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CREDIT EXPANSION AND ECOLOGY

A study on the impact of increased money supply on the utilization of renewable natural resources

Robin Rane† Erik Östgren‡

Abstract

During the recent decades there has been a growing awareness of that the natural resources we have previously thought abundant can not be taken for granted. Different economic schools of thought have different approaches of analyzing how this may affect our economy, and how we can organize our societies in a more sustainable fashion. This study uses a broad perspective of previous research to investigate the impact of credit expansion on the relative prices of renewable natural resources, and what this implies for ecological sustainability. This is done through the construction of a circular flow model where the interaction between the economical and ecological systems is studied through simulations. Our results support the notion that credit expansion *does* have an impact on the pricing of natural resources. The implications of this are overexploitation of renewable natural resources and an unsustainable ecological development.

JEL classification: E51, O42, Q01, Q21

Keywords: credit expansion, ecological population modeling, money endogeneity, sustainability

† 22112 ‡ 22136

Supervisor: Örjan Sjöberg

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Discussants: Vladana Boljanovic and Björn Wisaeus

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Introduction

During the last years there has been a growing apprehension that the abundance of nature, previously taken for granted, is no longer a realistic assumption. The rate at which natural resources are depleted soared with the "economic acceleration" of the twentieth century, and renewable resources like forest and fish have been harvested at a pace faster than that of their renewal (Costanza 2008).

Within the field of economics there have emerged several ways of analyzing this problem. Two schools of thought with, to some extent, diverging theories are the neoclassical and the ecological movements.

The orthodox view within economics is that of the neoclassical school of thought. These theories focus on how supply and demand determine relative prices, output and employment (Aspromourgos 1986). The forming of equilibria, human rationality and maximization are important features of neoclassical economics (Dequech 2007). In their view of sustainability, diminishing supply of natural resources leads to higher prices. This will in turn fuel investments in technology to better make use of the natural resources, or lead to substitution toward other factors of production. Within this school of thought the solution lies in letting the right prices of resources triumph, through for example clear property rights (Söderbaum 1992). That way it is harder for resources to be misused.

The view of ecological economists differs partly from that of orthodox neoclassical economists (Illge and Schwarze 2009). According to ecological economists, income from human made capital can only to a certain degree substitute for income received from renewable or non-renewable natural capital, and therefore the depletion of natural capital will have effects on the human economy. Consequently, ecological economists argue that there is a need to see the human economical system only as a subsystem of the ecological, and recognize the interaction between the systems (Costanza and King 1999, Xepapadeas 2008). They mean that the human economy is dependent on its environment to receive its flow of natural resources, and that the environment is to a large extent affected by the extraction of its resources, as well as the waste output of the economy (Røpke 2004). Taking into consideration this mutual influence of the systems, and understanding its implications, is essential to achieve a sustainable human economic system (van den Bergh 2001).

Several economists argue that the structure of the financial economy does not consistently mirror the real economy (Douthwaite 2012, Minsky 1993, Soddy 1926). This leads to a distortion of the market pricing mechanisms. They mean that speculative bubbles, expansion of the money supply through fractional reserve banking and quantitative easing programs by central banks contribute to the separation of the nominal prices from their correct, real correspondent values.

In the light of these views we aim to investigate how orthodox theories handle the problem of limited renewable natural resources when the pricing mechanism might be distorted. What if the nominal pricing of the economy, by neoclassical economists deemed the solution of the problem of sustainability, is unable to always truly reflect real values, even though the market seems to function well? Could this pose a problem to sustainability in a neoclassical analysis? We find that the link between expanded money supply and the utilization of natural resources has not been thoroughly examined.

We want to explore this by trying to answer the following two research questions: 1) Is the negative impact that price increases should have on utilization of renewable natural resources dampened by increases in the money supply? 2) If so, what impact does this have on the economic and ecological system, seen from a perspective of sustainability?

Our hypothesis is that the creation of new money can have a dampening effect on the price increases caused by scarcity. We believe that this, in turn, leads to increased utilization of renewable natural resources.

Through a deductive approach we start out by examining existing theory, and out of the identified fundamentals we model an economy characterized by the elements we set out to examine. From this we make simulations, and try to interpret the data to answer our research questions and test our hypotheses.

The study is structured as follows. We commence by presenting the previous research that has been done within the different areas of focus that we will need to address and synthesize in order to create our model. In the next section, named Analysis, we develop our model and discuss its different components, our underlying assumptions and the robustness of our model. Here we also make our simulations. These simulations are discussed in the section labeled Interpretation, where we elaborate on how the results can be interpreted in the light of what we already now. In our concluding remarks we summarize our study, discuss the limitations of our results and conclusions, and propose topics for further research.

Previous research

To build our model and interpret its simulations we need to familiarize ourselves with a wide range of previous research. Consequently, we find it necessary to begin the description of the current knowledge through a very broad outlook, narrowing it down as we approach constructing a model that incorporates the theories described. We will concentrate on areas of research that will have an impact on the construction and interpretation of our model, thus leaving out interesting perspectives such as environmental economics (Stavins 2008) and theories about the tragedy of the commons (Hardin 1968).

This section will begin by a brief overview of what areas of research we will look into, followed by a more in-depth description of the current state of knowledge.

We will look at the following topics: (1) money creation and endogeneity, (2) sustainability, (3) the growth imperative, (4) decoupling of the monetary and real economies and (5) ecologic population modeling.

What money really is, what it originates from, and how it affects other aspects of the economy are fundamental aspects of the economic system of today, with far reaching implications. Therefore, we here need to introduce some different thoughts on these questions, and how these might help answer our research questions.

Throughout this paper we are discussing the subject of sustainability. How different researchers define and think about sustainability is therefore worth looking deeper into.

During recent years there has been a growing discussion about economic growth. Economists and ecologists alike are debating whether the growth rate we have seen during the 20th century really is feasible in the long run, and if our economic and ecological system can sustain it (Jackson 2009, Sorrell 2010). By combining elements from the money endogeneity theories, researchers have also begun to question if our economic system can sustain zero-growth. These discussions include some aspects that contribute to our model, and the thoughts regarding growth are important when we are to interpret our simulations.

By combining economics with biology, researchers have developed methods to mathematically describe the development of nature, and how to put economic value to these resources. By investigating this field of research we aim to grasp how biological populations develop and how they are affected by economic activity.

Money creation and endogeneity

In most modern economies of today, the process of creating money primarily takes place in private banks, through a process called fractional reserve banking (Abel, Bernanke and Croushore 2007).

The term fractional reserve banking comes from a banking system where financial institutions only hold a fraction of deposits as reserves, the rest being lent out (Mankiw 2012). This fraction, how much of the deposited money that stays in the bank vault, is called the reserve ratio, and is decided upon by government regulation and bank policy (Colander 2007). As the banks lend, in the form of credit, the money not kept as deposits, they practically create money (Ray and Anderson 2011).

To clarify, consider an economy where there are only two persons and one bank. Initially there are \$100 in the economy, provided by some external source (for example a central bank) and owned by Person A. Suppose the Bank must hold 10% of its deposits as reserves. If Person A deposits the \$100 in the Bank, this means the Bank must keep \$10 (10%) of the deposits as reserves, and may lend \$90 to Person B, thereby putting it back to circulation. As the sum of currency in circulation (\$90) and checkable bank deposits (\$100) have risen from \$100 to \$190, the Bank has expanded the money supply and has, in effect, printed money (Ray and Anderson 2011, Mankiw 2012).

While there is a consensus regarding how the creation of money works on a individual bank level, there are some slightly different views on how the creation of money within a fractional reserve banking system can be described on an aggregate, system level.

The common notion is that the money supply is strictly governed by the central banks.

According to this theory, the monetary base is first created by central banks and then expanded by private banks, through lending, according to a "multiplier" (Colander 2007). This multiplier is determined by the required reserve ratio, i.e. how much money the bank must keep in their account in relation to their lending (Mankiw 2012). According to this notion the banks can continue to print money until all money is used within banks to supply new credit. The supply of money will thus amount to the original money stock (created by the central bank) M_0, divided by the fraction kept as reserves f: $M = \frac{M_0}{f}$.

In contrast to the neoclassical notion, there has been a different perspective presented by endogenous money theorists in the post-Keynesian and monetary circuit schools of thought. In this tradition money is viewed as a flow, often floating in a triangularity of debt between firms, banks and households (Rochon and Rossi 2004). An important difference from the neoclassical paradigm is the causality in the creation of money. Within post-Keynesianism loans are *first* extended by commercial banks, which *later* requires that the bank acquire reserves, either from depositors or other private sources of financing. In this view, the rate of money supply growth and, more important, credit availability, are fundamentally determined by demand side pressures within financial markets (Pollin 1991). Ergo, the consumer or firm demand for money is what drives lending. Or in the word of Alan Holmes, former New York Federal Reserve Bank senior vice president: "in the real world banks extend credit, creating deposits in the process, and look for the reserves later" (Holmes 1969, p. 73).

The first descriptions of these monetary circuits, through which money flows between the different actors, were given by Knut Wicksell (1936) and Joseph Schumpeter (1911). However, the concept was further developed and formulated by Basil Moore (1988a) in his book *Horizontalists and Verticalists* where he set out the core of the endogeneity hypothesis in the assertion that, in the words of Peter Howells, "demand for credit has its origins in the production decisions of firms" (Howells 2005). Moore is a strong critic of the conventional view of how money is created: "The textbook metaphor of the high-powered base- deposit 'multiplier' has been so thoroughly indoctrinated, [...] that challenging its correctness consequently appears only slightly less foolish than doubting that the sun will rise" (Moore 1988b, p. 372).

Some post-Keynesian and circuitist literature on endogenous money even argue that banks are not fully constrained by existing amounts of savings in the making of new loans. Man-Seop Park (2004) states that banks "can, if they want to, first create loans ex nihilo for creditworthy firms (investment projects) and then look for reserves (or economize on a given amount of reserves) required for the deposits that come out as the result of investment activity using loans" (Park 2004, p. 143). He then questions whether 'deposits generated through loans can be consolidated by the demand for them" (Park 2004, p. 143).

One of many researchers who have adopted the view of endogenous money is Mathias Binswanger, who in his money circuit model has left out the need for banks to first acquire savings (Binswanger 2009). Instead he models the bank behavior by restricting how much they can lend by a capital ratio-restriction, implying a rule on how much own capital the banks must keep in relation to their lending. This is similar to the regulations of banking activity in the world today (Basel Committee on Banking Supervision 2011, Calem and Rob 1999, Elizalde and Repullo 2007), and follows the main claims made by money endogeneity theorists that banks are only bound by capital restrictions, not reserve or funding constraints (Hannsgen 2004, Kuttner and Mosser 2002). By leaving out savings Binswanger uses the assumption from the post-Keynesian school of thought that the demand for loans comes first, and that savings will, in some way, be acquired later. As can be seen in our model, we have borrowed this way of thinking about how the bank system works.

