Monetaire hervorming; de mogelijkheid van een gezond financieel-economisch bestel

Dynamics of a sustainable financial-economic system

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Dit werkdocument (2e versie maart 2016) beschrijft lopend onderzoek in het kader van het Sustainable Finance Lab (SFL), een denktank die gericht is op een meer duurzaam financieel bestel. De bij deze studie gekozen uitgangspunten en geformuleerde conclusies zijn die van de auteurs en vertegenwoordigen niet noodzakelijkerwijze de opvattingen van het SFL.

Samenvatting

Om het functioneren van het huidige financieel-economische bestel te begrijpen en tot een wezenlijk beter alternatief te komen, is een systeem-dynamisch model ontwikkeld waarmee de wisselwerking tussen de reële economie en het financiële bestel wordt beschreven. De model-experimenten geven aanleiding tot de volgende conclusies:

- Het model bevestigt de hypothese van Minsky dat het huidige financiële bestel van nature (inherent) instabiel is. De afwisseling van perioden met groei ('boom') en perioden met krimp ('bust') kan goeddeels worden verklaard vanuit de door vastgoed (huizen-)prijzen gedreven kredietcyclus. Tijdens de groeifase stijgen de vastgoedprijzen, mede doordat banken steeds meer en steeds hogere leningen gaan geven (omdat de vastgoedprijzen stijgen). Het uit te lenen geld wordt door banken 'uit het niets' gecreëerd, door zowel aan de activa-kant als aan de passiva-kant van de bankbalans het uit te lenen bedrag als schuld respectievelijk als deposito bij te boeken. De bankbalans neemt daardoor toe met het uit te lenen bedrag. Op die manier is in Nederland sinds 1980 door private banken meer van 700 miljard € aan nieuw geld gecreëerd op basis van schuld. Zodra de oplopende schuld de economische draagkracht te boven gaat, komt het voortbestaan van banken in gevaar. Gegeven de huidige vervlechting van publieke en private verantwoordelijkheden, worden banken vervolgens door de overheid gered, ten koste van de belastingbetaler en de economie als geheel, met crisis als gevolg. Doordat er door de banken na de crisis omgekeerd juist te weinig geld wordt gecreëerd en de opgebouwde omvangrijke schuld moet worden terugbetaald, stagneert de economie nog decennia.

- De oorzaak van de crisis ligt in het gebrek aan coördinatie van de geldschepping door private partijen: teveel voor de crisis, te weinig erna. De mate van geldschepping is namelijk niet gebaseerd op het functioneren van de economie als geheel, maar op de waarnemingen en belangen van de individuele banken. Omdat monetaire economische groei door geldschepping een 'self-fulfilling prophecy' is, onder meer leidend tot stijgende huizenprijzen, ontstaat kuddegedrag, waardoor te veel geld wordt gecreëerd, wat vervolgens leidt tot dalende rente en (aanvankelijk) inflatie. Het vermogen van de Centrale Bank om via de rentestand het proces van geldschepping te beïnvloeden is volgens recente economische inzichten zeer beperkt, omdat de rentestand net zo goed het gevolg als de oorzaak van de economische ontwikkeling kan zijn.

- De modelsimulaties geven aan dat bij ongewijzigd beleid in de toekomst opnieuw crisissituaties zullen optreden als gevolg van de instabiliteit van het huidige bestel. Omdat de dynamiek van het systeem door ICT-ontwikkelingen binnen de financiële sector zelf steeds groter wordt, kan zo'n crisis al op vrij korte termijn optreden.

- Om tot een gezond financieel-economisch bestel te komen zullen oplossingen moeten worden gevonden voor de inherente instabiliteit van het systeem en voor de onhoudbare situatie dat geld om de economie te stimuleren alleen kan worden gecreëerd door schulden bij private banken aan te gaan. De oplossing van deze fundamentele problemen ligt in een systematiek waarin:
  1 (uitsluitend) de overheid het geld schept dat benodigd is om prijsstabiliteit (of volledige werkgelegenheid) te bereiken; het gaat dan om schuldvrij geld dat in omloop wordt gebracht in de vorm van extra overheidsuitgaven (bijvoorbeeld infrastructuur) en / of belastingverlaging bij gelijkblijvende uitgaven;
  2 burgers hun geld als 'wettig betaalmiddel' veilig op een door de staat gegarandeerde rekening met 0 % rente en 0 % risico kunnen zetten;
  3 banken (weer) makelaars worden op de financiële markten van vraag en aanbod van bestaand geld en hun maatschappelijke waarde ontlenen aan hun risico-expertise.

  Door deze publiek – private ontvlechting worden risico's op de juiste plaatsen teruggelegd, kan de markt zijn werk doen en kan het nu qua complexiteit onhoudbare toezicht sterk worden vereenvoudigd en daarmee alsnog uitvoerbaar worden.

- De op basis van prijsstabiliteit te creëren hoeveelheid geld wordt vastgesteld door een onafhankelijke 4e – financiële macht, vergelijkbaar met de onafhankelijke 3e rechterlijke macht. Het is aan de politiek om de besteding van dit geld te bepalen (bijvoorbeeld: infrastructuur, duurzame energie en/of belastingverlaging). Gegeven de nu bereikte Europese situatie zal invoering van het alternatieve systeem via de EU moeten verlopen. Dat betekent dat de Europese Centrale Bank (ECB), evenals de nationale Centrale Banken als onafhankelijke 4e financiële macht, volledig onderdeel van het overheidsbestel zouden moeten worden.

- Geldschepping door de overheid wordt niet alleen gelegitimeerd door de hier besproken stabiliteitsoverwegingen, maar ook door vele gezaghebbende filosofische, ethische en economische beschouwingen in de afgelopen eeuwen. Daarbij wordt geld gezien als een sociaal construct, als een maatschappelijke afspraak. Daarom moet het geld gedefinieerd, gecreëerd en in omloop worden gebracht door de gemeenschap, dus door de overheid. In de geschiedenis, ook in de laatste 60 jaar, was het niet de overheid, maar zijn het vooral private partijen geweest die teveel geld hebben gecreëerd.

- De overgang naar dit nieuwe monetaire bestel kan zeer geleidelijk verlopen en vrij eenvoudig vorm worden gegeven. Onder verantwoordelijkheid en toezicht van de nieuw gepositioneerde Centrale Banken zullen commerciële banken naast de huidige depositorekeningen een parallel (publiek) systeem van digitaal kasgeld moeten aanhouden met 0 % rente en 0 % risico.

- De modelexperimenten laten zien dat een dergelijk systeem goed kan functioneren. De economische ontwikkeling wordt weer (Keynesiaans) stuurbaar en geleidelijke economische groei komt weer binnen bereik. De kans op een volgende crisis neemt sterk af, al gaat die niet naar nul, omdat zich onder meer uitzonderlijke omstandigheden ook in de nieuwe situatie nog steeds een crisis kan voordoen. Maar die heeft dan veel minder effect op de publieke financiële infrastructuur.

- De hoeveelheid jaarlijks door de overheid te scheppen (en te besteden) geld is deels afhankelijk van de veronderstelde (technologie gedreven) groei van de fysieke economie en deels afhankelijk van het door de politiek wenselijk geachte inflatieniveau. In het model wordt op deze manier voor de jaarlijkse geldschepping een bandbreedte berekend van 2 – 4 % van het BNP, voor Nederland in de komende periode overeenkomend met ca. 10 a 25 miljard € / jaar, later verder toenemend.

- De in deze studie onderzochte monetaire hervorming kan een einde maken aan de monetaire crisis en een enorme (Keynesiaanse) stimulans voor de Europese economie betekenen, zonder de schuldenlast verder te vergroten. Een dergelijke economisch, staatkundig en moreel gelegitimeerde hervorming zou Europa nieuw elan kunnen geven.

Working Paper

Monetary Reform; dynamics of a sustainable financial-economic system

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This working paper (2nd version February 2016) describes research in progress by the authors in the framework of the Sustainable Finance Lab (SFL), 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 SFL.

Abstract

In order to understand the functioning of the current financial-economic system and explore the room for essential improvement of the system, 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 endogenously modeled crisis.
The current financial system appears to be fundamentally unstable, confirming Minsky's instability hypothesis. Lacking central coordination, euphoric herd behavior of the many private banks causes the unjustified creation of too much money, fueling ever increasing (asset) prices, GDP, wages, consumption and loans until financing cost becomes unbearable for individual households. As a consequence they will default on their loans, after which banks go bust and have to be recapitalized by the government, which has to increase taxation and decrease expenditures, altogether turning the system into the downward spiral of the bust, with subsequent stagnation of the economic system as a whole.

The model experiments show that money creation by the government, according to a 'money creation rule', for example 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 as well as consumption then follow a pathway of stable, continuous growth which reflects the increased productivity resulting from technical progress. Throughout history, money creation by the government is strongly legitimated and advocated by prestigious social, philosophical and economic thinking.

A smooth transition to the reformed monetary system seems feasible. Such a transition (only) requires the Central Bank(s) to be brought under governmental control and, under their independent supervision, the introduction of Digital Cash Accounts in existing commercial banks, parallel to the current demand deposits.

Given the current expectations about technology driven future growth of the physical economy, debt free money can, and has to be created at a rate of 2-4 % of GDP in order to achieve price stability. The higher end is reached in case an inflation rate (e.g. 2 % / year) would be preferred politically. The money can be used to lower taxation and / or to invest in democratically chosen projects, for instance in an efficient and renewable energy system. It would help the EU to overcome its current downward and unwinding spirals, and recover the road to the European dream.

Content

1. Introduction

Seven years after the 2007 /2008-financial crisis which 'no one saw coming' (Bezemer 2009), 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 serious threat (Tainter 1988). It might be comparable to that of a dysfunctional financial system. 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). His financial instability hypothesis 'is a theory of the impact of debt on system behaviour' (Minsky 1992).

Indeed, the huge creation of 'money as debt' 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 working 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 ; 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 end, 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 un-sustainability 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' 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 In the current version of the model, environmental constraints on the economic process are not yet taken into account.

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:
- 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 neoclassical 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.

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

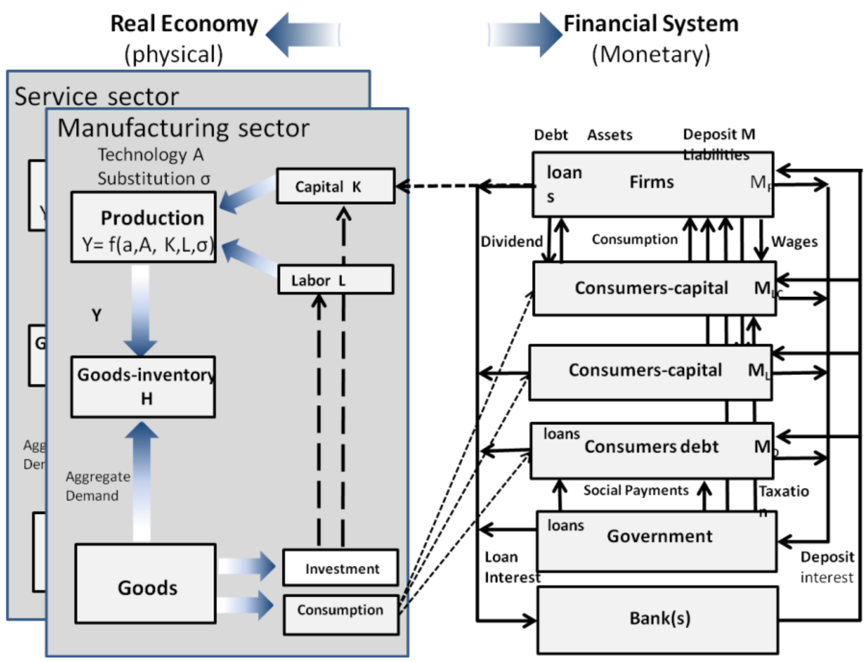

Figure 2.1 A schematic representation of the two parts of the Sustainable Finance model: the (real physical) economy (left) and the financial system (right) and their interconnections.

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

[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.

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.

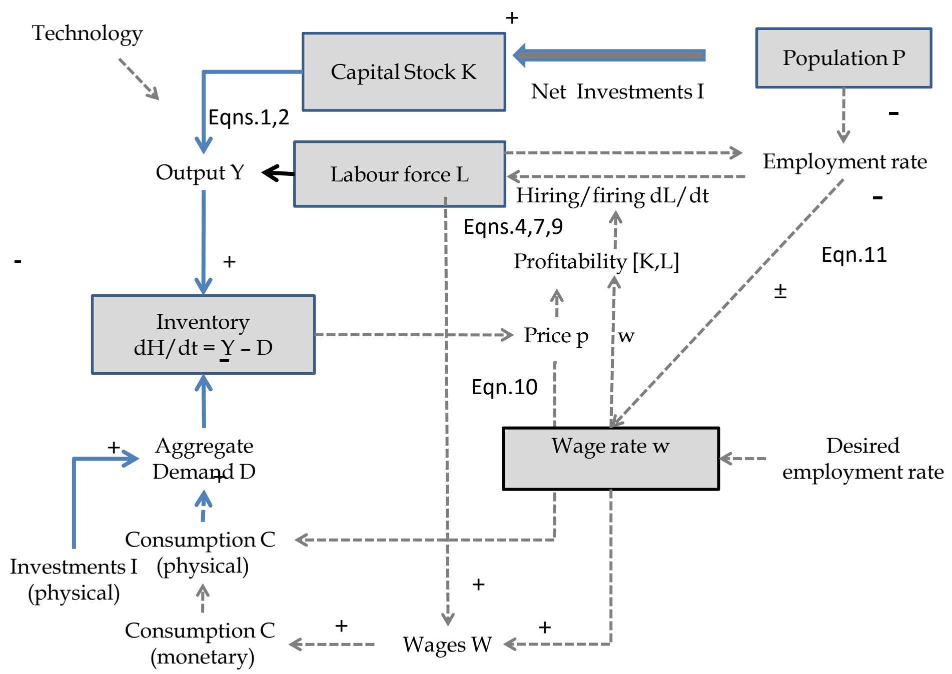

Figure 2.2 Scheme of the real economy model. Grey boxes indicate stocks that are governed by differential equations. Solid arrows indicate physical flows; dashed arrows indicate informational flows. Corresponding equations are indicated

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):

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

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 (σ > 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 σ =1, the CES production function is not defined and one can use the equivalent CD production function:

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

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 (σ = 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 δ K.

