Working Paper

Dynamics of a sustainable financial-economic system

N D van Egmond and B J M de Vries

Utrecht University

This working paper describes research in progress by the authors in the framework of the Sustainable Finance Lab, a think tank directed to a more sustainable financial system. The paper is published to elicit comments and to further debate. The views expressed in this Working Paper are those of the authors and do not necessarily represent those of the Sustainable Finance Lab.

Abstract

Along the lines of neoclassical theory, a system dynamics model has been developed to describe the most important mechanisms governing the physical output of goods and services in the economy in interaction with the financial system. The model gives a meaningful reconstruction of the overall long-term dynamical behaviour of the financial-economic system, including the endogenous modeled crisis. The occurrence of the boom- and bust-cycles can be understood and to a reasonable extent predicted from the asset price driven credit cycle. The model confirms Minsky's instability hypothesis, in which the euphoria over apparently ever increasing (asset) prices, GDP, wages, consumption and loans turn the system into the downward spiral of the bust, when financing cost becomes unbearable for individual households and the economy is no longer stimulated by a continuously decreasing interest rate when it approaches the zero level.

The current financial system appears to be fundamentally unstable. Lacking central coordination, decentralized money creation causes unjustified euphoric herd behavior of the many private banks, with then create monetary economic growth that is bound to suffer from boom-and-bust behavior.
The model experiments show that money creation by the government, according to a 'money creation rule' which is directed to price stability and / or employment, can stabilize the boom-bust cycles. At a constant price level, both the physical and the monetary production and consumption then follow a pathway of stable, continuous growth, which reflects the increased productivity which results from technical progress.
Price stability and the associated positive effects on employment and GDP can be realized by creation of debt free money at a rate corresponding to the growth of the real, physical economy (without inflation); in the model experiment this was about 1,5 % / year, resulting in an annual saving of government (and thus taxpayers') money in the order of 10 billion € / year, plus the additional reduction of interest to be paid on government debt (5 to 10 billion € / year) and the extra money to be created in case a certain level of inflation (e.g. 2 %) would be preferred politically (2 % is about 12 bn €).
This money can be used to lower taxes and to invest in physical and social infrastructure, for example in more sustainable energy and transport systems.

Content

1. Introduction

Seven years after the 2007 /2008-financial crisis which 'no one saw coming', the measures to improve the financial system appear to be limited to strengthening the supervisory network. But the associated flight forward into more Basel-regulations on top of the many which are already in place, will be counterproductive. Increasing regulation will show diminishing returns and exponentially increasing complexity at the same time. For civilized societies, increasing complexity is a threat which is comparable to that of a dysfunctional financial system (Tainter 1988). Apparently, solutions to the problem has to be found on a more fundamental level.

Already twenty years before the 2007 / 2008 crisis, that fundamental level was adressed by the American economist Minsky. He warned for the instability of the current financial-economic system: 'the Wall Streets of the world generate destabilizing forces, and from time to time the financial processes of our economy lead to serious threats of financial and economic instability, that is, the behaviour of the economy becomes incoherent' (Minsky 1986). Minsky regrets that 'what was lost was a view of an economy always in transit because it accumulates in response to disequilibrating forces that are internal to the economy; instability is an inherent and inescapable flaw of capitalism'. Succesful functioning of an economy will inevitably lead to 'euphoria', in which expectation grow irrationally high. In his 1970 paper, Minsky remarks that 'once euphoria sets in, financial institutions accept liability structures –their own and those of borrowers- that, in a more sober expectational climate, they woud have rejected' (Minsky 1970).
In this process, money does matter. The inherent instability is related to the creation of money: 'in a world in which money is mainly demand deposits at commercial banks, much of the financing of business involves the creation of money - as debts are entered upon the books of banks - and the destruction of money-as debts are repaid' (Minsky 1986). Minsky's financial instability hypothesis 'is a theory of the impact of debt on system behaviour' (Minsky 1992).

Indeed, the huge creation of 'money as debt' (MaD) since the deregulation in the 1990's, in combination with ICT and globalization, has led to serious volatilities and instabilities in regional economies. At the same time, it has burdened many governments with large debts, partly as a result of coming to rescue the banks that caused the crises, which leaves them with large interest payments on the one hand and insufficient financial means to stimulate necessary social transitions. A second motivation for a more fundamental approach is the importance of a well-functioning financial system for the now inevitable and coinciding societal transformations, forthcoming from the current crisis situations in climate change, energy, food and water supply and large scale migration out of numerous conflict areas.

This brings about the twofold objective of this paper:

- studying the functioning, in particular the instability of the current financial-economic system in order to explore the feasibility of policy measures for a more fundamental improvements, such as amongst others proposed by Positive Money in the UK (www.positivemoney.org; Jackson and Dyson 2012); and Benes and Kumhof 2012);

- exploring the contours of a financial-economic system which can support the transition to a sustainable society, following amongst others the approach of Jackson (2009) in his search for 'prosperity without growth'.

To this purpose, a dynamic simulation model has been developed to explore the interactions between the financial and the (real, physical) economic system. The focus is on the mechanisms that led to the financial-economic crisis of 2007 / 2008 and on the importance of loans as a cause of financial and economic instability. As such, the objective of the model exercise is the understanding and, eventually confirmation of Minsky's financial instability hypothesis. The model provides the 'laboratory' setting in which the instabilities and associated socio-economic unsustainability of the current financial-economic system can be studied and the feasibility of more sustainable alternatives can be explored. In particular, we study the gradual shift away from the current 'money as debt' paradigm towards a 'debt free money' (DFM) approach. The model aims to contribute to a reformulation of the conditions under which the financial system again can become a means to the ends of the economy.

2. Model description

'The conclusions based on the models derived from standard theoretical economics cannot be applied to the formulation of policy for our type of economy', wrote Minsky in 1986; 'the models don't deal with time, money, uncertainty, financing of ownership of capital assets, and investment'. More recently, after the crisis, Werner (2012) repeated the message that leading economic theories and models as well as influential advanced textbooks in macroeconomics and monetary economics do not feature money. Against this background Werner advocates a new interdisciplinary research program on 'banking and the economy'. He calls for, and presents an introduction to 'a concrete model linking banking and the economy via the reflection of a fundamental, yet usually neglected fact about banks of which both finance and economic experts are often unaware for the majority of their career: banks create the money supply through the process of 'credit creation' (Werner 2014).

The Sustainable Finance (SF) Model presented here is a system dynamics simulation model which indeed links both the real economy to the financial system and money. As a second important feature, the model explicitly considers disequilibria. Unlike traditional macro-economic models assume, the system is never in equilibrium; there are continuously feedback mechanisms and adjustment processes at work that make the system tend towards a steady-state in an oscillatory fashion. The SF model thus simulates the interaction between the economic and the financial system, as shown in Figure 2.1.:

1 The *economic system* is modeled as a two-sector closed economy in which goods and services are produced using capital and labour. The model simulates the interactions between producers (firms), consumers, banks and government in both monetary and physical terms[1]. There are two sectors (manufacturing and services) and three groups of consumers:

[1] Also the assets of pension funds are included but they play a minor role in the present version of the model.

- one with a negative net deposit (being the sum of their deposit minus debts) and a borrowing but no lending capability; these indebted consumers obtain their income from labour wages;
- a second group which has a positive net deposit and a lending capability. A part of the deposit is converted to government bonds. These consumers obtain their income from labour wages, interest on savings and bonds dividends;
- a third group, which obtains its income from labour , interest on savings and from dividends, both from bonds and from shares (capital investments).

Government, redistributes wealth by taxation and social payments and by providing societal functions (education, infrastructure etc.).

Thus, the real economy is modeled according to the mainstream economic theory in order to avoid unnecessary paradigmatic discussions. The model builds on work done by Godley and Lavoie (2007), Hallegatte et al. (2008), Yamaguchi (2010), Van Dixhoorn (2013) and others.

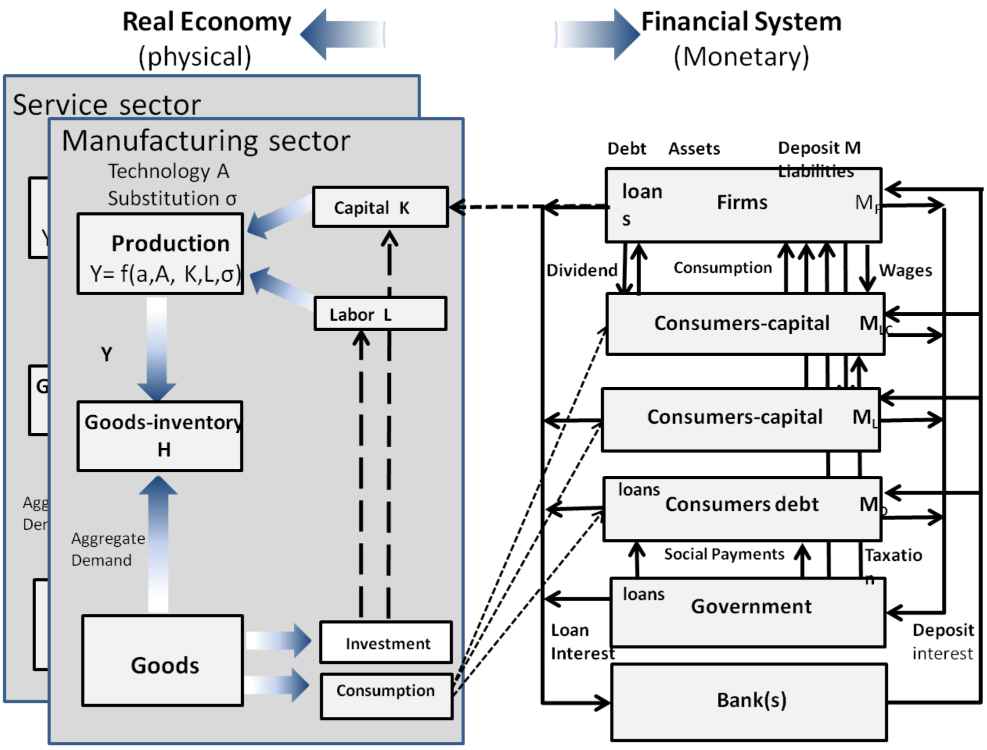


Figure 2.1 A schematic representation of the two parts of the Sustainable Finance model: the (real physical) economy (left) and the financial system (right) and their interconnections.

2 The *financial system* is represented by a balance sheet of a hypothetical bank. It can be seen as the aggregate of all commercial banks into a single Aggregate Bank (AB), which supposedly has the same properties as the individual banks. Banks then give loans to consumers, firms and the government, and have money from firms and consumers on the deposits at their liability side. It implies that money is merely seen as bank deposits (M1-M3) at the liability side of the balance sheet of the AB. The movements of money (in €) between the deposits of the AB are (only) dictated by the interactions between the productive and consumptive sectors of the real economy.

2.1 The Economic System

The mechanisms governing the real economic system both the manufacturing and the services sector [2] are summarized in Figure 2.2. Reference is made to the respective equations to be discussed below.

Production or output is denoted with Y_i and demand for the respective goods and services D_i, i=1,2 [3]. In general, the production of goods and services Y in period t+1 will not match the actual demand D in period t+1, because of divergent expectations among producers and consumers, as will be discussed in more detail later. This discrepancy is simulated by way of an *inventory H*, being the accumulated difference between supply and demand[4]. In formula: $dH/dt = Y – D$ Hallegatte et al. 2008).

In the model the inventory H tends towards zero because we include feedbacks via prices and employment. If more goods are produced than sold on the demand side ($Y > D$), the inventory H will increase. As a result, the price will decline, which permits consumers to purchase more goods and services at the same wages (and the same amount of money in circulation). If demand is higher than production ($D >Y$), the inventory H will decrease or become negative and the reverse will happen. So the discrepancy between actual *Output* ('supply') and *Aggregate Demand* determines the *Price* p.

A second disequilibrium is the one between actual employment and desired employment. In the model the *wage rate W* is the mediating variable that tends to bring actual and desired employment closer to each other, on the assumption that wages rise at above-desired and fall at below-desired employment levels (Hallegatte et al. 2008). The resulting *Price p* and *Wage level* influence the *Labour force L* through adjustments in the hiring/firing rate dL/dt, which influences indirectly the net *Investment* level. The resulting *Capital Stock K* and Labour force L determine *Output Y*, via an exogenous *Technology* factor. The product of the Labour force L and Wage rate w equals *Wagesum W*. Part of the *Wagesum W* is turned into monetary *Consumption C*, leaving the remainder for (not indicated) savings. Via the Price p, monetary consumption is translated into physical *Consumption C/p*, which together with the physical investments forms *Aggregate Demand*. These investments are determined by the calculated profitability.

[2] ,We distinguish the manufacturing and the services sector, because of the empirical evidence that the labour-capital ratio, the substitution mechanisms and productivity growth features are rather different, also over time, although the rapid growth in ICT may be depreciate such evidence.

[3] As is explained later on, we use the symbol $D = D_{mon}/p$ to denote demand in physical units, in contrast to D_{mon} in monetary units.

[4] H is also referred to as working capital or goods-in-process. It represents materially stored goods and services (H>0) or unmet demand for goods and services (H<0) in the 'marketplace'. In a system dynamics view, it is the physical equivalent of the financial bank deposits dealt with later on.

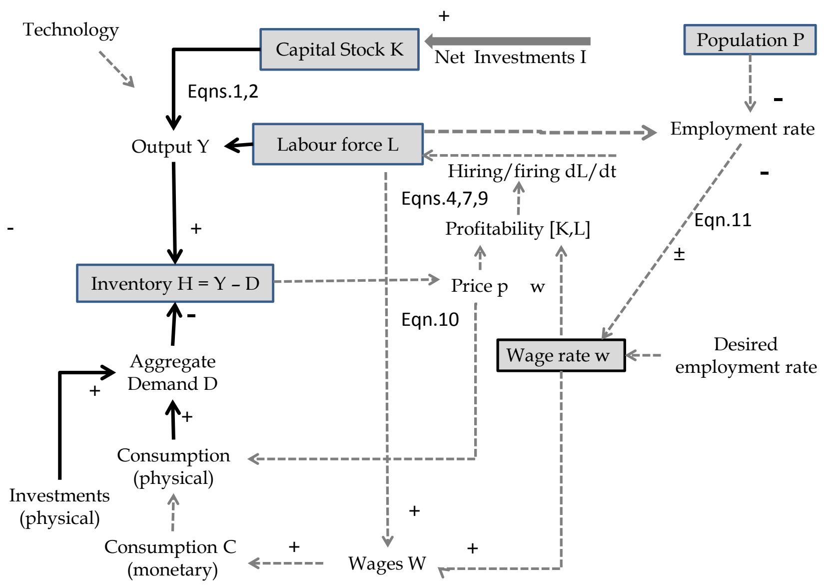


Figure 2.2 Scheme of the real economy model. Grey boxes indicate stocks that are governed by differential equations. Solid arrows indicate physical flows; dashed arrows indicate informational flows. Corresponding equations are indicated.

Production

In economic models, the production of goods and services by means of a combination of labour, capital and technology is formulated in the form of an – abstract – production function (cf. Appendix A). Often, economists use a (nested) production form of the simple form $Y \approx K^{\alpha} L^{(1-\alpha)}$, the so-called Cobb-Douglas (CD) production function. This formulation implies a unitary substitution elasticity between capital and labour and, therefore, a diminishing return upon ever more capital input. Recently Piketty (2014) has pointed to the empirical evidence of an increasing share of capital in the production process and in the national income. This suggests that there is no decline in the productivity of capital in the substitution process, one explanation being the subsequent waves of generic technologies such as ICT and robots.
To account for this tendency in the economic process and to relate Piketty's findings to the current model applications, a Constant Elasticity of Substitution (CES) production function is applied as it allows for higher and/or changing levels of the substitution elasticity. Its mathematical form is (Arrow *et al.* 1961; Jackson and Victor 2014):

$$Y(K, L, \sigma) = \left(a\, K^{\left(\frac{\sigma-1}{\sigma}\right)} + (1-a)\,(A\, L)^{\left(\frac{\sigma-1}{\sigma}\right)} \right)^{\left(\frac{\sigma}{\sigma-1}\right)} \qquad [G/yr]^{5} \qquad (1)$$

with σ the capital-labour substitution elasticity and a the parameter which distributes production (initially) to capital K and labour L. A represents technology-driven increase in labour productivity and is assumed to follow an exogenous exponential trend. Higher levels of σ ($\sigma > 1$) imply easy substitution between capital and labour (e.g. in robotization) which corresponds with the empirical evidence of rising capital share in production and income. The parameters a, A and σ have different values in the manufacture and the service sector.

In the special case in which the substitution elasticity $\sigma = 1$, the CES production function is not defined and one can use the equivalent CD production function:

[5] We indicate physical units with the capital letter G and monetary units with the capital letter M.

$$Y = K^{\alpha} . (A \; L)^{1-\alpha} . \qquad \text{[G/yr]} \qquad (2)$$

The exponent α now represents the (fixed) output elasticity of capital and equals in this formulation the fraction of output that befalls on the factor capital. To maintain transparency, the model is described in subsequent paragraphs on the basis of the CD function, as a special case ($\sigma = 1$) of the CES-production function. The model uses the CES function and thus takes into account the tendency towards increasing substitution elasticity and share of capital in the production process:

Y is expressed in physical units of (durable and non-durable) goods and services, with an aggregate price p and hence a monetary value pY. L is in person-years or person-hours and is converted into money through the wage rate w. K is in physical units too, i.e. machinery, equipment, buildings, infrastructure etc. and is converted into monetary values through the price of capital p_K. The capital stock K wears out with a depreciation rate δ, which is taken constant. Hence, the capital depreciation rate equals δK.

Total output Y consists of (durable) investment goods such as machinery, equipment, buildings and infrastructure, and (non-durable) consumption goods and services[6]. These goods and services are exchanged on the market at an aggregate price p, which links the real *physical* economy of production and the *monetary* economy of income for employees and investors through the following equation:

$$p\,Y \;=\; wL \;+ (\rho + \delta)\, p_K K \qquad \text{[M/yr]} \qquad (3)$$

with wL the rewards for labour, ρ the interest rate at which firms can acquire money (see below), δ the depreciation rate and $(\rho+\delta)\, p_K\, K$ the money flow to be paid to capital owners. The important question is: what drives changes in capital stock K and in labour force L in response to the demand for goods and services, and what drives this demand for goods and services? To answer this question, an incremental approach of the various decisions is followed, which differs from an approach in which macroeconomic identities are used to drive these decisions (Hallegatte *et al.* 2008, Keen 2011, Van Dixhoorn 2013).

Growth of output happens when investments are made in order to satisfy expected growth in demand. In the model simulation, investment takes only place as long as the additional profits from higher output sales exceed the cost of the additional investment i.e. as long as the net marginal capital productivity is positive. Similarly, additional labour is hired until the marginal labour productivity exceeds net revenues. Thus, both the desired levels of capital and of labour are driven by their respective marginal productivities. In this way the economy tends towards a steady-state in which production is efficient in the sense that it occurs on the production frontier given by the production function at employment level L and capital stock level K with an optimal i.e. least over-all cost K-L-ratio (see Appendix B).

Labour input: (un)employment

If the economy grows because it operates below its production frontier (Solow's optimal growth path in Appendix B) as given by the production function, or because of growth in the capital stock, the labour force and/or technological progress, there is hiring demand for more employees. For an increase in the labour force dL, the marginal production in each sector will increase at a rate of p dY in monetary terms, with p the price of goods and services respectively and Y the physical production in the respective sectors.
The cost of this additional labour equals w dL with w the wage level in monetary units (per hour). The marginal profit rate per additional labour expressed in wage units can thus be written as:

$$\pi_L = \frac{p.dY - w\,dL}{w\;dL} = \frac{p}{w}\frac{\partial Y}{\partial L} - 1 \qquad \text{[-]} \qquad (4)$$

[6] One should be aware that a society's capital stock is a very heterogeneous quantity, with buildings and structures amounting up to two third of the total manufacturing capital stock (De Vries 2013). It is thus an extreme simplification to describe an advanced society with two aggregate capital stocks. We do think, however, that in first instance the basic dynamics is simulated well enough for the purpose at hand.

Given the diminishing return character of the CD production function, additional labour input will result in decreasing marginal labour productivity $\partial Y/\partial L$ and the marginal profit rate will tend towards zero. Because

$$\frac{\partial Y}{\partial L} = \frac{(1-\alpha)}{L} A \,.\, K^{\alpha} \left(\frac{L}{A}\right)^{1-\alpha} = (1-\alpha)\frac{Y}{L} \qquad [-] \qquad (5)$$

it is seen that $\pi_L = 0$ for:

$$(1\text{-}\alpha)\ p\ Y = w\ L \qquad [M] \qquad (6)$$

at which level the net profit rate from labour force expansion has fallen to zero. This is the equilibrium value to which an economy with rational entrepreneurs tends to go.

The change in the labour force dL will be some function of the (expected) profitability of hiring additional labour i.e. of π_L. In first instance the simplifying assumption is made that the relationship is linear. This can be interpreted as saying that firms act upon a potential change in labour productivity on average proportional to their scale In equation form and assuming a certain relaxation time τ_L to represent labour market frictions and inertia:

$$\frac{dL}{dt} = \frac{\pi_L}{\tau_L} L = \frac{1}{\tau_L}\left(\frac{p}{w}\frac{\partial Y}{\partial L} - 1\right).L \qquad [hr/yr] \qquad (7)$$

Using that $\partial Y/\partial L = (1\text{-}\alpha)\ Y/L$ (eqn. 5), this equation says that as long as an additional unit of labour yields an (expected) net gain, that is, $p\ dY > w\ dL$ or $pY > wL/(1\text{-}\alpha)$, more labour will be hired, at a rate proportional to the marginal labour productivity expressed in wage units: $p\ (\partial Y/\partial L)\ /w$.

