ISSN: 2279-7807

Quaderni di Dipartimento

Schumpeter in a matrix: a Stock Flow Consistent analysis of technological change

Alessandro Caiani
(Università di Pavia)

Antoine Godin
(Università di Pavia)

Stefano Lucarelli
(Università di Bergamo)

175 (05-12)

Dipartimento di economia politica
e metodi quantitativi
Università degli studi di Pavia
Via San Felice, 5
I-27100 Pavia

Maggio 2012

Schumpeter in a matrix: a Stock Flow Consistent analysis of technological change

Alessandro Caiani[*]
University of Pavia

Antoine Godin
University of Pavia

Stefano Lucarelli
University of Bergamo

May 30, 2012

Abstract

Schumpeter showed that the boom and bust cycles are intrinsically related to the functioning of the capitalist economy. These boom and bust cycles are inherent to the rise innovation. Our paper analyses innovation cycles in a stock flow consistent framework. It focuses on the essential role of internal and external finance in the emergence of a new technological paradigm. We present two models. The first one, as a tribute to Schumpeter's work, follows strictly Schumpeter's description of the business cycles induced by technological change, except for the financial side. The second model presents a multi-sectorial economy composed of consumption and capital goods industries, a banking sector and two households sectors: capitalists and wage earners. The stock flow consistent approach allows us to track the flows of funds resulting from the rise of innovators in the system. The dynamics of prices, employment and wealth distribution among the different sectors is analysed. Above all, the role of financial-innovation nexus is underlined. The paper builds the grounds for a wider analysis of schumpeterian structural changes described in Schumpeter (1934/1912) and Schumpeter (1964/1939) We find this particularly relevant to understand the impact and potential sources of instability of an ever more financialized monetary economy of production.

Keywords: Schumpeter, Innovation, Stock Flow Consistent Models, Monetary Circuit

JEL Codes: O30, O4, E32

[*]Corresponding author. Email: alessandro.caiani@eco.unipv.it.

1 Schumpeterian technological change and finance

Schumpeter showed that boom and bust cycles are intrinsically related to the functioning of a capitalistic economy (Schumpeter, 1934/1912, 1964/1939). These cycles, inherent to the rise innovation, not only are an unavoidable consequence of the way in which market evolves and assimilates successive technological revolutions, but also constitute the very fundamental mechanism that makes development possible. In particular, every time a cluster of radical innovations emerges, it triggers a process of structural change in the economic system.

Schumpeter's analysis stressed that innovation can only emerge if new means of payment are created by the banking sector in order to finance entrepreneurs. This creates a redistribution of purchasing power from the old actors of the economic system to innovators. Finance and innovation are thus the two sides of the same coin, or rather, using Schumpeter's own words, credit is the 'monetary complement' of innovation.

Nevertheless, economists do not seem to pay attention to the role of credit money in the process of innovation: many historians of economic analysis affirm that the Schumpeterian theory of economic development is centred on the role of entrepreneur rather than on the role of banks; innovation economists, who find their roots in Nelson and Winter's research program (Nelson and Winter, 1982), have seldom inquired about the reciprocal influence between the financial systems and innovative activity. On the other hand theorists of the monetary circuit are very close to Schumpeter's theory of money, but they have not yet proposed an analytical framework able to clarify the meaning of credit creation when seen as the monetary complement of innovation. Notice that, according to Schumpeter himself, capitalism is characterized by the creation of credit money to finance innovative activity.

This contribution aims to describe the Schumpeterian economic development in a "monetary theory of production" framework. Following a Schumpeterian perspective, we emphasize, within different monetary circuits, both the monetary nature and the qualitative change of the capitalist system, that is the innovative process as whole[1].

We will first describe in this section the methodology we used to analyse Schumpeter's economic development. Section 2 will then sketch our simple model and its main characteristics. Section 3 will outline the features of dynamic innovation and the results of our simulations. Finally section 4 contains the description of a second, more complex model in an attempt to move towards reality.

[1] In this contribution, we refer to 'monetary theory of production' as the line of research that, in contrast with mainstream economics, supports the thesis of money non-neutrality, whereas we use the notion of 'monetary circuit' to intend a single production period in a pure credit economy with no government.

1.1 A tale of circuits and matrices

Each phase of the Schumpeterian process of cyclical development represents a different monetary circuit. The monetary circuit, as some scholars have demonstrated in the last decade Lavoie (2004); Zezza (2004); Accoce and Mouakil (2005), may be formalized by using the stock-flow consistent framework (SFC hereafter).

SFC models are based on the works of two schools of thoughts developed by Wynne Godley and James Tobin[2]. Both these approaches are centered on the importance of consistency between and among stocks and flows: each flow in the model comes from a sector (or account) and goes to another account. In each period, the sum of flows has to be nil. Stocks are the sum of inflows and outflows. The adoption of a SFC methodology thus imposes not to have black boxes explaining the links between real and nominal economic variables.

Our paper analyses innovation cycles by using the SFC framework. It focuses on the essential role of internal and external finance during the emergence and deployment of a new technological paradigm. The model presents a multi-sectorial economy composed of consumption and capital goods production industries, a banking sector and an household sector; capitalists and wage earners. Money is endogenous and it is created by the banking system. The economy depicted in this paper is, from this point of view, similar to the one defined by the circuitists as a 'pure credit money' system (Graziani, 2003).

The adoption of a SFC approach allows us to track the flows of funds resulting from the rise of a cluster of innovators in the system. For this reason, it appears especially adequate to analyze the interdependencies between technological change - affecting labor and capital productivity - and its finance. In particular, this approach helps to analyze the dynamics of prices, wages, profits, employment and wealth distribution among all sectors and social groups and across the different phases of the process of structural change triggered by innovation. Above all, the fundamental role of financial-innovation nexuses in shaping the cycle is underlined. For this reason, the paper presents two models.

In the first one, firms can borrow only from the banking sector. This representation of the economic system is the closest to the traditional view of Schumpeter's theory, as presented in Schumpeter (1934/1912, 1964/1939). This first version has to be interpreted, first of all, as a tribute to Schumpeter's work. Indeed, the model follows strictly Schumpeter's description of the business cycles induced by technological change, except for the financial side. We do not go into details of how the banking system operates the selection of the entrepreneurs to give credit nor do we consider the set of constraints that characterizes the functioning of the banking sector. Since we are considering a pure credit money system, in the sense of the circuitist approach, banks are always able and willing to satisfy the demand coming from entrepreneurs.

The second model, in an attempt to move towards reality, introduces more complex behaviors for the real sectors as well as for the banking sector. Further-

[2] See Dos Santos (2006) for a historical review of the emergence of SFC and Godley and Lavoie (2007) for extensive examples of SFC models.

more, it allows for firm to finance themselves by issuing shares. This represents a key aspect of technological change as today innovative firms seem to rely more and more on financial markets to finance their investment projects, as shown by Brown et al. (2009). At the same time, many scholars have stressed how the emergence of technological revolutions generally triggers a period of turbulence on financial markets characterized by great volatility both in shares issuing by firms and stock prices-market capitalization values (Schiller, 2000; Perez, 2009, 2010).

The paper thus builds the grounds for a wider analysis of the implications of the technological progress and structural change processes in a Schumpeterian perspective. This may contribute to the understanding of the effects on different sectors and groups during each phase of the adaptation process of the economic system to a new techno-economic paradigm (Perez, 2009). Furthermore, the analysis of financial markets both from the point of view of firms -looking for funding-, and from the point of view of investors -seeking remunerative opportunities-, may help to identify the potential sources of instability in the context of a financialized monetary economy of production, in particular during periods of radical technological change.

2 Model description

This section describes the model of the economy we will use to analyse the impacts of innovation. The first subsection sketches the different sectors and their connections. Then we will introduce the representation of technology and the technological change. Finally, we will outline the behavior of the different sectors. Appendix B.1 contains the list of all variables symbol and their signification.

2.1 A simple economy

The economy at hand, represented in fugure 1, is composed of three productive sectors; consumption good producers, traditional capital good producers and innovators, of a household sector and a banking sector. Households offer labor in exchange of wages. We assume perfect labor mobility and uniform and labor market clearing wages. As a consequence, there is no involuntary unemployment. We assume that all income is spent on consumption goods.

All goods, consumption and capital, are produced by firms out of labor and capital. Capital depreciates in each period and investments are financed via profits. Prices are market clearing in all producing sectors. Labor demand in each productive sector is determined through technology, capital being the determining factor. Furthermore, we assume that goods produced in one period are sold only in the next period. Firms thus have inventories equal to previous period output.

Finally, banks emit money through credit. This allow the production cycle to start and credit is repaid at the end of the producing period. We assume

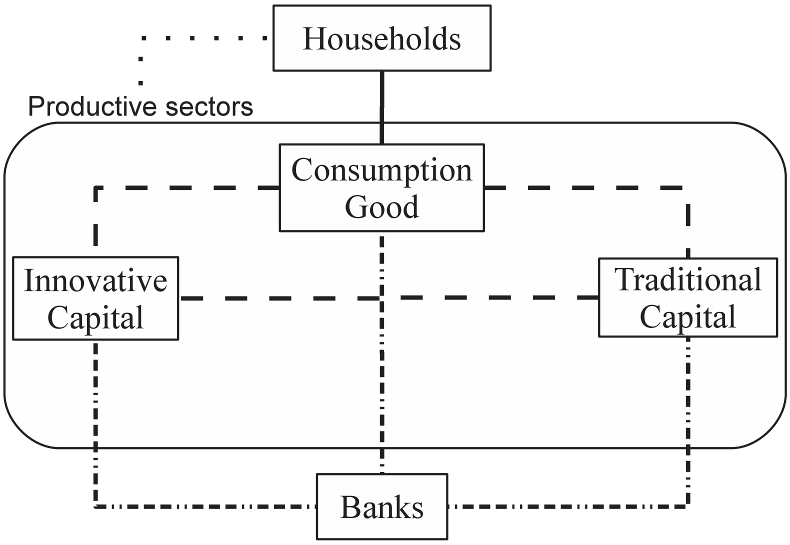

Figure 1: Flow diagram of the model: Households consume (solid line) all their wages (dotted line). All productive sectors use capital goods to produce (dashed line). They invest and pay their wage bills using bank loans (dash-dotted line).

that only firms save cash when their profits net of interests are positive. Given the monetary circuit, a productive sector saving implies a deficit for the other sector. We follow Schumpeter's definition of interests as a share of profits. If a firm is indebted but does not generate profits it does not pay interests.

The *Transaction Flow Matrix* (TFM, table 1) is a representation of the model. It ensures that the sum of all flows is always nil in each sector. A plus sign expresses an inflow while a minus sign represents an outflow. For instance, the fourth row shows that wages are paid by the three productive sectors to wage earners and thus come with a minus sign in the Consumption column and with a plus sign in the Households one. The change in stock is represented in the second part of the TFM. For example, we can see in the Bank column that all changes in loans has to be balanced by an equal change in cash holding.

Table 2 is the Balance Sheet. It represents how stocks are distributed among the different sectors. It shows that net worth of firms is equal to the sum of all assets (capital stock, inventories and cash holdings) minus loans. It also indicates that banks have no net worth as cash deposits is equal to loans granted to firms. Finally the balance sheet shows that households hold no wealth.

	Households	Consumption		Capital		Innovative		Bank		Σ
		Current	Capital	Current	Capital	Current	Capital	Current	Capital	
Consumption	$-C$	$+C$								0
Traditional investment			$-I_{c,t}$	$+I_t$	$-I_{k,t}$					0
Innovative investment			$-I_{c,i}$		$-I_{k,i}$	$+I_i$	$-I_{i,i}$			0
Wages	$+WB$	$-W_c N_c$		$-W_k N_k$		$-W_i N_i$				0
Retained earnings		$-RE_c$	$+RE_c$	$-RE_k$	$+RE_k$	$-RE_i$	$+RE_i$			0
Inventories		$+\Delta Inv_c$	$-\Delta Inv_c$	$+\Delta Inv_k$	$-\Delta Inv_k$	$+\Delta Inv_i$	$-\Delta Inv_i$			0
Profits		$-F_c$	$+F_c$	$-F_k$	$+F_k$					0
Change in traditional capital			$-\Delta K_{c,t}$		$-\Delta K_{k,t}$		$-\Delta K_{i,t}$			$-\Delta K_t$
Change in innovative capital			$-\Delta K_{c,i}$		$-\Delta K_{k,i}$		$-\Delta K_{i,i}$			$-\Delta K_i$
Change in cash			$-\Delta M_c$		$-\Delta M_k$		$-\Delta M_i$		$+\Delta M$	0
Change in loans			$+\Delta L_c$		$+\Delta L_k$		$+\Delta L_i$		$-\Delta L$	0
Change in net worth			$+\Delta V_c$		$+\Delta V_k$		$+\Delta V_i$			$+\Delta V$
Σ	0	0	0	0	0	0	0	0	0	0

Table 1: Transaction Flow Matrix

	Households	Consumption	Capital	Innovative	Banks	Σ
Capital stock		$+K_c$	$+K_k$	$+K_i$		$+K$
Inventories		$+Inv_c$	$+Inv_k$	$+Inv_i$		$+Inv$
Cash		$+M_c$	$+M_k$	$+M_i$	$-M$	0
Loans		$-L_c$	$-L_k$	$-L_i$	$+L$	0
Net Worth		$-V_c$	$-V_k$	$-V_i$		$-V$
Σ	0	0	0	0	0	0

Table 2: Balance Sheet

2.2 Technology and innovation

Technology is fully described by three characteristics:

1. $pr_k = \frac{y}{k}$, the average capital productivity, that is the output to capital ratio
2. $pr_N = \frac{y}{N}$ the average labor productivity or the output to labor ratio
3. $l_T = \frac{k}{N}$ the capital-labor ratio.

