# UNIVERSITY OF SIENA

Department of Economics and Statistics
Joint PhD Program in Economics of the Tuscan Universities
Scientific-disciplinary sector: SECS-P/01
XXXIII Cycle

Thesis submitted for the degree of Doctor of Philosophy in
ECONOMICS



# ESSAYS ON SECULAR STAGNATION IN THE USA

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Academic year 2020/2021

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# Preface and Introduction

Secular Stagnation, we have learned, is an economist's Rorschach test. It means different things to different people.

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B. J. Eichengreen (2015)

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The general rule is infallible, that, when by *increase of money, expensive habits of life, and taxes*, the price of labour comes to be advanced in a manufacturing and commercial country, more than in those of its commercial competitors, then that expensive nation will lose its commerce, and go to decay, if it doth not counterbalance the high price of labour, by the seasonable aid of mechanical inventions . . . *Nottingham, Leicester, Birmingham, Sheffield* &c. must long ago have given up all hopes of foreign commerce, if they had not been constantly counteracting the advancing price of manual labour, by adopting every ingenious improvement the human mind could invent.

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T. Bentley (1780)

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I first met *Secular Stagnation* on the columns of Project Syndicate in Fall 2018, when Prof. Summers and Prof. Stiglitz engaged in a debate on the ineffectiveness and insufficiency of monetary and fiscal stimuli set by US government to soothe the economy in the aftermath of the Great Recession. The observation of global mounting inequalities, climate changes and patchy de-industrialization all suggested me to delve into and take seriously this theory with a vaguely-apocalyptic taste into consideration, and my mind started believing that a real breakthrough in policy-making is necessary — hopefully sufficient — to divert mankind out of a long path of decadence.

As I ascertained quite soon, a tangle of different theories and beliefs holds back to the notion of Secular Stagnation. The concept was first introduced through the pioneering work by Alvin H. Hansen (1939) to describe the bleak picture in which the United States plunged after the

Great Depression of 1929; focusing on the high unemployment rate, Hansen identified Secular Stagnation with "sick recoveries which die in their infancy and depressions which feed on themselves and leave a hard and seemingly immovable core of unemployment". The doctrine blazed in the subsequent years but − as a flash in the pan − had largely dropped out of economics, especially once Hansen past away in 1975 (Backhouse and Boianovsky, 2016). However, that concept bloomed again in conjuction of the Great Recession in 2007: Prof. Summers (2014b)'s revival outlined a situation in which changes in the economic fundamentals might have brought about a shift in the natural balance between savings and investments, such that the natural rate of interest associated to full employment would have approached negative values. The macroeconomic outcome would then have featured scarce growth, under-utilization of capacity and financial instability.

As the first quotation above, *Secular Stagnation* is like the Rorschach test: different things for different people.  For example, Summers (2014b) tackles monetary and fiscal policy issues arising within the negative natural rate environment; Gordon (2015) and Ramey (2020) study the supply-side determinants of productivity growth and its relation with technological lulls, whereas Hein (2016) attributes Secular Stagnation to matters of Stagnation Policy, and so on. Accordingly, we move away from Summers's idea and focus on a particular stylized fact, the long-run tendency of productivity growth to fall since the early 1970s.

The dissertation analyzes the phenomenon with respect to the United States and consists of three essays.  The chapters are self-contained and can be read independently of one another, though the reader can find some reference to the previous paper in the subsequent one.  For this reason, we suggest to read the dissertation in an orderly manner.

The first chapter is entitled *"Does the Secular Stagnation hypothesis match with data?  Evidence from USA"*, and we take a historical view to see which characteristics the literature associates to Secular Stagnation are found in the data. The paper adds to the debate in four ways. Firstly, we focus our attention on US macroeconomic data about real GDP per capita, potential output, productivity measures and population since 1870, when possible.  The very simple setting allows us to grasp that the slow growth in real GDP per capita as in more recent times should not be interpreted as an evidence of Secular Stagnation; rather, it represents the return to the average growth rates experienced by the USA before the Golden Age of capitalism, 1950-1972. Secondly, it is apt to talk about Secular Stagnation in terms of productivity growth, since the decline is greater than any previous shortfall.  Thirdly, our findings cast some doubt on

Summers's hypothesis of negative natural rates, which suffers from heavy theoretical inconsistencies too; the careful analysis of data offers some evidence supporting Gordon's and Hein's stands. Moreover, this evidence shows that the use of the term *Secular Stagnation* in the literature is somewhat *misleading*, since it should concern a longer time span, possibly involving *more extended long runs*. Fourthly, the great heterogeneity of approaches implemented does not forbid complementarity or even convergence in policy implications to arise.

The second chapter, "*Secular Stagnation and innovation dynamics: An agent-based SFC model. Part I*", starts by noticing that the debate on Secular Stagnation paid little attention to the profound interplay between income distribution, innovation and productivity; in other terms, arguments lack of a *demand-side* perspective. The essay tackles that gap in the literature and sets Secular Stagnation into an agent-based computational economics (ACE) framework. We develop a model in the spirit of Dosi et al. (2010) and Caiani et al. (2016b). The model is complex, adaptive and structural in the sense of Tesfatsion (2006): *complex*, because the system is composed of interacting units; *adaptive*, since it involves environmental changes; and *structural*, because it builds on a representation of what agents do. In this context, *agents* are defined as an encapsulated set of data and behaviours representing an entity residing in a computationally constructed world. The model manages to replicate several well-established stylized facts of the literature. More precisely and with reference to the microeconomic level, firm's size is skewed and heavy-tailed distributed, and businesses are persistently heterogeneous in terms of productivity. Moreover, investment heterogeneity is an interesting outcome of the model. At the same time, the framework respects some empirical regularity of the macroeconomic world: a roller-coaster dynamics generates business-cycle fluctuations; the simulated time series for output and its component exhibit non-stationary properties; the unemployment rate and the investment series are more volatile than output and consumption, and cross-correlation patterns with respect to GDP are in tune with the literature.

The adoption of an agent-based perspective calls for justification. Some might ask, indeed, whether such a toolkit is really necessary or whether that modeling is able to exhibit insights *not visible* with standard methodologies, if any. We argue that, traditionally, economic agents have been modeled as rational optimizers with no role for the social context which they act upon. Moreover, such a Walrasian framework used to focus on allocation decisions and neither addressed − nor was meant to grapple with − how production, pricing and trade take actually place in real-world economies (Tesfatsion, 2006). ACE models observe instead economies

as *complex* systems, whereby a multitude of agents repeatedly interacts with each other and gives rise to the multi-faceted stylized facts observable at the macroeconomic level. Agents are therefore designed with autonomy and the ability of self-regulating, i.e. they *learn* (LeBaron and Tesfatsion, 2008).

We then scrutinize US capitalistic evolution of last fifty years and inspect the way the distribution of income between wages and profits can determine the rate of innovative activity and then further attainments in productivity. We consider major features of the US post-1972 economy like the progressive worsening of the functional distribution of income at the expense of the labour share and, on the other hand, the slower growth in R&D expenditure. We advance the idea that the continuous shrinkage of the labour share may have resulted in a smaller incentive to invest in R&D activity, entailing the evident decline in productivity performances that marks the US Secular Stagnation. The model in this chapter is none the less incomplete, since it does not deal with growth question but analyzes economic systems approaching and gravitating around a stationary state.

In the third chapter, "*Secular Stagnation and innovation dynamics: An agent-based SFC model. Part II*", we extend and complete the argument started with the second chapter. In other words, we develop an agent-based, stock-flow consistent model to analyze the nexus between income distribution and innovative search in determining economic growth. The model is still able to match a wide spectrum of stylized facts well in tune with the micro- and macroeconomic literature, such as endogenous and self-sustaining economic growth.

For what concerns to distributive policies and their relationship with innovation rates, theoretical policy implications do not change significantly from the second essay. However, they do change with respect to the role exerted by the interest rate. What we grasp as a side result is that the rate of interest has a non-linear and small effect upon innovation efforts and on the overall level of economic activity. More precisely, the very non-linearity in the R&D pattern comes out of the contrasting movement between the revenue and the cost components the R&D investment schedule is made of. On the one hand, the entrepreneurs increase consumption in absolute terms because more profits accrue to their pockets and their need to innovate rises; but on the other hand, they feel less afraid of the competitive pressure and reach a normal profit rate more easily, so their necessity to seek for labour-saving techniques looks reduced.

Last part of the paper does also involve econometrics. We want indeed to test some predictions from our model to the empirical ground. In so doing, we gather a panel of US manufacturing

industries with data on total R&D expenditures, hourly wage rates, productivity levels and values of shipments from 1958 to 2011. We carry out a twofold empirical analysis. First, we try to find empirical evidence of a positive and long-period linkage between R&D spending and its revenue and cost components. The latter are identified, respectively, with shipments and (productivity-adjusted) wages. We figure out that our series of interest are indeed cointegrated, i.e. there exists a long-run stochastic trend that joins them. We are then able to detect positive and long-lasting evidences, confirming the predictions of our ACE model. The robustness of the results are assessed through the different econometric procedures usually applied to datasets with both large $N$ and large $T$.

Second, we test the existence of a long-run relationship between R&D investments and the effective federal funds rate, on the one hand, and with the bank prime loan rate, on the other hand. We get the interesting result that no long-period well-established linkage exists between innovative effort and the interest rate, whatever measure we adopt for the latter. This means that any estimated regression of the former on the latter would provide us with spurious coefficients. Still, that does not conflict with our expectations.

All in all, the dissertation highlights the role played by the complex connections between income distribution and innovation in burdening the dynamics of productivity in the United States. However, we have to say that proposed rationales for Secular Stagnation are not the only valid explanations: non-technological motives, lower top marginal tax rates, increased low-skill immigration, rising trade with China and with other low-cost manufacturing countries or the rise of superstar firms are equally important. Eichengreen's Rorschach test means exactly that: paraphrasing Richard Goodwin's belief about economics, Secular Stagnation is "so impossible complex as to defy any completely satisfactory analysis". I promise to deal with these further issues in my future research.

Enjoy the reading!

# Chapter 1

# Does the Secular Stagnation hypothesis match with data? Evidence from USA

## 1.1 Introduction

The concept of Secular Stagnation has been introduced in the economic field by Hansen (1939) to describe the somber situation in which the US economy fell after the Great Depression in 1929. The author looked at the high unemployment as the principal problem for Americans and the expression of Secular Stagnation stood for "sick recoveries which die in their infancy and depressions which feed on themselves and leave a hard and seemingly immovable core of unemployment" (Hansen, 1939). Since then, the debate around Secular Stagnation tends to be raised whenever a strong recession takes place (Pagano and Sbracia, 2014), although the doctrine of Secular Stagnation had generally exited the economic discourse since the late Fifties, and almost disappearing from the macroeconomic research agenda (Backhouse and Boianovsky, 2016). To date, this expression has been re-evoked by Summers (2014a,b, 2015, 2018) to describe a situation in which changes in the economic fundamentals, after the Great Recession of 2007, might have caused a significant shift in the natural balance between savings and investments, lowering the equilibrium natural interest rate associated to full employment towards negative values. The outcome is a situation in which the achievement of adequate growth, capacity utilisation and financial stability appears increasingly difficult (Summers, 2014b).

Since then, many economists have dealt with this phenomenon, each of them underlining a peculiar aspect. In the present chapter, we decide to take a historical perspective in order to see

which characteristics associated to Secular Stagnation are found in the data. In particular, we focus our study on US macroeconomic data about real GDP per capita, potential output, productivity measures and population since 1870, when possible. This very simple setting allows us to prove that the slow growth in real GDP per capita as in more recent times should not be interpreted as an evidence of Secular Stagnation. Rather, it represents the return back to the average growth rates performed before the Golden Age period 1950-1972. It is apt to talk about Secular Stagnation in terms of labour and multifactor productivity growth, since their decline is greater than any previous shortfall. Our findings cast some doubt on Summers's hypothesis of negative natural rates, which suffers from theoretical inconsistencies as suggested by Di Bucchianico (2020) and Palley (2019). In contrast, a careful analysis of data offers some evidence supporting to Gordon (2014, 2015) and Hein (2015, 2016)'s Secular Stagnation hypotheses, among others. Moreover, this evidence shows that the use of the term "Secular Stagnation" in the literature is somewhat *misleading*, since it should concern a longer time span, possibly involving *more extended long runs*. Finally, we trace out a complementarity or even convergence to what policymakers should do to get away from this trap, albeit the great heterogeneity in the approaches often used.

The paper is organised as follows: Section II presents our empirical findings that help give a proper definition for Secular Stagnation; Section III looks at Secular Stagnation through the lens of the Great Recession, as in Summers (2014a,b) and Eggertsson et al. (2019); Section IV points to the supply-side determinants of the productivity slowdown in growth while Section V deals with its demand-side causes. Both Section IV and V frame Secular Stagnation in terms of productivity growth. Section VI provides policy implications while the last Section concludes and paves the floor for next chapters.

## 1.2   Secular Stagnation since the late nineteenth century

The concept of Secular Stagnation, as pointed out above, has been introduced in the economic field by Hansen (1939) to describe the somber situation in which the US economy fell after the Great Depression in 1929. The author looked at the high unemployment as the principal problem for Americans. Hansen believed that the events occurred in the first quarter of the twentieth century constituted a profound structural change not smaller than the one pro-

voked by the Industrial Revolution.[1] In this frame, he stressed three main points as the *causae causantes* of this stagnating growth process: a drastic decline in the rate of population growth, changes in the character of technological innovations and the availability of new territories. On the one hand, population growth, an increasing speed of technological innovation and colonial expansion in the past, with the conquest of new territories, the appropriation of the natural resources and the creation of new markets, fueled industrial development in many Western countries. On the other hand, population decline, a slowing down in the rate of technological innovation and the lack of new territories had a negative impact on the economies, causing a downturn.Policymakers should then have prompted a strong public investment in human and natural resources along with a gradual lowering of tax rates in order to soothe households and to strengthen their consumption expenditures. Of course, Hansen wrote the paper before World War II, the Golden-Age growth and all the subsequent events the humankind witnessed so far, the evolution undergone by the role of governments in most economic systems included. Moreover, Hansen had claimed since the Sixties that his notion of Secular Stagnation was another name for Keynesian underemployment equilibrium, being both problems about the difficulty from matching savings and investments (Backhouse and Boianovsky, 2016). Nevertheless, as claimed by Summers (2015), such changes do not imply that Secular Stagnation is just an old-fashioned and implausible ghost.

Since several economists have analysed the phenomenon adopting a variety of different perspectives once Hansen (1939) first used the concept, it is hard to find evidence of Secular Stagnation by simply looking at a unique macroeconomic indicator. For what concerns our analysis, we define Secular Stagnation as the tendency to the long-term slowdown in the growth rates of labour and total factor productivities, along with a decreasing potential output growth and a return to pre-1950 average growth rates of actual GDP, which starts in the early Seventies and reaches the trough with the Great Recession in 2007.[2] What is going on shows that *semantics* matters. As we will see below, the term *stagnation* implies the idleness of the economic activity relative to some historical benchmark, usually represented by the preceding years. However,

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[1]"He saw the concept as rooted in J. S. Mill's notion of the stationary state, suggesting that the term "mature economy" described Mill's formulation of the stationary state is a low-investment but high-consumption economy. However, unlike Mill's stationary state, Hansen's secular stagnation featured *chronicle unemployment*" (Backhouse and Boianovsky, 2016).

[2]Potential output is defined as the real GDP an economy can produce when its available resources are fully employed. Although a large body of literature consistently points that potential output is endogenous to actual output dynamics, entering such a debate is beyond our scope. The reader can refer to Fatás and Summers (2018) as an interesting reading on the topic.

since we consider a very long time horizon − more than a century − the word *secular* does not imply a *single* long run, but *more long runs*. This is a crucial point within the debate around Secular Stagnation.

As previously stated, this debate tends to be raised whenever a strong recession takes place. Moreover, a historical perspective suggests that current performances in GDP per capita growth rates are not different from what the capitalistic system experienced in the nineteenth century or in the first half of the twentieth. However, several studies disregard the pattern followed by productivity growth in last 150 years and therefore, looking at Secular Stagnation mostly as a productivity issue, we believe that the following questions deserve attention: is Secular Stagnation a fact? Is the slow growth since the early 1970s just a return to average performances similar to what happened to real GDP per capita after the exception of the Golden Age, or has it got any special feature?

In order to answer such a complex question, it is necessary to clarify why we prefer focusing on labour and multifactor productivity growth and why not solely on real GDP per capita. Neoclassical wisdom in particular believes that labour productivity and TFP are both as the key drivers of economic growth, changes in living standards and as a measure of international competitiveness and efficiency. By contrast, real GDP per capita is more volatile and very pro-cyclical, making its analysis less reliable.

We prefer restricting the analysis to the US using data from 1870 onward, whenever available. The reason is twofold: firstly, the literature on Secular Stagnation focuses mainly on the American economy and, secondly, the USA are one of the remaining superpowers and the economic science has identified them as the world's technology frontier since the early twentieth century (Pagano and Sbracia, 2014). Secular Stagnation began in the early Seventies, which were characterized by a slowing down of productivity growth.[3]

It is worth dividing the analysis of the results in two parts. The first part presents productivity statistics in Tabs. A.1 and A.2, as well as in Figs. A.1 to A.4. The second part focuses on output and population statistics, as reported on Tab. A.3 and graphed in Figs. A.5 and A.6.[4]

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[3]In this framework, the slight increase in the productivity growth rate which characterized the Nineties was determined by a short-run economic cycle which did not affect the long-run negative trend of productivity growth, but only served to conceal it.

[4]Since data contains both the trend and the cyclical components, we smooth the time series with the Hodrick-Prescott filter in order to capture the trend component and to focus the study on it. Nevertheless, we must recognize that thinking the cyclical and the trend components as *additive* is a very simplifying hypothesis.

The slowdown in growth performances during the post-Golden Age period did not simply represent a return back to the pre-Golden Age period. What makes the Secular Stagnation hypothesis consistent with data is the strong negative trend followed by productivity. For simplicity, we shall start by looking at the labour productivity pattern, with the aid of Tab. A.1, Figs. A.1 and A.2. The time trend has a negative sign and is statistically significant, although small in absolute value, from 1889 through 2017. This means that there has been a slow and steady decline in labour productivity growth over the period of interest. However, Figs. A.1 and A.2 show that such decline starts with the end of the Golden Age. If separate regressions are performed using data from 1889 through 1940, and from 1950 to 2017 (respectively), we find that the growth in labour productivity is *trendless* and slightly above 2% before World War II (1889-1940), while the second half of the $XX^{th}$ century is characterized by a consistently negative trend. Despite the great volatility of the actual growth rate, it is evident that the steady decline in labour productivity begins at the end of the Golden Age. Time only strengthens this trend reversion, as confirmed by the structural break in 1971. The rate of growth of labour productivity exhibits a timid recovery in the Nineties with another structural break in 1993, before starting a new and long-lasting collapse in the aftermath of the 2007 crisis.

For what concerns the multifactor productivity growth, we compare different data, in the line of Gordon (2010). Fig. A.3 plots our estimates on total factor productivity based on the accounting exercise which does not consider the composition adjustments concerning the aggregation of different components of capital and labour inputs.[5] These preliminary estimates are computed from 1889 to 2018. When it comes to the Post-Word War II period, however, we prefer using adjusted estimates provided by the Bureau of Labor Statistics, which allow for a more detailed analysis.

Considering the non-adjusted estimates, the results tend to confirm what Gordon (2010) obtained. In particular, we see that the period 1920-1950 benefits from the highest growth in TFP with a rate strictly above 2%, as the result of fifty years of continuous growth. In contrast, none of the following years exhibits a growth rate of productivity exceeding 2%. Moreover, structural breaks between 1968 and 1970 lead to further progressively smaller rates of productivity

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[5]In other words, we do not take into account the differences between ICT and non-ICT capital, and between skilled and unskilled workers. We instead computed TFP as the Solow residual from a standard Cobb-Douglas aggregate production function.

growth.[6]

The official BLS measures are in lines with our preliminary results, with the post-Golden Age itself representing a structural break followed by a plunge in TFP (Tab. A.2 and Fig. A.3).[7]

The second slot concerns some data about the growth rates in real GDP per capita, potential output and population. As can be see from Tab. A.3 and Fig. A.5, the actual growth path in real GDP per capita is almost trendless since the late nineteenth century. In addition to this, we can interpret its hump and subsequent decrease after the Golden Age period as the return back its average growth before the years represented by the Golden Age of capitalism; within this framework, it appears that Golden-Age years were somehow peculiar, characterized by a more sustained growth of the social product if compared to either preceding periods or subsequent decades.[8] Concerning potential output, the lack of historical data does enable us to say neither that its continuous decline in growth represents a return back to average pre-Golden Age performances nor that it is a new feature. Hence, it cannot be a support for our claim as well as for GDP per capita. We limit ourselves to back up a significant decreasing pattern in its growth rates.

To complete the second slot of statistics, we should have a glance on some demographic dynamics. Hansen (1939) first, Gordon (2014, 2015) and Summers (2014a,b, 2015) later, believe that declines in US population growth are one of the major determinants for Secular Stagnation. Data on Tab. A.3 and the picture drawn in Fig. A.6 show a plunge in population growth from 1870 until the end of World War II. The temporary leap in the growth rate of population during the Golden Age − the so-called *baby-boom generation*− has been totally offset by the clear-cut decrease of the last decades. Some could ask how a trendless growth in GDP per capita can coexist with decreasing productivity growth. The decomposition presented in (1.1) sheds light on that issue. On the left-hand side, we have the growth rate of GDP per capita; on the right-hand side, we see the former as the result of changes in labour productivity and per capita hours worked. The increasing number of working women and the entrance of the baby boomers into the labour market from 1965 through 1990 pushed per capita hours upward, but

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[6]As for the previous measures, the end of the second millennium and the onset of the third represent a temporary relaunch (the growth is 1.8 percent on average), but then the long-term decline reaches the bottom in the following years. The pattern is confirmed also by the structural breaks occurred in 1970, 1992 and 2009, respectively.

[7]TFP grows 1.7% on average during 1950-1972, then it collapses to one-third of that value in 1972-96 *only*. This growth rate doubles in the subsequent years (1.23 percent) but reaches the bottom in the post-2007 decade, that is 0.53 percent *only*.

[8]A full and exhaustive analysis of the rationales behind the Golden Age of capitalism is Armstrong *et al.* (1991).

the same years saw a decrease in labour productivity.[9]

$$\Delta ln \left( \frac{GDP}{Population} \right) = \Delta ln \left( \frac{GDP}{Hours} \right) + \Delta ln \left( \frac{Hours}{Population} \right) \tag{1.1}$$

It is worth spending a few words on the temporary recovery which marked the second half of the 1990s and lasted until the early 2000s.[10] As widely recognised in the literature, such a productivity upsurge is due to the expansion and diffusion of information technologies, from computers to software and communications equipment. On the one hand, TFP can be divided between growth in the ICT sector and growth in the non-ICT economy. On the other hand, ICT benefits can be traced out in the way capital deepening consists of more intensive application of ICT capital (Jorgenson et al., 2008). Before 1995 the contribution of ICTs to output and labour productivity growth is small. In particular, labour productivity grows 2.14 percent on average during 1959-2006, with 55% of such growth attributable to factors other than information technologies. On the contrary, in the Nineties important developments in information technologies lead to a substantial increase in the share of productivity growth attributed to the ICT sector, which soars from 43% in the period 1973-95 to 59% between 1995 and 2000. Nevertheless, the beginning of the $XXI^{st}$ century witnesses a decline in the contribution of ICT in productivity growth: the average labour productivity growth is almost constant but productivity growth is attributable in the greater part to capital deepening and TFP than to information technologies.[11]

To recap, since the early Seventies, the most advanced economy has experienced a slowdown in both labour and multifactor productivity growth. Compared to a century ago, the definition of Secular Stagnation does not imply a *simple* or *single* long run, but one more extended long run or even *more long runs*. This represents a crucial point. Such a definition of Secular Stagnation has two implications. Firstly, the years analyzed by Hansen (1939) did not seem

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[9]Ramey (2020) provides robustness to our results above. For what concerns per capita hours worked, she notices that they rose from 1975 to 2020, owing to the entry of the baby boomers into the labour force and rising female participation rates. Moreover, although the employment-population ratio exhibits a decline since the onset of the third millennium because of the aging of the baby boomers, that series displays a recovery since 2010, though not to the levels of the Nineties. The upward trend in the employment-population ratio since the 1930s looks still in place.

[10]Check Tab. A.4, which refers as to Jorgenson et al. (2008). The reader will notice that our computations are somewhat different from those in Tab. A.4, although they exhibit the same qualitative pattern. The reason lies in the different methods implemented to compute TFP growth, especially in the separation between skilled and unskilled workers, ICT and non-ICT capital, and the filter adopted to clean the time series from their cyclical components.

[11]Anyway, this does not render the contribution of ICT capital to growth negligible.

periods characterized by Secular Stagnation. The growth in GDP per capita, labour productivity and TFP were in fact *constant* or slightly increasing in the case of total factor productivity. Although population growth has indeed been slowing down, that would soon have changed with the baby-boom generation. Pagano and Sbracia (2014) and Ramey (2020) support our claim. The assertion that the progress in electricity and in the car industry were over well before the late 1930s is indeed false: the electrification of cities took place precisely after World War I. Secondly, although the US car industry did experience a crisis, it was not widespread. Such industry spread on the contrary to other countries.[12] In short, Hansen underestimated the potential of what technologies were already known in his time. The reason of this misinterpretation lies in the fact that the arrival of a revolutionary technology may be associated to negative events such as stock market crashes or productivity slowdowns, due to waves of reorganization (Ramey, 2020). Because of these counter-intuitive effects, technological revolutions might not be grasped immediately. This probably led Hansen not to recognize that the period he characterized by Secular Stagnation was actually "the most innovative decade of the 20$^{th}$ Century" (Ramey, 2020).[13]

This last statement explains why the long-run decrease in productivity growth comes to a halt in the late 1990s. The development of information technology emerges as the driving force behind the growth in labour and multifactor productivity in the mid-1990s, while they lose ground after 2000 to the benefit of capital deepening and TFP outside the ICT sector (Jorgenson et al., 2008).

These findings raise a further question: how does our definition of Secular Stagnation contribute to the debate on the topic? In other words, the question discussed below is how the Secular Stagnation hypothesis and the related policy implications developed in recent times meet the qualitative and quantitative evidence presented above. We begin with the natural rate view as promoted by Summers (2014a,b, 2015) and Eggertsson et al. (2019), which however considers Secular Stagnation as a trap begun with the meltdown in 2007. More coherent approaches on the productivity slowdown in growth follow.

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[12]A third inattention concerns the possibility that television broadcasting would have begun to replace radio in nearly all Western countries, whose process started during the early Thirties truly.

[13]The huge unemployment he underscored was due to a heavy but *cyclical* crisis.

## 1.3 Secular Stagnation through the lens of the Great Recession

The stream of literature considering the natural interest rate as the key factor for understanding Secular Stagnation is quite homogeneous and we are going to analyze Summers (2014a,b, 2015) and Eggertsson et al. (2019) as major contributions to the topic.[14] This framework focuses on persistent gaps between actual and potential growth in GDP. During his famous speech at the NABE Policy Conference in 2013, Larry Summers suggested that changes in the economic fundamentals, as consequences of the Great Recession, might have caused a significant shift in the natural balance between savings and investments, lowering the equilibrium natural rate associated to full employment towards negative values, and triggering a process in which the achievement of adequate growth, capacity utilisation and financial stability would be, at best, hard (Summers, 2014b).[15]

Why did the natural rate become negative? Summers (2014b) traces out different causes through the loanable funds theory and the changes which would have occurred either on the demand or on the supply sides. On the *demand side*, three main factors may have shifted the demand schedule for savings − the investment curve − to the left. Firstly, the deleveraging process which followed the strong leverage antecedent to the financial crisis of 2007. Secondly, a structural change in the economic system due to the progressive rise of technological companies like Google, Amazon or Facebook. These multinationals all achieved very high market values but they need not much capital investment, especially if compared to others. Thirdly, the fall in the growth rate of population reduced the demand for capital stock and housing finance, while at the same time it increased the supply of funds through capital funded pension systems.

On the *supply side*, along with the adverse effects associated with population dynamics, Summers points out that since the Eighties we are witnessing a progressive rise in top incomes and wealth shares at the expense of bottom incomes in nearly all countries, causing a higher *average* propensity to save in the economy.[16] Finally, rising retained earnings and tighter regulations

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[14]In what follows, the natural rate of interest is the Wicksellian one, defined as the rate "at which *the demand for loan capital and the supply of savings* exactly agree, and which more or less corresponds to the expected yield on the newly created capital" (Wicksell and Claseen, 1935); italics in original.

[15]The idea of negative Wicksellian natural rate is not new in economics: Klein (1947) already dreaded the possibility in a discussion with Pigou about Hansen's work. More on that in Backhouse and Boianovsky (2016).

[16]The debate on the increasing income and wealth inequalities since 1980s was risen by Piketty (2014, 2015), who was able to collect a very large historical dataset on national incomes and wealth, covering three centuries across several countries. Fig. A.7 and A.8 track their evolution in the USA over time. The analysis reported on a positive relation between wealth inequality and the difference between $r$ and $g$, where the former is the rate of return on capital while the latter is the economy's growth rate. In other words, "a higher gap between $r$ and $g$ works as an amplifier mechanism for wealth inequality" (Piketty, 2015). In contrast, the same term $r − g$ is not a helpful tool to discuss about the rising inequality of labour incomes: we will come back to this issue as soon as we deal with Gordon's Secular Stagnation.

for financial firms shifted to the right the supply curve for loanable funds. The upshot may be a *negative* equilibrium natural rate of interest. The presence of a negative natural rate renders the Central Bank's monetary policy ineffective, which explains the Zero Lower Bound on nominal rates and low inflation rates experienced nowadays.[17]

Summers's view is not exempt from criticism, however. The theoretical admissibility of a (negative) natural rate within the neoclassical framework has been challenged by Di Bucchianico (2020) and Palley (2019). We can appreciate the former criticism through a simple economy in which a single good is produced by means of capital and labour. For simplicity, we set inter-temporal optimizing behaviour aside and assume entrepreneurs maximize their profits. According to Summers, and regardless of any Zero Lower Bound influence, the entrepreneurs adopt very high capital-labour ratio techniques that the economy would reach a equilibrium position in correspondence of a negative marginal product for capital. The formal existence of a negative marginal product of capital can be investigated through the adoption of an aggregate production function of the type:

$$y = Ak^{\alpha}$$

$$f_K = A\alpha k^{\alpha-1} \tag{1.2}$$

in which $y$ is output per unit of labour, $A$ the Solow residual, $\alpha$ the capital share in output, $k$ the capital-labour ratio and $f_K$ the marginal productivity of capital. We notice that as long as the capital-labour ratio increases, the marginal product of capital keeps decreasing without approaching any negative value.[18] The economic intuition behind that and *within* the neoclassical framework is threefold. First, there always exists a positive rate of interest such that the demand for capital per capita is able to employ all the amount of savings supplied. Second, the very idea of a negative rate contradicts the neoclassical principle of profit maximization: why should rational entrepreneurs employ an amount of capital which gives back a negative marginal product? Clearly, they should not, since they can always use capital such that the marginal product would be, at most, null. And third, a negative rate would clash with the principle-of-exhaustion theorem. Di Bucchianico (2020) shows that the equalisation between

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[17]Summers' analysis helps understand why real rates and actual output dropped in recent times, but not why potential output fell. About this, Summers advocates on the theory of hysteresis and theorizes an "Inverse Say's Law", according to which lack of demand creates lack of supply. Actually, this expression might be misleading. Basically, the principle of effective demand is at work.

[18]In this case, the non-existence of a negative rate does depend neither on the functional form of the aggregate production function nor on the lack of capital depreciation.

natural rate and profit rate entails a labour share greater than the net product. Even if a negative rate were plausible, capitalists would still invest in real capital so to get a negative profit rate. In this setting, capital is *abundant* and not *scarce*; at the same time, labour would be *scarce* and not *abundant*: how can therefore Summers apply this theory to explain a persistently high involuntary unemployment?

Drawing upon Summers' insights, Eggertsson et al. (2019) provides a more general setting for the natural rate hypothesis. They develop an analytic overlapping generation model whose steady-state is characterized by a negative full-employment real interest rate.[19] The model can be split in two main parts: the endowment economy and the production economy. For simplicity we focus on the endowment economy, since the same properties and results hold when they introduce the production side in their model. In particular, the authors suppose that each representative household lives for three periods: when the individual is young, she does not receive income but she borrows from adult consumers; the adults receive an income and they consume part of it, while saving the residual for the old age; finally, the old men are given an income and consume all their endowment.

For our purpose, the most important characteristic of the model is its ability to show how the drop in productivity growth rates since the 1970s triggered the process of Secular Stagnation through negative natural rates. Indeed, the utility maximization and the equilibrium between the demand for and the supply of loans yield the following equilibrium interest rate:

$$1 + r_t = \frac{1+\beta}{\beta} \frac{(1+g_t) D_t}{Y_t^m - D_{t-1}} + \frac{1}{\beta} \frac{Y_{t-1}^o}{Y_t^m - D_{t-1}} \tag{1.3}$$

in which $r$, $\beta$, $g$, $D$, $Y^m$ and $Y^o$ represent, respectively, the equilibrium natural rate, the intertemporal discount factor, the population growth rate, the maximum level of debt a household can borrow, and the incomes of middle-aged and elderly people. For an appropriate combination of the parameters, Secular Stagnation arises as a result of a negative natural rate $r$.[20] Interestingly, setting the income levels as proportional to productivity $A$, say $Y_t = A_t \tilde{Y}$, a strong reduction in productivity pushes the natural rate further down. In particular, through the lens of the loanable funds theory on which the model builds upon, the decrease in productivity

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[19]The formalization involves a closed economy. Anyway, the results hold in the open economy as well. For details, check Eggertsson et al. (2016).

[20]"[I]n contrast to the standard representative agent model, the real interest rate will now, in general, depend on a host of factors in addition to the discount factor: the income profile over the life cycle, the debt limit, and population growth all influence the real interest rate" (Eggertsson et al., 2019). For instance, the strong deleveraging post-2007 helps reduce the first term on the right-hand-side of (1.3) as in Summers (2014a,b)

growth increases the supply of savings, since households face lower expected future incomes. On the other hand, lower productivity makes the borrowing constraint more binding for the young, pushing down their demand for savings.

The results from the endowment economy hold after the production side of the economy is introduced. What the authors discern from the complete model is that monetary policy can be ineffective, and they provide a plausible explanation of why actual monetary policies have been relatively ineffective in many contemporary economies: in order to escape from a Secular Stagnation equilibrium, monetary authorities need to increase the inflation target a lot, while for sufficiently negative real rates, a simple increase in the target does not restore the full employment equilibrium.[21] In contrast, the fiscal policy might be more effective in bringing the economy back to the full-employment path.[22] Overall, their model suggests that fiscal policy might help restore the economic resources to their full-employment levels.

However, Di Bucchianico's criticism holds in this framework too. The introduction of capital and monopolistic competition in the model developed by Eggertsson et al. (2019) gives rise indeed to an economy in which "the return on capital is high enough that it produces returns in excess of investment in the steady state, while the interest rate remains negative" (Eggertsson et al., 2019). The discrepancy arises because the rental rate of capital is the ratio between the corresponding marginal productivity and the mark-up, thus with positive mark-ups in equilibrium "there can be *social* returns to capital (even net of depreciation) while the rental rate (net of depreciation) and hence the real interest rate is negative" (Eggertsson et al., 2019). But, if the marginal productivity of capital is nonnegative — as we know from the standard Cobb-Douglas production function with constant returns to scale — while the natural rate of interest negative, the two values cannot coincide and thus this is not a steady-state solution at all. The steady-state condition requires in fact each agent be indifferent in yielding bonds and physical capital, since they provide the same rate of return. But in this case households would prefer selling their bonds — whose return is negative — and buying real capital — whose return is null. In the end, the true steady state will exhibit a *non-negative* uniform natural rate.