Capital input: investment

Similar to labour, there is a demand for capital investments in excess of the depreciation rate δ K if the economy operates below its production frontier and/or for a growth in the labour force and/or technology. As with labour, it is assumed that investors increase the capital stock with an amount dK. Then the net gain or profit in monetary units equals the additional output p dY minus the cost of the additional capital. Because the depreciated capital has to be replaced, it is also a cost. The additional costs of an increase dK is $p_K\ (\rho\ dK + \delta\ dK)$, with p_K the price of one unit of capital (see e.g. Mankiw 2006).

The variable ρ indicates the interest rate at which the firm can get a loan or some other form of capital, i.e. the base Central Bank interest rate plus a premium for the intermediaries such as banks and for a perceived risk. The marginal profit rate per additional capital expressed in capital cost units can now be expressed as:

$$\pi_K = \frac{p\ dY - p_K\,(\rho+\delta)\ dK}{p_K(\rho+\delta)dK} = \frac{p}{p_K}\frac{\partial Y}{\partial K}\frac{1}{(\rho+\delta)} - 1 \qquad [-] \qquad (8)$$

For convenience it is assumed that the trend in the price of capital coincides with the aggregate price p of goods and services, i.e. the price of capital p_K follows the general price level and $p/p_K \sim 1$. Then, investments will only be made if the marginal capital productivity $\partial Y/\partial K$ exceeds $(\rho+\delta)$[7].

The change in the capital stock will, besides depreciation, be some function of the (expected) profit of investing additional capital, reflecting the willingness of entrepreneurs to invest. Again, the simplifying

[7] Another way to derive this condition is to start from total output Y being equal to the wages w L plus gross profits Π. Because the existing capital stock has to be replaced, net profits equal: $\Pi = pY - wL - \delta\ p_K\ K$. The marginal profitability is now given by $\partial\pi/\partial K$ which equals $p\ \partial Y/\partial K - p_K(\rho+\delta)$.

assumption is made that the relationship is linear[8]. As gross investment includes the replacement investments δK, the dynamic equation for capital K, and thus (intended) gross investment I, becomes, in physical units:

$$I_{gross} = \frac{dK}{dt} = \frac{\pi_K}{\tau_K} K = \frac{1}{\tau_K}\left(\frac{\partial Y}{\partial K}\frac{1}{(\rho+\delta)} - 1\right) K \qquad [G/yr] \qquad (9)$$

assuming a certain relaxation time τ_K. The value of τ_K represents the time period over which entrepreneurs respond to the (change in) return on investment. Using that ∂Y/∂K = α Y / K, this equation states that firms will invest in new production opportunities as long as the (expected) profits are positive, that is, dY > (ρ+δ) dK or αY > (ρ+δ) K. It will be done at an overall rate proportional to the marginal capital productivity expressed in capital cost units: ∂Y/∂K / (ρ+δ). As with labour, additional capital input will result in decreasing marginal capital productivity and the marginal profit rate will tend towards zero. Thus, the simulated economy tends towards a stationary state which can be calculated by equating the marginal profit rates for labour and capital to zero (see Appendix B).

The interest rate is primarily calculated directly from the demand and supply of money, as given by the change in the liquid assets available on the financial markets, to be discussed in the next paragraph. Therefore, in the model the interest rate is supposed to be inversely proportional to the relative amount of money (M) on the bank accounts 'liquid assets' of consumers firms and government. In this paper we have defined net liquid assets as deposits of L-, LC- consumers and firms, minus consumption, bonds and shares:

$$d\rho = -\frac{1}{\tau_\rho}\frac{d\ M_{net\ liq\ ass}}{M_{net\ liq\ ass}} \qquad [-] \qquad (10)$$

Prices: supply demand adjustment

The primary adjustment mechanism that drives supply and demand towards equilibrium in the model is through the price p. There are consumers who demand goods and services D_C and there are investors who have a demand for investment goods D_I. Both make up the (monetary) aggregate demand D_{mon} = $D_C + D_I$. Under the assumption of equilibrium, economic output Y over the time period considered equals aggregate demand D in physical units, i.e. D = D_{mon} /p. In reality and in our model formulation, output Y will differ from demand D, and there will be a surplus (inventory) or a shortage (unmet demand), indicated by dH/dt = Y – D. We postulate that this feedback mechanism is via the ratio of the level of the inventory H and the demand D (Hallegatte *et al.* 2007):

$$\frac{dp}{dt} = -\frac{p}{\tau_{p1}}\left(\frac{H}{D}\right) \qquad [M/G/yr] \qquad (11)$$

with τ_p a relaxation parameter that represents the inertia in the system. Note that the price p is constant if H = 0 and dH/dt = 0. In case of a low price rigidity (τ_p is small), fluctuations in H are quickly accommodated by price adaptation. Increasing demand means higher prices and increasing production will result in lower prices. In case of a high price rigidity (τ_p is large), fluctuations in H are only slowly absorbed through price adjustments.

Wages: labour market adjustment

There is one more supply side mechanism in the model. When entrepreneurs decide to hire or fire labourers, there will be negotiations about and adaptations of the wage rate, based on the observation

[8] Such a relation implies that investments are considered, on average, proportional to the total profits made in the manufacturing and service sectors respectively. See e.g. Keen (2011) for a relationship with investments being a quadratic function of profitability. Hallegatte et al. (2008), following other authors, make the interesting distinction between investment decision-making in a managerial economy and a shareholder economy. Here, we follow the simplified rules assumed to be valid for a managerial economy.

that in a capitalist economy a shortage of labour will drive up wages whereas a surplus will do the reverse. Hence, a third differential equation is introduced concerning wages. The wage level w is assumed to be dependent on the employment level, following Rose (1967) and Hallegatte (2008):

$$\frac{dw}{dt} = w\frac{(e - e_{full})}{\tau_w} \quad \text{[M/hr/yr]} \qquad (12)$$

with e the actual employment level which equals L / Lmax, τ_w is the characteristic period during which the wage level changes as a result of the changing employment level; e_{full} the level of employment at which the maximum wage has to be paid on the labour market and L_{max} the maximum size of the labour force [9].

The wage rate w is constant when actual employment equals desired employment level, $L = L_{des}$ [10]. If the employment rate $e = L/L_{max}$ differs from a desired level of employment $e_{des} = L_{des}/L_{max}$ (which is associated with *full employment* and is supposedly some collective feeling about what it should be and is aspired by the government cq. society), then an equilibrating process starts through a delayed wage change. If e is still above the desired level e_{full} and the employment level e starts falling, the rate of change dw/dt is still positive and wages increase but at a declining rate; once e falls below the desired level e_{full}, dw/dt turns negative and wages will start to fall.

Consumption

From the vast literature on modeling consumption, three main categories of consumption functions emerge:

- In the first place, consumption is considered to be dependent on income level. Consumption is then written as $C = a + b\,pY$,
 in other words: there is a constant, independent consumption level (basic needs) and a part which is proportional to income Y ('discretionary income'). The proportionality constant b is the marginal propensity to consume. In general b is smaller than one, which expresses Keynes insight that 'men are disposed, as a rule and on the average, to increase their consumption as their income increases, but not as much as the increase in their income' (Davidson 2011:51).
- As a second line of thought, the propensity to consume b might be considered to depend on the interest level, rather than being constant. The assumption then is that consumers tend to increase their savings when interest rates, and thus the return on their bank deposits, fall, and vice versa. It reflects the underlying rationale of inter-temporal maximization of discounted utility and the Ramsey rule in economic theory (see e.g. Barro and Sala-i-Martin, 2004).
- Apart from dependency of consumption on the income level, consumption might simultaneously depend on the level of wealth , as proposed by Godley and Lavoie (2007). The underlying assumption is that a certain, small fraction of the wealth is consumed, wealth being defined here as the amount of money on the bank M.

After model simulations with these three types of consumption functions, the third approach was chosen, following Godley and Lavoie (2007) :

$$C = b_i \,.\, F_{net} + b_w \,.\, M \quad \text{(M/yr)} \qquad (13)$$

[9] This relationship is in its general form known as the Phillips curve. The assumption of a linear feedback is probably incorrect but made for simplicity reasons (Hallegatte *et al.* 2008). Keen (2011) uses a nonlinear function such that there is no change in wage rates when the ratio $L/L_{max} = 0.94$. Above it, there is a steep rise in wages; below it there is an increasing and below a value of 0.8 constant decline in the wage rate. In this equation and in the price equation (eqn. 10) we have experimented with additional terms that track the change in employment and inventory; such fine tuning is not included in the results presented here.

[10] Note also that in this way the tension between the optimal labour force L_{opt} from an efficiency point-of-view and the societally desired level L_{des} is simulated through a supply response of entrepreneurs and a societal negotiation process between labourers and entrepreneurs. The desired employment level is highly value driven and topic of current social debate.See also Appendix C.

where C is consumption, F_{net} is income minus taxation T, M is wealth and b_i and b_w the respective coefficients (constants). Consumption is calculated for the three categories of consumers with the dynamically changing levels of F and W. Depending on the category, net income is (mainly) comprised of income, dividend and / or social payments. The indebted consumers have a wealth level M close to zero or negative and are supposed to spend all their net income on consumption, implying $b_w = 0$ and $b_i = 1$.

Velocity

Money circulates through the production – consumption cycle. Given the total amount of money in the system, the so-called money base M being the sum of all deposits, the frequency with which it circulates through the economy can be calculated. This so-called velocity of money v is for a given annual output of pY given by:

$$p.Y = M. v \qquad [M/yr] \qquad (14)$$

The monetary output of the economy – pY which is the equivalent of GDP – thus can grow by increase of either the money base M, the velocity v or both. In case of a constant amount of money M in the financial system, growth of output pY can still be realized by an increase in velocity.
Eqn. 14 is not explicitly applied in this study, as there are serious doubts about its validity (Werner 2012).

2.2 the Financial System

Unlike in standard economic growth models where investments are assumed to match savings in the time period considered, there is a financial sector in the model which intermediates between savings and investments. This disequilibrium exists because investors asses their demand for money on the basis of a variety of signals, one of these being the mismatch between supply and demand.

As indicated in a previous section, the mismatch between supply and demand is simulated with a stock variable H that is defined as the difference between production Y and aggregate demand for consumption and investments D (Figure 1.1). It represents an inventory of not-sold or not-produced goods and services [11]. Simultaneously, the consumers base the decision on how much to consume and how much to save on a variety of factors too, in particular on their net income and on their bank deposits (M_D, M_L and M_{LC}). At first, the financial system model will be described, after which the connections between economic and financial system can be discussed.

Bank balance sheet: assets and liabilities

The financial system is modeled as the balance sheet of the Aggregated Bank (AB) with two entries: assets and liabilities (Figure 2.1). The total assets always equal the total liabilities. The stock of money equals the sum of all the liabilities on the right hand side. Only the ownership of money changes: there are continuous transactions of money between the various deposits, dictated by the processes which take place in the real economy. 'Money', in the form of bank deposits, always remains on the liability side of the AB. Unlike physical capital stocks which turn into waste or are recycled and formally 'depreciated', the total amount of money involved in these transfers remains constant and in the bank deposits, whatever happens in the real economy.

The interactions within the financial system are schematically presented in Figure 2.3 and by means of the 'Godley'-matrix of the mutual transactions in Table 1.

[11] It is the equivalent of the bank deposits with its reservoir function in the financial economy, to be discussed below.

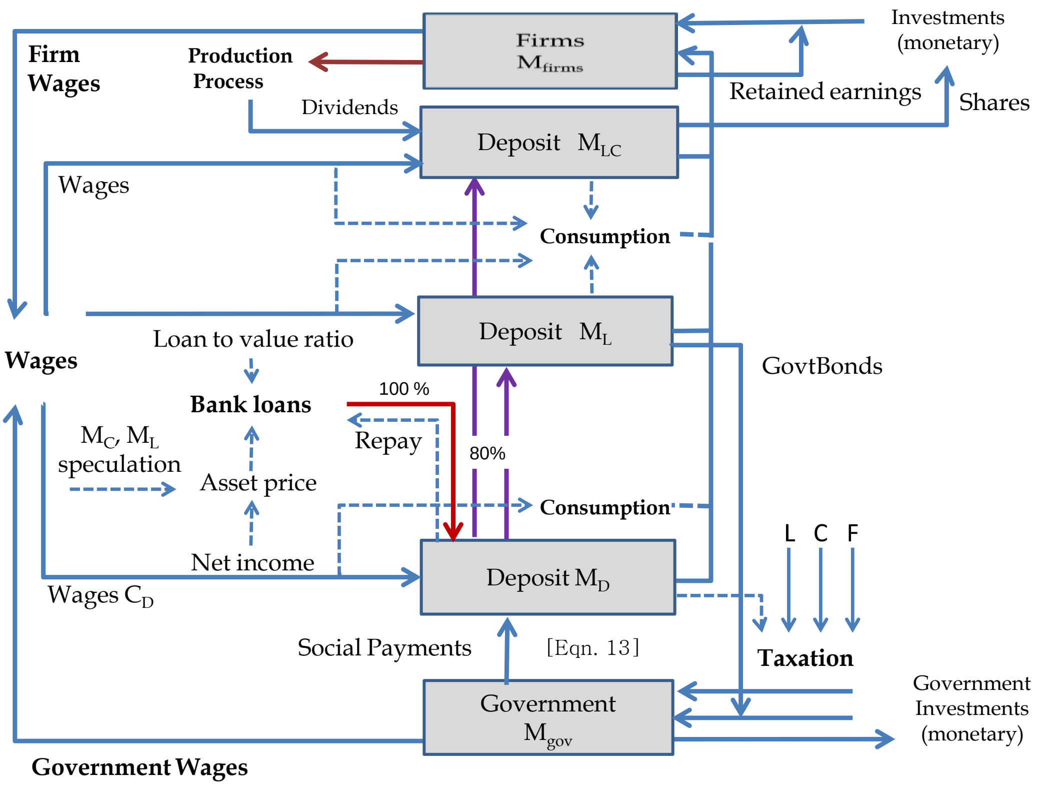


Figure 2.3 Scheme of the financial system model.

SFM transaction matrix						
	Consumers			**Firms**	**Government**	**Bank**
	in**Debt**ed labour income	Labour / Bonds income	Capital / labour income			
Consumption	$- C_D$	$- C_L$	$- C_{LC}$	$+ C$		
Government consumption				$+ C_{gov}$	$- C_{gov}$	
Shares			$- E$	$+ E$		
Investment				retained earnings		
dividends			+ Div	- Div		
Bonds		- B			+ B	
Repay bonds (and interest)		+ repay B			- repay B	
Wages	$+ W_M$	$+ W_S$	$+ W_D$	$- W_{firms}$	$- W_{gov}$	
Loans	$+ BL_D$			$+ BL_{firms}$	$+ BL_{gov}$	- BL
Repay of loans	- repay BL_D			- repay BL_{firms}	- repay BL_{gov}	+ repay BL
Interest on loans	$- \rho_l \times BL_D$			$- \rho_l \times BL_{firms}$	$- \rho_l \times BL_{gov}$	$+ \rho_l \times BL$
Asset transfers	$- 0.8 \times BL_D$	$+ 0.4 \times BL_D$	$+ 0.4 \times BL_D$			
Interest on deposits	$+ \rho_d \times M_D$	$+ \rho_d \times M_L$	$+ \rho_d \times M_{LC}$	$+ \rho_d \times M_{firms}$	$+ \rho_d \times M_{gov}$	$- \rho_d \times M$
Interest on bonds		$+ (\rho_d+0.02) \times B$			$+ (\rho_d+0.02) \times B$	
Social Payments	+ SP				- SP	
Taxation Income Profit Wealth	$- T_D$	$- T_L$	$- T_C$	$- T_{firms}$	+ T	
Value Added Tax	- taxrate x C_D	- taxrate x C_L	- taxrate x C_{LC}		+ taxrate x C	

Table 1 'Godley'-matrix of the mutual transactions within the financial system.

The liability side of the balance sheet of the AB holds the following deposits *(variable names in italics refer to Table 1)*:

Firms Firms acquire money on their deposits (*Mfirm*) by selling products to the three groups of consumers, holding deposits M_D, M_L and M_{LC}, and to public (*Government*) agents. They obtain interest over the deposits via the AB deposit (M_{bank}) with a deposit interest rate r_d. In order to produce goods and services, firms pay wages to the three groups of consumer / labourers (W_D, W_L *and* W_{LC}). The balance between costs (wages) and income (sales revenues) is net profit. Firms pay tax to the government over the net profit (*Firm tax*). Firms can borrow money for investments from consumers and banks.

Consumers As indicated, consumers are disaggregated into three categories: indebted (D-)consumers with loans, non-indebted (L-)consumers, having their income from labour and non-indebted (LC-)consumers having income from both labour and capital investments (*dividends*).

*In**D**ebted consumers* D-consumers can take up a bank loan BL, in particular to be used for acquisition of real assets (housing). The loan, over which interest (BL_D x interest rate r_l) has to be paid, has to be serviced over the repay term, resulting in a yearly *repay*. The loan is deposited onto the M_D*-deposit* from where 20 % is directly spent on consumption of goods and services. The remaining 80 % of the loan is transferred in equal amounts to the deposits of the L-, and LC-consumers, selling the real assets against the current *asset price*. Now the previous owner has the money on his deposit and the ownership of the physical is transferred to the borrowing, and thus now indebted D-consumer. So in case of mortgage loans to D-consumers, the principal sum ends up at the M_L *and* M_C *deposits* of L-, and LC-consumers.

***L**abour income consumers* The L-consumers (as well as the LC-consumers) buy *bonds* from the Government, which are repaid later with an interest level 2 % above the current interest rate on (normal) deposits r_d.

***L**abour-and **C**apital income consumers*

These LC-consumers receive, besides wages, *dividend* over the money they have lent to firms in the form of shares. They also receive interest over their deposit and the repayments over the part of the loans to Consmin that is used for real estate purchase, as explained above. These flows are annually transferred to the asset side of the Consplus (*Consplusdeposit*).

Financial Markets On the M_D, M_L, M_{LC}, M_{firm} *deposit*s, profits are accumulated, shares and bonds are bought. If corrected for the ‘own' and direct consumptions of these categories, the transactions between these deposits can be seen as representing the ‘financial markets'.

Government The government deposit M_{gov} is made up with income from taxation of firms *(tax)* and from consumers plus interest on the deposit. The deposit outflow are the expenditures in the form of wages to government employees (*government wages*), of social benefits (*social payments*) and of government consumption C_{gov} in the form of payments to firms for production of infrastructure, interest payments on government debts a.o.

Banks The interest over the various deposits is transferred by banks from the bank deposit (M_{bank}) to the deposits. On the other side of the balance sheet, banks pay interest to firms, consumers and government over their respective deposits. The interest rate on deposits r_d is lower than the one on loans r_l, reflecting the ‘spread' which generates the profit of the bank; this spread can be considered as ‘bank fee'. The rate r_d is chosen such that the received total interest on loans equals the total interest paid on deposits / liabilities, plus the spread.

Interactions between investments, savings and interest rate

Previously, it was seen that in the stationary state the savings rate $s = I/(pY)$ equals $\alpha\ \delta/(\rho+\delta)$ (Appendix B). In the process of economic growth, there is no such equilibrium as the savings rate s is determined by the decisions of the LC- consumers which are only indirectly related to the demand for investments. The decoupling of investment and consumption/saving decisions implies that investors cannot know whether the required investments as indicated by the profitability criterion (eqn. 9) can be satisfied.

In the model, investments are split up into:

- investments to replace existing, depreciated capital; these investments are paid by the firms themselves from retained earnings, accumulating on their deposit;
- investments to expand physical production capital; the funds for these investments come form shares, which are bought by the LC-consumers.

At the end of the day, all net profits, minus depreciation costs go to the LC-consumers as dividends.

The relevant feedback mechanism is that share holders check whether there is enough money on their bank deposits to buy shares. If not, the interest rate ρ will increase in proportion with the ratio of the required investment and the available deposit. This is the familiar presumed relationship between required investments and the cost of money i.e. real interest rate (see e.g. Mankiw 2007:61). This mechanism is introduced in the model by first checking the required investments as given by eqn. 9 against the availability of liquid assets in the financial markets:

$$pI_{gross} = \text{Min}\ (p\ I_{required},\ M_{C\ liq\ ass}) \qquad [M/yr] \qquad (15)$$

These liquid assets $M_{liq\ ass}$ are calculated as the LC-consumer and firms bank deposits minus LC-consumption (eqn. 13b). It represents the amount of money available after consumption for buying government bonds and / or firm shares.

Government: taxation, debt and social payments

In the model of the conventional financial system, government is represented explicitly by a flow of revenues from taxes and expenditures in the form of wages paid to government employees, investments in infrastructure and social payments. The taxes are raised from:

- firms on the basis of the net profit (i.e. after having paid dividend to the Consplus);
- consumers / workers on the basis of gross wages; in a later stage also the effects of a wealth tax is considered;
- consumption as value added tax (VAT) on the actual consumption goods and services.

Government debt is constrained to a maximum level of 60% of GDP, in accordance with the EU-directive. As soon as this level is reached, the level of taxation will increase and the level of government spending will decrease, in order to bring and keep the debt below the 60 % of GDP.

There are two mechanisms of social payments:

- the first one is proportional to the total wages of the indebted consumers, assuming that a certain fraction of them needs and gets financial support. Social payments are (also) allocated to the category of indebted consumers, as only in this category 100 % of net income is consumed.
- the second mechanism assumes social payments to be a function of both wages of indebted consumers and the level of unemployment. As a consequence, social payments by the government increase when unemployment rises. In combination with government revenues tending to decline with rising unemployment, the government has to take loans by the emission of bonds. This increases government debt.

Loans

Loans given by the aggregate bank (AB) to borrowers appear on the left hand asset side of the balance sheet. The increase in assets is balanced by the same increase in liabilities on the right hand side, in the form of new deposits. This happens also as a loan given by one bank will be deposited to another bank after one or more economic transactions. It results in a new balance between the asset and liability sides of the AB. Given our assumption of a single aggregate bank, the liabilities only increase to the extent that loans are given and decrease to the extent that loans are repaid. In the present model, the fundamental role of commercial banks is understood as *double entry bookkeeping*, in which money is created 'out of nothing' and disappears again later in the process when the created loan is repaid (Werner 2014). The scale on which banks can create loans is limited by the 'capital ratio' requirement, i.e. the requirement that the ratio between equity (own capital) and the sum of the outstanding loans of the bank does exceed a certain minimal (van Dixhoorn, 2013).