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 (ρ+δ) 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

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

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:

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

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:

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

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 $\partial Y/\partial L = (1-\alpha)\ Y/L$ (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-α), more labour will be hired, at a rate proportional to the marginal labour productivity expressed in wage units: p (∂Y/∂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 (ρ dK + δ 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 (ρ+δ)[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 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, the '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

[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 ∂π/∂K which equals p ∂Y/∂K – p_K(ρ+δ).

[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.

demand), indicated by dH/dt = Y – D. Following Hallegatte *et al.* (2007) we postulate that this feedback mechanism is via the ratio of the level of the inventory H and the demand D (

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

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 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):

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

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

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[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.

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) :

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

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:

$$p.Y \;=\; M.\,v \qquad [\text{M/yr}] \qquad (14)$$

The monetary output of the economy – pY which is the equivalent of GDP – thus (by definition) 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 (which is rather an identity than an equation) 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 assess 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 the usual 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.

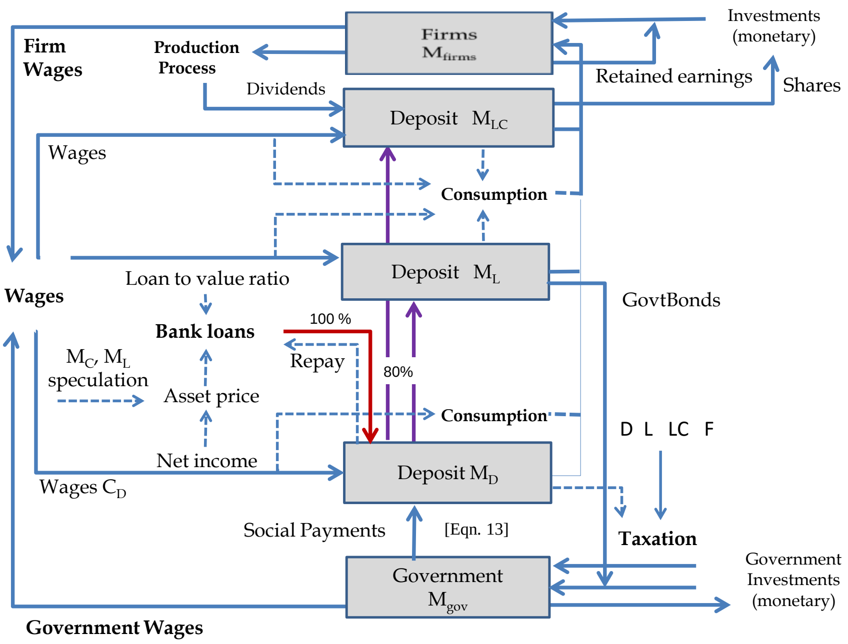

Figure 2.3 Scheme of the financial system model.

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

SFM transaction matrix						
	Consumers			Firms	Government	Bank
	inDebted 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	- ρ_l x BL_D			- ρ_l x BL_{firms}	- ρ_l x BL_{gov}	+ ρ_l x BL
Default on loans	+ f x BL_D					- f x BL_D
Recapitilization of banks					- f x BL_D	+ f x BL_D
Asset transfers	- 0.8 x BL_D	+ 0.4 x BL_D	+ 0.4 x BL_D			
Interest on deposits	+ ρ_d x M_D	+ ρ_d x M_L	+ ρ_d x M_{LC}	+ ρ_d x M_{firms}	+ ρ_d x M_{gov}	- ρ_d x M
Interest on bonds		+ (ρ_d+0.02) x B	+ (ρ_d+0.02) x B		+ (ρ_d+0.01) x 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 1 % 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; consumption as value added tax (VAT) on the actual consumption goods and services.

Under normal conditions, 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. In the special case of crisis, borrowers default on loans, after which bank go bust, unless saved by the government. The banks then are recapitalized to the minimum level of capital requirement (5 %).

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

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 loans given by the aggregate bank (AB) to a borrower appears on the left hand asset side of the balance sheet. At the same time this 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. 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, 70 % 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. As indicated earlier, the government debt is constrained 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 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, 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 that case ('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.

2.3 The Credit cycle and the 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.

In the SF-model the process is modeled 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 as the product of the asset price, the loan to value ratio and number of transactions (of mortgages). The asset price is derived from (the change in) net income, and speculative asset price inflation which is proportional to the (change of the) total amount of bank loans. As indicated earlier, a major part of these bank loans ends up on the deposits of the L- and LC-consumers, from where it will be used to a large extent for buying houses in the higher price segment. This implies that the money created in the mortgage lending process, partly remains in the housing market, with a subsequent asset price leveraging effect. This effect will be enhanced by speculative considerations with respect to continuously increasing asset prices. The result is a self-propelling process of (apparently) continuously increasing asset prices.

Higher asset prices result in higher bank loans, which also 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. 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:

- 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 have serviced their (mortgage) debt and eventually sell their houses Asset (house and land) prices are pushed upwards by speculative spending of this money.
- The ongoing rise in asset prices allows 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 households can no longer repay the principal and the interest; they will default on their loans. (n the model this threshold level of the gross and marginal residential quote is set to 0.35.
- Once the defaults become significant (25 bn under the 5 % capital requirement), the system experiences a tipping point: banks will go bust, unles saved by the government. In the model the Aggregate Bank is recapitalized by the government, backing up to bank equity to the capital requirement level.
- The saved banks reduce their ltv-ratio from the above-mentioned 120 % gradually to a lower level. More important, given the now vanishing expectations of continuously increasing asset prices, speculative behaviour vanishes too and asset prices become (only dependent of net income).
- 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 many 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. Lower income will result in lower asset prices. 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.

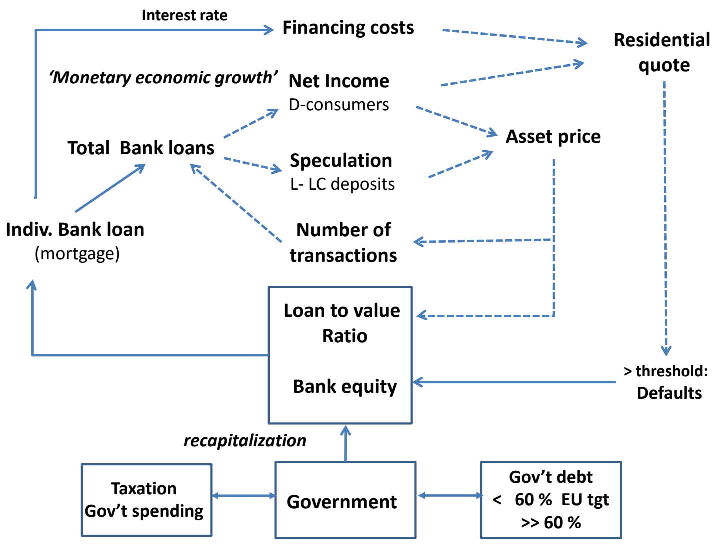

Figure 2.4 The asset driven credit cycle and the 'Minsky' moment at which the residential quote > 0.35, borowers increasingly default and banks have to be recapitalizedby the government.

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 to defaulting, particularly as when hit by unemployment. The subsequent deleveraging has also empirically been investigated (Cuerpo et al. 2015).

The resulting credit cycle sub-model

This process is modelled for the residential sector as these loans are in the Dutch economy by far the largest (Figure 2.4). Following the logic of Minsky's description, we postulate that the total amount of bank lending to the borrowing (D-) consumers causes asset prices to rise (80% of loans are assumed to be used for purchase of houses). This asset price inflation is reinforced by income growth and speculation. In the process, the loan-to-value (ltv) ratio which banks apply between loans and asset prices increases and the deregulation of the financial sector allows banks to accept values above what previously had been considered safe.
This process of giving out loans is modelled by making the (change in the) asset price p_{ass} a function of (the change in) net income $F_{D\ net}$ and the amount of 'financial' money i.e. money that is not part of transactions in the physical economy M_f [12]. Hence the following equation is used:

[12] We follow Werner (2012) in the assumption that part of the money stock is 'financial' money that is not active in the physical economy.

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

The loan given by a bank to a D-consumer-household equals p_{ass} times the ltv-ratio for each transaction, with the ltv-ratio given an exogenous time series that represents a value considered acceptable by the banks. The total loans BL_D given out by banks is now equated to the loan per D-consumer-household times the yearly number of transactions for existing housing and new housing n_{trans}:

$$BL = n_{trans} \cdot ltv \cdot p_{ass} \qquad (€/y) \qquad (17)$$

Under 'normal' economic conditions the yearly number of transactions n_{trans} is assumed to be a fixed fraction of the number of D-consumers - households, which as a long-term average has for existing houses estimated at 0,05. However, the actual number of transactions will also depend on the asset prices and the acceptable ltv-ratio. Decreasing asset prices and increasing ltv-ratio's provoke more transactions, hence:

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

with τ_{Bl} and $\tau_{p\,ass}$ specific time constants. Given empirical estimates of the average asset (house) prices, one can estimate the various parameters. In the model experiments, the above formulation causes a continuous increase in the loans given to the D-consumers as their income and the acceptable ltv-ratio increase.

As discussed, asset prices cannot go up forever. The ratio between debt servicing (interest plus repayment) and net income, also called the 'residential quote', reaches a level where an increasing number of households can no longer repay the (mortgage) principal and the interest. This results in defaults on bank loans and the subsequent writing off of these defaults from bank equity. Given the very low capital ratio of the bank(s) (5 %), defaults larger than 5 % imply a negative bank balance. At increasing defaults, banks will go bust (unless saved by the government).

At this 'Minsky moment' of crisis, three subsequent steps will be taken:

1 *Banks will gradually lower the loan to value-ratio* (eqn.17) as they become more prudent.

2 *Speculative increases in asset prices will immediately halt*, given the lower level of new bank loans and the subsequent expectation of deleveraging asset prices. This means that the speculative term in eqn.16 at least partly vanishes and τ_{spec} tends to ∞.
As an autonomous consequence, expressed by eqn.18, of both deleveraging bank loans and asset prices, the number of transactions decreases dramatically, amplifying the decrease in bank loans. As described by, amongst others, Biggs et al. (2010), the subsequent weakening of the flow of newly created credit implies a (moderate) decrease in aggregate demand and hence in consumption, via both income and wealth. This results in lower price levels (deflation; eqn. 11). The lower price levels result in lower 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.

3 *Government will recapitalize banks*, by restoring bank equity to the level of the (5 %) capital requirement. This will require tens of billions € and given the EU-constraint of maximum debt of 60 % GDP, will result in an increase of taxation and a decrease in government expenditures, both reducing aggregate demand and thus worsening the situation.
In the current European situation after the financial crisis, exceedence of the 60 % threshold level is temporarily allowed, in order to avoid further stress on the system . Additional model computations are made to explore the effect of increasing government debt rather than increasing taxes.

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.

Variable name	**Description**	**Unit**	**Value in base run**
K	Capital stock [manufacturing, services]	10^9 €	
L	Labour force	10^6	
Pop	Population	10^6	
e	Employment ratio (L/Pop)	-	
e_{des}	Desired em,ployment ratio (L_{des}/Pop)	-	0,9
p	Average price of goods and services (p_K = p)	1950=1	
w	Wage rate	10^3 €/pp	
ρ	Interest rate for investments	y^{-1}	3
δ	Depreciation rate (inverse of average lifetime of K)		0,15
τ_K	Time parameter investment adjustment		M 0,20 S 0,10
τ_L	Time parameter labour adjustment		M 0,05 S 0,025
τ_p	Time parameter inventory-price adjustment		2
a	Distribution parameter (eqn. 3)		M 0.3, S 0.2
A	Technology and organization parameter (TFP; eqn. 3)		5-15, 5-10
σ	Capital-Labour substitution elasticity		1 (2000) to 1,5 (2050)
b_{iLC}	Propensity to consume of LC-consumers (eqn. 13)		0,80
b_w			0,03
ltv	[Ceiling in] loan-to-value ratio i.e. residential quote		0,50

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; system inertia time constants:	yr								
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. The analysis is as follows:

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 65 / 8.2 = 7,9, from 9 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.