Before conclusion, it is worth spending a few words on a more general critique on the *ZLB economics* we have just treated. Palley (2019) develops an interesting criticism that runs as fol-

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[21]The simulations of the model show that small rises in the inflation target lead to a unique locally determined equilibrium, characterized by Secular Stagnation. In contrast, higher inflation targets give access to two possible locally determined equilibria: as prior, the one with Secular Stagnation and another constituted by full employment of labour.

[22]Extending the model to include taxes and government debt and spending, they find that an increase in public debt will rise the natural interest rate and this increase is expected to be permanent to the extent that a public deficit incurred today will not translate into greater taxes tomorrow.

lows: even though negative nominal rates were possible, monetary policy may be unable to remedy demand shortage and restore full employment. The reason lies in the investment unresponsiveness to lower interest rates when returns to investments are dominated by the returns on non-reproducible assets − fiat money, land, intellectual property right and so on. Lower interest rates can add further problems if savings rise in response to negative rates. In this way, there might be no natural rate of interest associated to full employment in a neoclassical framework too.

In conclusion, the Secular Stagnation hypothesis through the lens of the Great Recession offers a framework in which Secular Stagnation arises as due to productivity and GDP slowdown in growth. However, the theoretical and crucial assumption on negative natural rates associated to full employment of labour suffers from serious inconsistencies which undermine the solidity of the overall apparatus.[23] The following sections provide two different but more coherent approaches which find supply-side and demand-side long-run causes of Secular Stagnation which are not based on the cyclical after-effects of the Great Recession.

## 1.4   Productivity slowdown: supply-side determinants

The contributions we are going to examine in this section develop and analyze the supply-side long-run determinants of economic growth and disregard cyclical influences. The authors claim that the strong slowdown in productivity growth and the GDP return back to average pre-Golden Age growth rates were due to some *headwinds.* In this perspective, the low-growth economy becomes the *new normal*, until some exogenous event boosts supply-side growth.[24]

Gordon (2012) highlights the first important headwind and calls it "the demographic dividend". It took place in the twenty-five years between 1965 and 1990, which saw an increasing number of women finding employment, together with the children of the baby boom. This influx of workers increased the ratio between working hours and population, while increas-

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[23]Last point on Di Bucchianico (2020): the author develops his critique on the theoretical admissibility of a negative natural rate within the Euler equation and the Ramsey model frameworks too; in other terms, his results are not circumscribed to the Wicksellian frame as in Summers (2014b). Additionally, he reminds that the existence of a natural rate of interest is doubtful itself, once the results of the Cambridge capital controversy are taken into account. However, we do not consider the implications of that controversy over the Secular Stagnation hypothesis since it is beyond the scope of the present paper. Moreover, it is interesting to note that Klein (1947) already believed that negative natural rates would have been hard to justify in a Ramsey world.

[24]So the approach neglects the possibility of the principle of effective demand to work in the long run too. An intriguing exception is Gordon (2017) that we discuss below.

ing real GDP per capita more than labour productivity, by definition. However, we are now experiencing the opposite phenomenon, with the progressive retirement of the baby-boomers, diminishing population growth rates and the drop in hours per worker. Whenever the participation rate and hours per worker go down, output per capita grows less than productivity, again by definition (Gordon, 2012).[25]

The second headwind is outlined extensively by Gordon (2010, 2012, 2015, 2017) and Eichengreen (2015), and it concerns the revolution started by digital electronics, which ran out of steam, with the electronics facing diminishing returns. A scrupulous analysis of data leads Gordon to establish that, since the Seventies, labour productivity and TFP growth has slackened compared to the years from 1920 to 1972. Furthermore, although we observe a slow climb in productivity and the benefits enjoyed by many economic systems in the Nineties, production methods changed little throughout the period Gordon (2015). Gordon points to three main examples supporting his thesis: office, retailing and business dynamics implemented in short time all the innovations from digitalization, but once the transition was completed, the productivity improvements stopped. This view results complementary to what Eichengreen (2015) defines the *range of applicability*. The latter pertains to the number of productive sectors into which new innovations might be integrated. From this perspective, the computer revolution of last fifty years had a relatively smaller impact than preceding innovations like electricity during the Second Industrial Revolution. Computers found applications mainly in the financial sector, as well as in wholesale and retail trade. [26]

Even though the second headwind might provide a plausible explanation for the decline in productivity growth as noted in Section II, criticism comes from Crafts (2002), Eichengreen (2015) himself and Ramey (2020). Crafts (2002) carries out a growth accounting exercise to compare the growth contribution of ICT and the related TFP spillovers to previous breakthroughs such as steam engine and electricity. The study suggests that "even before the mid-1990s, ICT had a much bigger impact on growth than steam and at least a similar impact to that of electricity in a similar early phase" (Crafts, 2002). Therefore, when adopting a historical perspective it would seem quite ambitious to expect a contribution of greater magnitude and whose effects endured

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[25]Acemoglu and Restrepo (2017) find no negative relation between aging and GDP per capita growth; in contrast, countries undergoing more rapid demographic changes are more likely to adopt new automation technologies as robots, so bringing productivity improvements. Ramey (2020) shows moreover that the civilian employment-population ratio has in fact displayed a recovery since 2010.

[26]Eichengreen (2015) underscores the general decline in the relative price of investment goods. The cheapening of personal computers makes the point: carrying out investment projects in ICT commits ever smaller share of GDP, ending up with the decrease in the investment share across the economy, *ceteris paribus*.

for much longer than those of the ICT revolution.[27] Furthermore Eichengreen (2015) himself advances a thesis running counter to Gordon's, called the *range of adaptation*. It concerns to the wide re-organisation of productive processes necessary to introduce innovations and to trigger greater rates of growth for either GDP and productivity: the bigger the range of adaptation, the longer the time to re-organise the productive system. The range of adaptation hypothesis may shed light, for instance, on why some innovations did beget huge impacts in a short time − steam engine − and others − electricity and internal combustion engine − several years after their discovery. The IT revolution needs time to exhibit all of its potential to fueling economic growth. Yet, stagnation could be just *temporary* and not *secular* any more.[28]

The third headwind refers to inequality. Figs. A.7 and A.8 show that in the Eighties there is a jump in the share of total income and wealth going to the top 1%, accompanied by the corresponding plummeting of the share accrued to the bottom 50%. In other terms, the income and the wealth going to the top 1% of the population is steadily increasing and this trend shows no sign of reversing, while the share going to percentiles below 50 percent is stagnating.[29] According to Gordon, the increasing inequality has a negative impact on the accumulation of human capital. The problem of education is in fact worrisome at college levels, where students are ever more burdened by the loans they make to pay their college tuition.[30]

To conclude with arguments *à la* Gordon, there are some curious sentences in Gordon (2017) book that seem to contradict the main thesis: while discussing the *Great Leap Forward* of the US labour productivity, occurred in the middle-decades of the 1900s, he argued that the main determinants were the New Deal and strong labour unions, that hoisted real wages. Productivity leaped because higher real wages forced firms to introduce labour-saving techniques. As Nikiforos (2020) notices, this explanation contradicts the neoclassical theory of distribution and the

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[27]We must nonetheless point to as the results obtained by Crafts (2002) should be taken with care, since there are important lacunae in the available information.

[28]While in agreement with Gordon, Ramey (2020) argues that "the nature of technological change naturally leads to medium-run variations in productivity growth, and long periods of sluggish growth are a natural outcome of the process that drives technological change". She therefore calls this period as *technological lull*, so to remark its temporary state. However, this is an old argument by David (2007) that was used to explain the low TFP growth of the 1980s and early 1990s. Whether the same argument still holds today, after almost 40 years of "re-organization", is something to be examined with great care.

[29]The analysis of inequality must consider also the path covered by the wage share, hence the functional distribution of income. Since Gordon did not talk about it, we will deal with this topic later in the paper, when we analyze some theories that directly cope with it.

[30]Directly quoting Gordon (2015): "Americans owe $1.2 trillion in college debt, and an increased fraction of the next generation may choose not to complete college as they are priced out of the market for higher education". Note how this view is shared, among the others, by Piketty (2014, 2015).

main thesis according to which productivity growth is uniquely supply-side driven as above.[31]

There is actually another important headwind which the literature did not investigate in connection to Secular Stagnation, but only to the Great Recession. It is the progressive *monopolisation* of knowledge, as outlined in Pagano (2014). This contribution helps explain the ephemeral surge in productivity growth occurred in the Nineties, as described in Section II. The author focuses on the *intellectual* monopoly capitalism, that is the inclusion of knowledge as the most important capital asset of the firm. From a historical view, we can distinguish two stages: the first is denoted by the *roaring nineties*, during which the World Trade Organization is established. The concomitant creation of a legal monopoly of patents and the cheap availability of new technologies opened new ways for investments and, in that moment, the possibility of privatizing knowledge was a strong incentive for the enterprises to carry out further and further investments. This was crucial to the recovery in productivity growth in the mid-1990s. Nevertheless, this phase of technological developments came to an end at the turn of the $XXI^{st}$ century, as our data confirms. The upshot of this process entails either virtuous or vicious cycles: for individuals owning the intellectual property rights, the financialisation provides incentives to develop new knowledge and then new patents, hence the cycle is virtuous; in contrast, the cycle results vicious for many others, because their lack of intellectual property rights discourages the acquisition of skills and the lack of skills discourages the acquisition of intellectual property rights (Pagano, 2014).[32]

To summarize, this first set of contributions around Secular Stagnation provides a coherent supply-side framework for the slowdown in productivity growth and the return to pre-Golden Age GDP per capita growth rates we saw in Section II. However, they look at the supply side of the economy *only*, with the intruiging exception represented by Gordon (2017). The next section considers the other side of the coin, that is the demand-side dynamics which weakened the productivity and GDP per capita growth. Secular Stagnation is set within the framework of Stagnation Policy.

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[31]Still in the same book, Gordon points out that government deficit spending during WWII brought about an increase in financial assets that allowed a permanent surge of consumption patterns after the war. That again contradicts many neoclassical arguments on the relation between economic growth and public deficit spending.

[32]Moreover, the current monopolisation of knowledge works at a global level, hence the squeeze of investment outlets is not confined.

## 1.5  Productivity slowdown: demand-side determinants

Every contribution analysed so far, with the possible exception of Summers and Gordon, assumes no influence of aggregate demand in the negative evolution of productivity and GDP per capita growth. Moreover, this literature seems to exclude any influence originating from changes in institutions or power relationships between social classes (Hein, 2016). The weak performances in terms of output and productivity growth in the post-Golden Age era prompted some scholar to suggest that the rise of Secular Stagnation is the outcome of a precise stagnation policy-making.[33] In this framework, it is helpful to analyse the relationship between income distribution, financialisation and accumulation. As we shall see, it provides some insights into explaining both the post-Golden Age fall in productivity growth and the return back to pre-Golden Age average of GDP per capita growth rates.

During the Golden Age, the full employment of labour was at the centre of most government actions in many Western economies but, since the oil crisis in 1973, there has been a paradigm shift in policymaking towards price stability through restrictive monetary and fiscal policies. The policy shift resulted in reduced shares of income and wealth going to wage-earners and low-income households, as showed in Figs. A.7 to A.9.[34] The rise of income inequality and the application of restrictive policies fueled the financialisation of the economy. The rapid structural changes in the post-Golden Age era, marked by a shift to service economies, required more labour flexibility to meet firms needs. In addition to this, corporations' stakeholders started investing more heavily in higher-dividends firms, preferring short-run gains in financial markets to long-run achievements in the real economy. As might be expected, these new goals have been achieved through wage contraction and labour flexibility. However and in order not to jeopardize the consumption capacity for the greatest slice of population, the financialisation of the economy constituted a mean for the *substitution of loans for wages* (Barba and Pivetti, 2009).[35]

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[33]The main references are Hein and Dodig (2014) and Hein (2016); we have to admit as the references of non-neoclassical Secular Stagnation are very few. Additionally, the mentioned authors prefer speaking about Stagnation Policy instead of Secular Stagnation. Engaging in a dispute on proper labeling is beyond our scope; anyway, our focus concerns to Secular Stagnation as a precise *stylized fact*, while Stagnation Policy is about the rationales that led to this fact.

[34]The adjusted wage share in Fig. A.9 keeps decreasing since the late Sixties, when it was 70% almost, to the current minimum 60%.

[35]In this frame, the phenomenon of rising household debt, experienced in many advanced countries, can be viewed as the attempt made by low and middle-income consumers to keep constant or rising their relative standards of consumption, despite the continuous worsening of income distribution in favour of profits and with the approval of political and financial institutions.

The story does not end here: the redistribution of income at the expense of the labour share and the financialisation of the economy lowered the investments in capital stock, through an accelerator mechanism.[36]  Tab. A.5 shows the pattern of gross fixed capital formation and investment-to-GDP ratio.  We notice as the two decades after the Sixties point to a sharp decrease in fixed investments, with the trend of average growth rate plummeting from 5% to just over 3.5 percent. The average growth rate reaches a peak at 4.6% in the Nineties. However, the third millennium ushers a steady fall in average growth rate, with it going down to 2.8% between 2000 and 2007 and dropping to 1.8% after the crisis. In contrast, the investment-to-GDP ratio is constant throughout the period.[37] This process gave rise to two different but complementary capitalistic regimes (Hein, 2016). The "debt-led private demand" regime, which was established mainly in US and UK, and the "export-led mercantilist" one, as in Germany and China. The sharp decline in labour productivity and TFP growth we saw in Section II, which is not comparable to that in any of the previous years, could then be explained as a result of further falls in the growth rates of investments in capital stock, as well as due to income inequality and excessive financialisation. This unsustainable state of affairs would have culminated with the meltdown of 2007.

To sum up, a demand-side view interprets Secular Stagnation as the precise outcome of prolonged stagnating demand policies, which fed back negatively on productivity and output growth. Section VI presents the policy implications of the overall analysis we developed so far. Suggestions on how to reverse Secular Stagnation are found in the last section as well.

## 1.6   Policy implications

As related to the previous sections, current stagnation in the United States can be explained using different, but not mutually exclusive, theoretical frameworks. The compatibility between different studies on Secular Stagnation is particularly marked where policy implications are

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[36]An usual hypothesis in alternative non-neoclassical growth models is the positive influence on investments of the profit share. Although we do not want to enter theoretical issues the alleged influence arises, it is worth noting that the relation seems either not to hold or very weak on the empirical ground, as in Onaran et al. (2011). Furthermore, other *demand-side* factors look more important as determinants for investments: examples are in Girardi and Pariboni (2020), though the focus is on the investment share in GDP.

[37]The endogeneity of GDP helps us explain the constancy of the ratio: the debt-led consumption allowed for the compensation of the negative effects on consumption expenditure and income multiplier due to the reduction in the wage share, hence enabling the investment-to-GDP ratio to be invariant, the decline in private investments notwithstanding.

concerned. In particular, we should distinguish between supply-side and demand-side policies, all of which have direct impact on productivity as well as on GDP growth. Broadly speaking, the majority of economists agree that boosting investments behooves in order to circumvent the problem, for instance through innovation policies and a greater efficiency allocation of productive resources.[38]

Let us recall that Gordon, Eichengreen and Ramey − among the others − look mainly at the supply-side perspective of the economy and they provide a setting in which firms are allowed and provided incentives to undertake the necessary investment projects. In such a framework, contrasting Secular Stagnation requires structural reforms for the improvement of the educational system, the development of more efficient infrastructures and administrative simplification for start-ups along with antitrust policies. In particular, Glaeser (2014) focuses on individual-targeted policies, the most important of which considers the whole re-organisation of the American schooling system. [39]

While we agree with the policy implications of the supply-side economists concerning to the improvement and the development of more efficient infrastructures and for the overall rethinking of the American schooling system, which should be modeled on the European one (Glaeser, 2014), we shall nonetheless recognise that the aforementioned supply-side policies must be matched with strong demand-side policies. More precisely, Summers (2015) and Hein (2016), among the others, recommend a set of strong fiscal policies based on three pillars, often named Global Keynesian New Deal. The first pillar is the re-organisation of the financial system, in order to increase the transparency and to shift the shareholder's interest from short-term gains in the financial markets towards longer-term achievements in the real economy. Such a shift requires a higher profitability in the latter with respect to the former. The second pillar, connected to the first, demands that governments should increase and stabilize public autonomous expenditure growth, working on two levels. On the one hand, the public sector must invest on infrastructure, technology and R&D as it did during the Golden-Age period, thus creating the environment in which firms are willing to carry out new investments. Promoting exports constitutes a complementary policy and it may have a positive impact on the economic system through trade agreements and by prompting neo-mercantilist economies to rise demand for

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[38]In particular, current R&D is only about 4% of total government purchases; an increase in R&D subsidies would therefore have small budgetary consequences (Ramey, 2020).

[39]Although he does not address concretely the problem with practical purposes, he recommends the emulation of the "German apprenticeship programmes and to improve vocational training within the US" (Glaeser, 2014).

imports, thus benefiting other countries suffering from a lingering deficit in current accounts.
[40] On the other hand, governments should revise income policies: the progressive worsen-
ing experienced by personal as well as functional distribution of income should be stopped by
wage-led actions as the strengthening of trade unions' bargaining power and through general
reductions of shareholders' and rentiers' claims. The overall re-distribution of income must be
accompanied by tax policies aimed at extracting more resources from profits and less from low
and middle-income households, hence increasing the overall propensity to consume. Third, the
wage-led recovery should take into account "the reconstruction of the international macroeco-
nomic and monetary policy coordination and a new financial order so as to prevent export-led
mercantilist [. . . ] strategies" (Hein, 2016).

To conclude, Pagano (2014) suggests a *communism* of knowledge. Secular Stagnation needs
a knowledge produced *in* and *for* the public domain. Each state must invest on it and to dodge
free-rider problems and the widespread under-funding of many research institutions, at the ex-
pense of the ones which do invest, the international institutions, WTO *in primis*, must establish
that each country has to earmark a GDP fraction for investments in common knowledge.[41]

## 1.7   Conclusions

The present chapter introduced the concept of Secular Stagnation, as defined by Hansen (1939),
and examined its revival in the aftermath of the Great Recession by Prof. Summers and others).
Through a very simple analysis on US data since 1870, we showed that the term "Secular Stag-
nation" is somewhat misleading as used in the literature. On the one hand, it is applied to de-
scribe an economic system affected by an overall slowdown in real GDP per capita growth rate,
when actually this phenomenon consists of a return back to pre-Golden Age performances.
Moreover, the growth rate in GDP per capita has been trendless since 1870. On the other hand,
the Secular Stagnation hypothesis as formulated by Summers (2014a,b) suffers from serious
theoretical drawbacks. He limits his analysis to the post-2007 world and the weak economic
performances as resulting from the Great Recession. The crisis has persistently affected the
economy for sure, but it is reductive to explain every cause in terms of economic cycles. Addi-
tionally, Summers examines only the recent past. The idea on a negative natural interest rate

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[40]Perhaps (not so) surprisingly, Summers (2015) finds that fiscal policies would manage to reduce debt-to-GDP
    ratio in the medium-long term, hence tackling the sustainability problem.
[41]All this requires the Marxian policy of asset redistribution, the liberal pro-market policy against monopolies and
    the Keynesian policy of public investments (Pagano, 2014).

itself, as promoted by Summers, relies on contradictory hypotheses which undermine its actual admissibility, as clearly demonstrated by Di Bucchianico (2020) and Palley (2019).

The most important contribution of this chapter is that we should regard Secular Stagnation as a problem concerning labour and multifactor productivity growth: their decline in growth since the 1970s cannot be associated to any return back to past performances. In that case we should even speak about a phenomenon that involves not a *single* long period, but possibly *more* long runs. Our findings support (Hein, 2015, 2016)'s claim that stagnating-demand policies and the general increase of income inequality depressed investments and productivity growth, as well as more supply-side viewpoints *à la* Gordon (2014, 2015) and Eichengreen (2015). The two authors relate the decrease in productivity growth with the overall decline in population growth and the weakening in the propulsive thrust of the ICT technical change.

These heterogeneous contributions converge to a gradual homogeneity and complementarity when it comes to their policy implications. On the one hand, supply-side economists suggest the improvement of the educational system, the development of more efficient infrastructures and administrative simplification for start-ups and new businesses. On the other hand, a demand-side view focuses on strong fiscal policies for the stabilization of final demand. Active fiscal policies involve raising public spending to fight deflation and to contain the negative impact of an aggregate-demand crisis too. Furthermore they recommend the implementation of income policies is needed in order to stop the increase of income inequality, either personal or functional.

To conclude, the post-Golden Age era is characterized by slow growth in R&D expenditures and innovation activities. In particular, the slowdown in total and federal US R&D expenditures with respect to the Golden Age period (1950-72) is very remarkable . This evidence pools sectors as aerospace research, health and defense. The debate around Secular Stagnation in the United States paid little attention, if any, to the deep relationship between functional income distribution, firm innovative efforts and productivity growth; there is in particular a lack of a *demand-side* channel. We therefore tackle this issue in the following two chapters, through the development of an agent-based computational economics (ACE) model. In other terms, if we firstly sought evidence of Secular Stagnation as a stylized fact and secondly discussed the rationales from the literature, then we would analyze whether the interaction between income distribution and innovation are able to provide us with further insights to explain the rise of

Secular Stagnation in the USA. It would be interesting to show that innovation gains depend not only on supply-side factors, but it may be a *demand-story* as well as in Caminati and Sordi (2019). Last sentences in Hansen (1939) make the point:

> There are no easy answers to the problems that confront us. And because this is true, economists will not perform their function if they fail to illuminate the rapidly shifting course of economic development, and through such neglect unwittingly contribute to a dangerous lag in adjustments to change. Equally they will not perform their function if they fail to disclose the possible dangers which lurk in the wake of vastly enlarged governments. Choices indeed must be made, and scientific analysis and painstaking research can aid by exploring the probable consequences of alternative choices. The problems which I raised offer a challenge to our profession. The great transition [. . . ] calls for high scientific adventure along all the fronts represented by the social science disciplines.

# Appendix A

# Tables and Figures

| Time | Average growth rates (%) |
|---|---|
| $1889 - 20$ | 0.017 |
| $1920 - 50$ | 0.025 |
| $1950 - 72$ | 0.028 |
| $1972 - 96$ | 0.016 |
| $1996 - 07$ | 0.022 |
| $2007 - 18$ | 0.010 |

Trends and Bai-Perron test for labour productivity

| Time | Trend $\hat{\beta}$ | Sequential L+1 breaks vs. L | Sequential test all subsets |
|---|---|---|---|
| $1889 - 2018$ | $-0.004^{**}$ | 1916, 1935, 1993 | 1916, 1935, 1971, 1992 |
| $1889 - 1940$ | 0.007 | | |
| $1950 - 2018$ | $-0.029^{***}$ | 1971, 1993, 2008 | 1973, 1983, 1993, 2008 |

Note: trend $\hat{\beta}$s refer as to a simple OLS regression $y_t = \alpha + \beta trend + u_t$, which traces the evolution over time of our variable of interest. To ascertain information about the different specification of the Bai-Perron test, see Bai (1997) and Bai and Perron (1998). Values are computed over HP-filter trend components of individual time series. Star significance: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A.1. Statistics for labour productivity, $1889 - 2018$

| Time | Average growth rates (%) | |
|---|---|---|
|  | Non-adjusted estimates | BLS adjusted estimates |
| 1889 − 20 | 0.015 |  |
| 1920 − 50 | 0.024 |  |
| 1950 − 72 | 0.019 | 0.018 |
| 1972 − 96 | 0.009 | 0.006 |
| 1996 − 07 | 0.018 | 0.012 |
| 2007 − 18 | 0.009 | 0.005 |

Trends and Bai-Perron test for non-adjusted TFP

| Time | Trend $\hat{\beta}$ | Sequential L+1 breaks vs. L | Sequential test all subsets |
|---|---|---|---|
| 1889 − 2018 | −0.005*** | 1914, 1933, 1968, 1990 | 1914, 1933, 1968, 1991 |
| 1889 − 1940 | 0.029*** | 1916, 1925, 1934 | 1916, 1925, 1934 |
| 1950 − 2018 | −0.013*** | 1970, 1992, 2009 | 1960, 1970, 1992 |

Trends and Bai-Perron test for BLS TFP

| Time | Trend $\hat{\beta}$ | Sequential L+1 breaks vs. L | Sequential test all subsets |
|---|---|---|---|
| 1948 − 2018 | −0.021*** | 1972, 1994, 2008 | 1972, 1984, 1994 |

Note: trend $\hat{\beta}$s refer as to a simple OLS regression $y_t = \alpha + \beta trend + u_t$, which traces the evolution over time of our variable of interest. To ascertain information about the different specification of the Bai (1997) and Bai and Perron (1998). Values are computed over HP-filter trend components of individual time series. Star significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.2. Statistics for multifactor productivity, 1889 − 2018

| Time | Average growth rates (%) | | |
|---|---|---|---|
| | Real per capita GDP | Potential output | Population |
| $1870-20$ | 0.018 | | 0.021 |
| $1920-50$ | 0.028 | | 0.012 |
| $1950-72$ | 0.022 | 0.034 | 0.015 |
| $1972-96$ | 0.021 | 0.023 | 0.010 |
| $1996-07$ | 0.016 | 0.016 | 0.011 |
| $2007-16$ | 0.0086 | 0.014 | 0.082 |

**Trends for real per capita GDP**

| Time | Trend $\hat{\beta}$ |
|---|---|
| $1870-2016$ | $-0.001$ |

**Trends and Bai-Perron test for potential output**

| Time | Trend $\hat{\beta}$ | Sequential L+1 breaks vs. L | Sequential test all subsets |
|---|---|---|---|
| $1966-2016$ | $-0.045^{***}$ | $1974, 2006$ | $1974, 1981, 2006$ |

**Trends and Bai-Perron test for population**

| Time | Trend $\hat{\beta}$ | Sequential L+1 breaks vs. L | Sequential test all subsets |
|---|---|---|---|
| $1870-2016$ | $-0.01^{***}$ | $1925, 1946, 1967, 1988$ | $1916, 1946, 1967, 1988$ |
| $1870-1940$ | $-0.024^{***}$ | $1890, 1915, 1929$ | $1890, 1915, 1929$ |
| $1950-2016$ | $-0.013^{***}$ | $1964, 1979, 1989$ | $1964, 1979, 1989$ |

Note: trend $\hat{\beta}$s refer as to a simple OLS regression $y_t = \alpha + \beta trend + u_t$, which traces the evolution over time of our variable of interest. To ascertain information about the different specification of the Bai-Perron test, see Bai (1997) and Bai and Perron (1998). Values are computed over HP-filter trend components of individual time series. Star significance: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A.3. Statistics for real per capita GDP, potential output and population, $1870-2016$

| | 1959 – 06 | 1959 – 73 | 1973 – 95 | 1995 – 00 | 2000 – 06 |
|---|---|---|---|---|---|
| **Private output** | 0.036 | 0.042 | 0.031 | 0.048 | 0.030 |
| Hours worked | 0.014 | 0.014 | 0.016 | 0.021 | 0.005 |
| Average labour productivity | 0.021 | 0.028 | 0.015 | 0.027 | 0.003 |
| **Contribution of capital deepening** | 0.011 | 0.014 | 0.009 | 0.015 | 0.013 |
| Information technology | 0.004 | 0.002 | 0.004 | 0.010 | 0.006 |
| Non-information technology | 0.007 | 0.012 | 0.005 | 0.005 | 0.007 |
| **Contribution of labour quality** | 0.003 | 0.003 | 0.003 | 0.002 | 0.003 |
| **Total factor productivity** | 0.008 | 0.011 | 0.004 | 0.001 | 0.009 |
| Information technology | 0.003 | 0.001 | 0.003 | 0.006 | 0.004 |
| Non-information technology | 0.005 | 0.011 | 0.001 | 0.004 | 0.005 |
| **Share attributed to information technology** | 0.003 | 0.001 | 0.004 | 0.006 | 0.004 |

Source: Jorgenson et al. (2008).

Table A.4. Source of Output and Productivity growth in United States, 1959 – 2006

| Years | Gross Fixed Capital Formation | Investment-to-GDP ratio |
|-------|------------------------------|-------------------------|
| 1960 − 70 | 0.050 | 0.20 |
| 1970 − 80 | 0.032 | 0.20 |
| 1980 − 90 | 0.037 | 0.20 |
| 1990 − 00 | 0.046 | 0.21 |
| 2000 − 07 | 0.028 | 0.22 |
| 2007 − 17 | 0.018 | 0.20 |
| 1960 − 72 | 0.046 | 0.20 |
| 1972 − 96 | 0.037 | 0.20 |
| 1996 − 17 | 0.029 | 0.21 |

Note: author's own calculations on Ameco (European Commission) and Macrohistory Lab Bonn data. We use the HP-filter on Gross Fixed Capital Formation growth rates to base our focus on the trend component.

Table A.5. Statistics on Gross Fixed Capital Formation average growth rates and Investment-to-GDP ratio.
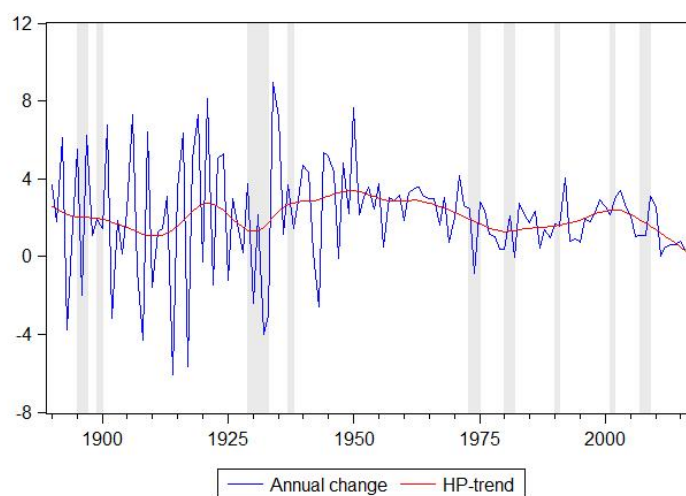
Note: labour productivity is measured as real GDP per hours worked; shaded areas refer to major crises. Source: author's own calculations on Kendrick (1961) and Penn World Table 9.1 data.

Figure A.1. Labour productivity in the USA, $1889 - 2018$
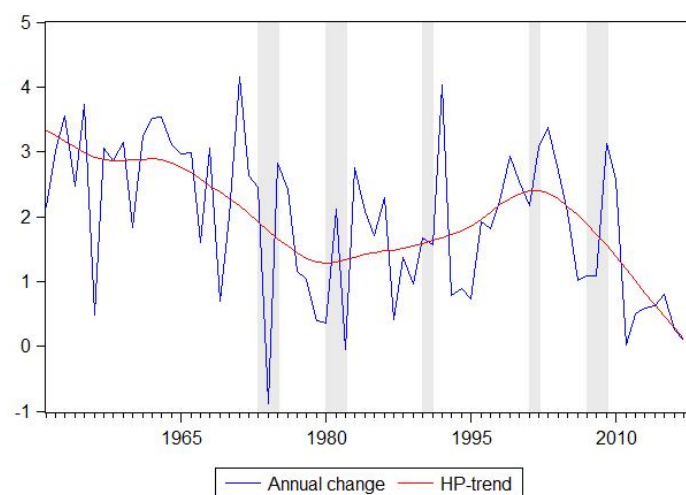


Note: labour productivity is measured as real GDP per hours worked; shaded areas refer to major crises. Source: author's own calculations on Penn World Table 9.1 data.

Figure A.2. Labour productivity in the USA, $1950 - 2018$
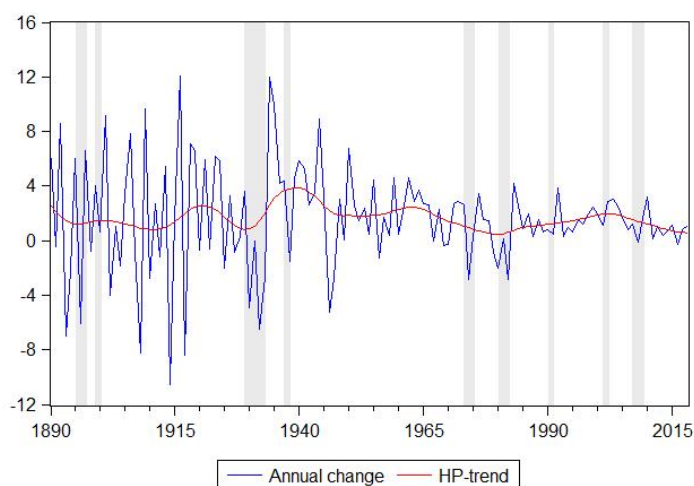
Note: TFP refers to Private Nonfarm Business Sector; shaded areas
refer to major crises. Source: author's own calculations on Kendrick
(1961) and Bureau of Labor Statistics data.

Figure A.3. Total factor productivity in the USA, $1889 - 2018$
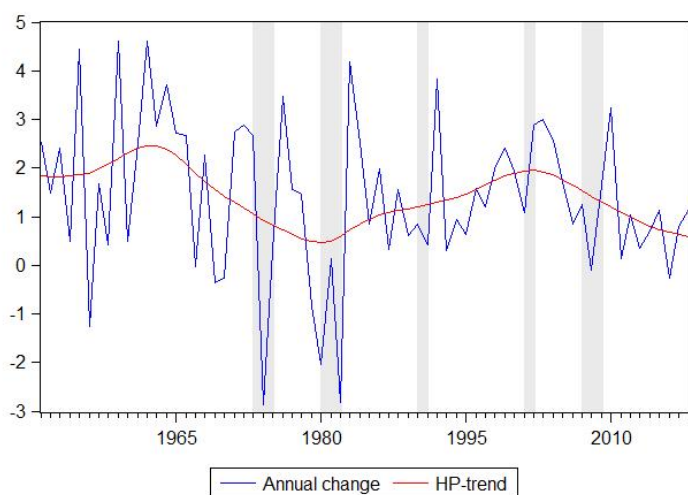


Note: TFP refers to Private Nonfarm Business Sector; shaded areas
refer to major crises. Source: author's own calculations on Bureau of
Labor Statistics data.

Figure A.4. Total factor productivity in the USA, $1950 - 2018$
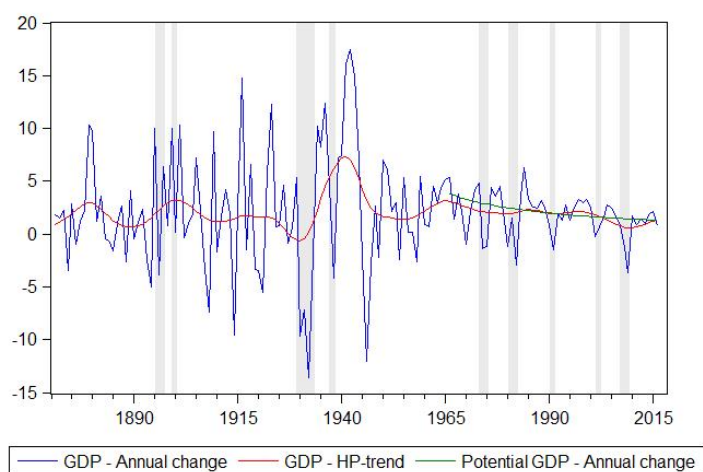
Note: data refer to the whole economy; shaded areas refer to major crises. Source: author's own calculations on Macrohistory Lab Bonn and Ameco data.