Firms can borrow money for investments directly from consumers by emitting *shares*, with the LC-consumers rewarded for it with *dividend*. They can also borrow money from the bank in the form of firm debts (BL_{firms}). This money appears on the asset side of the balance sheet and is simultaneously available for investment on the liability side as deposit. In the current model runs, firm investments are mainly financed from their own profits *(retained earnings)* and by *shares* sold to LC-consumers.

Government bonds

When expenditures exceed revenues, government needs additional funding by selling government bonds on the financial markets and/or borrow money from (private) banks. In the current model runs, 75 % of the government money is assumed to be funded by bonds which are bought by both the L- and the LC-consumers and 25 % is obtained as bank loans. Government policies are expected to balance expenditures and revenues within the constraints of its annual budget and its accumulated debt. In the model, the government debt is constraint to a fraction of 60 % of GDP, as practiced in the EU. When this level is exceeded, taxes are increased and expenditures are reduced. In political practice this is done in the ratio 1/3 versus 2/3, but in the model taxes and expenditures are increased and decreased respectively with the same rate for practical reasons.

Constraints; available deposits and bank capital ratio

There are two built-in constraints in the system. The first one concerns the availability of the M_L- and M_{LC} deposits to fund bonds and of the M_{LC}-deposit to fund shares. The L- and LC-consumers first they pay the expenditures for consumption from their deposit; the remaining, 'saved' money can be used for buying shares and/ or bonds. In other words: the M_L- and M_{LC}- deposits minus the L- and LC-consumption is considered as a model representation of the available liquidity. If the sum of the funding requirements for the shares and bonds is higher than the amount available in these 'liquid assets', buying of shares is constrained and, eventually, the buying of government bonds too.

A second constraint is related to bank equity. Banks are required to maintain a certain minimum ratio between own capital (*Bank equity*) and total loans, the so-called capital ratio. In the model this is set at 0.05. Income (interest over these loans) in surplus of the required reserve level, is paid as bank loan to all three categories of consumers (bank employees).
In case of financial crisis, with negative growth in output, a certain fraction of loans is assumed to default. In that case, non-serviced debts are written off against bank equity, shortening the bank balance sheet. In the current model, the mechanism is studied in which, in case of financial crisis ('Minsky moment') the government directly has to supply the funds to restore the reserve according to the capital ratio (bail out). This then results in increased government debt, which, given the EU-constraint on maximum national debt < 60 % of GDP, translates into increased taxation and/or reduced expenditures, which subsequently adds to the already existing stress on the system and intensifies the downward economic spiral. In order to study the role of money creation in the process leading to crisis, this bail out mechanism is studied separately.

2.3 The Credit cycle and he Minsky moment

Asset prices

In Minsky's financial instability hypothesis, bankloans ('credit') plays an important role, in interaction with asset prices and inflation. Bezemer an Zhang (2014) found the interaction between mortgage credit growth and house prices to be a good predictor of a credit boom. The larger the share of mortgage credit in total bank credit, the more likely booms turn into 'bad' busts, with subsequent credit growth contractions. Apparently, modelling the boom-bust cycles also requires to model the asset prices.

The process is modeled in the SF-model by the provision of credit to (thus indebted) D-consumers by banks (in this case the AB). In the case of credit for mortgage, which has historically been dominant in the Dutch economy, the physical asset (house) is the collateral and only matters as a risk avoiding condition for the bank to provide (and create) the money for the loan.
The amount of loans given (credit) depends on the lending risks perceived by banks and on the prices of the assets, in particular houses, for which potential buyers want to obtain a mortgage.

According to Goodhart et al. (2008) there is evidence of a significant multidirectional link between house prices,the amount of money, private credit, and the macro-economy. Money growth has a significant effect on house prices and credit, credit influences money and house prices, and house prices influence both credit and money. Also Fitzpatrick et al. (2007) found evidence of a long-run mutually reinforcing relationship between domestic bank credit and (Irish) house prices. This reinforcement is driven by the inflation which results from the lending and money creation process itself. It will stimulate the wage-price spiral, additionally supported by the lower interest rates, which result from the very process of money creation itself. This process leads to a continuously increasing amount of money which can be lend per household.

Given these strong indications for a multi-directional link between asset (house) prices and credit, the total amount of bank lending to the borrowing (D-) consumers is modelled via the asset price, which in turn is derived from net income, the ratio which banks apply between the loans and the asset prices and asset price inflation due to speculation Higher asset prices result in higher bank loans, which generate an increase in (at least monetary) GDP and subsequently in net income. The higher net income in turn allows higher asset prices and higher bank loans. This self propelling process is further stimulated by speculation by means of the (newly generated) money which has reached the L- and LC-deposits. Finally the deregulation of the financial sector allowed banks to increase the loan to value ratio (ltv-ratio). The overall result is an accelerating increase in asset prices, GDP and debt.

In this 'euphoric economy', growth is expected to continue forever and increasing debt is expected to be serviced by increasing income. But asset prices cannot go up forever. Minsky (1982) pointed out, in an analysis of stock market bubbles, that at a given, psychologically determined ('Minsky') moment, trust in ever rising price levels is lost, after which the level of lending is strongly reduced. The process proceeds in the following steps, which are illustrated in Figure 2.4:

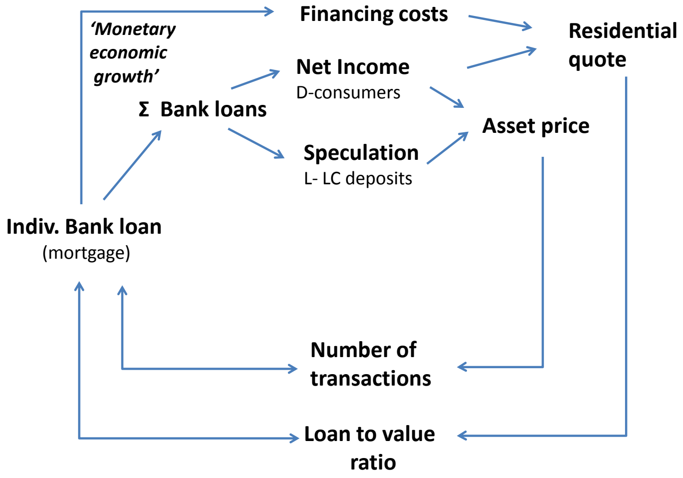


Figure 2.4 The asset driven credit cycle and the 'Minsky' moment at which further increased lending becomes unrealistic.
residential quote reaching the level of 0.5 defining the Minsky moment;
modelled asset price (eqn 16),
modelled number of transactions (eqn.18)
modelled resulting Bank loan (eqn. 17).

- initially banks anticipate (ever) increasing (net-) incomes and allow loan to value ratio's of over 100 % of the value of the real asset (house). Based on asset prices, this ltv-ratio was in the Netherlands about 75 % in the 1970's and increased to 120 % just before the 2007 / 2008 crisis. It actually went even higher because the period over which the loan has to be repaid was extended (non-repayment loans).
- Higher ltv-ratio's result in higher mortgages and thus in an increasing amount of newly created money. This money enters the economy and increases liquidity in the hands of the L- and LC-consumers who sell their houses or have serviced their (mortgage) debt. Asset (house and land) prices are pushed upwards by speculative spending of this money.
- The ongoing rise in asset prices allow banks to give higher mortgages at the same, already very high ltv-ratio's.
- The ratio between debt servicing (interest plus repayment) and net income, also called the 'residential quote', reaches the level where an increasing number of household can no longer repay the principal and the interest.
- Once the confidence that the loans can be paid back diminishes, the system experiences a tipping point: banks reduce their ltv-ratio from the above-mentioned 120 % to a lower level. The asset prices will follow but with a delay, because people do not wish to take their losses. Given the now rising discrepancy between asset prices and available financing (for individual mortgages), the number of transactions decrease. In the Netherlands the decrease was about 50 % for several years.
- The overall level of lending, and thus the credit flow, now decreases suddenly, due to the simultaneous decrease of ltv-ratio, asset price and number of transactions.
- As described by, amongst others, Biggs et al. (2010), the weakening of the credit flow implies a (moderate) decrease in aggregate demand and hence consumption via both income and wealth. This will result in lower price levels (deflation) and in a lower GDP (pY) level. The lower price levels result in lower labour/employment levels as producers respond with a delay to lower consumption. With lower investment levels, physical production Y decreases, though less dramatic than the monetary production pY because of the deflationary price drop and ongoing technological development.

The 'Minsky' moment is thus endogenously simulated. The only assumption is the evident relation between the residential quote and an increasing fraction of households defaulting on their loan. Empirical data (Schich and Ahn 2007) indicate for Portugal, for instance, that the average debt-over-income ratio was less than 6 for the four lowest and less than 8 for the two highest income groups, but had risen to values between 10 and 14 for the middle income groups. These were the most vulnerable households with respect tpo defaulting, particularly as when hit by unemployment. The subsequent deleveraging has also empirically been investigated (Cuerpo et al. 2015).

Boom-bust cycles will be amplified further by comparable psychological mechanisms, such as speculation and herding behavior of shareholders.

The resulting credit cycle sub-model

The change in the asset price p_{ass} is a function of the change in net income $F_{D\ net}$ and the level of speculation. The latter is assumed to depend in turn on the rate of change of the asset price as speculation on these assets will be more attractive at higher asset price levels (in particular at decreasing interest rates). Hence the following equation is used:

$$\frac{d\, P_{ass}}{P_{ass}} = \frac{d\, F_{Dnet}}{F_{Dnet}} + \frac{1}{\tau_{spec}} \cdot \frac{d\, P_{ass}}{P_{ass}} \qquad (-) \qquad (16)$$

The individual loan given by a bank equals p_{ass} x ltv-ratio for each transaction, with the ltv-ratio the loan-to-value ratio considered acceptable by the banks. The number of transactions n_{trans} is the sum of transactions for existing housing and new housing and is taken proportional to the number of D-consumers. The overall loans given in a year is then given by:

$$Bank\ loans\ = n_{trans} \, . \, ltv \, . \, p_{ass} \qquad (€/y) \qquad (17)$$

The long-term average of changes in ownership of existing houses is about 5% / year. changes annually, However, the actual number of yearly transactions will depend on the asset prices and loans banks are willing to give. Increasing (individual) bank loans and decreasing asset prices will provoke more (mortgage based) movements. The number of transactions thus is expected to change as:

$$d\, n_{trans} = \frac{d\ Bank\ loans}{\tau_{Bl}} - \frac{d\, p_{ass}}{\tau_{p\ ass}} \qquad (-) \qquad (18)$$

With τ_{Bl} and $\tau_{p\ ass}$ specific time constants. Now the total amount of new loans for mortgages can be derived from simulated asset prices, which can be related to empirical price levels.

Model experiments to explore system behavior

In Appendix A, model experiments are presented starting from the steady state condition of the model. By imposing sudden stepwise changes to the model, the response of the model to those changes can be demonstrated. Stepwise changes are imposed for (bank-) loans and for technological progress.

Model variables

List of model variables			Manufact. sector	Service sector	$Cons_D$	$Cons_L$	$Cons_C$	Firms	Gov	Bank
Y	Physical output		Y_M	Y_S						
AD	Physical aggregate demand		AD_M	AD_S						
H	Goods inventory		H_M	H_S						
K	Capital		H_M	K_S						
L	Labour; number of employed workers	10^6	H_M	L_S						
e	Employment L / labour force P									
A	Total factor productivity		A_M	A_S						
α	(Fixed) output elasticity of capital	_	α_M	α_S						
σ	Elasticity of substitution	_								
M	Consumer money stock	10^9 €			M_D	M_L	M_{LC}	M_{firms}	M_{gov}	M_{bank}
w	Wages	10^9 € / yr	W_M	W_S	W_D	W_L	W_{LC}	W_{firms}	W_{gov}	W_{bank}
Div	Dividends	10^9 € / yr								
I	Investments	10^9 € / yr	I_M	I_S						
δ	Depreciation rate	yr^{-1}								
ρ	Interest rate	yr^{-1}								
B	Bonds	10^9 €								
E	Shares	10^9 €								
Div	Debt	10^9 €			D_D			D_{firms}	D_{gov}	
BL	(Bank)loan	10^9 €								
F	Income	10^9 € / yr			F_D	F_L	F_{LC}			
C	Consumption	10^9 € / yr	C_M	C_S	C_D	C_L	C_{LC}		C_{gov}	
b_i	Propensity to consume on income	_			b_{iD}	b_{iL}	b_{iLC}			
b_w	Propensity to consume on wealth	_			b_{wD}	b_{wL}	b_{wLC}			
p	Price (€ per physical unit G)	€ /G	p_M	p_S						p_{assets}
π_L	Marginal labour profit rate	_	π_{LM}	π_{LS}						
π_K	Marginal capital profit rate	_	π_{KM}	π_{KS}						
v	Velocity of money	y^{-1}								
Π	Profit	10^9 € / yr								
T	Taxation	10^9 € / yr			T_D	T_L	T_{LC}	T_{firms}		
Sp	Social payments	10^9 € / yr								
τ	Relaxation parameters;	yr								
	system inertia time constants:									
τ_w	*wage level*									
τ_L	*labour level*									
τ_K	*captal investment*									
τ_r	*interest rate*									
τ_{spec}	*speculation on asset prices*									
τ_{trans}	*loan / mortgage transactions*									
q_r	residential quote	-								
n_{trans}	number of loan / mortgage transactions	-								
ltv	loan to value ratio	-								

3 Empirical data and model calibration

The model presented thus far should be tested against empirical data. Unfortunately, calibrating, let alone validating, macro-economic models is a difficult task (Sterman 2000). Most variables are aggregate mental constructs that are heterogeneous and not directly observable; often one can only rely on econometric relationships between a few variables.

The model is scaled to the economy of the Netherlands. However, it will be representative for the European Union as well, given the fact that the both the mechanisms and the ratio's between the economic parameters are comparable. Depending on which parameters are considered (GNP, working force, wages, consumption etc.), the overall ratio between the Dutch and the European economy is 15 to 20. As 80 % of Dutch foreign trade is realized within Europe, the interpretation of the model on the European scale attenuates the problem of the model as a closed system (omitting import and export).

Macro-economic indicators

To obtain first guess estimates for the most important model parameters, we first collect the empirical time series of GDP (~ pY), the labour force L, the consumer price index CPI and the capital stock K from investment and depreciation flows for the Netherlands 1950-2010. From these data the time-series for real output Y is reconstructed. Next, the Y-values for this period are reproduced by means of the CES-production function, taking a plausible combination of the various parameters a, σ and A (eqn. 1).

.

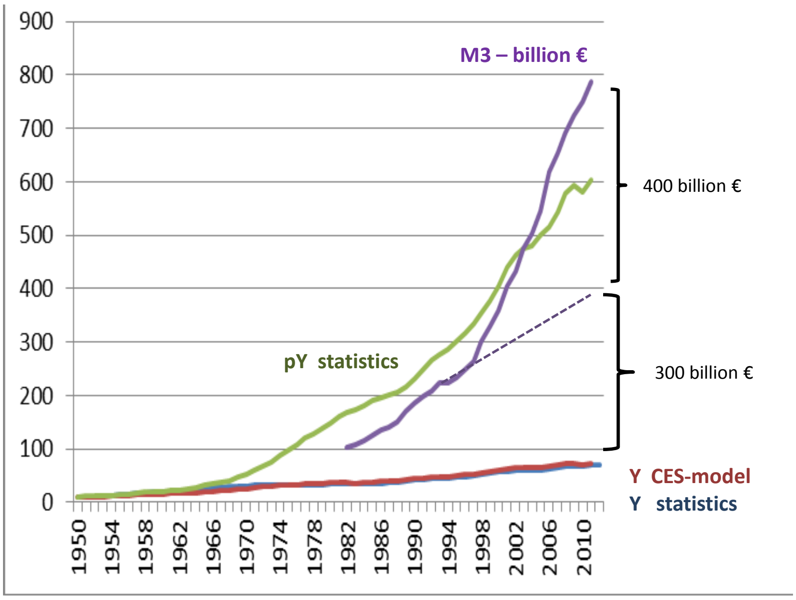


Figure 3.1 Physical production Y for the Netherlands 1950 – 2010 from statistical data (Y statistics); Y as estimated according to a CES-model.
pY (GDP) in billion €/year from historical data;
M3, the money quantity in the Dutch economy1982 – 2010 in billion €;
between 1982 and 2010, the money quantity has increased with 700 billion €.

The historical GDP (~ pY) time-series and the trajectory of physical production Y, thus reproduced with the CES production functions are shown in Figure 3.1 (cf. Appendix D). In the same figure, the amount of (M3-) money in circulation over the period 1982 – 2010 is shown. M0 and M1, also called narrow money, normally include coins and notes in circulation and other money equivalents that are easily convertible into cash. M2 includes M1 plus short-term time deposits in banks and 24-hour money market funds. M3 includes M2 plus longer-term time deposits and money market funds with more than 24-hour maturity. The amount of M3-money increases from 100 bn € in 1950 to 800 bn € in 2010. This money is created and brought into circulation by commercial banks in providing loans, in particular for mortgages. As a part of the loan is already paid back before the end of the period, the total amount of created money is higher than the 700 billion € increase of circulating money. Because the consumer price index CPI rose with a factor of about 1.8 between 1982 and 2010, it can be concluded that the total money stock has increased significantly above the inflation rate.

The analysis is as follows:

a) Over the period 1950 – 2010, GDP (~ pY) increased with a factor of 65 from 9 to 587 bn €/year. Over the same period the consumer price index has increased with a factor 8.2, indicating an increase in real production Y with a factor of about 7 from less than 10 bn € in 1950 to more than 70 bn € in 2010. The labour size increased from 3,8 to 6,7 million person-years, i.e. a factor of 1,75. The capital stock for producing goods and services is estimated to have increased in real terms in this period from 6.4 to 56.8, i.e. a factor 8.9.

b) To find plausible values of the parameters a and σ, the trend of increasing capital share in economic output as observed by Piketty (2014) is used. Assuming a fixed value of a = 0.28 throughout the period and assuming that the income share of capital did increase from 0.25 in 1950 to 0.33 in 2010 corresponding to the observed increase in capital share in some OECD-countries, σ is estimated to have increased with 0.003/year from a value of 1 in 1950 to 1.18 in 2010.

c) Given the real production Y and the increase in labour force L and capital stock K, and the estimates for a and σ, the labour-augmenting productivity increase A can be estimated. A is estimated to have risen from 1 in 1950 to about 4.4 in 2010, a growth rate of about 2.5 %/year.

d) Hence, on the basis of a CD production function, the factor L contributed $(AL)^{(1-\alpha)} \sim 4.35$ and the factor K contributed $K^{\alpha} \sim 1{,}85$ to the nearly 7-fold growth of real output Y. Combining the two yields a total increase in physical production over the period 1950 – 2010 of 7.7, which is close to the empirically found value of about 7.

It is remarkable that the rate of lending increases in the early 1990's: the M3-curve is significantly steeper after 1995 than before. The rate of money creation before 1995 is about 5 % of GDP, temporarily reaching 10 % in the early years of the 21st century. Most likely the increased money creation after 1995 results from the deregulation of the financial sector in the early 1990s and the increased lending to speculative ends within the financial system itself.

Asset prices

The major part of the increased lending since the early 1990's results for mortgage lending and thus is related to the price level of real assets (houses). Data on asset prices, transactions and mortgage lending are available for the Netherlands (CBS 2015). For the year 2005 the following values apply:

- Asset price (on average) 223 000 €
- Number of transactions 207000
- Loan to value ratio (on average) 1.05

These numbers gives an estimated overall bank loan of 48,5 bn €/year (eqn. 17). With an estimated repay level of 10 to 15 bn €/year, the net yearly increase in the mortgage debt (of the D-consumers) amounts 35 to 40 bn €/year, which corresponds to the empirical data on mortgage debt. It also roughly corresponds to the increase in the amount of M3-money shown in Figure 3.1.

The net amount of about 40 bn €/year is lent into circulation and affects the functioning of the real economy. This amount will end up on the deposits of the L- and LC-consumers, from where it contributes to inflation and a decrease of the interest rate. The real economy is affected to the extent that this newly created money stimulates consumption (and thus aggregate demand) via income of the D-consumers and via wealth of the L- and LC-consumers. The final outcome of this process is a GDP (pY) of about 600 bn €/year in 2005.

This allows a certain level of calibration / validation of the model: the overall cumulative bank loan, with a marginal increase of about 50 bn € in 2005, has to result in a GDP of 600 bn €/year by then.

Financial assets

As shown in Figure 3.2, the total bank balance in the Netherlands has grown much more than suggested by the data presented above. As 100 % of GDP corresponds in Figure 3.2 to about 600 bn €/year, it is seen that the estimate for the mortgage loans (light blue) does correspond to the data derived above. However, the SF-model does not account for most of the remainder. Banks have also given loans to firms, government and other financial institutions; apart from loans to firms (eqn. 15), these are not taken into account. Lacking information on loans to financial institutions and the role of financial assets in the process, it is assumed that these loans do not affect the price level and thus the GNP (pY) level.