However all three characteristics are interrelated $pr_N = pr_k l_T$ and we may thus use the couple $\{pr_k, l_T\}$ to define a technology.

Capitalist development is defined by Schumpeter (1934/1912) as a discontinuous quantitative and qualitative change induced by innovation. Innovations are 'new combinations' put forward by 'new business men', the entrepreneurs. Schumpeter identified five cases that come under the definition of 'innovation'[3].

[3] These are:

Although Schumpeter based his explanation on the case of the diffusion of innovative consumer goods, our choice is instead to focus on the case of the introduction of an innovative investment good. On one hand, we argue that this is not going to change significantly Schumpeter's analysis of the way an economic system reacts to the emergence of innovation, triggering a process of selection based on 'creative destruction'. But, regardless of this argument, our choice finds its main justification in the central role played by capital goods during all the great surges of development since the second half of the XVIII century. Indeed, looking to the description of the historically given techno-economic paradigms presented in Perez (2002, 2009), we can easily observe that the new technologies at the base of each technological revolution are in most cases represented by new capital goods.

Our model thus describes an economy in which, at a certain point, an innovative capital good is introduced in the capital good market. Once the innovative good is produced and sold, there are two different capital goods (traditional and innovative) and three different productive sectors (consumption, capital and innovative). Each combination of the couple capital good-sector thus defines a particular technology of production represented by the couple $\{pr_x, l_{yx}\}$, where pr_x is the productivity of type x capital and l_{yx} is the labor/capital ratio requested by capital good x when employed in sector y. Table 3 describes the different technologies at hand. For simplicity reasons we assume that the productivity of the traditional investment good and the capital-labor ratio are the same in both traditional sectors ($l_{c,k} = l_{k,k} = l_k$). We further assume that the capital-labor ratio are the same in all sectors when producing with the innovative good ($l_{c,i} = l_{k,i} = l_{i,i} = l_i$). These assumptions however do not affect in any significative way the dynamics of the model.

Sector \ Capital good	Traditional	Innovative
Consumption	$\{pr_k, l_k\}$	$\{pr_i, l_i\}$
Capital	$\{pr_k, l_k\}$	$\{pr_i, l_i\}$
Innovative	$\{pr_k, l_{ik}\}$	$\{pr_i, l_i\}$

Table 3: Technology characterization according to sector and capital good used.

2.3 Sectorial behaviors

As already mentioned, there are five different sectors in our economy: a household sector, three productive sectors and a banking sector. We will go through

1. The introduction of a new good.
2. The introduction of a new method of production.
3. The opening of a new market.
4. The conquest of a new source of supply of raw materials-half manufactured goods.
5. The carrying out of a new organization of any industry.

the salient features of our model in order to be able to analyse how these generic behavior interact in the different phases of the innovative process in section 3.

2.3.1 Employment and wages

Employment in each sector is determined by labor productivity (2.1) where l_x is the capital-labor ratio defining the technology $x \in \{k, i\}$ for the sector $y \in \{c, k, i\}$.

$$N_y = \frac{k_y}{l_x} \tag{2.1}$$

Wage are equal in all sectors and are labor market clearing. Wage level is given by (2.2) where $N = N_c + N_k + N_i$ is total employment.

$$W = \alpha + \beta N \tag{2.2}$$

2.4 Output and inventories

Output is determined through the capital stocks in sector $x \in \{c, k, i\}$ and its productivity (2.3). As already mentioned, output in each period is stored as inventories to be sold in the next period (2.4) and (2.5).

$$y_x = k_y pr_k + i_x pr_i \tag{2.3}$$

$$inv_x = y_x \tag{2.4}$$

$$s_x = inv_{x,-1} \tag{2.5}$$

2.4.1 Prices

Workers consume and buy all inventories of consumption goods. Since we assume market clearing prices, (2.6) represent the consumption good price, where WB is the wage bill. Capital goods price in sector $x \in \{k, i\}$ is determined through nominal demand, Y_x divided by s_x, the capital available for sale(2.7).

$$p_c = \frac{WB}{s_c} \tag{2.6}$$

$$p_x = \frac{Yx}{s_x} \tag{2.7}$$

3 Dynamics of innovation

This section describes the different phases in which technological change occurs: the steady state circular flow followed by two sub-phases in which the innovative capital good is produced and then sold. The following section describes each of these phases.

3.1 Steady state circular flow

The *Theory of Economic Develoment* starts with the description of an economic system similar to the one described by Walras' general economic equilibrium theory[4]. The circular flow depicts a pure exchange economic system, self-reproducing and without any quantitative or qualitative variation. The system reproduces himself without net profit, savings and accumulation. The theoretical construction of the circular flow plays an instrumental role to clarify Schumpeter's conception of economic development, and to highlight the necessary, from a logical point of view, conditions for its start up.

In this phase, which represents the starting point of a new cyclical development, there is no credit for innovation but there is credit for normal production activity. Schumpeter considers nil the rate of interest on credit for normal production activity because banks play a role that does not enable them to claim any remuneration since there is no surplus[5]. Since the sequential flow of the economic process is synchronized (Messori, 2004); and does not give any employment of money that necessitates its accumulation beyond the measure that enables the individual to pay for his current purchases there is no reason to hoard money. Hence money is considered only as an intermediary tool for exchange.*Money only performs the function of a technical instrument, but adds nothing new to the phenomena* (Schumpeter, 1934/1912, page 51).

The present subsection describes our simple economy in the particular case of steady state circular flow. All the variables have reached their steady state value, what is produced in each period allows to produce the exact same quantity in the next period. The stock of capital is constant, all capital produced is equal to capital depreciation in each sector. We will depict the circular flow following the circuitist school of thought approach, thus starting from money creation through credit and ending with money destruction through credit repayment Graziani (2003)[6]. The following equations will have a $\star$ superscipt to indicate

[4]It is the author himself to underline his intellectual debt to Walras regarding the theoretical construction of the circular flow, although some authors, including Sylos Labini - in his introduction to the Italian edition of The Theory of Economic Development -, tend to debunk that debt.

[5]Because circular flow may be also defined as a situation in which innovative process ends, banks could continue the practice of claiming interest on credit for consumption or for normal production activity, as if it were a routine. But there is no longer the prerequisite (i.e. the innovative process) for a positive interest (De Vecchi, 1993). The reason is explained by Schumpeter himself: *"Interest is a premium on present over future means of payment, or, as we will say a potiori, balances. Interest is the price paid by borrowers for a social permit to acquire commodities and services without having previously fulfilled the condition which in the institutional pattern of capitalism is normally set on the issue of such a social permit, i.e., without having previously contributed other commodities and services to the social stream. For a positive premium to emerge, it is necessary that at least some people should estimate a present dollar more highly than a future dollar."*(Schumpeter, 1964/1939, p.124).

[6]For simplicity reasons we consider a *pure credit money economy*, thus excluding from the model both the Government and the Central Bank. Hence money is present only in the form of credit money, created by the bankig sector. Credit money is created whenever an agent spends money granted to him by a bank and is destroyed whenever a bank credit is repaid. Money is thus produced and introduced into the market by means of negotiations between banks and firms. Note that in a pure credit money system where all exchanges are

that these are steady-state values.

3.1.1 Loans

Firms ask for loans to banks in order to start the production and pay wages (3.1) and (3.2). Wages and employment follow the rules sketched in section 2.3.1.

$$L_c^\star = W^\star N_c^\star \tag{3.1}$$
$$L_k^\star = W^\star N_k^\star \tag{3.2}$$

3.1.2 Consumption market

Workers consume and buy all inventories of consumption goods. Price is determined through the principle described in section 2.4.1 and is thus given by (3.3). Because we are in a steady state,output is equal to inventories (3.4). Finally, profits is given by the difference between nominal income and nominal costs, that is the wage bill (3.5). We assume that consumption good producers use all their profits to buy new capital, which is equal to capital depreciation since there is no variation in capital in a steady state of affairs (3.6).

$$p_c^\star = \frac{WB^\star}{y_c^\star} = \frac{W^\star\left(N_c^\star + N_k^\star\right)}{y_c^\star} \tag{3.3}$$
$$y_c^\star = inv_c^\star = k_c^\star pr_k \tag{3.4}$$
$$F_c^\star = Y_c^\star - W^\star N_c^\star = W^\star N_k^\star \tag{3.5}$$
$$s_{k,c}^\star = d(k_c^\star) \tag{3.6}$$

3.1.3 Capital market

Capital producing firms decide $s_{k,k}$ how much capital they want to buy and ask a credit $L_{k,k}^\star = s_{k,k}^\star p_k^\star$ to the banks in order to buy that capital[7]. In a steady state situation, firms keep what is needed to replace capital depreciation $d(k_k^\star)$[8].

$$s_{k,k}^\star = d(k_k^\star) \tag{3.7}$$

All remaining capital is bought by the consumption good firms. In steady state, the capital bought is equal to the depreciation of the capital stock of consumption good producers. Market clearing price is given by (3.8), while capital output is given by (3.10). Revenues and profits are given by (3.11) and (3.12). From the profits equation it is obvious that in the end it is the capital producers who decide how capital is distributed. Indeed, if the loan

regulated by transferring bank deposits and legal tender is not required (and then there is no compulsory reserve ratio), the credit potential of the banking system becomes unlimited, that is the banking sector meets no limits in the expansion of credit.

[7] Remember that the sector is an aggregate of firms. It is thus reasonable to assume that capital producers buy capital from other firms.

[8] Bhaduri (1972) presents a depreciation function based on the lifetime of capital n: $d(k,t) = ke^{(t-n)}$

they requested to the bank is not high enough to insure them the quantity of capital they desire, they can always ask for a larger amount. There is no risk of non performing loans since their profits is exactly equal to the loan they requested.

$$p_k^\star = \frac{F_c^\star + L_{k,k}^\star}{s_k^\star} \tag{3.8}$$

$$s_k^\star = inv_k^\star = s_{k,k}^\star + s_{k,c}^\star \tag{3.9}$$

$$y_k^\star = k_k^\star pr_k = inv_k^\star \tag{3.10}$$

$$Y_k^\star = W^\star N_k^\star + LK_k^\star \tag{3.11}$$

$$F_k^\star = Y_k^\star - W^\star N_k^\star = L_{k,k}^\star \tag{3.12}$$

3.1.4 End of period

At the end of the period, firms repay their loans and all goods produced are stored as inventories to be sold in the next period. No firms has any profits and there are no remaining debt to banks[9].

3.2 Breaking the stationary state

The emergence of entrepreneurs breaks up the stationary state of the economy. Nevertheless, the process of innovation may emerge only when banks finance new firms promoted by entrepreneurs. Banks create ex novo purchasing power. In the pages dedicated to the 'fundamentals of economic development', the logical relevance of the circular flow appears clearly. *Every concrete process of development finally rests upon preceding development. But in order to see the essence of the thing clearly, we shall abstract from this and allow the development to arise out of a position without development. [...]However if we wish to get at the root of the matter, we may not include in the data of our explanation elements of what is to be explained* (Schumpeter, 1934/1912, p.64).

As a consequence, as noted by De Vecchi (1993), in order to explain how the entrepreneurial function breaks the circular flow, we cannot rely on the case, altough very common in real economies, that the entrepreneur already owns the necessary monetary means, or finds credit among other individuals. These two conditions represent a situation already in motion. Hence, if we based the explanation of the way in which entrepreneurial activity occurs on these two assumptions, we would incur the mistake of including in the premises the phenomenon we want to explain. The circular flow depicts an equilibrium situation with full employment of all productive factors and absent savings, in which every production finds its demand and each individual have already

[9] Because no firms has any profits, interests are null. Using traditional interests based on the amount of loans requested at the beginning of the period would not change much the results. We would just have to assume that interests are either all consumed (and then no change at all in the circuit) or saved (and then firms end up with a deficit, that could be financed through stocks, for example).

decided the destination of his income. Therefore, the entrepreneur can exert its capitalistic function and innovation can emerge only if a share of the existent resources are transferred from the old producers to the entrepreneurs. In an economy based on private property, this can happen only through a squeeze of old producer's purchasing power in favour of entrepreneurs. While those who have already contributed to the production have received an income, the entrepreneur can obtain the means of payment required to start the production process only by a bank. The *ex novo* creation of means of payment is therefore the proper method of a capitalist economy to achieve productive change.