Figure A.5. Real GDP per capita and potential output in the USA, $1870 - 2016$
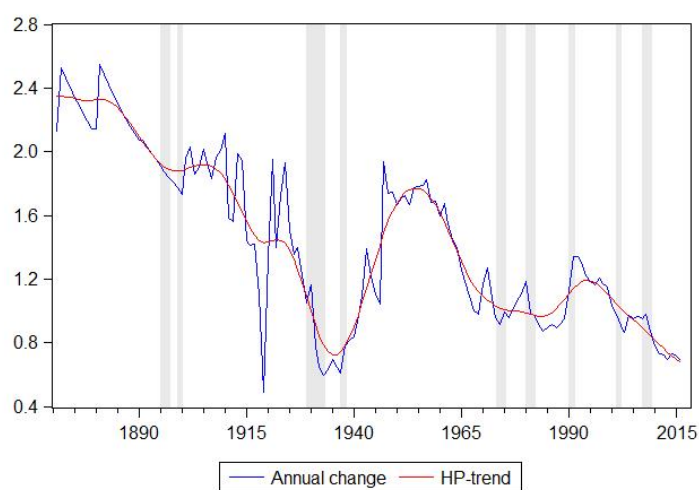


Note: shaded areas refer to major crises. Source: author's own calculations on Macrohistory Lab Bonn data.

Figure A.6. Population in the USA, $1870 - 2016$
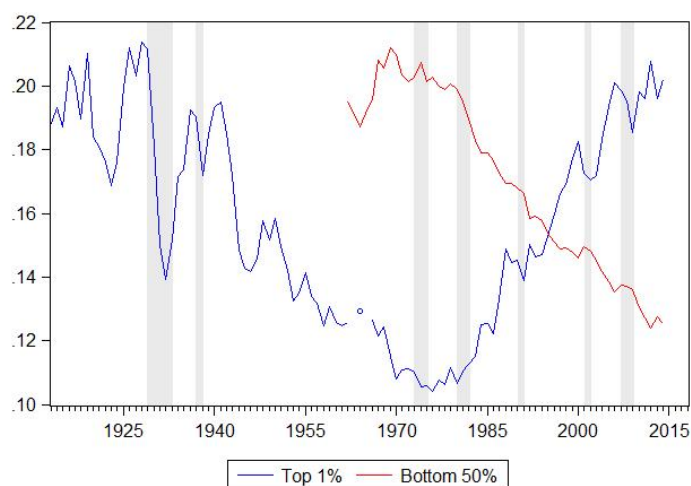
Note: shaded areas refer to major crises. Source: author's own calculations on World Inequality Database data.

Figure A.7. Income inequality in the USA, $1913 - 2014$
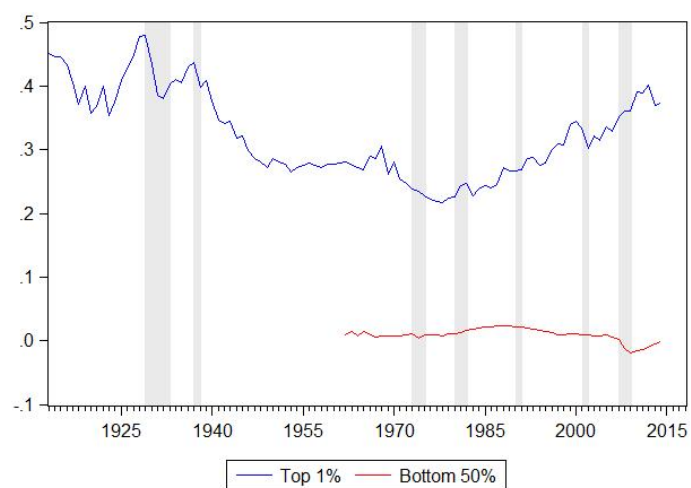


Note: shaded areas refer to major crises. Source: author's own calculations on World Inequality Database data.

Figure A.8. Wealth inequality in the USA, $1913 - 2014$
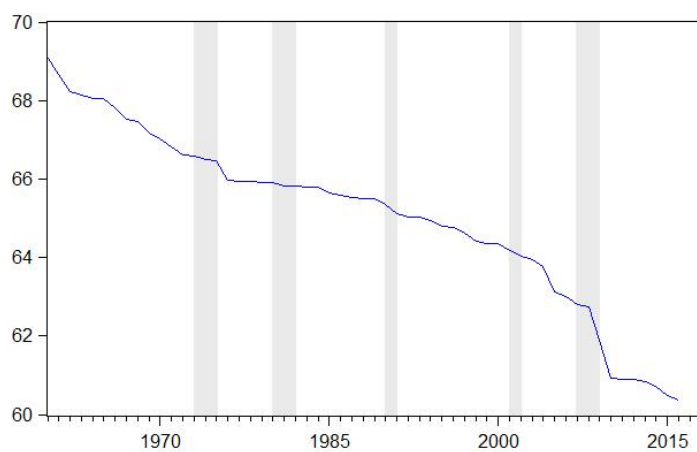
Note: shaded area refer to major crises. Source: author's own calculations on Ameco data.

Figure A.9. Adjusted wage share in the USA for total economy, $1960 - 2016$

# Chapter 2

# Secular Stagnation and innovation dynamics: An agent-based SFC model. Part I

## 2.1 Introduction

Prof. Larry Summers re-evoked in recent times the old concept of Secular Stagnation to describe a situation in which changes in the economic fundamentals after the Great Recession of 2007 might have caused a significant shift in the natural balance between savings and investments, making the achievement of adequate growth, capacity utilisation and financial stability increasingly difficult Summers (2014a,b). Many economists dealt with that phenomenon thus far, each underlining a peculiar aspect. However, the debate paid little attention to the deep relationship between income distribution, innovation and productivity.

The paper fills that gap in the literature and sets Secular Stagnation into an agent-based framework. We focus on the US capitalistic evolution of the last fifty years and study in which way the distribution of income between wages and profits can determine the rate of innovative activity and then further attainments in productivity. In particular, we depart from Summers's definition and look at Secular Stagnation in the USA as the tendency to the long-term slowdown in the growth rates of labour and total factor productivities which starts in the early Seventies and reaches the trough with the Great Recession in 2007. Moreover, we consider other major features of the US post-1972 economy like the progressive worsening of the functional distribution of income at the expense of the labour share and, on the other hand, a slower

growth in R&D activity.

In this contribution, we develop an agent-based, stock-flow consistent (AB-SFC, hereafter) model in the line of Dosi et al. (2010), Caiani et al. (2016a) and Godley and Lavoie (2006). The model involves a one-good two-class closed economy with no government sector. The good can be used either for consumption or for investment purposes. Households are divided between workers, that supply labour inelastically at the going wage rate, and capitalists, which own the firms and act as entrepreneurs. The latter invest in innovative research activity a percentage revenue from past sales while trying to reach a normal profit rate. In our model, the micro-foundation of the endogenous innovation process is essential to avoid *isomorphism* between micro and macro phenomena and to remark the evolutionary character of the theoretical base. The adoption of an agent-based perspective needs to be justified. Some may ask, indeed, whether such an evolutionary framework is really necessary or, in other terms, if that modeling allows to show up insights *not visible* with the standard representative-agent modeling or with a more aggregate perspective, if any. We reply that both standard representative-agent models or the aggregate perspective suffer from, among the others, a lack of micro-heterogeneity, interpreted as the multiplicity of interactions among agents with no a priori commitment towards any reciprocal consistency (Dosi et al., 2010). Agent-based models are particularly suitable to the task since the user knows by construction the micro data-generating process and can explore the features of macro-variables as properties emerging out of the evolutionary dynamics (Dosi et al., 2018). In other words, to explain aggregate outcomes we cannot sum the predicted individual behaviours, because the actions taken by the single agent influence the behaviour of the others (Bowles, 2009). This kind of modeling recognizes, on the one hand, the importance of Solow (2008)'s call for micro-foundations more realistic than usual. On the other hand, micro-foundation is absent in many macro-aggregate models, which do not enable the researcher to fully understand processes occurring at the micro- and meso-level of economic activity.

The contribution of the paper to the literature on Secular Stagnation lies on its capability to show the way phenomena at the macro-level affect the dynamic path of variables at the micro-level. More precisely, it is interesting to show that the shrinkage of the labour share impacts negatively on firms' propensity and ability to innovate. Wages indeed sustain consumption and, indirectly, investments. The lower aggregate demand after a fall in the wage share reduces capitalist's incentive to invest either on tangible capital or on innovative search at the

micro-economic level. The result will be an overall bad economic performance on aggregate. We advance the idea that the continuous shift of income from wages to profits may have resulted in a smaller incentive to invest in R&D activity, entailing the evident decline in productivity performances that marks the US Secular Stagnation. We have to admit, of course, that this is not the *only* valid explanation for the long-run tendency of productivity growth to fall. Non-technological motives, like lower top marginal tax rates, increased low-skill immigration, rising trade with China and low-cost manufacturing countries or the rise of superstar firms (Autor et al., 2020) are equally plausible.

Back to the model, we test additionally the role exerted by the rate of interest and the loosening of barriers to innovation and imitation. On the one hand, the decrease in the interest rate leads to particular results: it helps increase aggregate production and employment levels but impacts negatively on labour productivity, since the entrepreneurs reach more easily a normal profit rate and prefer organizing the production process to less labour-saving techniques. On the other hand, loosening the barriers to the interaction among firms and increasing the possibility to exchange ideas through imitation allow for further innovation and better economic performances as a whole, but the effect is circumscribed to the long run only.

The paper is organised as follows: Section II deals with the literature; Section III presents empirical evidence on income distribution, innovation and productivity; Sections IV to VI are about the model and related experiments; Section VII concludes. The Appendices contain tables, figures and convey some information on the main matching processes. Although the model approaches to a stationary state and does not refer to *growth* questions (yet), it represents the first step toward the development of a growth model. The latter will be developed in the next chapter.

## 2.2 Relation with the literature

Several fields of research contribute to define the background literature of the present work. First and foremost, the paper inserts into the literature of Secular Stagnation, here defined as the tendency to the long-term slowdown in the growth rates of labour and multi-factor productivities, which starts in the early Seventies and reaches the trough with the Great Recession

of 2007.[1] Albeit for a different context, the concept was introduced with the pioneering work by Hansen (1939) to describe the somber situation in which the US economy fell after the Great Depression in 1929.[2] To date, the concept was re-evoked by Summers (2014a,b) to outline a situation in which changes in the economic fundamentals, after the Great Recession, might have led to a significant shift in the natural balances between savings and investments. The equilibrium natural interest rate associated to full employment of labour would have reached negative values. The related outcome is a situation in which the achievement of adequate growth, capacity utilisation and financial stability appears increasingly difficult Summers (2014b).[3] However, his analysis is limited in scope in that he focuses on Secular Stagnation through the lens of the Great Recession only. Summers examines the very recent past and the remarkable decline in productivity growth finds no place in that framework.[4]

Many economists recovered the concept after him: we find Gordon (2015), Eichengreen (2015) and Hein (2016), among the others. Their approach is historical data-driven. On the one hand, Gordon (2015) and Eichengreen (2015) adopt a supply-side view to analyze the long-period determinants of productivity growth and disregard cyclical influences. They suggest that mounting inequality impacted negatively on the accumulation of human capital, since students are ever more burdened by the loans they take to pay their college tuition. Furthermore, they are concerned to the revolution started by digital electronics, which ran out of steam, with the electronics facing diminishing returns. Their idea is that innovation achievements of the last fifty years had a relatively smaller impact on productivity than, for example, innovations at the turn of the $XX^{th}$ century. On the other hand, Hein (2016) points out that the redistribution of income at the expense of the labour share, stagnating-demand policies and the overall surge of personal income inequality squeezed investments in capital stock through an accelerator mechanism and productivity growth.[5]

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[1]The productivity-growth decline is a well-documented fact of the literature. We nonetheless present some empirical evidence on that in the following Section.

[2]The author looked at the high unemployment as the principal problem for Americans and the expression of Secular Stagnation stood for "sick recoveries which die in their infancy and depressions which feed on themselves and leave a hard and seemingly immovable core of unemployment" (Hansen, 1939).

[3]Eggertsson et al. (2019) draws upon Summers (2014b) and provides a general setting for the natural rate hypothesis. They develop an analytic overlapping generation model, the steady state of which is characterized by a negative full-employment real interest rate.

[4]Additionally, the (negative) natural rate hypothesis suffers from important theoretical weaknesses: see Palley (2019) and Di Bucchianico (2020).

[5]We should remark that Hein (2016) contrasts the concept of Secular Stagnation to that of Stagnation Policy. We believe that such a juxtaposition could be misplaced: the former should concern to some stylized fact or empirical evidence, while the latter to the rationales. Anyway, we do not discuss that since it is beyond the scope of the present work.

The second stream of research is about the Schumpeterian and evolutionary tradition (Aghion and Howitt, 2008; Bowles, 2009; Schumpeter, 1982). It deals with "dynamic processes causing qualitative transformation of economies driven by the introduction of innovation in their various and multifaceted forms and the related co-evolutionary process" (Hanusch and Pyka, 2007).[6] Innovation turns out to be the most important force driving productivity and economic growth. Moreover, it is strongly related with uncertainty in its *Knightian* sense, causing complex modes of behaviour. Although innovation occurs at the micro-level of the economy through the creation of novelties and many entrepreneurial decisions, its potentiality manifests at the industry or *meso*-level of the economic activity (Dopfer et al., 2004).

Third, we refer to the agent-based literature, that considers economic systems as populated by many heterogeneous interacting agents without any central coordination (Caiani et al., 2016b).[7] Several works study the interplay between innovation, income distribution and economic performances. Dosi et al. (2010, 2016, 2018) and Napoletano et al. (2012) are key contributions to the topic. The family of their $K + S$ models investigates the way innovations affect macro-variables, through endogenous generation of supply shocks at the micro- and meso-levels. Their models are structural since they build on a representation of what agents do. An important characteristic is that they link the Schumpeterian tradition of innovation-driven economic growth with the Keynesian theories of demand generation. In other terms, the Schumpeterian engine fuels growth only in the presence of Keynesian policies, which do contribute to reduce output volatility and unemployment rates. On the same line of research is Wirkierman et al. (2018), focused on the distributional impacts of innovation. The public sector invests directly in R&D and licenses to private firms access to the new technology to produce the final good. Increasing the wage share allows the public sector to drive the process of innovative search toward an outcome in which the distributional impacts of innovation reflect the distribution of contributions to the innovative process.

The afore-mentioned methodology suffers from some drawbacks. Many former AB models vi-

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[6]An eminent precursor of evolutionary and complex economics is Von Hayek (1937) with the notion of *spontaneous order*. Briefly, chaotic processes at the micro-economic level may entail some form of regularity at the macro-aggregate perspective. Markets are viewed as places for learning and discoveries, hence a place for innovation and imitation. In that framework, the evolution of institutions is the product of countless interactions, the aggregate outcome of which is often unintended (Bowles, 2009).

[7]Economies are seen as complex dynamic systems, whereby a multitude of micro-agents locally interact and give rise to the multifaceted stylized facts for growth rates, employment, income distributions and institutions (Tesfatsion, 2006). Additionally, aggregate outcomes condition local interaction patterns.

olated accounting consistency requirements, with some financial flows arising out of nowhere. Caiani et al. (2016a) starts from this point and builds a fully decentralised stock-flow consistent model with heterogeneous interacting agents, where consistency is applied since the micro-economic level to account for the structural interrelatedness of agents. Although the model does not concern to *growth* questions, it is promising in the field of bank regulation and macro-prudential issues. Additionally, this contribution offers interesting guideposts to calibrate, validate and adapt the basic framework to alternative research questions. Based on the above consolidated framework, Caiani et al. (2019) investigates the nexus between inequality and growth, assessing the impact of several distributive regimes on innovation dynamics and economic development. The crucial feature is the segmentation of the labour markets in four tiers, according to the role assumed by each worker in the hierarchical organisation of the firm. The distributive regimes concern to the implementation of more, or less, progressive tax schemes and higher, or lower, downward wage rigidity of lower-tier workers. The results are in tune with the literature that emphasizes wage-led growth regimes in a closed economy. In other words, more progressive tax systems and measures to sustain low and middle income households help foster economic development and innovation.

## 2.3    Data on wages, productivity and innovation since 1950

We said that the literature on Secular Stagnation paid little attention to the interplay between income distribution, innovation and productivity developments. The mounting shift of income from wages to profits, on the one hand, and the reductions in productivity growth, on the other, have manifested since the end of the Golden Age of capitalism (1950-1973). Hence, what we represent in Tab. B.1 and in Fig. D.1 is a well-documented fact in the economic debate. Starting from the late Sixties, when it was near to 70%, the adjusted wage share keeps decreasing to the current minimum value around 60%. For what regards to labour productivity, there has been a slow and steady decline in the growth rate over the period of interest. The rate of growth exhibits a timid recovery in the Nineties, before the new and long-lasting collapse in the aftermath of 2007 crisis. The same holds for TFP growth, that follows the same qualitative trajectory. TFP grows 1.7% on average during 1950-1973, then it shrinks to one-third of that value in 1973-1995. It rebounds in the Nineties and eventually reaches the bottom 0.6% in the post-2007 decade. As above, Gordon (2015) suggests that soaring inequality impacted negatively on the accumulation on human capital and then on productivity, since students are

ever more burdened by the loans they take to pay their college tuition. On the demand side, Hein (2016) points out that the redistribution of income at the expense of the labour share lowered investments in capital stock through an accelerator mechanism. For what concerns to the relation between innovation and productivity, the literature refers to Eichengreen (2015) and still to Gordon (2015). Their idea is that the innovation achievements of the last fifty years had a relatively smaller impact on productivity than, for example, innovations at the turn of the $XX^{th}$ century. What is missing on the analysis around Secular Stagnation is the *demand-side* channel between functional distribution of income, innovation and productivity. Sylos-Labini (1983) first, and Allen (2009, 2011) and Carnevali et al. (2020) later, explain the role of a distribution favourable to the wage share in triggering a process of economic development, through continuous investments in innovative activities and further achievements in productivity. Is it possible that the same process occurred in the opposite way? In other terms, does any positive relation exist between wage share, investments in R&D and productivity enhancements? Tab. B.2 to B.6 and Fig. B.2 present data on the evolution of R&D expenditures in United States since 1950, whenever possible.Tabs. B.2, B.3 and the upper panels of Fig. B.2 evidence the striking decline in growth of R&D expenditure since late 1960s, either *by source* or *by function*.[8] The careful observer may object that the Golden Age in US was a particular period marked by the necessity of *winning* the Cold War against the Soviet Union. That would explain why, for instance, space expenditure growth rates surged toward extraordinary values until the end of the Sixties and then fell sharply after the first moon landing. Therefore, we analyzed the time trend of each variable since 1973, finding that the majority of sources and functions exhibited a steadily downward trend in growth.[9] Tabs. B.4, B.5 and the lower panels in Fig. B.2 concern to the evolution of R&D shares. It is interesting to notice that private R&D as percentage of Fixed Investments kept increasing throughout the period, the decline in growth showed above notwithstanding. Furthermore, Arora et al. (2018) notes a shift away from science by large corporations between 1980 and 2006. Although science remains an important input for innovation, their empirical evidence points to a reduction of the private benefits of internal research, which leads to closing and downsizing their labs.[10] Therefore, albeit firms are committing a higher

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[8]*Source* refers to federal, industry, non-profits, universities, other and total. *Function* refers to federal expenditures in defense and non-defense, energy, general science, health, natural resources, space and other. Categories are established by the AAAS database.

[9]For the sake of brevity, we did not report tables on trend regressions, since what asserted is visible in Tabs. B.2, B.3 and Fig. B.2. They are anyway available upon request.

[10]Although Bloom et al. (2020) agree on this point too, we must point however that innovative investments in the private sector is now very disseminated in a multiplicity of small-size firms and start-ups, often *unrelated* to the investing firm from a *corporate* point of view. That may invalidate, at least partially, the empirical evidence by Arora et al. (2018).

share of investments in R&D, it does correspond to the redirection of resources and attention from more exploratory scientific research toward more commercially-oriented projects (Arora et al., 2018). By the same token, federal R&D shares kept decreasing from late 1960s onwards, either as share of discretionary outlays or as share of total budget.[11] Moreover, they kept decreasing regardless to the destination, whether defense or non-defense.

To sum up, Tab. B.6 shows that wage share, innovation rates and productivity measures are significantly and positively correlated. We advance the idea that the ongoing shift of income from wages to profits may have resulted in a smaller incentive to invest in R&D, entailing the evident decline in productivity growth. Secular Stagnation, as defined above, might have originated from that. In what follows we develop an AB-SFC model to highlight whether that hypothesis grounds on a micro-founded framework too. AB models are particularly suitable to the task since one knows by construction the micro-economic data-generating process and can explore the characteristics of macro-economic variables as properties arising out of the evolutionary dynamics (Dosi et al., 2018).

## 2.4    The model

The analysis concerns to the role of income distribution and demand in affecting the economic performance. We focus on a one-good two-class closed economy with no government sector that approaches and gravitates around a stationary state.[12] We describe the economy as populated by heterogeneous interacting agents with the help of Fig. B.3.[13] Precisely:

- A collection $N_s$ of households: on the one hand, $N_s - F$ agents offer labour inelastically at the going wage rate; on the other hand, the remaining households are capitalists. Regardless of their status, households spend part of their income in the purchase of the (consumption) good. Savings are held in the form of bank deposits, *only* and *always*. Moreover, they own the bank proportionally to their wealth and receive banking profits as dividends.

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[11]The US Senate defines discretionary spending the spending budget authority and outlays controlled in annual appropriation acts. Total outlays or total budget identify the amount of expenditure set out by the federal government.

[12]Following Caverzasi and Godin (2015), we define a stationary state as a logical construction where all stocks and flows do not change over time and that can be reached if all the behaviours were *fixed* after a transition period.

[13]To be precise, the model is complex, adaptive and structural in the spirit of Tesfatsion (2006): *complex* because the system involves interacting units; *adaptive* since concerns to environmental changes; *structural* because built on what agents do.

- A collection $F$ of firms owned by the entrepreneurs organizing the production process and taking investment decisions. They produce a homogeneous good that can be used either for consumption or for investment purposes. Additionally, they may apply for loans to finance production and investment.

- A consolidated bank, whose activity is limited to providing firms with loans and households with deposits at given interest rates. So doing, the big bank is an input supplier.

During each period of the simulation, agents interact on five markets:

- The (capital) goods market: firms interact with each other to buy and sell (capital) goods.

- The (consumption) goods market: households purchase (consumption) goods from firms.

- The labour market: capitalists interact with workers through hiring and firing.

- The credit market: the consolidated bank provides firms with loans.

- The deposit market: the consolidated bank gathers households' deposits.

The behavioural equations for households and firms are in line with the AB-SFC literature as in Caiani et al. (2016a,b) and Godley and Lavoie (2006). We further assume no population growth; however, labour supply is exogenous and unbinding, since in a mature capitalist economy as the USA are there is usually a pocket of unemployment, while episodes of labour shortages, if any, are solved through exogenous migration flows. A crucial feature of the model is the role assumed by innovation, which turns out to be the driver of productivity and economic development. Though it occurs at the micro-level of the economy through several entrepreneurial decisions, its potentiality gets fully fledged at the industry or meso-level of the economic activity. The model exhibits evolutionary roots since it envisages path dependencies and irreversibilities.[14]

For the sake of simplicity, we split the exposition as follows: timeline of events, production firms, labour market, households, innovation and imitation processes, banking system, prices and inflation expectations.

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[14]The heterogenous agents show close and frequent interactions and the "outcome of evolutionary processes is determined neither *ex ante* nor as a result of global optimizing, but rather is due to true uncertainty underlying all processes of novelty generation" (Hanusch and Pyka, 2007). Italics in the original text.

### 2.4.1  Timeline of events

Production firms are endowed with a unit of (capital) good at $t = t_0$. After that, micro-economic decisions occur with this sequential order any given period $t$:

1. Firms compute their target level of capital.

2. Capitalists draw from previous accumulated wealth, if any, and borrow from the banking system in order to have enough funds to hire workers and buy the (capital) goods they need.  Once this has been done, they set up production to build the (capital) goods they are ordered by the other firms and to satisfy the demand for (consumption) goods from households.

3. Workers receive a wage.  Regardless of their status, agents purchase the (consumption) good with part of the received income and save as money deposits what remains.  Businessmen earn a profit as residual claim, if any.

4. The aggregate bank gathers interest payments from firms and pays interests on household's deposits.  Then, it distributes profits to households.

5. Firms update their production plans according to the demand they face.  Moreover, they invest on capital stock and on R&D to improve their technology level, save manpower and earn further $-$ extra $-$ profits.  New machines and productivity enhancements due to the R&D activity, if any, will be available at $t + 1$.

### 2.4.2  Production firms

We start describing how production takes place and how entrepreneurs take their decisions. The economy produces a single good that can be used either for consumption or for investment purposes. There are no inventories and production adapts to demand. Output components are all expressed at constant prices. The first equality is about production at firm level:

$$y_j = c_{f,j} + i_{s,j} + i_{rd,j} \tag{2.1}$$

where $y$ is the amount of good produced by the single firm, split into production of (consumption) and (capital) goods, and innovative activity respectively, while $j$ always refers to the single firm if not otherwise specified. The production technology employs labour and capital

in fixed proportions, following the usual Leontief production function:

$$y_j^P = min \left[ \varphi \cdot k_j; a_j \cdot N_s \right] \tag{2.2}$$

where $y^P$ is the productive capacity of the $i$-th firm, $k$ its capital endowment, $\varphi$ the inverse of the capital-output ratio and $a$ is the labour productivity within the same firm. Entrepreneurs target a certain capital stock $k^T$.[15] For simplicity, we assume that a constant proportion $\delta$ of the existing stock of capital depreciates period-by-period and that capitalists set aside an amount of funds exactly sufficient to replace the used-up equipment:

$$da_j = \delta \cdot k_{-1,j} \tag{2.3}$$

$$af_j = da_j \tag{2.4}$$

$da$ and $af$ define the depreciation allowances and the amortization fund, respectively. Let us turn on the investment decisions. The entrepreneurs distinguish between investments on tangible capital − i.e. machines − and intangible capital − i.e. R&D. Investments on tangible capital increase the productive capacity but do not improve technology and labour productivity, whereas investments on R&D do. In other words, since inventive activity is costly, capitalists have two alternatives: capital accumulation and innovation. Both types of investment raise total earnings, but in different ways: innovation reduces unit labour costs in production, while capital accumulation increases the size of a firm's business.[16] Gross investments on tangible capital consist of a modified version of the standard partial-adjustment accelerator model:

$$i_{k,j} = i_0 + i_{1,j} \cdot \left( k_j^T - k_j \right) + af_j \tag{2.5}$$

where $i_k$, $i_0$ and $i_1$ represent the investment in physical capital, the autonomous investment or *animal spirits* and the adjustment coefficient, respectively.

Firms invest in innovative search to save labour and to earn extra-profits. In line with the Schumpeterian literature, we posit the amount invested in innovative activity is made up of

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[15]Even if production adapts to demand, firms maintain excess capacity and this does not reflect a wrongful process of expectations formation, but rather the rational decision of the firm to be able to accommodate fluctuations in demand (Ciccone, 1986). In addition to this, a further clarification is apt: we hypothesize productivity improvements result in different technologies. That allows to keep the capital *productivity* as constant through time; the same holds for the capital to labour ratio along the same technology. In other words, the adoption of new technologies leads to discrete jumps in the capital to labour ratio, which keeps its constancy with respect to a given technology.

[16]For simplicity, there is no trade-off between different types of investment.

two components:

$$i_{rd,j} = \vartheta_{0,j} \cdot c_{f,av,j} + \vartheta_{1,j} \cdot \left( \bar{\varrho} - \varrho_j \right) \tag{2.6}$$

The first component on the right-hand-side captures firm's expectations about future demand that are equal to the average revenue from past sales of consumption goods.[17] The other component reflects the cost-side of the expected profit rate, provided that the actual profit rate can be seen as an indicator for expected profitability.[18] Firms' profits are sales minus amortization fund, interest payments on past loans and wages:

$$f_j = y_j - af_j - r_l \cdot ld_{-1,j} - wb_j \tag{2.7}$$

where $r_l$ is the given interest rate, $ld_{-1}$ the stock of loans from the past and $wb$ the wage bill.

An important clarification is now necessary: $i_k$ and $i_{rd}$ represent the expenditure each firm does to ameliorate its technology. Since the expenditure related to the investment in capital stock is commissioned to other firms, we call (2.8) the investment *demand*. The random pattern of interactions among firms leads to a configuration in which the single firm produces an average amount of (capital) goods for the others, as in (2.9):

$$i_{d,j} = i_{k,j} + i_{rd,j} \tag{2.8}$$

$$i_{s,j} = \bar{i}_{k,j} \tag{2.9}$$

The capital stock, $k$, is the result of past (depreciated) equipment plus gross investments in physical capital $i_k$:

$$k_j = (1 - \delta) \cdot k_{-1,j} + i_{k,j} \tag{2.10}$$

To conclude this subsection, how do firms finance their (net) investments? We have three options. First, all net investment is financed out of new loans; second, all net investment is financed out of past accumulated wealth; third, the net investment is financed partly out of wealth and partly out of new loans. We adopt the third way and suppose that the entrepreneur contributes to finance her investment decisions with part of past accumulated wealth, say $q \cdot$

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[17]"Firms in the capital-good industry "adaptively" strive to increase their market shares and their profits trying to improve their technology both via innovation and imitation. Both are costly processes: firms invest in R&D a fraction of their past sales" (Dosi et al., 2010). Moreover, $c_{f,av} = \frac{\sum_{i=0}^{t-1} c_{f,i}}{t-1}$.

[18]We suppose firms wish to obtain a normal profit rate $\bar{\varrho}$.

$mh_e$, while the remaining need will be financed out of new loans as follows:

$$dl_{d,j} = i_{d,j} - af_j - q \cdot mh_{-1,j,e} \tag{2.11}$$

where $dl_d$ is the change in loans demand. Furthermore, the single firm can borrow whatever sum it needs from the banking system at a constant rate $r_l$ for convenience.

### 2.4.3 The labour market

Each firm needs a certain amount of effective labour to set out the production process, that is it must consider the productivity of each worker within the enterprise. Denoting with $a$ the effective labour productivity, the labour demand for the single firm is:

$$nd_j = \frac{y_j}{a_j} \tag{2.12}$$

The distribution of income at firm level is divided between profits and wages. The model follows what found in the literature: the worker is given a wage rate and entrepreneurial profits are determined as a residual. We can translate what said in the following equations:

$$w_r = (w_0 - w_1 \cdot u_{r,-1}) \cdot pr_t \tag{2.13}$$

$$wb_j = w_r \cdot nd_j \tag{2.14}$$

The first equation identifies the wage rate $w_r$ as the result of the positive constant $w_0$ and it is a negative function of the unemployment rate $u_r$, since $w_1 > 0$. The wage rate is updated every period to account for inflationary pressures, as denoted by $pr_t$. (2.13) says the lower the unemployment rate and the higher the inflation expectations, the higher the wage rate.[19] The wage bill at firm level $wb$ is the simple product between the wage rate and the number of employees. We mentioned earlier that the labour supply is exogenous and unbinding. We integrate it with the assumption that every worker is willing to accept a job at the going wage rate. Therefore, no firm faces (labour) supply constraints. In other words, the setting admits no over-employment but unvoluntary unemployment.

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[19]It reflects the logic assumed by the new-Keynesian Phillips curve.

### 2.4.4  Households

Households consume and save. They are distinguished between capitalists and workers according to their propensity to save. The flows of income they may receive consist of four components: wage rate, entrepreneurial profits, an amount of bank's profits proportional to their wealth, $\sigma_{mh} \cdot F_{b,t}$, and interest payments on past deposits $int_{mh}$.[20] We write the households disposable income $ydh_i$ as equal to:[21]

$$ydh_i = \begin{cases} w_r + \sigma_{mh,i} \cdot F_{b,t} + int_{mh,i} & \text{if} \quad i = w \\ f_i + \sigma_{mh,i} \cdot F_{b,t} + int_{mh,i} & \text{if} \quad i = e \end{cases} \tag{2.15}$$

For simplicity, agents consume part of their disposable income and part of their accumulated wealth, that takes the form of deposits[22].

$$c_{inc,i} = \begin{cases} \alpha_0 + \alpha_{1,i} \cdot w_{r,-1} & \text{if} \quad i = w \\ \alpha_0 + \alpha_{2,i} \cdot f_{i,-1} & \text{if} \quad i = e \end{cases} \tag{2.16}$$

$$c_{wea,i} = \alpha_{3,i} \cdot (m_{h,-1,i} + \sigma_{mh,i} \cdot F_{b,t} + int_{mh,i}) \tag{2.17}$$

$$c_i = c_{inc,i} + c_{wea,i} \tag{2.18}$$

(2.16) says that the current consumption out of income is composed of an autonomous component $\alpha_0$ and a portion from past income: $\alpha_1$ and $\alpha_2$ are the marginal propensities to consume out of disposable income. (2.17) represents the current consumption out of wealth, dividends and interest payments, equal to a percentage $\alpha_3$ applied to that sum. The consumption function $c$ is the sum of $c_{inc}$ and $c_{wea}$ as in (2.18). What is not consumed is saved ($dm_h$) and accumulated to the stock of deposits:

$$dm_{h,i} = ydh_i - c_i \tag{2.19}$$

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[20]Where $\sigma_{mh} = \frac{m_h}{M_{h,t}}$.

[21]$i = w$ for workers; $i = e$ for capitalists.

[22]For convenience, we suppose households differ in the way they consume the income out of work. No difference exists in the way they consume wealth, interest payments and banking profits, since the marginality of that consumption component.

$$m_{h,i} = \begin{cases} m_{h,-1,i} + dm_{h,i} & \text{if } i = w \\ m_{h,-1,i} + dm_{h,i} - q \cdot m_{h,-1,i} & \text{if } i = e \end{cases} \tag{2.20}$$

### 2.4.5 Innovation dynamics

Innovation is very affected by uncertainty. Potential innovators do not know whether their effort and expenditures to promote technological improvements will succeed or not. A well established evolutionary tradition models firm's innovative activity as a two-step stochastic process (Caiani et al., 2019; Dosi et al., 2010)). We decided to depart from that tradition for two reasons: firstly, we want to keep the model as simple as possible; secondly, we want to respect some empirical regularity in the innovation process. It does not mean nevertheless that our way to analyze innovation does not reflect what found in the Schumpeterian literature: for instance, we may imagine innovation as it took place with the hiring of researchers devoted to the development of a software, the latter improving the technological apparatus of the firm. To begin, we provide the reader with some basic definitions: we shall denote with $a_{jj}$ the labour productivity of the $j^{th}$ firm as result of its effort in R&D, with $a_{ji}$ the labour productivity of the $j^{th}$ firm as result of the imitation process, and $a_j$ the effective labour productivity of the $j^{th}$ firm at some point in time, that is equal to the maximum between $a_{jj}$ and $a_{ji}$ as below. For simplicity, we assume their equality at the very beginning of the analysis, precisely $a_j = a_{jj} = a_{ji} = 1$. Firms incur new loans to improve their technology levels. The literature often emphasizes the R&D expenditure as share of output as the determinant for the growth in productivity or for the innovation rate in the economy. In this contribution, however, we want to stress the role of the total amount of funds invested on innovative research. In fact, two firms may devolve the exact share but if the absolute amount differs, the larger firm will have higher probability to innovate than the smaller one.[23] As said, the more a firm invests on innovative activities, the more probable it innovates. To represent this process, we can define a logistic probability distribution as an increasing function of the amount invested in R&D:[24]

$$\lambda_j = \frac{1}{1 + \exp^{-\varepsilon \cdot i_{rd,av,j} \cdot t}} \tag{2.21}$$

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[23]Think about the comparison between a large firm as Apple and a much smaller one. Suppose both of them invest twenty percent of retained profits: for Apple this share amounts to million dollars; for the smaller one, it can amount to thousand dollars only, at best. Who will be the most probable innovator in the field?