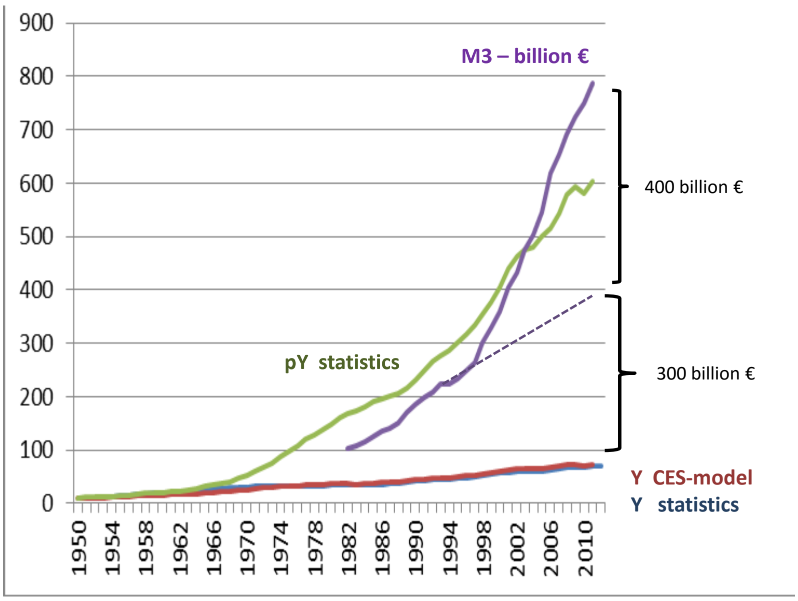

Figure 3.1 Physical production Y for the Netherlands 1950 – 2010 from statistical data (Y statistics); Y as estimated according to a CES-model.
pY (GDP) in billion €/year from historical data;
M3, the money quantity in the Dutch economy1982 – 2010 in billion €;
between 1982 and 2010, the money quantity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

The substitution rate σ in the CES production function is assumed for both sectors to increase from 1 to 1,4, starting in 1975, as a way to represent the ongoing technology-driven ICT, robotization and the like. As a result, the share of capital in national income increases from 0.30 to 0.40 for the manufacturing and from 0.20 to 0.22 for the service sector [13]. The parameters a and A have different values in the manufacturing and the service sector.

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.

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.

Price stability, as the core objective of the Central Bank , apparently has not been met over the past 57 years before the 2007/2008-crisis. Defining price stability as a 2 % inflation rate, prices are expected to have increased with a factor 3.1. However the real increase of the overall price level amounts the above mentioned factor 8.2. Overall average inflation thus have been higher (3.8 %), as a result of too much money creation.

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 35 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.

[13] Of course, the increasing share of capital in output has other causes, such as favourable tax regimes, rent seeking behaviour of corporations and others (Stiglitz 2012).

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 which are not taken into account in the model. 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.

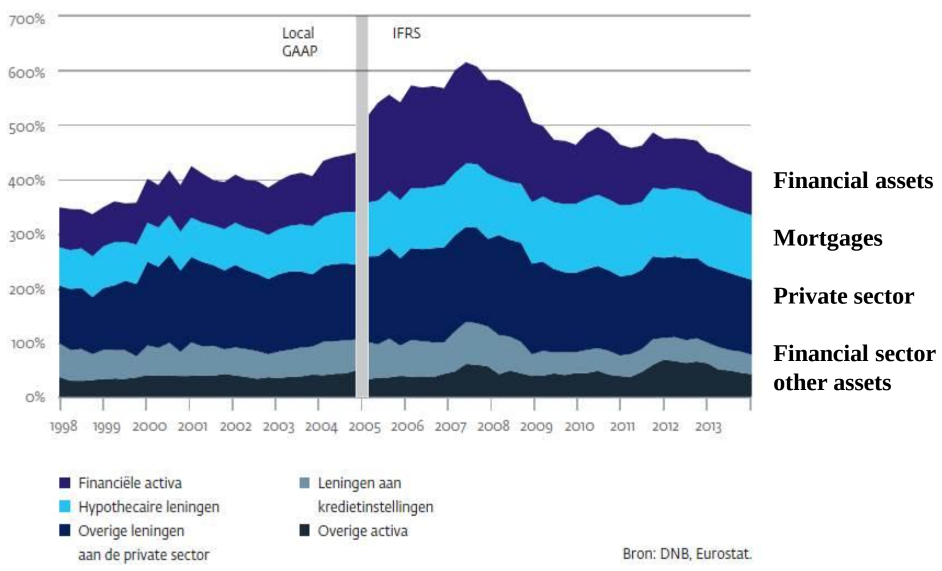

Figure 3.2 Overall balance of (Dutch) banks; 100 % of GNP (left y-axis) corresponds to 600 bn €/year. Source; De Nederlandsche Bank DNB, Eurostat

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 between 1975 and 2050, 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 manufacturing sector and from 0.20 to 0.23 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 gross and marginal residential quote (financing costs / net income) of 0.35 is reached. This gross level is rather higher than the empirical net level of about 0.25 as the (for the Netherlands very significant) tax dispensation on mortgage interest is not accounted for in the gross residential quote. The net quote is in reasonable correspondence with the empirical value of 0.25. It is marginal in the sense that it represents the net income and financing costs of mortgages taken in the last year.

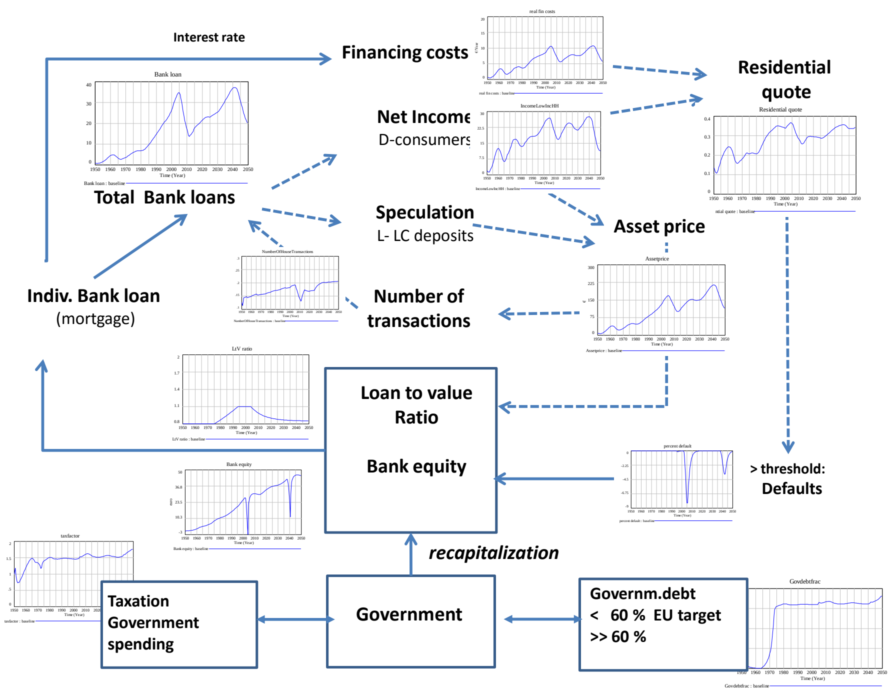

Figure 4.1 Results for the credit cycle and the 'Minsky' moment, when a gross (and marginal) residential quote of 0.35 is exceeded, borrowers default and banks have to be recapitalized by the government.

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.

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 4.2 and 4.3. For the period 1950-2000, the trajectories of monetary output (GDP), price, employment,interest rate and investments reproduce 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 4.2 lower right).

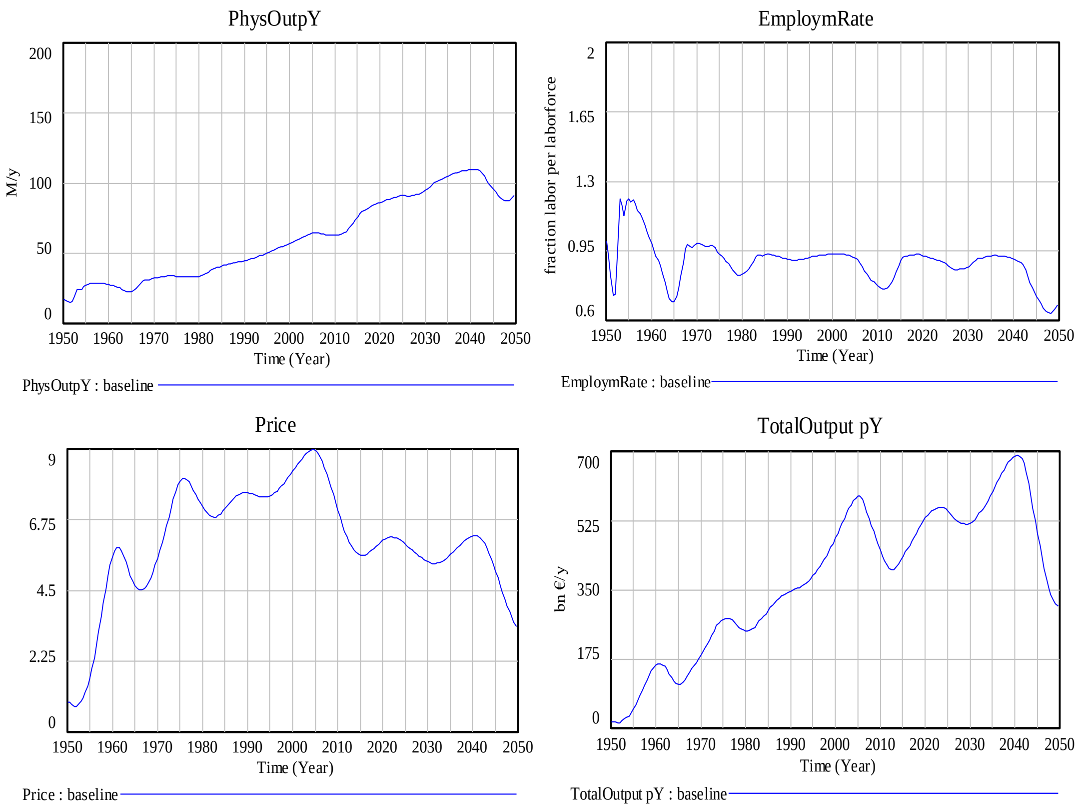

Figure 4.2 Results for the modelling period 1950 -2050 for total production (Y), employment, price (M- and S-sector) and monetary production (pY);

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 nine 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 400 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 lower left; total liabilities) of about 550 bn € fall short of the 800 bn € as derived from the empirical data of Figure 3.1. This discrepancy might be explained form the additonal (money creating) loans to financial institutions, as discussed in chapter 3.

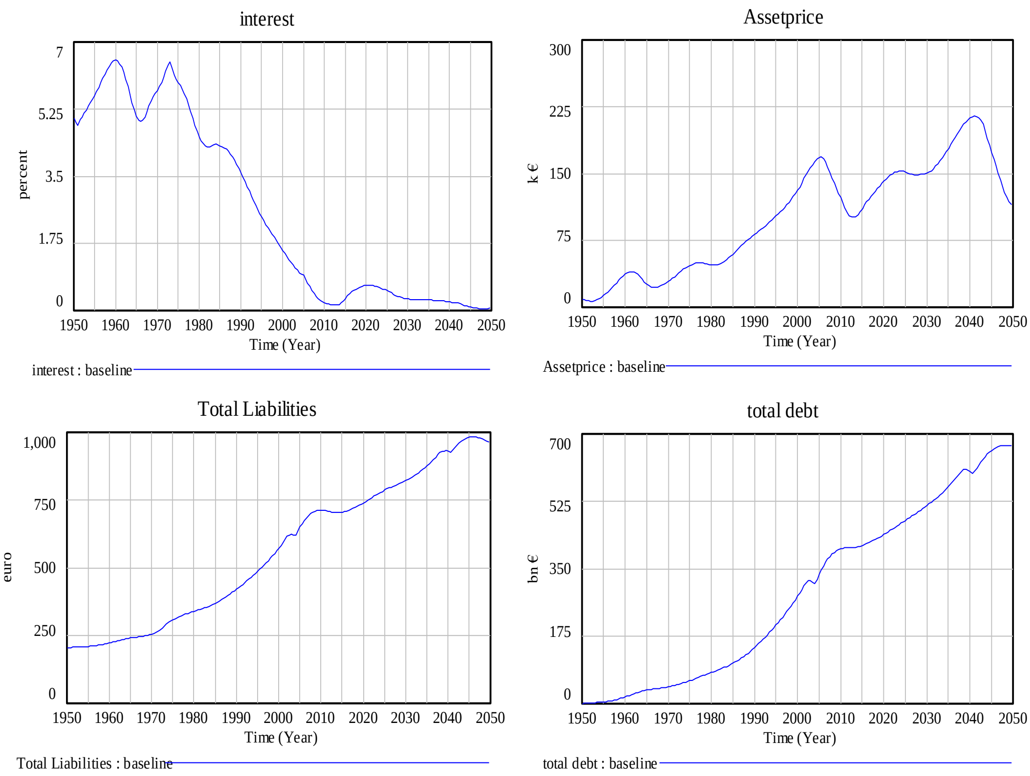

Figure 4.3 Results for the modelling period 1950 -2050 for the financial sector variables interest rate, asset price, total liabilities and total (consumer) debt.