Sustainability

To be able to evaluate and draw conclusions from the results of our model, we need to be aware of the different thoughts about what would be an ideal state, and what aspects of any economy that are desirable. Sustainability is used by several economists as a minimum criterion for a well functioning economy. In order to use this as a standard, we need to define what we mean with that term, and how it relates to a modern economy.

The Brundtland Commission in 1987 defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987). In the ongoing discussion of the concept, three constituent pillars are identified: economic sustainability, ecological sustainability and social sustainability (World Health Organization 2005).[1] On an individual firm-level Thomas Dyllick and Kai Hockerts (2003) connect these three parts of sustainability with three types of capital: economic capital, natural capital and social capital, and define how to achieve sustainability in each type of capital.

Kenneth Boulding (1966) was an early advocate of thinking about sustainability in a much bigger perspective in his essay *The economics of the coming spaceship Earth*. Here he describes the past open economy, dependent on apparently unlimited natural resources. In contrast to this, he wants to look upon earth as a spacecraft with only one external source of energy: sunlight. This spacecraft also has a stock of resources, which depends on what you take onboard pre take-off. When that stock is consumed the expected lifetime of the spacemen is reduced, unless they can find a way to recycle water and materials. The essay highlighted the need to look upon earth as a closed circular system, a stance that has been adopted by ecological economists (Pearce and Turner 1989).

Robert Costanza and Herman Daly (1992) continue the discussion of ecological sustainability on a global level, and stress the importance of trying to merge ecological and economical perspectives. As described in the introduction, ecological economists emphasize the need to see the economic system as subordinated the environmental system, recognizing the economy's dependency on nature to receive its flow of resources (Costanza and King 1999, Røpke 2004, Xepapadeas 2008). In their analysis Costanza and Daly (1992) discuss natural capital as opposed to human-made capital. Natural capital consists of both renewable natural capital, such as forests and fish populations, and non-renewable natural capital, such as minerals and fossil fuels. Human-made capital consists of what we usually associate with the term capital: manufactured capital, such as factories and machines; as well as human capital: the stock of education, culture, skills and knowledge.

When discussing sustainability in relation to increased human wealth, Costanza and Daly (1992) make a conceptual distinction between growth and development. Growth is defined as to increase naturally in size by the addition of material through assimilation or accretion. In practice this means pushing more matter-energy through the economy.

[1] In recent discussions it has been suggested that the pillar of social sustainability should be divided into a political and a cultural pillar (United Cities and Local Governments 2010).

Development, on the other hand, is defined by the authors as "squeezing more human want satisfaction out of each unit of matter-energy that passes through" (Costanza and Daly 1992, p. 43). By this definition growth is destructive of natural capital and harmful in the long run, while development is merely an improvement of organizations and processes, making the creation of wealth more efficient. In the end growth will cost more than it benefits us, that is - the sacrificed natural capital will be worth more than the output that it is used for. Development, on the other hand, does not come at the expense of natural resources.[2]

Using these distinctions for analysis, Costanza and Daly discuss criteria for what ecological sustainability means operationally. They reach the conclusion that the fundamental principle must be to limit the human activity to a level that is bearable for the remaining natural capital. In the case of renewable natural capital, this means that it should be exploited on a profit-maximizing sustainable yield basis. In practice, this implies that harvesting rates should not exceed regeneration rates. Throughout this thesis, we will use this definition when discussing sustainability.

Out of Costanza and Daly's work the question arises as to what extent development can substitute for growth in improving wealth.

The growth imperative

Some scientists believe that there are big possibilities for efficiency increasing human development, i.e. sustainable development, without having to resort to resource consuming growth (Lovins and Lovins 1987). This paradigm of "weak" ecological sustainability argues that natural capital can be substituted for human capital, thereby compensating for decreased use of matter energy by technical advancement (Beckerman 1994). This view is largely supported by the neoclassical tradition. However, others think of ecological sustainability as "strong," believing that the link between matter or energy and growth is stronger (Costanza 1980). According to them, the notion that technology can always be substituted for natural resources is a very strong assumption, and one of the fundamental glitches in the neoclassical theory (Daly 1997).

[2]Throughout this paper the tenor of the words growth and development will depend on the context. When the strict meanings defined by Costanza and Daly are used it will be stated explicitly.

An important dilemma is the issue of growth and development in poorer countries. If we are striving for social sustainability, the wealth difference between underdeveloped and developed countries needs to be equated. The conclusion in the Brundtland Commission's report is dual (WCED 1987). On one hand the scale of the current economy is inconsistent with a sustainable utilization of the world's resources. On the other hand an economic expansion by a factor of 5 to 10 is necessary to facilitate an improvement for the unindustrialized parts of the world, without having to resort to measures such as thorough birth control and extensive redistribution of wealth.

Given this we could ask ourselves if economic growth in the industrialized world really is desirable. Would zero-growth in the developed part of the world be a viable alternative to achieve ecological and social sustainability? A steady-state, zero-growth economy has indeed been presented as an option by several economists (Jackson 2009, Sorrell 2010). According to the neoclassical theory this is a feasible alternative: "Nothing is easier for [the economy] to do than remain in a stationary state, and for a real person, growth is a matter of taste" (Gordon and Rosenthal 2003, p. 26).

However, according to some economists, a point that neoclassical growth theory misses is the ability of private banks to create money. The endogeneity of money, described above, has fundamental implications on how an economy behaves, and might put obstacles in the way of reducing growth. John Maynard Keynes (1937a, 1937b, 1939) and Schumpeter (1911) elaborated on the role of banks and emphasized that modern economies (where the private banks, not central banks, create most of the money) have fundamental differences from traditional economies. However, aside from post-Keynesian economists and money circuits, few have continued these thoughts that Keynes and Schumpeter had about the importance of banks as money creators, and the implications this has on the real economy.

One of their followers is Binswanger, who builds on the thinking of post-Keynesian economists and recognizes the important implications that the financial world has on the real economy (Binswanger 1997, Park 2004). He investigates the consequences of an economy without growth and draws the conclusion that, in a fractional reserve banking economy, "[...] in the long run, abstracting from business cycle fluctuations, capitalist economies can either grow (at a sufficiently high rate) or shrink if the growth rate falls below a positive threshold level" (Binswanger 2009, p. 708). Thanks to the debt creation through fractional reserve banking, a zero-growth or negative growth economy would lead to a downward spiral of decreasing demand and firm bankruptcies (Binswanger 2009). What this suggests is that if the economic system of today is imperatively forced to grow in the long run, a steady state economy cannot be possible without major transformation of the current economic system (Blauwhof 2012, Sorrell 2010).

Decoupling the of the monetary and real economy

The conclusion by Binswanger that a zero-growth economy cannot be economically sustainable because of the construction of the financial system underlines an interesting interdependency between, on one hand, the flows of real goods and services in an economy, and, on the other hand, the flows of money and debt. According to his study, the structure of the monetary flows in the economy is imposing an imperative on the flows of goods and services to grow in order for them not to diminish (Binswanger 2009).

To further discuss the implications of this, we need to define what we mean with the two different flows. The part of the economy that is concerned with the actual production of real goods or services we call the real economy. In contrast to this we put the monetary, or financial, economy, which is the part concerned with banking and the nominal monetary values (Financial Times Lexicon). There is an interdependency between the worlds since the financial economy is allocating resources to the real economy in order for it to be more efficient.

Within economics a central aspect is the idea of the classical dichotomy. The expression was first used by Don Patinkin (1956), referring to the view, originating from the classical economists, that real and nominal phenomena are completely separated and have no influence on each other. This means that monetary occurrences and shocks, for example an increased money supply, should only affect the general price level (a part of the financial world), but not relative prices and real quantities (part of the real world) (Tobin 2008).

From this notion of complete separation did the quantity theory of money develop, advocated by Irving Fisher (1911) and, most notably, Milton Friedman (1956). The theory states that there is a direct proportional relationship between the money supply and the price level. For example, since the monetary economy can have no effects on the real world, an increase in the money supply, perhaps through fractional reserve banking, will inflate the general price level, so that the real prices of goods remain unchanged (Friedman 2008). Today it is agreed upon by mainstream economists that the relationship is substantial, at least in the long run (Dwyer and Hafer 1999, McCandless and Weber 1995, Poole 1994). However, criticism has been leveled against its validity in the short run, arguing that the inflation may be subject to stickiness (Barksy 1987; Cogley, Primiceri and Sargent 2010; Stock and Watson 2007).

An early critic of the quantity theory of money was Keynes (1937b). He emphasized the connection between money printing and real economic growth, and meant that without new money it is impossible to finance new production. "In a monetary economy of production, credit is needed to enable firms to continue and expand production. There is a definitive link between bank credit and economic growth" (Rochon and Rossi 2004, p. 146). More recent studies have also investigated how credit expansion can, in itself lead to real economic growth: "if the amount of money in circulation increased [...], more energy could be produced from fossil-fuel sources to give value to that money" (Douthwaite 2012, p. 2).

Another economist who was early in exploring the interaction between the real and monetary worlds was Hyman Minsky. In a way, his ideas have been rediscovered in the aftermath of the financial crisis of 2008. Minsky chose to analyze the economy as a system itself, rather than seeing it as an aggregate of individual agents (Minsky 1993). With his financial instability hypothesis he showed that the financial markets are partly decoupled from the real economy. The theory of decoupling describes how the monetary side of the economy expands without relation to the real economy, thus causing fluctuations through the speculative bubbles created in prosperous times, and the recession caused by their bursts. He builds the hypothesis on the classic description of debt deflation offered by Irving Fisher (1933), but where Fisher describes how bubbles burst, and their economic effects, Minsky explains how these bubbles form through the decoupling between the real and monetary world.

The decoupling between real wealth and the financial economy was also examined by Frederick Soddy. He argued that if real wealth is the goods and services created, debt is the exchange of present real wealth for future real wealth (Soddy 1926). The problem is, according to Soddy, that while real wealth is based on the present physical world, debt is purely mathematical and so is its growth; implying that there is a limited extent to which "present surpluses can be exchanged for perennial streams of future reserves" (Daly 1980, p. 475). Soddy claims that at some point the growth discrepancy between the financial and the real economies will lead to a collapse of some sort (Daly 1980).

The two ideas of the classic dichotomy and the decoupling of economies lead to different conclusions on how stable an economic system really is. The classic dichotomy predicts a very stable system where shocks are immediately neutralized, whereas the theory of decoupling is one of recurring booms and busts. When constructing and interpreting our model these theories will have important implications.