Schumpeter stressed that each entrepreneur has to ultimate the organization of the new productive process, before being able to supply the final goods. He argued that *"the carrying into effect of an innovation involves, not primarily an increase in existing factors of production, but the shifting of existing factors from old to new uses"* (Schumpeter, 1964/1939, p.110) and that the entrepreneur *"withdraws, by his bids for producers' goods, the quantities of them he needs from the uses which they served before"* (Schumpeter, 1964/1939, p.133). The process of economic development has to be divided in two distinct sub-phases: in the first one, entrepreneurs obtain loans L_i from the banking sector and organize the production of the new capital good. In the second one, entrepreneurs are ready to supply their final goods on the market, to realize profits and to pay interest to the banks which granted credit.

3.3 First sub-phase

According to Schumpeter, once the entrepreneur has obtained the *ex novo* created purchasing power through credit, he purchases means of production and hires workers (partly subtracting them to the old producers). The first result of the emergence of entrepreneurs is thus a tendency towards an increase in employment, wages and capital goods prices, while - in this phase - consumption goods prices remain costant. However here Schumpeter's analysis is not clear. In fact, while it is certainly true that the new demand for capital goods coming from entrepreneurs is going to increase their price[10], the effect on employment and wages is not granted. It must be stressed that Schumpeter does not accept the marginalist labor supply function: according to neoclassical theory the entrance of the entrepreneur should determine, assuming an initial situation of full employment, an increase of money wages and *then* an increase in labor supply. Schumpeter proposes instead a completely reversed logical and temporal sequence: *"The new demand [...] is chiefly a demand for labor. Therefore employment must first increase and with it the sum total of wages of labor, then the rate of pay and with it the income of the individual worker"* (Schumpeter, 1934/1912, p.248). Hence the rise of wages is driven by the rise of employment. But since we are still in a situation of full employment of all resources, the supply of capital goods is constrained. As a consequence, the quantity of

[10] Since we are starting from a situtión in which there are not unemployed resources to start with, any extra demand is bound to increase prices.

investment goods bought by the entrepreneurs must be offset by an equal reduction of the quantity of investment goods that traditional sectors, taken as a whole, can now buy. Ergo, the demand for labor coming from traditional sectors should fall although the labor market now faces a new demand for labor coming from entrepreneurs. Which effect prevails in this first sub-phase depends on the characteritics of the production processes in use in the different sectors. In particular, it depends on whether the capital-labor ratio implied by the technology of production in the traditional sectors - from which the capital has been withdrawn - is higher, lower or equal with respect to the one requested by the new production process organized by innovators to produce the new good. The variation of wages shall follow the dynamic of employment.

In the model innovative firm purchases from the traditional investment good sector the means of production required to produce the innovative good. We assume that the traditional capital good has the same productivity pr_k than in the other sectors and requires the same amount of labor per capital[11]. The technology used by entrepreneurs - combining traditional goods to produce innovative goods - is thus defined by the couple $\{pr_k, l_{ik}\}$.

The innovative good has the same productivity pr_i in all sectors. The labor-capital l_i ratio is also identical in all sectors. We assume that there is a productivity gain when using the innovative good $pr_i > pr_k$ while labor-capital ratios are identical $l_i = l_k = l_{ik}$[12].

3.3.1 Credit to Innovation

The amount of credit to innovation provided by the banking sector and the amount of interest to pay for it are the result of a bargaining between entrepreneurs and the banks. The banking sector is willing to finance the entrepreneur since it understands the profit creating potential of the innovation. By financing the entrepreneur, the banking sectors expects to obtain a share of this future profits through interest payments. The entrepreneur, in turn, is willing to pay a positive interest since he need today means of payment to organize the new productive process. Interest thus takes the form a tax on profits realized by entrepreneurs, as stated by Schumpeter.

Banks and entrepreneur thus decide together the amount of loans on the base, first of all, of an initial targeted market share[13] ψ. But the amount of

[11] Obviously the need to specify the characteristics of the technology used by innovators in this sub-phase implies a discretional choice by the modeler. Since it seems to us that both the labor-capital ratio and the productivity of a machinery depend fundamentally on the technical-mechanical features of the machinery itself -hence neither of the two are likely to change significantly when the same machinery is used in a different sector-, we choose this simple specification. Different specifications would affect the dynamic of employment, wages and consumption prices. This implications will be treated in a more extensive way in section 3.3.2. However, it must be noticed that the effects of this choice on the dynamics of the model are substantially confined only to the stage that precedes the market launch of the innovative investment good.

[12] This assumption has important implication that will be discussed later on, in section 3.4

[13] Note that, since prices clear the market and therefore all that is produced it is sold, the market share target is fundamentally an output target.

loans granted must also reflect the fact that the entrepreneur, whose final aim is to come to dominate the market by progressively increasing its market share, will also have a target for the growth of its output in the next periods[14]. Thus the total amount of loans granted by the banking sector L_i must be sufficient, first, for purchasing the traditional capital goods k_i requested to achieve both the targeted market share and the targeted output growth, and then for hiring the N_i workers required to employ it in the production process.

The two targets must allow the firm to realize, at least after a few periods, a level of profit sufficient to cover the banks' expected profits via interest payments and to leave a satisficing level of profit for the entrepreneur[15]. For tractability reasons, we do not endogenize this bargaining process and we simply assume that that the bank is willing to finance the entrepreneur with a stream of credit that enable the innovative firm to purse a given initial market share target ψ and a given output growth target τ for the next periods. The amount L_i of new credit is thus determined by these targets. The formal equations determining L_i on the basis of ψ and τ will be described in section 3.3.5.

3.3.2 Labor market

Wages are paid to workers at the beginning of the period. Employment may increase or decrease according to the labor-capital ratio characterizing the technology used by innovators to produce the new capital good. Having $l_{ik} = l_k$ the emergence of innovators leads to no increase in employment and thus no

[14]This implies that a share of the production realized in the first sub-phase will be retained by the firm to be used to increase the scale of production for the next period.

[15]Note however that it is not requested that the newborn firm is immediately able to realize profits starting from the very first period in which its production appears on the market. Indeed this very often is not the case even in a real economy. This consideration enters in the definition of the terms of the contract between the firm and the banks. Furthermore, in the model, like in real world, firms can ask new credit to a bank, even for a larger amount, with which they pay interest accrued in the previous period and re-start the production process. In real word this usually takes the form of refinancing the credit contract and implies the postposition of debt repayment and/or interest payments.

Furthermore it should be noted that, given the properties of our private money monetary circuit the means of payment created ex novo by banks in order to finance the entrepreneur must necessarily increase the profit of either the traditional capital good sector or the innovative firms. In fact, since wage earners spend all their income on consumption goods, an increase of wages determines an increase of consumption good firms' revenues. Since these firms in turn use all their their revenues net of wage bill to buy capital, their profit after investment is always null and their higher revenues go to either traditional or innovative capital goods producers. Hence, even in the case in which entrepreneurs initially produce at a loss, this loss will be offset by positive profits (precisely equal to the absolute value of entrepreneur's deficit) in the traditional capital good industry. A positive interest will thus rise even for the 'routine' credit given to managers of this sector. This implies that the initial deficit experienced by entrepreneurs does not determine a loss for the banking sector taken as a whole. In the extreme case of a unique bank, it can be sure that, regardless of the amount that it grants the entrepreneur, both the principal and the interests will always be repaid at maturity.

increase in wages[16].

$$\Delta N = k_i \frac{l_k - l_{ik}}{l_{ik} l_k} = 0 \quad (3.13)$$

$$\Delta W = \beta k_i \frac{l_k - l_{ik}}{l_{ik} l_k} = 0 \quad (3.14)$$

3.3.3 Capital market

Capital producing firms decide first how much of their inventories they want to buy. As the traditional firms are still in the steady-state mind of affairs, this part is equal to the depreciation of capital $d(k_k^\star)$, allowing them to produce their steady state level of output (3.17). The amount requested to buy their desired investment depends on the price of capital which is going to be higher than its steady state value (3.16).

$$s_{k,k}^\star = d(k \star_k) \quad (3.15)$$

$$L_{k,k} = s_{k,k} p_k \quad (3.16)$$

$$y_k^\star = pr_k k_k^\star \quad (3.17)$$

All available traditional capital for sale is bought by consumption and innovative firms. Innovative firms use all reminder of their loans ($L_i - WN_i$) to buy as much as possible capital goods while consumption goods firms use their profits ($F_c = Yc - WN_c = W(N_i + N_k)$. Market clearing price is thus given by:

$$p_k = \frac{W^\star N_k^\star + L_i + L_{k,k}}{s_k^\star} \quad (3.18)$$

Revenues and profits are given by (3.19) and (3.20)[17]. Since we assume that all profits not invested are saved as cash, we have (3.21).

$$Y_k = W^\star N_k^\star + L_i + L_{k,k} \quad (3.19)$$

$$F_k = L_i + L_{k,k} \quad (3.20)$$

$$\Delta M_k = F_k \quad (3.21)$$

[16]On the contrary by assuming $l_{ik} > l_k$ we should expect an increase in employment, followed by an increase in wages. This is likely to produce an upper shift in the price of consuption good since the supply on the market has been produced in the previous period and thus is given. Therefore, in this case, profits arising from the appearance of the entrepreneurs' demand would be shared between traditional capital producers and consumption good producers. The implications of the $l_{ik} < l_k$ case are straightforward.

[17]We clearly see here that all the ex novo credit obtained by the innovative firm ends as profit for the traditional capital producers. This results depends on the fact that consumption good producers use all their profits to buy capital goods. If that assumption was released, part of the new credit would end-up as retained earnings in the consumption good industry. However, our assumption does not change quantitatively the results we obtain during the simulation. For simplicity we will keep the full profit investment assumption.

3.3.4 Consumption market

Workers buy all inventories of consumption goods. Since we assume market clearing prices and since both total employment and wages have not increased while supply of consumption goods remained constant, consumption price remains constant:

$$p_c = \frac{W^\star (N_c + N_k + N_i)}{inv_c^\star} = p_c^\star \tag{3.22}$$

Revenues and profits are given by (3.23) and (3.24). Given the fact that consumption producers could not buy the steady state amount of capital, their production for the first sub-phase is lower than its steady state level (3.25).

$$Y_c = W^\star(N_c + N_k^\star + N_i) \tag{3.23}$$

$$F_c = W^\star(N_k^\star + N_i) \tag{3.24}$$

$$y_c = k_c pr_k = (k_c^\star - k_i)pr_k \tag{3.25}$$

3.3.5 The quantity of credit needed to finance innovation

The following system of equations allows to determine the quantity of credit L_i needed to finance innovation as a function of the targeted market share (ψ, 3.26), the targeted output growth (τ, 3.27) and the mark-up that innovative firms obtain on the traditional price (ϕ, 3.28). The innovative price $p_i = (1+\phi)p_k$ is equal to the traditional capital good plus a markup equal to the gain in productivity it gives (3.28)[18]. The new capital goods implies an higher level of capital productivity ($pr_i > pr_k$) and required the same labor-capital ratio of traditional firms ($l_i = l_t$). y^e is the expected output in the next production period, described by (3.29). L_i is distributed between employment costs and capital costs (3.32). Market clearing price for traditional capital is given by (3.37).

$$\psi = \frac{s_i p_i}{s_i p_i + s_k p_k} = \frac{s_i(1+\phi)}{s_i(1+\phi) + s_k^\star} \tag{3.26}$$

$$\tau = \frac{y_i^e - y_i}{y_i} \tag{3.27}$$

$$\phi = \frac{pr_i - pr_k}{pr_k}\left(1 + \frac{W}{p_k l_t}\right) \tag{3.28}$$

$$y_i^e = i_i pr_i + k_i(1 - d(k_i))pr_k \tag{3.29}$$

[18]This is the result of market clearing price assumption and on $l_i = l_k$. If $l_i \neq l_k$, traditional firms preferences over traditional or innovative capital good would be based not only on capital productivity but also on capital-labor ratios. This would imply that the difference in price would also have include the variation in wage that the use of one or the other capital good use would create, via employment variation. The $l_i = l_k$ assumption simplifies thus capital goods comparison without loss of generality. By assuming that innovative firms define a mark-up equal to the productivity gain implied by the new good we are implicitly saying that traditional firms will be indifferent between the two types of capital good, a necessary condition for market-clearing.

$$y_i = i_i + s_i \tag{3.30}$$

$$N_i = pr_k k_i \tag{3.31}$$

$$L_i = W^{\star} N_i + p_k k_i \tag{3.32}$$

$$p_k = \frac{W^{\star}(N_i + N_k^{\star})}{s_k^{\star}} \tag{3.37}$$

../Figure 2 shows how L_i varies depending on the values of the targeted market share ψ, of the targeted growth rate τ and productivity gain pr.