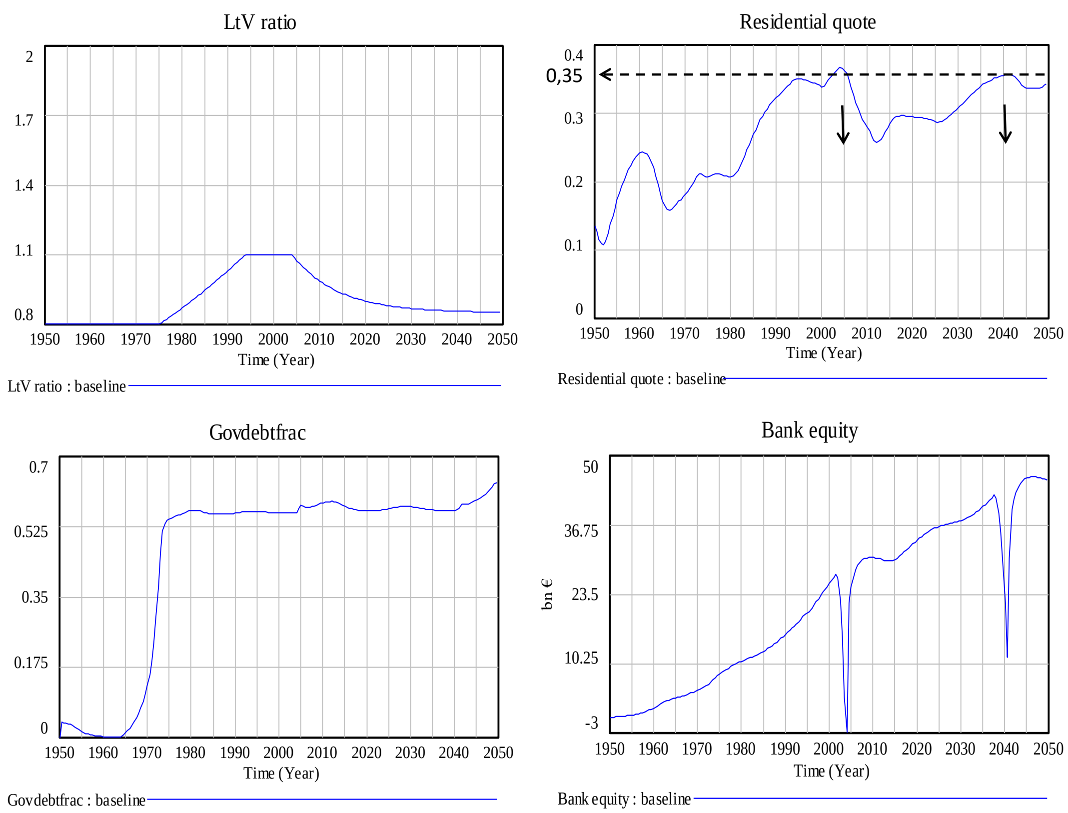

Figure 4.4 Credit cycle related variables in the baseline run:, loan to value ratio, residential quote, government debt fraction, bank equity and asset price.

In Figure 4.4 upper right it is shown how the residential quote exceeds the theshold of 0.35 around 2005, after which increasing defaults on loans forces bank equity to fall many billions euto's below the capital requirement, as shown in Figure 4.4 lower right. Recapitalization by the government restores bank equity to the 5 % capital requirement level. After the crisis, the asset price recovers, as shown in Figure 4.3 upper right. Notwithstanding the gradual decrease of the loan to value ratio after the first crisis (after 2005), the recovering net income in combination with the same asset price mechanism as before the crisis c auses the residential quote to gradually increase again, exceeding the 0.35 threshold again after which the next crisis is immanent. In the model this second crisis occurs in 2040, under the conditions that the mechanism after the 2007 / 2008 crisis is the same as before. But given the continuous increase in new IC- technologies, the current mechanism might be more dynamic and evolve faster, suggesting a next crisis to occur earlier.

4.3 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 / or directly from banks. For the current model runs, it is assumed that the government acquires 70 % of the money on the financial markets by selling government bonds. This then reduces the amount of 'liquid assets' on these markets (as formed by the deposits of both the L- and the LC-consumers, minus their consumption). The remaining 30 % is lend from private banks, which implies that this money is newly created.

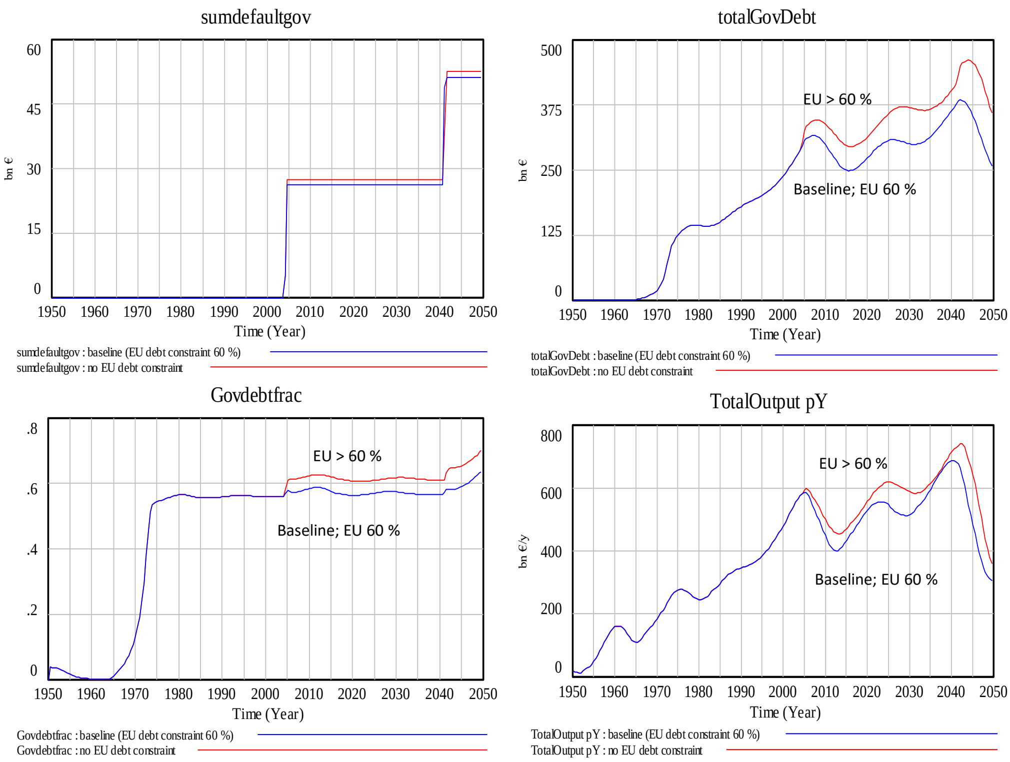

Figure 4.5 Model results in case government debt is constrained to the EU 60 % of GNP target (baseline) and in the case unconstrained debt > 60 % GDP : Recapitalization by government, total government debt, actual fraction of government debt and resulting level of pY (GDP).

In the baseline run, the government debt is constrained to 60 % of GDP (~ pY) according to EU-regulations. In case the debt, including the debt which results from the instantaneous recapitalization of banks, is increasing above this level, government spending is reduced and taxation is increased to meet the 60 % constraint with consequences for the economic system as a whole. In Figure 4.5 upper left, the recapitalizations for the first and the second crisis are shown, summing up to some 50 bn €.

However, in the current political context, debt is allowed to exceed the 60 % of GDP level, in order to avoid too much negative impact on the economy as a whole. In that second case, the constraint no longer applies and debt increases (slightly) over 60 %, corresponding to an increase in total government debt of 50 bn € as shown in Figure 4.5 upper right. In this case, taxation is not increased, government expenditures not decreased and total monetary production (GDP) would be tens of billions € higher than in the baseline case, in which the EU-constraint is maintained.

During the 2007 / 2008 crisis, the real increase in debt (in the Netherlands) was about 100 bn €, two times as high as the 50 bn € in the constrained case baseline simulation in Figure 4.5. Model experiments have been made in which the recapitalization of banks by the government amounted to this 100 bn €, under the EU-constraint. But in this case the increase in taxes and the decrease of government expenditures brought the system to collapse, i.e. monetary production spiraled down to zero. This seems to support the current policy of allowing exceedance of the 60 % debt constraint.

4.4 Accumulation of non-productive money

As pointed out by Werner (2012) the mechanism in which money is created to finance non- productive assets like houses (mortgages) is expected to lead to an increasing amount of money on the L- and LC-deposits which does not play an active role in the economy. Apart from mortgages, this also holds for money which is created for speculative ends on financial markets. It thus is expected that the velocity v = pY / M will decrease in the process. In Figure 4.6 the velocity for the combined L- and LC- deposits is given. Indeed the velocity gradually decreases after the initialization period. The fraction of the deposits which is continuously circulating in the real economy of wages, dividends, consumption and investments becomes smaller over time. Apparently a large part of the newly created money ends up as 'dead money' on the L- and LC-deposits and does not create value added in the real economy as does credit for production and consumption.

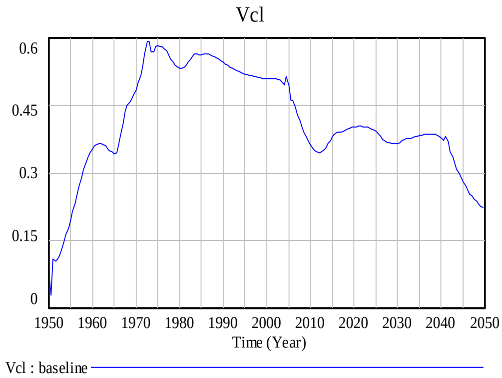

Figure 4.6 Velocity v = pY / M for the L- and LC-deposits combined

4.5 Economic stagnation

As indicated by Figure 4.6, an increasing amount of money which is accumulating on the L- and LC-deposits, is not used for consumption, investments or for buying government bonds. . Apparently the amount of money in the system is adequate and it is not surprising that in eq.15 the investments never have been constrained by the liquidity on the L- and LC-deposits. As discussed above with respect to the asset price driven credit cycle, the money on these accounts to a certain extent plays a role in the acquisition of illiquid assets. Another part may be involved in extra investments in shares, as a result of (not modeled) stock market bubbles, in which actual share prices are higher than would be expected from demand and supply of money for investments. So lack of investments cannot explain the overall stagnation of the economic system as a whole, as reflected by total output pY (GDP) in the figures presented above.

As demonstrated by Figure 4.2, the stagnation of the system as a whole in the first place is a monetary stagnation, in particular for the first crisis (around 2007); the second crisis around 2040 shows a far stronger effect on the material consumption and production.
After the first crisis, physical production (Y) and aggregate demand only show a temporary stagnation with only a slight decrease in absolute levels, partly due to the rather optimistic model assumptions with respect to ongoing technological progress. The stagnation of aggregate demand is associated with the increasing amount of debt, which has a moderating effect on the consumption of the indebted D-consumers. The much stronger monetary effect is the result of the significant reduction of bank loans after the crisis. Apparently the same herd behavior which resulted in too much money creation before the crisis, results in too less money creation afterwards.

4.6 Conclusion: lack of coordination

The model can give a meaningful reconstruction of the overall long-term dynamical behaviour of the Dutch economy. 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 economy which increases aggregate demand and drives partially inflated growth. Rather than the Central Bank target of 2 % inflation / y, overall and average inflation increases to almost 4 % / y. Apparently too much money is created. With the rapid extension of lending for mortgages and financial transactions, the newly created money increasingly ends up the deposits of the non-lending L- and LC-consumers. As a significant part of this money is reinvested into assets, the prices of assets increase proportionally stronger than net income. As a consequence the residential quote increases as well. The process halts as soon as the residential quote reaches a threshold value after which an increasing number of households cannot service their debts any longer. Banks have to write –off these loans beyond their very low bank equity levels. The subsequent bail out of banks by the government to restore their capital ratio's aggravates the situation further, as taxation has to increase and government expenditure (consumption) has to decrease, thus resulting in lower aggregate demand.

At this 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 repayment 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 system, the same dynamics will repeat itself. In the model this results in a crisis around 2040. However, in reality the dynamics of the system are expected to increase, given the expected increase in ICT-technology. This implies that a next crisis might occur earlier.

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, 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 that 'the interest rates appear as likely to follow economic activity as to lead it' (Werner, 2012). Lacking central coordination, (monetary) economic growth by decentralized money creation is a self-fulfilling prophecy which brings about the unjustified herd behavior of the many private banks creating too much money based on the expectation of ongoing growth in incomes and asset prices. After the inevitable decline as a result of similar herd behavior, the system has to be rescued by the government through centralized coordination, which can only be done, at least partly, at the expense of the taxpayer.

5 A sustainable financial-economic system

In search for an alternative, more 'sustainable' financial-economic system, the fundamental flaws of the current system have to be overcome. The findings of the previous paragraph suggest room for improvement in the centralization of the money creation process. Money creation by the one central monetary institution instead of the many private banks can continuously be adjusted to the actual state of the economic system. . At least in theory, this adjustment of the amount of money on the basis of societal objectives has the potential to mitigate or even eliminate the boom – bust cycles characteristic of the present system.

5.1 There is an alternative

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. They even predict large output gains approaching 10%, as a result of a transition in which all existing bank deposits are converted overnight into state issued money, whereby the government receives seignorage which is used for reduction of public and private debts. The model presented in this working paper however does not contain such an overnight conversion. It proposes a more gradual transition to an economy based on state issued money, in connection with the development of a digital cash money system, that supports direct payments from payer to payee. Digital Cash Accounts are no part of any banks balance sheet, apart from a bank's own Digital Cash Accounts. Digital cash payments do not involve clearance between banks.

Assuming that such an alternative has to be realized at EU-level, the alternative for the current system can be summarized as follows:

a ***Public and private responsibilities are fully disentangled***; there is no public responsibility for private risks. This disentanglement of responsibilities is achieved by separating money from bank credit. This is implemented by the creation of a digital cash system based on a key registration of digital cash holdings by the (EU-)government.

Digital cash is held on Digital Cash Accounts (wallets) outside the credit system, provided by the government but administered via payment service providers, such as currently existing banks. Money on a Digital Cash Account is not lent out, as bank deposits are, but is the property of the accountholder, and 100% free of credit risks. No one other than the account holder can use the money on these accounts for money transactions, such as making loans or payments. The Digital Cash Key Register has a similar position regarding the possession of money as cadastral systems have for land ownership.

Bank deposits remain what they actually are: bank credit that is made available to commercial banks to finance their operations. It is therefore subject to (systemic) credit risks. This implies that depositors cannot use their deposits for making payments, without first withdrawing these deposits. The risks involved with bank deposits are no longer supported by government. The payment system based on bank deposits is phased out. The current interbank clearing system is divested from the public sphere, or discontinued.

Banks can borrow money from the public, in the form of digital cash, via the banks own Digital Cash Accounts. Such lending is risk bearing. There might be gains and losses in the process, both for the banks and for the lenders. Profits and losses however are only of private, not public concern. The public is not obliged to seek risk and profit, as it has the option to store money safely in the form of digital cash. As payment service providers, banks have the option to offer both risk bearing accounts, and risk free Digital Cash Accounts, which are basically held with the public Digital Cash Key Register.