Ecologic population modeling

By using an interdisciplinary approach, economists and biologists have tried to describe ecological systems with economic models and thinking. To describe the economic values of an ecologic system researchers often begin with investigating how ecological populations develop (Bostedt 2013).

Mathematical models depicting the evolution of a species population in a particular time and place have been particularly popular in the research of fish and forests (Clark 1990), but theoretically similar models can be used to study any population or biomass (Xepapadeas 2008). In the simplest forms of these models $x(t)$ denotes the population of a certain species at the time t. The evolution of the population can be described by a simple differential equation.

$$\frac{dx}{dt} = birth - natural\ death + migration - harvesting. \tag{1}$$

In the analysis of population models it is common to assume that the migration is zero. Also, the "natural growth" of a population (birth minus natural death, i.e. the evolution of the population not taking into account the effects of human activities) is usually represented by $F(x)$ (Xepapadeas 2008). Left we have a simple, introductory population function (Clark and De Pree 1979):

$$\frac{dx}{dt} = F(x,t) - h(t). \tag{2}$$

$F(x,t)$ can be specified in different ways depending on what system is being studied and what level of detail that is desired. A simple function that has been widely used to describe different populations is the logistic population growth function (Achcar, Mazucheli and Coelho-Barros 2011; Clark and De Pree 1979), first introduced by Pierre François Verhulst (1838):

$$F(x,t) = gx(1 - \frac{x}{K}). \tag{3}$$

According to Verhulst, the population will not continue to grow indefinitely. Instead there is a certain carrying capacity K within the population, which, in the case of a forest, can be thought of as the maximum number of trees that will exist if the forest is kept completely unattended. The growth rate will then depend on how close the current population is to this carrying capacity. When the population is small, there will be a quicker growth rate that will diminish until the carrying capacity is reached.

An unrealistic feature of the logistic equation is that the population growth is positive for all population levels between zero and the carrying capacity. For example it does not take into account the general population problems with inbreeding and the difficulty of finding a partner that are likely to emerge within a very small population. By introducing the minimum viable population x_{mvp} we obtain a limit for how small the population can be and still have growth. If the population falls under this level, this will result in negative growth.

$$F(x,t) = gx(\frac{x}{x_{mvp}})(1 - \frac{x}{K}). \tag{4}$$

It is a large simplification to assume that the population growth is always negative when the population falls beneath a certain level, and that it is always positive above that level. However, in all its simplicity it is a good tool for analyzing population developments, without having to make unnecessary complications (Bostedt 2013).

Concluding remarks on previous research

We believe that by integrating these different subjects, we can address the question of the impact of money printing on sustainability from a somewhat new angle. By taking the concepts of endogeneity of money and the notion of a decoupling of the monetary and real economies, together with aspects of neoclassical theory, we aim to find how the overutilization of resources can be explained. Below we will outline the model, from which we will gather results for interpretation.

Analysis

Outlining the model

In our model we will let the ecological and economic systems interact and mutually influence each other, thereby enabling us to analyze how they behave under given assumptions. The interaction that is to be studied is that of how a diminishing supply of natural resources, to be considered originating from the ecological system, is negatively influencing the output of an economy through elevating relative prices of natural resources. We want to see how the human economy, characterized by a monetary system where credit is created through a system of fractional reserve banking, may be reducing this negative impact on real output, which might result in overexploitation of the natural resources.

In building a model we try to isolate the phenomena we set out to examine. By using assumptions founded upon existing theories, and sometimes used in models by other authors, we try to make the model as valid as possible for our cause. In our model we sometimes abstract from aspects of reality in order to simplify our interpretation.

Our model is built on the fundamentals of neoclassical theory, where income constrained agents make rational choices to maximize their utility, and prices, output and income distribution are determined through supply and demand and the forming of equilibria (Campus 1987). However, to the conventional neoclassical characteristics we add aspects originating from two other schools of thought. First, neoclassical economists tend to focus on the influences the human economy has on the ecology, and ignore their mutual interaction. Since we want to examine the two-way inter-dependency between a human economy and its environment, we include the concept of mutual influence that is a characteristic for the ecological economical approach (Illge and Schwarze 2009). Second, we use endogeneity theories from the post-Keynesian school of thought when describing how money is created through fractional reserve banking. According to this tradition neoclassical theories abstract from the ability of the banks to create money on their own (Binswanger 2009). By including this we can investigate how credit expansion affects the economy, without needing to include a central bank, something that would complicate the model significantly. This way of integrating different schools of thought has been used by several researchers (Ayres and Kneese 1969; Bouman et. al 2000; Walter, Baek and Koo 2012).

We consider a closed economy with one consumption good: furniture, and two factors of production: labor and wood. There are four different types of agents: Banks, Firms and two different households: Laborers and Forest-owners. The economy of our model is centered on the production of the consumption good. The firms are the producers and the households are the consumers of furniture, as well as the suppliers of the factors of production to the firms. The banks provide the economy with loans, and are enabled to expand the money supply through fractional reserve lending. We assume that all agents, given their role and conditions, are acting rationally to maximize their utility, and that there are clear property rights and no common property.

We abstract from governments and other agents in order for the interpretation of the simulations to be as easy as possible. Adding another actor in the form of a government, with taxes or other ways of intervening in the economy, would not contribute to better understanding of how the pricing mechanism may be distorted by credit expansion. Instead, this would only complicate the construction of our model and the understanding of its implications.

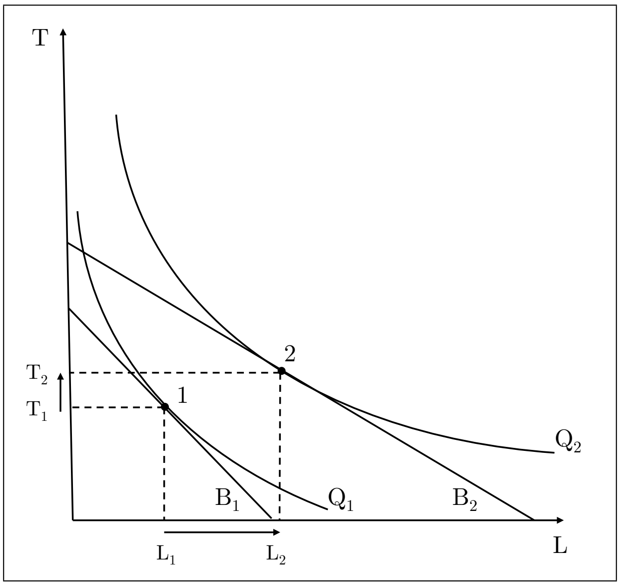
The model takes the form of a circular flow of income where the streams of income and real goods flow between the different agents. Money flows to the producers from the consumers in the form of payments for consumption. There is also a money flow in the opposite direction, from the producers to the consumers, in the form of wages and payment for wood. In parallel to the monetary flows there is also a flow of real goods from the producers to the consumers, as well as a flow of factors of production from the consumers to the producers. By separating the monetary flow from the real flow one can analyze how they develop in relation to each other.

Our modeled economy is placed inside the other part of our model: the ecological system. This ecological system consists of a forest, owned and managed by many forest-owners. This natural resource stock is diminished by utilization of wood, and has a growth rate dependent on the population size relative to the carrying capacity and the minimum viable population. When the utilization rate is higher than the growth rate, we call it overexploitation, which, according to the criteria discussed by Costanza and Daly (1992) is an unsustainable development.

The human economic system is considered subordinated the ecological system in the sense that the ecological system could function very well without interacting with the human economic system, whereas the human economic system is dependent on the ecological system to provide wood to the production of furniture. This interaction and dependence correspond to the thinking of ecological economists such as Malte Faber (2008) and Jeroen van den Bergh (2001).

In the economy, money, consisting only of banknotes, is the only exchange medium, and its nominal value is not tied to any real values. Money is created when banks lend money to households and firms through the fractional reserve banking system. Although money creation over time, everything else equal, leads to diminished purchase power per unit of money, the inflationary effects of money creation is considered to be sticky, meaning that the printing of new money will have short-term stimulating effects on demand. The tendency for inflation to lag is a common assumption within macroeconomic theory, and its effect on the real economy has been confirmed by many studies (Barksy 1987; Cogley, Primiceri and Sargent 2010; Stock and Watson 2007).

Figure 1: Allocation of factors of production



The firms manufacture furniture Q by using different combinations of labor L and wood T. This choice of combinations, pictured in Figure 1, forms a central part in the model. The budget constraint B_1 is the total amount of money the firm has available to cover its production cost, and to which combination of wood and labor this corresponds.[3] As the firms try to maximize their utility, they strive to produce as much furniture as possible. According to basic microeconomic thought, the highest possible level of production is where the production curve tangents the budget constraint (Pindyck and Rubinfeld 2009). Thus, in point 1 in Figure 1 we have the combination of labor, L_1, and wood, T_1, that will ensure that the highest number of new furniture is produced in period 1. In the following period 2 the relative price of wood has changed, the budget constraint is expanded and the new equilibria can be found in point 2. This equality will then continue to reform in each period, finding new equilibria. Below we will describe this process and how the different actors affect the outcome of the model.

[3] See Table 1 and 2 in Appendix I for complete listings of variables and parameters.

Banks

Our modeling of the behavior of banks is based on the theories laid forward by money endogeneity theorists such as Park (2004) and Moore (1988b), in the sense that the demand for new money is a fundamental driver of lending. From these theories we also borrow the notion that even though the banks might be capital constrained, they are usually not reserve or funding constrained (Hannsgen 2004, Kuttner and Mosser 2002).

Banks are able to lend part of their reserves to the households and the firms, with the only restriction that the banks need to keep a fraction of their lending as own capital. Since there is no government that can regulate the economy, we think about the reserve requirement as a social contract that the banks need to follow. This way of modeling bank behavior resembles the circular flow model by Binswanger described above (Binswanger 2009). Each period the firms and households pay interest on their current debt. These interest payments are net interest income, meaning that the interest payments are the total profit that can be accumulated in the banks' own capital. As the own capital increases, the banks can supply more lending. As higher lending means higher profits, the banks will want to maximize the lending in each period, creating a spiral of new debt, where the demand is driven by the consumers' willingness to consume. This is similar to the ideas within post-Keynesianism discussed above. As a result, in each period the loans of households and firms are growing. To make the model more pedagogical we assume that the banks pay no dividend or wages, something that would only lead to an additional flow of money with no change in the development of our simulations.[4]

The banks charge a nominal interest r_t^n on the loans outstanding. This interest rate is adjusted for inflation so that banks will always receive the real interest rate r^r, which is constant in all periods.

$$r_t^n = r^r(1 + i_t). \tag{5}$$

The amount of new money created in each period is governed by the interest payments made by households and firms in the previous period. The interest rate r_t^n is multiplied

[4]Adding for example rents or dividends would not change the main outcomes of our model since these money flows would eventually flow back to the households and be used for consumption.

with the previous period's sum of debt in the economy $(d^h_{t-1} + d^f_{t-1})$, divided by the fraction f the banks are obliged to keep as own capital. This equals the new credit, and thereby money ΔM_t, that is being created in each period.

$$\Delta M_t = \frac{r^n_t(d^h_{t-1} + d^f_{t-1})}{f}. \tag{6}$$

The newly created money is then allocated to firms and households in a way that creates an equilibrium where the consumer demand for furniture is maximized, while the firms are able to meet this demand. This mirrors the role of the financial sector as an efficient allocator of resources. The fraction x_t of ΔM_t is the amount of new money that will be distributed to the firms to invest in production goods. Correspondingly, the households will borrow the fraction $(1 - x_t)$ of the new money for consumption. The ratio x_t will be elaborated upon below.