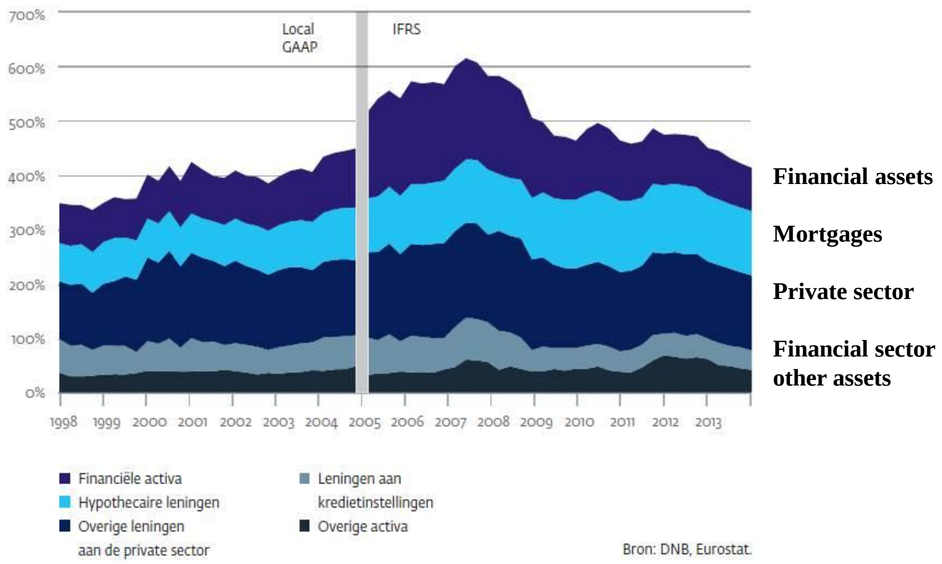


Figure 3.2 Overall balance of (Dutch) banks; 100 % of GNP (left y-axis) corresponds to 600 bn €/year. Source; De Nederlandsche Bank DNB, Eurostat (vermeld sites??)

4 Model results: the Dutch financial-economical system 1950-2050

In the previous sections, the equations and parametrization for the model have been introduced. In this section the resulting computations for a simulation of the Dutch economy in the period 1950-2050 are presented. Taking into account the empirical data presented in the previous chapter, the financial-economic development over this period has been reconstructed. The computations were made with values $b_{iL} = b_{iLC} = 0.8$ and $b_w = 0.03$ for the propensities to consume with respect to income and wealth respectively (eqn. 13). The substitution rate σ is assumed to increase from 1 to 1.5, as a way to represent the ongoing technology-driven ICT, robotization and the like and to account for Piketty's observation of an increasing share of capital in the national income (eqn. 1). These shares increase from 0.30 to 0.40 for the manufacture sector and from 0.20 to 0.25 for the service sector.

4.1 Endogenous crisis generated by the credit cycle

The results for the modeled credit cycle are presented in Figure 4.1. The ('Minsky') moment of crisis is reached as soon as the residential quote (financing costs / net income) of 0.5 is reached. This level is rather high compared to the empirical level of about 0,25 as the (for the Netherlands very significant) tax dispensation on mortgage interest is not accounted for. Taking this tax reduction into account would result in a residential quote in reasonable correspondence with the empirical value.
At the moment the threshold value is reached, and defaults on mortgages strongly increase, banks reduce the loan to value ratio for mortgages substantially, implying lower individual bank loans. Given the slower reaction of the asset prices, lower bank loans result in a significantly lower number of transactions (sales) . The lower level and the lower number of mortgages reduces the creation of money and subsequent monetary economic growth (of pY). After this change from the boom to the bust cycle, the system deleverages via deflation and wage reduction, reduced consumption and lower production; in that final stage also the physical economy (Y) slows down.

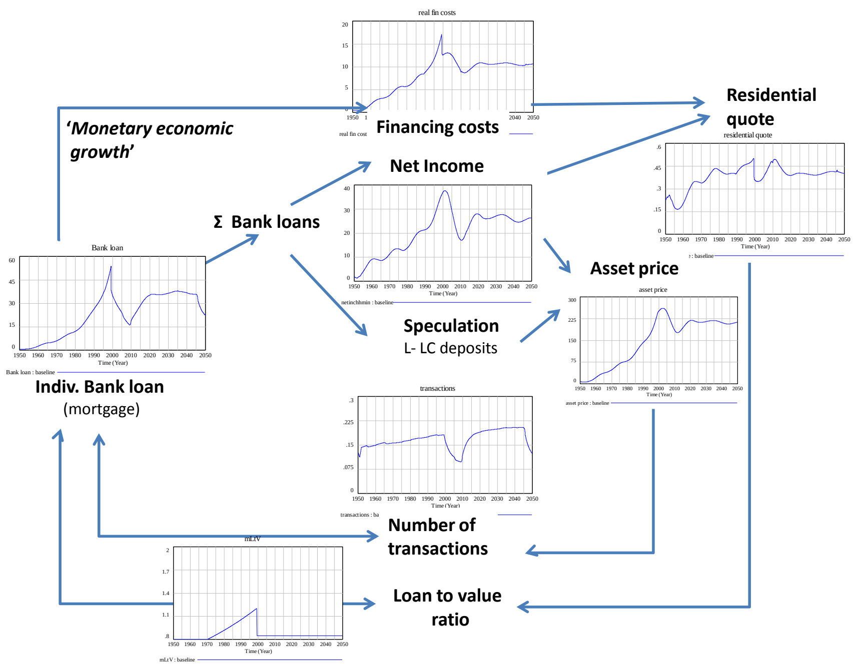


Figure 4.1 Results for the credit cycle and the 'Minsky' moment, as soon as a residential quote of 0.5 is reached.

The Minsky (crisis) moment is simulated under the previously discussed assumption that the residential quote is linked statistically to the amount of defaulting mortgage lenders. The higher the fraction of net income to be spent on mortgage costs, the higher the tendency to default. To explore when this happens in time (the so called 'Minsky moment') in time, the model was run for a range of values for the maximum allowable residential quote. The results, presented in Figure 4.2 show a rather limited time window of about 10 years for residential quotes over the wide range from 0,45 to 0,65. Depending on the choice for the residential quote, the Minsky (crisis) moment occurs in the model experiments between 1993 and 2005. A residential quote of 0,5 is adopted as a reasonable average.

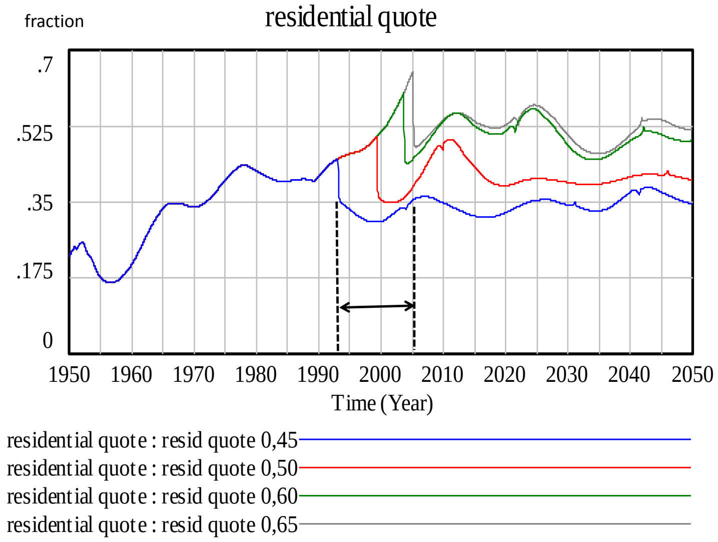


Figure 4.2 Minsky moments (crisis) as a function of residential quote in the range of 0,45 to 0,65; for residential quote values of the this wide range, endogenous crisis is reached within a small time window of about 10 years. (Residential quote does not include tax dispensation on mortgage interest)

Weakening credit flow and vanishing interest rate

Apart from the above mentioned mechanism of a weakening credit flow, the change from the upward boom to the downward bust cycle around the year 2000 is also caused by a second mechanism: the interest rate approaching the zero level. In Figure 4.3 it is shown how in the period up to 2000 the total amount of money in the system (total liabilities) has increased by about 650 bn €. As a direct consequence of this large increase of the amount of money, the interest rate decreases as is shown in the same Figure. This continuous decline in the interest rate stimulates investments, more lending and consumption. This results in continuous (monetary) economic growth. This contribution to growth halts as soon as the interest rate reaches its lowest, zero level. Given the acceleration of the process in the last part of the boom period (1980 – 2000), the zero level of the interest rate coincides with the sharp increase of the residential quote.

In Figure 4.3 the reconstruction of the monetary economic development (pY) is given. The Minsky (crisis) moment occurs when the residential quote reaches the level of 0,5 and the interest rate approaches the zero level. In the same Figure, the (hypothetical) experiment is shown what happens when the defaulting starts at a residential quote value of 0,7. As the graphs show, there are now two maxima. The first maximum, around the year 2000, is caused by the stagnating effect of the till then decreasing interest rate. The second maximum occurs around 2025, when the residential quote passes the hypothetical value of 0,7, after which the above process starts of increasing defaults, lower ltv-ratio's, lower number of transactions, less bank loans, less money creation, weakening of the credit flow etc. The resulting deleveraging of the system at this moment represents the (pure) Minsky moment The experiment demonstrates that the downturn from the boom to the bust phase is caused by two mechanisms: the halting of the continuous decrease in interest rate (reaching its lowest level) and the Minsky moment in which the credit cycle reaches its tipping point.

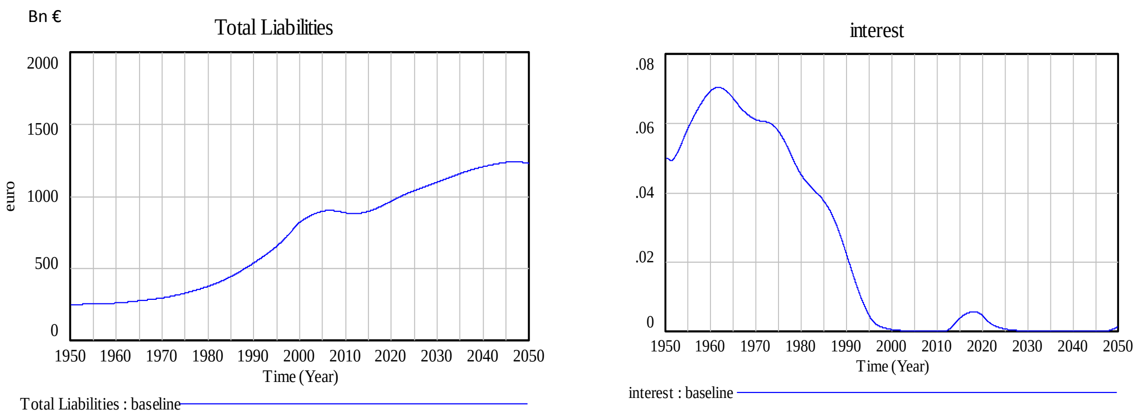


Figure 4.3 Results for the modelling period 1950 -2050 for total liabilities and interest rate.

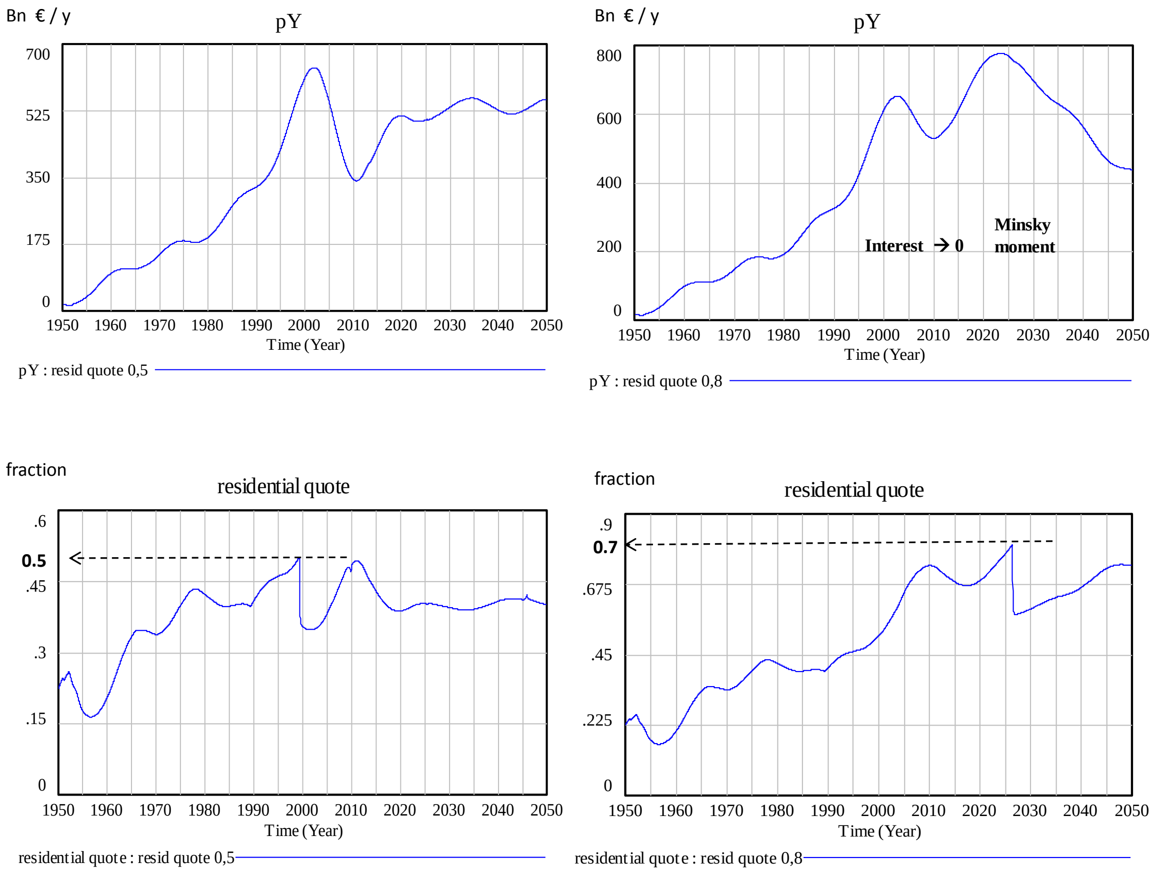


Figure 4.4 Modeled (monetary) economic development (pY) for the baseline case (left) with residential quote = 0.5, and the hypothetical case where the residential quote = 0.7 (right). In the latter case the separate effects of the interest rate approaching zero and the Minsky moment of suddenly weakening credit flow becomes visible.

Summarizing, it can be concluded that the large scale granting of credits and the inherent creation of money by commercial banks provokes financial crisis along two routes:

- the creation of large amounts of money borrowed in mortgages makes it increasingly probable that the part of the households (L-consumers) will default. This is simulated as a discrete event at a certain threshold level of the residential quote and is dynamically tantamount to a tipping point in the system (Minsky moment),
- the large amounts of (new) money brought into the system also results in a continuous decrease of *the interest rate*, which in itself stimulates (monetary) economic growth via increased investments and increased consumption. Approaching the zero level, this stimulation will stagnate, resulting in economic stagnation as well;

4.2 Simulations for the Dutch economy 1950 -2050

The integral results of the reconstruction of the period 1950 -2010 and the simulated extrapolation for the period 2010 -2050 is given in the Figures 4.5 a and b. For the period 1950-2000, the trajectories of monetary output (GDP), price, consumption, employment and investments are reproducing the historical time-series rather well. In the first few decades (1950-1990), the high investment rate in combination with increases in labour productivity by means of new technology and organization, leads to accelerating growth in GDP (~ pY; Figure 4.1a upper left). Therefore, the employment rate remains above or close to the high desired level, despite the growing population and thus labour force (Figure 4.1b upper left). Indeed, the model indicates a continuously tense labour market, which is partly a model artefact as we keep the desired employment level constant. Historically one can read the wave of immigrants and the gradual introduction of women on the labour market into these numbers.

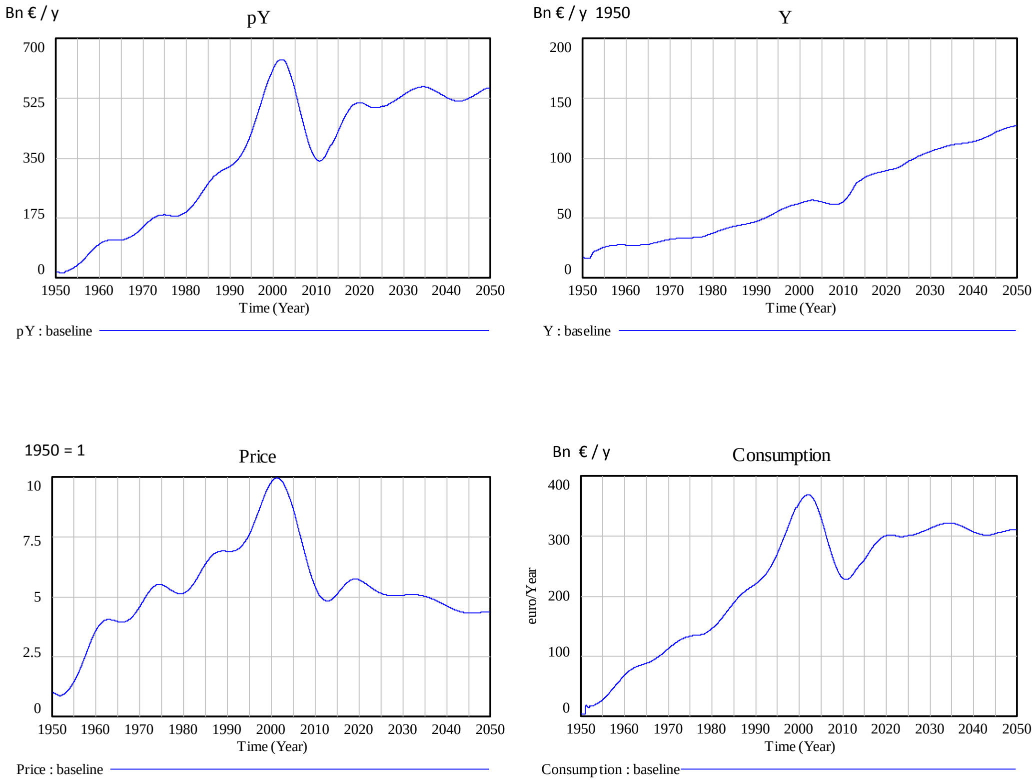


Figure 4.5a Results for the modelling period 1950 -2050 for monetary production (pY), total production (Y), Price (M- and S-sector) and consumption; b_i = 0.8 b_w = 0.03 and σ=1.3.

As part of the wage-price spiral and central bank policies, in combination with psychological and political processes, the money stock has increased at such a rate that prices and wages kept increasing throughout these decades; the price level in 2000 was ten times the price level of 1950. If the money stock had remained constant, prices would have declined as all productivity increase would have been absorbed in the price (deflation). In the reference run, the net additional money creation as 'debt of consumers' amounted to some 550 bn € around 2000 apart from an additional 100 bn € of loans of private banks to the government. The level of money creation (Figure 4.3 left; total liabilities) is in overall agreement with the empirical data of Figure 3.1.

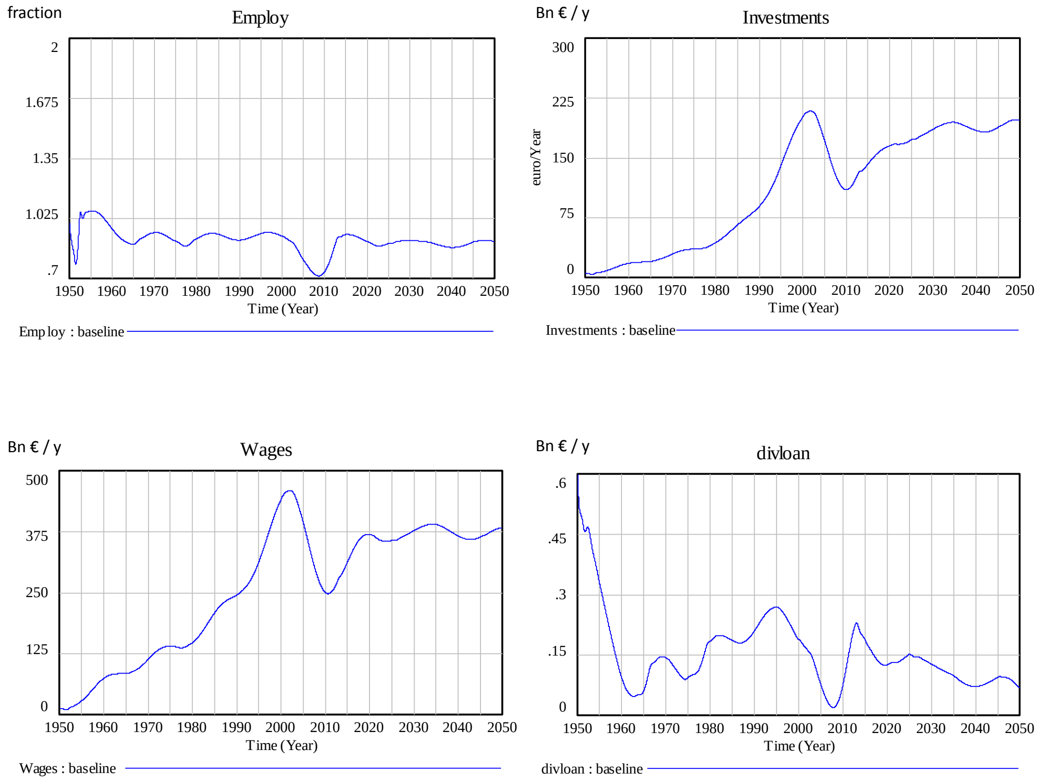


Figure 4.5b Results for the modelling period 1950 -2050 for employment, monetary investents, wages and the fraction of shares (versus retained earnings) in overall investments.

In the lower right of Figure 4.5b the investments by the emission of shares is given, as fraction of total investments (eqn. 15). In the first phase (of rapid econmic growth) investments are mainly financed by share emissions. In later periods of less pronounced economic growth, the investments via retained earnings .become more important

The role of Government

Government spending on direct investments and social payments has to be balanced against taxation. In case spending exceeds income from taxation, the government has to borrow from the financial markets and directly from banks. For the current model runs, it is assumed that the government acquires 75 % of the money on the financial markets by selling government bonds. This then reduces the amount of 'liquid assets' on these markets (as formed the deposits of both the L- and the LC-consumers, minus their consumption). The remaining 25 % is lend from private banks, which implies that this money is newly created.