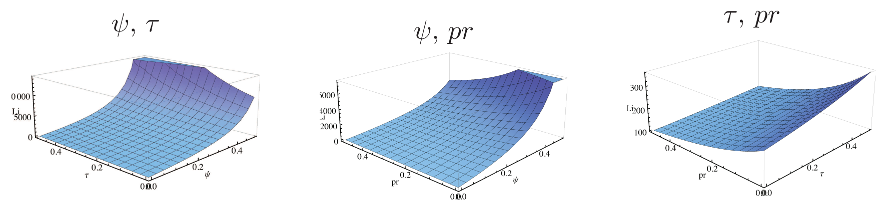

Figure 2: Credit needed to finance innovation (L_i) changes when the targeted market share ψ, the targeted growth rate τ and the productivity gain pr vary. The higher the market share and the growth rate, the higher L_i. The higher the productivity gain, the lower L_i.

3.3.6 End of period

At the end of the period, traditional firms repay their loans (equal to their respective wage bills) and all goods produced are stored as inventories to be sold in the next period. It is important to note that while the capital stock of traditional firms producing capital goods is still equal to the steady state level, the stock of capital of consumption good producers has decreased. The level of inv_c thus decreases while the level of inv_k does not change. On the other hand, capital stock has increased in the innovative sector, leaving total capital stock across the three sectors unchanged from its steady state value. Prices of the capital good have also increased given the fact that nominal demand has increased due to the entry of the innovative firm. Traditional capital producers make a profit equal to the deficit of the innovative firm. All the cash created through the ex novo loans obtained by the innovative firm ends up as cash holding by the traditional capital sector. Table 4 and 5 summaries all the changes in stock and flows due to arrival of innovative firm.

3.4 Second sub-phase

In the second sub-phase, the innovative capital goods enters the capital goods market.We assume that both traditional sectors might use the innovative but that this use does not affect the type of output they produce (i.e. they keep producing traditional goods). As for the first sub-phase, the following subsection

	Cons. sector	Capital sector	Innovative sector	Total
Capital Stock	$\swarrow$	$\rightleftharpoons$	$\nearrow$	$\rightleftharpoons$
Inventories	$\swarrow$	$\rightleftharpoons$	$\nearrow$	
Loans requested	$\swarrow$	$\rightleftharpoons$	$\nearrow$	$\nearrow$

Table 4: Stocks situation at the end of the first sub-phase

	Cons. sector	Capital sector	Innovative sector	Total
Wages	$\rightleftharpoons$	$\rightleftharpoons$	$\rightleftharpoons$	$\rightleftharpoons$
Employment	$\swarrow$	$\rightleftharpoons$	$\nearrow$	$\rightleftharpoons$
Price	$\rightleftharpoons$	$\nearrow$		$\nearrow$
Profits	$\nearrow$	$\nearrow$	$\nearrow$	$\nearrow$
Retained earnings	0	> 0	< 0	0

Table 5: Flows situation at the end of the first sub-phase

will go through the different markets in the second sub-phase of technological change. However, the second sub-phase is composed of more than one production period. It starts when the innovative firm enters the market and ends when the traditional capital good producers exit the market. The equation we will present represent the flows and stock variation generated in each production period. Each production period starts as in the circular flow with firms ask for loans to banks in order to start the production and pay wages.

3.4.1 Capital market

Both traditional sectors having observed the innovative good and the productivity gain it brings, they decide to buy it[19]. Traditional capital producers decide to invest in both capital goods following a simple rule: first they decide the growth of their output for the next period g_{yk} looking at the inflation rate of the capital good they produce. When inflation is positive, they desire to produce more and viceversa, (3.33). Once defined g_{yk} equation (3.34) gives $s_{i,k}$ and $s_{k,k}$, the amount of traditional and innovative capital they need to achieve the desired output growth. (3.35) indicates that traditional capital producers have no preferences over one or the other capital good. All remaining capital goods (both traditional and innovative) is bought by the consumption good producers. Consumption goods firms use all their profits ($F_c = Y_c - WN_c$). Traditional capital goods producers will have to use a part χ of $M_{k,-1}$ their holding as cash (3.36) to buy the desired amount of the two investment goods. This share χ is determined togheter with the prices of the two capital goods (p_k, p_i), and with (γ, κ) - respectively the share of consumption good producers profits and the share of traditional capital producers' cash dedicated to traditional capital good

[19]We assume uniform diffusion of the good in both traditional sector.

purchase - by the system of simultaneous equations going from (3.36) to (3.39). Each capital stock x in the sector y is then updated according to investment $s_{x,y}$ from y in capital x minus depreciation $d(x_{y,-2})$ following the generic equation (3.44).

$$g_{yk} = \xi \pi_k y_{k,-1} \tag{3.33}$$
$$g_{yk} = (s_{i,k} - d(i_{k,-1}))\, pr_i + (s_{k,k} - d(k_{k,-1}))\, prk \tag{3.34}$$
$$\frac{s_{i,k}}{s_i} = \frac{s_{k,k}}{s_k} \tag{3.35}$$
$$\chi M_{k,-1} = s_{k,k} pk + s_{i,k} p_i \tag{3.36}$$
$$p_k = \frac{\gamma F_c + \chi \kappa M_{k,-1}}{s_k} \tag{3.37}$$
$$p_i = \frac{(1-\gamma) F_c + \chi (1-\kappa) M_{k,-1}}{s_i} \tag{3.38}$$
$$p_i = (1+\phi) p_k \tag{3.39}$$
$$s_k = inv_{k,-1} \tag{3.40}$$
$$s_k = s_{k,k} + s_{k,c} \tag{3.41}$$
$$s_i = inv_{i,-1} - s_{i,i} \tag{3.42}$$
$$s_k = s_{i,k} + s_{i,c} \tag{3.43}$$
$$\Delta x_y = s_{x,y} - d(x_{y,-1}) \tag{3.44}$$

3.4.2 Labor and consumption markets

Total employment depends on the quantity of capital (k_x and i_x) held in each sector $x \in \{c, k, i\}$. Households consume all their income[20] and buy all inventories of consumption goods. Consumption good price might increase or decrease, depending on the effect that technology has on employment.

$$N_x = \frac{k_x}{l_k} + \frac{i_x}{l_i} \tag{3.45}$$
$$p_c = \frac{W\,(N_c + N_k + N_i) + int_k + int_i}{s_c} \tag{3.46}$$

3.4.3 Profits

As before, net profits in the consumption sector are null since all gross profits are used to buy capital goods. Profits in both capital sectors depend on prices and investment decisions. Variation in cash held by traditional capital producers is equal to profits net of interests (F'_k), may they be positive or negative (3.50). Assuming that interest are equal to a share λ of gross profits, interests paid to

[20] Since we have assumed that any sector making positive net profits has to pay interests and that all interests are distributed to household, households income is composed of the wage bill and interests paid to banks.

bank are equal to (3.48) or (3.52)[21], leaving (3.53) as net profits (F_i') for the innovative firm, these being used to repay part of their loans (3.54).

$$F_k = Y_k - WN_k - s_{i,k}p_i - s_{k,k}p_k \tag{3.47}$$

$$int_k = \lambda F_k \tag{3.48}$$

$$F_k' = (1-\lambda)F_k \tag{3.49}$$

$$\Delta M_k = F_k' \tag{3.50}$$

$$F_i = Y_i - WN_i \tag{3.51}$$

$$int_i = \lambda F_i \tag{3.52}$$

$$F_i' = (1-\lambda)F_i \tag{3.53}$$

$$\Delta Li = F_i' \tag{3.54}$$

3.5 The dynamic of development

According to Schumpeter, during the first sub-phase, the managers of the circular flow are the one who improve their position, in particular those producing capital goods, whose price has now risen as a result of the appearance of the entrepreneurial demand. Obviously, some of the old firms will be affected by the rise of production costs, due to the inflationary tendency triggered by the ex novo created means of payment. *There will be both gains and losses. In spite of the losses in some industries, which must be expected to be a feature of the situation, all old firms taken together will, of course, show a net surplus.* (Schumpeter, 1964/1939, p.134).

In our model[22], the emergence of credit to innovation (in period 21) increases traditional capital good price, thus generating temporary positive profits for traditional capital good firms. Consumption good firms always have zero profits since they use all their profits to buy capital goods. Since employment and wages do not change in this phase, consumption prices are costant too. Hence the retain earnings of consumption good producers are no longer sufficient to buy the steady state level of capital due to the rise in traditional capital price[23].

However, this situation is only temporary since *"The new products come on the market after a few years or sooner and compete with the old; the commodity complement of the previously created purchasing power -theoretically more than counterbalancing the latter - enters [...] The appearance of the new products must result in deflation, not only as against the price level of the boom period, but theoretically also against that of the preceding period"* (Schumpeter, 1934/1912, p.232). In fact the innovation carried out by the entrepreneur has reduced the unitary costs of production. Once *"the equivalence between money and commodity streams is more than restored, the credit inflation [is] more than*

[21]It is one or the other. The monetary circuit is such that only one capital good producer can have positive profits in each production period.

[22]The value of the parameters used for simulations may be found in appendix B.2

[23]In the model the first sub-phase lasts only a period. A longer period of 'gestation' would simply stretch the phase in which traditional producers benefit from entrepreneurial demand but would not change in any way the dynamic of the model in the following periods.

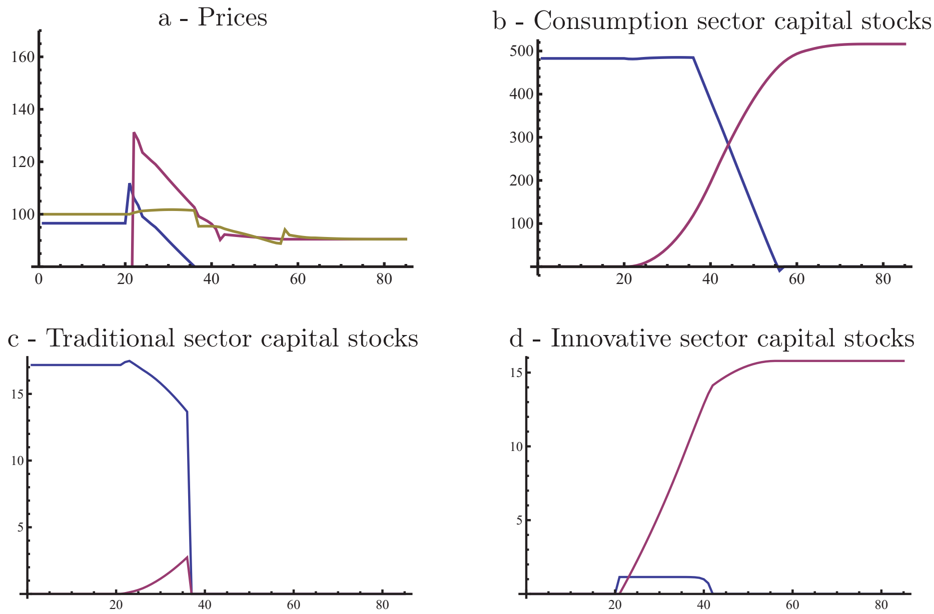

Figure 3: Prices (graph a) in both capital prices (blue line for traditional, red line for innovative) observe a short strong inflation when the innovator enters (period 21) and then decrease constantly until the exit of the traditional firm (period 36). Consumption prices (yellow line) increase slowly from the entrance of the innovators until the end of traditional firms. After the exit o traditional capital producers, both capital and consumption prices fluctuates until reaching their steady state values. Capital stock in the consumption sector (graph b) sees a replacement of traditional capital (blue) by innovative capital (red). Capital stock in the traditional capital sector (graph c) shows a small increase in traditional capital (blue) followed by a replacement from traditional capital by innovative capital (red). Capital stock in the innovative capital sector (graph d) shows that the initial investment in traditional capital (blue) is kept until totally depreciated. On the other hand, its innovative capital stock (red) increases steadily until reaching its steady state value after the traditional producers exit the market.

eliminated, [...] so that it may be said that there is no credit inflation at all in this case - rather deflation - but only a non-synchronous appearance of purchasing power and of the commodities corresponding to it, which temporarily produces the semblance of inflation." (Schumpeter, 1934/1912, p.110). While credit initial effect on prices has been temporary, the productive structure of the economy has been definitively modified, thus disproving the neoclassical dogma of a dicotomy between real and monetary spheres.

Again, the model presents a tendency very close to Schumpeter's analysis: when the innovative goods enter the market in period 22, prices of traditional capital goods starts to fall. The deflationary effect caused by the increase in the supply of capital goods is incremented by the fact that traditional firms spend only a share χ of the previously accumulated cash holdings.

The innovative good is characterized by an higher level productivity. Traditional capital producers replace part of their depreciated traditional capital with the innovative one. Furthemore, innovative firm buys traditional capital good only in the first sub-phase. Hence, as shown in figure 3.c-d, as the share of innovative good used in production of both traditional and innovative capital good sectors increases[24], the output of capital goods producers increases thus exacerbating the deflationary tendency. This tendency is only partially moderated by the fact that traditional capital good producers, as they observed that the price of their product is falling, reduce their investments, see equation (3.33).