[24]Since there are several probability distributions that may do it for us, we tried an *inverse* exponential function and the Gumbel probability distribution. Results do not change significantly.

$$i_{rd,av,j} = \frac{\Sigma_{i=0}^{t} i_{rd,j}}{t} \tag{2.22}$$

(2.21) is the probability to innovate and it is a sinusoidal function approaching 1 as $t \rightarrow \infty$. The speed with which it tends to 1 is governed by the cumulated amount of resources invested in research and development. This means that the probability each firm has to innovate strictly depends on how much the same firm spends on average. The logistic function has been used quite often in the literature to illustrate the progress of creation and diffusion of an innovation through its life cycle.[25] Precisely, the introduction of new products or processes in the economies spurs an intense amount of research and development leading to strong improvements in cost reduction and quality. The *mid-term* outcome consists of a rapid growth of that industry. Clear examples from the past are railroads, urban electrification, cars, light bulbs and so on. However, once those improvements exhausted, new products or processes are so widespread that markets saturate. Back to (2.21), it is important to underline that $\lambda$ changes from firm to firm, pointing that the ability and probability to introduce innovations are a direct function of the own R&D effort.[26]

To know whether innovation occurs, every firm is assigned a random number drawn from a uniform distribution $p_{inn} = \zeta_1$, where $\zeta_1 \sim U[0;1]$. If this number is smaller than the threshold $\lambda$, the firm innovates. Innovation takes place in the economy as an improvement in labour productivity. Recalling the model focuses on levels and not on growth, labour productivity is a direct function of the average outlay in innovation activities:

$$a_{jj} = a_0 + a_1 \cdot i_{rd,av,j} \tag{2.23}$$

in this way we take into account firm's ability to learn from past achievements.

The imitation process is similar to the innovative one. Let us look at firms as if they were people walking in the street. The single person has got a certain probability to meet somebody. We assume for simplicity that one person cannot meet more than three people in the same period. Moreover, meetings are fully random. We can image each meeting as the single possibility to copy the technology of the competitor. The imitation process occurs with the same law followed by the innovation process.[27] To formalize it, we define a $F \times F$ network matrix, called

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[25] De Tarde (1903) was the first.

[26] That is tantamount to introduce path dependency and irreversibility in the model.

[27] We assume individuals make use of only local knowledge and make transaction with positive probability as long as it is beneficial to them.

$imi_{net}$. Its cells take value 1 if a connection between two firms is established, and 0 otherwise. Once we got all the linkages, we record in $a_{ji}$ all the potential productivity levels that a firm can reach through the imitation of its competitors. Then, the firm compares the productivity levels from imitation and home-innovation, choosing the best-performing technique and updating its productivity. As before, every firm is assigned a number drawn from a uniform distribution, $p_{imi} = \zeta_2$, which is compared to the $\lambda$ threshold above. This represents an important feature of the model: the probability the firm has to imitate strictly depends on its amount of innovative investments. In other terms, we do exclude *free-rider* or opportunistic behaviours. Therefore, if $p_{imi} < \lambda$ a firm may imitate when $i_{rd} > 0$. Then:

$$a_j = max\ [a_{jj}; a_{ji}] \tag{2.24}$$

### 2.4.6   The banking system

Schumpeter (1982) places the banking system side by side with the creative entrepreneur, as is the case of a symbiotic relationship. The former makes innovative investments possible through the opening of a credit line for the necessary expenditures, while at the same time the banker is offered a possibility to earn money by the innovative businessman.[28]

In reality banks discriminate between clients according to their credit worthiness by credit rationing. In the AB literature, it is quite common to assume banks discriminate through higher or lower interest rates on loans. Since we are not very concerned to banks' behaviours in financial markets, we suppose that the banking sector is composed of an aggregate bank and constitutes a pure accommodating agent. It provides production firms with loans to finance their investment plans and gathers whatever amount of deposits the public wishes to hold. For simplicity, households' accumulated wealth takes the form of bank-account deposits only. For the same reason above, the big bank sets constant interest rates: it finances loans at a rate $r_l$ and rewards deposits with a rate $r_h$. Obviously, $r_l > r_h$ strictly holds. The equations describing the bank's behaviour are the following:

$$int_{ld,j} = r_l \cdot \sigma_{ld,j} \cdot L_{d,t-1} \tag{2.25}$$

$$int_{mh,j} = r_h \cdot \sigma_{mh,j} \cdot M_{h,t-1} \tag{2.26}$$

$$F_{b,t} = r_l \cdot L_{d,t-1} - r_h \cdot M_{h,t-1} \tag{2.27}$$

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[28]For simplicity, we assume no credit constraints.

(2.25) describes the interest payments the bank picks from each firm according to its share on total loans, $\sigma_{ld} \cdot L_{d,t-1}$.[29] (2.26) reflects how the bank rewards the single household's deposit, according the its share on total wealth, $\sigma_{mh} \cdot M_{h,t-1}$. (2.27) is the banking profits equation. To ensure consistency, bank's profits are distributed to households as in (2.15).

### 2.4.7 Prices, mark-up and inflation expectations

The model does not involve the production of public goods, hence the prices we should consider come from the unit price of private output. Firms set the price as a mark-up over unit labour costs:

$$p_j = (1 + \mu_j) \cdot \frac{w_r}{a_j} \tag{2.28}$$

The mark-up is set by the entrepreneurs according to the market-share *differential*:

$$\mu_j = \mu_0 + v \cdot (\sigma_{m,-1,j} - \bar{\sigma}) \tag{2.29}$$

where $\mu_0$ and $v$ are constant while $(\sigma_{m,-1,j} - \bar{\sigma})$ indicates that the mark-up increases when the market share is above the median market share and decreases in the opposite case.[30]

The market share will be determined accordingly as follows:[31]

$$\sigma_{m,j} = \frac{y_j}{Y_t} \tag{2.30}$$

The inflation rate is the percentage change in the (average) price level and it is obtained once average prices are computed:

$$\bar{p} = \frac{1}{F}\Sigma_{j=1}^{F}p_j \tag{2.31}$$

$$\pi_t = \frac{\bar{p}_t}{\bar{p}_{t-1}} - 1 \tag{2.32}$$

Inflation enters the model through its influences on investment and consumption decisions.[32] We define the expected inflation rate $\pi^e$ as:

$$\pi^e = \psi_0 + \psi_1 \cdot (\pi^T - \pi_{t-1}) + \pi_{t-1} \tag{2.33}$$

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[29]Where $\sigma_{ld} = \frac{l_d}{L_{d,t}}$.

[30]The assumption resembles and simplifies what found in Dosi et al. (2010).

[31]$Y_t$ is the value of aggregate production in the economy.

[32]We adopt a *regressive* inflation-expectations process since it "[...] provides a more accurate approximation of how economic agents make their decisions in the real world" (Sawyer and Passarella, 2019).

where $\pi^T$ is the target inflation rate while $\psi_0$ and $\psi_1$ are non-negative parameters. The expected price level $p^e$ is:

$$p_t^e = (1 + \pi^e) \cdot \bar{p}_{t-1} \tag{2.34}$$

The final step consists of introducing the following term into the target-capital and wages functions, defined as the ratio between expected and actual prices:

$$pr_t = \frac{p_t^e}{\bar{p}_t} \tag{2.35}$$

## 2.5   Empirical validation

The model is run through 450 periods on quarterly basis. It does not allow for analytical, closed-form solutions. The latter is a general characteristic of AB models and comes from the many non-linearities in the agent decision rules and patterns of interaction. Most coefficients and initial values of variables are either borrowed from the literature or given reasonable values. For instance, each firm is endowed with a single unit of (capital) good in the first period of the simulation. The symmetry condition is borrowed from Caiani et al. (2016b). However, key coefficients of key behavioural equations are given stochastic values varying agent by agent. Examples are the marginal propensities to consume out of income, the coefficient in the R&D investment function and so on. Tab. B.7 clarifies which parameter varies and which does not. It is important to underline that the symmetric condition of agents' initial characteristics does not prevent that heterogeneity emerges in subsequent stages of the model, as outcome of interactions among agents. The adoption of stock-flow norms since the very beginning dampens the arbitrariness of behavioural parameters and influences from purely stochastic factors. At the same time, we perform 100 Monte Carlo runs to wash away the variability across simulations. As clarified by Dosi et al. (2010): "Monte Carlo distributions are sufficiently symmetric and unimodal to justify the use of across-run averages as meaningful synthetic indicators".[33]

Fig. B.4 displays average trends surrounded by their standard deviations for the main variables of interest. The figure shows that the model first experiences the usual *burn-in* period, converging to a relatively stable configuration after 50 periods circa. We call this situation a *stationary state* as defined in the footnote above. However, convergence toward a stationary state does not imply *stasis*: a roller-coaster dynamics generates persistent fluctuations at the

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[33]We must nonetheless recognise that averages flatten differences within and between simulations, possibly hiding some interesting features occurring in each simulation.

business-cycle frequencies.[34]  This is confirmed also by the amplitude of standard-deviation intervals around the average trend.[35]  In addition to this, the model is stock-flow consistent as plotted in Fig. B.5: the adoption of stock-flow consistency norms since the very onset diminishes the arbitrariness of behavioural parameters and the influences from purely stochastic factors.

Output, consumption and the unemployment rate exhibit a unit root, so they are nonstationary: that can be ascertained through Tab. B.8 in which we applied either the ADF test or the KPSS test for unit roots. By contrast there is uncertainty for aggregate investments: the ADF test does not find a unit root in the time series, but the KPSS does.

Fig. B.6 compares the volatility structure of main aggregate variables in the model through a comparison of their cyclical components: consumption, investment, output, investment in physical capital and innovative research, productivity and the unemployment rate. We have separated trends and cyclical components using the Hodrick-Prescott filter. However, we are well aware of that assuming trends and cycles as *additive* is a very simplifying hypothesis. Furthermore we normalized the cyclical component by the trend to allow for a comparison on same scales. The artificial time series replicate well-known empirical evidence such as in Napoletano et al. (2006), Fagiolo et al. (2008). In particular, investment components and the unemployment rate are indeed more volatile than output and consumption, while the latter is almost as volatile as output.[36]

Fig. B.7 exhibits the auto-correlation function of our de-trended series, looking similar to what observed in empirical data.[37]  Most variables possess positive and significant auto-correlations which do not go beyond the fifth lag, while labour productivity does not show any significant auto-correlation. More precisely, aggregate investment, its components and the unemployment rate have significant first-order auto-correlations, while consumption and output extend the significance until the fifth lag. By contrast, the result for labour productivity is probably

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[34]A recent debate on the literature emphasizes the surge of Harrodian instability in agent-based models (Botte, 2019; Franke, 2019; Russo, 2020). More precisely, although firms strive to reach a normal capacity utilization rate at the micro-economic level, the accelerator effect from their investment schedule does not allow firms to satisfy their goal on aggregate (Botte, 2019). The present setting does not suffer from such an instability for several reasons: first and foremost, it does not deal with economic growth, so firms attain a stationary state in their rate of capacity utilization, and second, the heterogeneity among firms helps avoid the puzzle as highlighted by Russo (2020). We do not report the figure corresponding to the aggregate capacity utilization rate for brevity; it is none the less available on request.

[35]A common practise in AB models is that of doing away the initial periods of the simulations. They concern to the transient phase before convergence and they are strongly affected by initial conditions. We nonetheless display also those periods for completeness of exposition and for the reasons in Caiani et al. (2016a).

[36]Consumption should actually be a bit less volatile than output. This is not very clear in the model probably due to our assumption about consumption functions.

[37]Dashed lines in the plots indicate whether correlations are significant.

due to the imitation process, that allows for *breaks* with respect to preceding developments. Fig. B.8 captures the cross-correlation function of the previous variables with respect to aggregate production. In tune with the literature above, consumption and aggregate investments are pro-cyclical and lead output. Productivity displays a clearly pro-cyclical and slightly leading pattern while unemployment is counter-cyclical and lagging. We have to spend nonetheless some words on the investment behaviour at micro-economic level. There is an important body of literature showing that investment decisions are dictated by an opportunity-cost effect: if firms experience a sales boom and in the absence of tight credit constraints, they will prefer allocating their human and physical assets to current production. Hence, longer-term (innovative) investments should be counter-cyclical, while short-term investments are pro-cyclical.[38] However, Napoletano et al. (2006) found empirical evidence that aggregate investments are pro-cyclical and synchronized with − or slightly leading − the business cycle. Our model does not explicit any remarkable trade-off between short-term or long-term investments or between investments in tangible and intangible assets. Additionally, we do not model any particular credit-market constraint. So, our results are consistent with either Aghion et al. (2010, 2012) or Napoletano et al. (2006), since R&D investments are counter-cyclical but aggregate investment is pro-cyclical. The reason lies in the greater amount of investments in tangible capital at firm level, which is pro-cyclical. This feature more than counterbalances the counter-cyclicality in R&D on aggregate. Anyhow, the debate is still open on that point and we deserve further attention in future research.[39]

Beside these macroeconomic stylized facts, the model is able to replicate micro- and meso-economic empirical evidence. First of all, we have properties about firms size distribution. The literature on the topic says that manufacturing industries are characterized by skewness and heavy-tailedness in firms distribution (Bottazzi and Secchi, 2003, 2006). We consider three proxies for size: sales of consumption commodities, production of either consumption and capital goods, and the employment level. The threefold choice helps us to gain some robustness in the results. Fig. B.9 shows an interesting outcome: our proxies can be perfectly fitted by a gamma probability distribution, which is right-skewed and presents a tail heavier than normal distribution. In other words, the model leads to a configuration in which the economy is populated

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[38] In contrast, the huge presence of credit constraints makes long-term investments pro-cyclical. For further detail, see Aghion et al. (2010, 2012), Chiao (2001) and Rafferty and Funk* (2004).
[39] Still, for further detail, check Stock and Watson (1999).

by many small firms and few big enterprises.[40]

Bottazzi and Secchi (2003) deal with moments of firm size too; they argue that moments are generally stationary and trendless, with some exception about the mean. Tab. B.9 and Fig. B.10 display our findings. Although moments are clearly stationary according to the standard ADF test, we cannot express a uniform opinion about trends. Precisely, there is no doubt about the trendless-ness of skewness and kurtosis for each proxy of firm size; however, either the means or the standard deviations seem to exhibit a significant trend, a trend which is positive for employment while negative for production and sales. We have to remark that, albeit statistically significant, the corresponding trend magnitude is very tiny.

A further feature out of the model is the heterogeneity in productivity that distinguishes our firms, as we may appreciate from Fig. B.11. We are not able to provide a good probability distribution for productivity differentials; nevertheless, it is clear that heretogeneity takes the form of high skewness with the right tail heavier than in the normal distribution case. Bartelsman and Doms (2000) claim that productivity levels are quite dispersed and differentials reflect the differences in the outcomes of technological bets: even if the entrepreneurs bet the same, they may not reap the same rewards because of uncertainty.

Finally, investments are heterogenous and possibly lumpy as in Figs. B.12 and B.13, i.e. firms do experience investment spikes and co-exist with near-zero investment firms (Dosi et al., 2010). Abundant literature shows that investments in manufacturing is characterized by periods of intense activity interspersed with periods of much lower one (Caballero, 1999; Doms and Dunne, 1998). However, we should remark that lumpiness has been modeled in economics through $(S, s)$ investment functions. This family of schedules are able to display discontinuities not visible with linear investment functions as ours. So, if our framework gets lumpiness, that arises out of two main determinants: the matching process between firms and consumers, and the process of creation and diffusion of innovations. Such mechanisms allow for discontinuities in the demand each firm faces, so they affect investment patterns leading to high-investment periods followed by a longer calm.

To conclude this Section, Tab. B.10 reports to the wide spectrum of real stylized facts matched by the model. We remark again that our firm-level analysis has been possible through the adoption of the AB procedure. Standard macro-models, for instance, do not allow for such a

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[40]We will see in the next chapter that economic growth let firm size move from a gamma toward a log-normal distribution, which looks more skewed and heavier-tailed. Additionally, the latter is in line with the shapes described by Bottazzi and Secchi (2003).

deepening. Furthermore, the empirical validation gives robustness to our policy experiments. The outcomes we get suggest that the observed correlation structures are not simply dependent on specific parametrizations of the model: as explained by Caiani et al. (2016a), if we changed the parameters of the model, we would obviously get differences in the behaviour of the agents and consequently aggregate results would differ; however, the inherent properties of the model in term of correlation structure and the way variables impact on each other would be the same and not tied to a specific set of parameters.

## 2.6 Policy experiments

Once the model approaches to the stationary state, we shock it. In other terms, we modify the value of some parameter or exogenous variable to see how the economy reacts and then compare the different stationary states. Six policy options are tested in the next few pages, namely:

- a decrease in the exogenous coefficient of the wage equation, $w_0$;

- an increase in the exogenous coefficient of the wage equation, $w_1$;

- a cut in the interest rate on loans, $r_l$;

- a cut in the interest rate on deposits, $r_h$ ;

- an increase in the meetings per unit of time, *meet*;

- an increase in the parameter of the threshold function $\lambda, \varepsilon$.

The first and the third policies are the most important, since they concern to the role played by the functional distribution of income and the interest rate. The second and fourth policies help check if the model works as expected and help us confirm previous results. Finally, the last two are about an enlargement of innovation and imitation possibilities.[41]

### 2.6.1 The role of income distribution

The reason to test the role exerted by wages lies in the general disagreement found in the literature.[42] On the one hand, some can argue that high wages squeeze profits and reduce

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[41] A caveat for the reader: Fig. B.14 through B.19 exhibit policy results in values relative to the baseline surrounded by the standard deviation, as common to the literature.

[42] Check Stockhammer (2017) and Onaran and Galanis (2012) for further detail.

investments, while keeping them in check frees resources and helps increase output and employment. On the other hand, high wages foster aggregate demand, enhancing investment outlets and providing incentive for a dynamic mechanization of the productive process. Positive effects are then reflected on higher profits.

The parameter $w_0$ can be seen as the balance of the social conflict between workers and entrepreneurs in the economy as a whole. In contrast, $w_1$ allows for the endogenization of the wage rate and represents the influence exerted by the unemployment rate of precedent period. Fig. B.14 displays the results of a social compromise more favourable to capitalists, hence a lower $w_0$. If compared to the baseline scenario, lower wages result in worse economic performances. Wages sustain indeed consumption and, indirectly, investments. A lower aggregate demand reduces capitalist's incentive to invest either on capital stock or on innovation activity at the micro-economic level. The reason lies in the fact that firms try to adjust the capital stock to reach a normal capital-output ratio as in (2.2). If target output declines, so does target capital and firms start disinvesting. On the same line, the decrease in sales, on the one hand, and the concomitant smaller discrepancy between the normal and the actual profit rate, on the other hand, do not provide the incentive to perform R&D and save labour. Firms will find more convenient to adapt the productive process to less labour-saving techniques. The result will be a worse general economic performance on aggregate.[43]

The same holds in Fig. B.15 from an increase of $w_1$: as in (2.12), that policy is another way to shifting income toward profits. Although results are qualitatively similar to the above, the impact of this change is very tiny, if compared to the former.

In conclusion, we trace out from the first set of policy experiments the positive influence of higher wages in triggering a process of economic development and innovation achievements. To put things differently, the improvement of labour market regulation, the centralization of the industrial relation system or other pro-worker measures help achieve better results in terms of long-run performances, such as lower unemployment rates or higher capital accumulation and productivity. This is line with Allen (2009, 2011) and Dosi et al. (2018).

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[43]The shift toward less labour-saving techniques could have resulted in higher employment rates, which in turn might have prompted an increase in aggregate demand. In that case, a distribution of income more favourable to profits would have resulted in better economic performance. However, the negative effect of low wages more than compensated that *positive* effect, as clear in the bottom-left panel of Fig. B.14.

## 2.6.2   The role of interest rates

The economic literature always asked whether, and how, the interest rate spurs the economic activity. The neoclassical belief is that a cut in the rate of interest stimulates the expansion of production since capitalists are less burdened by the service of debt. Theoretical arguments in the line of Petri (2004) and Girardi (2016) assume the rate of interest does not directly influence investment decisions. Although we follow this line of reasoning, there are yet several channels through which the interest rate could affect investments and the economic performance as a whole: an example is the impact of a lower service of debt as mentioned earlier. Fig. B.16 shows the effect of a decrease in the rate of interest on loans applied to firms, $r_l$. As we can see, the result is interesting. A lower service of debt increases the amount of profits in capitalists' pockets; that translates into higher consumption levels out of capitalist income, which contribute to sustaining aggregate demand. Investments in capital stock will rise accordingly at the micro-economic level, since the entrepreneurs will adjust the capital stock to fulfill a higher target capital requirement. Nevertheless, we notice a different pattern for the innovative search and for productivity. The decrease in the interest rate on loans raises the profit rate of the individual firm, so it eases the entrepreneur to reach a normal profit rate. Facing lower competitive pressures, the capitalist reduces her innovative investment and labour productivity will be lower than in the baseline scenario. To put that differently, we have a disentanglement: although the economic activity stands in higher levels of aggregate production and employment, the innovative rate at firm level is not encouraged since entrepreneurs prefer adapting production to less labour-saving techniques.[44]

In contrast, Fig. B.17 displays the effect of a cut in the interest rate on money deposits, $r_h$. It is easy to see that our variables of interest are affected in no way. Lower interest rates on savings diminish the load of interests paid to households and increase bank profits accordingly. The outcome is a reduction in the households' disposable income. However, on the other hand, we assumed that banking profits are fully distributed to households according to their wealth share. Moreover, we posited in (2.17) that the marginal propensity to consume out of interest payments and banking profits is the same, $\alpha_3$. Therefore, what comes out of door, as interests, falls through the window, as profits. The economic system performs as nothing happened.

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[44]We should however say that the reduction in the innovative search is quantitatively little, albeit qualitatively important.

### 2.6.3    Experiments on the innovation possibilities

The last set of experiments consists of loosening the *barriers* to innovation and imitation. The economic theory spent a lot of effort to judge whether the protection of intellectual property rights is a vehicle, or not, for further innovation attainments, coming to heterogeneous conclusions. Our simple setting does not allow for very complex analyses, but it could nonetheless provide some insights. In what follows we test an increase in the maximum number of meetings per unit of time, *meet*, and an increase of a parameter in the threshold function $\lambda$, $\varepsilon$. Both of them may affect the innovation and the imitation rates in the economy, increasing the flow of ideas at the meso-economic level.

Fig. B.18 is about an increase in the parameter *meet*. In Section IV we described it as the measure of the network size around the single capitalist. More meetings per unit of time consist of more potential competitors from which to imitate and, at the same time, more exposure toward competitor's imitation. However, the first hypothesis seems prevailing: the higher capability to imitate raises labour productivity at firm level and profits. More profits, more spending out of capitalist income and hence more sales. Further achievements in labour productivity are then possible through (2.21). The new stationary state is higher than the baseline. However, the positive effects are evident in the very long run only, while in the short-to-medium run results are very uncertain, because of the increased volatility around the average trends. Furthermore the impact on the unemployment rate is doubtful in the long term too.

Something similar occurs through a slight increase in $\varepsilon$. In (2.21) it represents the speed with which the logistic function $\lambda$ converges to 1. We recall that $\lambda$ is the probability to innovate and imitate according to the level of R&D outlays. The greater $\varepsilon$, the greater $\lambda$, the greater the labour productivity and the firm's profits. The economy gravitates around higher stationary states as in Fig. B.19. Anyway, the positive outcomes, if any, are circumscribed to the very long period.

## 2.7    Conclusions

The aim of Part I was to set Secular Stagnation into the agent-based perspective and to provide some insights on the matters affecting the US economy since the end of the Golden Age of capitalism (1950-1973). Crucial features of the American economy are the very remarkable slowdown in growth of federal R&D expenditures and the redirection, by many leading firms, of resources and attention from more exploratory scientific research towards more commercially-

oriented projects (Arora et al., 2018). They accompany the mounting retrenchment of the wage share and the decreasing productivity growth noticeable since 1973.

We developed a simple agent-based, stock-flow consistent model for a one-good two-class closed economy without government sector. The distribution of income between wages and profits is pivotal to determine the intensity of R&D activity within the economic system. Though the very simple framework, the model shows that distributions of income more favourable to wages, the improvement of the social protection system, the centralization of the collective bargaining structure or any other pro-labour policy result in better economic performances on aggregate, since production, capital accumulation and labour productivity would gravitate around higher stationary states. The American economy experienced a strong weakening of all these institutions in the last decades and that can help give a justification for the problem of Secular Stagnation as we define it. Obviously, we admit that this is not the *only* valid reason for the long-run tendency of productivity growth to fall. Non-technological motives, like lower top marginal tax rates, increased low-skill immigration, rising trade with China and low-cost manufacturing countries or the rise of superstar firms (Autor et al., 2020) are equally plausible. As a side exercise, we tested also the role exerted by the rate of interest and the loosening of barriers to innovation and imitation. On the one hand, the decrease in the interest rate leads to particular results: it helps increase aggregate production and employment levels but impacts negatively on labour productivity, since the entrepreneurs reach more easily a normal profit rate and prefer organizing the production process to less labour-saving techniques. On the other hand, loosening the barriers to the interaction among firms and increasing the possibility to exchange ideas through imitation allow for further innovation and better economic performances as a whole, but the effect is circumscribed to the long run only.

To conclude, though we are aware of the limitations of the model, the adoption of an agent-based framework helps reply to Prof. Robert Solow's call for more realistic micro-foundations (Solow, 2008). On the one hand, agent-based models allowed us to get and study the emergence of skewness and heterogeneity in firm's size distribution and productivity differentials; moreover, the firm-level analysis with its implications would not have been possible with standard economic models otherwise. As in Bowles (2009): "An adeguate theory must illuminate the process by which group structure emerges in a population of individuals, how the boundaries among the resulting higher-level entities are maintained, and how they pass out of existence". Nonetheless, the model cannot deal with *growth* questions yet. We promise therefore we would improve the model in future research to address these topics, namely in the last chapter.

# Appendix B

# Tables and Figures

| Time - Variable | Adjusted wage share | Labour Productivity | TFP |
|:---:|:---:|:---:|:---:|
| 1950 − 73 | 0.674 | 0.027 | 0.018 |
| 1973 − 95 | 0.656 | 0.017 | 0.006 |
| 1995 − 07 | 0.642 | 0.026 | 0.012 |
| 2007 − 19 | 0.613 | 0.015 | 0.005 |

Note: author's own calculations on Ameco and BLS data. Data on wage share are available since 1960. We applied the HP-filter to focus on the trend component only.

Table B.1. Average wage share and average growth rates for labour productivity and TFP

| Time - Variable | Federal | Other - Gov't | Industry | Non-profits | University | Total |
|:---:|:---:|:---:|:---:|:---:|:---:|:---:|
| 1953 − 73 | 0.028 | 0.032 | 0.027 | 0.035 | 0.036 | 0.028 |
| 1973 − 95 | 0.004 | 0.014 | 0.022 | 0.023 | 0.028 | 0.014 |
| 1995 − 07 | 0.008 | 0.016 | 0.016 | 0.030 | 0.023 | 0.014 |
| 2007 − 17 | −0.001 | 0.005 | 0.014 | 0.021 | 0.019 | 0.010 |

Note: author's own calculations on AAAS data. Data are available since 1953 for each variable. We applied the HP-filter to focus on the trend component only.

Table B.2. Average growth rates in US R&D expenditures by source

| Time - Variable | Defense | Energy | General Science | Health | Natural Resources | Non-defense | Other | Space |
|---|---|---|---|---|---|---|---|---|
| $1953 - 73$ | 0.027 | 0.066 | 0.043 | 0.065 | 0.042 | 0.062 | 0.046 | 0.082 |
| $1973 - 95$ | 0.008 | 0.003 | 0.005 | 0.018 | 0.005 | 0.002 | $-0.001$ | $-0.011$ |
| $1995 - 07$ | 0.012 | $-0.024$ | 0.023 | 0.025 | $-0.004$ | 0.013 | 0.003 | $-0.001$ |
| $2007 - 18$ | $-0.020$ | 0.019 | 0.006 | 0.001 | 0.002 | 0.002 | $-0.004$ | 0.002 |

Note: author's own calculations on AAAS data. Data are available since 1953 for each variable. We applied the HP-filter to focus on the trend component only.

Table B.3. Average growth rates in US Federal R&D expenditures by function

| Time - Variable | R&D as % of GDP | Private R&D as % of Fixed Investments | Federal R&D as % of Discretionary Outlays | Federal R&D as % of Total Outlays |
|---|---|---|---|---|
| $1950 - 73$ | 0.022 | 0.078 | 0.144 | 0.092 |
| $1973 - 95$ | 0.026 | 0.104 | 0.117 | 0.052 |
| $1995 - 07$ | 0.027 | 0.137 | 0.124 | 0.045 |
| $2007 - 18$ | 0.029 | 0.155 | 0.109 | 0.038 |

Note: author's own calculations on AAAS and BEA data. Data are available since 1962 for variables referred to Federal R&D. We applied the HP-filter to focus on the trend component only.

Table B.4. R&D shares, I

| Time - Variable | Defense as % of Defense Outlays | Non-defense as % of Total Budget | Non-defense as % of Non-defense Outlays |
|---|---|---|---|
| $1962 - 73$ | 0.119 | 0.041 | 0.197 |
| $1973 - 95$ | 0.120 | 0.022 | 0.114 |
| $1995 - 07$ | 0.141 | 0.019 | 0.107 |
| $2007 - 18$ | 0.116 | 0.017 | 0.103 |

Note: author's own calculations on AAAS data. We applied the HP-filter to focus on the trend component only.

Table B.5. R&D shares, II

| Ordinary Correlation — | Adjusted Wage Share | Labour Productivity | TFP | Federal | Industry | Non-profits | Other - Gov't | Universities | Total |
|---|---|---|---|---|---|---|---|---|---|
| Adjusted Wage Share | 1 | | | | | | | | |
| Labour Productivity | 0.354*** | 1 | | | | | | | |
| TFP | 0.482*** | 0.940*** | 1 | | | | | | |
| Federal | 0.319*** | 0.294*** | 0.172 | 1 | | | | | |
| Industry | 0.512*** | −0.349*** | −0.123 | 0.185 | 1 | | | | |
| Non-profits | −0.040 | 0.174 | 0.054 | 0.409*** | 0.196 | 1 | | | |
| Other - Gov't | 0.555*** | 0.445*** | 0.457*** | 0.602*** | 0.417*** | 0.680*** | 1 | | |
| Universities | 0.702*** | 0.286** | 0.475*** | 0.496*** | 0.710*** | 0.221 | 0.770*** | 1 | |
| Total | 0.158 | −0.207 | −0.205 | 0.739*** | 0.655*** | 0.564*** | 0.522*** | 0.538*** | 1 |

Note: author's own calculations. Star significance: *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$.

Table B.6. Ordinary correlation among some variables

| Notation | Description | Value |
|---|---|---|
| $Time$ | Time span | 450 |
| $MC$ | Monte Carlo runs | 100 |
| $F$ | Firms | 100 |
| $N_s$ | Workers-Consumers | 500 |
| $\alpha_0$ | Autonomous consumption | 0.001 |
| $\alpha_1$ | Worker's marginal propensity to consume out of income | $[0.75; 0.9]$ |
| $\alpha_2$ | Capitalist's marginal propensity to consume out of income | $[0.5; 0.7]$ |
| $\alpha_3$ | Marginal propensity to consume out of wealth | $[0; 0.1]$ |
| $a_0$ | Labour-productivity initial value | 1 |
| $a_1$ | Coefficient in the productivity equation | 0.75 |
| $\delta$ | Capital depreciation | 0.05 |
| $\varepsilon$ | Parameter in the threshold function | 0.05 |
| $\varphi$ | Inverse normal capital-output ratio | 1 |
| $i_0$ | Autonomous investment | 0.8 |
| $i_1$ | Partial-adjustment coefficient | $[0.15; 0.2]$ |
| $\mu_0$ | Coefficient in the mark-up equation | 0.075 |
| $meet$ | Meetings per unit of time | 5 |
| $\psi_0$ | Coefficient in the price expectations function | 0 |
| $\psi_1$ | Coefficient in the price expectations function | 0.01 |
| $q$ | Share of capitalist wealth re-invested | 0.0027 |
| $r_l$ | Interest rate on loans | 0.0075 |
| $r_h$ | Interest rate on deposits | 0.0025 |
| $\vartheta_0$ | Coefficient in the R&D investment function | $[0.007; 0.008]$ |
| $\vartheta_1$ | Coefficient in the R&D investment function | 0.15 |
| $v$ | Coefficient in the mark-up function | 0.02 |
| $w_0$ | Coefficient in the wage equation | 0.7 |
| $w_1$ | Coefficient in the wage equation | 0.005 |
| $\zeta_1$ | Stochastic component from a uniform distribution | $[0; 1]$ |

Note: shaded lines denote variables whose value differs between agents.

Table B.7. Time span, number of agents, parameter setting and exogenous variables

|  | ADF test | KPSS test |
|---|---|---|
| Output | −1.7895 | 2.1682 |
|  | (0.3855) | (0.739) |
| Consumption | −1.5761 | 2.1783 |
|  | (0.4938) | (0.739) |
| Investment | −6.9708 | 1.6494 |
|  | (0.000) | (0.739) |
| Unemployment rate | −1.7992 | 2.1657 |
|  | (0.3807) | (0.739) |

Note: ADF test assumes unit root in the null hypothesis, while the KPSS test supposes time-series are stationary. We delete the first one hundred period simulations to focus entirely on the stationary state.

Table B.8. Unit root test on selected aggregate variables

|  | Sales | | Production | | Employment | |
|---|---|---|---|---|---|---|
|  | Trend $\beta$ | ADF test | Trend $\beta$ | ADF test | Trend $\beta$ | ADF test |
| Mean | $-6.80E-05^{*}$ | $-8.1309^{***}$ | $-0.0001^{***}$ | $-17.8379^{***}$ | $0.0007^{***}$ | $-11.4832^{***}$ |
| Standard deviation | $-0.0003^{***}$ | $-14.7695^{***}$ | $-0.0005^{***}$ | $-17.27723^{***}$ | $-2.50E-05$ | $-6.4327^{***}$ |
| Skewness | $-0.0001$ | $-19.7903^{***}$ | $-0.0001$ | $-19.5577^{***}$ | $-0.0001$ | $-20.4145^{***}$ |
| Kurtosis | $0.0003$ | $-12.6002^{***}$ | $7.17E-05$ | $-19.0745^{***}$ | $5.45E-05$ | $-19.3862^{***}$ |

Note: moments are computed after $t = 100$, so when the model already gravitates around the stationary state. ADF test assumes unit root in the null hypothesis, while the KPSS test supposes tie-series are stationary. Star significance: $^{***}p < 0.01$, $^{**}p < 0.05$ and $^{*}p < 0.1$.