According to EU-regulations, the government debt is constrained to 60 % of GDP (~ pY). In case the debt is increasing above this level, government spending is reduced and taxation is increased, both with consequences for the economic system as a whole. As shown in Figure 4.6 the government debt is maintained on the level of 60 % GDP during the first part of the modeling period (Govdebtfrac). In Figure 4.6 lower right, also the relative level of taxation is presented. In the years after the crisis taxation is increased in an attempt to stay within the 60 % constraint on government debt. The level of government spending (consumption) is correspondingly reduced (not shown).

It should be remarked that the bail out of banks by the government to restore their capital ratio after large scale default on loans at the Minsky moment is not included in the baseline computation presented here, as the model does not (yet) allow for incidental debts > 60 %. As a consequence, the model increases the relative tax level (in Figure 4.6 lower left) such that the 60 % debt level is maintained. This tax increase aggravates the crisis situation significantly, resulting in a relative dramatic effect. In Figure 4.6 lower right, the modeled overall decrease in GNP (pY) for a 40 bn € bail out is presented, showing the dramatic effect.. For the time being it is concluded that the government bail out response to the crisis is a third factor, apart from the interest rate approaching the zero level and the sudden reduction of the credit flow, in the downturn of the economic situation.

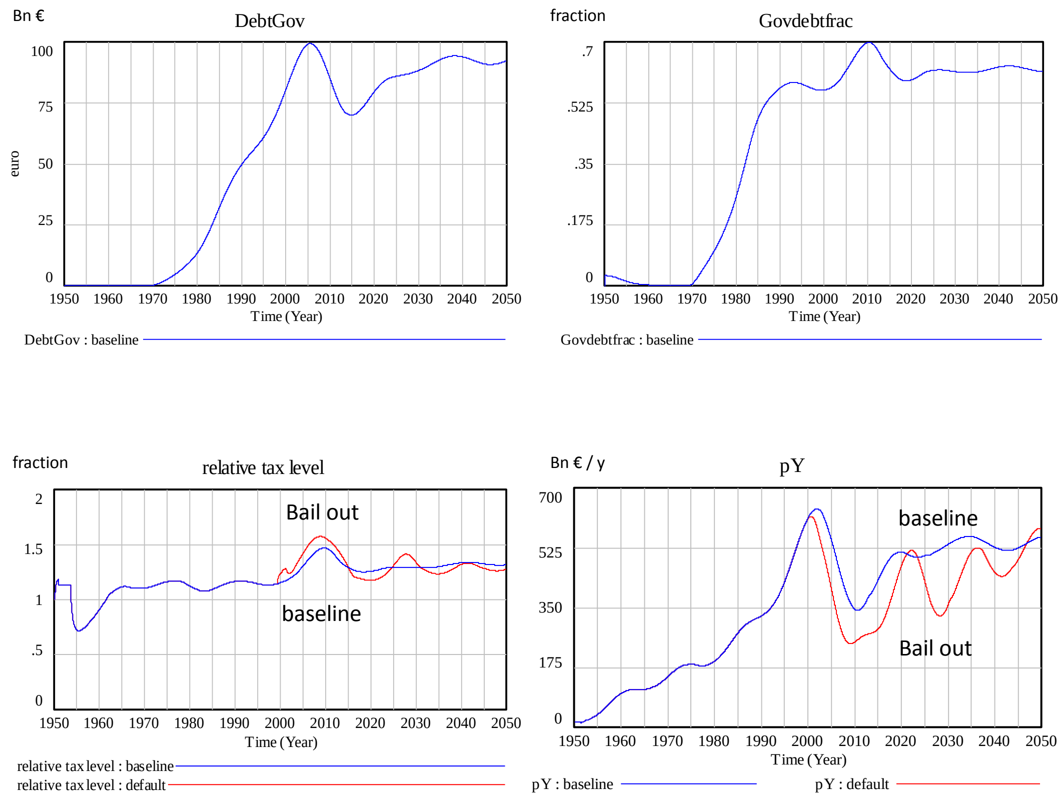


Figure 4.6 Government debt, debt as fraction of GDP (pY), with the 60 % EU-constraint (upper right), relative taxation level (lower left) and monetary economic development (lower right) under 40 bn € bail out by the government.

Conclusion; lack of coordination

It is concluded that the model can give a meaningful reconstruction of the overall long-term dynamical behaviour of the financial-economic system. With the restricted set of assumptions, the occurrence of the boom- and bust-cycles can be understood and to a reasonable extent predicted.
At first, increased lending generates a continuous flow of newly created money into the (consumptive) economy which drives partially inflated growth. This flow halts as soon as the residential quote reaches the tipping point for large scale default on loans and, due to the same lending process, the interest rate approaches zero. Eventual bail out of banks by government to restore their capital ratio's aggravates the situation further.

At the moment of crisis, the positive effect on consumption, and thus on production and employment, is lost and a downward wage–price spiral sets in. During the subsequent bust period, the repay gives the reversed signal to the system, keeping it downward sloping, until ongoing technological progress restores growth of the physical production, allowing the monetary economy finally to recover. However in the current situation, then the same dynamics will repeat itself, with the same, predictable outcome.

The current financial system appears to be fundamentally unstable. The boom and bust cycle of euphoric upswings and disrupting downturns has its underlying cause in the lack of coordination in the process of money creation. Money is created by private banks, which decide on the basis of (local) company and financial market indicators and not on indicators of the system as a whole e.g. stability. The Central Bank, who has the required oversight of the system as a whole, does not have the possibility to control the decentralized money creating process. The Bank's ability to determine the (lending) interest rate is not effective, in line with the growing insight (Werner, 2012) that 'the interest rates appear as likely to follow economic activity as to lead it'. Lacking central coordination, (monetary) economic growth by decentralized money creation is a self fulfilling prophecy which brings about the unjustified euphoric herd behavior of the many private banks creating too much money, believing in the ongoing rise of asset prices and monetary GNP-growth. After the inevitable disruption, the system has to be recovered by the government through centralized coordination, which can only be done, at least partly, at the expense of the tax payer.

5 A sustainable financial-economic system

In search for an alternative, more 'sustainable' financial-economic system, the fundamental flaws of the current system has to be overcome. The findings of the previous paragraph suggest room for essential improvement in the centralization of the money creation process. Money creation by the one Central Bank instead of the many private banks, could be continuously adjusted to the actual state of the economic system. This as rational as possible adjustment of the amount of money, together with the control of the interest rate, would allow a significant, if not complete elimination of the boom – bust cycles and would bring about the associated stabilization of the financial- economic system.

To explore the merits of such a reformed financial system with Central Bank coordinated money supply, numerical experiments were made in which the system was switched (hypothetically) to the new, centralized system, after the financial crisis of the current system (shortly after the year 2000).
The reformed system is based on two main elements; full reserve banking and debt free money creation (NEF 2013, van Dixhoorn 2013, www.positivemoney.org). Prior to that, the current liability deposits are replaced by two types of accounts; transaction accounts and investment accounts as proposed by Positive Money (Jackson, 2012):

Transaction accounts are actual money, formally at the Central Bank and thus are guaranteed for 100 %. Private banks can administer these accounts on behalf of the customer, but these banks cannot use the money on these accounts for making loans or funding its own investments. Electronic payment services and money transfers operate on these transaction accounts. Transaction accounts have the same position for money ownership as cadastral systems have for land ownership. Ownership is guaranteed by the State and cannot be affected by any private intervention whatsoever.

Investment accounts are records of money that has been provided (by customers) to private banks to be invested. The money on these accounts are risk-bearing liabilities of the private banks to the customer. There might be gains and losses in the process, both for the banks and for the customers.

Full Reserve Banking

In the case of Full Reserve Banking (FRB), banks give loans as well but in this case the loan has to come from investment accounts and has to be backed for 100 %. Via banks as a service providing intermediary, the 'usufruct' of the money on the Investment account is temporarily transferred from the investment accounts of lending consumers to the accounts of the borrowing, indebted consumers. This implies that holders cannot withdraw the corresponding part of their Investment account .
Banks thus become brokers on the financial markets. As the money used by the borrower is 'existing' money, brought in, among other ways by savings, there is no new money created; the total amount of liabilities remains the same.

This mechanism is modeled by transferring the lend money from the L- and LC- deposits to the D-deposit of the indebted consumers (leaving he total liabilities unchanged). However, from these L- and LC-deposits also the government bonds and firm shares are to be paid. Lending from plus- to min-consumers, via the bank as intermediate, is restricted by the amount of money which remains available as the 'liquid assets' part on the L- and LC- deposits, after the bonds and shares have been paid.

As an alternative, the bank may borrow money from the Central Bank. The commercial bank lends this money to the borrower at a higher interest rate, which accounts for the risk of non-repayment and on the availability of money. In the process, the Central Bank can create the money eventually out of nothing, in the same way as this is done in the present situation by commercial banks

Debt Free Money and the money growth rule

As a consequence of Full Reserve Banking, the amount of money is fixed. However, in a physically growing economy, where more goods and services become available while the total amount of money stays the same, prices have to go down (deflation; cf. chapter 3). To keep prices at a constant level in a physically growing economy, the amount of money has to increase at the same rate as physical production is increasing (cf. section 4.2).

Instead of creating 'money as debt' in the form of debt which borrowers have with banks, the government has the (legitimate) right to create 'debt free money'(DFM) herself. This money is created without the need to pay back or to pay interest. Governments channel the created money in three ways into the real economy:

- money can be lent to commercial banks as intermediates between the Central Bank and investors, in the way it has been described in the previous chapters and
- money can be invested directly in democratically chosen projects without interference of the financial system. Such investments, in physical (roads, railways, renewable energy etc.) and social (health, education etc.) infrastructure increase aggregate demand and stimulate the economy, as suggested by Keynes.
- tax-levels can be reduced; in doing so, not the government, but the consumers (are expected to) stimulate aggregate demand into a social / political desirable direction.

Depending on the economic situation, government can partition the money created between these three channels. The common objective of Central Banks has been the stabilization of prices, but other objectives are possible too, e.g. a certain level of (un)employment. In all cases, the amount of money to be created follows from an explicitly formulated 'money growth rule'. By giving a legal status to such a money growth rule (and its independent body, the 'Money Creation Committee, as suggested by Positive Money, Jackson, 2012), the fear that governments would be seduced to create too much money becomes hypothetical. In model terms, this means that money which is created and brought into circulation by the government (via the Central Bank) is introduced into the financial-economic system via government expenditures and/or tax reductions. Both stimulate the real economy. In case of centralized, constraint money creation, interest levels will go up, given the increased demand for a limited amount of money. In that case it is a political choice to maintain or to increase the amount of money creation. In all cases the Keynesian stimulation of the economy can be far more effective than by means of interest rates only.

The experiments presented in this chapter are based on the target of price stability as this is the primary objective of Central Bank. As a consequence, there is no inflation or deflation. Eventually the choice for a moderate inflation could be incorporated in the money growth rule. However, the choice for inflation (and also deflation) is a political one.

Price stability by means of Debt Free Money creation

To explore the effects of the combined full reserve banking (FRB) and debt free money (DFM) approach against the current money as debt (MaD) system, model experiments are made in which money is created from the simulated Minsky moment by the government at a rate at which the price level p remains constant (price stability as objective). An additional target can be to gradually reduce the existing government debt.

The results of the experiment are shown in Figure 5.1 to Figure 5.4. Herein, the baseline represent the current MaD system and the FRB- DFM trajectories describe the alternative FRB-DFM-approach for the period up to 2050. Comparing the two, the following observations are made:

- As a result of money creation, total liabilities (the stock of money in the system) increase as shown in Figure 5.1. During the first half of the period, before the crisis, the simulated liabilities rise from an (estimated) initial 200 bn € to 850 bn €. After the transition around the year 2000, the total stock of money keeps rising in both experiments to about 1200 bn € by 2050. However, in the FRB-DFM experiment the money creation has become the prerogative of government and money becomes debt-free (DFM). In the current model simulations, the objective of maintaining price stability requires that money is created at a rate of 1,5 % to 2 % of GDP (~ pY) per year (Figure 5.2 right).

- In the simulation, the government debt as a fraction of GDP is gradually reduced from the current level of 60 % to a much lower level at the end of the simulation period because of the assumed repayments. (Figure 5.1 lower right).

- Under the FRB-DFM conditions, the interest level is expected to be lower than in the MaD case because of the combined result of money creation and decreasing government debt. On the other hand, the indebted consumers are now borrowing from the deposits of the L- and LC-consumers, with intermediation by banks, and without money creation. This brings the interest rate over all on a higher level (Figure 5.1 lower left).

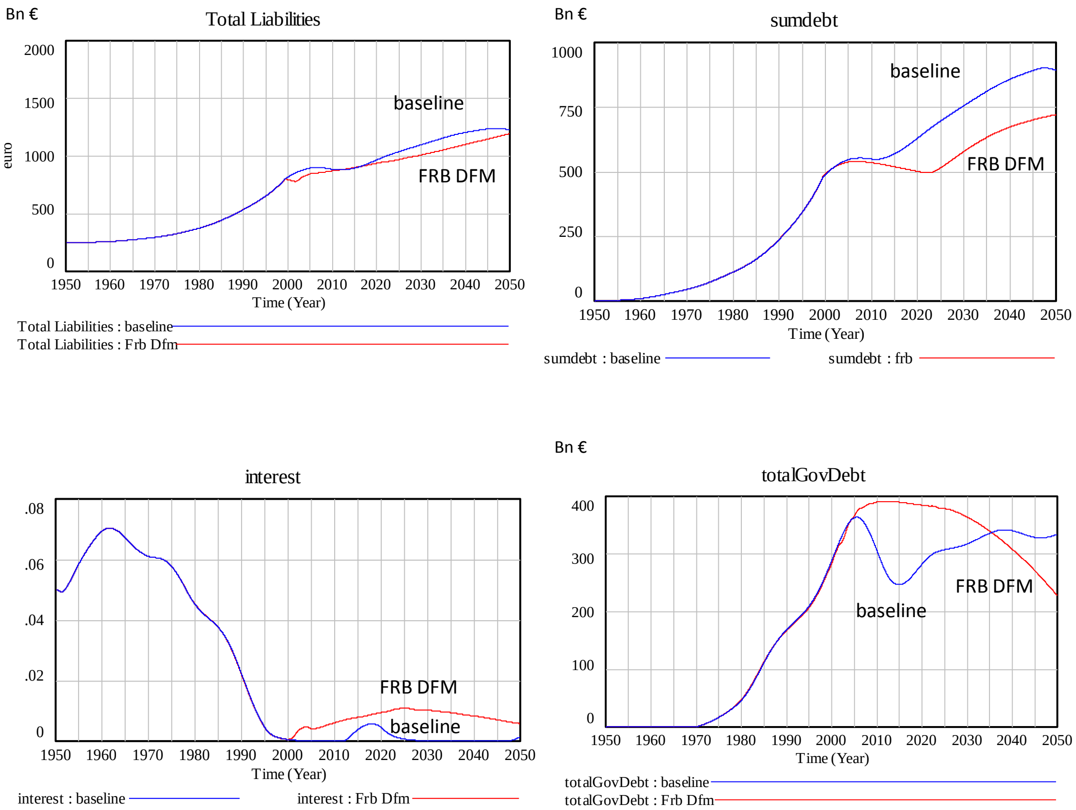


Figure 5.1 Model results for MaD (before 2000) and FRB-DFM (after 2000); Total liabilities (upper left), Consumer debt (sumdebt; upper right), Interest rate (lower left) and Total government debt (lower right) (cf. Figure 4.3 and 4.6).

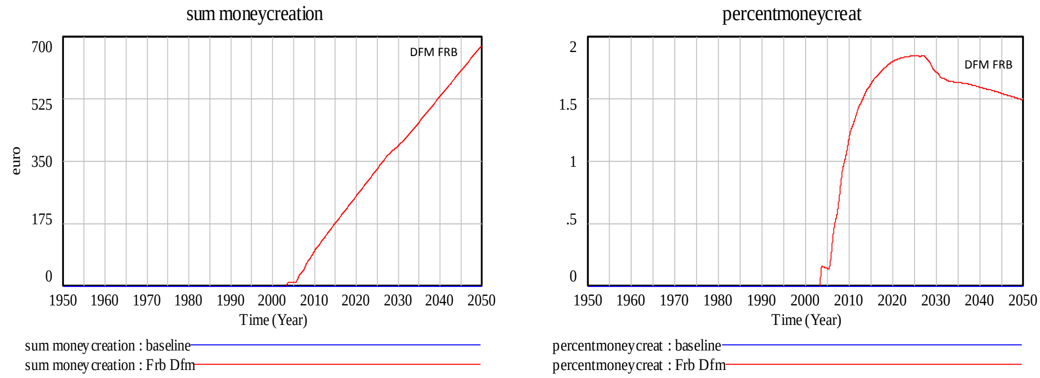


Figure 5.2 *Money creation (absolute and in %/year) under FRB-DFM to achieve a constant price level.*

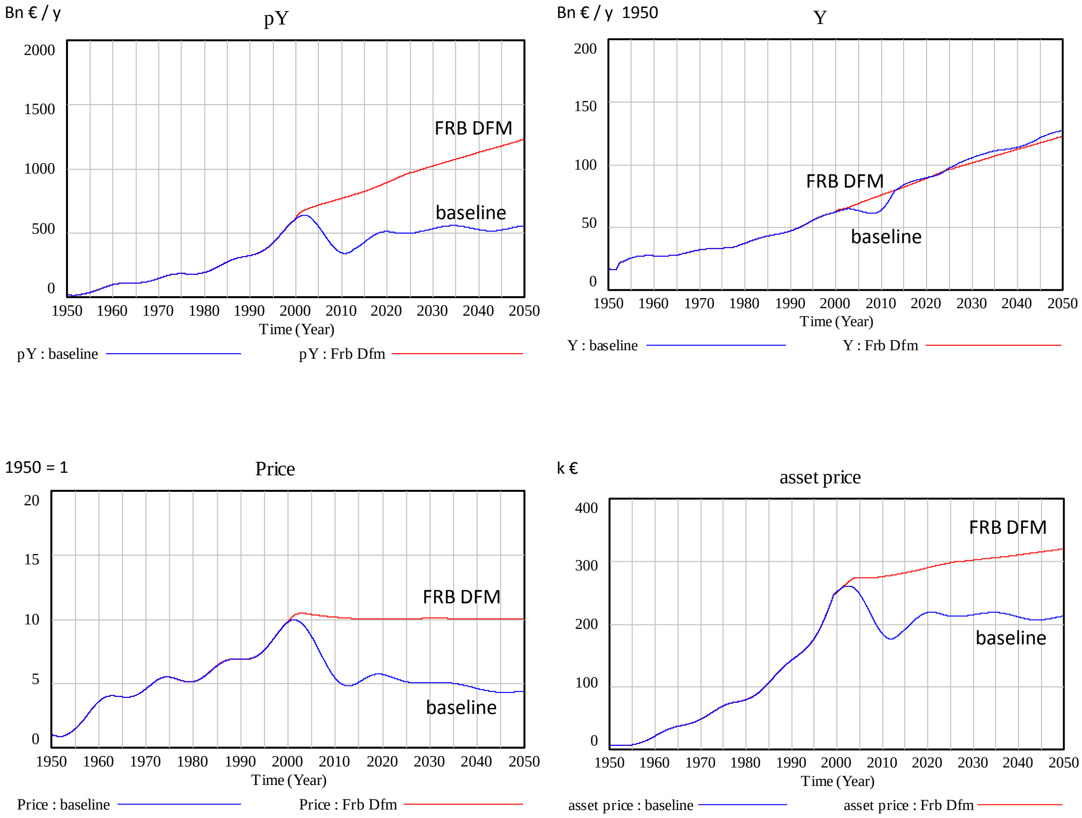


Figure 5.3 Model results MaD (before 2000) and FRB-DFM (after 2000); GNP (pY; upper left), physical production Y (upper right) , Price (lower left) and Asset price (lower right).

- As a consequence of the money growth rule, the average price level remains constant after the (Minsky) moment of crises (Figure 5.3 lower left). The technology-induced deflation in the base run is countered.

- Unlike in the base run, both GDP (~ pY) and the physical production (Y) show a continuous increase in the FRB-DFM experiment. This stems from the real increase in productivity (Y/L) which results from technological progress. The change in pY corresponds to the change in physical production Y times the (constant) price level. In other words, the amount of newly created money keeps pace with the growth of the real, physical economy.

- Although the money creation is not targeted directly at employment, the employment level can be maintained near the 'full employment' goal of 90 % of the labour force (Figure 5.4 upper left).