Banks 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 in the system remains the same.

b ***Money is created debt-free by the (EU-)government*** via a distinct governmental body (e.g. a Reformed Central Bank – RCB), as a separate (4^{th}) power of government, according to a legally agreed money growth rule. Although separated, the money creating power is accountable to the other branches of government, and subject to legislation that specifically sets the scope and standards for the use of its powers. The current Quantitative Easing (QE) program of the ECB comes close to a debt-free alternative for the present financial system, although the ECB is currently not properly equipped for direct and targeted monetary steering. As the ECB operates now, it brings new money in the economy in an ineffective and dangerous way. It brings too much liquidity in the credit system by buying bonds from financial institutions (banks, pension funds etc.) with little positive effects for demand driven economic growth. A transition to the alternative system could start within the framework of the European Monetary System (EMS), but would require negotiations on the European level for its proper implementation. It would allow direct investments in Europe-wide infrastructure with positive aspects on economic growth on social cohesion and sustainability.

In this alternative which will be denoted as ‘Reformed Monetary System’ (RMS), commercial banks can still play a relevant societal role as real intermediaries on the financial markets. Their core expertise in risk analysis is a key functionality in intermediating between the money creating government and the public on the one hand, and the need for finance from the side of business and consumers (stock, loans, mortgages) on the other. This implies full separation of public money creation responsibility and the private function of credit mediation.

Increasing (Basel-) regulation, in order to control the current public-private entanglement, leads to more complexity and inefficiency. By public-private disentanglement, the complexity of the private part of the financial system can be left to the complexity reducing market mechanism. As a consequence, supervisory monitoring of the private, market oriented part of the financial system can be reduced to a minimum. Like in other market sectors, the government only has to ensure adequate consumer information, in this case with respect to actual risks on financial transactions.

Money creation

Under the Reformed Monetary System (RMS), 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. section 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’ 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:
- by spending money directly in democratically chosen projects without interference of the financial system. Such investments, in physical (renewable energy, transportation etc.) and social (health, education etc.) infrastructure increase aggregate demand and stimulate the economy, as suggested by Keynes;
- by reduction of taxes (through compensation of the deficit by new created money); in this case not the government, but the consumers (are expected to) stimulate aggregate demand into a social / political desirable direction;
- by lending money to commercial banks, who in their turn lend it out to finance the real economy.

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 'Reformed Central Bank' (RCB), the risk that governments would be seduced to create too much money becomes much less. In model terms, this means that money which is created and brought into circulation by the government (via the Reformed Central Bank) is introduced into the financial-economic system via government expenditures and/or tax reductions. Both stimulate the real economy. Such a Keynesian stimulation of the economy can be far more effective than stimulation by means of interest rates only.

Money growth rules

In the model experiments presented below, money creation has been directed to price stability which is the most common objective of Central Banks. As a consequence, there is (by definition) no or minor inflation or deflation. A moderate inflation (e.g. 2 %/yr) could be incorporated in the money growth rule – it is a political choice. One could also introduce employment as an additional target variable. Because the level of real physical growth is difficult to predict, the amount of money to be created from year to year cannot be determined exactly. However, a similar problem occurs when the government budget for future years has to be established (by the CPB-bureau). Next year estimates correct eventual mismatches in the estimate for the previous year. Such minor deviations from the optimal path of money creation should be compared to the instabilities of the past 25 years during which far too much money was created by private banks.

Second, money growth could be structured as an anti-cyclic response to pro-cyclic behaviour. And if desired from a political point of view, a certain fraction of the money to be created could be reserved for direct lending to mediating, credit supplying banks. The constraints on the total amount of money to be created by the government will then result in an increasing interest rate. In this way the market itself can regulate the scale at which credits are granted.

In the case of eventual decline of the physical production, the question remains how to reduce the amount of money in the system. Here the reverse route has to be followed as in the case of money creation. Instead of spending more (not yet existing money) or lowering taxes, the government now has to spend less money than obtained from taxation, thus 'destroying' the money which has been 'saved' in this way. However, this 'taxing money out of circulation' is seen as hypothetical, as under conditions of decline (bust), the government should spend more money (at the demand side) or lower taxes in order to stimulate consumption and thus the economy.

5.2 The Transition

The transition to the Reformed Monetary System (RMS) should be as smooth and simple as possible, avoiding discontinuity and unforeseen complications. To that end and taking into account the present structure of the European financial system, a market driven transition, as suggested by Wortmann (2016a and 2016b) is seen as the most promising. In that approach, the following changes are made and steps are taken in the transition:

- A public facility ('Digital Cash Key Register') owned and run by the state, provides the above mentioned Digital Cash Accounts, on which consumers and firms can put their money at 0 % interest and 0 % risk. Payment service providers, such as existing banks, can offer such accounts to the public, as a front-end facility under supervision of the Reformed Central Bank. Digital Cash Accounts are interoperable with the current inter-bank clearing system, allowing digital cash payments to and from current bank deposit accounts, in the same way as payments via demand deposits are made in the current situation.

- Government gradually dismantles its support, including deposit guarantee schemes, for the use of bank deposits as a means of payment and a store of value; bank deposits are risk bearing investments, not savings. Interbank clearing is phased out as the prevalent core of the payment infrastructure, and replaced by a digital payment system, based on the Digital Cash Key Register, in which money is directly transferred from payer to payee. Interbank clearing will in due course be divested from (EU)-Government / the RCB, or discontinued.

- The Central Bank is reformed to the central monetary institution that is a separate (4^{th}) power of government. The Reformed Central Bank (RCB) is the core of the public digital money system on the condition that it brings and keeps its exposure to credit and commercial risks to zero. It basically transforms into a non-banking governmental organization, and has to sever its special ties with commercial financial institutions, such as banks. The Reformed Central Bank cannot serve as an interbank clearing-organization. Money in the reformed system is information, neither credit nor a liability, and is in itself not exposed to any risk, apart from fraud and mismanagement of the (digital) money system. It is not backed by anything apart from the power of central (EU)-government, strengthened with transparency, democratic control and institutional oversight.

- Payment service providers, such as commercial banks, offer their customers front-end Digital Cash Accounts under direction and final responsibility of the RCB, besides the current bank deposits. Clients now can choose to transfer (a part of) their bank deposits to these accounts, which makes their savings in-active and free of risk.

- Having the Digital Cash Accounts now running parallel to the current bank deposit accounts, the payment system can be migrated without discontinuity, from operating on bank deposits to Digital Cash,, guaranteeing a smooth transition to the new system.

- By the client driven transfer of (a part of the) bank deposits to Digital Cash Accounts, the sum of the bank deposits will decrease. As this might distort the bank balance sheet, such conversion can be accompanied, if needed, by government (RCB) lending to banks. Such credit has to be repaid as 'old' bank loans, in the form of bank deposits, mature.

- The RCB creates 'digital state issued money' (digital cash) according to the legally certified 'money creation rule', which implies a level of money creation in such a way that price stability is maintained, the real economy is sufficiently supplied with money and credit, and the in-activation of money, due to the conversion of bank deposits to digital cash, is compensated.

- The reformation of Central Banks implies that interest rates are no longer centrally managed, but are fully subject to market forces in which supply and demand of money for lending, and the risks involved are reflected. These 'liberated' interest rates can serve as an indicator for the need of additional public money-creation to support the real economy by the (EU)-government and allocated via commercial banks and other financial institutions.

- Public debts are gradually reduced: government does not lend money anymore from banks. Government starts to pay off existing debts and buy back existing bonds.

- Private debts are gradually reduced: tax reductions can result in reduction of private debts, as the public might chose to spend tax windfalls to debt payoffs.

- The resolution mechanism for insolvent banks has to be adapted to the public Digital Cash system. Resolution does not involve an asset and liability transaction, but a forced conversion of bank deposits in Digital Cash, according to predetermined conversion rules.

The net requirement for the new system to operate is the repositioning of the Central Bank(s) and the European Central Bank and, under their supervision, the installation of Digital Cash Accounts in existing commercial banks, running in parallel with the current (demand) deposits.

On the surface the effects of this transition are not disruptive whatsoever. The transition can be fashioned in a way that the public experiences no discomfort at all. At the same time the stability and resilience of the monetary system enhances considerably, while the credit market is liberalized which improves competition, and thereby the financing of the productive economy.
Preferably this transition is implemented on the level of the Euro currency union. It would help the EU to overcome its current downward and unwinding spirals, and recover the road to the European dream.

5.3 Numerical experiments

To explore the merits of such a reformed financial system with Central Bank coordinated debt free money supply, numerical experiments were made in which the system was switched (hypothetically) to the above described alternative system, shortly after the 2007 / 2008 financial crisis. In the experiments the aggregate bank is considered to become an investment account bank which intermediates the lending of existing money to borrowers.
This mechanism is incorporated in the SF-model by transferring the money lent from the L- and LC-deposits to the D-deposit of the indebted consumers (leaving he total liabilities unchanged). From these L- and LC-deposits also the government bonds and firm shares are to be paid. Lending from L- and LC-consumers to D-consumers, via the bank as intermediate, thus 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.
So an eventual transfer of money to the (public) transaction account is not modeled as this money does not take part in the process and (for the time being) is simply replaced by government loans, to allow stable bank balance sheets during the transition process.

In the Reformed Monetary System (RMS) the money is created by the government, starting at the simulated Minsky moment (about 2007) 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 5.3. Herein, the baseline represent the current MaD system and the RMS trajectories describe the alternative RMS-approach for the period up to 2050. Comparing the two, the following observations are made:

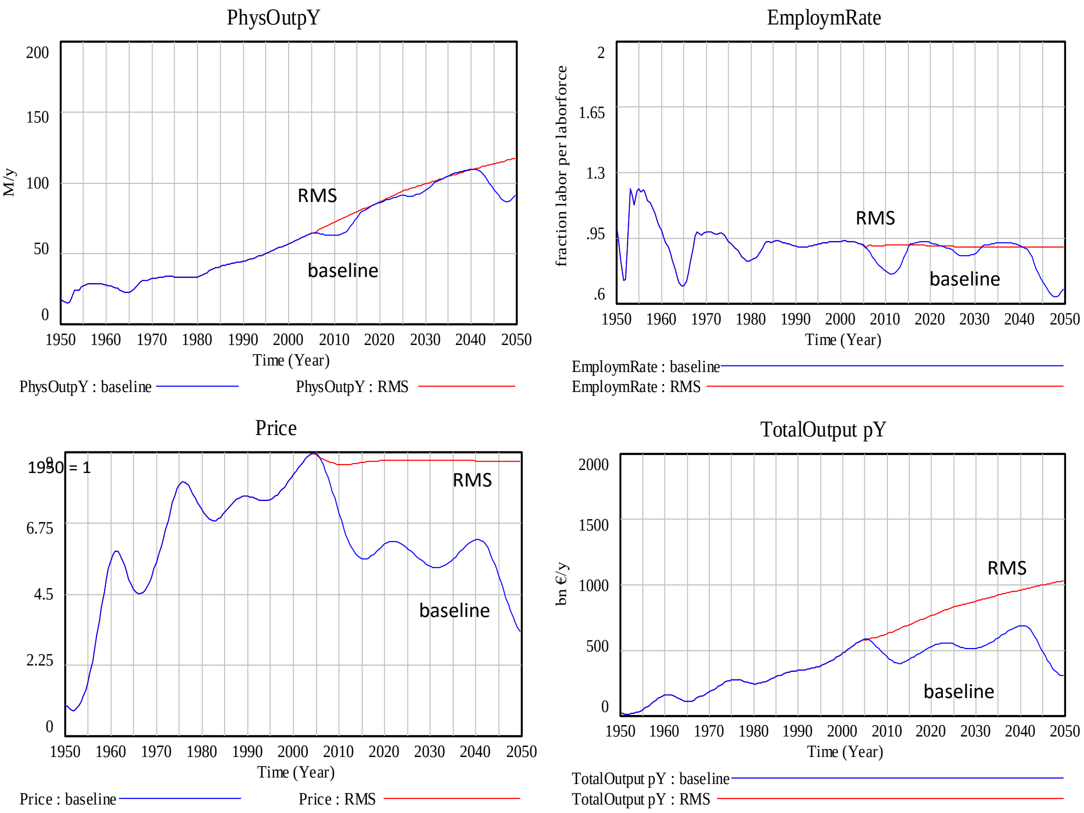

Figure 5.1 Model results over the full period 1950-2050, under money as debt (MaD) before 2007 and RMS after 2007; Baseline is MaD; total production (Y), employment, price and monetary production (pY , GDP).

- As a consequence of the money growth rule, money is created such that the average *price level* remains constant after the (Minsky) moment of crises (Figure 5.1 lower left). The technology-induced deflation in the baseline run is countered.

- Unlike in the base run, the *physical production* (Y; Figure 5.1 upper left) and its monetary equivalent *monetary production* or GDP (pY; Figure 5.1 lower right) show a continuous increase in the RMS 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 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’ target of 90 % of the labour force (Figure 5.1 upper right).

- As a result of money creation, *total liabilities* (the stock of money in the system) increase as shown in Figure 5.2. During the first half of the period, before the crisis, the simulated liabilities rise from an estimated initial 200 bn € to 750 bn €. After the transition around the year 2000, the total stock of money keeps rising in both experiments to about 1000 bn € by 2050. However, under the RMS regime, the money creation has become the prerogative of government and money becomes debt-free (DFM).

- Under the RMS 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. A second important factor is the absence of government lending on the capital market via bonds (70 %). This results in less scarcity of liquidity and thus lower interest levels. 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 on a somewhat higher level. The net result of these effects is a somewhat lower interest rate in the RMS case (Figure 5.2 upper left).