Table B.9. Moments of firms size distribution

| Stylized facts | Tables - Figures | References |
|---|---|---|
| **Micro-economic level (firms)** | | |
| Skewness and heavy tailed-ness firm size distribution | Fig. B.9 | Bottazzi and Secchi (2003, 2006) |
| Moments of size distribution are stationary | Tab. B.9, Fig. B.10 | Bottazzi and Secchi (2003); Dosi et al. (2010) |
| Heterogeneous productivity across firms | Fig. B.11 | Bartelsman and Doms (2000); Bottazzi and Secchi (2003) |
| Investment heterogeneity and lumpiness | Figs. B.12- B.13 | Caballero (1999); Doms and Dunne (1998) |
| **Macro-economic level (aggregate)** | | |
| Fluctuations at business-cycle level | Fig. B.4 | Caiani et al. (2016a); Stock and Watson (1999) |
| Stock-flow consistency | Fig. B.5 | Godley and Lavoie (2006) |
| Output components and unemployment are non-stationary series | Tab. B.8 | Blanchard and Summers (1986); Hamilton (2020); Nelson and Plosser (1982) |
| Volatility of output, investment, consumption and unemployment | Fig. B.6 | Stock and Watson (1999) |
| Cross-correlations among macro-variables | Figs. B.7- B.8 | Stock and Watson (1999) |

Table B.10. Stylized facts matched by the model
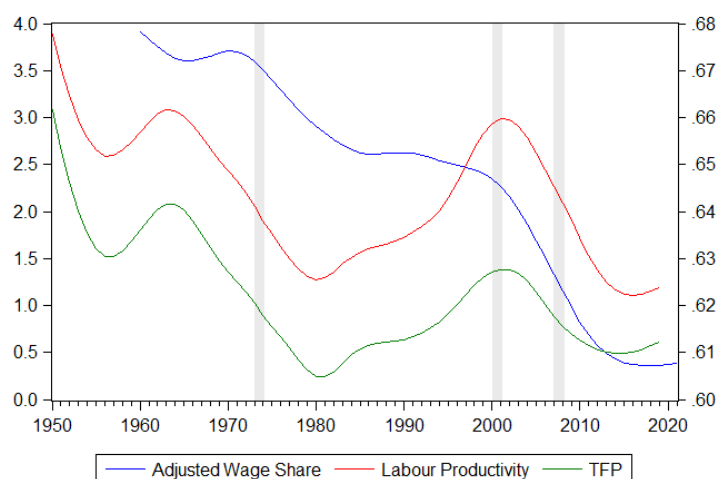
Note: left axis refers to productivity growth rates, right axis to the wage share; shaded areas indicate major crises; we reported results of the HP-filter trend component of real time series so to focus on the long-run component. Source: author's calculations on Ameco and BLS data.

Figure B.1. US adjusted wage share and productivity growth rates, 1950-2018
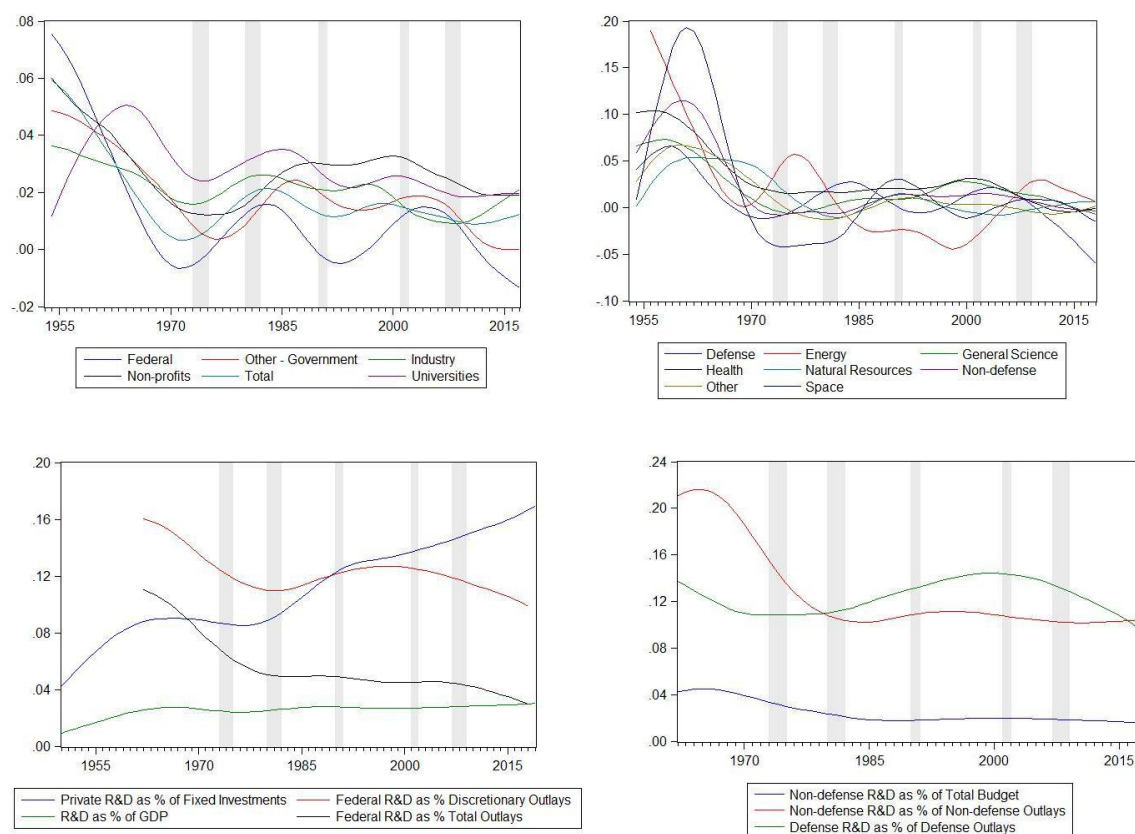
Note: top-left graph points to R&D expenditure by source, top-right graph refers to R&D expenditure by function, bottom graphs point to R&D shares in some aggregate; shaded areas indicate major crises; we reported results of the HP-filter trend component of real time series so to focus on the long-run component. Source: AAAS data.

Figure B.2. US R&D expenditures, 1953-2018
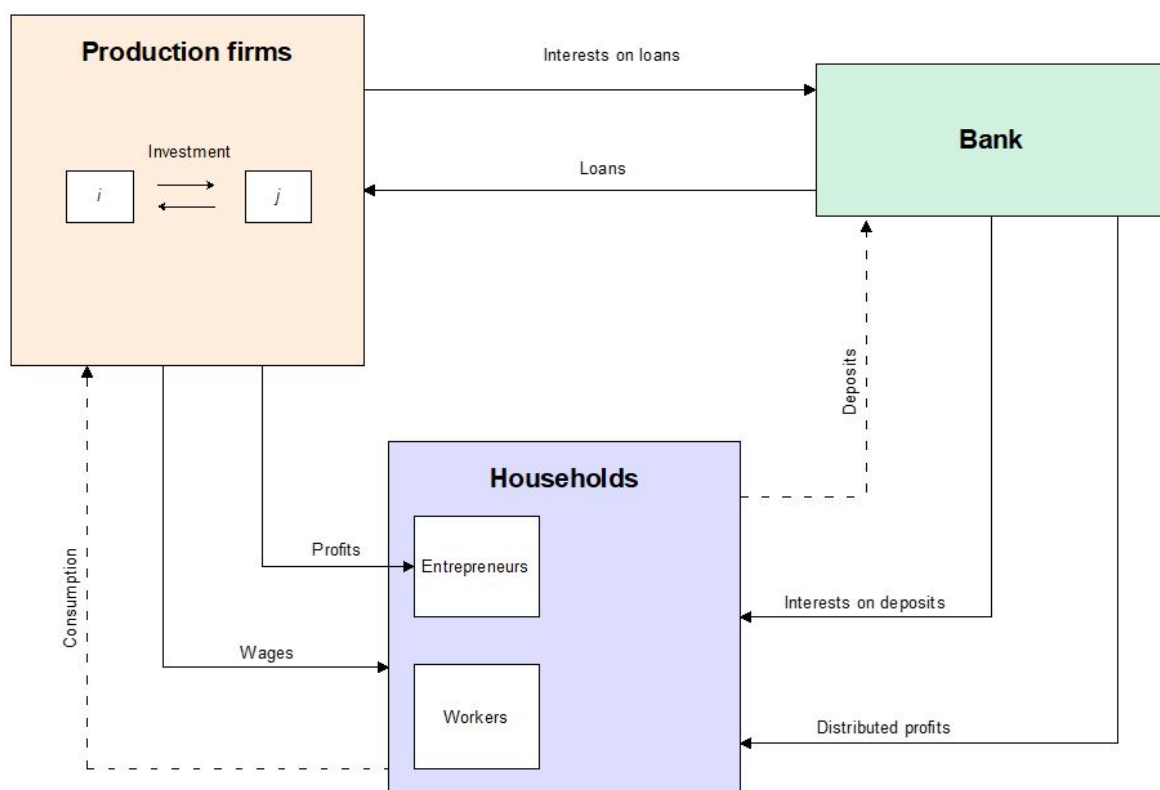
Note: arrows point from paying sectors to receiving sectors.

Figure B.3. Flow diagram of the model
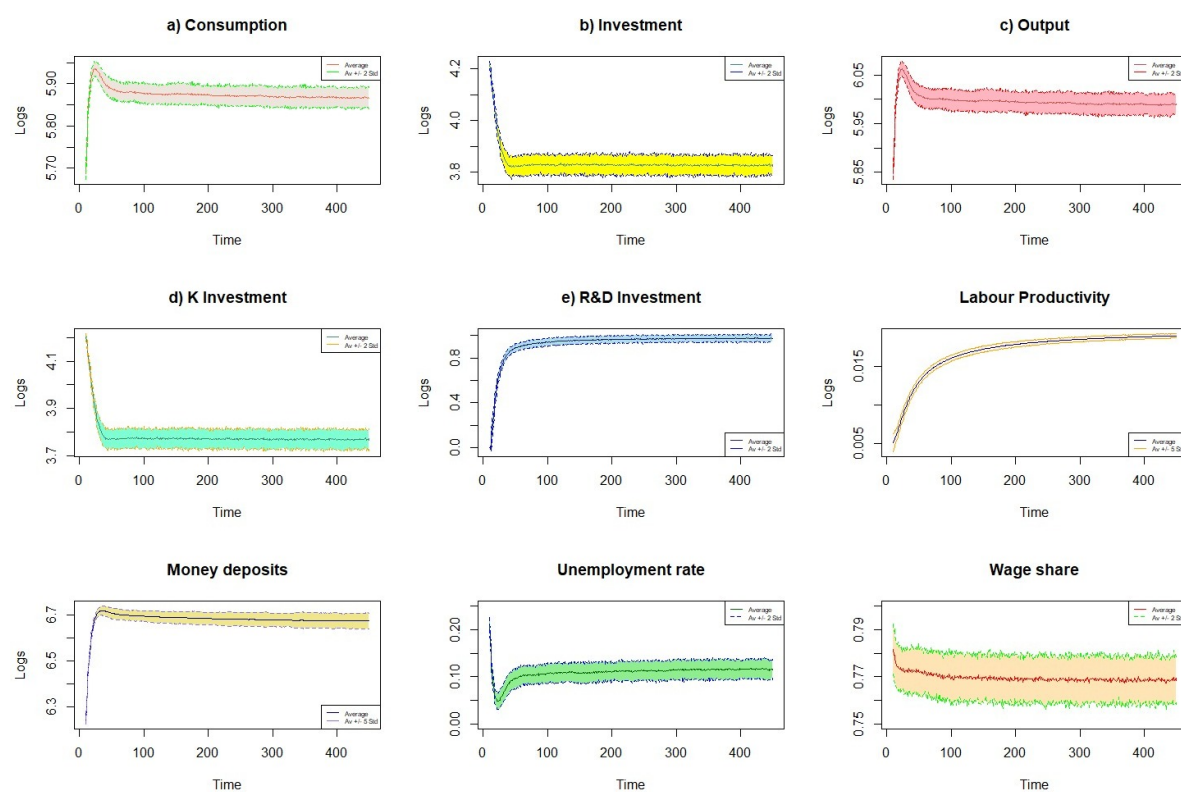
Note: levels in log terms.

Figure B.4. Baseline model
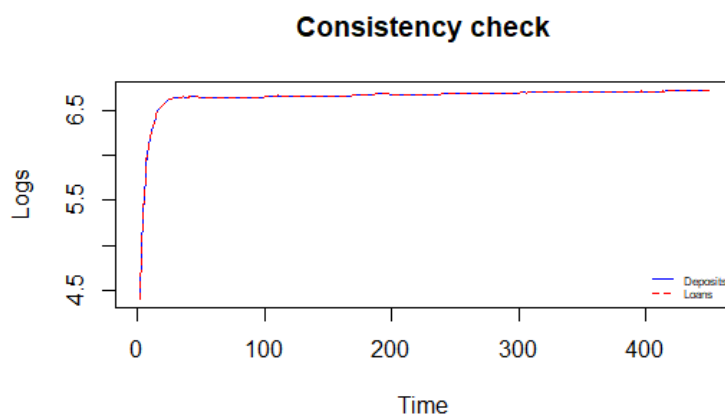


Note: deposits equal loans every period.

Figure B.5. Consistency check
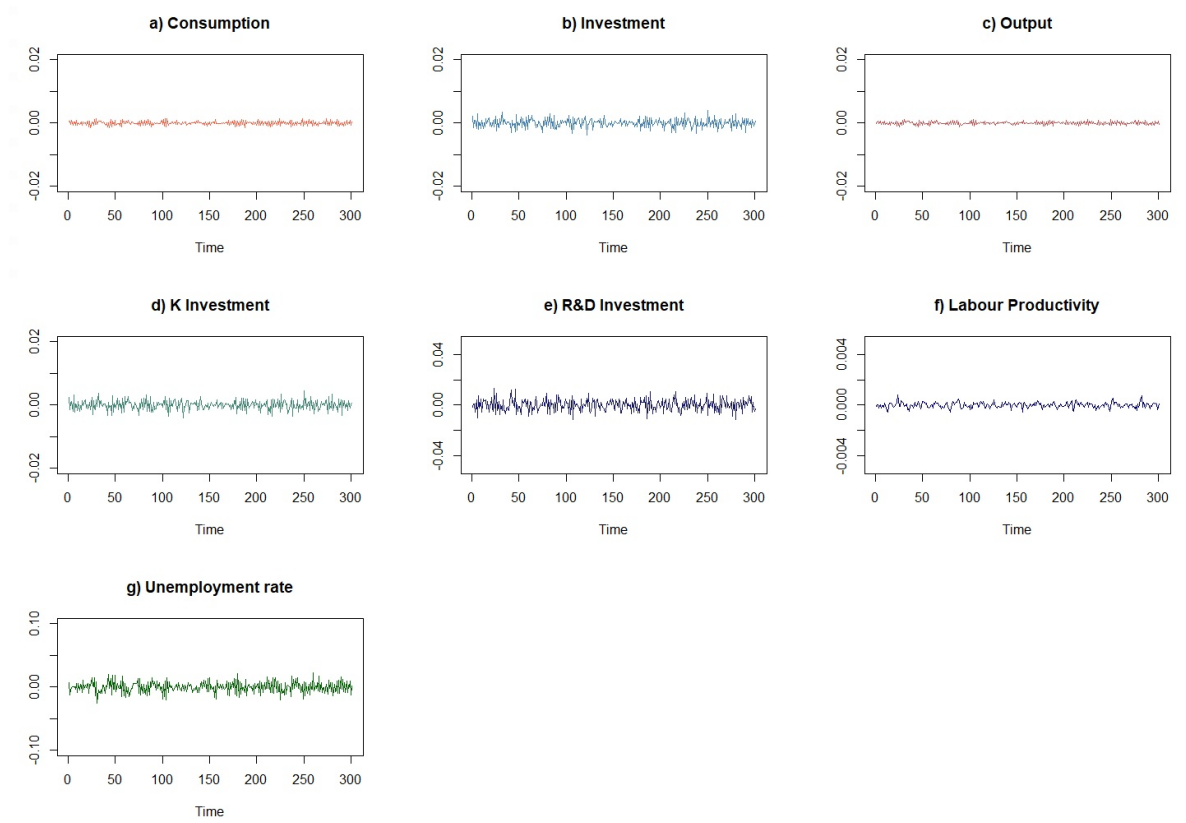
Figure B.6. Cyclical components of simulated time series for some aggregate variables
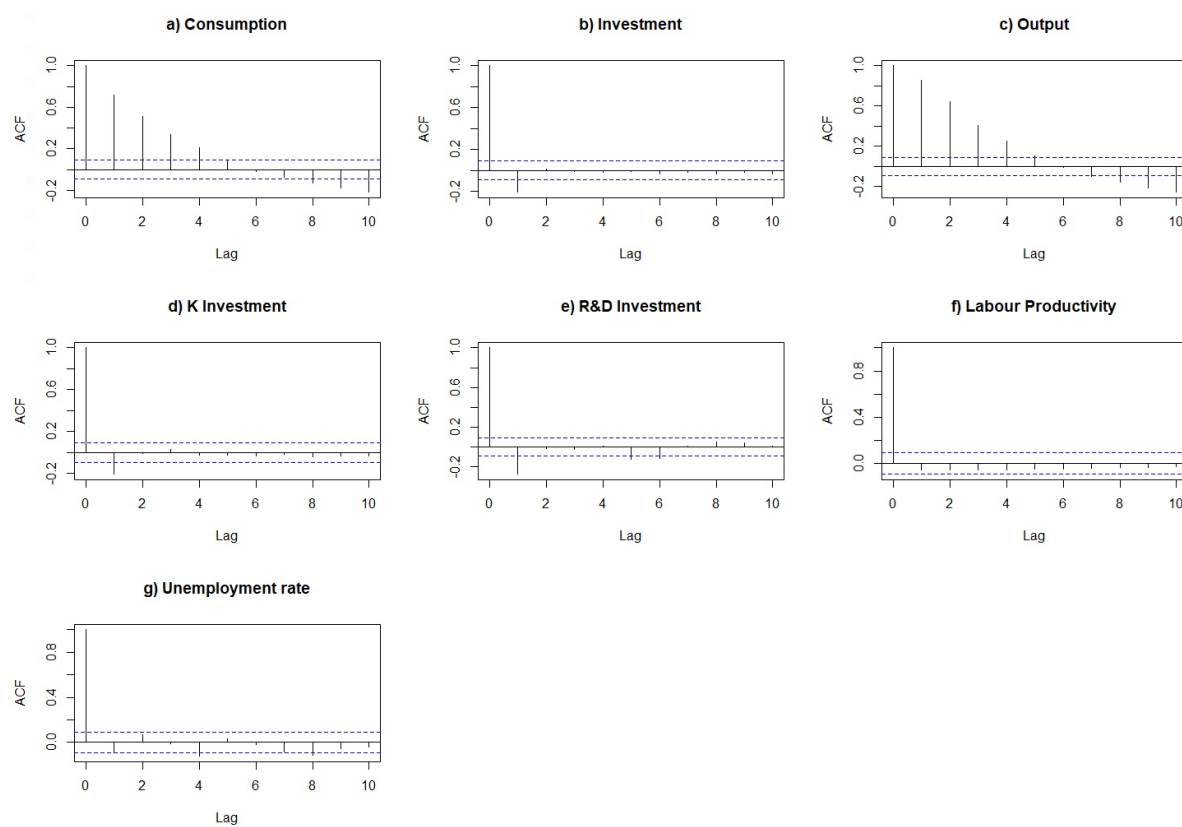
Figure B.7. Baseline model: auto-correlations
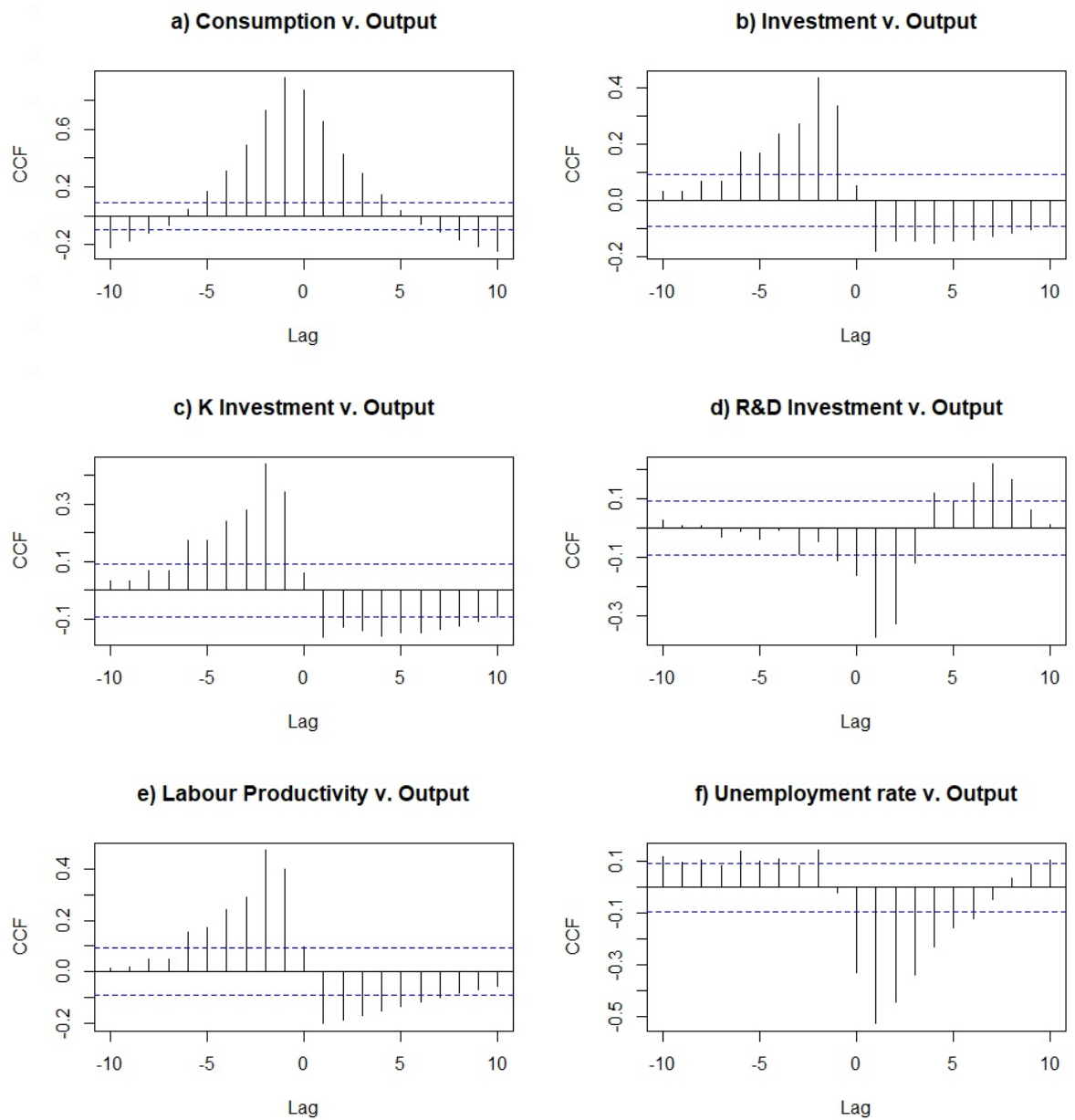
Figure B.8. Baseline model: cross-correlations with respect to aggregate output
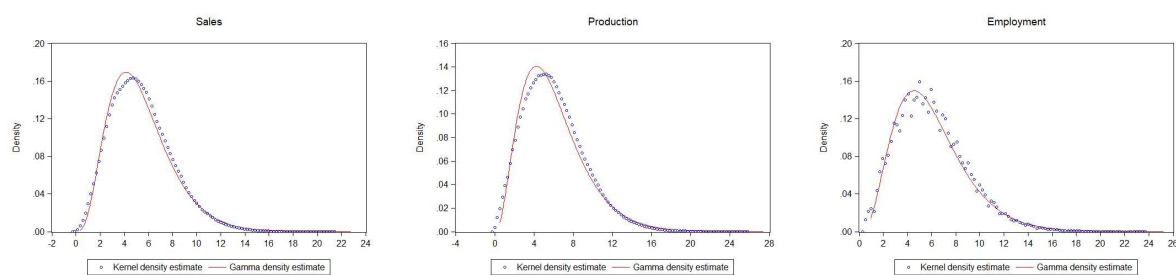
Note: sales refer to shipments of consumption good, while production is about shipments of consumption and investment goods.

Figure B.9. Firm size distribution
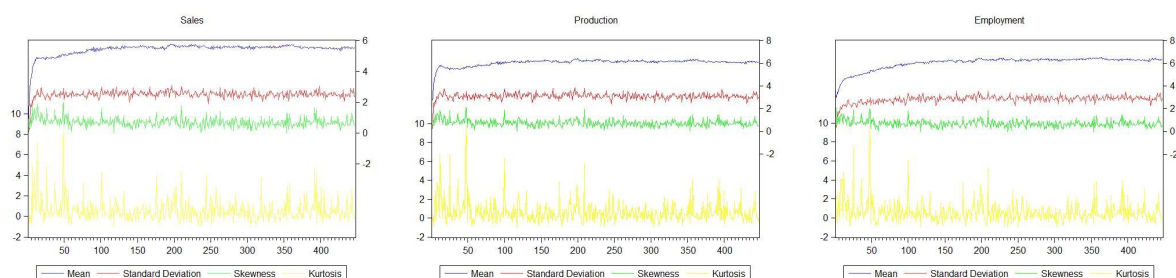


Note: sales refer to shipments of consumption good, while production is about shipments of consumption and investment goods.

Figure B.10. Moments of size distribution
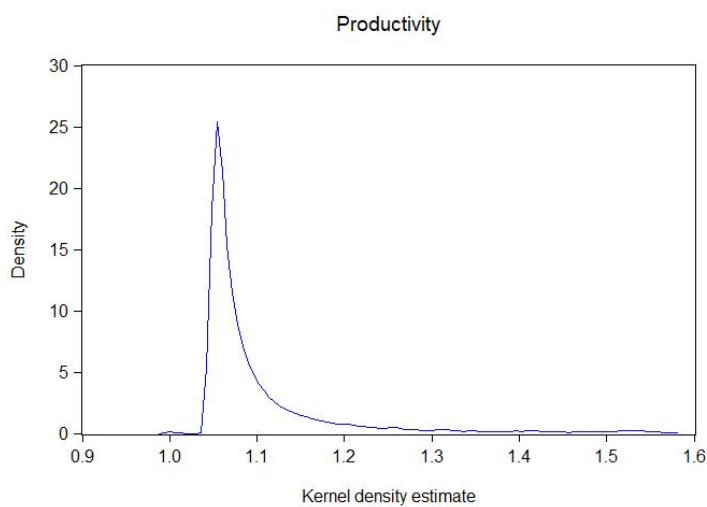


Figure B.11. Productivity differentials at firm level
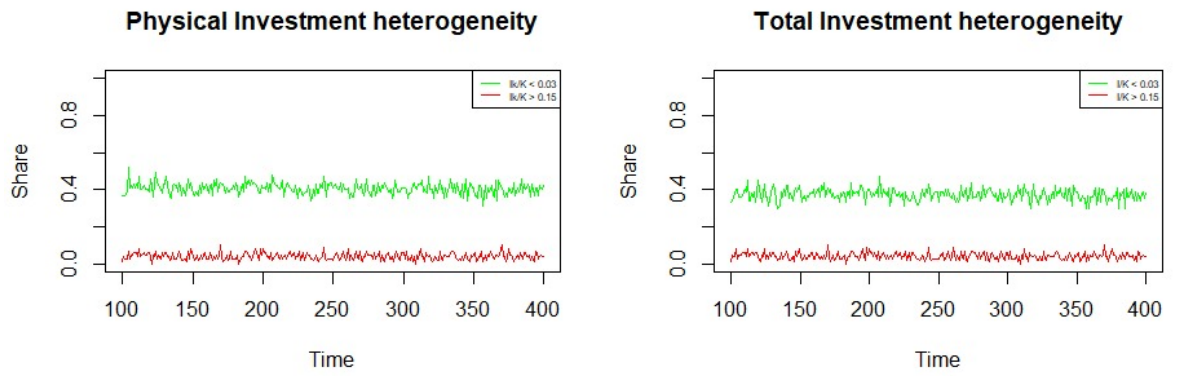
Figure B.12. Investment heterogeneity at firm level
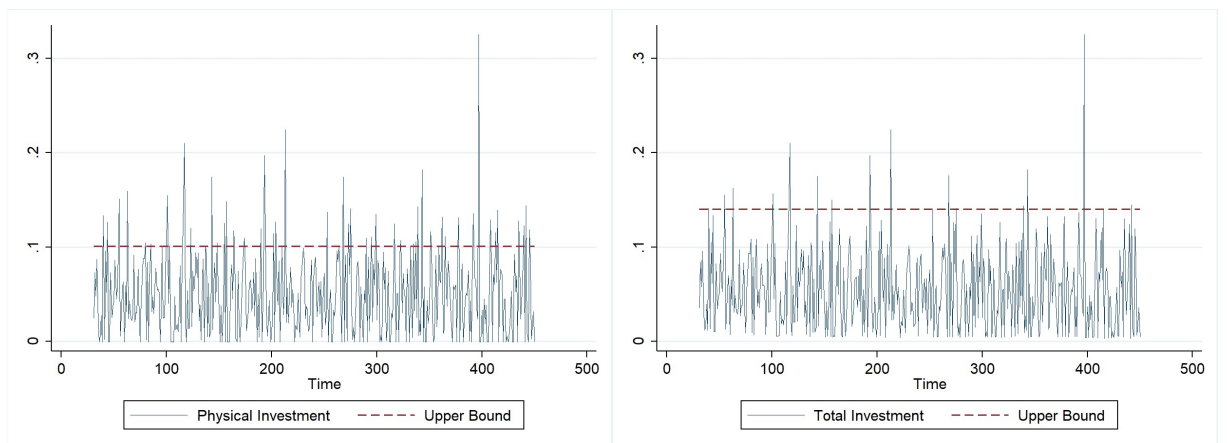


Note: investment patterns from a selected firm; the upper bound is determined as median value plus one standard deviation.

Figure B.13. Investment lumpiness
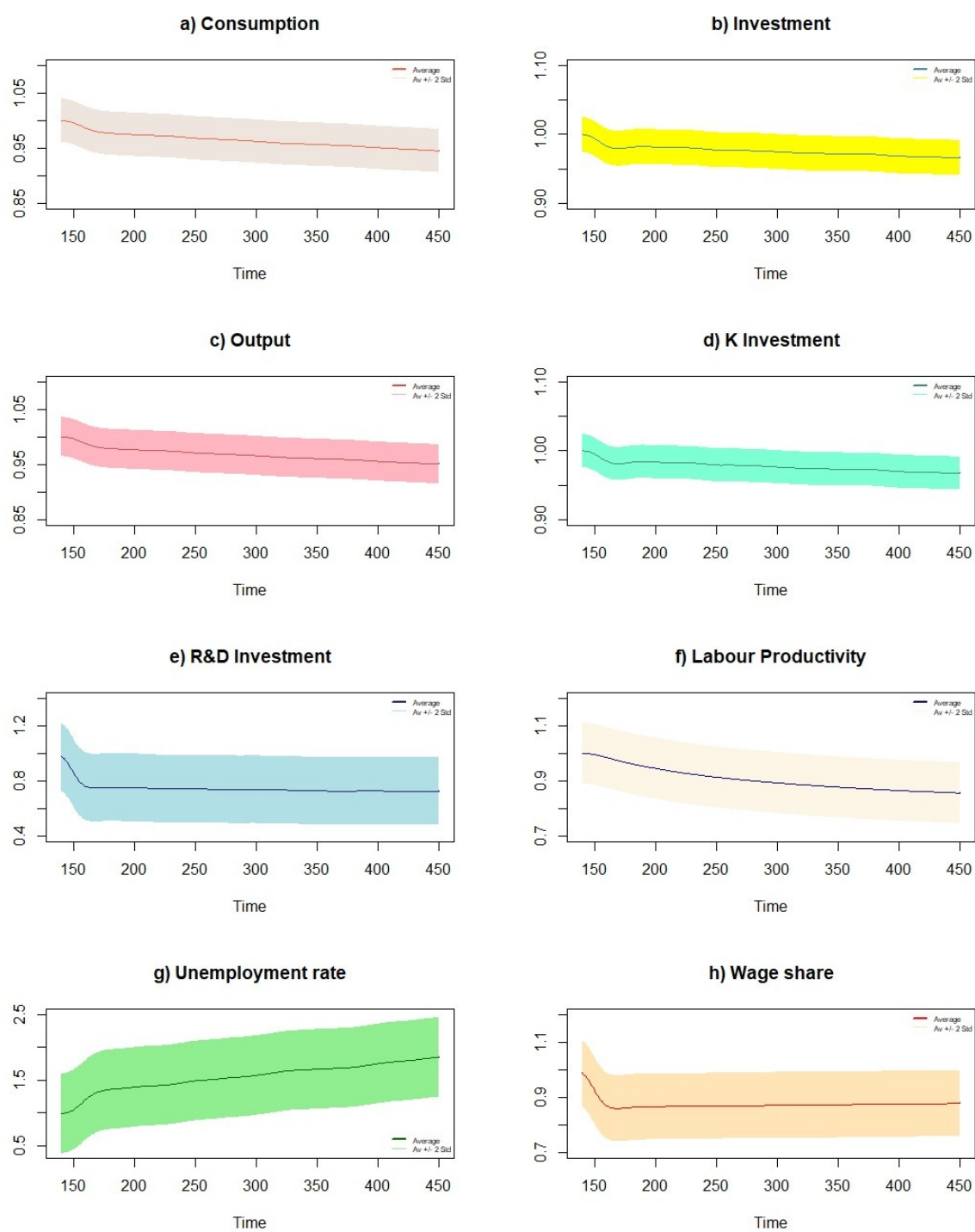
Note: values relative to the baseline surrounded by the standard deviation; ratios are computed between HP-trend components.

Figure B.14. Policy experiment: a decrease in the parameter $w_0$
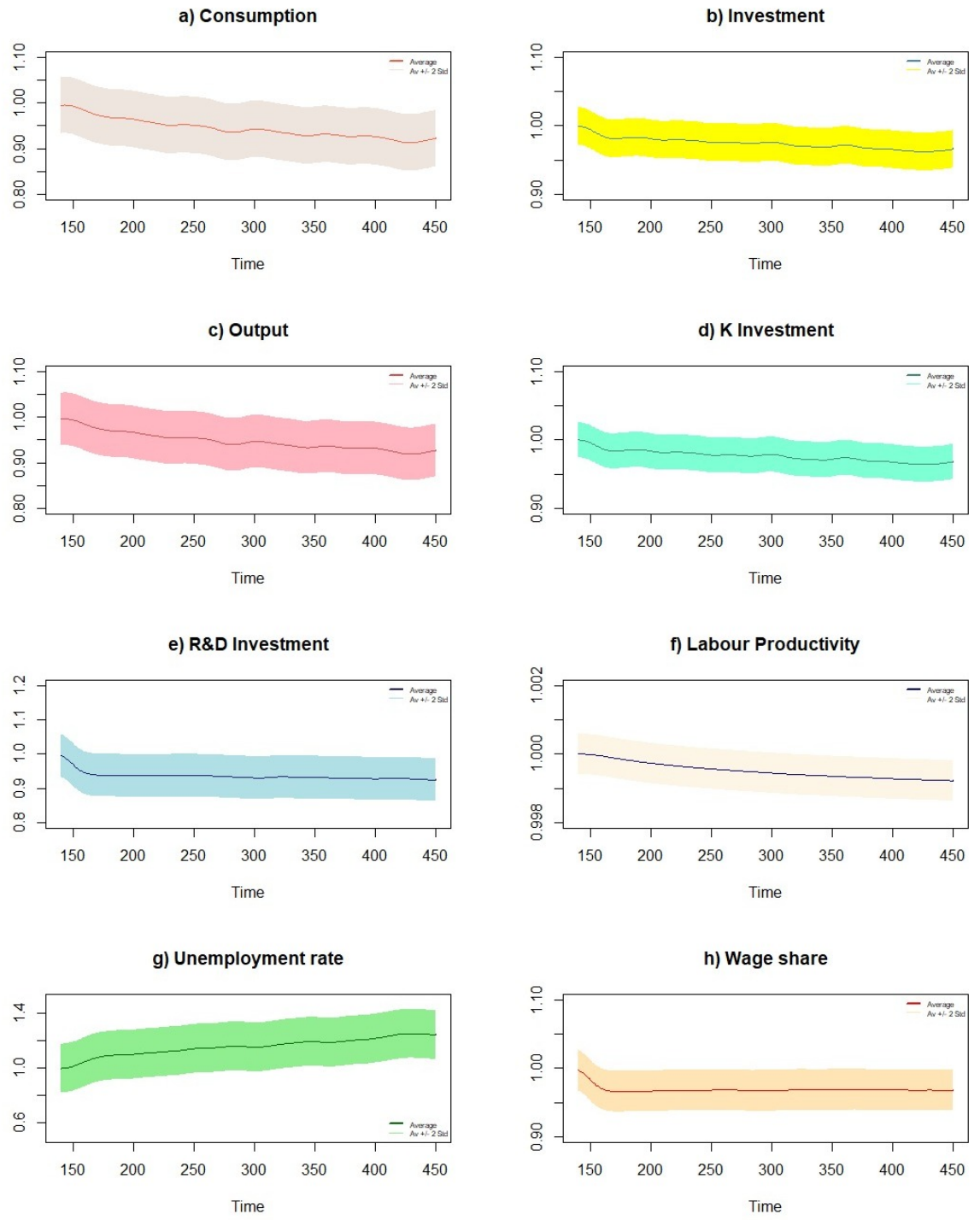
a) Consumption

b) Investment

c) Output

d) K Investment

e) R&D Investment

f) Labour Productivity

g) Unemployment rate

h) Wage share

Note: values relative to the baseline surrounded by the standard deviation; ratios are computed between HP-trend components.