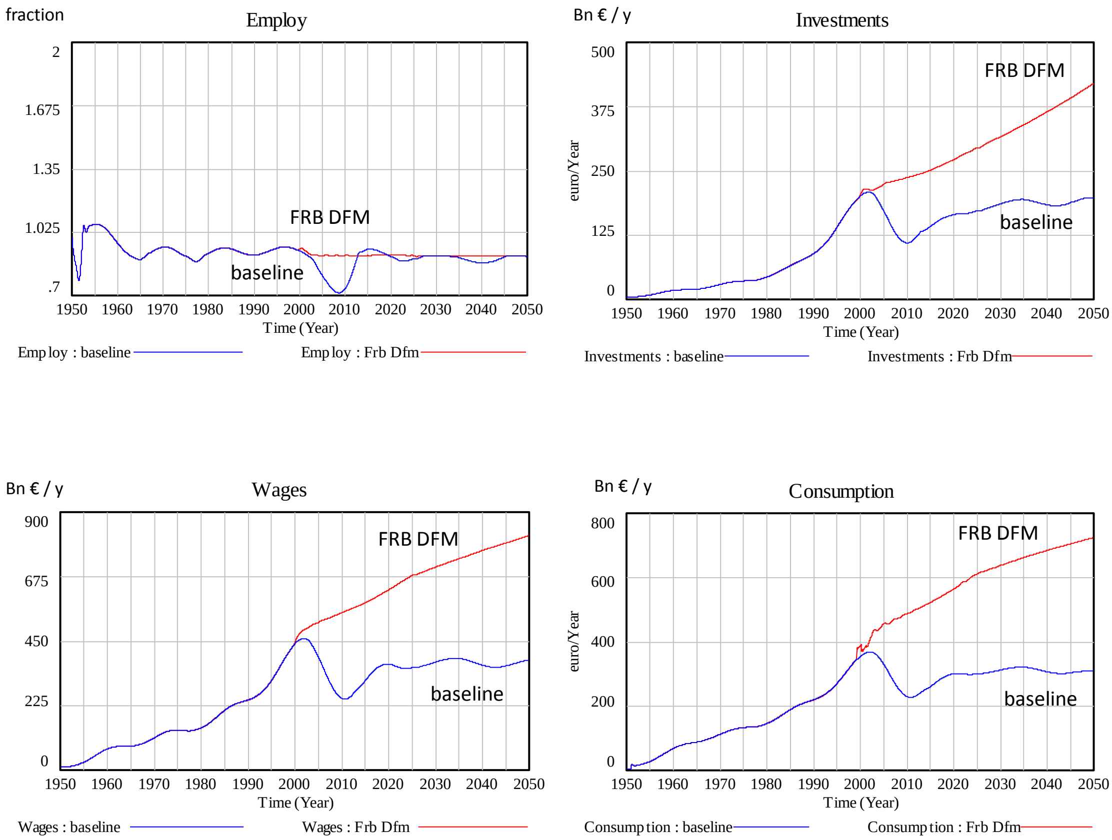


Figure 5.4 Model results under money as debt (MaD) before 2007 and combined full reserve banking (FRB) and debt free money creation (DFM) after 2007; money creation is targeted at maintaining a constant price level. Baseline is MaD over the full period 1950-2050.

Conclusion

These model experiments show that money creation by the government, according to a 'money creation rule' which is directed to price stability and / or employment, indeed can stabilize the boom-bust cycles that occur in the present Money-as-Debt situation. At a constant price level, Both the physical (Y) and the monetary production and consumption (pY) can be made to follow a pathway of stable, continuous growth, with constant prices and technology-induced income growth in the real economy.

In the current simulations, and without an eventually (politically) desired inflation, this requires of debt free money(DFM) at a rate of 1,5 - 2 % of GDP per year, which is significantly below the range of 3 – 10 % per year at which private banks have been creating money over the last 50 years. The government-created money can be spent by the government. At the current GDP (~ pY) level of 600 billion €/year, this would amount to 10 to 15 billion € per year, apart from the saved interest payments on the declining government debt which is at the current low interest rate in the order of 10 billion € /year as well. In case an inflation rate of 2 % would be required, an additional 12 bn € has te be created, raising the total amount of money to be spent by the government (including lower tax rates) to over 30 bn € / year.

6 Wealth effects

One interesting, additional aspect of the model simulations is the evolution of wealth, i.e. the average net bank deposit, for the three different consumer classes. As stated previously, the model distinguishes three groups of consumers:

- the L-consumers, who earn income from labour and consume all their income (partly on interest and repayment), with a negative net wealth level M_D;
- the L-consumers, who also obtain their income from labour but have a positive net wealth M_L, which permits them to get loans; and
- the LC-consumers, who obtain income from both labour and capital, and buy shares and obtain dividends. Their wealth level is M_{LC}.

The last two categories are assumed to buy government bonds, in the current computations in the same amounts.

In Figure 6.1 the results are presented for the M_L and M_{LC} deposits, as well as the consumption and wealth ratio's per household for both groups of consumers.

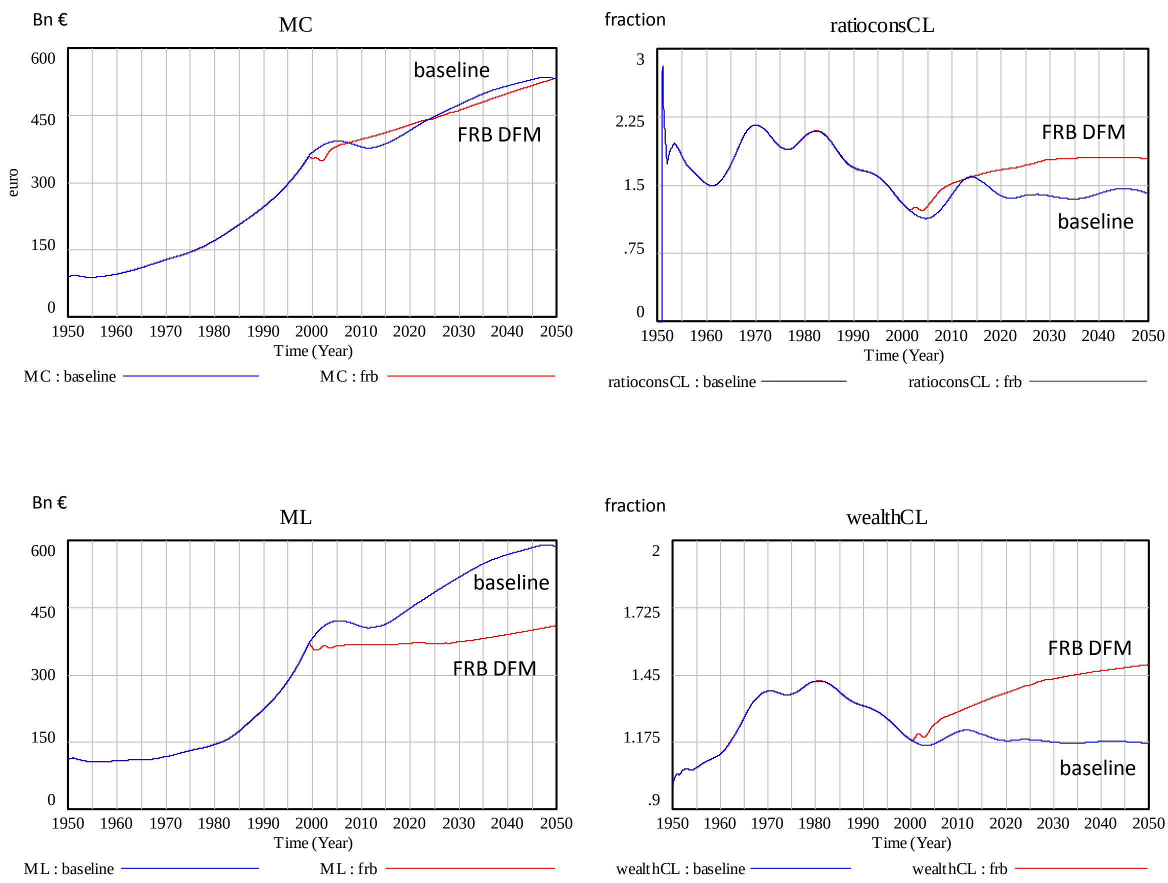


Figure 6.1 *Model results MaD (before 2000) and FRB-DFM (after 2000);*
M_{LC} and M_L-deposits;
Consumption ratio between LC and L consumers (upper right)
Wealth ratio between LC and L consumers (lower right).

In the FRB-DFM case, the M_L-deposit stays more or less at a constant level, significantly below the baseline situation (lower left). This is explained as follows:
In the baseline, newly created money for mortgage loans ends up in equal amounts on the M_L and M_{LC} -deposits, as it has been assumed that both categories sell assets to the indebted consumers. In the FRB-DFM experiment, loans are not given by banks but by the L- and LC-consumers via banks as intermediates. So both groups of consumers lose this source of 'income' from newly created money. in the alternative FRB-DFM case, the newly created money enters the financial-economic system via government spending and tax reductions, thus directly stimulating economic activity. The LC-consumers, who supply the capital investments and receive the dividend, profit from this economic stimulation and thus compensate their 'income' loss.

In all cases the level of income of the LC-consumers is higher than that of the L-consumers, because both groups obtain the same level of wages but the LC-consumers acquire on top of that capital income. In the FRB-DFM case, where the L-consumers no longer profit from the influx of new money, the wealth of the LC-consumers thus steadily increases over the wealth of the L-consumers. The effect is relatively small, given the fact that the LC-consumers spent proportionally more of their income and wealth on consumption (eqn. 13). This effect of higher consumption of the LC-consumers, as a result from both higher income and higher wealth, mask the insight into the partitioning of wealth over the respective consumer groups.

To overcome this masking effect, the propensities to consume b_{iL} and b_{iLC} are adjusted in such a way that the consumption levels of both groups become more equal. For b_{iL} = 0.85 and b_{iLC} = 0.75, with b_w =0, the results for this hypothetical experiment are shown in Figure 6.2. Both for the baseline as for the FRB-DFM case, the consumption levels now are more or less the same for the LC- and the L-consumers; Figure 6.2 left. The wealth of the LC-consumers is now increasing significantly compared to the wealth of the L-consumers: Figure 6.2 right.

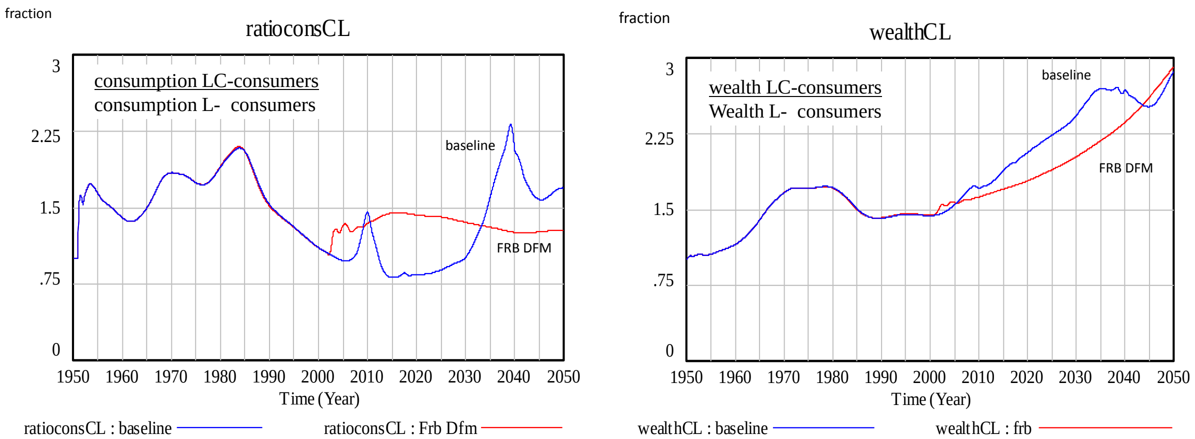


Figure 6.2 Consumption and wealth ratio's between LC- and L-consumers for the hypothetical case in which b_{iL} = 0.85, b_{iLC} = 0.75 and b_w = 0

The wealth of the LC- and L-consumers, inasfar as it is not used for investments in firms (shares) or in government (bonds), remains 'outside' the economic process (Werner, 2012). Re-introducing this money into the real-economy by means of a wealth tax, could have more or less the same result as money creation for stimulating aggregate demand (Piketty 2014). This additional income for governments can be used to lower income taxation e.g. or for specific investments in for example infrastructure. In all cases this would imply stimulation of the real economy. In the FRB-DFM experiment, this means that less money has to be created as the economy is stimulated by existing rather than new money.

The results for application of a 2 % wealth tax in the reformed FRB-DFM system are shown in Figure 6.3 and 6.4:

- It is evident that the wealth of the L- and LC-consumers is reduced. Given the capital income of the LC-consumers, the reduction on their M_{LC}-deposit is smaller than the effect on the M_L-deposit.
- Indeed the wealth tax results in a decrease of the money stock that is needed to maintain price stability (Figure 6.3 lower left). This confirms the mutual exchangeability of the sources from which money is mobilized to enter the real economy, be it from the ('unused') liquid assets M_{LC} by increasing consumption (b), money lending from L- and / or LC-consumers to indebted consumers, or debt free money creation (DFM).

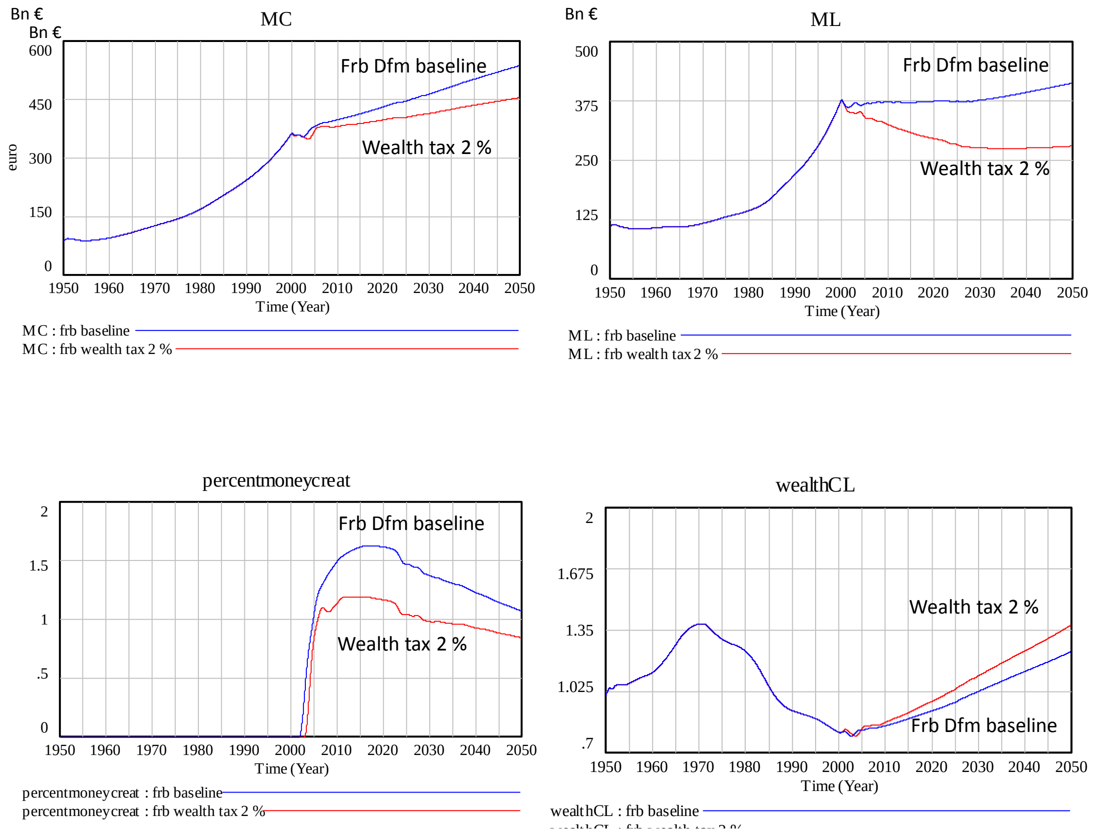


Figure 6.3 Model results for the FRB – DFM baseline and for a 2 % wealth tax applied to the M_{LC}- and the M_L-deposit:
M_{LC}- and the M_L-deposit, the (wealth) ratio between these two categories of consumers and the percentage of (Central Bank) created money (with respect to pY).

As shown in Figure 6.4, the effect of the 2 % wealth tax on GNP (pY) is small and negative. This also holds for the effect on physical production Y. which can be explained from a substantially reduced level of investments. These effects can be explained by the increased interest level (lower left). In the FRB-DFM simulation, loans are no longer given by creating new money but by transferring existing money from the lender to the borrower. This reduces the liquidity on the M_{LC}- and the M_L-deposits, which causes an increase in the interest rate. A higher interest rate directly hampers the level of economic activity. But this activity now can be stimulated, partly in a preferred direction, by means of the money creation of the Central Bank / government. The higher interest rate restores the necessary market condition for money lending and as such the rationalization of the economic process.

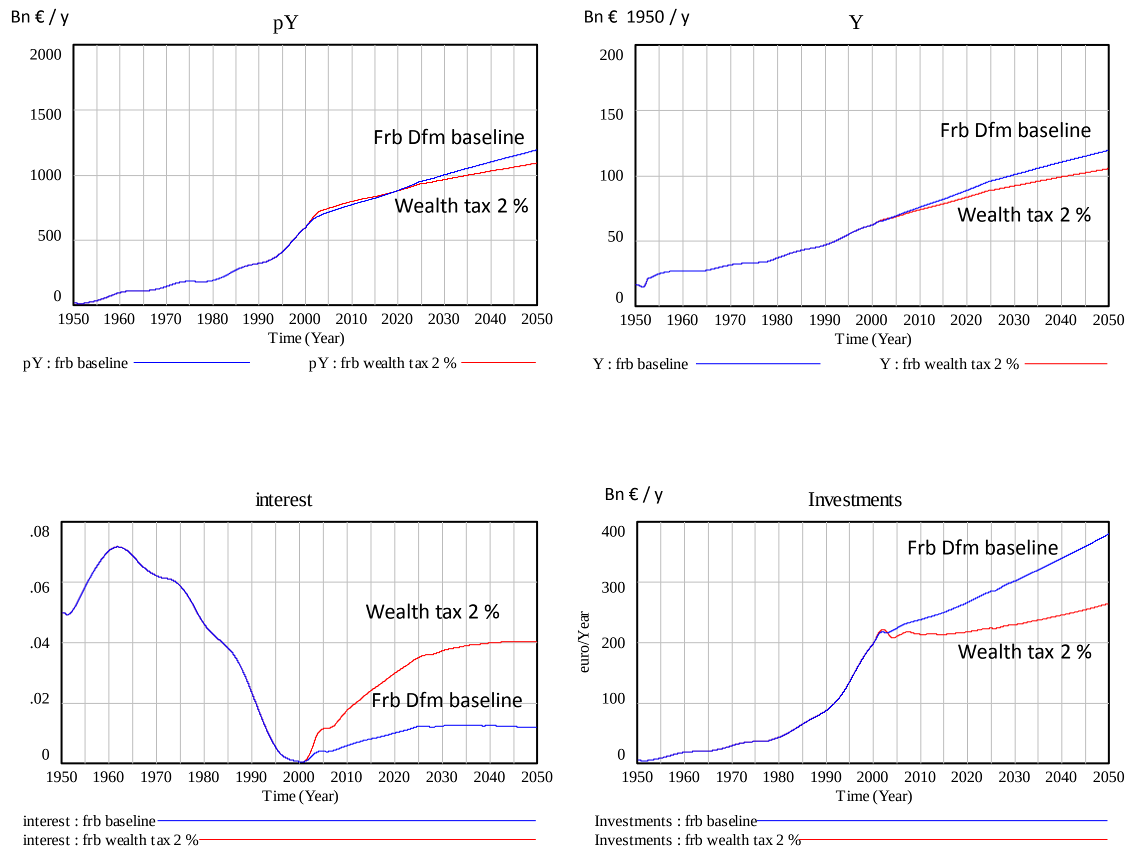


Figure 6.4 Model results for the FRB – DFM baseline and for a 2 % wealth tax applied to the M_{LC}- and the M_L-deposit, for pY, Y, interest and investments

Conclusion

Wealth effects are mainly governed by the income of capital additional to labour and by asset related transfers, such as the sale of real estate (houses) which has increased in price during the 'euphoric' part of the boom-bust cycle. In the current system, (average) wealth effects between consumers with both labour and capital income and consumers with only labour income are relatively small, given the more or less equal, and substantial contributions from these asset transfers. Both categories profit in the same manner from the creation of new money in the process of providing mortgage loans.

In the reformed situation, this is no longer the case as newly created money (by the government) is directed to additional and targeted government spending and to tax reductions, to stimulate the economic process. This also supports the rewards of capital, which in the form of dividends contributes to the wealth of investors, who have funded investments via shares.
The simple model applied here so far suggests that the consumers with capital income will have of larger and continuous growth of their wealth, compared to the consumers with only labour income.

A wealth tax (2 %) applied on the L- and LC-deposits, naturally reduces these deposits, and thus increases interest rates, with a slight negative effect on economic growth.
But a wealth tax reduces the amount of money which has to be created to stabilize the economy via stabilization of the price level. The money which now ends up at the deposits of LC- and L-consumers than (for a small part) is recirculated into the real economy, via additional government spending or reduction of other tax rates, such as value added tax, thus stimulation aggregate demand and economic activity.

7 General conclusion

Along the lines of neoclassical theory, a system dynamics model has been developed to describe the most important mechanisms governing physical output of goods and services in the economy in interaction with the financial system. The model has been parameterized for a 600 bn €/year (Dutch) economy 1950-2010 in order to reproduce and investigate the time paths of some key economic variables. In particular, the model distinguishes explicitly the financial system and the process of money creation and debt formation. Some of the mechanisms are illustrated with separate model experiments, notably on the effect of loans, the role of technology and the increasing share of capital (as with e.g. robotization) in the production process (see Appendix A). The model experiments allow the following conclusions:

- The model can give a meaningful reconstruction of the overall long-term dynamic behaviour of the financial-economic system. The occurrence of the boom- and bust-cycles can be understood and to a reasonable extent predicted from the asset-price driven credit cycle. The model confirms Minsky's instability hypothesis, in which the euphoria over apparently ever increasing (asset) prices, GDP, wages, consumption and loans turn the system into the downward spiral of the bust, when financing cost becomes unbearable for individual households and the economy is no longer stimulated by a continuously decreasing interest rate towards zero.

- The current financial system appears to be fundamentally unstable. The boom and bust cycle of euphoric upswings and disrupting downturns has its underlying cause in the lack of coordination in the process of money creation. Money is created by private banks, who decide on other criteria than the stability of the system as a whole. Lacking central coordination, (monetary) economic growth by decentralized money creation brings about the unjustified euphoric herd behavior of the many private banks creating too much money, in the belief of and speculating on an ongoing rise of asset prices. The Central Bank does not have the possibility to control the decentralized money creating process. The Bank's ability to determine the interest rate is not effective. After the inevitable disruption, the system has to be rescued from societal chaos by the government through centralized coordination, at least for a large part at the expense of the tax payer.