Households

The households consist of laborers and forest-owners and represent the consuming sector of the circular flow of income. The household demand for furniture is assumed to be monotonic, meaning that more is always preferred to less (Varian 2010). We also assume that the households will spend all their disposable income on consumption, and that they will borrow all money available to maximize consumption in each period. We assume this for two reasons. First, this incorporates the idea among money endogeneity theories that lending is determined by the demand for credit among households and firms (Pollin 1991). Second, by doing this strong but simplifying assumption we avoid having to create a much more complicated model for household behavior, which would not help us answer our research questions.

Thus, the total nominal value of furniture demanded in period t, D_t, is made up of the total disposable income in that period. This consists of the sum of the total income from supplying factors of production during the previous period, I_{t-1}, plus the portion of new loans allocated to them $(1 - x_t)\Delta M_t$, minus the interest that the households pay on their total debt in the previous period $r^n_t d^c_{t-1}$:

$$D_t = I_{t-1} + (1 - x_t)\Delta M_t - r_t^n d_{t-1}^c. \tag{7}$$

The households either work in the furniture industry and receive wages, or are the owners of the forests and receive money from selling wood to the furniture industry. Thus, the total income from supplying factors of production is the sum of the wages paid during the period $w_t L_t$, and the value of all trees sold $P_t^T T_t$:

$$I_t = w_t L_t + P_t^T T_t. \tag{8}$$

In the economy labor is abundant and it is always possible for the workforce to supply one more unit of labor for the firms, without increasing marginal cost. As a result, the wages w_t are subject to inflation only:

$$w_t = w_{t-1}(1 + i_t). \tag{9}$$

We do this simplification since we in this model want to isolate and describe the effects money creation has on the utilization of natural resources. Rather than helping examining the subject, increasing marginal cost of labor would complicate the interpretation of the effect of changing relative price of wood.

Firms

The furniture-producing firms are acting on an efficient market where there is perfect competition and no profits for individual firms. The firms aim at satisfying the demanded nominal value of furniture D_t by producing the corresponding actual number of furniture Q_t, given the price of wood P_t^T and labor w_t. The firms know in the beginning of each period what the nominal value of the demand D_t will be, and, since there are no profits for the individual firm (revenues equal costs), they budget for an equal amount of production cost B_t:

$$B_t = D_t. \tag{10}$$

Similar to corresponding studies, we assume that the costs of the firms are borne in the beginning of the period, while the revenues are received in the end of the period (Howells 2005, Moore and Threadgold 1985). Thus, in the beginning of period t, the total budget available for production will be the firms' income from the previous period R_{t-1}. Added to this will be the allocated portion of new lending created by the banks $x_t \Delta M_t$, minus the interest payments on the previous period's debt $r_t^n d_{t-1}^f$:

$$B_t = R_{t-1} + x_t \Delta M_t - r_t^n d_{t-1}^f. \tag{11}$$

As stated above, the new loans are allocated to firms and households in order to equate and maximize demand and supply for furniture. Given that the nominal value of furniture demanded is matched with the nominal value budgeted for production, as seen in equation (10), we can find how large the fraction of the new loans is that will be portioned to firms, x_t, and to households $(1 - x_t)$ by using the equations (7), (10) and (11). See Appendix II for derivations.

$$x_t = 0.50 + \frac{I_{t-1} - R_{t-1} + r_t^n (d_{t-1}^f - d_{t-1}^h)}{2\Delta M_t}. \tag{12}$$

For the firms we use a simple Cobb-Douglas type production function to describe their production of furniture Q_t (Cobb and Douglas 1928). It shares some similarities with Nicholas Georgescu-Roegens's interpretation of the attempt by Robert Solow and Joseph Stiglitz to incorporate natural resources into the Cobb-Douglas function (Georgescu-Roegens 1979).

$$Q_t = A T_t^{\alpha} L_t^{\beta}. \tag{13}$$

According to Figure 1 the budget constraint will be used together with the production function (13) to find the combination of factors of production, wood T_t and labor L_t, which maximizes furniture output, given the prices of trees P_t^T and wages w_t. Since there are no profits for the individual firms (implying that revenues equals cost), the whole budget constraint budget B_t is used to finance the factors of production.

$$B_t = P_t^T T_t + w_t L_t. \quad (14)$$

By using equations (10), (13) and (14) these optimum combinations can be obtained. The derivations for obtaining equations (15) and (16) can be found in Appendix II.

$$T_t = \frac{D_t}{P_t^T(1+\frac{\beta}{\alpha})}. \quad (15)$$

$$L_t = \frac{\beta D_t}{w_t(\alpha+\beta)}. \quad (16)$$

The quantity of furniture produced Q_t is then sold to the households for the unit price of P_t. Since there is perfect competition, the price will equal marginal cost:

$$P_t = \frac{w_t L_t}{Q_t} + \frac{P_t^T T_t}{Q_t} \quad (17)$$

The total revenue that the firms will receive will then equal the nominal value of the quantity demanded, which will be used to finance the costs in the beginning of the next period:

$$R_t = D_t = Q_t P_t. \quad (18)$$

The forest population of trees

When looking at the evolution of the forest, the change in forest population can be described by equation (2), where $F(x,t)$ denotes the "natural growth" of the tree population and $h(t)$ denotes the harvesting rate. Acknowledging that the ecological population models that are used today have advanced far beyond the logistic growth function, we will nevertheless base the population growth upon Verhulst's (1838) equation. The point of this is to be able to model how prices of wood could evolve in a plausible way, and using a more advance model would not contribute to fulfilling this purpose.

The population dynamics of the forest is described with the logistic growth function, to which is added a carrying capacity and minimum viable population:

$$\frac{\Delta S_t}{S_t} = g(\frac{S_t}{S_{mvp}} - 1)(1 - \frac{S_t}{K}) \tag{19}$$

where S_t is the population of trees in the forest in a certain period t, ΔS is the change in the number of trees, g is the intrinsic growth rate of the forest, S_{mvp} is the minimum viable population, and K is the carrying capacity.

The ones owning and managing the forest are the forest-owners, who in the model are representing the link between the human economic system and the ecological space. The forest is wholly owned by the forest-owners[5] and it is through the felling of trees that the interaction between the systems takes place in this model. The harvesting rate $h(t)$ is defined as the population of trees cut down T_t, divided by the total forest size at that time S_t:

$$h_t = \frac{T_t}{S_t}. \tag{20}$$

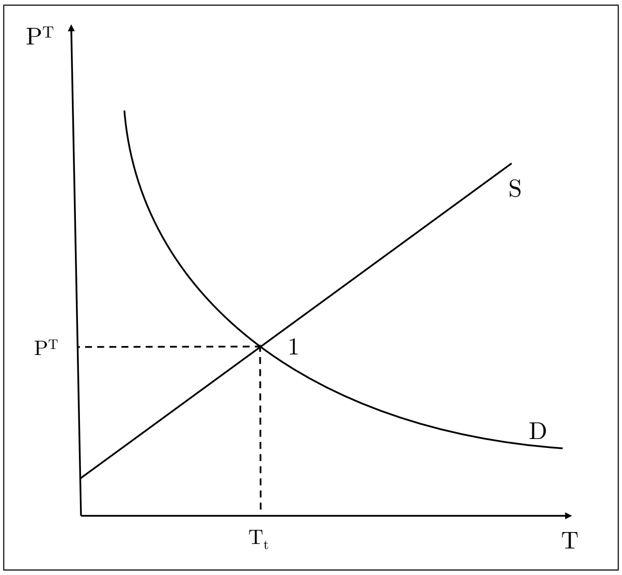
This gives us the following function for the population of trees:

$$S_t = S_{t-1}\left[1 + g(\frac{S_{t-1}}{S_{mvp}} - 1)(1 - \frac{S_{t-1}}{K})\right] - T_{t-1} \tag{21}$$

where T_{t-1} is the number of trees used in furniture production in the previous period.

[5]Consequently, there is no risk for the forest being misused in the way described by Garett Hardin (1968) in his essay *The Tragedy of the Commons.*

Figure 2: Price of wood



Since the real price of labor is constant, all changes in the price of wood are directly influencing the relative price of wood. When modeling the wood pricing we first and foremost try to be pragmatical. The model should be able to give an adequate relationship between the price of wood and the price of labor without being too complicated. This means that we want the relative price of wood to be high when the population of trees is low, and vice versa. We do this by assuming that the pricing of wood can be understood by looking at a standard supply and demand relationship (see Figure 2). The firms' demand for wood T_t^d, is given by equation (15) above.

For the supply curve we go back to the ecological population models presented in the previous research section. We assume that the suppliers of wood ground their pricing in a base price $P_{0,t}^T$, here assumed to be the inflated final price of the previous year:[6]

$$P_{0,t}^T = P_{t-1}^T(1 + i_t). \tag{22}$$

However, this price is adjusted to take into account the scarcity of the forest. The scarcity is included by adding a percental price premium, proportional to the difference between the harvesting rate and the growth rate of the forest. To incorporate aversion

[6]Included in the base price of period 0 $P_{0,0}^T$ is the operational cost of harvesting one tree

to deforestation amongst the forest-owners, we can magnify the impact of the difference between harvesting rate and growth rate by the factor Ω:

$$P_t^T = \overbrace{P_{0,t}^T}^{\text{base price}} + \overbrace{P_{0,t}^T \Omega \left[\frac{T_t^s}{St} - g(\frac{S_t}{S_{mvp}} - 1)(1 - \frac{S_t}{K}) \right]}^{\text{scarcity aversion}}. \tag{23}$$

From this we get our supply function where the quantity of trees supplied T_t^s is a function dependent on the price of wood P_t^T:

$$T_t^s = S_t \left[\frac{P_t^T}{P_{0,t}^T \Omega} - \frac{1}{\Omega} + g(\frac{S_t}{S_{mvp}} - 1)(1 - \frac{S_t}{K}) \right]. \tag{24}$$

Combining equation (15) and (24) we get equation (25) for the price of trees. Derivations are found in Appendix II.

$$P_t^T = \frac{P_{0,t}^T [1 - g\Omega(\frac{S_t}{S_{mvp}} - 1)(1 - \frac{S_t}{K})]}{2} \pm \sqrt{\left(\frac{P_{0,t}^T [1 - g\Omega(\frac{S_t}{S_{mvp}} - 1)(1 - \frac{S_t}{K})]}{2} \right)^2 + \frac{D_t P_{0,t}^T \Omega}{(1 + \frac{\beta}{\alpha}) S_t}}. \tag{25}$$

Inflation

Since inflation in the economy affects the prices of the factors of production, we need to describe how prices develop in the economy. Money is not tied to any values, meaning that the prices in the economy are floating. Although money creation eventually leads to inflation we assume “stickiness” in the prices, that the money created in period t inflates the prices of factors of production in period $t + 1$.