Figure B.15. Policy experiment: an increase in the parameter $w_1$
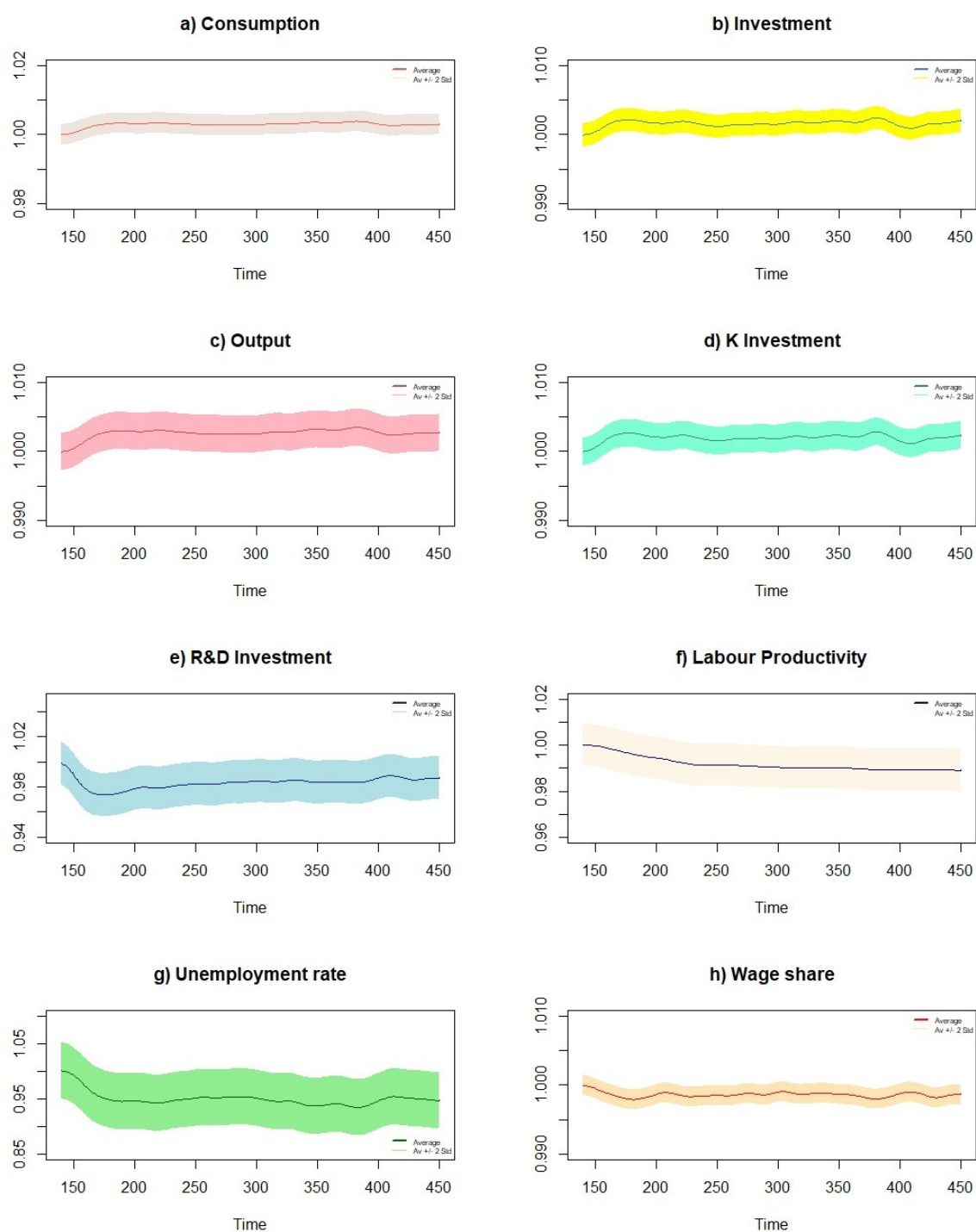
Note: values relative to the baseline surrounded by the standard deviation; ratios are computed between HP-trend components.

Figure B.16. Policy experiment: a decrease in the rate of interest $r_l$
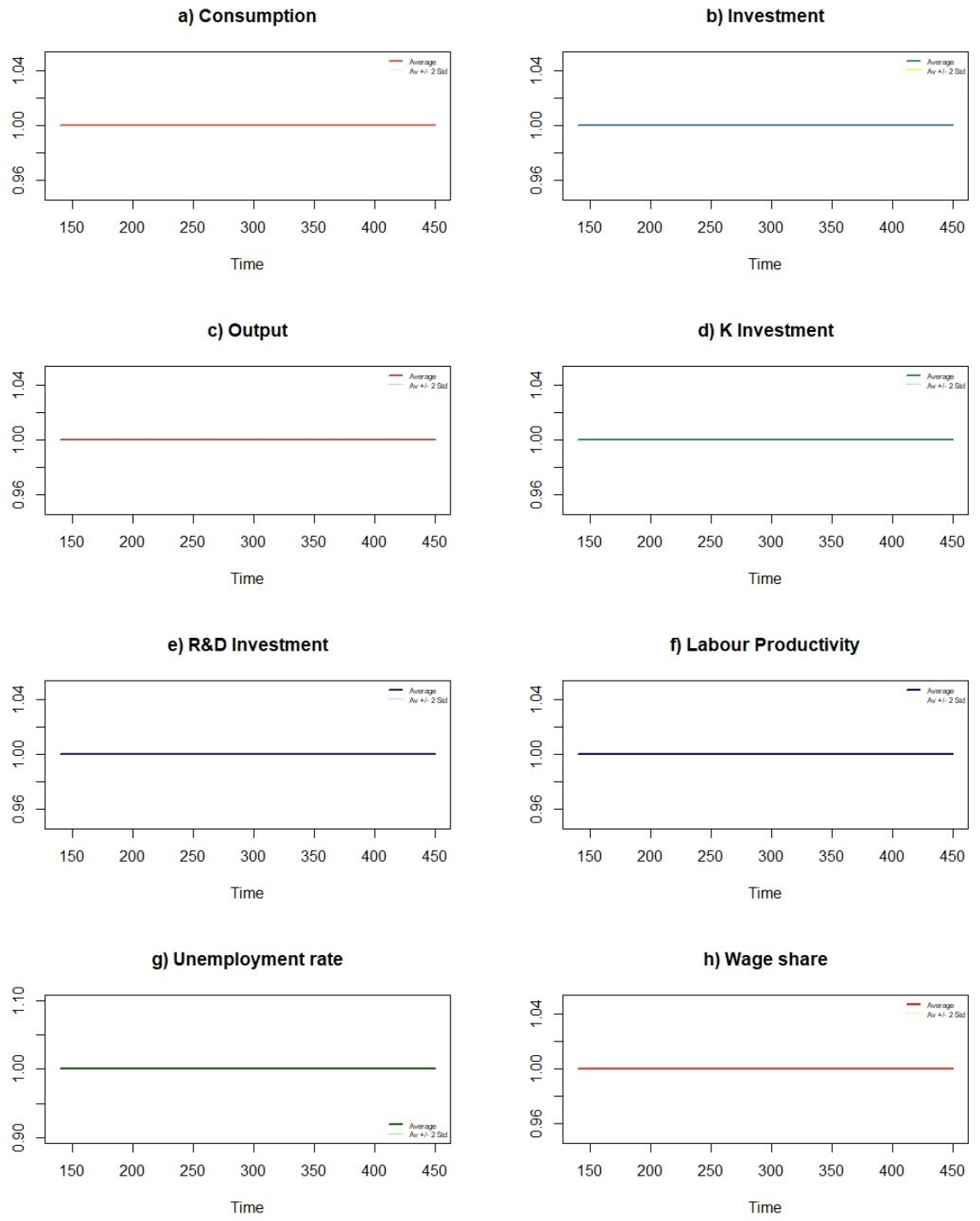
## a) Consumption



## b) Investment



## c) Output



## d) K Investment



## e) R&D Investment



## f) Labour Productivity



## g) Unemployment rate



## h) Wage share



Note: values relative to the baseline surrounded by the standard deviation; ratios are computed between HP-trend components.

Figure B.17. Policy experiment: a decrease in the rate of interest $r_h$
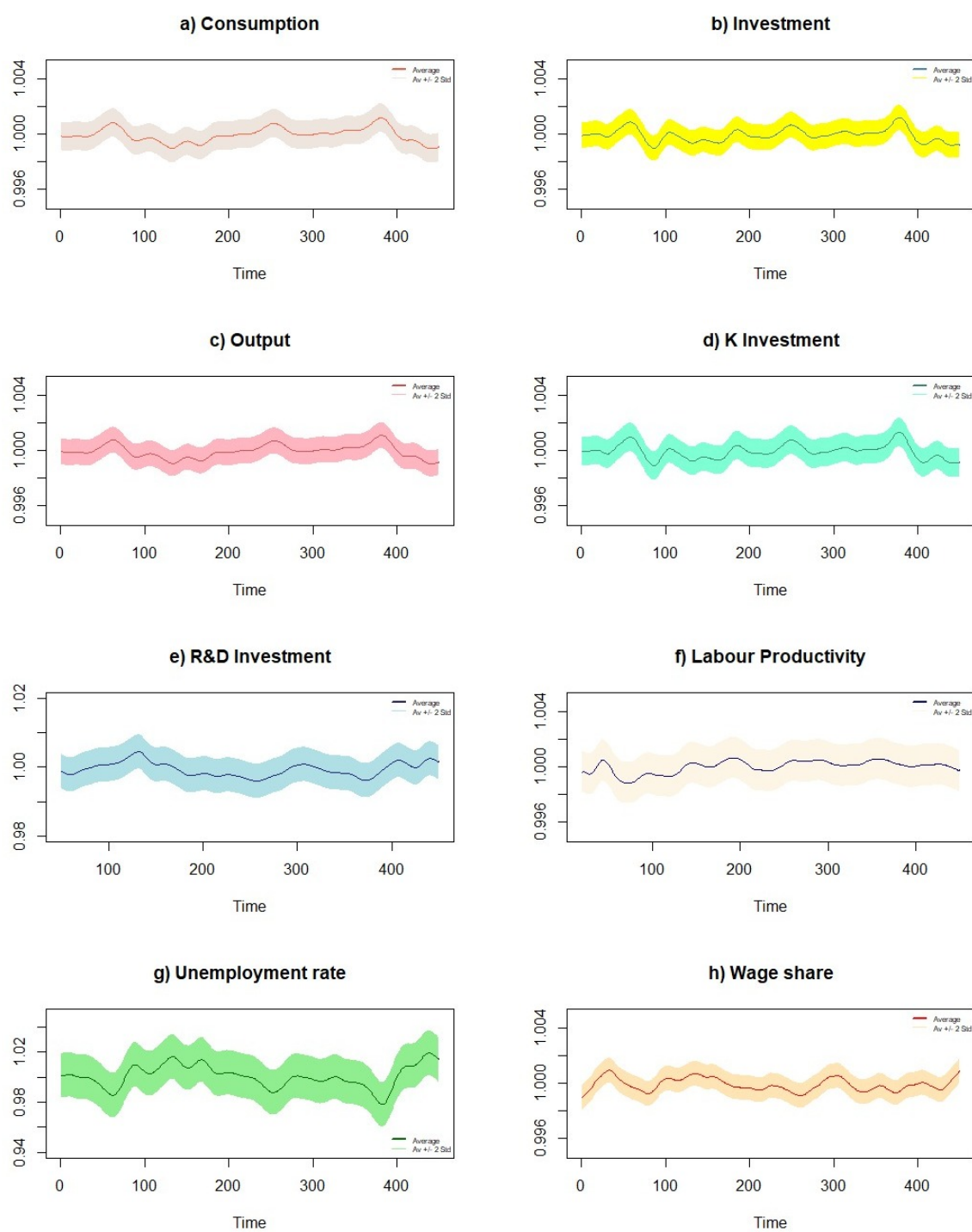
Note: values relative to the baseline surrounded by the standard deviation; ratios are computed between HP-trend components.

Figure B.18. Policy experiment: an increase in the parameter *meet*
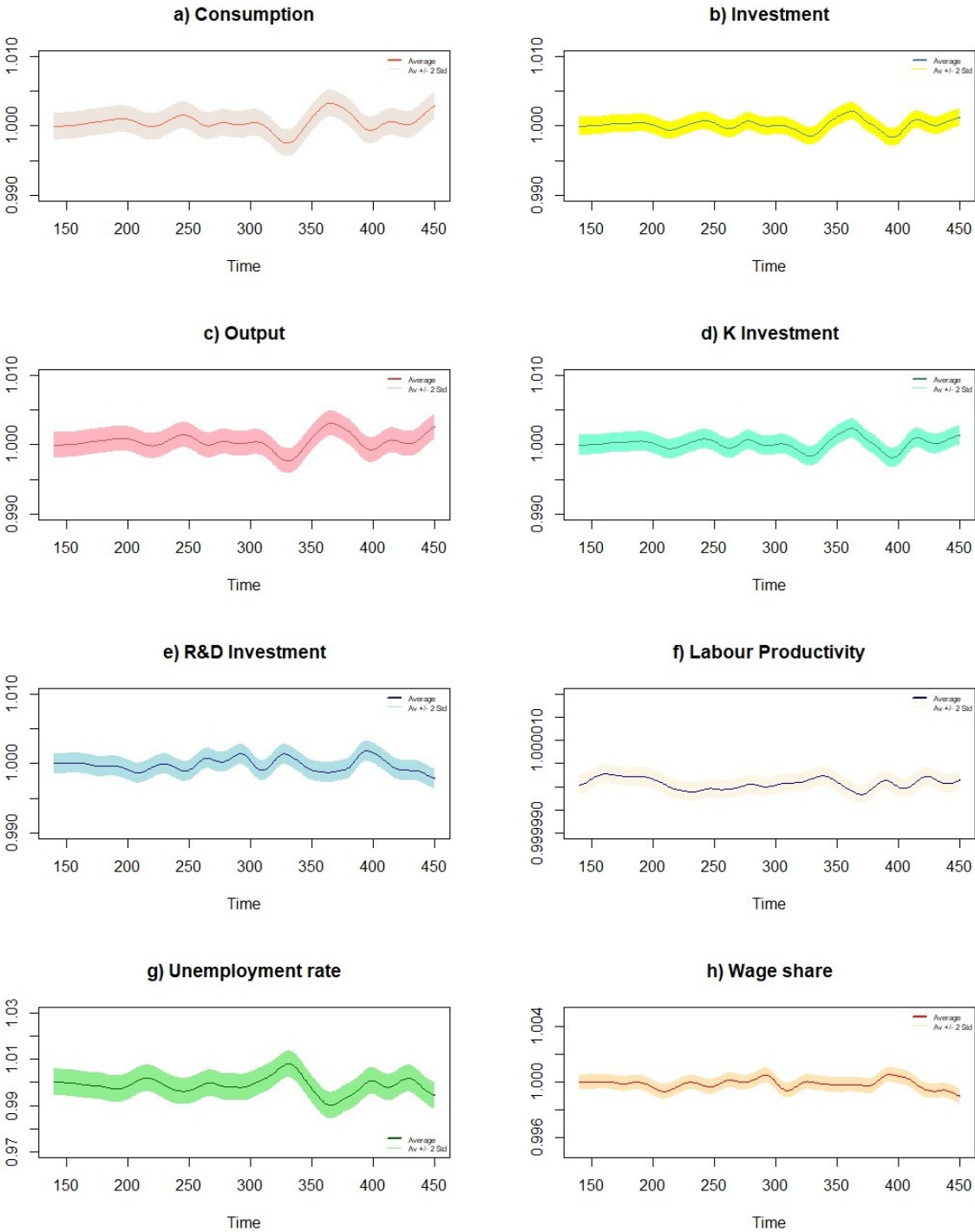
a) Consumption

b) Investment

c) Output

d) K Investment

e) R&D Investment

f) Labour Productivity

g) Unemployment rate

h) Wage share

Note: values relative to the baseline surrounded by the standard deviation; ratios are computed between HP-trend components.

Figure B.19. Policy experiment: an increase in the parameter $\varepsilon$

# Appendix C

# More on the model: notes on the matching process

This subsection provides few notes on the matching process between firms and workers-consumers, and how it is possible to get the demand faced by each firm. The first step of our procedure creates a $F \times N_s$ matrix, called $fw_{net}$. It represents the firms-workers network. The cells take value 1 if a link between a firm and a worker is established and 0 otherwise. We sample random cells and set them equal to 1: precisely, every row will count a number of 1s equal to the labour demanded by the single firm. For instance, if the first row of the network contains ten 1s, then the employment in the first firm amounts to ten workers, and so on.[1] The procedure allows for the establishment of a simple random matching, repeated across time.[2]

Let us deal with the formation of the demand schedule.[3] We discern from each period the wage vector $\mathbf{w'_r} = [w_{r,1}, \ldots, w_{r,i}, \ldots, w_{r,F}]$, being $w_{r,i}$ the wage paid by the $i$-th firm. We can transform the wage vector in a $F \times F$ diagonal matrix as below:

$$\mathbf{w'_r} \rightarrow \mathbf{w_{r,diag}} = \begin{bmatrix} w_{r,1} & \ldots & 0 \\ \vdots & w_{r,i} & \vdots \\ 0 & \ldots & w_{r,F} \end{bmatrix}$$

The approach allows to determine the $F \times N_s$ matrix of disposable incomes **inc** referred to

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[1]To be precise, it amounts to nine workers and one manager, the entrepreneur.

[2]To avoid the matching be invariant across simulations, we limit to define the network inside the for-loop. However, capitalists do not change over time.

[3]We do not consider firms' and bank's profits or interest payments in what follows to streamline the discussion. Anyway, the same argument holds as well.

each worker for every period:

$$\mathbf{w_{r,diag}} \times \mathbf{fw_{net}} = \begin{bmatrix} w_{r,1} & \cdots & 0 \\ \vdots & w_{r,i} & \vdots \\ 0 & \cdots & w_{r,F} \end{bmatrix} \times \begin{bmatrix} 1 & 0 & \cdots & 1 \\ \vdots & 1 & 0 & \vdots \\ 0 & 0 & \cdots & 1 \end{bmatrix} = \begin{bmatrix} w_{r,1} & 0 & \cdots & w_{r,1} \\ \vdots & w_{r,i} & 0 & \vdots \\ 0 & 0 & \cdots & w_{r,F} \end{bmatrix}$$

$$\mathbf{w_{r,diag}} \times \mathbf{fw_{net}} = \mathbf{inc}$$

We may imagine a $F \times N_s$ matrix as something observed from the point of view of the firms. Its $N_s \times F$ transpose matrix is the same object looked from the point of view of the workers. Why is the reversal perspective useful? If every worker were assigned a random marginal propensity to consume out of income, we could adopt the same diagonalization as above to derive the consumption demand out disposable income, $c_{inc}$. In particular, the transpose matrix makes clearer that the propensity to consume varies between workers but not with respect to the single firm: that is, if the $j$-th worker is supposed to have a marginal propensity to consume equal to 0.6, then this value is the same regardless of the firm to which the agent decides to consume. Formally we have:

$$\alpha_1' = [\alpha_{11}, \ldots, \alpha_{1i}, \ldots, \alpha_{1N_s}] \rightarrow \alpha_{1,diag} = \begin{bmatrix} \alpha_{11} & \cdots & 0 \\ \vdots & \alpha_{i1} & \vdots \\ 0 & \cdots & \alpha_{1N_s} \end{bmatrix}$$

$$\alpha_{1,diag} \times \mathbf{inc^T} = \begin{bmatrix} \alpha_{11}w_{r,1} & \cdots & 0 \\ 0 & \alpha_{1i}w_{r,i} & 0 \\ \vdots & 0 & \vdots \\ \alpha_{1N_s}w_{r,1} & \cdots & \alpha_{1F}w_{r,F} \end{bmatrix} = \mathbf{c_{inc}}$$

We repeat the same procedure to obtain the consumption out of wealth and the total consumption function $c$. Updating every time the $fw_{net}$ network allows that each agent works potentially for every firm during the simulation span, and then $\mathbf{c}$ represents a $N_s \times F$ matrix with the amount spent by the single agents in consumption goods, hence a full demand schedule. Transposing and row-aggregating the consumption matrix $\mathbf{c}$ return the amount of consumption demand faced by the single enterprise, $c_f$.[4]

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[4]This overall procedure is very little time-consuming since it requires no for-loops at all. Every operation is performed through the help of matrix algebra.

For what regards to the process matching firms with consumers, we re-adapt that in Riccetti et al. (2015) and Caiani et al. (2016b). Agents meet on the (consumption) good market and act following the same protocol: potential consumers observe a subset of prices from a restricted and random set of suppliers, reflecting their imperfect information. They choose the *best* seller according to the lowest selling price. Each period agents have the opportunity to switch to another supplier with a certain probability, the latter depending on the price differential:

$$Prob = \begin{cases} 1 - e^{\chi_1 \cdot \frac{p_{new} - p_{old}}{p_{new}}} & \text{if} \quad p_{new} < p_{old} \\ 0 & \text{otherwise} \end{cases} \tag{C.1}$$

Eq. C.1 says that the larger the price differential between the old and the new supplier, the higher the probability to switch to the new. The assumption considers the empirical fact that consumers establish a durable relationship based on trust and reciprocity to solve problems from asymmetric information.[5]

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[5]The literature on behavioural economics is endless. We suggest Bowles (2009).

# Chapter 3

# Secular Stagnation and innovation dynamics: An agent-based SFC model. Part II

## 3.1 Introduction

The debate on Secular Stagnation has strengthened since 2014, when Larry Summers (2014a,b, 2015) recalled that old-fashioned concept to describe the US economy since 2007. The focus was on structural changes in the economic fundamentals that have caused a significant shift in the natural balance between savings and investments, such that adequate growth, capacity utilization and financial stability would have become hard to achieve. Moreover, as Barry Eichengreen acknowledged, while the term "Secular Stagnation" spread quite fast over the literature, it is like Rorschach test: it means different things to different people (Baldwin and Teulings, 2014; Eichengreen, 2015). Accordingly, we move away from Summers's idea about Secular Stagnation and focus on a particular stylized fact: the long-run tendency of productivity growth to fall since the early Seventies.

The literature on the topic spent very few words on the relationship between functional distribution of income and innovative efforts at the industrial level. The paper therefore tackles that issue and extends the analysis on Secular Stagnation started in the previous chapter. In other terms, if we focused on a stationary state-gravitating economy before, we now develop an endogenous self-sustaining growth model, characterized by fluctuations at the business-

cycle frequencies. There obviously are similarities between the former and the current model. Firstly, both are agent-based and stock-flow consistent in the spirit of Caiani et al. (2016a) and Dosi et al. (2010). Secondly, the economy still involves a single sector populated by two main classes of agents, i.e. capitalists and workers. Among the other things, the entrepreneurs undertake innovative activity to save labour and earn further profits.

Apart from that, we have to justify the use of such a *complex* framework. On the one hand, agent-based models are particularly suitable to the task since the user knows by construction the micro data-generating process and can explore the features of macro-variables as properties emerging out of the evolutionary dynamics (Dosi et al., 2018). Additionally, this kind of modeling answers to Solow's call for more realistic micro-foundations (Solow, 2008). On the other hand, agent-based models allow us to study the surge of skewness and persistent heterogeneity in firm's size distribution and productivity differentials, as we will see below. This firm-level analysis is not possible in standard aggregate models, for example.

We contribute to the literature on Secular Stagnation in three ways. First of all, the theoretical model helps us show that the increase of the profit share at the expense of the wage share impacts negatively on firm's propensity and ability to innovate. When wages soar, the profit rate drops and the entrepreneurs will be forced to introduce labour-saving techniques through R&D, so to increase productivity and reduce unit labour costs. As a side result, we are able to see that the interest rate has non-linear and small effects on either economic growth or innovative activity. The very non-linearity arises because of the contrasting movement that the rate of interest spurs on consumption and innovative search. Thirdly, we believe our theoretical results can be thought as reasonable for two reasons: a) the model is able to replicate a good spectrum of stylized facts at both the meso- and the macro-economic level and b) we carry out an econometric analysis on a US panel database that covers all two-digit manufacturing industries since 1958. Although simple, the panel cointegration study finds empirical evidence of our predictions. On the one hand, we find robust empirical evidence of a positive long-period relationship between innovative effort and (unit) labour costs at the industrial level; in addition to this, the positive effect is statistically significant in most specifications. On the other hand, panel cointegration tests lead us to claim the lack of any clear and well-established long-run linkage between innovative activity and the rate of interest, the latter measured with the effective federal funds rate or the bank prime loan rate. So doing, we find at least some plausible explanations for the rise of Secular Stagnation in the United States, among the other rationales

often examined.

The paper is therefore organized as follows: Section II reviews the literature; Section III sketches the model; Section IV offers a broad view of the stylized facts we are able to match and the related policy experiments; Section V tests some theoretical results empirically; Section VI concludes.

## 3.2  Literature review

The article draws upon several fields of research. We split between a *theoretical* side and a more *methodological* one to ease the exposition. On the first side, the paper enters the debate on Secular Stagnation, a body of research started by Hansen (1939) and re-evoked more recently by Summers (2014a,b, 2015) and Gordon (2014, 2015, 2017), among the (many) others.[1][2] The definition introduced by Alvin Hansen aimed at describing the very bad picture in which the American economy sank into after the Great Depression in 1929. The huge unemployment was the main problem and Secular Stagnation identified "sick recoveries which die in their infancy and depressions which feed on themselves and leave a hard and seemingly immovable core of unemployment" (Hansen, 1939). While dismissed in subsequent periods, that concept bloomed again in conjunction of the Great Recession in 2007:[3] Larry Summers (2014a,b, 2015), indeed, recalls it to outline a situation in which changes in the economic fundamentals might have brought about a shift in the natural balance between savings and investments. The corresponding natural rate of interest associated to full employment would then have decreased toward negative values, making monetary policy ineffective.[4] The relative outcome would feed a state of affairs that makes the attainment of adequate growth, capacity utilization and financial stability very arduous.

However, we decide not to borrow from Summers's insights in the subsequent pages for two reasons: first and foremost, his analysis looks at Secular Stagnation through the lens of the last deep crisis and seemingly examines the very recent past only; second, the theoretical admissi-

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[1]Baldwin and Teulings (2014) offers an interesting symposium on the topic.

[2]Steindl (1976, 1979) is certainly a reference for some current theory about Secular Stagnation, albeit he used to refer to generic stagnating tendencies intrinsic to mature capitalist economies.

[3]Cf. Pagano and Sbracia (2014): the authors sustain that Secular Stagnation "is a *cyclical question* that has been raised after all deep and prolonged recession" (italics in original). While we agree on that, it is questionable whether we should consider the current revival as comparable to the past. The body of research now involved looks in fact very remarkable.

[4]It is worth noting that Summers refers to the Wicksellian natural rate.

bility of the (negative) natural rate is itself doubtful and debatable.[5]

In contrast, we want to focus on Secular Stagnation as a matter of productivity growth, in line with Gordon (2015), Eichengreen (2015), Hein (2016) and Storm (2019), among the others.[6] Accordingly, we define it as the tendency to the long-run slowdown in the growth rates of productivity, a process begun in the early Seventies that reached the trough with the Great Recession in 2007. In Tab. B.1 and Fig. D.1 we average out growth rates of labour productivity and TFP over the period 1950 through 2019 and we observe a steady downward movement in the trend component for both the growth rates since 1950. In particular, labour productivity grows 2.7 percent on average from 1950 to 1973 while TFP a percentage point less along the same period. In constrast, the growth declines to 1.5% and 0.6%, respectively, after the Great Recession. The period from mid-Nineties to the crisis's eve witnesses a temporary rebound in occurrence with the dotcom bubble: in this case the rates surge to 2.6% for labour productivity and 1.2% for TFP.

Gordon (2015) and Eichengreen (2015) develop a supply-side view and argue that the backlash in productivity growth is ought to some *headwinds*. On the one hand, the revolution started by digital electronics ran soon out of steam and faced diminishing returns. In other words, they believe that the innovations from last fifty years had a relatively smaller impact on productivity than, for instance, the electricity at the turn of the $XX^{th}$ century. On the other hand, the increase of income inequality influenced negatively the accumulation of human capital, because students are very burdened by college debt and may choose not to complete college as they are priced out of the market for higher education (Gordon, 2015).[7]

Hein (2016), Storm (2019) and Kiefer et al. (2020) stand on a quite different point of view. The overall belief is that the redistribution of income at the expense of the labour share shrank investment opportunities through the old-fashioned accelerator mechanism. Moreover, productivity growth is endogenous with respect to changes in distribution even in the long period: Storm (2019) decomposes TFP growth as function of labour productivity and real wage growth. Data about the latter strictly point to their decrease since the end of the Golden Age of

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[5]See Palley (2019) and Di Bucchianico (2020).

[6]Still, Hein (2016) counterposes the notion of Secular Stagnation with the one of Stagnation Policy. We do not enter the debate on that in the following pages. Yet, we can affirm that there is no contrast between the way we define Secular Stagnation as *stylized fact* and the meaning of Stagnation Policy, which concerns more to the *explanations*.

[7]For a full deepening of the other headwinds, such as the *demographic dividend*, check Gordon (2000, 2010, 2012, 2014, 2017). In contrast, Acemoglu and Restrepo (2017), Crafts (2002), Eichengreen (2015) himself and Nikiforos (2020) are highly recommended for some criticism.

capitalism, with a negative effect on TFP performance.[8]

Always on the theoretical side but from a quite different angle, we focus on the Schumpeterian and evolutionary tradition, in the lines of Schumpeter (1943, 1982), Von Hayek (1937), Sylos-Labini (1983), Aghion and Howitt (2008) and Bowles (2009). This wide body of literature looks at innovation as the driving force behind the dynamic processes that lead to qualitative improvements of economies, together with productivity growth. Furthermore, innovation is associated with uncertainty in its Knightian meaning, because nobody knows whether the innovative efforts will be successful or not.[9]

For what regards to the *methodological* side, we underline that the Secular Stagnation literature lacks in modeling, which is weird if compared to the surge of interest it spurred. The most important formalization is Eggertsson et al. (2019) and it draws on Summers (2014a,b, 2015). The authors build an analytic overlapping generation model and provide a general setting for negative natural rates of interest. Nevertheless, the same criticism applied to Summers holds in this context as well, and so we refer to a previous footnote. Because of that, we choose to deal with the literature on agent-based computational economics (ACE, hereafter), which looks at economies as systems populated by many heterogeneous interacting agents without any central coordination (Caiani et al., 2016b). To put that differently, economies are seen as complex dynamic systems, whereby a multitude of micro-agents locally interacts continuously and gives rise to the multi-faceted global stylized facts for growth rates, employment, income distributions and institutions. At the same time, these macro-outcomes feed back into the local interactions (Tesfatsion, 2006; Tesfatsion and Judd, 2006). The loop results in the agent's learning through the change in her behaviour based on past experience. As argued by Tesfatsion in her several works, the most important pro of ACE modeling, compared to the standard Walrasian methodology, is that agents are designed with more autonomy and with the capacity of

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[8]Kiefer et al. (2020) provides a new measure of potential output growth derived from a specification that builds on the interactions between the wage share and the rate of capacity utilization. With a focus on the US economy, the results clearly confirm a positive long-run relationship between economic growth and wage share, although no explicit causal linkage is emphasized. Anyway, we choose not to deal with GDP growth for the remainder of the article, but only on productivity growth. The reason lies in the fact that there is a lot of empirical evidence suggesting that the current slowdown of output growth resembles what US capitalism experienced in the seven decades before the Golden Age itself. In other words, the US GDP growth rate has averaged around 2 percent since late nineteenth century, with the exception represented by Golden-Age years. Furthermore, we suggest Hein and Tarassow (2010) and Hein (2012) for recent and interesting analyses on the relation between productivity and income distribution, albeit not embedded in the Secular Stagnation literature.

[9]As emphasized by Dopfer et al. (2004), innovation takes place at the micro-economic level, while its potentiality gets fully fledged at the meso-economic level.

self-regulating (LeBaron and Tesfatsion, 2008; Tesfatsion, 2002, 2006).[10] Markets are viewed as places for learning and discoveries, hence a place for innovation and imitation. This is what Dosi et al. (2010, 2016, 2018) and Napoletano et al. (2012) do through the development of the "Schumpeter meeting Keynes" model, in which they investigate the way micro-economic innovations turn out in and affect global outcomes. This family of models are structural since they build on a representation of what agents do. Additionally, they can be considered as an exercise in *general disequilibrium* analysis (Dosi et al., 2010). In so doing, they go beyond the standard Walrasian framework, that was not meant to address and describe how production, pricing and trade actually arise in real-world economies.

However, the afore-mentioned methodology suffers from some issues. Firstly, many ACE models violate accounting consistency requirements, with financial flows possibly arising out of nowhere. Caiani et al. (2016a, 2019) solve the problem and provide a fully-decentralized stock-flow consistent (SFC, hereafter) model with heterogeneous agents. In that way, they bridge the SFC framework in the spirit of Godley and Lavoie (2006) with the ACE literature. Moreover, these contributions offer interesting suggestions on how to calibrate, validate and apply the basic framework.[11]

Secondly, the family of $K + S$ models neglects the deep role of bank money in the introduction of innovation: Schumpeter (1943) clearly showed that the availability of money is a necessary condition for the production of goods. Bertocco and Kalajzić (2020) delevop a $K + S$ model that implements an interesting monetary theory of production in the lines of Keynes and Schumpeter.[12]

## 3.3    The model

In what follows we develop an agent-based, stock-flow consistent model to analyse the nexus between income distribution and innovative search in determining economic growth. The model is complex, adaptive and structural in the sense of Tesfatsion (2006) and Dosi et al. (2010). First, it is *complex* because the system is composed of interacting units. Second, it is *adaptive* since involves environmental changes. And third, it is *structural* because it builds on a

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[10]The other face of the coin shows however that ACE models require that intensive experimentation is carried out over a wide array of initial specifications: predicted results would not be robust otherwise.

[11]Caiani et al. (2019) investigates the nexus between inequality and growth, evaluating the impact of several distributive regimes on innovation outcomes.