- Control, or at least significant weakening of the boom-bust cycle, and herewith avoiding inflation during the boom- and deflation during the bust-phase, can be achieved by centralized control over money creation. The model experiments show that money creation by the government, according to a 'money creation rule' which is directed towards price stability and / or employment, indeed can stabilize the boom-bust cycle (as demonstrated for the most recent cycle). At a constant price level, both the physical and the monetary production and consumption then follow a pathway of stable, continuous growth, which reflects the increased productivity which results from technical progress.

- Without inflation price stability and the associated positive effects on employment and GDP can be realized at a 1,5 % / year creation of debt-free money, significantly below the range of 3 – 10 % money creation by private banks over the last 50 years. At the current GDP level of 600 billion €/year, this would mean about 10 billion €/year, not counting the saved interest payments on the declining government debt (at the current low interest rate in the order of 10 billion € /year). This results in in an annual saving of government (and thus taxpayers') money of some 20 billion €/year. In case a certain level of inflation would be politically desired (e.g. 2 %), an additional 12 bn € could be created (and spent). The overall money flow of about 20 - 30 bn € / year can be used to lower taxation and for democratically chosen investments in for instance an efficient and renewable energy system;.
- In the current simulations government debt was gradually eliminated. Full employment as a societal goal could be achieved within the context of the current model assumptions, in particular with respect to the propensity to consume.
- Additional model experiments suggest that a wealth tax can reduce the need for new money to be created.

8 Discussion

In 1936 the so-called Chicago Plan was launched, with the intention to give an answer to the financial crises of 1929. It focused on a restructuring of the financial system by centralizing money creation with the government and disentangling private and public responsibilities. In a recent IMF-study, Benes et al. (2012) concluded on the basis of simulations with a Dynamic Stochastic General Equilibrium (DSGE) model that the original claims of the 1936-Chicago Plan are valid. Our simulations with the SF-model confirm the results of this recent IMF-study.

Taking into account the recommendations of the (revisited) Chicago plan and the UK-proposals of 'positive money'(Jackson and Dyson, 2012), and assuming that such an alternative has to be realized at EU-level, the alternative for the current system can be summarized as follows:

- Money is created debt-free by the (EU-)government via an independent body (European Central Bank - ECB), according to a legally agreed money growth rule. Although independent, the money creating institution ECB is under full governmental / democratic control (European Parliament). Under the Maastricht Treaty of 1992, money creation by national governments is not anymore allowed within the framework of the European Union. Nevertheless, the current Quantitative Easing (QE) program of the ECB comes close to the government led, debt-free alternative for the present financial system, be it that the money is used to buy bonds from financial institutions (banks, pension funds etc.) with less positive effects for demand driven economic growth. A transition to the alternative system is possible within the framework of the European monetary system. It would allow direct investments in Europe-wide infrastructure with positive aspects on economic growth and European cohesion, without interfering in the present discussion on the mutual obligations of the individual European countries.

- Public and private responsibilities, rights and risks are fully separated and internally consistent; there is no public responsibility for private risks. This disentanglement of responsibilities is achieved by distinguishing:
    - public, *transaction accounts*, which customers (formally) have at the Central Bank (eventually administered via commercial banks), and which are fully guaranteed by the State. The electronic payment system is part of this public infrastructure and does not depend (only) on the continuity of commercial banks.
    - private *investments accounts*, which function via private financial institutions (banks) and are risk-taking. Profits and losses are only of private, not public concern. Bail-outs of banks by public money has become unnecessary and impossible. Moral hazard is eliminated.

- In this alternative, commercial banks still can play a very relevant societal role as intermediates on the financial markets. Their core expertise in risk analysis is a key functionality in intermediating between the money creating government, private savings and pension funds on the one hand, and the need for finance from the side of business and consumers (mortgages) on the other.

- Increasing (Basel-) regulation, needed to control the current public-private entanglement, leads to more complexity, with rapidly increasing inefficiency. Complexity can be reduced by public-private disentanglement, leaving the private part to the complexity reducing market mechanisms. In that case, monitoring of the private part of the financial system can be minimized to consumer information.

The current EU quantitative easing program

As illustrated by the model results, after the financial crisis prices will decrease and inflation during the boom-cycle is replaced by deflation in the bust cycle. Recently, the ECB launched its bid to revitalize the Eurozone economy and counter the too low inflation rate with a €60 bn-a-month bond-buying program. Based on comparable practices in the UK in 2009, Lyonnet and Werner (2012) amongst many others have criticized this specific form of the more general Quantitative Easing approach. The enormous amounts of newly created money accumulate within the financial system, without direct stimulation of the economy. They propose that the Central Bank should more directly target the growth of bank credit by QE for GDP-transactions. Only in that case a QE-program might fit in the proposal for reform discussed here (Benink et al. 2015).

Legitimacy of money creation by the government

Although beyond the scope of this paper, the proposed reform can also be motivated from a more fundamental point of view and in addition to the considerations with respect to system instability as discussed here. As already pointed out by Aristotle in his Ethica Nicomachea (350 BC), 'money exist by law, not by nature'. Money is not a commodity, but a social construct (Van Dixhoorn 2013). This implies that money has to be created by (groups in) society, in practice usually the State and that the money supply is a government prerogative. . Since Aristotle, numerous philosophers, economists and politicians including Locke, Franklin, Paine, Berkeley, de Montesquieu , Ricardo, Lincoln, Jefferson and Jackson have supported this view.

The current money-as-debt (MaD)system, with money creation by private banks, cannot be considered beforehand as 'normal'. On the contrary, the system is from a relatively recent date, the end of the 17th century, when in the 'Glorious Revolution' the concept of the Bank of Amsterdam was transferred to London and ownership changed from public (the city of Amsterdam) to private (…?). William Paterson, the founder of the Bank of England stated that 'the bank hath benefit of interest on all moneys which it creates out of nothing' (Zarlenga, 2002). Since then the struggle for power over the creation of money has caused many conflicts and even wars.

The usual argument in favor of privatized money creation is the alleged assertion that poorly run money systems of the past were under governmental control. In most cases these assertions refer to developing countries and the German hyperinflation of 1923. However, closer examination of the hyperinflation in interwar Germany points to the contrary: it was rather the pressure from the World War I allies (UK, USA) to privatize the German Bank rather than public governmental control that brought he inflation about. After taking control back by the government by Reichskanzler Schacht, the hyperinflation was halted within one year (Zarlenga 2002). It also should be realized, as shown in this paper, that over the last decades private banks and not governments have created the enormous amounts of money that have led to the 2007 / 2008 financial crisis.

From a political point of view, the Central Bank is under full governmental and democratic control, though legally independent in order to prevent interference by short-term oriented political forces. Comparable to the judicial power as the 'third power', the Central Bank would be part of a 'fourth power', which can act with great independency according to a priori defined rules but, at the end of the day, under full democratic control.

9 Acknowledgements

The authors are indebted to prof Dirk Bezemer and prof Hans Visser for their detailed comments and discussions. They also want to thank Hans van Steenbergen for his comments on the paper and the implications of the 'Positive Money' reform.

10 Literature

Aristotle (350 BC). Ethica Nicomachea. Edited by I. Bywater (2010), Cambridge University Press.

Ark, B. van (1995). Sectoral Growth Accounting and Structural Change in Post-war Europe. GCDD, Groningen (http://www.ggdc.net/publications/memorandum/gd23.pdf)

Arthur, W. (1994). Increasing Returns and Path Dependence in the Economy. Ann Arbor. The University of Michigan Press

Ayres, R., and B. Warr (2005). Accounting for growth: the role of physical work. Structural Change and Economic Dynamics 16 (2005) 181–209

Barro, R., and X. Sala-i-Martin (2004). Economic Growth. Cambridge University Press, Cambridge. 2nd ed.

Benes, X , and M. Kumhof (2012). The Chicago Plan Revisited. IMF Working Paper 12/202

Benink, H. en R. Van Tilburg (2015) Naar een Duurzame Euro. SFL –discussie paper.www.sustainablefinancelab.nl

Bezemer, D.J. (2009). 'No one saw this coming': understanding financial crisis through accounting models. MPRA Paper no 15892, June 16 2009. http://mpra.ub.uni-muenchen.de/15892/

Bezemer, D. J. and L. Zhang (2014). From Boom to Bust in the Credit Cycle; the Role of Mortgage Credit. Faculty of Economics and business, Groningen University.

Bezemer, D.J., M. Grydaki and L.Zhang (2013) Is Financial Development Bad for Growth ? Faculty of Economics and business, Groningen University.

Biggs, M, Th Mayer and A. Pick.(2010). Credit and Economic Recovery: demystifying Phoenix miracles. http://ssrn.com/abstract=1595980

Borio, C.E.V. and P.W, Lowe (2002). Asset Prices, Financial and Monetary Stability: Exploring the Nexus. BIS Working Paper 114.

Carroll C.D. (2001). A Theory of the Consumption Function, with and without liquidity constraints. Journal of Economic Perspectives, Volume 15, number 3 p23-45.

CBS statline (2015). Bestaande koopwoningen; verkoopprijzen. The Netherlands Central Bureau of Statistics; http://statline.cbs.nl/StatWeb/publication/?DM=SLNL&PA=81884NED

Chiarella, C., P. Flaschel and W. Semmler (2013). Reconstructing Keynesian Macroeconomics Volume 1 and 2. Routledge Frontiers of Political Economy. Davidson, P. (2011). Post Keynesian Macroeconomic Theory (2nd ed.). Edward Elgar, Cheltenham UK.

Cuerpo, C., I. Dumond, J. Lendvai, P. Pontuch and R. Raciborski (2015). Private sector delevaring in Europe. Economic Modelling 44(2015)372-383

Dixhoorn, C.van (2013). The Nature of Money. M Sc thesis Sustainable Development, Utrecht University (downloadable at www.sustainabilityscience.eu)

Egmond, N.D. van (2014). Sustainable Civilization. Palgrave Macmillan

Fisher, I. (1936). 100 % Money and the Public Debt. Economic Forum, Spring Number, April-June 1936, 406-420
2007)
Fitzpatrick, T and K. MCQuinn (2007). House Prices and Mortgage Credit; empirical evidence for Ireland. The Manchester School Vol 75 No. 1 January 2007
1463–6786 82–103

Friedman M. (1957). A Theory of the Consumption Function; the permanent income hypothesis. Princeton University Press.

Godley, W and M. Lavoie (2007). Monetary economics : an integrated approach to credit, money, income, production and wealth. Palgrave Macmillan, Basingstoke, UK.

Gomez, T. (2015). Money and Sustainability – A System Dynamics Modelling Approach. M Sc thesis, Utrecht University

Goodhart, C. and B. Hofmann (2008). House prices, money, credit, and the macro economy. Oxford Review of Economic Policy, Volume 24, Number 1, 2008, pp.180–205

Goodwin, R. (1967). A Growth Cycle. In: C. Feinstein (Ed.), Socialism, Capitalism and Economic Growth. Cambridge University Press, Cambridge.

Hallegatte, S., M. Ghil, P. Dumas, J.C. Hourcade (2008). Business cycles, bifurcations and chaos in a neo-classical model with investment dynamics. Journal of Economic Behaviour & Organisation 67(2008)55-77.

Helpman, E. (2004). The Mystery of Economic Growth. Harvard University Press, Boston.

Jackson, A and B. Dyson (2012). Modernising Money. www.positivemoney.org.

Jackson, T (2009). Prosperity without Growth. Earthscan, London.

Jackson, T. and P. Victor (2014). Does slow growth increase inequality? http://www.prosperitas.org.uk/assets/does-slow-growth-increase-inequality---paper.pdf.
Jones, H. (1976). An Introduction to Modern Theories of Economic Growth. Economics Handbook Series. McGraw-Hill.

Junginger, M., W. van Sark and A. Faaij (Eds.) (2010). Technological Learning in the Energy Sector. Edward Elgar, Cheltenham UK.

Keen, S. (1995). Finance and Economic Breakdown; Modelling Minsky's Financial Instability Hypothesis. Journal of Post-Keynesian Economics 17.4; 607-35.

Keen, S. (2011). Predicting the "Global Financial Crisis"—Post Keynesian Macroeconomics. Submitted paper.

Kümmel, R., J. Henn and D. Lindenberger (2002). Capital, labour, energy and creativity: modeling innovation diffusion. Structural Change and Economic Dynamics 13(2002)415–433.

Lyonnet R.V. and R. Werner (2012). Lessons from the Bank of England on 'quantitative easing' and other 'unconventional' monetary policies. International Review of Financial Analysis 25 (2012) 94–105

Mankiw, G. (2007). Macroeconomics, 6th edition. Worth Publishers, New York.

Minsky H.P. (1970). Financial Instability Revisited: The Economics of Disaster. Hyman P. Minsky Archive. Paper 80. http://digitalcommons.bard.edu/hm_archive/80.

Minsky, H. P.(1982). Can 'It' happen again ? A reprise. Challenge 25 (3) 5-13. 86, 221-235.

Minsky, H. P. (1986). Stabilizing an Unstable Economy. *Hyman P. Minsky Archive*. Paper 144. http://digitalcommons.bard.edu/hm_archive/144; 35, 125, 134

Minsky, H.P. (1992). The Financial Instability Hypothesis. Working paper no 74. Handbook of Radical Political Economy. P. Arestis and M. Sawyer, editors. Edward Elgar, Aldershot.(p 6)

New Economics Foundation (2013). Strategic Quantitative Easing ; stimulating investment to rebalance the economy.

Piketty, T. (2014). Capital in the TwentyFirst Century. Cambridge, Mass.

Pottier, A. (2014). L. Economie dans l'impasse climatique. Thèse d'Economie, CIRED. Paris

Romer, P. (1990). Endogenous Technological Change. Journal of Political Economy 98(1990)5:S71-S102.

Schich, S., and J.-H. Ahn (2007). Housing Markets and Household Debts: Short-term and Long-term Risks. Financial Market Trends Vol. 2007/1

Sterman, J. (2000). Business Dynamics.

Tainter, J.A. (1988). The collapse of complex societies. University Press Cambridge

Vries, Bert J. M. de (2013). Sustainability Science. Cambridge University Press, Cambridge.

Weber, M., B. Volker and K. Hasselmann (2005). A multi-actor dynamic integrated assessment model (MADIAM) of induced technological change and sustainable economic growth. Ecological Economics 54(2005)306-327.

Werner, R.A. (2012). Towards a new research programme on 'banking and the economy' -Implications of the Qunatity Theory of Credit for the prevention and resolution of banking and debt crises. International Review of Financial Analysis 25 (2012) 1-17.

Werner R.A. (2014). Can banks individually create money out of nothing ? – The theories and empirical evidence. International Review of Financial Analysis 36 (2014) 1-19.

Yamaguchi, K. (2010). On the Liquidation of Government Debt under a Debt-Free Monetary System; 28th international conference on system dynamics, Seoul.

Zarlenga, S. (2002). The Lost Science of Money. Valatie, NV, American Monetary Institute.

Appendix A Model experiments to explore system behaviour

In order to understand the dynamical behaviour of the model, some computational experiments are made to study the reaction of the model system to (sudden) changes in loans and technology, as these factors appear to be significant in the process of understanding the relation between the economic and the financial system. To this end the model is run without the sub-systems for government and banks, without technological growth and with a constant population (labor force). After an initial period of about 20 years, the model reaches the stationary state, which allows the study of the effects on stepwise changes for loans and technological progress.

The amount of money in the model only increases when it is created in the form of loans (money as debt). In order to explore the effect of loans on the behaviour of the system, a hypothetical bank loan of 5 billion (bn, 10^9) € is given during a 10 year period starting arbitrary in year 40 (Figure A.1 upper left). The experiment is made both for the case the loan is repaid and the case it is not repaid. The results are presented in Figures A.1 and A.2.

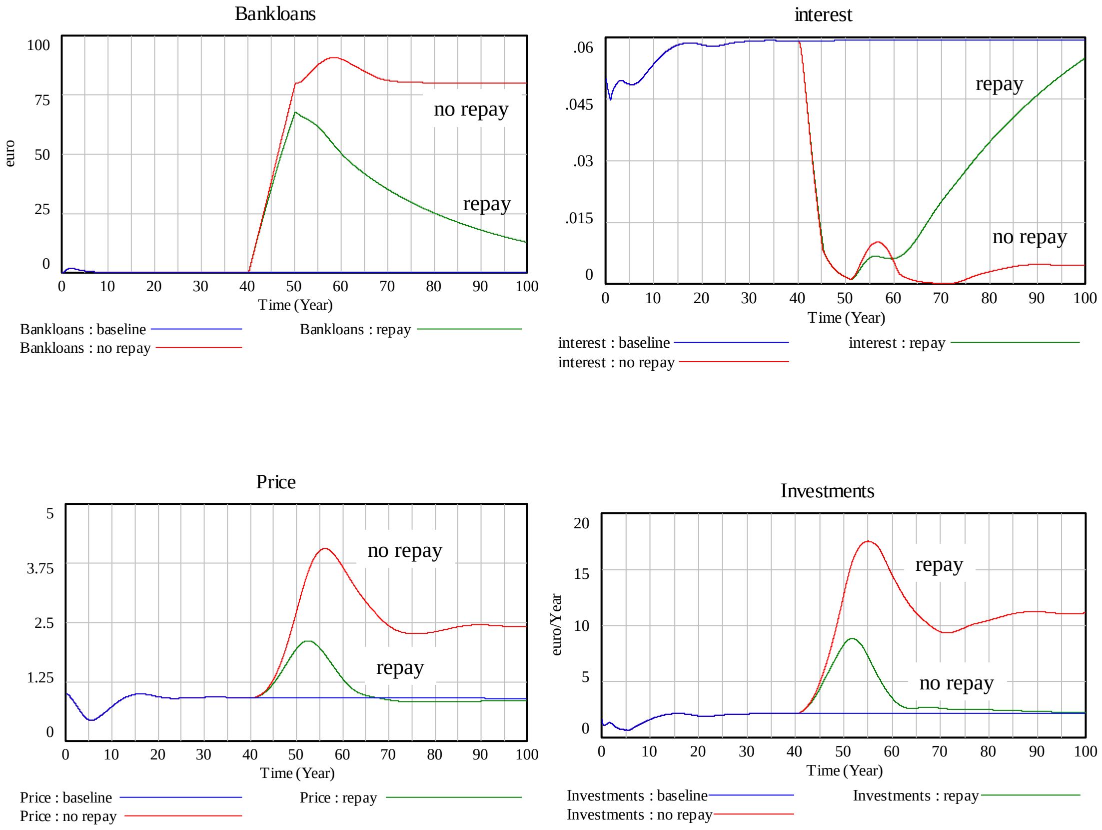


Figure A.1 Model response to an annual loan of 5bn € during a 10 years period.

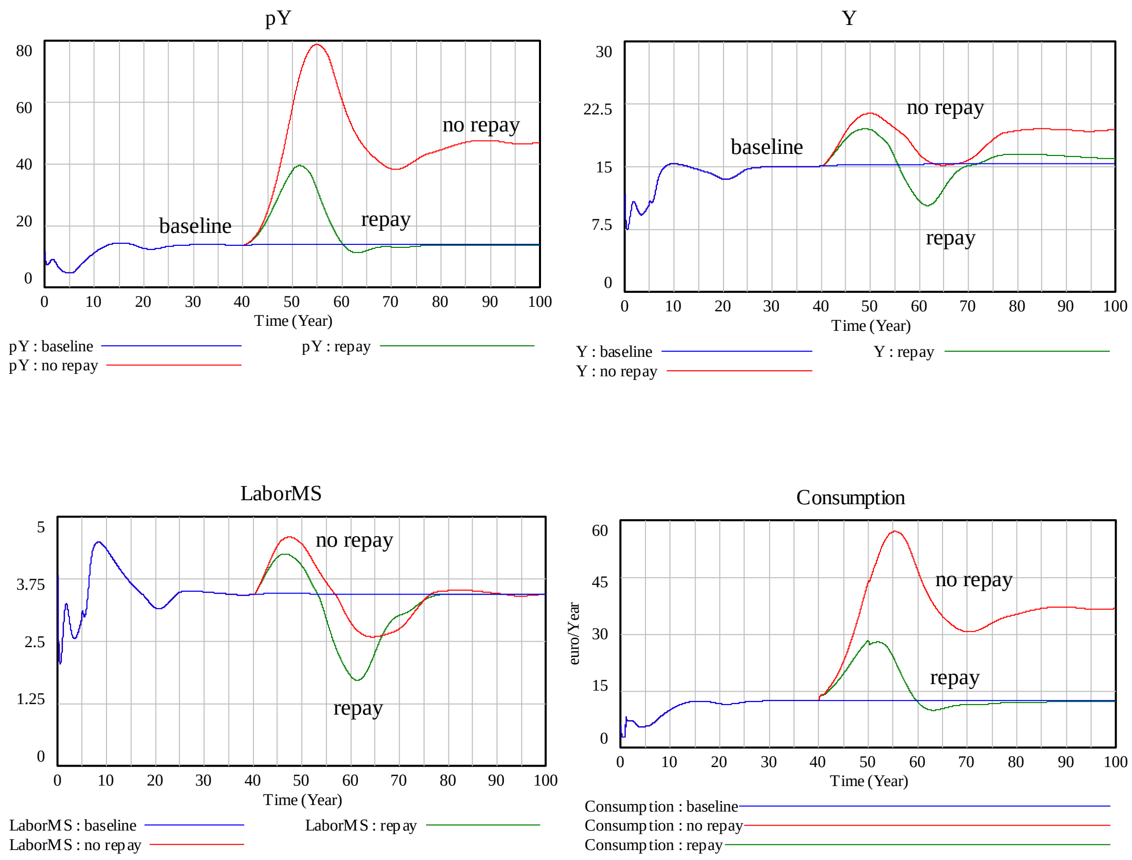


Figure A.2 Model response to a annual loan (with and without repay) of 5 bn € during a 10 year period.

As the lending comes to an end (in the year 50), the effects on both the real and monetary economy become negative as the loans have to be repaid and physical consumption and production decrease below initial levels. After repayment, the system returns to its initial, stationary state (baseline). Lending, and thus money creation, has a temporary effect on the economy, initially positive, negative later. This confirms the conclusions of Bezemer et al. (2013) in a study on the significance of financial development for growth: 'even though credit flows may give a short tem stimulus to growth, the longer term effect of financial development is negative'.