According to the quantity theory of money the prices in the economy are dependent on the amount of money in circulation M_t, the velocity of money V_t, as well as the quantity of final goods and services Q_t (Friedman 2008):

$$M_t V_t = P_t Q_t. \tag{26}$$

In the modeled economy money only flows through the economic system once each period. Thus, the velocity of money V_t, is constantly 1. The percental change in prices ΔP_t is therefore dependent on the percental change of money supply in the previous period $\frac{M_{t-1}}{M_{t-2}}$, where the money supply in each period M_t equals the money supply in the previous period M_{t-1}, plus the new money created in the current period ΔM_t:

$$M_t = M_{t-1} + \Delta M_t. \tag{27}$$

The price level change is also dependent on the change in the quantity of goods for sale during the previous period $\frac{Q_{t-1}}{Q_{t-2}}$:

$$i_t = \Delta P_t = \frac{M_{t-1} Q_{t-2}}{M_{t-1} Q_{t-1}}. \tag{28}$$

The inflationary process of our model is given by (28), and affects the prices of factors of production, trees and labor, at the beginning of each period, as depicted in equation (9) and (22).

Simulations

The purpose of the model is to investigate how the pricing mechanism and utilization of renewable natural resources are affected by the continuous creation of money in private banks. By using the model to simulate the development of our variables, we will be able to analyze the implications of a fractional reserve banking system.

When we make our simulations we set up two different economies and compare the effects. We call these scenarios "Fractional reserve banking," and "100%-reserve." In the fractional reserve banking scenario banks have the ability to create money by the lending of deposits. In the 100%-reserve economy the ability of the banks to create money is removed, since they must hold all deposits as reserves. Our focus lies on comparing the difference in development between the two scenarios. Thus, no emphasis is put on the absolute values that our simulations render, since these are dependent on the arbitrary values given to them in period 0.

Before we start the simulation we have to decide upon two kinds of arbitrarily chosen values.[7] First, we have the exogenous parameters that we decide upon ourselves. We have tried to make these reflect the real world economy as far as possible, while keeping the figures simple for adequate interpretation of results. Second, we have variables that are endogenous in period 1 and forward, where we have to assign some initial arbitrarily chosen values in period 0 to get the model started.

Assuming perfect competition implies constant returns to scale in our Cobb-Douglas type production model (Djivre and Menashe 2010). This means that in our production function alpha and beta must summarize to 1. Due to the simplified nature of the model we choose the simplest form for these values and assume that $\alpha = \beta = 0.5$. The constant A does not contribute to answering our research questions, and to facilitate interpretation we set it to 1.

In the fractional reserve banking scenario we set the interest rate to 5%, an arbitrarily chosen value. Changing the interest rate does not alter the characteristics of the simulations, but only changes the pace of the development. When we look at an economy without the fractional reserve banking system, where no new money or debt is created by private banks, we set the interest rate to 0%. Without the possibility for the banks to create new money there would be no reason for them to accumulate capital. Instead the bank-profits would be distributed as dividends, go back to the economic system and be used for consumption. For the economy as a whole, this would be the same as having an interest rate of zero, with the exception that part of the consumption would be postponed one period. However, we choose to neglect this small difference in order to not complicate the interpretation of our results, and set the interest rate to zero in the 100%-reserve economy.

The minimum bank capital ratio is set to 50%. This is a higher value than we see in the real world, where a more realistic figure is 10-15% (Moody's 2012). However, if we set the capital ratio to 10% or 15% we will see the same development as in the 50% case, with the exception that the modeled economy evolves at a higher pace since the possibility to create more money leads to a faster spiraling economy. In order to get the results spread over more periods, enabling us to capture more details, we choose a higher capital requirement ratio.

In the case of the exogenous parameters of the forest we choose these simply to facilitate

[7] See Table 3 and 4 in Appendix I for complete listings of these variables and parameters.

interpretation and to make their values relative to each other logical. We set the intrinsic growth rate g to 2%, the carrying capacity population K to 100 and the minimum viable population S_{mvp} to 10% of the carrying capacity population.[8] The initial size of the forest S_0 is set to 70% of the carrying capacity K. The parameter capturing aversion to deforestation, Ω, is set to 5, meaning that when the rate of deforestation $\frac{T_t}{S_t}$ is 1 percentage point higher than the natural growth rate of the forest (i.e. when the forest shrinks by 1% during the period) the price of trees will rise by 5%.

The initial arbitrary chosen values for the otherwise endogenous variables are chosen to be consistent with the assumptions we have made, and to facilitate interpretation. As is elaborated upon in the section called Model robustness, the money quantity in period 0, M_0, and the quantity of furniture produced in period 0, Q_0 are chosen to minimize the impact of inflation in the first periods. Thus, Q_0 is set to equal the quantity of furniture produced in period 1, Q_1, while M_0 is set to 500. These are the only two initial arbitrary variable values that on their own have a strong influence on the development of the model variables.

The initial values of the price of wood P_0^T and wages w_0 are both set to 5. They are set to equal each other since we are looking at the development and changes in the relative price of wood. The initial debt levels of consumers and firms are assumed to be equal to each other and are set to 10. The household income of period 0 is assumed to equal the firms' initial budget, and is set to 100. The inflation in period 0 i_0 is set to 0%. As stated above, these interrelationships and values are chosen to make the interpretation of simulations easier.

Model robustness

It is important to point out the limitations of our model and its sensitivity to changes. In this section we will discuss two aspects of this. First, we discuss how our underlying assumptions affect the outcome of our model, and second, we look at our choices of exogenous parameters and initial values for our variables.

[8]In practice this gives us a maximum yield $\frac{\Delta S}{S}$ of about 4%. It is worth emphasizing that we do not compare this value to any real-world equivalent, but only want it to give us a reasonable expression of forest growth. From that aspect, this value is in line with the views of researchers on the subject (Lundqvist 2012, Bømer 1957)

Small changes in the underlying assumptions of the model could have rendered different results. We have tried to build the model as logically consistent as possible, and therefore believe that our assumptions are in line with our attempt to fulfill our purpose. Maybe the most important of these premises is the one of sticky inflation. Without this assumption, the printing of new money results in an instantaneous increase of the general price level, thus immediately neutralizing the effect of expanded money supply. The result is that no stimulating effects will arise and there will be no difference in the outcome of the two scenarios. Consequently, most of the results presented depend on this assumption. However, that prices do not adjust instantaneously, thereby implying some degree of inflation stickiness, is a common assumption among economists (Barksy 1987, Stock and Watson 2007, Cogley 2010, Primiceri and Sargent 2010).

Another important assumption of this model is that households spend all their disposable income on the consumption of furniture, and that they will borrow money to be able to buy more furniture. Without this assumption we would have had to construct the model in a different fashion, maybe through introducing a limitation on how much the households are willing to borrow in relation to their savings level or income. However, this would have introduced many more variables into the model, making it substantially more complicated. Since we are investigating the impacts of credit expansion, we believe that this would only have complicated the interpretation of this model, without adding any explanatory value, or helping us answering the research questions.

We will not make a full variable analysis in this section. However, due to the arbitrariness of some of our initial values and exogenous parameters, we find it important to dwell upon how different choices might have affected our simulations.[9]

To begin with, our model, generally, show strong resilience toward changes in the exogenous parameters and initial values. We can divide the exogenous parameters and initial values into two categories: those who substantially change not only the actual numbers, but also the basic characteristics of our results, and those who have an impact on the actual figures, but not the general outcome. Most of our variables, with some exceptions, apply to the second category.[10]

[9] This analysis of the impact of the chosen values is made by looking at how each individual parameter or variable affect the outcome of the whole model. This is done manually, step by step, and no advanced analysis tool is being used.

[10] However, when some these second category-variables and parameters are set to zero or negative figures it may lead to very different results, or a total collapse, of the model. However, it is worth

The following parameters and variables apply to this second category. Making changes in these only lead to differences in the scale of our results, without changing the main conclusions one can draw from the simulations: $d_0^f, d_0^h, w_0, I_0, S_0, B_0, P_{0,0}^T, \Omega, g, A, f, r^r, K, S_{mvp}$.

The main reason why some variables apply to the first category, and substantially impact our simulations, is because they generate extreme inflation values. This is true in the case of α and β. Even though changing the relation between the two parameters does not substantially change our results, deviating from the assumption of constant return to scale has implications of the conclusions we can draw from our simulations. Assuming increasing return to scale mainly affects the 100% -reserve scenario by leading to its collapse. Without diving too deep into model technicalities the reason is that we after some periods get extreme inflation-values in the economy, causing the prices of factors of production to increase rapidly. Assuming decreasing returns to scale has no effect on the main characteristics of the results.

In a similar fashion our choice of the initial money supply M_0 and output Q_0 affects the inflation of the first periods ($i_1 = \frac{M_1 Q_0}{M_0 Q_1}$), which, in turn, has an impact on the rest of the modeled economy. As seen above, to solve this we have put $Q_0 = Q_1$ and assign a value to M_0 that will not render an extreme inflation.

Interpretation

Before presenting the results of our simulations we return to our research questions. In this section we begin by addressing our first research question by investigating the impact money supply has on the real economy. In the following interpretation of our results we discuss the second research question, regarding the impacts on sustainability.

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emphasizing that in these cases, negative or zero values are completely inadequate assumptions.