Schumpeter noted that the emergence of entrepreneurial profit enables innovators to repay their debt, so that the original bank credit disappeared with only profits and interests remaining in circulation. Credit deflation exacerbates the already going deflationary tendency, although Schumpeter stressed that there might be some counteracting factors[25]. In the model, entrepreneur initially produces in deficit but, after a few periods, as their market share increase, they begins to realize profits (figure 4.a-b). While part of these profits goes to banks as interest payments, entrepreneur are now capable of repaying their principal, thus reducing the amount of money in the circuit. Since the disappearance of the original credit to innovation is not compensated by the opening of new credit lines, this strenghtens the deflationary process.

Schumpeter's analysis proceeds by observing that prices instability usually increases uncertainty about the future, thus further complicating the calculation of the likely costs and revenues related to investment projects. This therefore reduces the incentive for innovation and investment. Moreover, while the costs of production has already risen for some of the old firms in the first sub-phase,

[24]Notice that, since we chose Bhaduri (1972) exponential depreciation function based on a capital lifetime of 20 periods, this implies that the depreciation of the capital bought at a certain period is not smoothed among all the periods of its lifetime but is very low, nearly 0, at the beginning, and then shows a strong increase in the final periods. This appears clearly if we look at the dynamic of the traditional capital stock bought by entrepreneur in the first sub-phase.

[25]Among these we mention: the expenditure decision of the entrepreneur who have realized a net-profit and of the bank that have received interest payments, the possibility that banks allow entrepreneurs to defer and smooth debt repayments, government public spending.

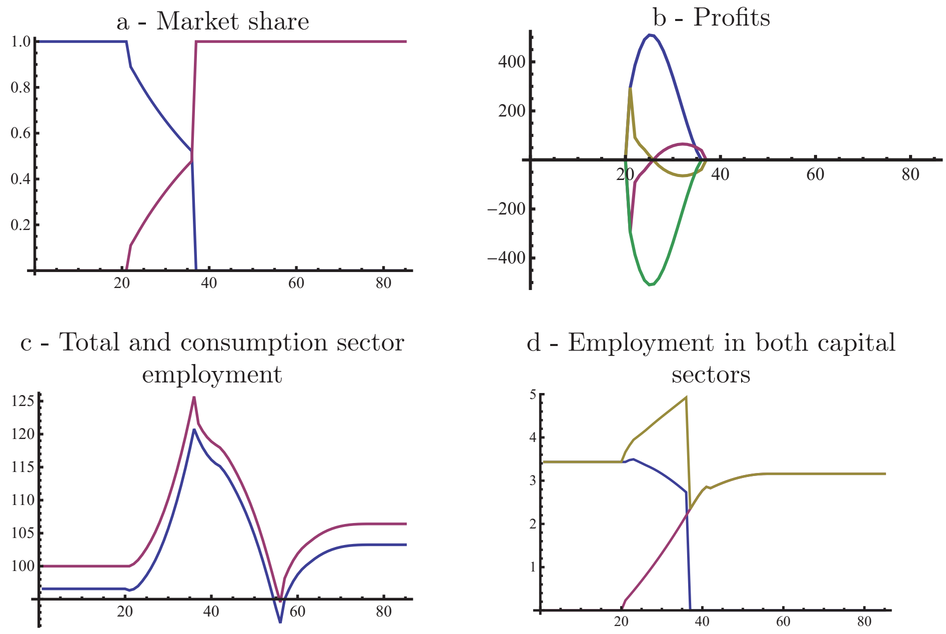

Figure 4: Market share (graph a) of the traditional producers (blue) decrease brusquely when the innovator (red) enters the market. Until the exit of the the traditional producers (period 36), the market share show opposite trends. Profits (graph b) in the traditional sectors (yellow line) are positive for a few periods and then are negative until their cash holdings (blue) is equal to 0. This is he signal for them to exit the market. Profits (red) and credit (green) in the innovative sector are the exact opposite of profits and cash holding in the traditional sector. Total employment (red, graph c) increase during the periods where both capital producers are present in the market. Employment in the consumption sector (blue) decrease during the first sub-phase and then increases until the exit of the traditional producers. After the exit of traditional producers, employment fluctuates until it reaches its steady state value. Graph d shows that employment loss in the traditional sector (blue) is more than replaced by employment in the innovative sector (red), implying that total employment in capital producers (yellow) increases until the exit of the traditional producers. After the exit, total employment reaches slowly its steady state value.

their receipts begin to drop also in this second phase. First for those firms with whom the innovation comes into direct competition, and then also for the others. The deflation period is thus the context in which the schumpeterian process of ”creative destruction” takes place. The old firms have to adapt to the new situation, otherwise being doomed to disappear. The recession[26] that follows the first inflationary phase thus marks the beginning of what Schumpeter defined as *”the struggle for a new equilibrium position”* (Schumpeter, 1934/1912, p.243). Something similar happens in our model: the deflationary dynamic implies that old producers, having higher unitary costs of production (i.e. lower capital productivity), will not be able to survive, under the growing competitive pressure coming from innovators. When the innovative firm reaches a market share of approximately 45%, prices have been fallen so much that old producers are no longer able to meet their financial obligations and they are forced to exit the market. Schumpeter argued that, once the old producers are pushed out of the market, employment may fall, if the new businesses are not able to absorb the labor force expelled by traditional sectors[27]. This is exactly what happens in the model: employment first increases as a result of the growth experienced by both the innovative firm - this effect more than compensating the contraction of traditional capital sector - and the consumption sector (figure 4.c-d). However, when the old capital good producers go bankrupt, employment starts to fall. Employment decreases since people employed in the old sector have lost their job (4.d). But employment decreases also in the consumption good sector: the reason has to be found in the fact that the innovative sector is still too small to provide an amount of investment goods sufficient to offset the depreciation of capital of the consumption sector (by far the largest sector of the economy), figure 3.b. Employment in the consumption sector drops as a result of a fall in capital stock.

As the traditional capital good producers exit the market, the innovative firm's market share becomes equal to one and by this time, the innovative firm holds for itself, in each period, an amount of capital goods equal to the one retained in the last period before the bankruptcy of the traditional sector. Hence the innovative firms goes on growing until the depreciation of capital becomes equal to this amount. As the innovative firms continues to grow, the supply of capital provided to consumption goods firms, at period 56, becomes sufficient to exceed the amount of depreciated capital, leading to a recovery of consumption industry's capital stock and employment. Total employment then recovers as the innovative firm continues to grow until it reaches the steady state.

Notice that unemployment generated by the failure of the old producers causes another drop of the price of the innovative good. Indeed, unemployment

[26]Actually Schumpeter used the term 'depression' instead. We use the term recession in order to avoid misunderstadings.

[27]This tendency can be aggravated, according to Schumpeter, by the progressive disappearance of the demand for traditional investment goods coming from entrepreneurs and by the possible emergence of technological unemployment, as a result of the mechanization of productive processes.

reduces the wage bill. This in turn, significantly reduces consumer good sector revenues (previoulsy given by $W(N_i + N_k)$, and now only by $W'N_i$ with $W' < W$) and consequently also its nominal demand for capital goods. The price of the innovative investment good must thus fall further.

Consumption good prices, on the other hand, first increase and then decrease, their dynamic being fundamentally correlated to the dynamic of employment and nominal wages. It must be stressed that, as stated by Schumpeter, the new level of prices in the steady state is lower than the initial one, due to the fact that the emergence of innovation has definitively changed the productive structure. ../Figure 3.a shows prices movements.

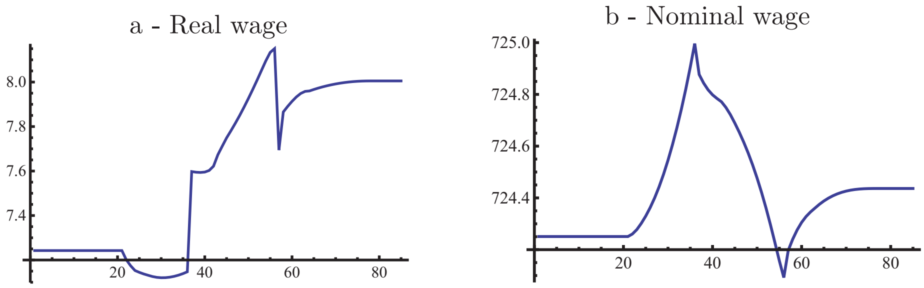

Figure 5: Real wages (graph a) start decreasing as soon as the innovators enters the market (period 21) due to a decrease in output and an increase in employment. It then starts increasing as the increase in output due to productivity gains in the consumption sectors overcome the increase in employment. At the exit of traditional producers (period 36), the decrease in employment resulting form the loss of labor demand in that sectors implies an important increase in real wages. After that, real wages fluctuates before reaching its steady state value, well above it previous steady state value. Nominal wages (graph b) follows the same trend as total employment (figure 4.c), that is an increase until the traditional sector leaves followed by a period of fluctuation as the economy reaches its steady state.

If nominal wages increase and decrease following the dynamic of employment, real wages $\frac{W}{P} = \frac{s_c}{N}$ instead shows a more complex dynamics, see figure 5.a. First, real wages decrease as a consequence of the fact that total employment grows while the output of consumption firms decreases due to the reduction of its capital stock caused by the emergence of entrepreneurial demand. Then, they recover, as the increasing use of innovative capital good by consumption firms increase their average productivity:], consumption firms output thus increase more than employment, pushing up real wages. As the traditional capital producers exit the market, employment drops suddenly while consumption goods produced remains constant, implying the instantaneous spur in real wages observed in period 36. Then, real wages decrease slightly as real output of consumption goods decreases, due to the depreciation of traditional capital, which cannot be replaced anymore. This is due to the larger than one productivity. As soon as the supply of innovative capital more than compensate for the depreciation of traditional capital goods, real wage start rising again. The sudden drop in real wages around period 57 is due to the large depreciation of traditional capital[28] which cannot be compensated by innovative capital goods. A drop of employment is also observed but the productivity is such that output decrease more than proportionally to employment. The end of the series shows that real wages increase slowly towards its steady state value as capital stocks rebuilds in the consumption good industry.

The dynamic process just presented refers to Schumpeter's "first approximation" of his business cycle theory: the case of an isolate entrepreneur. The more general version of the model starts by considereing that entrepreneurs usually appear in swarm for a number of reasons, not only economic, but also sociological, cultural, and psychological. The fact that entrepreneurs appear *en masse* is the fundamental reason why we observe economic cycle. The appearance of entrepreneurs is usually followed by the emergence of a *'secondary wave'* of imitators, feeding in turn a secondary boom. Schumpeter noted that the effects related to this secondary wave of entrepreneurs are generally more relevant from a quantitative point of view - compared to the 'primary' one - , as well as easier to observe, since they pertain to the 'surface' of the development process. Moreover, they play an important role in the process of development because they can act as an amplifier of the unavoidable business cycle, feeding speculation during the prosperity period, then causing abnormal and unnecessary liquidations during the recession. Nevertheless, Schumpeter himself considered these aspects *inessential* in order to define the underlying logic of the process of development.

For the same reason, this first work does not address these issues, preferring to focus upon the structural characteristics of the process of change and development triggered by innovation.

The results presented in this section show how this model, though simple, is able to reproduce many of the most interesting insights of Schumpeter's theory of development and business cycle, by formalizing it inside the coherent framework provided by SFC models and the theory of monetary circuit. In the next section, in an attempt to move towards more realism, we will develop a more complex model, based on more realistic behaviors and more plausible assumptions, largely derived from post-keynesian tradition.

4 Banks, Financial Markets and Innovation: towards a more comprehensive model

In this section, we present the basic structure of an augmented version of the previous model. Our aim, at this stage, is to build the ground for a more realistic and accurate analysis of the functioning of real capitalist economies. We thus

[28] The functional form of the depreciation function is such that most of the capital "depreciate" in the end of its life.

abandon some of the most simplifying and implausible assumptions (such as market clearing prices and full capacity utilization) that were justified in the first model by the attempt to remain as close as possible to Schumpeter's original thought. The main aspect of novelty, however, is the introduction of financial markets, which allows firms to issue shares in order to finance their investment, as an alternative to loans granted by banks. This implies that firms now decide not only how much to invest but also how to finance their investment. On the other hand banks now discriminate between different producers by applying different rates of interest, on the base of the perceived risk related to each loan granted. Investors finally based their portfolio choices on expectations formed by looking at the past performance, in terms of dividends and capital gains, of the different types of securities.

In this way, the model aims at providing an explanation of technological rooted business cycle that explicitly takes into account the interaction between real and financial side of the economy. The adoption of a SFC framework is a key aspect in this respect since it ensures to avoid black boxes between real and nominal variables.