In case the loans are not repaid, the money which is created in the lending process is not destroyed by repayments but remains in the system. As the graphs in Figure A2 show, the economy now does not return to its initial state. In particular, the interest rate will remain at a lower level than in the baseline case because more money remains available as 'liquid assets' (Figure A.1 upper right). As a consequence of the lower interest rate and thus higher investment level, and in combination with the stimulation of consumption (aggregate demand) by the loan, also the physical output Y remains on a higher level than before the loan was given.

Technological progress

The response of the system to a sudden, stepwise technological improvement (breakthrough) in the manufacture sector is given in Figure A.3. Overall physical production Y increases significantly, which at the same time results in a corresponding drop in price level for the manufacture sector. As a consequence the effect of the monetary economy (pY) is negligible.

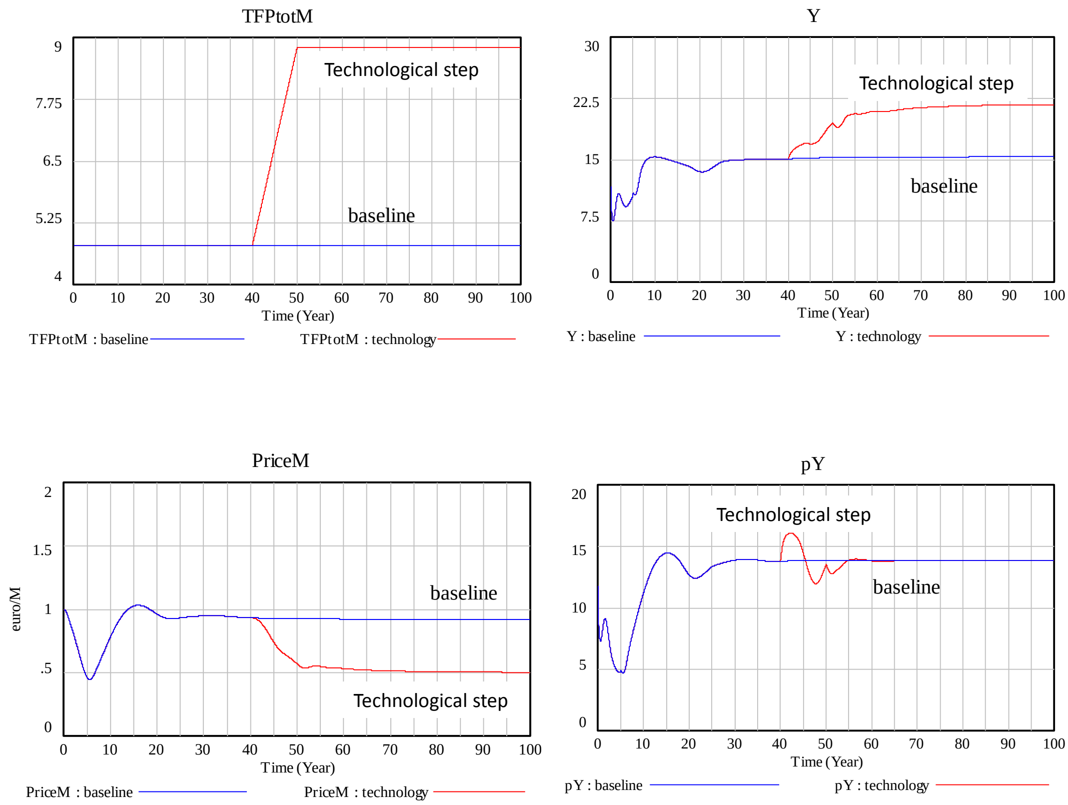
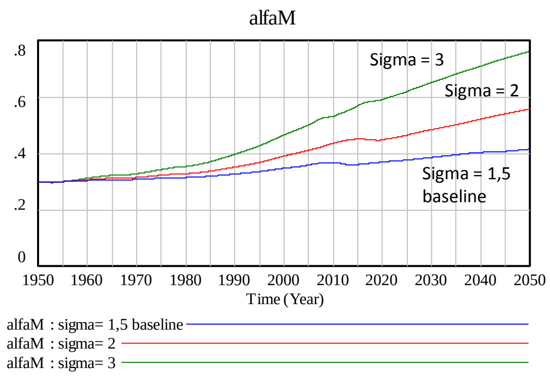


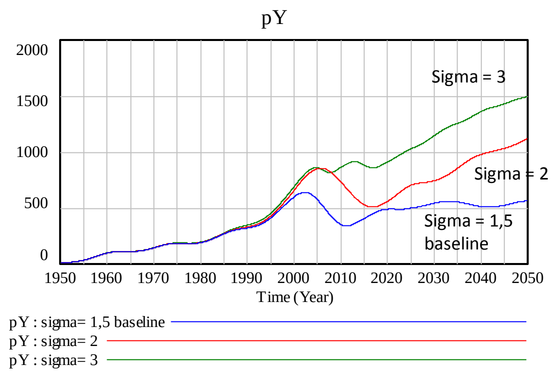
Figure A.3 System response to a stepwise change in the total factor productivity, as the result of a technological breakthrough.

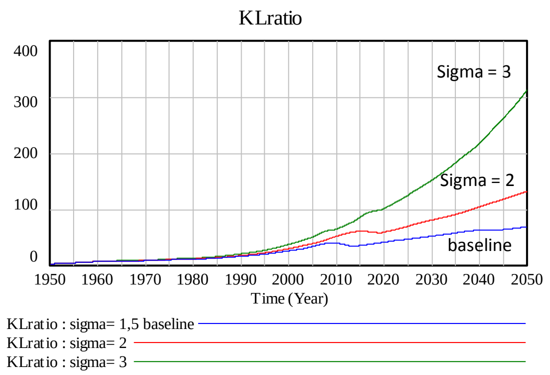
Increasing share of capital in national income

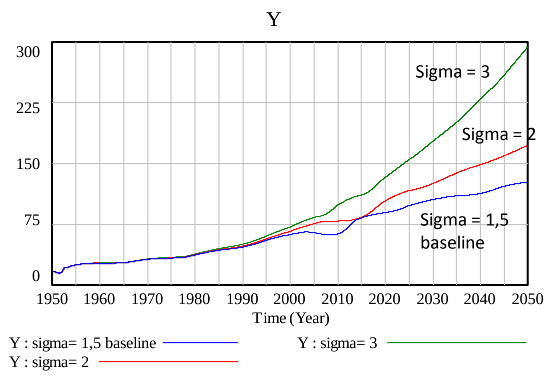
Empirical data indicate that the share of capital in the national income shows an increasing trend (Piketty 2014:222). This trend is explained by, among others, the increasing substitution elasticity σ which might reflect that capital increasingly can substitute labour through application of ICT and robots in many economic and social domains. As this is expected to be an important factor in explaining the GDP (~pY) growth from its constituting factors (growth accounting), the effect of an increasing substitution elasticity σ was studied.

The experiment is made for the full model over the modeling period 1950 - 2050. The results are presented in Figure A.3, for sigma σ -values, increasing from 1 in 1950, to 1.5 (baseline), 2 and 3 in 2050. The corresponding time development of α_M (upper left) show an increase from the initial 0.3 in 2050 to 0.4 in the baseline case, up to a (hypothetical) 0.7 for $\sigma = 3$. The KL-capital-labour ratio shows the increasing share of capital in the production process, with comparable implications for physical production Y. The increase in pY (GDP) is less pronounced, given the decline in price level, although this deflation in less in case of larger capital share.
Employment (not shown) remains on a higher, more constant level compared to the baseline case. This is a consequence of the (model-) behavior in which production at higher capital inputs increases to a higher overall level, thus creating again full employment.


alfaM
.8
.6
.4
.2
0
Sigma = 3
Sigma = 2
Sigma = 1,5
baseline
1950 1960 1970 1980 1990 2000 2010 2020 2030 2040 2050
Time (Year)
alfaM : sigma= 1,5 baseline
alfaM : sigma= 2
alfaM : sigma= 3


pY
2000
1500
1000
500
0
Sigma = 3
Sigma = 2
Sigma = 1,5
baseline
1950 1960 1970 1980 1990 2000 2010 2020 2030 2040 2050
Time (Year)
pY : sigma= 1,5 baseline
pY : sigma= 2
pY : sigma= 3


KLratio
400
300
200
100
0
Sigma = 3
Sigma = 2
baseline
1950 1960 1970 1980 1990 2000 2010 2020 2030 2040 2050
Time (Year)
KLratio : sigma= 1,5 baseline
KLratio : sigma= 2
KLratio : sigma= 3


Y
300
225
150
75
0
Sigma = 3
Sigma = 2
Sigma = 1,5
baseline
1950 1960 1970 1980 1990 2000 2010 2020 2030 2040 2050
Time (Year)
Y : sigma= 1,5 baseline
Y : sigma= 3
Y : sigma= 2

Appendix B Stationary state

This appendix contains a brief description of the mathematics of the real economy model. A more thorough analysis of the set of differential equations of both the real and the monetary economy has been made recently in Mathematica (Gomez 2015). This analysis indicates that the equations used in the SF-model represent a quite stable system, but that the propensity to consume and the fraction of firm investments that is taken up as loan are two assumption for which the model outome is sensitive, The simulation experiments also suggest that debt-based money does not imply a growth imperative.

Stationary states and optimality

The basic differential equations governing the behavior of the model economy are the following:

$$\frac{dK}{dt} = \frac{\pi_K}{\tau_K} K = \frac{1}{\tau_K}\left(\frac{\partial Y}{\partial K}\frac{1}{\rho+\delta} - 1\right) K \qquad \text{[G/yr]} \qquad \text{(B1)}$$

$$\frac{dL}{dt} = \frac{\pi_L}{\tau_L} L = \frac{1}{\tau_L}\left(\frac{p}{w}\frac{\partial Y}{\partial L} - 1\right) L \qquad \text{[hr/yr]} \qquad \text{(B2)}$$

$$\frac{dw}{dt} = \frac{w}{\tau_w}\left(\frac{L}{L_{max}} - e_{full}\right) \text{ with } e = L/L_{max} \qquad \text{[M/hr/yr]} \qquad \text{(B3)}$$

$$\frac{dp}{dt} = -\frac{p}{\tau_p}\left(\frac{H}{D^*}\right) \qquad \text{[M/G/yr]} \qquad \text{(B4)}$$

$$\frac{dH}{dt} = Y - D \qquad \text{[-]} \qquad \text{(B5)}$$

These derivations use a CD production form Y ~ $K^{\alpha}L^{1-\alpha}$ (eqn. 1). Recall that the output elasticity of a production factor X equals X (dY/dX) / Y. Inclusion of the additional feedbacks from a supply-demand mismatch and the financial model equations makes a formal analysis of the system more complex. It is postponed to a subsequent report.

When the net gain on hiring an additional unit of labour equals the net gain of investing an additional unit of capital, the optimal input of capital and labour occurs (production frontier) (eqn. B2). In this situation:

$$\pi_L = \pi_K \leftrightarrow \frac{p}{w}\frac{\partial Y}{\partial L} - 1 = \frac{\partial Y}{\partial K}\frac{1}{(\rho+\delta)} - 1 \qquad \text{[-]} \qquad \text{(B6)}$$

It follows that L_{eq} = (1-α)·(p/w)Y, if we make the simplifying assumption that there is no supply-demand mismatch (dH/dt = 0) or that the response from mismatch to labour market is infinitely slow (τ_L = ∞). Similarly, from the first equation B1 it is seen that the capital stock will be constant for K_{eq} = [α/(ρ+δ)]Y which tends to be about 1,65·Y (α=1/3; r=δ=0.1). It implies a capital productivity of 0,6. It also indicates that ρ has to be interpreted as the net rate of return on investments in the manufacturing capital stock. Thus, in the simulated economy, labour and capital are growing according to their respective (weighted) marginal productivities. The economy thus tends towards a stationary or equilibrium state given by {K_{eq}, L_{eq}} = [α pY / (p_K (ρ+δ)), (1-α) pY / w].

In the stationary state, (p/p_K) ∂Y/∂K = (ρ+δ). Using that ∂Y/∂K = αY/K, it is seen that for a vanishing profit rate we get:

$$\alpha p\, Y = p_K(\rho + \delta)K \qquad \text{[M/yr]} \qquad \text{(B7)}$$

At a vanishing profit rate, dK/dt = 0 and the economy is in a stationary state with I_{gross} = zero and K_{eq} = (1-α) pY / (p_K (ρ+δ)) assuming $p/p_K \sim 1$. The capital-output ratio is then given by K/Y = (1-α) / (ρ+δ) (cf. 'first law; Piketty 2014). Because in the stationary state the net investment rate has to equal the depreciation rate, we get for the savings rate:

$$\sigma = (p_K\,\delta\,K) / (pY) = \alpha\delta / (\rho+\delta) \qquad [-] \qquad (B8)$$

for $p/p_K \sim 1$, which provides a check on the actual values chosen[12].

Using eqns. B1 and B2 it is seen that this equality implies that:

$$\frac{K}{L} = \frac{\alpha}{(1-\alpha)}\ \frac{w}{p.(\rho+\delta)} \qquad [G/hr/yr] \qquad (B9)$$

This is the familiar equation of neoclassical economics (see e.g. Jones 1976), with K multiplied by p to convert it into monetary units and including the cost of depreciation. It shows that the growth path of the economy tends towards an efficient economy, that is, one in which the output Y is produced at the lowest total cost C = w L + (ρ+δ) K given the production function (eqn. 1). Investor behavior is such that the economy tends towards efficient allocation of the two production factors, in an attempt to reach Solow's 'balanced growth' path.

The behavior of the other three state variables, H, w and p, is simpler. The *price* change is a second order relaxation towards the situation that output Y equals the exogenous demand D. In the situation that demand D equals output Y (dH/dt = Y- D = 0) and H = 0 at time 0, the price remains constant (eqn. B4). Price stability thus requires that there is no supply-demand mismatch (H = dH/dt = 0), which was also the simplifying assumption in calculating L_{eq}.

The *wage* level w tends towards the situation that L = e_{full} * L_{max}, i.e. a situation of full employment (eqn. B3). In order to keep the wage rate constant, dw/dt = 0, the condition is that L = L_{des}. However, this has to coincide with L = L_{eq} which is the optimal level of the labour force from a supply point-of-view. In other words, the labour market is only in equilibrium if the labour force that is optimal from a producer point-of-view is also the socially desired level (L_{opt} = L_{des}). If L deviates from the level L_{eq} at which dL/dt = 0, i.e. L = (1-α)·p Y/w, the system will be in disequilibrium. The model thus stipulates that wage level w and labour force L oscillate around a stable attractor of the value [w,L] = [(1-α)pY, L_{full}] at the intersection of the two isoclines.

The above formulation largely follows the neoclassical description of the investment process, in as far as it presumes the existence of a production function in physical units that can be transformed into one in monetary units and the existence of a group of entrepreneurs who collectively have information on the prevailing productivity of capital in order to invest towards a net zero profitability. Such a view has been criticized by several economists, among them Keynes and later Minsky and Godwin (Davidson 2011).

[12] Using α = 0,33, ρ = 0,1 and δ = 0,1, the savings rate equals 0,165.

Appendix C Production functions

Aggregate economic production functions, such as the one proposed by Cobb and Douglas, have notorious shortcomings in describing modern economic growth. For instance, Helpman (2004) points out that the production function *per se* has little to offer in explaining economic growth patterns and con- and divergence; Pottier (2014) discusses the flawed reasoning that follows from the lack of empirical foundations. It is nevertheless widely used due to its mathematical convenience and the relevance of capital-labour substitution in, particularly, manufacturing. Improvements are possible, usually paid for with more awkward mathematics. For instance, the assumption of a substitution elasticity of unity implicit in a Cobb-Douglas (CD) production function is inadequate in the context of income and wealth inequality and Jackson and Victor (2014) suggest the use of a Constant Elasticity of Substitution (CES) production function.

The substitution dynamics in production functions can explain only a quite limited part of economic growth, a major reason being that productivity increase is being driven by technology and organization. In the Cobb-Douglas production function an explicit representation of *technology* is absent. The role of technology has been dealt with by introducing technological progress into the total factor productivity TFP, here indicated with A (Romer 1990; cf. eqn. 1). Because of the variety and complexity of technology dynamics, technology is often simulated with TFP as a simple exponential or logistic function, but also more endogenous descriptions have been proposed. In the current model, which covers a 100-year time period (1950 -2050), the role of technological progress has been and will be significant. We assume that labour productivity increases exogenously at a rate reflecting historical data for European economies and the Netherlands in particular.

The omission of the role of other production factors such as energy and materials, despite their important role in the prospects for long-term economic development, is another shortcoming.. An alternative for this inadequacy is the production function in capital stocks only, associated with the economist Leontief. This approach has been followed in the model of Goodwin (Goodwin 1967, Keen 2011), where output Y is expressed as proportional to the capital stock K and to the labour stock L with the labour productivity Y/A rising exponentially. Other approaches are e.g. Weber and Hasselmann (2005) who propose a dynamic economic model in which skilled labour is considered the only production factor. Ayres and Warr (2005) and Kümmel et al. (2002) consider explicitly the role of energy in long-term economic growth. In this study, we have postponed the explicit introduction of energy and materials to a next model version.

One important feature of a production function is the extent to which they can substitute each other is of great importance. This is known as the elasticity of substitution σ, defined as:

$$\sigma = \frac{d\, ln(K|L)}{d\, ln\left(\frac{\partial Y}{\partial L}\middle|\frac{\partial Y}{\partial K}\right)}$$

and it is a measure how responsive the ratio in factor use is to a change in the ratio of marginal factor productivity. For a Cobb-Douglas production function, σ can be shown to be unity (σ = 1). The effect of substitution is then neutral in the sense that an increase in the marginal productivity of capital (i.e. the return to capital) relative to labour (i.e. the wage rate) corresponds to an equal decrease in the capital-labour ratio k = K/L (cf. eqn. 10).
More elaborate production functions such as the Constant Elasticity of Substitution (CES) production function has more flexibility in the extent of substitution (see e.g. Victor and Jackson 2014). In case 0 < σ < 1, an increase in the productivity ratio implies a smaller than proportional decrease in k: labour is less easily substituted by capital, and vice versa, capital less easily substituted by labour. This might be the case in traditional, agriculture-based societies. In case σ > 1, an increase in the productivity ratio means a larger than proportional decrease in k and a continuous substitution of capital for labour is possible. An example of the latter are generic productivity-increasing technologies such as ICT and robotization.

Appendix D Historical data - the Netherlands 1950-2010

The model has been calibrated with statistical time-series for the period 1950-2010 for Dutch economy. To this purpose, we first calculate from statistical time-series the key variables that are to be reproduced in the historical model simulation: GDP (prices), K and L. The procedure is as follows.

We start with the historical time-series of GDP, which is equated to p Y taking p(1950) = 1 (cf. eqn. 1). The labour force L is taken exogenous as the product of the historical time-series for population P and for labour participation e; the latter is taken constant (0,4) for 1950-1970 and from statistical time-series thereafter. Assuming A(1950) = 1, K(1950) can be calculated for a given value of the K-L substitution elasticity α (assumed to be constant).

Next, the annual investment rate is reconstructed. For the period 1970 -2010 statistical data on firm investments are available. For the period 1950 – 1970 investments are derived by means of eqn. 10 from pY and estimates of the labour output elasticity α (assumed to be constant) and of the average depreciation rate δ (assumed to be constant) and the average annual interest rate r. This permits the calculation of the time-series of the variable pair {A_0,K}. The thus estimated values of the capital stock K are very sensitive to the choice of α: the higher it is, the faster capital will accumulate. They are less sensitive to the choice of δ, higher values meaning a faster depreciation and thus a lower rate of capital accumulation. Higher interest rates r will also decelerate capital stock growth.

In order to account for differences in the manufacturing and the services sector, we distinguish an M- and an S-sector and implemented the above variables with the assumption that the labour participation in each sector is 50 % and that the two sectors have different values for δ and α. The data suggest an increase of the capital-labour ratio K/L with a factor 3 between 1950 and 1989; this is in reasonable agreement with estimates by Van Ark (1995) for OECD-countries. The estimated productivity increase in real (volume) terms is for the period 1979-2004 in the same range as the estimate produced in the GCDD database. The resulting savings rate σ in this calibration starts around 0,3 in the 1950s, drops to values around 0,15 in the 1980s and slowly rises again to about 0,2 (cf. eqn. 11). These values are also in the range of other estimates.

Variable/parameter	Unit	value in base run	Source; comment
GDP	10^9 €	10,2 (1950)	Timeseries 1950-2010 CBS; pY equal to GDP
Capital stock K_0	10^9 €	K_0 = 8,4	Calculated from eqn. 1; value for NL 1950 assuming p=1
	10^9 €	K_{0M} =3	
	10^9 €	K_{0S} = 1	
Depreciation rate δ	[-]	δ_M = 0,15	Based on estimate of average rate of 10%/yr (M) and 5 %/yr (S)
	[-]	δ_S = 0,12	
Population P	10^6 p	10,1(1950) – 18 million (2050)	Timeseries 1950-2010 CBS
Employment rate e = L/P	[-]	0,38 until 1970; rising to 0,41	Fixed value for NL 1950-1970, time-series CBS thereafter
Desired employment rate e_{des}	[-]	0,9	Economic literature; model calibration
Labour force L_0	10^6 p	4.4 (1950)	Calculated from eqns 4 - 7
Sectoral labour force L_0	10^6 p	2,2 (1950)	Assumption: fraction of services 50 %
	10^6 p	2.2 (1950)	
Labour output elasticity a (in CES production function)	[-]	a_M = 0,28	Economic literature; model calibration
	[-]	a_S = 0,20	
Substitution elasticity σ (in CES production function)	[-]	σ_M = σ_S = 1(1950), then increasing to σ_M = σ_S = 1.2 (2050); baseline run	Economic literature; Piketty (2014); model calibration.
Consumer price p	1950=1		CBS