Figure 3: Output in fractional reserve banking scenario

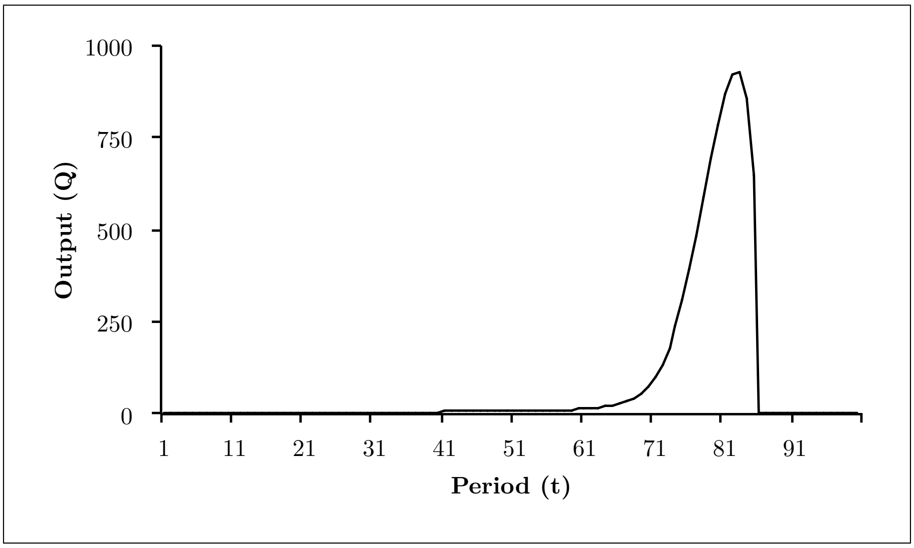
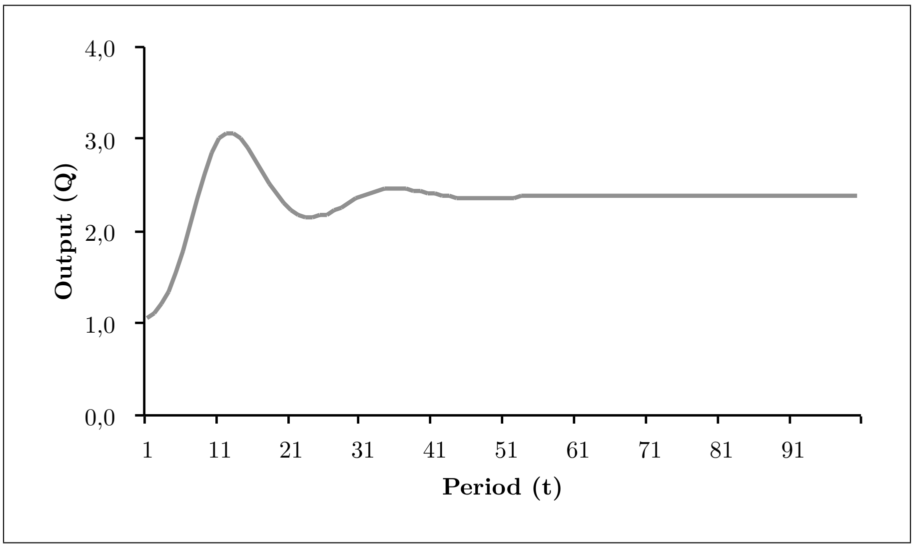
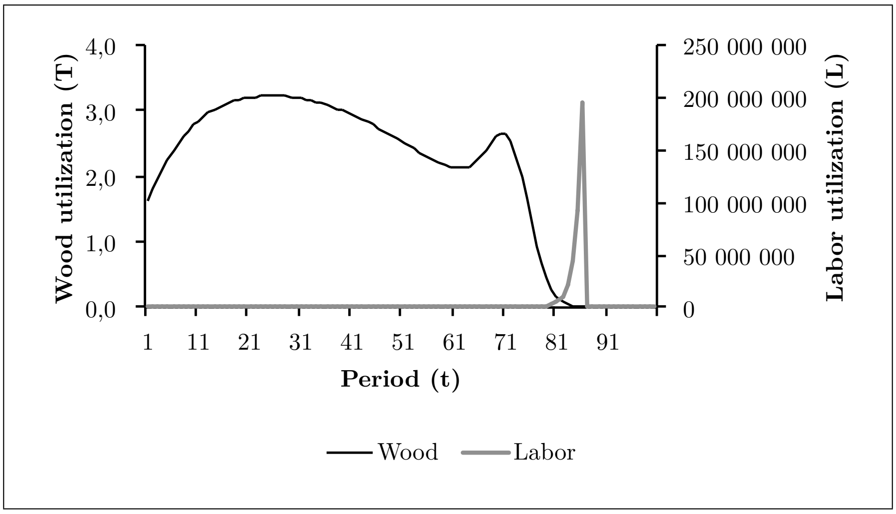


Figure 4: Output in 100%-reserve scenario



In Figure 2 and 3 we see how output, the production of furniture, develops in the two different economies during 100 periods. We can see that in the fractional reserve banking scenario there is an exponential growth in the first 80 periods, until the production of furniture collapses. In contrast, the output of furniture in the 100%-reserve scenario oscillates for a number of periods, until it converges toward a steady state. When the production in the fractional reserve banking economy peaks in the 83rd period we see a production, measured in the amount of furniture manufactured, that is almost 400 times as large as in the 100%-reserve economy.

Figure 5: Utilization of factors of production in fractional reserve banking scenario



We continue to look at the utilization of the factors of the production during the first 100 periods. On the left vertical axis we show the utilization of wood, and on the right vertical axis we show the utilization of labor. In the fractional reserve banking economy (Figure 5) we see that the utilization of labor explodes in relation to the utilization of wood, simultaneously as the relative price of labor falls.

Figure 6: Utilization of factors of production in 100%-reserve scenario

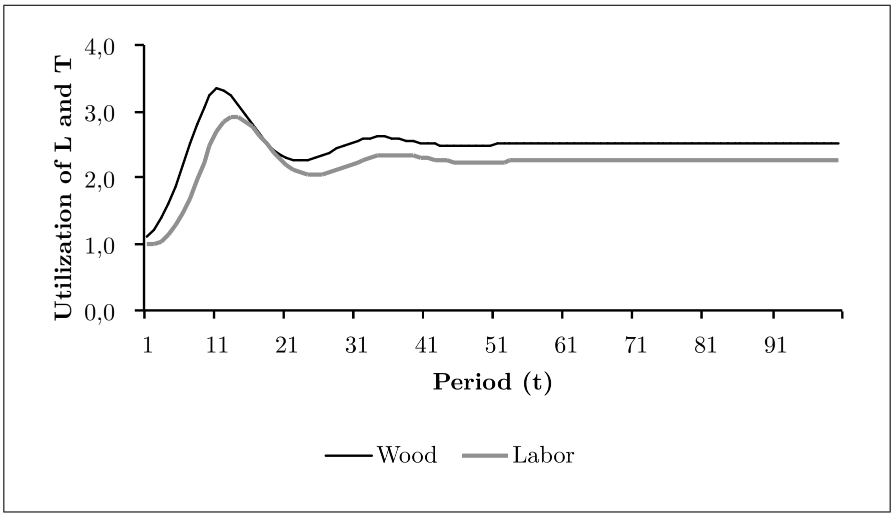
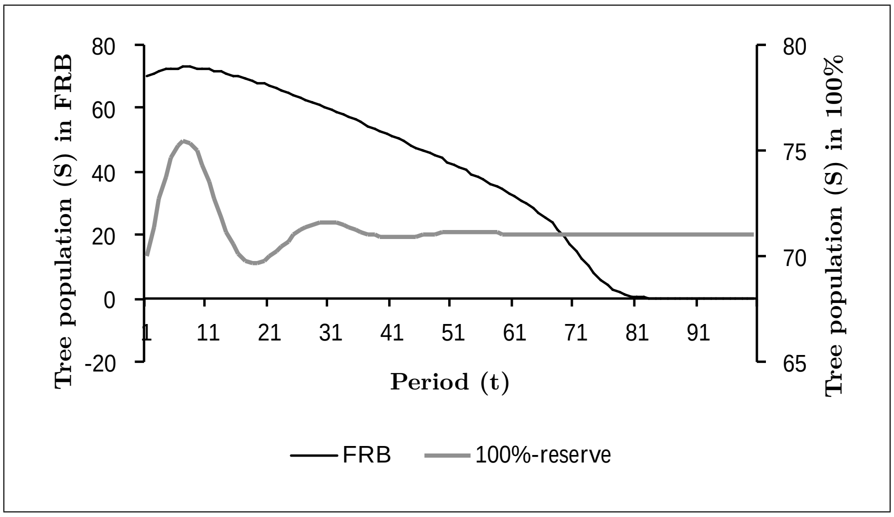


Figure 6 depicts the corresponding data in the 100%-reserve economy, and shows a very different pattern. Here there are some initial oscillations in both the utilization of wood and labor, until both variables converge toward a steady state level and stabilize. We can see that the utilization of wood is quite similar in both economies. However, as can be seen in Figure 7 below, the slightly higher utilization in the fractional reserve banking economy will have a large impact.

Together the figures above suggest an answer to our first research question: the creation of money that takes place in our simulation of a fractional reserve banking system dampens the effect of higher prices of wood, thus stimulating the economy.

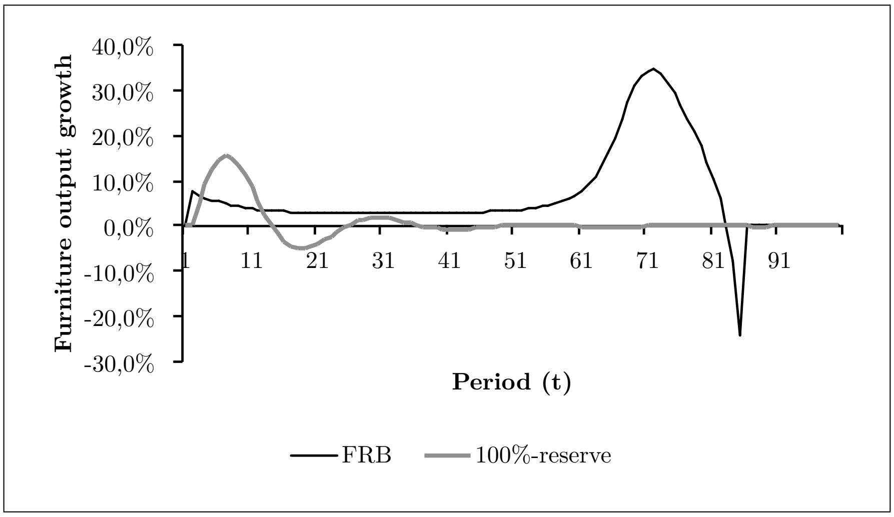
Figure 7: Forest population of trees in fractional reserve banking scenario



By continuing the analysis it can be seen in Figure 7 how differently the total tree population of the forest develops in the two scenarios, even though the utilization of trees are quite similar. The slightly higher, but persistent, harvesting of trees in the fractional reserve banking scenario makes the forest diminish slowly, until a critical level is reached and the forest runs out of trees in the 85^{th} period. This is followed by a total collapse in the production of furniture, and a crash of the model and the economy. In the 100%-reserve scenario the forest finds a steady state after some initial oscillations. At this steady state the growth rate of the forest and the harvesting rate of trees have both stabilized at an equal level.