../Figure 6 depicts the flow diagram of the economy at hand. We have divided the household sector into two sectors: wage earners and capitalists. Wage earners offer labor in exchange for a wage and capitalists own the firms through shares and receive dividends. Both sectors are saving part of their income as cash and thus build a stock of financial wealth. As in the previous model, all productive sectors need capital to produce their own good. Furthermore, they obtain credit from banks in order to start the production but also, diverging from our simpler model, to finance their investment. Indeed, each industry now has three separate source of financing: profits, emission of equities and credit. The following section will describe the behavioral equations of each sector. Table 6 in appendix A, shows the transaction flow matrix of the economy. A list of all variables and their signification may be found in appendix C.1

4.1 Household sectors

Before describing each household sector characteristic, we will depict how consumption decision are taken. Real consumption level is function of expected real disposable income and previous period real wealth (4.1). Expected real disposable income is is based on previous period expected and observed real disposable income (4.2). Nominal consumption is then computed using consumption good price (4.3). All nominal income that is not spent is saved.(4.4).

$$c = \alpha_1.yd^e + \alpha_2.v_{-1} \tag{4.1}$$

$$yd^e = \epsilon.yd_{-1} + (1-\epsilon)yd^e_{-1} \tag{4.2}$$

$$C = c.p_c \tag{4.3}$$

$$\Delta V = YD - C \tag{4.4}$$

$$v = \frac{V}{p_c} \tag{4.5}$$

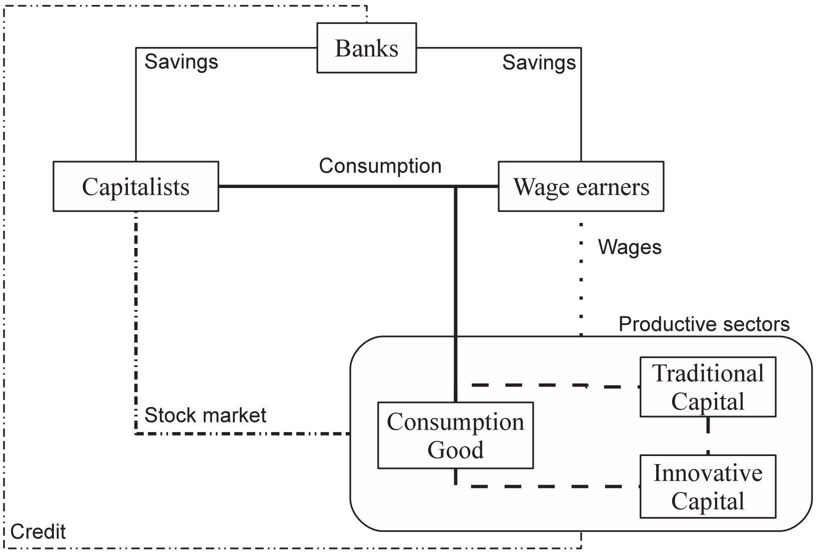

Figure 6: Flow diagram of the model with savings and equities. Both household sectors consume (thick solid line) goods from the consumption good industry. Wage earners obtain wages (dotted line) in exchange from labor from all productive sectors and save (thin solid line) what is not consumed. Capitalists obtain dividends from the equities they hold (thick dash-dotted line) and store as cash (thin solid line) the remaining of their wealth. Banks store deposits from both sector households and grant credit (thin dash-dotted line) to all three productive sectors. Finally all productive sectors need capital traditional or innovative to produce their own goods (thick dashed line).

4.1.1 Wage earners

Wage earner's nominal income is composed from wage received from all industries (4.6). Real disposable income, defined à la Haig-Simons[29], is equal to real income minus inflationary impacts on wealth (4.7). All wealth is saved as cash (4.8).

$$YD_w = W_c N_c + W_k N_k + W_i N_i \tag{4.6}$$

$$yd_w = \frac{YD_w}{p_c} - \pi_c \frac{V_{w,-1}}{p_c} \tag{4.7}$$

$$M_w = V_w \tag{4.8}$$

[29] Haig (1921) and Simons (1938) define income as the sum of consumption and variation in wealth. According, to (Godley and Lavoie, 2007, pp 293-294), Haig-Simons' real disposable income is composed of real disposable income minus the loss of real wealth due to inflation.

4.1.2 Capitalists

Capitalists' personal income is composed of dividends from all industries as well as from banks (4.9). Capitalists' disposable income is composed of their personal income and capital gains (4.10).

$$YP_c = FD_c + FD_k + FD_i + FD_b \tag{4.9}$$

$$YD_c = YP_c + CG \tag{4.10}$$

$$CG = \sum_{j \in c,k,i} e_{j,-1} \Delta p_{j,e} \tag{4.11}$$

$$yd_c = \frac{YD_c}{p_c} - \pi_c \frac{V_{c,-1}}{p_c} \tag{4.12}$$

Capitalists' wealth V_c is formed by the sum of cash M_c and financial wealth V_{ec} (4.13). V_{ec} is composed of equities out of the production sectors (4.17). We assume that their cash demand is a fraction of nominal consumption (4.14). Capitalists compute an expected total wealth V_c^e based on their previous wealth, their expected disposable income, their nominal consumption and their desired cash holding (4.15)-(4.17). Variation in nominal wealth is computed at the end of the period as the difference between nominal disposable income and nominal consumption (4.18). Financial wealth is computed by summing the values of equities holding (4.20) resulting from their portfolio choice decision. Cash holding is the residual and might be different from its desired level (4.13.A).

$$V_c = M_c + V_{ec} \tag{4.13}$$

$$M_c^d = \beta_c C_c \tag{4.14}$$

$$YD_c^e = p.yd_c^e + \pi_c \frac{V_{c,-1}}{p_c} \tag{4.15}$$

$$V_c^e = V_{c,-1} + YD_c^e - C_c \tag{4.16}$$

$$V_{ec}^e = V_c^e - M_c^d \tag{4.17}$$

$$\Delta V_c = YD_c - C_c \tag{4.18}$$

$$v_c = \frac{V_c}{p_c} \tag{4.19}$$

$$V_{ec} = e_c p_{c,e} + e_k p_{k,e} + e_i p_{i,e} \tag{4.20}$$

$$M_c = V_c - V_{ec} \tag{4.13.A}$$

Capitalists have to make a portfolio choice in each period. We follow a Tobinesque approach of portfolio choice (Brainard and Tobin, 1968). Nominal holding in equities depends on expected capital gains and expected returns in that industry (4.21)-(4.23). The supply of equities being determined by firms, prices are such that the market clears. There are no preferences among sectors expressed in the portfolio choice equations. This assumption simplifies the model without affecting its dynamics.

$$e_c p_{c,e} = \left(\zeta_1 \frac{cg^e_c}{cg^e_c + cg^e_k + cg^e_i} + \zeta_2 \frac{r^e_c}{r^e_c + r^e_k + r^e_i} \right) V^e_{ec} \tag{4.21}$$

$$e_k p_{k,e} = \left(\zeta_1 \frac{cg^e_k}{cg^e_c + cg^e_k + cg^e_i} + \zeta_2 \frac{r^e_k}{r^e_c + r^e_k + r^e_i} \right) V^e_{ec} \tag{4.22}$$

$$e_i p_{i,e} = \left(\zeta_1 \frac{cg^e_i}{cg^e_c + cg^e_k + cg^e_i} + \zeta_2 \frac{r^e_i}{r^e_c + r^e_k + r^e_i} \right) V^e_{ec} \tag{4.23}$$

$$\zeta_1 + \zeta_2 = 1 \tag{4.24}$$

Expectations on capital gains and return rate in each sector go along the line found in Le Heron and Mouakil (2008). They follow auto-corrective processes based on previous expected and observed values where θ and χ are the velocity of error corrections.

$$cg^e = \frac{CG^e}{e_{-1} p_{e,-1}} \tag{4.25}$$

$$CG^e = CG_{-1} + \theta \left(CG_{-1} - CG^e_{-1} \right) \tag{4.26}$$

$$r^e = \frac{FD^e}{e_{-1} p_{e,-1}} \tag{4.27}$$

$$FD^e = FD_{-1} + \chi \left(FD_{-1} - FD^e_{-1} \right) \tag{4.28}$$

4.2 Productive sectors

Before analysing each sector peculiarities, we'll observe general behaviors, common to all productive sectors.

4.2.1 Wages and unit costs

In each industry, nominal wage is a function of its targeted real wage (4.29). Targeted real wage depends from that sector labor productivity $\overline{pr_x}$ and $\frac{N}{LF}$, the aggregate employment rate(4.30). Productivity in each sector is determined by an average of the capital stock productivity (4.31.A).

$$W = W_{-1} + \Omega_3 \left(\omega^T - \frac{W_{-1}}{p_{c,-1}} \right) \tag{4.29}$$

$$\omega^T = \Omega_0 + \Omega_1 \log(\overline{pr_x}) + \Omega_2 \log(\frac{N}{LF}) \tag{4.30}$$

$$\overline{pr_x} = pr_k l_t \frac{N_{x,k}}{N_x} + pr_i l_i \frac{N_{x,i}}{N_x} \tag{4.31}$$

$$= \frac{k_x}{N_x} + \frac{i_x}{N_x} \tag{4.31.A}$$

Unit costs are defined as the wage bill divided by real output. If only one kind of capital is used to produce, then unit costs reduces to (4.32).

$$UC = \frac{WN}{y} = \frac{W\frac{y}{pr.l}}{y} = \frac{W}{pr.l} \tag{4.32}$$

However, in the case of the consumption good industry or of the innovative firm, two kinds of capital are used: traditional and innovative. Hence, unit costs are based on the quantity of innovative and traditional capital goods used. Because the innovative capital is more productive, it is reasonable to assume that firms chose to first produce using innovative goods and then using traditional goods[30]. We thus face a piecewise unit cost function depending on total output produced. If demand in consumption good y is lower than the maximum level of output produced by innovative goods (y_{fci}, 4.33), then, since only one source of capital is used, (4.32) is valid. However, if $y > y_{fci}$, both capital are used and unit costs depends on wages, employment and output. Total output is produced using both capital following (4.34) where $u_{x,k}$ is the utilisation rate of traditional capital in the given sector (4.35). Employment is determined through the number of employees needed to use all innovative goods plus those needed to use the quantity of traditional capital requested to respond to demand (4.36). Unit costs, in this case takes the form (4.32.A) which can be simplified to (4.32.B) using the assumption $l_k = l_i$.

$$y_{fci} = i.pr_i \tag{4.33}$$
$$y = i.pr_i + u_{x,k}k.pr_k \tag{4.34}$$
$$u_{x,k} = \frac{y - y_{fci}}{k.pr_k} \tag{4.35}$$
$$N = \frac{i}{l_i} + u_{x,k}\frac{k}{l_k} \tag{4.36}$$
$$UC = W\frac{il_t + u_{x,k}kl_i}{(i.pr_i + u_{x,c}k.pr_k)l_i l_k} \tag{4.32.A}$$
$$= W\frac{y + i(pr_k - pr_i)}{l_k pr_k y} \tag{4.32.B}$$

The piecewise unit cost function in the consumption good production industry is thus given by (4.37). ../Figure 7 represents such a unit cost function.

$$UC(y) = \begin{cases} \frac{W}{pr_i l_i} & \text{if } y \leq y_{fci} \\ W\frac{y+i(pr_k - pr_i)}{l_t pr_k y} & \text{if } y > y_{fci} \end{cases} \tag{4.37}$$

[30]In this paper, we follow Robinson (1969) in that firms might make mistakes in their estimation of output growth creating unwanted excess capacity; and Lavoie (1992) as firms also plan some excess capacity in order to avoid to constrain demand in case of large growth in demand. Firms maintain an excess of total production capacity and not an excess of capacity per type of capital.

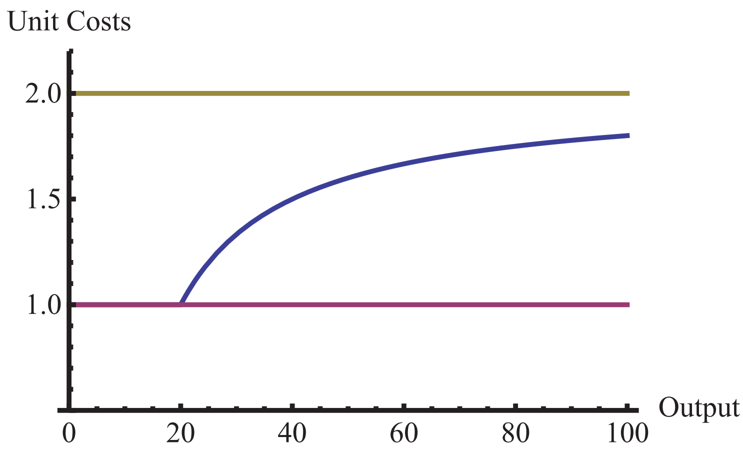

Figure 7: Piecewise unit cost function in the consumption good production industry. Unit costs are constant at the innovative unit costs (in this case 1.0) up to full capacity utilisation of innovative capital (20) and then is an increasing function of output, tending towards the traditional unit costs (2.0). The more the consumption good producer own innovative capital, the larger is the quantity of output produced at innovative unit costs.