[12]We should however signal that Bertocco and Kalajzić (2020) do not go into the details of the agent-based model but consider the aggregate perspective only, hence setting plausible interesting features of agents' interaction aside.

representation of what agents do. In this context, we shall define as *agent* an encapsulated set of data and behaviours representing an entity residing in a computationally constructed world (LeBaron and Tesfatsion, 2008).[13]

Here we focus on a one-good two-class closed economy with no government sector, whose economic growth and development is driven by the introduction of productivity-enhancing technological innovations. The good can be used for consumption or investment purposes. Fig. B.3 helps describe the population in this simplified world:

- A collection $N_s$ of households, split between workers and entrepreneurs. In other words, $N_s - F$ agents offer labour inelastically at the going wage rates, while the remaining are capitalists. Additionally, both categories consume and save regardless to their status.

- A collection $F$ of firms, each owned by a different capitalist. Production and investment decisions unfold within the firm environment.

- An aggregate and consolidated bank: its activity is directed, on the one hand, to provide firms with loans to fund their investments and, on the other hand, to gather household savings in the form of deposits. Profits will be distributed as dividends.[14]

We hypothesize each period of the simulation sees agents interacting on five different markets:

- The (capital) goods market: firms buy and sell (investment) goods.

- The (consumption) goods market: firms trade goods with households.

- The labour market: capitalists hire and fire workers.

- The credit market: the bank provides firms with loans at a given interest rate.

- The deposit market: the bank rewards deposits at a given interest rate.

The interactions envisage what the literature calls *procurement process* (Tesfatsion, 2006). For instance, if we considered the consumption good market, customers would have to decide how

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[13]Such entities may generally range from active decision-makers with well-developed learning capabilities to passive entities with no cognitive functioning.

[14]For the sake of simplicity, we assume that each household has ownership of the bank and receives dividends proportionally to her wealth. Moreover, wealth takes the form of deposits, only and always.

much to purchase and at what prices. In other terms, they must choose a partner among a narrow set of potentials. Once a seller is selected, the customer-supplier relationship involves a long-term commitment. The assumption considers the empirical fact that consumers establish a durable, but not everlasting, relationship of trust and reciprocity to solve problem of asymmetric information.[15]

The behavioural equations we are going to show resemble what found in the agent-based SFC literature as in (Caiani et al., 2016a, 2019, 2016b) and Dosi et al. (2010). We further assume no population growth; however, labour supply is exogenous and unbinding, since in a mature capitalist economy as the USA are there is usually a pocket of unemployment, while episodes of labour shortages, if any, are solved through exogenous migration flows. As said above, it is worth underlining the role played by innovation, driver of productivity and economic growth: it occurs at the micro-economic (firm) level but its potentiality exhibits at the industry or meso-level of the economy. Finally, a crucial feature of the model is the agent learning capability: they change their behaviour according to past experience. So the outcome of the evolutionary process is not determined by the modeler through a simple maximization, but the true uncertainty determines the processes of interactions and novelty generation (Hanusch and Pyka, 2007).

We shall focus on the following details for the sake of convenience: timeline of events, production firms, labour market, households and consumption, Schumpeterian innovation, and the banking system.

### 3.3.1 Timeline of events

We endow production firms with a single unit of (capital) good at the dawn of time, say $t = t_0$. After that, firms and workers adopt the following behavioural rules in each simulation time step, that roughly corresponds to a quarter:

1. Firms compute the target level of the capital stock.

2. In order to have enough funds to setup production, the entrepreneurs draw from preceding accumulated wealth, if any, and borrow from the consolidated bank at a given interest

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[15]"Individuals take decisions according to the limited set of information they have, rational decisions are substituted with reasonable decisions, optimal choices with *satisfying* choices, rational expectactions with experience-based *rules of thumb*" (Bassi and Lang, 2016). This is tantamount to say that agents have a Simon-type rationality schedule.

rate. So doing, they start producing to satisfy the demand of (consumption) goods asked by households and to construct the (capital) goods ordered by the other firms.

3. Workers are paid at the going wage rate. Agents, then, buy the (consumption) good with part of their income and save as deposits what left. The entrepreneurs are residual claimant and get profits, if any.

4. The banking system gathers interest payments from firms and rewards households deposits. Banking profits are distributed among households.

5. Firms update their production plans and hire workers to perform innovative search. Improvements in productivity and new (ordered) machines will be available at $t + 1$.

6. Aggregate variables are computed and the cycle restarts.

### 3.3.2  Production firms

In this subsection we describe how entrepreneurs take their decisions about production and investments. As above, the economy produces a single commodity that can be adopted interchangeably for consumption and investment purposes. Moreover, we suppose no inventories and production adapts to demand. Output components, that is consumption and investments, are expressed at constant prices. The first equation concerns to the production at firm level:

$$y_j = c_{f,j} + i_{s,j} + i_{rd,j} \tag{3.1}$$

in which $y$ denotes the production of the single firm, which can be split into production of (consumption) and (capital) goods, and innovative activity, respectively, while $j$ always refers to the single firm if not otherwise specified. As common to the literature, we adopt the Leontief technology that considers labour and capital as means of production employed in fixed proportions:

$$y_j^P = min\left[\varphi \cdot k_j; a_j \cdot N_s\right] \tag{3.2}$$

where $y^P$ represents firm's productive capacity, $k_j$ the capital stock, whereas $\varphi$ and $a_j$ are the output-to-capital ratio and the labour productivity within the firm, respectively. As in the first point of the timeline, capitalist wish to reach a target level for the capital stock, that we call $k_j^T$ and set as a constant proportion from past production. It can be ascertained directly

from (3.2).[16]

For the sake of simplicity, a constant proportion $\delta$ of the existing equipment depreciates every period and capitalists set aside an amount of funds exactly equal to replace the worn-out capital:

$$da_j = \delta \cdot k_{-1,j} = af_j \tag{3.3}$$

$da_j$ and $af_j$ define, respectively, the depreciation allowances and the amortization fund. We shall focus now on the investment decisions. The setting envisages two kinds of investment: the first is on tangible capital as machines, and the second is about innovative search. The former increases the productive capacity but it is not productivity-enhancing; in contrast, the innovative search results in productivity gains, when successful. In other terms, capitalists can choose from two alternatives, which raise total revenues but in differing ways: investments in physical capital increases the size of firm's business; by contrast, successful innovations reduces labour costs.[17]

From the above, it is clear that what drives economic development and productivity growth is the investment on R&D. To the scope, we model the growth rate of innovative investments as consisting of two components:

$$g_{ird,j} = \vartheta_0 \cdot \bar{g}_{y,j} + \vartheta_1 \cdot \left( \frac{\bar{\varrho} - \varrho_j}{\bar{\varrho}} \right) \tag{3.4}$$

on the right-hand-side of (3.4) we have, indeed, the growth rate of R&D expenditure as function of a *revenue* component that captures firm's expectations about future demand, for simplicity a (moving) average of past growth rates of production, and a *cost* term reflecting the desire to narrow the discrepancy between the actual profit rate $\varrho_j$ and the normal rate $\bar{\varrho}$. In other terms, firms strive to increase their market shares and their profits both via innovation and imitation. For what concerns instead to the investment in capital stock, we simply set a standard accelerator equation, in which the expenditure adapts to the exogenously-growing animal spirits $i_{0,j}$,

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[16]We could even used past sales as indicator, but since we posit no inventories, past sales of consumption and investment goods coincide with past production. Furthermore, even if production adapts to demand, firms maintain excess capacity and this does not reflect a wrongful expectation formations, but rather the rational decision of the firm to be able to accommodate fluctuations in demand (Ciccone, 1986; Setterfield and David Avritzer, 2020).

[17]For simplicity, there is no trade-off between different types of investments. We can instead see these investments as complementary: innovation allows for a reduction in unit price while a greater capital stock permits to satisfy a higher turnout. So, if combined, they both raise total earnings.

and the adjustment of capital to the target level, $\left(k_j^T - k_j\right)$:

$$i_{k,j} = i_{0,j} + i_{1,j} \cdot \left(k_j^T - k_j\right) + af_j \tag{3.5}$$

Profits, $f_j$, are computed as residual claims, i.e. sales minus the amortization fund, the interest payments on past loans and wage bill at firm level:

$$f_j = y_j - af_j - int_{ld,j} - wb_j \tag{3.6}$$

where $int_{ld,j}$ are the interests paid on past loans and $wb_j$ the wage bill.

We should make clear now that $i_{k,j}$ and $i_{rd,j}$ represent the amount of expenditure a firm does to improve its capital and technological level, respectively. Since the firm orders machines to other firms, we shall define with $i_{d,j}$ in (3.7) the investment *demand*:

$$i_{d,j} = i_{k,j} + i_{rd,j} \tag{3.7}$$

However, the first term on the right-hand-side generally differs from what the $j$-th firm is ordered by the other firms. So we create another variable that accounts for that, say $i_{s,j}$, and we record the actual (capital) goods production as:

$$i_{s,j} = \bar{i}_{k,j} \tag{3.8}$$

the term on the right-hand-side points out that firms randomly interact with each other, leading to a configuration in which the single firm produces an average amount of (capital) goods for the others, $\bar{i}_{k,j}$.

The capital stock $k_j$ will be the result of past (depreciated) equipment plus gross investment $i_{k,j}$:

$$k_j = (1 - \delta) \cdot k_{-1,j} + i_{k,j} \tag{3.9}$$

How do firms finance their investment projects? For simplicity, we suggest that two sources of funds contribute to that financing: past accumulated wealth, on the one hand, and new loans, on the other. To put that differently, the capitalist allocates a share from past wealth, say

$q$, while the remaining requirement is covered out of new loans as in (3.10):

$$dl_{d,j} = i_{d,j} - af_j - q \cdot m_{h,-1,j} \tag{3.10}$$

where $dl_{d,j}$ is the change in loans demand.[18]

### 3.3.3 Labour market

We make the assumption that the real wage does not clear the market in a Walrasian fashion to ensure the full employment of labour. In contrast, the framework admits unvoluntary unemployment as the rule.[19] The labour supply is exogenous and unbinding: in other terms, workers accept a job at the established wage rate. For what concerns to the labour demand, firms have to consider the effective productivity of workers currently employed.[20] Once defined with $a_j$ the labour productivity at firm level, the demand for labour of the $j$-th firm $nd_j$ is simply the following ratio:

$$nd_j = \frac{y_j}{a_j} \tag{3.11}$$

The social product is split between wages and profits: the wage rate is the result of the social compromise between the different classes whereas business profits accrue to capitalists as residual. Moreover, we suppose the wage rate grows with the evolution of institutional and market factors as in (3.12)

$$g_{w_r} = w_1 - w_2 \cdot u_{r,t-1} \tag{3.12}$$

$w_1$ represents all the institutional factors as social norms, unionization, market structures and political effects that tie the wage rate to a certain growth path, while $w_2$ is meant to mimic the endogenous evolution of workers bargaining power in relation to the employment dynamics. Every period, the monetary wage rate is corrected to account for inflationary pressures:

$$w_r = w_0 e^{g_{w_r} t} \cdot pr_t \tag{3.13}$$

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[18]To keep things as simple as possible, we suppose that the $j$-th firm can borrow whatever sum it needs from the banking system at a constant rate $r_l$.

[19]Full employment might occur but it would be the very exception.

[20]The model assumes labour contracts last for a period only and that workers cannot set the employment rate through their bargaining power, which is actually determined by firms according to their effective need. A similar assumption has been adopted by Bassi and Lang (2016) too.

The wage bill at firm level $wb_j$ is the simple product between the wage rate and the number of employees:

$$wb_j = w_r \cdot nd_j \tag{3.14}$$

### 3.3.4 Households and consumption

Although households are distinguished according to their propensity to save out of income, they consume and save. In particular, we assume that workers and capitalists consume with propensity $\alpha_{1,i}$ and $\alpha_{2,i}$ out of expected real disposable income, respectively. For simplicity, the propensity to consume out of expected real wealth $\alpha_{3,i}$ varies only across agents and independently to the status. Therefore, we define the disposable income as

$$ydh_i = \begin{cases} w_r + \sigma_{mh,i} \cdot F_{b,t} + int_{mh,i} & \text{if} \quad i \quad \text{is worker} \\ f_i + \sigma_{mh,i} \cdot F_{b,t} + int_{mh,i} & \text{if} \quad i \quad \text{is capitalist} \end{cases} \tag{3.15}$$

(3.15) shows the flow of income may consist of four components: wage rate, entrepreneurial profits, bank profits proportional to agent's wealth $\sigma_{mh,i} \cdot F_{b,t}$ and the interest payments on past deposits $int_{mh,i}$. The consumption functions are:[21]

$$c_{inc,i} = \begin{cases} \alpha_0 + \alpha_{1,i} \cdot w_{r,-1} & \text{if} \quad i \quad \text{is worker} \\ \alpha_0 + \alpha_{2,i} \cdot f_{i,-1} & \text{if} \quad i \quad \text{is capitalist} \end{cases} \tag{3.16}$$

$$c_{wea,i} = \alpha_{3,i} \cdot (m_{h,-1,i} + \sigma_{mh,i} \cdot F_{b,t} + int_{mh,i}) \tag{3.17}$$

$$c_i = c_{inc,i} + c_{wea,i} \tag{3.18}$$

What is not consumed is saved, $dm_{h,i}$, and accumulated as stock of deposits:

$$dm_{h,i} = ydh_i - c_i \tag{3.19}$$

$$m_{h,i} = \begin{cases} m_{h,-1,i} + dm_{h,i} & \text{if} \quad i \quad \text{is worker} \\ m_{h,-1,i} + dm_{h,i} - q \cdot m_{h,-1,i} & \text{if} \quad i \quad \text{is capitalist} \end{cases} \tag{3.20}$$

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[21] $\alpha_0$ is a small autonomous component. Moreover, even though interests on deposits and banking profits are flows, we assemble them to wealth because of the marginality of that consumption component.

We conclude the subsection with some notes on the matching process in the consumption-good market. We have re-adapted the mechanism developed in Riccetti et al. (2015), according to which buyers and sellers meet in the market for commodities and act through a simple procurement process: potential customers observe a subset of prices from a narrow and random bunch of producers, as outcome of imperfect information. The *best* seller will be chosen according to the lowest price. Every period the single customer is given the opportunity to break the relationship with the previous trade partner and switch to another producer with a certain probability. We define the latter as:

$$
Prob = \begin{cases} 1 - e^{\chi_1 \cdot \frac{p_{new} - p_{old}}{p_{new}}} & \text{if} \quad p_{new} < p_{old} \\ 0 & \text{otherwise} \end{cases} \tag{3.21}
$$

The simple probability rule tells us that the larger the price differential between the former and the new potential supplier, the higher the probability to select the new. The assumption considers the empirical fact that consumers try to establish a durable relation of trust and reciprocity to solve problems of asymmetric and imperfect information (Bowles, 2009).

### 3.3.5 Schumpeterian innovation

The capitalists innovate to save labour and earn further profits. Innovation takes place through the hiring of workers as researchers with the aim of improving the technological apparatus of the firm.[22] Innovation is very affected by uncertainty in its *Knightian* form, interpreted as the lack of any quantifiable knowledge about some possible occurrence. In other words, the keen entrepreneurs do not know whether their effort and expenditures to promote technological development will be successful or not, because they are limited by a fundamental degree of ignorance and by an essential unpredictability of the future.

The way we model innovation occurrence somehow differs from the established tradition.[23] The enterprise has access to several *potential* productivity gains, either through home innovation or from imitation. To be clear, it is worth introducing the reader with some basic definitions: we identify with $a_{jj}$ the labour productivity in the $j$-th firm as result of its own innovative

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[22]Endogenous-growth models *à la* Romer (1990) conceptualize innovation in the same way, i.e. through the hiring of scientists. Nevertheless, the neoclassical apparatus envisages innovation as fully driven by supply-side factors and adopts the standard representative-agent framework. Our setting is opposite from this point of view, because of the role play by the principle of effective demand and the implemented ACE approach.

[23]Dosi et al. (2010), Caiani et al. (2016b) and their evolutionary tradition set firm's innovative activity as a two-step stochastic process, that involves random draws from Bernoulli and Beta distributions.

search, with $a_{ji}$ the productivity of the $j$-th firm as outcome from imitation and with $a_j$ the effective productivity in the $j$-th firm at some point in time; the latter is the maximum between the former, as we will see soon.[24] Innovation is a costly process that firms finance part out of new loans and part out of past wealth, as above. We stress the role of cumulative spending as the determinant of innovation accomplishment.[25]

To model this process, we select a logistic probability distribution, which is increasing with the cumulative investment on R&D:

$$\lambda_j = \frac{1}{1 + e^{-\varepsilon \Sigma_1^t i_{rd,j}}} \tag{3.22}$$

The sinusoidal function approaches to 1 as long as the cumulative investment augments over time.[26] It is crucial to remark that $\lambda_j$ changes from firm to firm, pointing that the ability to discover and introduce productivity-enhancing innovations depends on the own innovative search. To ascertain whether innovation actually occurs, a random number is drawn from a uniform distribution. If the drawn number is lower than $\lambda$, the entrepreneur successes in innovating and productivity will grow accordingly:

$$a_{jj} = a_{-1,jj} \cdot e^{g_{ird,-1,j}} \tag{3.23}$$

The imitation process reflects to the above. Entrepreneurs meet a narrow sample of competitors randomly. The meeting gives the entrepreneur the chance to imitate and copy the technology of her competitors. However, we exclude free-riders and adopt the law in (3.22) to state that the probability the capitalist has to imitate is a positive function of her cumulative investments. Once the probability to copy fulfills, the innovative entrepreneur has to evaluate which productivity gain is higher: thus she compares the gains from home innovation with the gains from imitation and adopts the maximizing-productivity technology:

$$a_j = max \left[ a_{jj}; a_{ji} \right] \tag{3.24}$$

---

[24]We assume $a_j = a_{jj} = a_{ji} = 1$ at the dawn of time. As can be ascertained, labour productivity is firm-specific and subjected to inter- and intra-organizational capabilities too.

[25]It is often remarked in the literature the role of R&D share in output as determinant of innovation rates. However, we do not believe that it is the right way to proceed: two firms may devolve the exact share but if the absolute amount of invested funds differs, the firm with the highest expenditure will have the highest probability to innovate.

[26]The logistic function has been used quite often in the literature to illustrate the process of creation and diffusion of technological improvements, cf. De Tarde (1903). Since there are nonetheless many probability distributions that may do it for us, we tried an inverse exponential function and the Gumbel distribution: results do not change significantly. Additionally, the mechanism works if and only if the firm does invest.

To conclude the subsection, we remark that the innovation process allows for the emergence of heterogeneity across firms, a *path-dependent* heterogeneity that accounts for firm's ability to learn from past experience and competitors. The *learning* ability is the crucial feature of the ACE and it is a key departure from more standard approaches, since the events are driven by agent interactions only, had the initial conditions been specified (Tesfatsion, 2006).[27]

### 3.3.6 Banking system

Schumpeter (1943, 1982) sets the banking system in a symbiotic relationship with the innovative entrepreneur. In particular, he argued the bank money is of prominent importance in the working of capitalist economies. The firms could not introduce or even finance innovations without money: as in Bertocco and Kalajzić (2020) no money leads to no innovations, no economic development and then no capitalism. The banking system makes innovative investments possible through the opening of a credit line at the disposal of the potential innovator, offering at the same time the possibility to earn a profit to the banker herself.[28] In our model we are not very interested in the behaviour of banks in the financial markets, nor that bank discriminates through credit rationing or through higher and lower rates of interest. To keep things as simple as possible, we suppose the existence of an aggregate big bank that accommodates the demand for loans from the business sector. We further assume any credit constraints away, so the bank provides producers with enough money to cover their investments plans and collects whatever amount of deposits from the public at given interest rates. The equations describing bank behaviour are the following:

$$int_{ld,j} = r_l \cdot \sigma_{ld,j} \cdot L_{d,t-1} \tag{3.25}$$

$$int_{mh,j} = r_h \cdot \sigma_{mh,j} \cdot M_{h,t-1} \tag{3.26}$$

$$F_{b,t} = r_l \cdot L_{d,t-1} - r_h \cdot M_{h,t-1} \tag{3.27}$$

(3.25) defines firm interest payments on loans as share on total loans; (3.26) reflects how the bank rewards household deposits as share on total wealth. Last equation, (3.27), computes banking profits that will be redistributed to households in proportion to their stock of wealth;

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[27]We are going to see in the Section IV the distributive properties of the emerged heterogeneity.

[28]Banks are "the instrument allowing these "new men" [the innovative entrepreneurs] to gain control over the productive factors, and in particular over the workforce required to realize innovative investments" (Bertocco and Kalajzić, 2020).

$r_l$ and $r_h$ are the interest rates on loans and deposits, respectively.[29]

### 3.3.7 Pricing and inflation expectations

How do firms set prices? The model does not involve the production of public goods, so the prices we should consider are from the unit price of private output. Given the current stock of machines, firms set prices as a mark-up over unit labour costs:

$$p_j = \left(1 + \mu_j\right) \cdot \frac{w_r}{a_j} \tag{3.28}$$

where $p_j$, $\mu_j$, $w_r$ and $a_j$ are, respectively, the unit price, the mark-up, the wage rate and the labour productivity at firm-level. In particular, firms benefit from some market power that enables them to increase the mark-up according to the market-share *differential*:

$$g_{\mu,j} = v \cdot \left(\sigma_{m,j} - \bar{\sigma}\right) \tag{3.29}$$

The evolution of the mark-up, $g_{\mu,j}$, is a function of the difference between the market share of the previous period, $\sigma_{m,j}$, and the median share in the market, $\bar{\sigma}$.[30] Once we got the price vector, we can model the inflation rate as the percentage change in the average price level:

$$\bar{p}_t = \frac{\Sigma_{j=1}^{F}}{F} = p_j \tag{3.30}$$

$$\pi_t = \frac{\bar{p}_t}{\bar{p}_{t-1}} - 1 \tag{3.31}$$

So doing, inflation enters the model through its influences on investment and consumption decisions: the idea is that higher inflation decreases the real value of capital goods and the amount of desired consumption. Furthermore, we adopt a *regressive* inflation-expectations process since it provides an accurate approximation of how economic agents behave in the real world (Sawyer and Passarella, 2019). To this purpose, we shall denote with $\pi^e$ the expected inflation rate:

$$\pi^e = \psi_0 + \psi_1 \cdot \left(\pi^T - \pi_{t-1}\right) + \pi_{t-1} \tag{3.32}$$

In (3.32) $\pi^T$ is the target inflation rate while $\psi_0$ and $\psi_1$ are non-negative parameters. The ex-

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[29] $r_l > r_h$ strictly holds.

[30] The logic behind says that when the market share is above (below) the median share, the firm tends to increase (decrease) the mark-up and thus the unit price.

pected price level $p_t^e$ is then:

$$p_t^e = (1 + \pi^e) \cdot \bar{p}_{t-1} \tag{3.33}$$

The final step consists of identifying an inflationary-correcting term to insert into the target-capital and wage functions:

$$pr_t = \frac{p_t^e}{\bar{p}_t} \tag{3.34}$$

## 3.4   Validation and policy experiments

### 3.4.1   Empirical validation: stylized facts

The model is run through 400 periods that roughly correspond to quarters.[31]  As common to the majority of ACE models, it does not allow for analytical, closed-form solution. The reason stands in the many non-linearities that distinguish agent decision rules and their pattern of interactions. Agents, firms *in primis*, start from a symmetric condition. For example, firms are endowed with an equal amount of capital goods at the beginning of the simulation. However, the starting symmetry does not prevent at all that heterogeneity comes out in the subsequent stages of development, as outcome of agent interactions. For what concerns to parameters and exogenous coefficients, we either borrowed from the literature or given reasonable values to match and not to clash with the former.[32]  Precisely, key coefficients in key behavioural equations are given stochastic values that vary agent-by-agent.[33]

How does the model fare with the empirical facts? In what follows we carry out an empirical validation so to check whether the model is able to replicate at least some of the wide spectrum of macro-economic and micro-economic stylized facts.

Fig. D.2 shows the general pattern of key variables of interest: output, consumption, investments and related components, labour productivity, deposits, unemployment rate and the wage share. A common practice in ACE models is that of doing away the initial periods of the simulations. They concern to the transient phase before convergence to a stable path and they are strongly affected by initial conditions. Therefore, we cut the first hundred of periods so to focus on the well-behaved path.

The model manages to generate endogenous and self-sustaining growth path characterized by

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[31]The baseline scenario is performed along 100 Monte Carlo simulations to wash the variability across runs away.

[32]Tab. D.1 is the parameter list.

[33]Examples are the marginal propensity to consume out of income and out of wealth, resembling Keynesian arguments.

clear fluctuations at the business-cycle frequency. In particular, the latter displays the roller-coaster dynamics exhibited in real data. The unemployment rate converges and gravitates around the reasonable value between 10 and 15 percent, while the wage share converges to 70% in the very long run. The model is stock-flow consistent as plotted in Fig. D.3: the adoption of stock-flow norms since the very beginning dampens the arbitrariness of behavioural parameters and the influences from purely stochastic factors.

A recent debate in the literature emphasizes the problem of Harrodian instability in agent-based models (Botte, 2019; Franke, 2019; Russo, 2020). More precisely, although firms strive to reach a normal capacity utilization rate at the micro-economic level, the accelerator effect from their investment schedule does not allow firms to satisfy their objective on aggregate (Botte, 2019).[34] However, the heterogeneity among firms can help solve the puzzle: Russo (2020) introduces firm-specific shocks in their demand expectations that lead to endogenous business-cycle fluctuations where capacity utilization does not exhibit explosive dynamics anymore. Our setting has several sources that may tame such an instability. First, firms are highly heterogeneous in their investment behaviour and expectations about future demand; moreover, we will see that firms' size distribution is very skewed and heavy-tailed, such that few big firms coexist with many smaller firms. In this picture, the matching process between firms and consumers helps lead to a configuration in which optimistic expectations may be counterbalanced by pessimistic ones on aggregate. Secondly, innovative investments are productivity-enhancing: this process has *ceteris paribus* a negative effect on employment rates such that aggregate consumption could fairly decrease.[35]

Tab. D.2 computes some brief statistics on output, its components and the unemployment rate. The simulated time series present strictly positive average rates of growth and exhibit a unit root. The latter is ascertained through two different unit-root tests so to get robust results. Either the ADF or the KPSS test confirm that all the variables exhibit a unit root, well in tune with the empirical evidence.[36]

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[34]Botte (2019) finds that full-employment ceiling stops the upward Harrodian instability, while an autonomous source of expenditure helps tame the downward instability. Franke (2019) shows the emersion of Harrodian instability from a neo-Kaleckian agent-based model in which firms continuously switch between optimistic and pessimistic expectations. Nevertheless, once he adds a third state with *neutral* expectations, the Harrodian instability is tamed if the economy settles into an equilibrium with an equal share of optimists and pessimists that coexist with a higher share of neutrals.

[35]Fig. D.4 shows the long and gradual convergence of capacity utilization toward an average 70 percent. In addition to this, it is worth remarking that business cycles are not a product of stochastic factors but they are endogenous to the model: the matching with consumers and the rise of heterogeneity subject a firm to experience periods of booms and recessions, and to revise its expectations accordingly.

[36]The unemployment rate follows a fat-tailed distribution whose related figure is not reported for the sake of brevity; it is however available upon request.

Fig. D.5 compares the volatility structures of the most important variables of interest: consumption, investment, output and the unemployment rate. Still in tune with observed real data, unemployment and investments turn out to be more volatile than output and consumption, the latter exhibiting almost the same pattern.[37]

The model is also able to match the business-cycle properties about correlation structures, as Tab. D.3 displays. In particular, investments and labour productivity appear pro-cyclical and leading while consumption tends to synchronize with the business cycle; the unemployment rate is counter-cyclical and lagging. We get from the same table that R&D is pro-cyclical. There is an interesting debate in the literature on the cyclicality of innovative expenditures: the basic argument says that whenever firms experience a sales boom and in the absence of tight credit constraints, they prefer allocating their human and physical assets to current production; hence, longer-term innovative investments should be counter-cyclical, while short-term investments are pro-cyclical (Aghion et al., 2010, 2012; Chiao, 2001; Rafferty and Funk*, 2004). Empirical evidence on that is contrasting and our results are more in line with Dosi et al. (2018), Napoletano et al. (2006) and Wälde and Woitek (2004).

Let us turn on the micro-economic stylized facts. The literature on firm size distribution argues that the size in manufacturing industries is stationary in moments and characterized by a log-normal shape, which is a skewed and heavy-tailed distribution (Bottazzi and Secchi, 2003, 2006). Fig. D.6 reflects what found in the literature above. To get robust results, we analyzed three proxies for firm size: sales of consumption goods, production and employment levels. The figure shows two types of plots: on the left-hand-side, we plot the Kernel density of the log-transformed data surrounded by a normal distribution; on the right-hand-side, we compute the simple normal probability plot. As we can see, simulated data can be well approximated by a log-Gaussian distribution with a sign of bi-modality.[38]

For what concerns to the moments, Tab. D.4 and Fig. D.7 show that standard deviation, skewness and kurtosis are stationary processes though they present a very tiny time trend. The first moment, in contrast, exhibits a unit-root process according to the standard ADF test. This holds

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[37]We have separated trends and cyclical components using the Hodrick-Prescott filter; cf. Napoletano et al. (2006) and Fagiolo et al. (2008).

[38]Cf. Dosi et al. (2010) for contrasting evidence. In addition to this, it is interesting to make a quick comparison with the model in Chapter II. When the model gravitates around a stationary state, the gamma distribution fits perfectly firm's size distribution. The gamma function in our case is either less skewed or less heavy-tailed than the present log-normal distribution. Therefore, the presence of economic growth in the model favours the rise of higher asymmetry and inflates the kurtosis in firm's size distribution. This, again, can be obtained through an ACE models only, being standard aggregate models not able to outline such an evidence.

for the size proxies of sales and production but not for employment. The non-stationarity of the mean is in tune with Dosi et al. (2010) but not with Bottazzi and Secchi (2003), albeit in the latter the first moment presents a significant and positive trend.

Our firms are very heterogeneous in terms of productivity and, again, are described by a log-normal distribution.[39] Additionally and still in tune with observed real data, productivity growth rates at firm level are Laplace distributed, so again the distribution is fat-tailed in Fig. D.8.[40]

Still, investment is heterogeneous and *lumpy* as in Figs. D.9 and D.10: on aggregate, firms experiencing investment spikes co-exist with firms having *near* zero investment. A wide body of literature finds that investments in manufacturing plants is characterized by periods of intense activity interspersed with periods of much lower one (Doms and Dunne, 1998). Moreover, investment spikes correspond to single episodes and are unlikely to wash out on aggregate (Caballero, 1999). This features rises the question on whether investment is lumpy in our model. Lumpiness means that the same firm switches from periods of high- to period of very low investment expenditures. We plot in Fig. D.10 the investment-to-capital ratio pattern of a selected $j$-th firm and we notice the presence of few high-investment periods alternating periods of much lower activity.[41]

However, we should judge that evidence with care: investment lumpiness in modeling comes out of $(S, s)$ investment functions as in Caballero (1999). Although we did not posit a discontinuous investment schedule, such discontinuities arise out of two main determinants: on the one hand, the matching process between firms and consumers continuously modifies the demand each single firm faces; on the other hand, productivity within the firm may jump to higher values as the result of innovation and imitation, with the important consequences in terms of demand for labour. This all leads to high-investment periods followed by longer periods of stillness.

The last stylized fact we want to stress is the *persistence* of R&D investments at firm level as in Tab. D.5. Firstly highlighted by Caballero and Hammour (1991), the persistence in R&D ex-

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[39]We computed the Jarque-Bera test for our log-transformed variables for each time period: we could not reject the null hypothesis of normality for the strictly vast majority of the cases. Results are not displayed for brevity reasons; they are available upon request. Furthermore, heterogeneity in productivity is more pronounced than in Chapter II.

[40]"Of basic findings related to productivity and productivity growth, the most significant is the degree of persistent heterogeneity across firms." In other terms, productivity levels are quite dispersed and differences reflect the differences in the outcomes of technological bets: even if the entrepreneurs bet the same, they may not reap the same rewards because of uncertainty (Bartelsman and Doms, 2000).

[41]The upper bound is computed as the median value across time plus the standard deviation. Similar pictures are discernible for each other firm, whose related graphics are available upon request.

penditures reflects the fact that researchers cannot be hired and subsequently fired without a substantial loss of firm-specific know-how that cannot be easily re-allocated to other activities (Falk, 2006). In other terms, the creation of a R&D lab implies a long-run commitment characterized by sunk costs and firms will have a strong tendency to smooth innovative spending over the business cycle more than what they usually do with ordinary physical investments (Mulkay et al., 2001).[42] For simplicity, we detect persistence by testing for unit roots in the panel of firms simulated by our model: we find that all innovative investments are $I(1)$ processes, i.e. they exhibit a high degree of persistence and serial correlation across time. The source of persistence comes out of the watchful process of reflection through which firms do continuously, though slowly, adapt their expectations over future demand.

To conclude and to pass to the next subsection, Tab. D.6 reports to the wide spectrum of real stylized facts matched by the model. We want to point out, in addition to the above, that the observed features are not simply dependent on a specific parameterization of the model: the inherent properties of the model, in terms of correlation structures and so on, and the way variables impact on each other would be the same and not tied to the specific set of parameters (Caiani et al., 2016a).

### 3.4.2   Policy experiments

In the previous subsection we have ascertained the ability of the model to replicate some facts observed in real data. The aim of this one is to ask the model how the economy behaves when we change the value of some parameter of particular interest. In other words, we investigate the properties of the model over a different set of scenarios and then we compare the results. The model has been developed to study the problem of Secular Stagnation in the USA from a demand-side perspective, and precisely we want to study the role played by the functional distribution of income in spurring firm innovative search. Besides that, we want to assess whether the rate of interest does play any role in stimulating the introduction of new technologies.

The reason to test the role exerted by income distribution lies in the general disagreement found in the literature.[43] Some might argue, indeed, that a distribution of the social product

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[42]The literature emphasizes two other major causes for the persistence in R&D spending: the "knowledge accumulation" hypothesis, that relates the experience in innovation with learning-by-doing mechanisms, and the "success-breeds-success" hypothesis, that sheds light on the simultaneous influence between innovation and long-lasting profitability. On the several reasons behind R&D persistence, we suggest Harhoff (2000); Manez et al. (2009); Suárez (2014). Le Bas and Scellato (2014) is a further synthetic review on the issue.

[43]Cf. Onaran and Galanis (2012) and Stockhammer (2017).

more favourable to wage earners dampens firm dynamism. In other terms, profit-financed investments would be reduced because of the lower funds aimed at supporting them. Therefore, keeping working power in check and setting a distribution of income more favourable to profit earners free resources and increase output and employment. However, on the other hand, we can claim as well that high wages and a pro-labour distribution of income foster aggregate demand, enhance investment outlets and provide an incentive for the dynamic mechanization of production, because firms will try to introduce labour-saving technology so to increase productivity and keep unit costs under control. Positive effects are then reflected into higher volumes of trade.