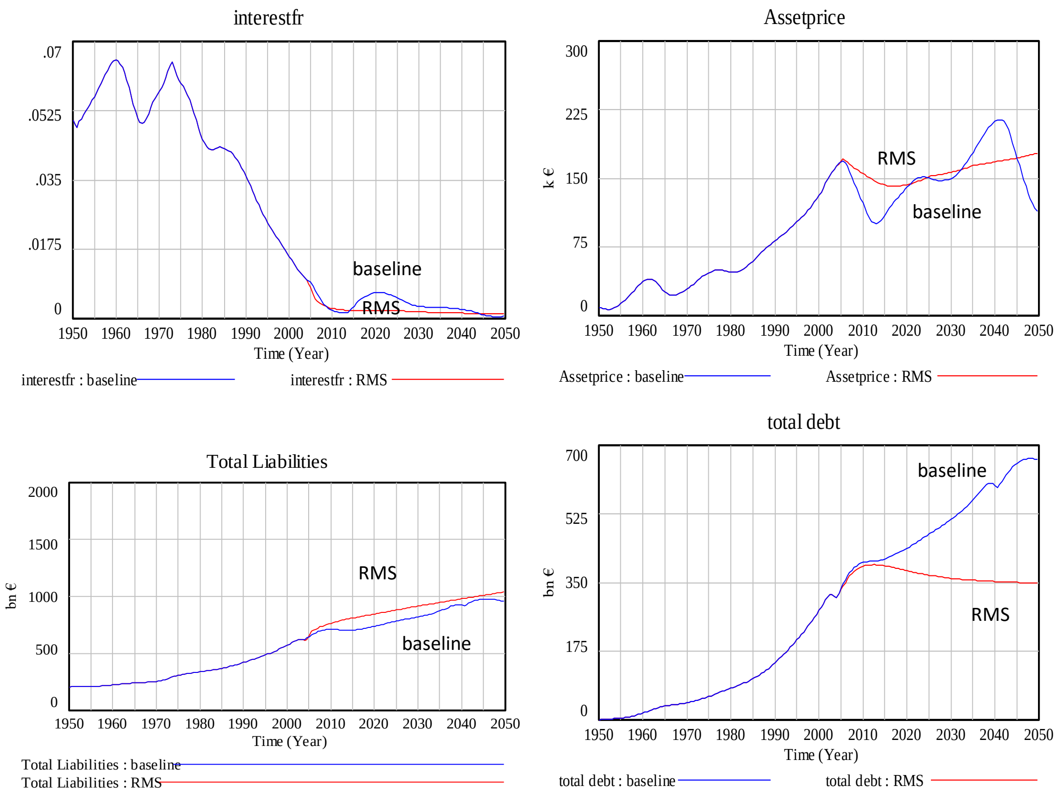

Figure 5.2 Model results MaD before 2007and RMS after 2007;
interest rate, asset price, total liabilities and total (consumer) debt.

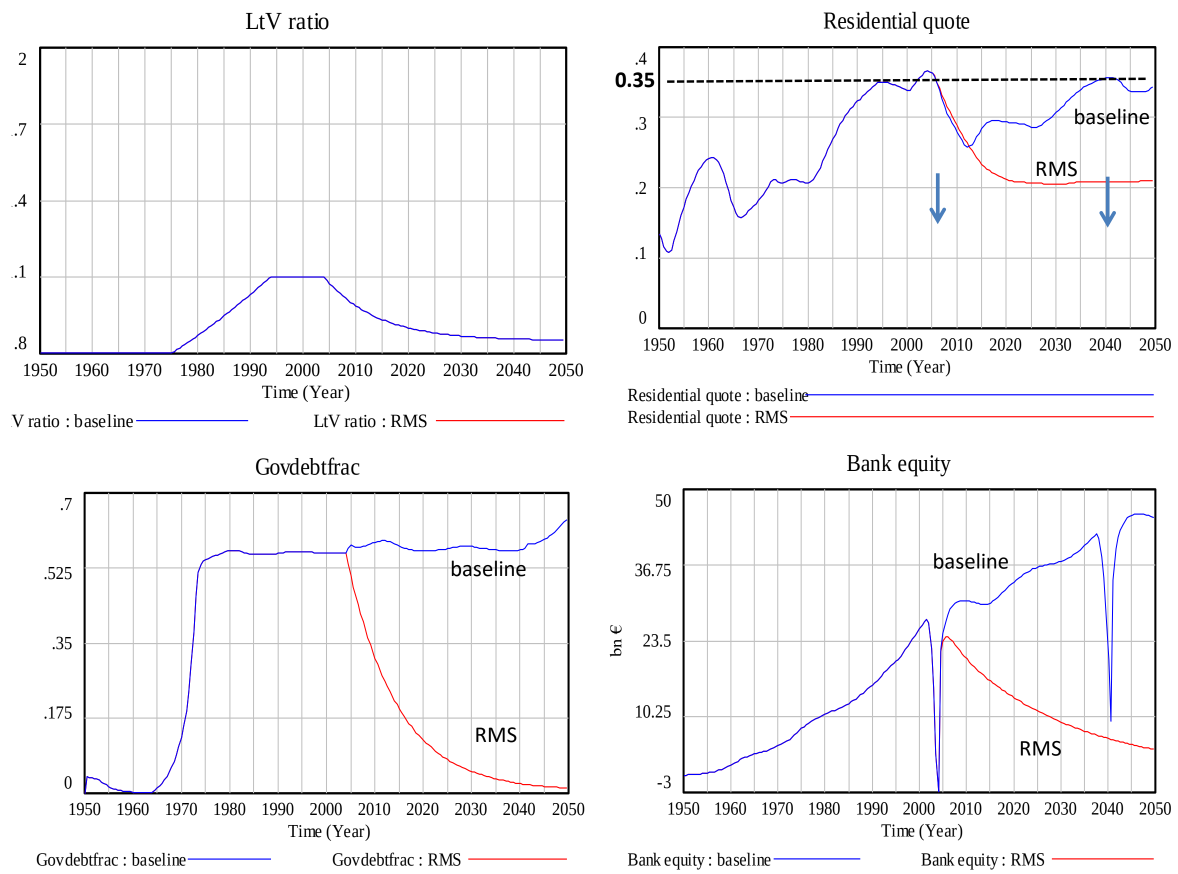

Figure 5.3 Model results 1950 – 2050 with MaD before 2007 and RMS after 2007; ltv-ratio, residential quote, government debt fraction and bank equity.

- After the crisis (Minsky moment) government is assumed to take no new loans from banks and emit no new bonds on the capital market. Instead, there is only repayment and the government debt as a fraction of GDP is gradually reduced from the current level of 60 % to a very low level at the end of the simulation period because of the repayments (Figure 5.3 lower left).

- In combination with the stabilized asset price (Figure 5.2 upper right), the lower ltv-ratio results in a residential quote which is decreasing to the level of 0.2, suggesting a far lower risk on crisis in the RMS than in the baseline case. However, the structurally lower level of transactions plays such an important role here, that further exploration of the mechanism with respect to the number of transaction is necessary:

The stability of the Reformed Monetary System

In Figure 5.4 upper left, the number of transactions for the (normal) RMS- case is shown. Given the now stabilized levels of bank loans and asset prices, the number of transactions does not recover after the 2007/2008 crisis and remains on the lower level of 3 % of total housing rather than the 5 % transactions under ‘normal’ economic conditions (cf eqns 16-18). With a slight tendency of the number of transactions to increase, bank loans and asset prices will increase as well. With bank loans increasing faster than asset prices, the initial increase in the number of transactions is reinforced (eqn 18). This ‘hysteresis’ process restores the number of transaction to its initial 5 %- level (upper left). Notwithstanding the gradual decrease of the ltv-ratio, the combined increase in both asset prices and net income will result in an increase of the residential quote, as shown in the lower right graphs. The residential quote asymptotically approaches the 0.35 threshold level, exceeding it around 2040.

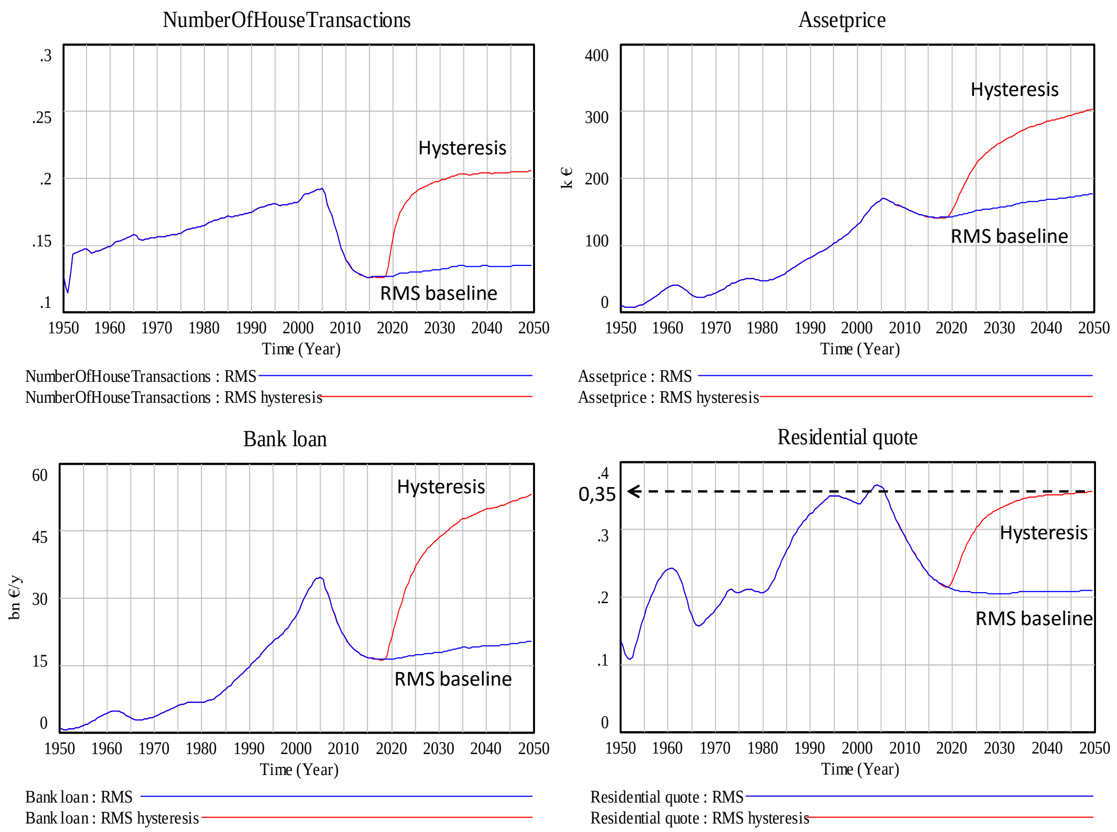

Figure 5.4 RMS model results under the assumption that the number of housing transactions are restored to the original level (of about 5 %); transactions, asset price, bank loans and residential quote.

It is concluded that in this case, where the number of transactions is forced to return to the 'normal' level of 5 % housing mutations per year, loan defaults might occur as well. Although significantly less than the current (MaD-) system, in the alternative RMS there is also room for euphoric behavior. Also in the alternative system crises might occur, although they are less likely, given the now far more stable development of both net income and asset price The risk for crisis is further reduced by the direct link between profits and risk. The existing money is lend out by the L- and LC-consumers to the D-consumers, and these lending consumers experience the risk of default directly. In case this risk is perceived as to high, they will accept lower interest rates and will insist on lower loan to value ratio's. So, in contrast to the current situation money lending will be more subject to the market mechanism.

Money creation

The amount of money to be created can be 'explained' by and large from the identity given by eqn.14, notwithstanding the earlier mentioned doubts about its practical validity. Eqn. 14 can be rewritten in differential form as :

$$p\,dY + Y\,dp = v\,dM + M\,dv \qquad (16)$$

The velocity v (Figure 5.6 lower right) for the system as a whole (not to be confused with the velocity for the L- and LC-accounts as presented in Figure 4.6) tends to unity which indicates that pY is of the same magnitude as the total liability M. This can be understood from the mechanism in the model that the economic activity pY depends on the interest rate, which in turn depends on the available, free liquidity. As a consequence money is invested until the free liquidity becomes scarce, which implies that the total liquidity (M) will almost entirely be activated in the process pY. As a consequence the velocity will tend to '1'.

