markets for savings, loans, and equity. Subsequently, the firms prepare their investments. This starts by choosing a mode of production, i.e the firms decide whether they will produce with or without capital (Chapter 4.1). After that, the firms manage their liquidity position and distribute those funds that they have no immediate use for as dividends (Chapter 4.3). In the next step the capital-using firms invest in machinery (Chapter 4.5.2). At this point the machine producers have already completed their sales and update their sales strategy (Chapter 4.2). Moreover, those firms who have purchased machines now revise their production plans. Based on these updated plans all firms make job offers in the labor market (Chapter 4.4). The households, in turn, calculate their reservation wages taking into account the newly received dividends and then apply for jobs with the offering firms (Chapter 3.2).

Now the general market activities set in. In a random order, firms carry out investments while households purchase consumer goods and buy saving contracts or equity shares from banks (Chapter 3.1 and 4.5.1). The investments of the firms also involve the hiring of workers as well as the issuance of credit. All contracted payments are carried out immediately and these transactions immediately create demand on the part of the sellers. The trading activities only end when all desired goods are sold out or no agent desires a further purchase. Throughout this entire phase the households keep looking for jobs, but they can only place applications with one firm at the time.[6] Note that this setup avoids any assumption about the chronological order in which market activities take place. All actions before and after the general trading activities are either strategic or have a clearing character.

After trades have been made, the firms which are not of type A set their sales strategy for the next time period and all firms update their offered wage (Chapters 4.2 and 4.5.2). The banks also update their strategies (Chapter 5.2) and the households consume their consumer goods. Thereafter, the banks and the firms pay their credit obligations and the banks pay out dividends. Firms and banks that are unable to serve their debt file for bankruptcy while all other firms finally resume production. The products of these production processes are available for sale in the next time period.

[6] For details about the organization of this process see Chapter 4.4.

2.5 National accounting

Tables 2.1, 2.2, and 2.3 equally refer to individual agents as well as entire sectors. Hence an economy-wide accounting system emerges from the accounting practices of the individual agents. That is, since the agents constantly monitor their own balance sheets the model automatically monitors all components of the system of national accounts. It is this feature that makes the model intelligible from a macroeconomic viewpoint, despite its complex microeconomic structure.

In particular, the national account details can be computed as shown in Table 2.4. The gross value of output is the sum of all consumption and investment expenditures that are made in a given time period. Investments here include operating expenditures. Deducting from the gross value of output the book value of all goods that were sold in that time period yields the gross domestic product. [7] From there, one may compute gross investment by subtracting the consumption expenditures. Furthermore, net national income is defined as gross domestic product minus the depreciation of fixed assets. [8]

Based on net national income it is possible to conduct an income and expenditure compilation of the accounting figures. Subtracting from net national income the consumption expenditure or the wage payments yields the figures for net investment and net operating surplus, respectively. By definition, net investment is equal to national saving. Further inspection of the accounting identities reveals that net investment can also be interpreted as the sum of the changes of the values of fixed assets and inventories.

The ratio between net investment and national income is the national savings rate. There are, however, other possible ways of defining the savings rate. Some countries measure the national savings rate in gross terms, i.e. as the ratio between gross investment and gross domestic product. Moreover, there is the household savings rate which describes a relationship between the saving activity of households and their disposable income. Again, different ways of defining this rate are possible. In the following three different savings rates are considered, the national savings rate both in net and in gross terms and a household savings rate that is taken as the amount that households spend on equity and saving contracts divided by the total budget that was available to the households in that time period. This total budget consists of the households' initial money holdings and all revenue that

[7] Note that this deviates from standard practices of national accounting, but is a consequence of the historical-cost accounting applied by the firms (cf. SNA 2008, para 1.60).

[8] The computation abstracts from financial intermediation services, indirectly measured (FISIM). Since there is no government intervention, gross domestic product could equally be labeled gross value added or gross national income. Depreciation also includes the write-down of inventories of bankrupt firms.

Production approach	
Gross value of output ($= C_t + W_t + X_t + I_t$)	
./. Intermediate consumption (In_t^s)	
Gross domestic product (GDP_t)	
./. Depreciation ($\tau_\kappa \cdot (K_{t-1} + I_t)$)	./. Consumption expenditure
Net national income (NNI_t)	Gross investment (I_t^{gr})
	./. Depreciation
	Net investment (I_t^{net})

Expenditure approach	**Income approach**
Net national income	Net national income
./. Consumption expenditure	./. Compensation of employees
Net investment (national saving)	Net operating surplus

Table 2.4: The system of national accounts for the modeled economy.

they obtain prior or during the general trading activities, i.e. dividend and wage income. The three savings rates can thus be summarized as

$$sav^{net} = \frac{I^{net}}{NNI} \quad sav^{gr} = \frac{I^{gr}}{GDP} \quad sav^{h} = \frac{Ex^{eq} + Ex^{td}}{M^{budget}} \,. \tag{2.3}$$

Furthermore, using the microeconomic data that the agents provide, it is also possible to measure the gross domestic product in real terms. This quantity is defined as a Laspeyres quantity index and it is here calculated from the total expenditures and traded quantities in all goods markets and the labor market. [9] Thus,

$$GDP_t^{real,index} = \frac{\sum_i s_{i,t} \cdot Ex_{i,t=1} / s_{i,t=1}}{\sum_i Ex_{i,t=1}} \cdot 100 \,. \tag{2.4}$$

Moreover, an index for nominal GDP is introduced, which is defined as

$$GDP_t^{index} = \frac{GDP_t}{GDP_{t=1}} \cdot 100 \,.$$

Together these indices define the GDP deflator. Also, an index for real consumption is computed based on the principle of Equation (2.4) while summing over markets for consumer goods only.

[9] This method is the single-indicator method suggested in SNA 2008, para 15.135. The direct double-deflation method, which is the theoretically sound one, is here not applied as it would require market-value accounting. Moreover, real GDP is here calculated on a fixed-price basis because of the distortions that the strong fluctuations of the model impose on chain indices.

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