4.2.2 Pricing decision and investment

Prices are kaleckian mark-up on unit costs (4.38). Following Lavoie (1992), the mark-up is endogenously determined through $r_{x,k}$, the desired return on capital in sector x, and expected output and expected unit costs, y^e and $UC(y^e)$ respectively, (4.39). Expected output growth is inversely proportional to price inflation (4.40).

$$p = (1+\phi)\,UC \tag{4.38}$$

$$\phi = \frac{r_{x,k}(p_{k,-1}k_{-1} + p_{i,-1}i_{-1})}{UC(y^e)y^e} \tag{4.39}$$

$$y^e = y_{-1}(1-\pi) \tag{4.40}$$

Instead of defining the usual capital stock growth function, we define a practical full capacity[31] growth function. Indeed, while it is easy to define a capital stock growth function when only one type of capital exists, it is more convenient to define a *maximum output* growth function in the case of multiple sorts of capital. This full capacity growth function reduces to a capital stock growth function for both capital good sectors since they only use one type of capital. We will here analyse the growth function and leave the detail of how capital stock adjust for

[31] *Practical* or *engineer-rated* full capacity is the maximum level of production such that it allows normal maintenance and renovation of machinery to take place without impeding production (Eichner, 1976), (Steindl, 1952).

each sector's description. Output growth is a function[32] of capacity utilisation u, real interest rates rr_l, leverage level λ and Tobin's q (4.41). Capacity utilisation (4.42) is defined as the ration of actual output (y) and practical full capacity output. Tobins' q is defined here as the ration between the market value of the firms and its net worth (4.43).

$$g_y = \eta_0 + \eta_1(u^T - u_{-1}) + \eta_2 rr_l \lambda_{-1} + \eta_3 q_{-1} \tag{4.41}$$

$$u = \frac{y}{k.pr_k + i.pr} \tag{4.42}$$

$$q = \frac{e.p_e}{p_k k + p_i i - L} \tag{4.43}$$

4.2.3 Financing decision

As already explained, firms have three sources of funds to finance investments: profits, equities emission and bank credit. We assume that firms always use all their profits net of interests $F = Y - WN - r_{l,-1}L_{-1}$ to finance investment I. If profits are larger than investments, the remaining part of profits are distributed as dividend, $FD = F - I$. If the need for finance is larger than profits, firms then have to decide how to finance the remaining part $I_f = I - F$. We assume that the share Ψ of investments funded by equities emission is a function of cg, the capital gains relative to the firm's market value (4.45) and loans' interest rate r_l (4.44). The quantities of equities emitted e^s depends on previous period equities price $p_{e,-1}$ (4.46). The quantities of equities on the market is thus equal to their previous period number plus new emission (4.47). Finally, loans is the residual between need for finance and the quantity of funds raised by equities emission, which depends on the realised market price for equities (4.48). ../Figure 8 shows how Ψ reacts to capital gain and interest rate variations.

$$\Psi_c = \frac{1}{1 + \exp\left[\psi(r^T - cg - r_l)\right]} \tag{4.44}$$

$$cg = \frac{CG}{p_{e,-1}e_{-1}} \tag{4.45}$$

$$e^s = \frac{\Psi I_f}{p_{e,-1}} \tag{4.46}$$

$$e = e_{-1} + e^s \tag{4.47}$$

$$\Delta L = I_f - e^s p_e \tag{4.48}$$

4.2.4 Consumption good sector

Real demand in consumption goods is determined by the consumption decision of both household sectors $y_c = c_c + c_w$. Consumption good industry follows the

[32] We use here a simplified version of Fazzari and Mott (1986-1987), and Lavoie and Godley (2001-2002), since we assume that firms have fixed return rates. The effect of these normally non fixed variable is thus contained in η_0.

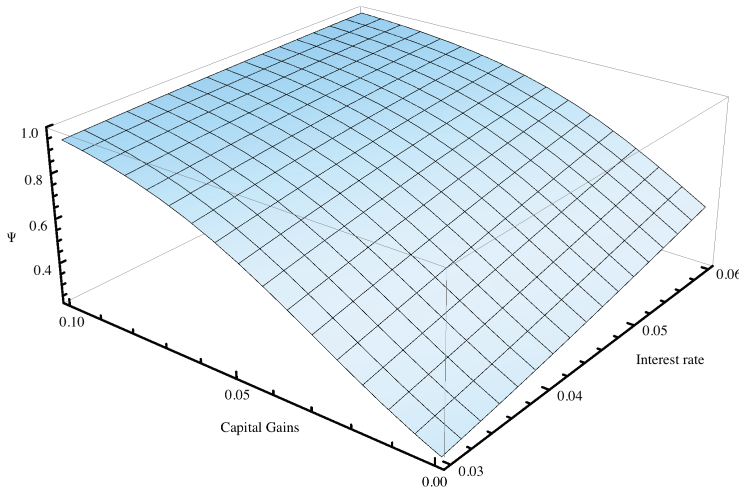

Figure 8: Share of investments financed via equities emission Ψ as a function of relative capital gains and interest rates. If either one of these value increase, firms' increase their share of investment financed via equities.

pricing and investment decisions described in section 4.2.2. However, the real interest rate in the case of the consumption good sector is particular. Indeed, real interest rate is defined as the nominal interest rate deflated by inflation. However in our case, there are two prices for capital, we have thus defined a capital price inflation based on consumption good industry's stock of both capital and their relative price inflation (4.50).

$$rr_{lc} = \frac{1 + r_l}{1 + \overline{\pi_c}} - 1 \tag{4.49}$$

$$\overline{\pi_c} = \frac{k_{c,-1}\pi_k + i_{c,-1}\pi_i}{k_{c,-1} + i_{c,-1}} \tag{4.50}$$

As mentioned earlier, consumption good producers use both kinds of capital and thus may choose to invest in any of these type of capital. Given the desired growth in productive capacity, they have to choose in which kind of capital to invest. We assume they do so based on the relative cost of the two kinds of capital (4.52). Because their demand in one certain type of capital might be frustrated, we have to take into account these situation (4.53)-(4.59) where i_s and k_s are the quantity of innovative and traditional goods available. The investment decision is thus a two steps process: first capital producers announce their price and the quantity of goods available, then the consumption good producers decided how much to invest based on their capacity utilisation rate and the real interest rate they face and in which good to invest based on relative costs and availability of goods. The finance of this desired investment in capital follows the rule determined in section 4.2.3 and is not repeated here.

$$g_{yc} = \eta_{c,0} + \eta_{c,1}(u_c^T - u_c) + \eta_{c,2} rr_{l,c} \lambda_{c,-1} + \eta_{c,3} q_c \tag{4.51}$$

$$cost_k = \frac{p_k}{pr_k},\ cost_i = \frac{p_i}{pr_i} \tag{4.52}$$

$$\begin{aligned} i_{c,i} &= z_1 \left[z_2 i_s + (1 - z_2) \frac{g_{yc} y_{c,-1}}{pri} \right] + \\ &\quad \ldots (1 - z_1) z_3 \left[z_4 i_s + (1 - z_4) \frac{g_{yc} y_{c,-1} - k_s pr_k}{pr_i} \right] \end{aligned} \tag{4.53}$$

$$\begin{aligned} i_{c,k} &= z_1 z_2 \left[z_5 k_s + (1 - z_5) \frac{g_{yc} y_{c,-1} - i_s pr_i}{prk} \right] + \\ &\quad \ldots (1 - z_1) \left[z_3 k_s + (1 - z_3) \frac{g_{yc} y_{c,-1}}{pr_k} \right] \end{aligned} \tag{4.54}$$

$$z_1 = 1 \text{ if } cost_k > cost_i,\ 0 \text{ otherwise} \tag{4.55}$$

$$z_2 = 1 \text{ if } \frac{g_{yc} y_{c,-1}}{pr_i} > i_s,\ 0 \text{ otherwise} \tag{4.56}$$

$$z_3 = 1 \text{ if } \frac{g_{yc} y_{c,-1}}{pr_k} > k_s,\ 0 \text{ otherwise} \tag{4.57}$$

$$z_4 = 1 \text{ if } \frac{g_{yc} y_{c,-1} - k_s pr_k}{pr_i} > i_s,\ 0 \text{ otherwise} \tag{4.58}$$

$$z_5 = 1 \text{ if } \frac{g_{yc} y_{c,-1} - i_s pr_i}{pr_k} > k_s,\ 0 \text{ otherwise} \tag{4.59}$$

4.2.5 Traditional capital good industry

The traditional capital good industry face a demand composed of investment decision by the three productive sectors $y_k = s_{c,k} + s_{k,k} + s_{i,k}$[33]. They follow the pricing, investment and financing rules defined in section 4.2.2 to 4.2.3. However, it is interesting to note that since traditional capital good producers only use one kind of capital, they face constant unit costs (4.60). Full capacity growth reduces to a capital stock growth as they only invest in traditional capital (4.62).

$$UC_k = \frac{W}{pr_k l_k} \tag{4.60}$$

$$g_{yk} = \eta_{k,0} + \eta_{k,1}(u_k^T - u_k) + \eta_{k,2} rr_{l,k} \lambda_{k,-1} + \eta_{k,3} q_k \tag{4.61}$$

$$g_{k,k} = \frac{g_{yk}}{pr_k} \tag{4.62}$$

[33] The innovative firm will invest in traditional goods only in the first sub-phase, i.e. when they need capital to produce their first batch of the innovative capital good. See section 4.3 for more information.

4.3 Innovative capital good firm

Before entering the capital good market, innovative firm must produce their first batch of capital good. In order to produce it, they need to buy traditional capital goods. We assume that firms and banks determine the quantity of credit needed in order to have enough capital good so that when entering the market they attain a certain market share ψ and growth rate of potential output τ. The parameters ψ and τ might be seen as the result of a bargain ensuring that the firm will make profits soon enough to be able to repay part of their loans. The system of equations determining the credit L_i is the following:

$$y_i = k_i pr_k \tag{4.63}$$

$$y_i = s_i + i_i \tag{4.64}$$

$$i_i = y_i \frac{1+\tau}{pr_i} \tag{4.65}$$

$$s_i p_i = \psi(s_i p_i + Y_k) \tag{4.66}$$

$$p_i = \frac{W_t N_i}{y_i}(1+\phi_i) \tag{4.67}$$

$$N_i = \frac{ki}{pr_k l_t} \tag{4.68}$$

$$L_i = k_i p_k \tag{4.69}$$

where i_i is the quantity of produced capital good retained to ensure a production capacity growth equal to τ and i_s is the remaining of output that is sold at price p_i.

The innovative firm starts producing in the next period, selling its capital to consumption good producers. The demand they face is composed from investment decision from their part and from the consumption good industry $y_i = i_{c,i} + i_i$. Employment and unit costs follows the same rule as in the consumption good sector since the innovative firm use both kind of capital[34]. Growth of capital stock follows (4.70), excepted from the first period of production where it is fixed to τ.

$$g_{yi} = \eta_{i,0} + \eta_{i,1}(u_i^T - u_i) + \eta_{i,2} rr_{l,i} \lambda_{i,-1} + \eta_{i,3} q_i \tag{4.70}$$

$$g_{i,i} = \frac{g_{yi}}{pr_i} \tag{4.71}$$

We assume that the innovative firm is not present at first on the stock market and enters the market only after 5 period of positive profits. Once it has entered the market, it follows the same rules as the other productive sectors to finance their desired investments. Before entering the market, all investments are finance through profits and loans.

[34]The innovative firm use both type of capital until the traditional capital bought in the first period of their life is fully depreciated.

4.4 Banking sector

Banks hold deposit accounts from both household sectors and loan cash to firms. We assume that banks always accomodate loans requests and that there are no non performing loans. Banks do not have any leverage and thus cash deposits are always equal to loans. Banks only source of income are the interests paid by firms. Banks do not have any operating costs and do not pay any interests on cash deposits by households. All income are distributed as dividend to capitalists. We assume that banks charge different interest rates based on the risk perceived to lending to the different sectors[35]. Risk evaluation is proxied using the difference between an exogenously determined benchmark return rate r_b and the average net-of-interest return rate on capital generated during the last 5 periods (4.76)-(4.81).

$$FD_b = r_{l,c}L_{c,-1} + r_{l,k}L_{k,-1} + r_{l,k}L_{i,-1} \tag{4.72}$$

$$M_s = M_w + M_c \tag{4.73}$$

$$L_d = L_c + L_k + L_i \tag{4.74}$$

$$M_s = L_d \tag{4.75}$$

$$r_{l,c} = r_l\left(1 + \frac{1}{1 + \exp[\kappa(\overline{r_c} - r_b)]}\right) \tag{4.76}$$

$$r_{l,k} = r_l\left(1 + \frac{1}{1 + \exp[\kappa(\overline{r_k} - r_b)]}\right) \tag{4.77}$$

$$r_{l,k} = r_l\left(1 + \frac{1}{1 + \exp[\kappa(\overline{r_i} - r_b)]}\right) \tag{4.78}$$

$$\overline{r_c} = \frac{1}{5}\sum_{n=1}^{5} \frac{F_{c,-n} - r_{l,c,-n}L_{c,-(n+1)}}{p_{k,-(n+1)}k_{c,-(n+1)} + p_{i,-(n+1)}i_{c,-(n+1)}} \tag{4.79}$$

$$\overline{r_k} = \frac{1}{5}\sum_{n=1}^{5} \frac{F_{k,-n} - r_{l,k,-n}L_{k,-(n+1)}}{p_{k,-(n+1)}k_{k,-(n+1)}} \tag{4.80}$$

$$\overline{r_i} = \frac{1}{5}\sum_{n=1}^{5} \frac{F_{i,-n} - r_{l,i,-n}L_{i,-(n+1)}}{p_{k,-(n+1)}k_{i,-(n+1)} + p_{i,-(n+1)}i_{i,-(n+1)}} \tag{4.81}$$

[35] For more information on how banks set interest rates, see Gambacorta (2008).