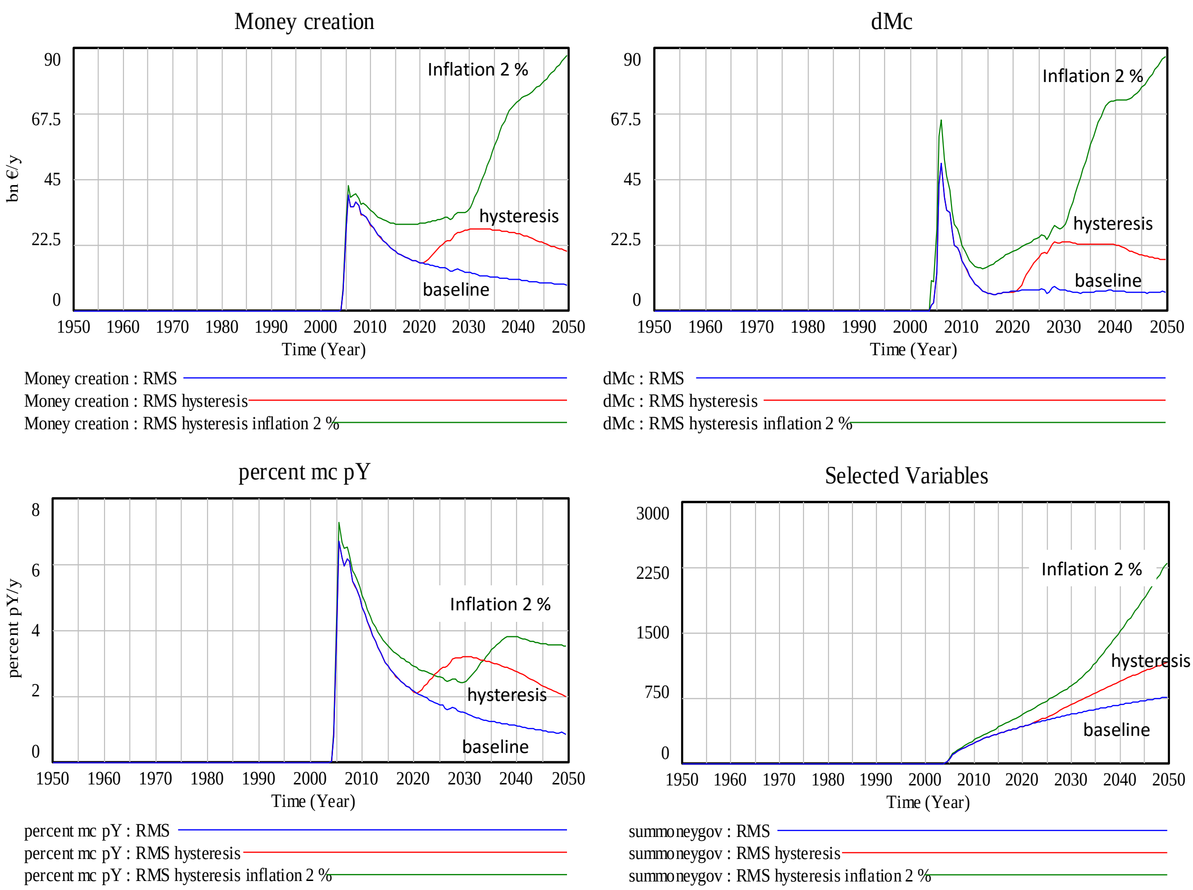

Figure 5.5. Money creation under RMS (called baseline) with housing mutations returning to the 5 % level (hysteresis) and additional money creation with 2 % inflation (on purpose); velocity (pY / M), physical production Y, (numerically modeled) money creation and money creation according to eq. 16.

As the modeled velocity (upper left) asymptotically approaches v=1 and dv =0. In case of price stability, being the objective under the RMS-regime, also the change in price level dp =0. As a consequence eq.16 becomes pY = dM, which can be seen as a first proxy of the amount of money to be created.
At the constant price level of about 9 and a dY of about 1.45 (Figure 5.6 upper right) , the amount of money to be created dM = p . dY = 9 x 1.45 = 13 bn € / y. This reasonably corresponds to the modeled baseline result as given in Figure 5.5 upper left. The baseline estimate dMc according to eq.15 in the upper right graphs is somewhat lower, given the still increasing level of v (Figure 5.6 lower right) and the thus remaining significance of the term Mdv in eq.16.

It will be clear that the amount of money to be created will depend on the assumptions with respect to the future growth of the physical production dY. As shown in Figure 5.6 upper right, the model assumptions about technological progress and capital-labour substitution add up to a continuation of the current (physical) growth level at first, decreasing later.
Under these assumptions, the amount of money creation, needed to maintain price stability for the RMS baseline case (Figure 5.5 upper left) initially amounts about 30 bn /year and thereafter gradually decreases to about 10 to 15 bn € /year, for the economic scale of the Netherlands. More generally this respectively corresponds roughly to 5 %, and 2 % of GDP (pY), as shown in Figure 5.5 lower left. In case the transactions in the housing sector would return after some time to their original level as discussed above ('*hysteresis*'), the amount of money to be created goes up to about 20 bn €/year (3 % of GDP), given higher bank loans, asset prices etc.

In case a certain level of *inflation*, for example 2 %/yr, would be preferred politically, an additional amount of money can be (and has to be) created. Model results in which the price level is allowed to increase at a rate of 2 %/yr in the baseline case are also shown in Figures 5.5 and 5.6. In this case an increasing amount of money in the order of 3 % to 4 % of GDP (pY) has to be created, soon after the transition to the reformed monetary system.

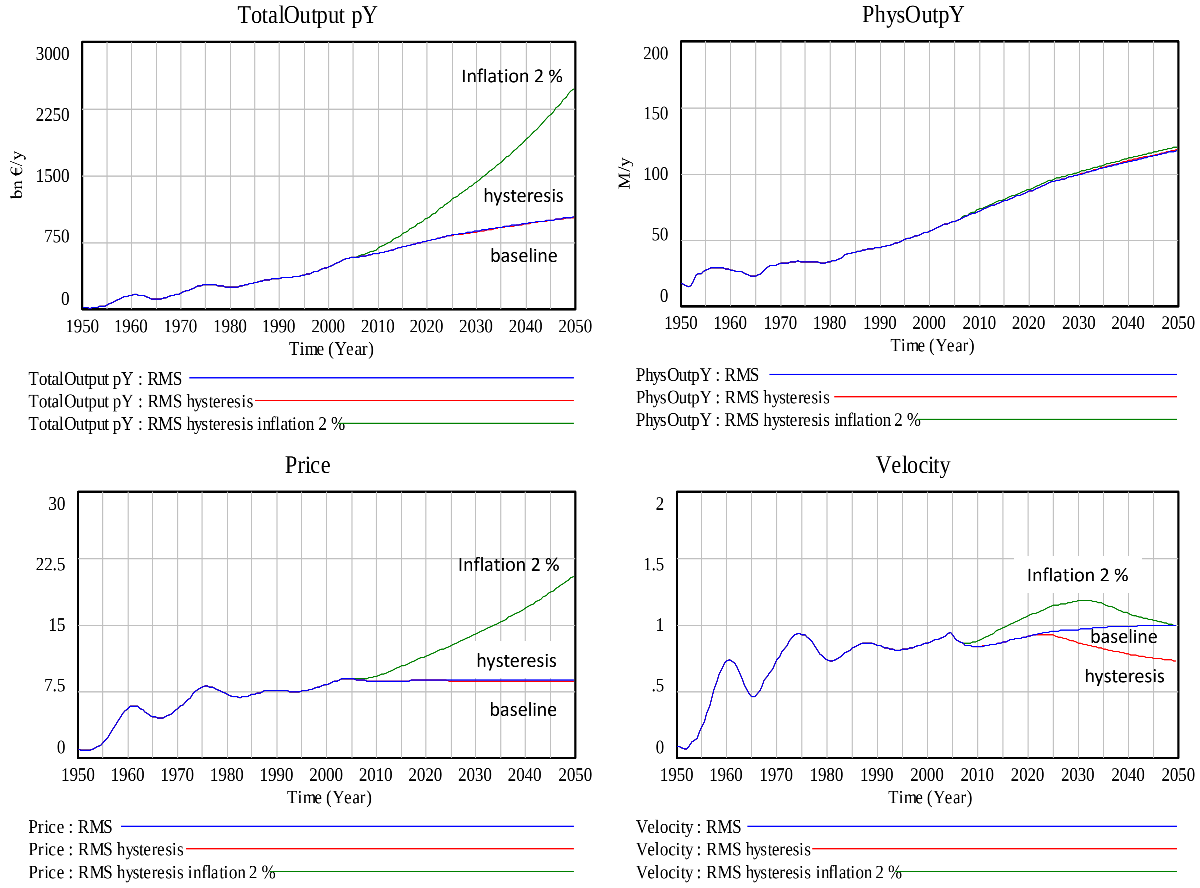

Figure 5.6 Money creation in the RMS-baseline case, baseline with hysteresis (returning to 5 % housing mutations) and in case of a desired inflation rate of 2 %; money creation as % of pY, price, money creation (bn € / y) monetary production pY.

The amounts correspond to Ydp, the second term in Eqn.16. With Y ~75 bn € , p=9 and thus dp = 0.18 (2 % of 9), the initial (extra) amount, given by the term Ydp ~ 14 bn € /year. Assuming a preferred inflation rate of 2 % continuously over time, this amount increases continuously over time as well.

In the hypothetical case that the amount of money in the system should be reduced, which means that deflation rather than inflation is stimulated, the process works the other way round. Reduced government spending in combination with higher taxes would drain liquidity from the system. However this situation is very hypothetical, as too much money creation gives rise to too much inflation will be corrected by less money creation, not by absolute reduction of the amount of money In the system. In case of a stagnating economy, Keynesian stimulation of aggregate demand always will imply some extra (debt free) money creation and thus inflation.

5.4 Accumulation of money

In Figure 5.5. upper left, the overall velocity asymptotically tends to the value ‘1’, as explained above. Herein the velocity is based on the total amount of money in the system (total liabilities). In case Bank equity and Firm deposits would be excluded and the velocity would only be based on the L- and LC-deposits, the picture looks different. After the initial phase up till 1970, the combined velocityon the Land LC-deposits starts to decline, as shown in Figure 5.7. As discussed, this is the result of the transfer of 80 % of the newly created money to these deposits. Yearly 3 % of this wealth comes into circulation via consumption (according to eq.13) and apart from this rather small contribution to overall consumption, there is no further stimulation of aggregate demand. An increasing part of the money remains inactive for the productive economy on the L- and LC-deposits. To a certain extent it is the counter value for assets, owned and sold by these consumers.

In the RMS case the newly created money comes into circulation via decrease of taxation and increase in government expenditures, and as such more directly stimulates aggregate demand.
As shown in Figure 5.7 the velocity now remains on a more or less constant level, confirming that a larger part of the wealth on the L- and LC-deposits contributes to the real economy. In case the number of housing mutations returns to the original 5 % level ('hysteresis') the RMS-curve is somewhat lower, but still much higher than in the baseline. Apparently in the RMS-system the created money more efficiently effects the real economy.

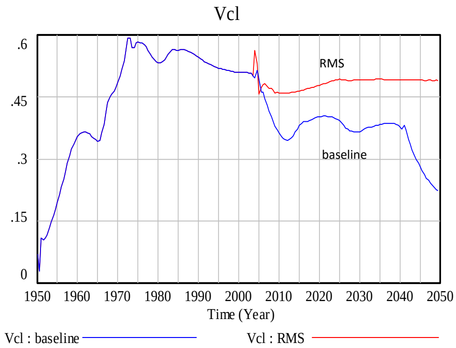

Figure 5.7 Velocity for the combined L- and LC-deposits; baseline MaD case and RMS.

5.5 The current EU quantitative easing program

As illustrated by the model results, after the financial crisis prices fall 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 (QE) 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).
These suggestions are confirmed by the model results. In case the debt free ECB-money was targeted at projects which stimulate aggregate demand (on infrastructure etc) rather than buying government bonds (or even bank bonds), the QE-program would come close to the alternative system as explored by the model-experiments. In case the ECB created money was spent on concrete projects the European economy would have been stimulated in Keynesian sense, deflation would be halted and increasing unemployment would be curbed.

5.6 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 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 the 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 significant inflation and the 2007 / 2008 financial crisis.

From a political point of view, the Central Bank in its new role 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.

5.7 Conclusion

The model experiments show that money creation by the government, according to a 'money creation rule' which is directed to for example 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. The created money contributes more efficiently to the real economy.

In the current simulations, debt free money can, and has to be created at a rate of 2 - 4 % of GDP, which is the lower end of the range of 3 – 10 % of GDP at which private banks have been creating money over the last 50 years. The higher end of the 2 – 4 % range is reached in case an inflation rate (e.g. 2 % / year) would be preferred politically. These estimates strongly depend on the expectations with respect to future (technology driven) physical economic growth.

6 General conclusion

In order to explore the feasibility of an essentially improved financial – economic system, 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. 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, banks go bust and have to be recapitalized by the government which has to increase taxation and decrease expenditures, thus aggravating the situation further.

- 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, as the Bank's ability to determine the interest rate is not effective. As a consequence, average inflation over the 57 years before the 2007/2008 crisis amounts almost 4 %, rather than the Central Bank objective of 2 %. After the inevitable crisis, the system had to be rescued from societal chaos by the government through centralized coordination, via recapitalization of banks at the expense of the tax payer.
  After the crisis, the same herd behavior results in too less money creation by banks, which subsequent impacts on the monetary consumption and production in the first place and to a lesser extend also on physical consumption and production. This then adds up to increasing debt levels, which temper consumption. The overall result is economic stagnation.

- The model confirms the hypothesis (Werner) that the money which has been created as debt, finally accumulates on the deposits of the non-lending consumers. An increasing part of this *'dead' money* does not take part in the productive economic process, while stimulating the increase of asset prices over net income, thus contributing to the instability of the system.

- The forward model simulations suggest that another crisis will occur if the present system is unchanged within a few decades, depending on such unknowns as the trends in ICT-applications in the financial sector.

- 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 in such a Reformed Monetary System money creation by the government, according to a 'money creation rule' which is for example 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.

- Such a Reformed Monetary System (RMS) is *a less volatile, more stable* alternative to the current 'money as debt'-system. The residential quote as an important measure for the risk on significant defaults is more stable, given the increased stability of both net income and financing costs, which in turn benefit from lower interest rates and more gradual, less volatile development of asset prices. The (modeled) interest rate is lower in the baseline case as the funding needs for the government are lower, resulting in less demand for liquidity and subsequent lower interest rates. Nevertheless, also in the reformed monetary system crises may occur, although less likely than in the current money-as debt system.

- For the current expectations with respect to future (technology driven) physical economic growth, debt free money can, and has *to be created at a rate of* 2 - 4 % of GDP in order to achieve price stability. This is the lower end of the range of 3 – 10 % of GDP at which private banks have been creating money over the last 50 years. The higher end of the range is reached in case an inflation rate (e.g. 2 % / year) would be preferred politically. For the specific scale of the Dutch economy, the amount of money to be created would be in the order of magnitude of 25 bn € / year for the coming years, increasing later. The money can be used to lower taxation and / or to invest in democratically chosen projects, for instance in efficient and renewable energy systems.