Looking ahead of the 100 periods it can be seen that there is no more economic activity in the fractional reserve banking economy, as there are no more trees to use in production. In the 100%-reserve economy the oscillations gets smaller until there are virtually no changes in the variables any more.

Figure 8: Output growth



In Figure 8 we see that the output growth levels in the two different scenarios develop very differently. In the 100%-reserve scenario the growth rate oscillates in the first periods until it levels out at 0%. In the fractional reserve banking scenario on the other hand, we see a fairly constant growth rate for the first periods. After some 50 periods the growth rate picks up and accelerates until the economy collapses when the tree supply reaches zero. This goes back to the discussion presented above regarding how to obtain a sustainable economy through zero-growth. Binswanger (2009) presented how a zero-growth economy is incompatible with a fractional reserve banking economy. He concludes his paper by leaving the question open if zero-growth could be possible in another economic system. What we see in our results is that within a 100%-reserve economy, zero-growth seems like a feasible alternative.

As the forest diminishes in the fractional reserve banking economy the relative price of wood rapidly increases, something that, according to neoclassical economists, should result in a lower utilization of wood. However, at the same time new money is created, which drives demand for furniture. The net result is that the price of wood never reaches a level where it can offset the stimulating effects of money printing.

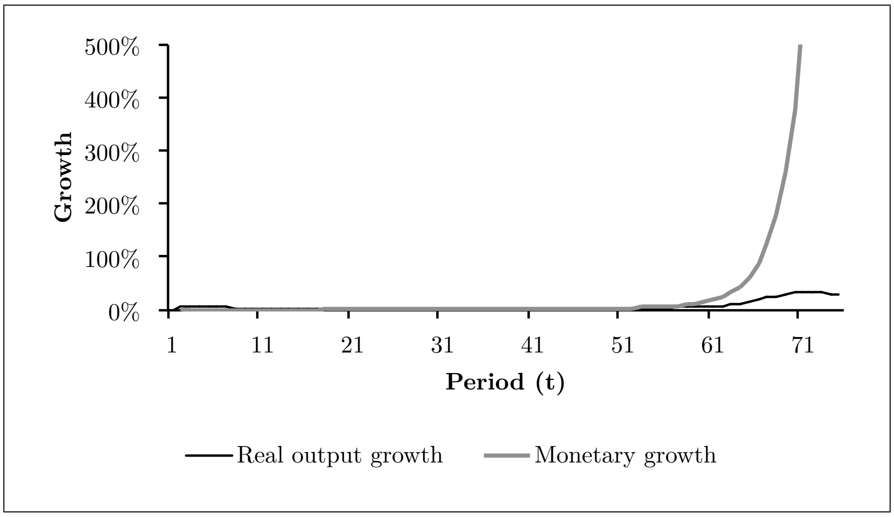
The parameter Ω can be thought of as the aversion by forest owners to scarcity. What is interesting is that no matter what value we assign to this parameter, we cannot change the final outcome of the model. If we put a very high value on Ω, thus simulating very strong aversion to deforestation, we get a somewhat lower total output in the economy, but the basic characteristics of a booming and collapsing fractional reserve banking economy still persist. According to neoclassical theory, a functioning pricing mechanism would lead to wood eventually being so expensive that no more trees are harvested than are regrown. This would lead to the economic growth slowing down. Instead, our simulations show that wood is used in production until ultimately there is no forest left. That we do not see this development in the 100%-reserve economy leads to the interpretation that the expanding money supply in the fractional reserve banking system distorts the dampening effect that the pricing mechanism should have.

As discussed, this is not possible according to the idea of classic dichotomy: the monetary phenomenon of increased money supply should not be able to affect the production of real goods. However, as outlined when introducing the model, we deviate from the classic dichotomy when assuming inflation stickiness, consequently opening up for interactions between the real and monetary world.[11] What is interesting is *how* the monetary side affects the real economy

Two of the most prominent critics of the classic dichotomy are Soddy (1926) and Minsky (1993), and our results are similar to those predicted in their studies on decoupling. It can be seen in Figure 9 that while the growth of money and the growth of real output are well-tied in the first periods, the monetary growth increases at a much higher level than the real output as the economy develops more rapidly, thus making the decoupling evident.

[11] The effects of not assuming sticky inflation are discussed in the subsection named Model robustness.

Figure 9: Real output and monetary growth



Our simulations are similar to the development predicted by Soddy: that debt evolves and multiplies without any connection to real goods produced. The results depict the mathematical characteristics of debt that Soddy presented, and how it can grow without any connection to physical goods. Just as Soddy predicted, the discrepancy between the physical and monetary worlds eventually leads to a collapse (Daly 1980, Soddy 1926). The conclusion we can draw from this is that yielding, even slightly, on the notion that the quantity theory of money holds even in the short run has very large effects on the whole economy. In the case of this particular model, the implication is a much higher consumption within the fractional reserve banking scenario. The price that has to be paid for this is borne by the ecological system, which brings us back to our second research questions, and the discussions about sustainability.

With the definition of sustainable development presented by The Brundtland Commission and the practical interpretation by Costanza and Daly in mind, it is clear that, in our model, the choice of banking system determines whether the economy will be sustainable or not (Costanza and Daly 1992, WCED 1987). When we analyze our results in the light of their definition, we can conclude that the 100%-reserve economy becomes ecologically sustainable as it approaches its steady state. In this steady state no more natural resources is depleted than is regrown, and we can see that the total tree population of the forest remains unchanged. In contrast, we can see that in the fractional reserve banking economy the pricing mechanism is unable to support sustainability. In this scenario more trees are constantly depleted than are regrown.

Our results show that, given the framework of our model, the pricing mechanism, which, according to neoclassical theory, should be able to shift production away from wood and lead to sustainability, is distorted by the fractional reserve banking system and therefore is unable to handle a limited supply of natural resources. The artificially low price of wood leads to the development that we see in our results.

This underlines the common notion among ecological economists that the neoclassical view of the world struggles to give fruitful solutions to the problem of overexploitation (Illge and Schwarze 2009). In conclusion: the notion that the pricing mechanism is the answer to the problem of sustainability does not seem to hold when private banks are able to expand the money supply. However, what is worth noticing is that the pricing mechanism actually works in an economy where the money supply is constant. This suggests that further examination may be needed to fully investigate the mechanisms and consequences of credit expansion.

The rapidly expanding production of furniture in the fractional reserve banking economy is dependent on the firms being able to substitute the more expensive wood for labor. In our economy, labor can be thought of as some labor-equivalent factor of production.[12] This means that this substitution can be thought of as firms using more advanced tools and factories in order to reduce dependence on natural resources. To some extent this makes sense, the problem arises when this is done in absurdum, and virtually no wood at all is used in production.

The assumption of close to unlimited possibility to substitute natural resources for technology and human made capital is similar to the ideas behind the notion of "weak" ecological sustainability, discussed in the previous research-section. This is an important characteristic of the neoclassical theory, where natural resources are often neglected, either because unlimited possibility for substitution is assumed, or sometimes because they are assumed to be abundant. In the words of William Nordhaus and James Tobin:

[12] If we think of the substitution in our model as firms investing in technology, and not necessarily as people working more hours, we must, by construction of our model, think about these improvements as flowing back to the workers. Consequently, the technological development in our model does not lead to reduced labor costs, but increased capacity. For example we can think about a firm where the labor force works 10 hours per period. If this firm invests in a robot that increases production by 10 labor-equivalent hours, this must mean that the workers get paid for the total 20 hours.

within neoclassical theory "reproducible capital is a near perfect substitute for land and other exhaustible resources" (Nordhaus and Tobin 1972, p. 14).

This characteristic of the neoclassical theory is one of the major criticism that is being leveled by ecological economists advocating the "strong" ecological sustainability paradigm. Robert Ayres questions the somewhat unfeasible notion that "in the distant future the economic system need not produce significant amounts of material goods at all" (Ayres 1996, p. 12). Daly (1997) likens the neoclassical neglect of the role of natural resources to a recipe instructing how to bake a cake with only a cook and his kitchen, thus ignoring the need for flour, wheat and eggs. Some of the peculiar results in our model show a similar picture as these notions. For example, in period 83, just before the collapse of the economy, the use of wood relative to labor amounts to less than 10^{-10}.

Whereas incorporating a limitation on the possibility to substitute away natural resources lies beyond the scope of our model, it actually puts further pressure on the sustainability of the simulated fractional reserve banking economy. It is believable that there would be more pressure on the forest population if firms did not have the same possibilities to substitute wood for labor, leading to an even faster exploitation. Within the 100%-reserve economy on the other hand, it is doubtful that restrictions on substitution would result in any large changes of the results. In this economy there is no overexploitation of resources or elevation of wood prices, meaning that there is no need to substitute between factors of production.

In our model we did not include any mechanisms for technological progress. However, we can look at the tendency in the fractional reserve banking to substitute wood for labor as investments in efficiency improving technology or working methods. The firms' substitution of throughput of natural resources for more efficient production per unit of natural resource can be viewed as an example of what Costanza and Daly defines as development (Costanza and Daly 1992). What is interesting is that in our modeled framework this technological substitution is driven by the fractional reserve banking system, as we see no similar development in the 100%-reserve economy. As the high consumer demand is sustained by the creation of money, firms competing to meet the high demand would try to find ways to rationalize the use of wood as it gets more expensive. According to this interpretation, money creation could drive technological innovation under circumstances of changing relative prices. However, in our framework this technological innovation is not in itself enough to stop the unsustainable harvesting of trees. This again suggests that further examination of the mechanisms and consequences of credit expansion would be necessary.

Concluding remarks

The aim of this study was to shed some light on how the financial system affects the real economy, and the utilization of its resources. Through a deductive approach we wanted to investigate the consequences of credit expansion on the exploitation of renewable natural resources. More specifically we wanted to address two questions. First, whether increasing money supply dampens the negative impact price increases should have on utilization of natural resources. Second, if is the case, what impact this has on sustainability. Our aim was to assess this by building an economic model. By simulations we hoped to receive results that could be valuable for interpretation.

We embarked upon this by looking at the current state of knowledge within a broad range of research. From this we developed a model with two different scenarios: a fractional reserve banking economy, where money was continuously created in private banks, and a 100%-reserve economy where this ability to create money was removed.

Through simulations we have found that money creation, by distorting the pricing mechanism, may be dampening the negative impact of increasing natural resource prices on the economy. We have also found that this distortion of the pricing mechanism may lead to an ecologically unsustainable development. Our results show that by assuming price stickiness, our economy shows a very similar development to those predicted by economists concerned with the decoupling between the financial and real economies (Douthwaite 2011, Minsky 1993, Soddy 1926).