References

J.V. Accoce and T. Mouakil. The monetary circuit approach: A stock-flow consistent model. In Eckhard Hein and Achim Truger, editors, *Money, Distribution and Economic Policy: Alternatives to Orthodox Macroeconomics*. Edward Elgar Publishing, 2005.

A. Bhaduri. Unwanted amortisation funds. *Economic Journal*, 1972.

W. C. Brainard and J. Tobin. Pitfalls in financial model building. *American Economic Review*, 58(2):pp. 99–122, May 1968.

J. R. Brown, S. M. Fazzari, and B. C. Petersen. Financing innovation and growth: Cash flow, external equity, and the 1990s r&d boom. *The Journal of Finance*, 64(1):151–185, 2009.

N. De Vecchi. *Schumpeter Viennese: Imprenditori, Istituzioni e Riproduzione del Capitale*. Bollati Boringhieri, 1993.

C. H. Dos Santos. Keynesian theorizing during hard times: stock-flow consistent models as an unexplored frontier of keynesian macroeconomics. *Cambridge Journal of Economics*, 30(4):541–65, 2006.

A. S. Eichner. *The Megacorp and Oligopoly: Micro Foundations of Macro Dynamics*. Cambridge University Press, 1976.

S. M. Fazzari and T. L. Mott. The investment theories of kalecki and keynes: An empirical study of firm data, 1970-1982. *Journal of Post Keynesian Economics*, 9(2):171–187, 1986-1987.

L. Gambacorta. How do banks set interest rates? *European Economic Review*, 52:792–819, 2008.

W. Godley and M. Lavoie. *Monetary Economics An Integrated Approach to Credit, Money, Income, Production and Wealth*. Palgrave MacMillan, New York, 2007.

A. Graziani. *The Monetary Theory of Production.* Cambridge, Cambridge University Press., 2003.

R. M. Haig. The concept of income - economic and legal aspects. In *The Federal Income Tax*, pages 1–21. New York: Columbia University Press, 1921.

M. Lavoie. *Foundations of Post-Keynesian Economic Analysis*. Aldershot, UK: Edward Elgar., 1992.

M. Lavoie. Circuit and coherent stock-flow accounting. In Richard Arena and Neri Salvadori, editors, *Money, Credit, and the Role of the State: essays in honour of Augusto Graziani*, pages 136–151. Ashgate: Aldershot, 2004.

M. Lavoie and W. Godley. Kaleckian models of growth in a coherent stock-flow monetary framework: A kaldorian view. *Journal of Post Keynesian Economics*, 24(2):277–311, 2001-2002.

E. Le Heron and T. Mouakil. A post-keynesian stock flow consistent model for dynamic analysis of monetary policy shock on banking behaviour. *Metroeconomica*, 59(3):405–440, 2008.

M. Messori. Credit and money in schumpeter's theory. In Richard Arena and Neri Salvadori, editors, *Money, Credit and the Role of the State. Essays in Honour of Augusto Graziani*. Ashgate: Aldershot, 2004.

R. Nelson and S. G. Winter. *An Evolutionary Theory of Economic Change*. Harvard University Press,, Cambridge, MA., 1982.

C. Perez. *Technological Revolutions and Financial Capital: The Dynamics of bubbles and Golden Ages*. Cheltenham, Elgar, 2002.

C. Perez. The double bubble at the turn of the century: technological roots and structural implications. *Cambridge Journal of Economics*, 33(4):779–805, 2009. doi: 10.1093/cje/bep028. URL http://cje.oxfordjournals.org/content/33/4/779.abstract.

C. Perez. Technological revolutions and techno-economic paradigms. *Cambridge Journal of Economics*, 34(1):185–202, 2010. doi: 10.1093/cje/bep051. URL http://cje.oxfordjournals.org/content/34/1/185.abstract.

J. Robinson. A further note. *The Review of Economic Studies*, 36(2):260–262, 1969.

R. J. Schiller. *Irrational Exuberance*. Princeton University Press, Princeton, US, 2000.

J. A. Schumpeter. *The Theory of Economic Development*. Cambridge, MA, Harvard University Press, 1934/1912.

J. A. Schumpeter. *Business Cycle. A Theoretical, Historical and Statistical Analysis of the Capitalist Process*. abridged edn, New York, McGraw Hill., 1964/1939.

H. C. Simons. *Personal Income Taxation: The Definition of Income as a Problem of Fiscal Policy*. Chicago, Il: Chicago University Press, 1938.

J. Steindl. *Maturity and stagnation in American capitalism*. Blackwell, 1952.

G. Zezza. Some simple, consistent models of the monetary circuit. Working paper 405, Levy Economics Institute, 2004. URL http://www.levyinstitute.org/pubs/wp405.pdf.

A TFM of model simple

	Wage earners	Capitalists	Consumption		Capital		Innovative		Bank		Σ
			Current	Capital	Current	Capital	Current	Capital	Current	Capital	
Consumption	$-C_w$	$-C_c$	$+C$								0
Traditional investment				$-I_{c,k}$	$+I_k$	$-I_{k,k}$					0
Innovative investment				$-I_{c,i}$		$-I_{k,i}$	$+I_i$	$-I_{i,i}$			0
Wages	$+WB$		$-W_c N_c$		$-W_k N_k$		$-W_i N_i$				0
Profits		$+FD$	$-F_c$	$+RE_c$	$-F_k$	$+RE_k$	$-F_i$	$+RE_i$	$-F_b$		0
Interests			$-r_{l,c,-1} L_{c,-1}$		$-r_{l,k,-1} L_{k,-1}$		$-r_{l,i,-1} L_{i,-1}$		$\sum r_{l,-1} L_{-1}$		0
Traditional capital				$-\Delta K_{c,k}$		$-\Delta K_{k,k}$		$-\Delta K_{i,k}$			$-\Delta K_k$
Innovative capital				$-\Delta K_{c,i}$		$-\Delta K_{k,i}$		$-\Delta K_{i,i}$			$-\Delta K_i$
Deposists	$-\Delta M_w$	$-\Delta M_c$		$-\Delta M_c$		$-\Delta M_k$				$+\Delta M$	0
Loans								$+\Delta L_i$		$-\Delta L$	0
Equities		$-\Sigma \Delta e.p_e$		$+\Delta e_c \cdot p_{c,e}$		$+\Delta e_k \cdot p_{k,e}$		$+\Delta e_i \cdot p_{i,e}$			0
Net Wealth		$+\Delta V_c$									$+\Delta V$
Σ	0	0	0	0	0	0	0	0	0	0	0

Table 6: Transaction Flow Matrix: Model with savings and equities.

B Notation for the simple model

B.1 Variables

Symbol	Description
N_x	Employment in sector $x \in \{c, k, i\}$
k_x	Traditional capital stock in sector $x \in \{c, k, i\}$
i_x	Innovative capital stock in sector $x \in \{c, k, i\}$
y_x	Output in sector $x \in \{c, k, i\}$
Y_x	Nominal income in sector $x \in \{c, k, i\}$
p_x	Price in sector $x \in \{c, k, i\}$
inv_x	Inventories stock in sector $x \in \{c, k, i\}$
s_x	Sales in sector $x \in \{c, k, i\}$
L_x	Loans requested in sector $x \in \{c, k, i\}$
F_x	Gross profits in sector $x \in \{c, k, i\}$
W	Wages
N	Total employment
$L_{k,k}$	Loans requested by traditional sector to buy traditional capital
$s_{x,y}$	Sales from capital producers $x \in \{k, i\}$ to sector $y \in \{c, k, i\}$
M_x	Cash holdings in sector $x \in \{c, k, i\}$
ϕ	Innovative mark-up applied on traditional capital prices
g_{yk}	Output growth desired by traditional good producers
χ	Share of traditional capital producers money holdings used to invest
κ	Share of traditional capital producers investments going to traditional capital
γ	Share of consumption good producers investments going to traditional capital
int_x	Interest paid by sector $x \in \{k, i\}$

B.2 Parameters

Symbol	Parameter	Value
l_k	Capital-output ratio of traditional technology	5
pr_k	Capital productivity of traditional technology	1.5
n	Capital life	20
ψ	Targeted market share when innovators enter the market	3%
τ	Targeted growth rate for innovators	5%
l_i	Capital-output ratio of traditional technology	5
pr_i	Capital productivity of traditional technology	1.65
α	Wage curve intercept	721.351
β	Wage curve slope	0.0289977
λ	Percentage of profits paid as interests	%
ξ	Investment parameter for traditional sector	1%

C Notation for the more comprehensive model

C.1 Variables

Symbol	Description
c_x	Real consumption for household sector $x \in \{w, c\}$
C_x	Nominal consumption for household sector $x \in \{w, c\}$
yd_x^e	Expected real disposable income for household sector $x \in \{w, c\}$
yd_x	Real disposable income for household sector $x \in \{w, c\}$
YD_x	Nominal disposable income for household sector $x \in \{w, c\}$
v_x	Real wealth for household sector $x \in \{w, c\}$
V_x	Nominal wealth for household sector $x \in \{w, c\}$
M_x	Cash holding for household sector $x \in \{w, c\}$
YP_c	Personal income for capitalist sector
CG	Capital gains for capitalist sector
V_{ec}	Capitalists wealth held as shares
V_c^e	Expected capitalists wealth
V_{ec}^e	Expected capitalists wealth held as shares
M_c^d	Desired cash holding for capitalists
YD_c^e	Expected nominal disposable income for capitalists
cg_x^e	Expected relative capital gains in sector $x \in \{c, k, i\}$
CG_x^e	Expected capital gains in sector $x \in \{c, k, i\}$
CG_x	Capital gains in sector $x \in \{c, k, i\}$
r_x^e	Expected return rates on equities in sector $x \in \{c, k, i\}$
FD_x^e	Expected distributed dividends in sector $x \in \{c, k, i\}$
FD_x	Dividends distributed in sector $x \in \{c, k, i\}$
W_x	Wages in sector $x \in \{c, k, i\}$
ω_x^T	Targeted real wages in sector $x \in \{c, k, i\}$
$\overline{pr_x}$	Average productivity in sector $x \in \{c, k, i\}$
N_x	Employment in sector $x \in \{c, k, i\}$
$N_{x,y}$	Employment in sector $x \in \{c, k, i\}$ using capital $y \in \{x, i\}$
N	Total employment
UC_x	Unit costs in sector $x \in \{c, k, i\}$
k_x	Traditional capital stock in sector $x \in \{c, k, i\}$
i_x	Innovative capital stock in sector $x \in \{c, k, i\}$
y_x	Output in sector $x \in \{c, k, i\}$
Y_x	Nominal income in sector $x \in \{c, k, i\}$
p_x	Price in sector $x \in \{c, k, i\}$
ϕ_x	Mark-up in sector $x \in \{c, k, i\}$
y_x^e	Expected output in sector $x \in \{c, k, i\}$
π_x	Inflation in sector $x \in \{c, k, i\}$
g_{yx}	Output growth in sector $x \in \{c, k, i\}$
rr_{lx}	Real interes rate in sector $x \in \{c, k, i\}$
λ_x	Leverage level in sector $x \in \{c, k, i\}$

Symbol	Description
u_x	Capacity utilisation in sector $x \in \{c, k, i\}$
q_x	Tobin's q in sector $x \in \{c, k, i\}$
I_x	Nominal investment in sector $x \in \{c, k, i\}$
F_x	Gross profits in sector $x \in \{c, k, i\}$
Ψ_x	Share of investment financed through equities emission in sector $x \in \{c, k, i\}$
e_x^s	Equities emitted in sector $x \in \{c, k, i\}$
e_x	Number of equities in sector $x \in \{c, k, i\}$
$p_{e,x}$	Price of equities in sector $x \in \{c, k, i\}$
L_x	Loans requested in sector $x \in \{c, k, i\}$
$cost_x$	Relative costs of capital good $x \in \{k, i\}$
$i_{y,x}$	Investment capital good $x \in \{k, i\}$ by sector $y \in \{c, k, i\}$
r_{lx}	Interes rate in sector $x \in \{c, k, i\}$
$\overline{r_x}$	Average net-of-interest return rate of capital in sector $x \in \{c, k, i\}$