- 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.

- Money creation by the government is not only legitimized by the above stability-considerations, but also by millennia of philosophical and ethical thought in which money is considered to be a social construct, implying that *money has to be defined and created by the community*.

- A *smooth transition* to the reformed monetary system seems feasible. Such a transition requires the reformation of the Central Bank(s) to a separate (4^{th}) power of government. Under supervision of these reformed Central Banks, Digital Cash Accounts are introduced in existing commercial banks, running in parallel with the current (demand) deposits. The payment system is migrated from operating on bank deposits to this state issued Digital Cash, as the government gradually dismantles its support for use of bank deposits as a means of payment and a store of value.

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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.

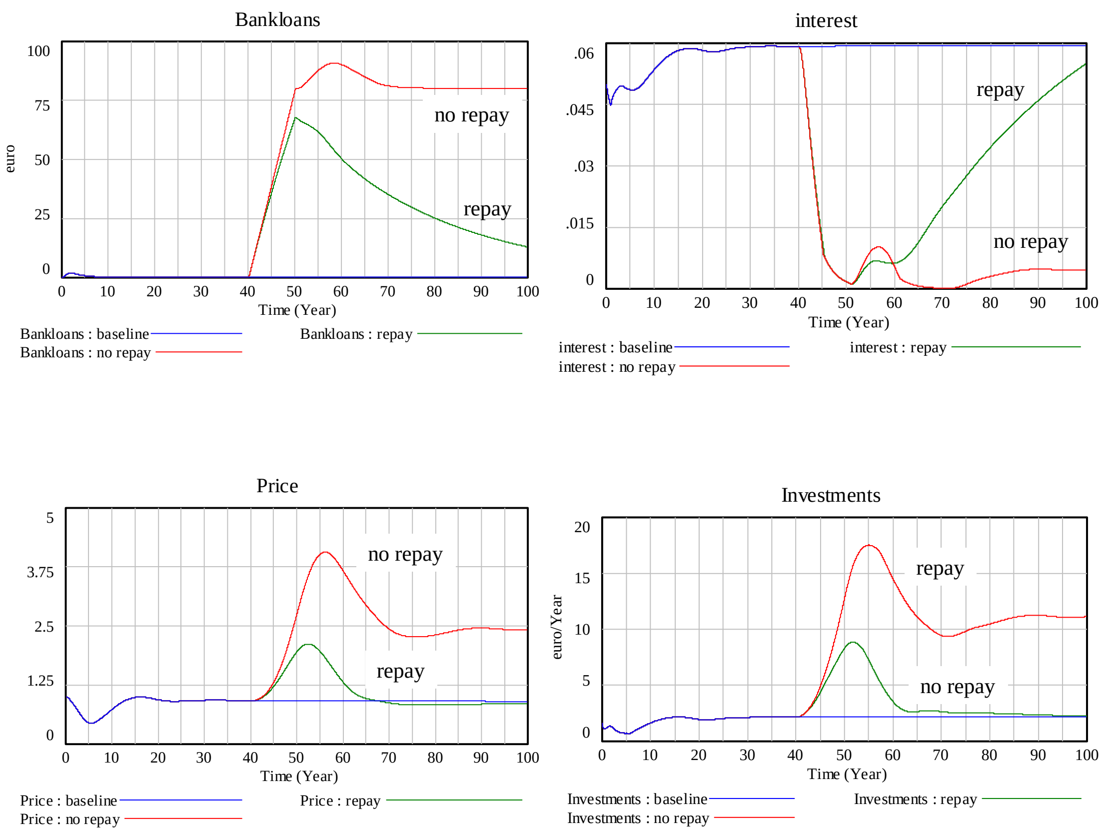

Figure A.1 Model response to an annual loan of 5bn € during a 10 years period.

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 term stimulus to growth, the longer term effect of financial development is negative'.

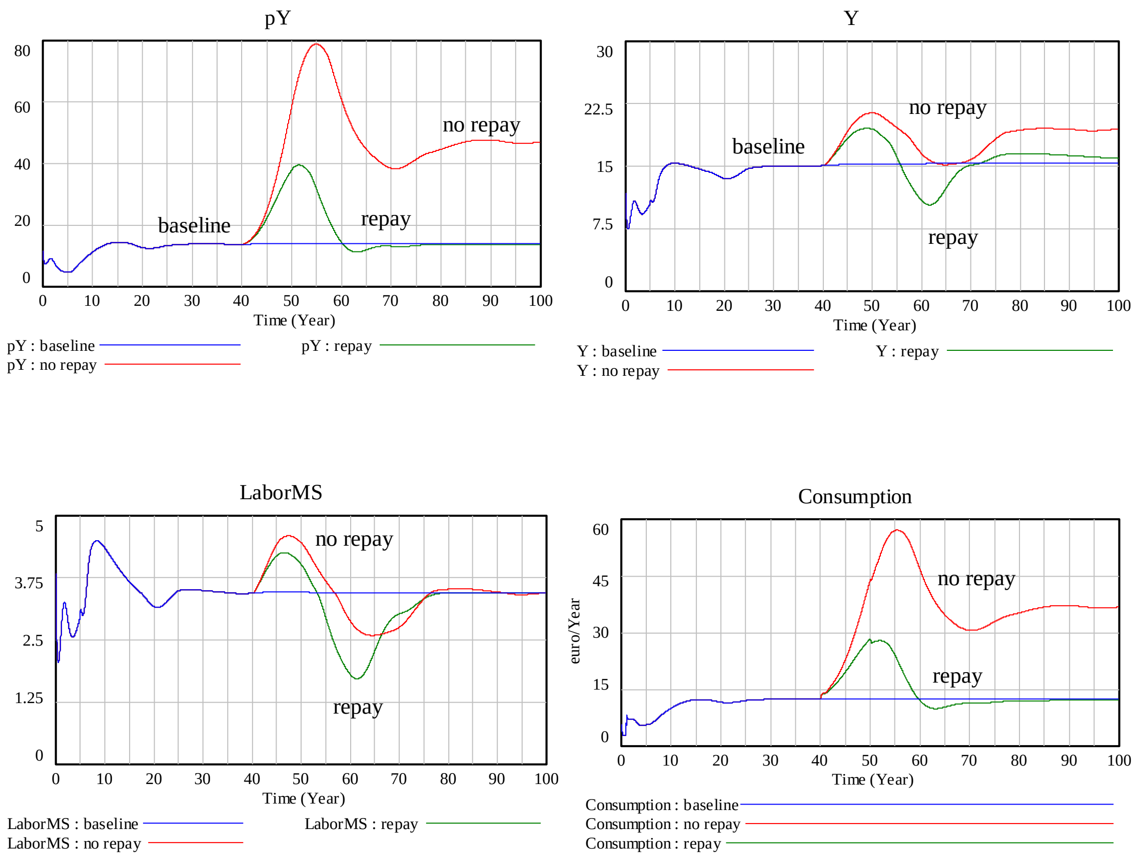

Figure A.2 Model response to an annual loan (with and without repay) of 5 bn € during a 10 year period.

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.

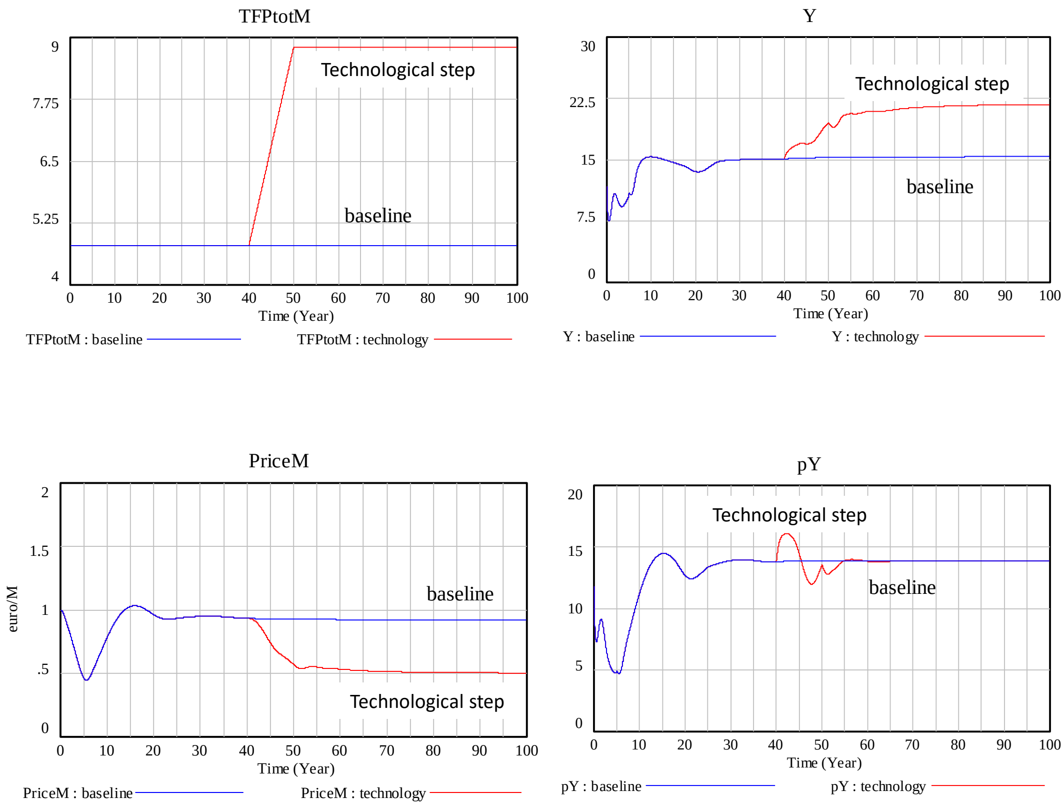

Figure A.3 System response to a stepwise change in the total factor productivity, as the result of a technological breakthrough.

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.

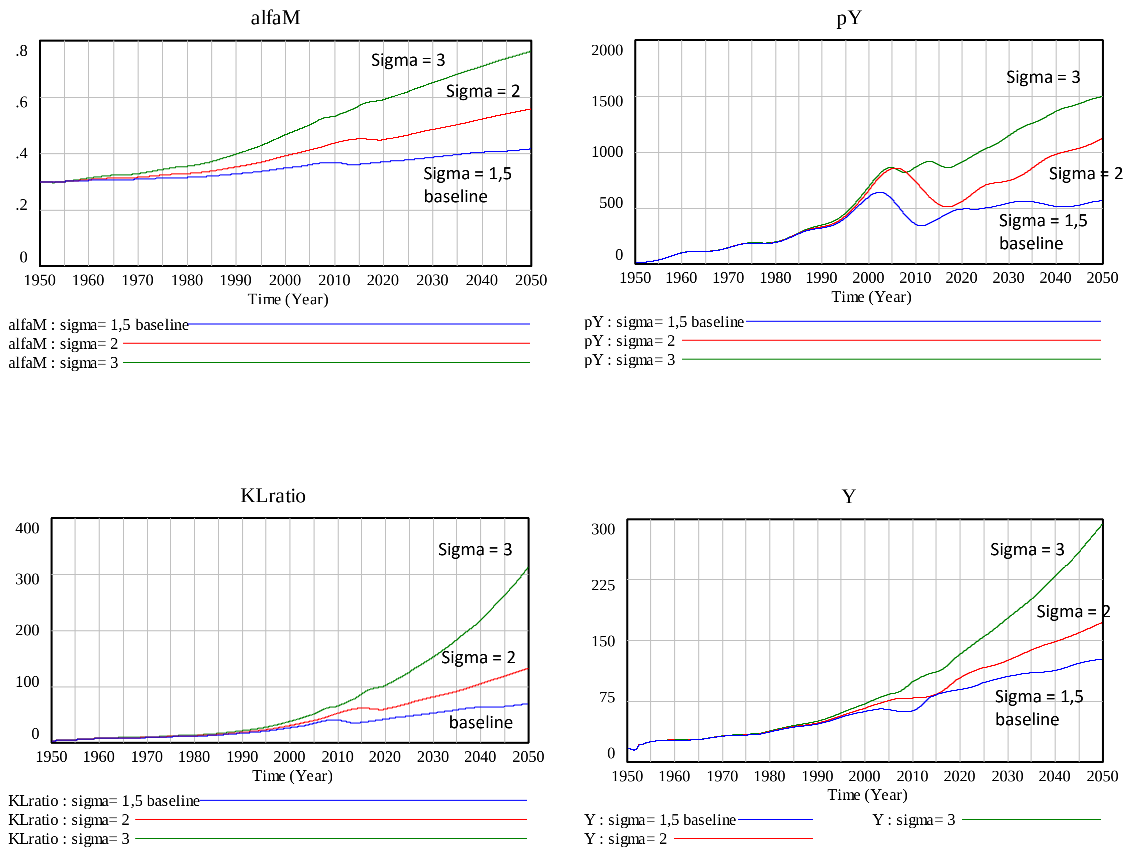

Figure A.3 System response to increasing substitution elasticity σ for
$\alpha_{M,}$, *monetary production pY (GDP), capital-labour ratio KL and physical production Y*

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.4, 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 σ = 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.

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 outcome 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 ~ $K^{\alpha} L^{1-\propto}$ (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:

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

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 ~ 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[14].

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

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

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 $C = w\ L + (\rho+\delta)\ K$ 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. $L = (1-\alpha)\cdot p\ Y/w$, 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 $[w,L] = [(1-\alpha)pY, L_{full}]$ 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).

[14] 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)	[-]	$\sigma_M = \sigma_S$ = 1(1950), then increasing to $\sigma_M = \sigma_S$ = 1.2 (2050); baseline run	Economic literature; Piketty (2014); model calibration.
Consumer price p	1950=1		CBS