However, our findings are not entirely without concern. When constructing our model we have included aspects of theories originating from different schools of thought, with, on some topics, contradicting fundamental assumptions and distinctive methodologies. This undoubtedly puts us at risk of stumbling upon faults when combining different theories, and the fundamentals of our analysis may lose adequacy. It is important to remain conscious of this when interpreting our results, and to be careful not to draw too strong conclusions.

As discussed, our model builds on several simplifying assumptions about human behavior and how the economy works. Changing these assumptions may have rendered different results, especially in the cases of non-constant return to scale, perfect substitution, consumer demand, endogeneity of money and inflation stickiness. We have tried to mitigate this risk by making consistent assumptions that have strong foundations in the fields of research that have been explored in this paper. Still, its simplified nature prevents us from making strong parallels to reality in this paper.

The limitations of this thesis open up for further investigation of what we set out to examine. We leave for future research to apply our analysis on empirical data to be able to compare the theoretical results of our simulations to real data. By doing this, conclusions of higher significance could to be made.

In this paper we have chosen to focus on ecological sustainability. As we have seen, many economists emphasize the importance of also looking at economical and social sustainability, and understand how all of these are interconnected. Distorted pricing mechanisms could lead to misallocation of investments, resulting in economic unsustainability. Unequal economic development and ecological crises may be large contributors to social unsustainability, conflicts and political instability. Social demographic imbalances could lead to economic unsustainability and poverty could lead to unsustainable utilization of natural resources. These subjects could have been incorporated into our model, but we leave them open for future researchers to look deeper into.

We have also discussed the strong assumption of unlimited possibilities for substitution. As described, this is a criticized aspect of the neoclassical production functions, and it would be interesting to include in our model a limitation on this possibility. The mechanisms of the credit expansion itself are also a subject worth examination. We have used the theory of money endogeneity in our analysis, and we believe that the considerable impacts that this feature has on our results point to the necessity of further research on the subject, and its connection to sustainability.

Allowing ourselves to be more speculative, we can think about what implications our results would have on policy making. Governments around the world are stimulating economies by injecting money through quantitative easing programs and other monetary policies. One could ask whether this, together with fractional reserve banking, lead us on a development path that is not supported by the real economic and ecological systems. Has the economic development leading to the high standard of living we enjoy today been supported by them, or is it a result of unnatural stimulus? We believe that the results shown in this thesis encourage further examination of these questions.

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Appendix I - variables and parameters

Table 1: Exogenous paramters

Parameter	Description
α	Output elasticity of wood
β	Output elasticity of labor
Ω	Aversion to deforestation
A	Total factor of productivity
f	Required capital ratio
g	Intrinsic forest growth rate
K	Forest carrying capacity
r^r	Real interest rate
S_{mvp}	Minimum viable population of trees

Table 2: Variables

Varaible	Description
B_t	Firm budget
D_t	Nominal value of demand
d_t^f	Firm debt
d_t^h	Household debt
h_t	Harvesting rate
I_t	Household income
i_t	Inflation rate
L_t	Labor used in production
M_t	Amount of money in the economy
P_t	Price of furniture
P_t^T	Price of wood
$P_{0,t}^T$	Base wood price
Q_t	Furniture production
R_t	Firm revenue
r_t^n	Nominal interest rate
S_t	Tree population in forest
T_t	Wood used in production/trees cut down
T_t^d	Wood demand
T_t^s	Wood supply
V_t^T	Velocity of money
w_t	Labor wage
x_t	Fraction of new money allocated to firms

Table 3: Exogenous paramters

Parameter	Description	Value
α	Output elasticity of wood	0.5
β	Output elasticity of labor	0.5
Ω	Aversion to deforestation	5
A	Total factor productivity	1
f	Required capital ratio	50%
g	Intrinsic forest growth rate	2%
K	Forest carrying capacity	100
r^r	Real interest rate	0%
S_{mvp}	Minimum viable population of trees	10

Table 4: Initial variable values

Variable	Description	Value
B_0	Firm budget	10
d_0^h	Household debt	5
d_0^f	Firm debt	5
I_0	Household income	10
M_0	Amonut of money in economy	500
P_0^T	Price of wood	5
S_0	Tree population in forest	70

Appendix II - derivations

In this appendix equations that have been introduced previously in the thesis are labeled with their original number. New equations are only numbered when it is necessary in order to follow our derivations.

Equation (12)

$$D_t = I_{t-1} + (1 - x_t)\Delta M_t - r_t^n d_{t-1}^h. \tag{7}$$

$$B_t = R_{t-1} + x_t \Delta M_t - r_t^n d_{t-1}^f. \tag{11}$$

$$B_t = D_t. \tag{10}$$

$$R_{t-1} + x_t \Delta M_t - r_t^n d_{t-1}^f = I_{t-1} + (1 - x_t)\Delta M_t - r_t^n d_{t-1}^h.$$

$$x_t \Delta M_t - (1 - x_t)\Delta M_t = I_{t-1} - r_t^n d_{t-1}^h + r_t^n d_{t-1}^f - R_{t-1}.$$

$$\Delta M_t(2x_t - 1) = I_{t-1} + r_t^n(d_{t-1}^f - d_{t-1}^h) - R_{t-1}.$$

$$x_t = 0.50 + \frac{I_{t-1} - R_{t-1} + r_t^n(d_{t-1}^f - d_{t-1}^h)}{2\Delta M_t}. \tag{12}$$

Equation (15) and (16)

As discussed, the optimal, maximized production is where the production function touches the budget constraint. This is were the derivative of B_t is equal to the derivative of Q_t. Since there are no profits in the economy, the nominal value of the demanded furniture D_t will equal the total costs for the firm B_t. The optimal combination of wood T_t and labor L_t is given below.

$$B_t = P_t^T T_t + w_t L_t. \tag{14}$$

$$B_t = D_t. \tag{10}$$

$$T_t = \frac{D_t}{P_t^T} - \frac{w_t}{P_t^T} L_t. \tag{i.i}$$

$$\frac{dT_t}{dL_t} = -\frac{w_t}{P_t^T}. \tag{i.ii}$$

$$Q_t = AT_t^{\alpha} L_t^{\beta}. \tag{13}$$

$$T_t = \left(\frac{Q_t}{AL_t^{\beta}}\right)^{\frac{1}{\alpha}} = \left(\frac{Q_t}{A}\right)^{\frac{1}{\alpha}} L_t^{-\frac{\beta}{\alpha}}. \tag{ii.i}$$

$$\frac{dT_t}{dL_t} = -\frac{\beta}{\alpha}\left[\left(\frac{Q_t}{A}\right)^{\frac{1}{\alpha}} L_t^{-\frac{\beta}{\alpha}}\right] L_t^{-1}. \tag{ii.ii}$$

$$\left(\frac{Q_t}{A}\right)^{\frac{1}{\alpha}} L_t^{-\frac{\beta}{\alpha}} = T_t. \tag{ii.i}$$

$$\frac{dT_t}{dL_t} = -\frac{\beta}{\alpha} T_t L_t^{-1} = -\frac{\beta}{\alpha}\frac{T_t}{L_t}. \tag{ii.iii}$$

The derivative of B_t equals the derivative of Q_t, $(i.ii) = (ii.iii)$:

$$-\frac{w_t}{P_t^T} = -\frac{\beta}{\alpha}\frac{T_t}{L_t}.$$

$$L_t = \frac{\beta}{\alpha}\frac{T_t}{w_t} P_t^T.$$

$$T_t = \frac{D_t}{P_t^T} - \frac{w_t}{P_t^T} L_t \tag{i.i}$$

$$= \frac{D_t}{P_t^T} - \frac{w_t}{P_t^T}\left[\frac{\beta}{\alpha}\frac{T_t}{w_t} P_t^T\right] = \frac{D_t}{P_t^T} - \frac{\beta}{\alpha} T_t.$$

$$T_t = \frac{D_t}{P_t^T(1 + \frac{\beta}{\alpha})}. \tag{15}$$

$$L_t = \frac{\beta}{\alpha}\frac{T_t}{w_t} P_t^T = \frac{\beta}{\alpha}\frac{P_t^T}{w_t}\left[\frac{D_t}{P_t^T(1 + \frac{\beta}{\alpha})}\right].$$

$$L_t = \frac{\beta D_t}{w_t(\alpha+\beta)}. \tag{16}$$

Equation (25)

$$T_t^s = S_t \left[\frac{P_t^T}{P_{0,t}^T \Omega} - \frac{1}{\Omega} + g(\frac{S_t}{S_{mvp}} - 1)(1 - \frac{S_t}{K}) \right]. \tag{25}$$

$$T_t^d = \frac{D_t}{P_t^T(1+\frac{\beta}{\alpha})}. \tag{15}$$

$$\frac{D_t}{P_t^T(1+\frac{\beta}{\alpha})} = S_t \left[\frac{P_t^T}{P_{0,t}^T \Omega} - \frac{1}{\Omega} + g(\frac{S_t}{S_{mvp}} - 1)(1 - \frac{S_t}{K}) \right].$$

$$\frac{D_t}{S_t(1+\frac{\beta}{\alpha})} = \frac{(P_t^T)^2}{P_{0,t}^T \Omega} + P_t^T \left[g(\frac{S_t}{S_{mvp}} - 1)(1 - \frac{S_t}{K}) - \frac{1}{\Omega} \right].$$

$$\frac{D_t P_{0,t}^T \Omega}{S_t(1+\frac{\beta}{\alpha})} = (P_t^T)^2 + P_t^T P_{0,t}^T \Omega \left[g(\frac{S_t}{S_{mvp}} - 1)(1 - \frac{S_t}{K}) - \frac{1}{\Omega} \right].$$

$$\frac{D_t P_{0,t}^T \Omega}{S_t(1+\frac{\beta}{\alpha})} = (P_t^T)^2 + P_t^T \left[P_{0,t}^T (g\Omega(\frac{S_t}{S_{mvp}} - 1)(1 - \frac{S_t}{K}) - 1) \right].$$

$$(P_t^T)^2 + P_t^T \left[P_{0,t}^T (g\Omega(\frac{S_t}{S_{mvp}} - 1)(1 - \frac{S_t}{K}) - 1) \right] - \frac{D_t P_{0,t}^T \Omega}{S_t(1+\frac{\beta}{\alpha})} = 0.$$

$$P_t^T = \frac{P_{0,t}^T[1 - g\Omega(\frac{S_t}{S_{mvp}} - 1)(1 - \frac{S_t}{K})]}{2} \pm \sqrt{\left(\frac{P_{0,t}^T[1 - g\Omega(\frac{S_t}{S_{mvp}} - 1)(1 - \frac{S_t}{K})]}{2} \right)^2 + \frac{D_t P_{0,t}^T \Omega}{(1+\frac{\beta}{\alpha})S_t}}. \tag{25}$$