We can test which theory prevails through the parameter $w_1$. To remind, it identifies all the institutional, social and political factors that help the growth of the wage rate. Higher values of that mean greater labour bargaining power and so higher wage growth. Fig. D.11 shows the effect of different scenarios, each representing the economy with different values of $w_1$.[44] Wages sustain the demand for consumption commodities, on the one hand, and innovative investments on the other. The Schumpeterian entrepreneurs will invest in physical capital to enlarge the stock and not to lose clients. When wages soar, the profit rate drops with respect to the target; the entrepreneur will be forced to introduce labour-saving techniques through the R&D so to rise labour productivity and reduce unit labour costs. In other words, the need to counterbalance the increase in the labour cost with the introduction of enhancing-productivity techniques is essential to reduce the unit price or to keep it constant, at least. This is crucial for her competitive position in the market. Firms find more convenient to adapt production to more labour-saving techniques. However, it is worth remarking that the positive effect prevails over a negative and counterbalancing effect caused by wage rises. In other words, nothing prevents the innovation rate to grow more than wages so to lead a situation of technological unemployment associated to stagnant demand and declining growth rates.[45] A symptom of this perverse effect can be found in the higher unemployment rate we definitely get. Anyhow, the overall result is a better economic performance on aggregate, with higher output growth, higher productivity growth though with slightly higher unemployment.

For what regards to the rate of interest, the economic literature always asked whether, and how, the interest rate stimulates economic activity. The neoclassical belief is that a cut in the rate of interest triggers a twofold mechanism. Firstly, the cut stimulates production since capitalists

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[44]Every scenario is performed along 25 Monte Carlo runs.
[45]In this case, a wage rise would invalidate long-period growth.

are less burdened by the service of debt. Secondly, the negative elasticity of the investment function is determined by direct and indirect substitution mechanisms: when the interest rate goes down, entrepreneurs tend to increase the capital-labour ratio of their production processes to save on the factor become *costlier* − i.e. labour; in addition to this, the relative prices of more *capital-intensive* goods decrease, augmenting the previous argument. Therefore, the overall demand for capital increases (Girardi, 2016; Petri, 2004). To sum up, the neoclassical argument expects positive effects either on growth performance and innovation rates after a decline in the interest rate. As argued and justified by Girardi (2016) and Petri (2004), we did not assume that the rate of interest directly influences investment decisions. Yet, there are several channels through which the interest rate can affect investment and the economic performance. An example is the impact of a lower service of debt, as mentioned above. Figs. D.12 and D.13 depict the effect of several scenarios with varying interest rates. What is grasped is that the interest rate has non-linear and small effect on the level of economic activity. The very non-linearity in the investment pattern arises because of the contrasting movement that the rate of interest spurs on consumption and innovative activity. On the one hand, the entrepreneurs feel less burdened by interest payments so a greater amount of resources accrue to their profits. They are enabled to consume more in absolute terms, and the increase in the latter feeds production and employment. However and on the other hand, higher profits increase the profit rate and the discrepancy with the target rate shrinks. Moreover, the fear for competition seems attenuated: why should capitalists mechanize production further? Looking at aggregate investment, the non-linearity along monotonic decreases in the rate of interest reflects the different balancing between the increase of aggregate demand on the one side and the lessened need of innovative investment on the other. So we can say that even if the economy seems to perform better in terms of aggregate production and employment, that is reached at the expense of technological progress and innovation rates.

Among the several admissible causes of Secular Stagnation in the USA, the experiments help us single out also two important processes that have likely contributed to.[46] The experiments help us to frame and explain Secular Stagnation in the USA as the outcome of two important processes. First, social compromises more favourable to capital owners and the strong dejec-

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[46]We have to admit, of course, that the following are not the *only* valid explanations for the long-run tendency of productivity growth to fall. Non-technological motives, like lower top marginal tax rates, increased low-skill immigration, rising trade with China and low-cost manufacturing countries or the rise of superstar firms (Autor et al., 2020) are equally plausible.

tion of pro-labour reforms as witnessed by the American economy resulted in strictly lower incentive to invest on innovative activities, and the economy experienced a retardation in the growth rates of output and labour productivity. Indeed, innovative investments measured by the amount of R&D expenditure financed by private industries has drastically declined in growth terms since the end of the Golden Age of capitalism, as we showed in Chapter II.[47] At the same time, lower rates of interest do not seem to be effective in triggering investments in R&D or in physical capital, thus questioning the very effectiveness of monetary policies that keep the interest rate down to very low values. The next Section tries to find empirical evidence of our predictions through a simple econometric analysis on US manufacturing industries.

## 3.5  Empirical analysis

Once the model is developed and assessed through some experiment it is interesting to find empirical evidence, if any, of theoretical results. It is worth establishing since the beginning that what follows does not aim to provide exhaustive results. We instead want to look at the data and check whether our conclusions on the influence of labour costs and interest rates on the innovative effort may be reasonable. In so doing, we shall split the Section into three parts: namely, we start with a description of the data we are going to use; then we dedicate a subsection for the relationship between innovative search and labour costs and another one for the link between innovation and interest rates. As will be clear soon, the first empirical check involves a panel cointegration analysis in the line of Kao and Chiang (2001); Kao et al. (1999), Phillips and Moon (2000) and Pedroni (2001, 2004); by contrast, the interplay between innovation and rates of interest is detected through simple descriptive statistics only, because of the lack of any good specification for that.[48]

### 3.5.1  Data

We focus on a yearly panel dataset of fourteen ISIC-based manufacturing industries that represent the full manufacturing sector in the United States over the period $1958 - 2011$. Variables at our disposal concern to R&D expenditure, wages paid to production workers, value of shipments, labour productivity, and two different but close measures for the interest rate: effective

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[47]The same holds for public investment as well, but we reserve to study that issue in future research. Anyway, the interested reader can refer to Deleidi and Mazzucato (2020) and Pallante et al. (2020).

[48]A trigonometrical specification may do it for us; however, the interpretation of that would not be straightforward and any specific functional form can be rejected as implausible or *mis-specifying*. More on that below.

federal funds rate and bank prime loan rate.  While many statistics are straightforward and *easily* available from international sources, the same does not hold for R&D funds; therefore it is worth spending some words on how to get that measure.

The OECD's Anberd database provides data on R&D activities carried out by the business sector and regardless of the origin of funding.  The unit of analysis is disaggregated across a hundred of manufacturing and service industries since 1987.  However, the long-run character of our analysis would prefer a larger time span; thus we have to cover a period that goes back to the late Fifties at least.  The NSF's Survey of Industrial Research and Development − SIRD, now BERD − is the natural candidate.  SIRD was the primary source of information on R&D expenditures for profit-seeking, publicly or privately held companies with ten or more employees in the US.[49]  Moreover, data are clustered and provided at two-digit or industry-level, not at firm-level.  SIRD data allowed us to enlarge R&D time series back to 1958.

A further problem may be the compatibility between the old US SIC system and the current OECD ISIC classification.  We solved that through a scrupulous process of aggregation and check between the different sources.  Precisely, we compared the overlapping time span to verify whether SIRD and Anberd gave the same value for a given industry in a given year.  Yet, the compatibility need leaves us with a narrow, though comprehensive, cross-section sample, as in Tab. D.7.[50]

Wages, values of shipments, and labour productivity data come directly from the NBER Manufacturing Productivity Database, developed by Bartelsman and Gray among the others.  Wages are computed as the ratio between production worker wage bill and number of production worker hours; so it is a measure of hourly wage rate.  In contrast, value of industry shipments are based on net selling values after discounts and allowances, and they include receipts for contract work and miscellaneous service provided by a given plant to other (Bartelsman and Gray, 1996); labour productivity is computed as real value added over production working hours.[51]

Last two variables are the effective federal funds rate and the bank prime loan rate.  The former is the interest rate at which depository institutions trade federal funds, i.e. balances held at FED banks, with each other overnight.  The latter is the interest rate that commercial banks

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[49]A company is broadly defined as one or more establishments under common domestic ownership or control.

[50]For any issues or curiosities about SIRD and Anberd surveys, we suggest to consult the related documentation available at https://www.nsf.gov/statistics/srvyberd/prior-descriptions/overview-sird.cfm and http://www.oecd.org/innovation/inno/anberdanalyticalbusinessenterpriseresearchanddevelopmentdatabase.htm, respectively.  Moreover, we applied the same procedure for our covariates as well.

[51]Please refer to Bartelsman and Gray (1996) for any kind of issues and curiosities on the NBER database.

charge to their most creditworthy customers. Data and previous definition are from the FRED St. Louis Fed series. Tab. D.8 provide some statistics on our variables of interest.[52]

### 3.5.2 Estimation results: R&D and labour costs.

A clear result from the ACE model above is that wages sustain the demand for consumption commodities, on the one hand, and innovative investments on the other. Entrepreneurs invest in physical capital to enlarge the stock and not to lose clients, and at the same time they will be forced to introduce labour-saving innovations. The need to counterbalance the increase in the labour cost with the introduction of enhancing-productivity techniques is essential to reduce the unit price. This is crucial for their competitive position in the market.

Therefore we figure the problem of Secular Stagnation in the USA as due even to a progressive shift of income and bargaining power from labour to capital, that resulted in a smaller incentive to undertake innovative effort, among the other plausible rationales. The steady negative pattern of R&D and wage growth or wage share at the industrial level is clearly visible in Figs. D.14 and D.15 since 1972, i.e. the period we identified as Secular Stagnation; the same holds for industry-level productivity growth.[53]

From the above we ascertain that we can frame R&D investments at the industrial level as (positive) function of a *cost* component and a *revenue* component:

$$R\&D = f\left(wages; shipments\right) \quad f_s, f_w > 0 \tag{3.35}$$

The aim is to check whether this theoretical long-run relationship holds on the empirical ground. Several econometric techniques that rely on panel analysis are available to estimate our relation. In particular, the large temporal dimension at our disposal suggests to implement the panel time-series analysis as in Pesaran et al. (1999), Phillips and Moon (2000) and Kao and Chiang (2001) among the others. For the sake of simplicity, we shall assume a long-period relation of the form:

$$rd_{it} = \beta_{0,t} + \beta_{1,t}w_{i,t} + \beta_{2,t}s_{i,t} + \beta_{3,t}d73w_{i,t} +$$
$$+\beta_{4,t}d07w_{i,t} + \beta_{5,t}d73s_{i,t} + \beta_{6,t}d07s_{i,t} + \mu_i + \varepsilon_{i,t} \tag{3.36}$$

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[52]Every variable has been deflated with the GDP implicit price deflator, so to get real terms. We did not deflate the interest rates.

[53]The wage share at the industrial level has been computed as wage bill over value added. Moreover, regressions that show steady negative trends are available upon request.

where $i = 1, \ldots, N$ is the number of manufacturing industries; $t = 1, \ldots, T$ the number of periods; $rd$ the log of real R&D expenditure; $s$ the log of real value of shipments; $w$ the log of real wage rate; $d73$ and $d07$ are dummies that account for any structural change occurred in 1973 and 2007, respectively.[54] So the corresponding interaction terms with the regressors help us detect the presence of any regime switch in the long-run relation with the dependent variable. Finally, $\mu$ is group-specific effect whereas $\varepsilon$ a disturbance term independently distributed across $i$ and $t$.

The econometric procedure involves three steps. Firstly, the long time span rises the problem of unit-roots in the series; therefore, we have to test whether innovation investments, wages and shipments are stationary or not. Tab. D.9 reports to the results of four specific tests for panel data. The LLC test assumes the presence of a common unit root process in the null hypothesis, while the others are less restrictive and suppose an individual unit root process. As we can see, all but the LLC test − the latter only with reference to wages − agree on assessing the three variables of interest as nonstationary processes.[55]

Secondly, we have to establish whether any cointegrating relationship exists between them. Cointegration is the condition required for the regression of $y$ on $X$ regressors not to be spurious, i.e. for $\hat{\beta}$ to be consistent for the true value $\beta$. In other words, if $y$ and $X$ are $I(1)$, then the disturbance $u$ is $I(0)$ and it does not *swamp* the signal. Through cointegration, $y$ and $X$ have a common stochastic trend which is removed by linear combination (Fuertes, 2016).[56] Tab. D.10 shows the results of seven different panel cointegration tests. They all refer to Pedroni (2001, 2004), which proposed multiple tests for the null hypothesis of no cointegration in nonstationary panels that admit for heterogeneity among cross-sectional relationships. The seven statistics we report point simply out the degree of evidence, of lack thereof, for cointegration in panels among some variables.[57] Through rejecting the null in all the specifications, results seem to agree that our variables are cointegrated, so there exists at least a long-period relationship that tie them.

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[54]We choose these dates because it is licit to suspect a structural change in the relationship between regressors, due to the oil shock in 1973 and the strong financial crisis in 2007. Moreover, we define Secular Stagnation as a period started precisely between 1972 and 1973.

[55]Interestingly, Fleissig and Strauss (1997) applied the LLC test on real wage panel data finding that real wage innovations for the G7 countries, except for the US, are temporary with half-lives generally less than three years.

[56]It is worth emphasizing that panel data spurious regression estimates provide a consistent estimate of the true value of the parameter for $N, T \to \infty$. This is in sharp contrast with the pure time-series case because panel estimators average out across cross-sections and the information leads to stronger overall signal. For further details, check Pesaran and Smith (1995) and Baltagi (2008).

[57]We have to admit that the relative power of each test and the theoretical intuition behind them are not very straightforward. Still, check Baltagi (2008) for further insights on that problem.

Thirdly, last step is about estimation. We have three estimators at our disposal: the pooled mean group (PMG) estimator, the fully-modified least-squares (FOLS) estimator and the dynamic least-squares (DOLS) estimator. The first was developed by Pesaran et al. (1999) as an intermediate technique between the mean group estimator and the standard fixed-effect one. The developers argue that long-period relationship among variables can be the same across groups, while allowing short-run influences and variances to vary over them. It is a maximum-likelihood type estimator which, however, posits that regressors are strictly exogenous. In our setting, yet, we cannot exclude causality runs in both the directions.[58]

The second estimator (FOLS) implements a correction that clears out any problem due to long-run correlation between cointegrating equation and stochastic regressor's innovations; the resulting estimator is asymptotically unbiased and has fully efficient mixed-normal asymptotics. In other terms, FOLS estimator accounts for endogeneity of the regressors, and correlation and heteroskedasticity of the residuals (Phillips and Moon, 2000).[59]

Finally, the DOLS estimator involves augmenting the cointegrating regression through adding lags and leads of the regressors first differences, so to wash away asymptotic endogeneity and serial correlation.

Tab. D.11 presents the outputs of the regressions based on (3.36). To get oriented, we carry out two different models for each chosen estimator. *Odd*-number models do not take into consideration possible changes in the long-run relations between dependent variables and regressors, captured by the interaction of dummies and covariates. By contrast, *even*-number models do.[60] We grab first that the revenue component identified with shipments exerts positive but not always significant effect on the total amount of R&D expenditure. Precisely, a 1 percent increase in the value of real shipments leads from 0.2 to 0.6 percent increase in the R&D spending at industrial level, depending on the specification. Additionally, the interaction terms do not turn out to be very relevant, being the exception represented by Model II, in which the parameter

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[58]Rafferty and Funk* (2004) argue nonetheless that shipments, meant as proxies for demand, can be consider as (weakly) exogenous. The advantage of this demand variable over the other proxies for sales is that the latter are an endogenous mixture of supply and demand forces, while shipments is an exogenous mixture of the current and future demand firms *observe* and consider when deciding R&D budgets. We must handle this belief with caution anyway: that sentence may hold in the short term, but it is well plausible shipments are influenced by successful R&D in the longer run.

[59]We shall emphasize that FOLS estimator is subject to asymptotic bias regardless of how individual effects and deterministic regressors are contained if the regressors are nearly rather than exactly unit root processes (Baltagi, 2008). In this case, the DOLS estimator looks more promising.

[60]Capital stock in the form of equipment and plants is used as control in every regression; both are from the aforementioned NBER database.

associated with $d07s$ clearly shows that the long-run relationship between R&D and shipments has changed and reinforced significantly since 2007. In contrast, for what concerns the cost component, that is hourly wages, results are more uniform: in particular, a 1% increase in the wage rate leads from 0.7 to 0.8% increase in R&D funds when significantly different from zero.[61]

We have nonetheless to signal a caveat: in the above we did not consider the fact that entrepreneurs may not have any reason to undertake innovative investments if productivity simply increases with wages. We therefore repeat our estimations adjusting wages through productivity; this works as a robustness check too. Results are displayed in Tab. D.12 and look quantitatively but not qualitatively different from the above. The expected sign of our coefficients of interest are indeed positive and statistically significant in most cases. Additionally, the interaction terms turn out to be relevant in the majority of the models.[62]

Precisely, we can say that whatever specification we observe, the revenue component exerts a positive and significant effect of the dependent variable: a 1 percent increase on that leads to a 1% increase in R&D spending at the industrial level. In contrast, results are less uniform for what regards to our measure of unit labour costs. The PMG and the DOLS estimations without interaction terms finds no significant relationship between R&D and labour cost, while FOLS estimate does. However, including interaction variables allows us to say that a 1 percent increase in the adjusted wage rate is accompanied roughly to a 0.5 percent increase in R&D funds, at least and when significant. Still, the significance of the coefficients related to the interactive terms shows that the relationship changes through time, especially after 2007.[63]

All in all, we find empirical evidence of our theoretical results, in that either the *cost* component and the *revenue* component are positively related with expenditures on R&D with respect to the US manufacturing industries since 1958. Results are qualitatively robust to whether we adjust hourly wages with hourly labour productivity. Next step involves the analysis of the relation between R&D and the interest rate, which is going to be set through simple descriptive

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[61]Even though Pedroni tests found cointegrating relationship, it is always worth checking if the estimated residuals are stationary processes. We applied panel unit root tests for them and we found that they are actually stationary. Results available upon request.

[62]Adding interaction terms indeed drastically changes the interpretation of the coefficients: for example $\hat{\beta}_2$ cannot be interpreted as the unique effect of shipments on R&D anymore. The same holds later for labour costs.

[63]In Model VI we applied the grouped panel method as in Pedroni (2001, 2004). Moreover, the residual diagnostics in each regression shows that residuals are $I(0)$ processes, so we have not the problem of spurious results, though we said in a previous footnote how spurious regressions are not such a huge problem in panel econometrics.

statistics for the reasons below.

### 3.5.3   Estimation results: R&D and interest rates.

To investigate the relationship between innovative search and the rate of interest is somehow complicate. To remind, we have found more appropriate not to include the interest rate among the direct determinant of R&D investments because of the theoretical reasons above. However, as we have discussed, there may still be room for some indirect effects. What we grasp from the previous Section is that the interest rate has a non-linear and small effect upon innovation efforts and on the overall level of economic activity. More precisely, the very non-linearity in the R&D pattern arises because of the contrasting movement between the revenue and the cost components. On the one hand, capitalists increase the consumption in absolute terms because more profits accrue to their pockets and their need to innovate rises; but on the other hand, they are less afraid of the competitive pressure and reach a normal profit rate more easily, so the necessity to seek for labour-saving techniques looks reduced.

From an empirical point of view, we cannot handle the non-linearity, or to find evidence of it, by simply posing a quadratic or more complex specification in a standard regression model. All of them would be econometric mis-specifications, since we could not detect a well-established or predictable form from our simulations. Fig. D.13 shows indeed that different but close values of the rate of interest determine different schedules in the innovation pattern of the economy, and we are not able to foresee what could be the effect of an increase in the interest rate, as tiny it might be. In other words, a straightforward connection between the two probably does not exist. Although we do not suggest or assume any specific relationship between them, we can still perform an econometric cointegration test to see whether any long-run meaningful relation actually exists. Tab. D.13 shows the results of Pedroni residual cointegration tests. In particular, we test the existence of a long-run relationship between R&D investment and the funds rate, on the one hand, and with the prime rate, on the other hand. We obtain the interesting result that no long-run linkage exists between innovative search and the interest rate, whatever measure we adopt for the latter. This means that any estimated regression of the former on the latter would provide us with spurious coefficients.[64]

Because of that, we have decided to set any econometric and parametric analysis aside, and

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[64]We computed also a simple correlation coefficient with the data at our disposal and the value was very small, 0.0444, and not statistically significant from zero.

plot a few descriptive statistics only. Figs. D.16 through D.19 display different ways of conceiving the time-evolution of R&D and interest rate. The first way is to compute the ratio between the level first − and the growth rate later − of R&D spending and the bank prime loan rate. For what regards to the ratio between R&D in levels and prime rate, it fluctuates around a slightly increasing average trend, while the ratio that considers the R&D growth rates in the numerator swings around a trendless average. These results are clear especially for the cross-sections not affected by missing data.

Another way to check the behaviour of these variables is to plot R&D against the prime rate. This method looks closer to the results of our model, in which simple jumps in the rate value prompt change in the innovation pattern. And apparently that is what we see from Fig. D.17: different values in the prime rate are associated with different growth rates of R&D. Additionally, they do fluctuate around a flat zero mean. Finally, Figs. D.18 and D.19 repeat the same exercises using the funds rate in the place of the prime rate; results do not change significantly.

We can conclude this Section with a little recap. Among the plausible explanations for Secular Stagnation in the USA, we emphasized the negative effect that the shift of income and bargaining power from wage-earners to profit-earners led to a reduction in the growth rate of R&D investments. The simplest argument ran as follows: a low bargaining power of employees and their labour unions, as experienced since the early Seventies, will stop the increase in nominal and real wages, that will finally generate a rising profit share and hence a lower wage share. That will decelerate firms' efforts to improve productivity growth through innovation, because there is no decrease in the profit share to prevent (Hein, 2012). We tested this theoretical implication at the empirical level, focusing on a panel of US manufacturing industries from 1958 to 2011. We adopted different panel cointegration techniques and found that a positive relationship between labour costs and innovation rates generally holds since 1958, with some exception notwithstanding. It contributes to explain the decline in productivity growth, as Secular Stagnation is identified through this work, also by the negative influence exerted by the diminished wage share on firm's innovative search. Moreover, this linkage tends to strengthen since the Seventies, i.e. the period in which we set the theoretical onset of Secular Stagnation, and after the crisis of 2007.

In a second exercise, we detected the existence of any relationship between R&D and interest rates through a basic descriptive line, but we did not find any clear or well-established interplay between them. Moreover, panel cointegration tests do not allow us to reject the null hypoth-

esis of no cointegration in each specification. This again does not conflict with our theoretical arguments but deserves further research.

## 3.6  Conclusions

The aim of Part II was to extend and accomplish the line of reasoning started with Chapter II. We studied the problem of Secular Stagnation in the United States, arisen since the early Seventies as a long-run slowdown in the growth rates of productivity, that reached the trough with the Great Recession of 2007. To this aim, we developed a complex, adaptive and structural ACE growth model in the line of Dosi et al. (2010), Caiani et al. (2016a), Tesfatsion (2006), among the others. The ability of the model to satisfy some empirical regularity in terms of firm size distribution, productivity heterogeneity, investment asymmetry − and possibly lumpiness, among the other facts, helps us to strengthen our theoretical results in terms of policy implications. More precisely, we investigated the nexus between income distribution and firm's effort to invest on innovative search. We concluded that a low bargaining power of employees and their labour unions, as experienced since the early Seventies, contained the growth of nominal and real wages, that finally generated a rising profit share; firms' effort to improve productivity growth through the introduction of new labour-saving innovations diminished accordingly, since there was no decrease in the capital income share to prevent.

Furthermore, we addressed the neoclassical belief about the negative interest-elasticity of the investment function as a side result, since our model showed that decreases in the interest rate on loans are not associated to surges in the capital accumulation. They do lead instead to non-linear and unpredictable effects.

Finally, we carried out a simple empirical analysis for the main theoretical achievements. The focus was on US manufacturing industries from 1958 to 2011. We found empirical evidence confirming our suggestions, with some exception notwithstanding. On the one hand, we find robust empirical evidence of a positive long-period relationship between innovative effort and (unit) labour costs at the industrial level; in addition to this, the positive effect is statistically significant in most specifications. On the other hand, panel cointegration tests lead us to claim the lack of any clear and well-established long-run linkage between innovative activity and the rate of interest, the latter measured with the effective federal funds rate or the bank prime loan rate.

Obviously, we are not in the position to argue that our explanations for Secular Stagnation in the USA are the only valid rationales. Many other reasons such as the rise of superstar firms or the growing trade with Chinese manufacturing can provide useful information to explain the falling pattern of productivity growth. We intend to deal with these issues in a future research.

# Appendix D

# Tables and Figures

| Notation | Description | Value |
|---|---|---|
| *Time* | Time span | 400 |
| *MC* | Monte Carlo runs | 100 |
| *F* | Firms | 40 |
| $N_s$ | Workers-Consumers | 600 |
| $\alpha_0$ | Autonomous consumption | 0.0075 |
| $\alpha_1$ | Worker's marginal propensity to consume out of income | [0.6; 65] |
| $\alpha_2$ | Capitalist's marginal propensity to consume out of income | [0.5; 0.55] |
| $\alpha_3$ | Marginal propensity to consume out of wealth | [0; 0.06] |
| $a_0$ | Labour-productivity initial value | 1 |
| $a_1$ | Coefficient in the productivity equation | 0.75 |
| $\delta$ | Capital depreciation | 0.05 |
| $\varepsilon$ | Parameter in the $\lambda$ function | 0.005 |
| $i_0$ | Autonomous investment at $t = t_0$ | 0.8 |
| $i_1$ | Partial-adjustment coefficient | [0.25; 0.35] |
| *meet* | Meetings per unit of time | 3 |
| $\mu_0$ | Mark-up at $t = t_0$ | 0.075 |
| $\psi_0$ | Coefficient in the price expectations function | 0 |
| $\psi_1$ | Coefficient in the price expectations function | 0.01 |
| $q$ | Share of wealth re-invested | 0.0216 |
| $r_l$ | Interest rate on loans | 0.0075 |
| $r_h$ | Interest rate on deposits | 0.0025 |
| $\vartheta_1$ | Coefficient in the R&D investment growth equation | [0.01; 0.02] |
| $\vartheta_2$ | Coefficient in the R&D investment growth equation | [0.025; 0.035] |
| $v$ | Coefficient in the mark-up growth equation | 0.85 |
| $w_0$ | Wage rate at $t = t_0$ | 0.5 |
| $w_1$ | Coefficient in the wage growth equation | 0.007 |
| $w_2$ | Coefficient in the wage growth equation | 0.0045 |
| $\chi$ | Consumer's links | 5 |

Note: shaded lines denote variables whose value differs between agents.

Table D.1. Time span, number of agents, parameter setting and exogenous variables

|  | Output | Investment | Consumption | Unemployment |
|---|---|---|---|---|
| Average | 0.011 | 0.006 | 0.008 | 0.125 |
| ADF test | −0.832 | −0.094 | −1.649 | −1.365 |
|  | (0.809) | (0.948) | (0.457) | (0.60) |
| KPSS test | 2.472 | 2.474 | 2.472 | 0.359 |
|  | (0.739) | (0.739) | (0.739) | (0.347) |

Note: averages refer to growth rates for output and its components. P-values and critical value at 1% in brackets for the ADF and the KPSS tests, respectively. For what concerns to the unemployment rate, KPSS critical value corresponds to 10% significance level.

Table D.2. Output, investment, consumption and unemployment statistics

| Series (HP cycle) | Output (HP cycle) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  | $t-5$ | $t-4$ | $t-3$ | $t-2$ | $t-1$ | $t$ | $t+1$ | $t+2$ | $t+3$ | $t+4$ | $t+5$ |
| Consumption | −0.035 | 0.045 | 0.268* | 0.401* | 0.814* | 0.88* | 0.578* | 0.36* | 0.172* | 0.036 | −0.066 |
| Investment | 0.103 | 0.155* | 0.326* | 0.391* | 0.696* | 0.601* | 0.13* | −0.051 | −0.208* | −0.264* | −0.28* |
| Output | −0.07 | 0.045 | 0.214* | 0.429* | 0.724* | 1* | 0.724* | 0.429* | 0.214* | 0.045 | −0.07 |
| K Investment | 0.108 | 0.166* | 0.323* | 0.405* | 0.685* | 0.632* | 0.287* | 0.007 | −0.232* | −0.323* | −0.354* |
| R&D Investment | 0.077 | 0.11 | 0.273* | 0.3* | 0.593* | 0.447* | −0.15* | −0.139* | −0.131* | −0.121 | −0.11 |
| Productivity | 0.078 | 0.11 | 0.273* | 0.299* | 0.595* | 0.445* | −0.154* | −0.141* | −0.132* | −0.122* | −0.109 |
| Unemployment rate | 0.137* | 0.085 | 0.124* | −0.009 | 0.071 | −0.286* | −0.737* | −0.485* | −0.314* | −0.165* | −0.067 |

Note: star for statistical significance at 5%.

Table D.3. Correlation structure

|  | Consumption | | Production | | Employment | |
|---|---|---|---|---|---|---|
|  | Trend $\beta$ | ADF test | Trend $\beta$ | ADF test | Trend $\beta$ | ADF test |
| Mean | 0.006 | 0.791 | 0.006 | 0.876 | −0.0001 | −4.109 |
|  | (0.000) | (0.994) | (0.000) | (0.995) | (0.014) | (−0.001) |
| Standard deviation | 0.003 | −4.812 | 0.0002 | −5.527 | 0.0001 | −8.429 |
|  | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Skewness | 0.001 | −18.765 | 0.001 | −10.828 | 0.001 | −10.978 |
|  | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Kurtosis | $8.10E-05$ | −18.426 | 0.0003 | −17.820 | 0.001 | −17.815 |
|  | (0.900) | (0.000) | (0.390) | (0.000) | (0.106) | (0.000) |

Note: p-values in brackets.

Table D.4. Moments of (log)size distribution

| Panel unit root test | LLC | IPS | ADF-Fisher $\chi^2$ | PP-Fisher $\chi^2$ |
|---|---|---|---|---|
| R&D | 32.422 | 13.322 | 1.229 | 72.702 |
| | (1.000) | (1.000) | (1.000) | (0.706) |

Note: numbers in brackets denote p-values; we adopt the Schwarz-Bayesian criterion to select the optimal lag length. The null hypothesis assumes a common unit root process in the LLC test, while individual unit root process in the others.

Table D.5. R&D persistence at firm level

| Stylized facts | Tables - Figures | References |
| --- | --- | --- |
| **Micro-economic level (firms)** | | |
| Skewness and heavy tailed-ness in firm size distribution | Fig. D.6 | Bottazzi and Secchi (2003, 2006) |
| Moments of size distribution are stationary (but not the mean) | Tab. D.4, Fig. D.7 | Bottazzi and Secchi (2003); Dosi et al. (2010) |
| Heterogeneous productivity and Laplace-distributed growth rates | Fig. D.8 | Bartelsman and Doms (2000); Bottazzi and Secchi (2003) |
| Investment heterogeneity and lumpiness | Figs. D.9 - D.10 | Caballero (1999); Doms and Dunne (1998) |
| Persistence of R&D | Tab. D.5 | Caballero and Hammour (1991); Harhoff (2000); Le Bas and Scellato (2014) |
| **Macro-economic level (aggregate)** | | |
| Endogenous and self-sustained growth | Fig. D.2 | Caiani et al. (2019); Dosi et al. (2010) |
| Fluctuations at business-cycle level | Fig. D.2 | Caiani et al. (2016a); Dosi et al. (2010); Stock and Watson (1999) |
| Stock-flow consistency | Fig. D.3 | Godley and Lavoie (2006) |
| Output, investment, consumption and unemployment are non-stationary | Tab. D.2 | Blanchard and Summers (1986); Hamilton (2020); Nelson and Plosser (1982) |
| Cross-correlation among macro-variables | Tab. D.3 | Stock and Watson (1999) |
| Pro-cyclical R&D | Tab. D.3 | Wälde and Woitek (2004) |
| Volatility of output, investment, consumption and unemployment | Fig. D.5 | Caiani et al. (2016a); Dosi et al. (2010); Stock and Watson (1999) |

Table D.6. Stylized facts matched by the model

| ISIC Rev.4 | Industry |
|---|---|
| 10 − 12 | Food, beverages and tobacco |
| 13 − 15 | Textiles, wearing apparel, leather and related products |
| 16 | Wood and related products |
| 17 | Paper and related products |
| 18 | Printing and reproduction of recorded media |
| 19 | Coke and refined petroleum products |
| 20 − 21 | Chemical and pharmaceutical products |
| 22 − 23 | Rubber, plastics and other non-metallic products |
| 24 | Basic metals |
| 25 | Fabricated metals |
| 26 − 27 | Electronic and electrical equipment |
| 28 | Machinery equipment |
| 29 − 30 | Transport equipment |
| 31 − 33 | Furniture and miscellaneous manufacturing |

Table D.7. List of manufacturing industries

| Variable | Obs | Mean | Sd | Min | Max |
|---|---|---|---|---|---|
| R&D expenditure | 634 | 5589.518 | 21881.55 | 5.01961 | 318768 |
| Wage rate | 756 | 8.55767 | 15.65058 | 0.45845 | 177.2766 |
| Value of shipments | 756 | 139852 | 294536.1 | 4103.765 | 3954613 |
| Labour productivity | 488 | 239.3435 | 879.8563 | 2.739767 | 16890.46 |
| Effective federal funds rate | 756 | 0.0553454 | 0.0335722 | 0.00095 | 0.1551 |
| Bank prime loan rate | 756 | 0.0753165 | 0.0316482 | 0.0325 | 0.1887 |

Note: values are expressed in millions of 2010 dollars. Sources: author's own computations on OECD Anberd database, NSF SIRD survey, FRED St. Louis Fed, NBER Manufacturing Productivity Database.

Table D.8. Dataset - descritive statistics

|  | R&D | Wage | Adjusted Wage | Shipments |
|---|---|---|---|---|
| LLC | $-0.4415$ | $-1.5344$ | 2.1876 | $-1.0927$ |
|  | (0.3294) | (0.0625) | (0.9856) | (0.1373) |
| IPS | 1.9607 | 0.2908 | 6.1719 | 0.5879 |
|  | (0.9750) | (0.6144) | (1.000) | (0.7217) |
| ADF - Fisher $\chi^2$ | 13.7763 | 16.9224 | 5.4676 | 16.4977 |
|  | (0.9887) | (0.9501) | (1.000) | (0.9578) |
| PP - Fisher $\chi^2$ | 13.5362 | 16.7784 | 5.0658 | 15.0528 |
|  | (0.9902) | (0.9528) | (1.000) | (0.9779) |

Note: panel unit root tests consider individual effects as exogenous variables and we adopt the Schwarz-Bayesian criterion to select the optimal lag length. The null hypothesis assumes a *common* unit root process in the LLC test, while *individual* unit root process in the others.

Table D.9. Panel unit root tests

|  | Statistic | (Weigthed) Statistic |
|---|---|---|
| Panel v-stat | 3.6834*** | 1.9165** |
| Panel $\varrho$-stat | $-6.6651$*** | $-2.0218$** |
| Panel PP-stat | $-8.1807$*** | $-3.0154$*** |
| Panel ADF-stat | $-7.7646$*** | $-2.9305$*** |
| Group $\varrho$-stat | $-3.7770$*** |  |
| Group PP-stat | $-6.4648$*** |  |
| Group ADF-stat | $-7.1560$*** |  |

Note: results refer to Pedroni residual cointegration tests where the null hypothesis is of no cointegration; we assume no deterministic trend and we adopt the Schwarz-Bayesian criterion to select the best lag length. Star significance: ***$p < 0.01$, **$p < 0.05$ and *$p < 0.1$.

Table D.10. Panel cointegration tests

| Dependent variable: R&D | PMG | | FOLS | | DOLS | |
| --- | --- | --- | --- | --- | --- | --- |
| | Model I | Model II | Model III | Model IV | Model V | Model VI |
| $w$ | 0.7195*** | 0.7849*** | 0.8538*** | 0.8123*** | 0.7836*** | 0.3299 |
| | (0.1105) | (0.1238) | (0.1207) | (0.1609) | (0.1424) | (0.2989) |
| $s$ | 0.2728*** | 0.1562 | 0.1968 | 0.2446** | 0.2449* | 0.6007** |
| | (0.1084) | (0.1081) | (0.123) | (0.1249) | (0.1422) | (0.2704) |
| $d73w$ | | 0.1257 | | −0.0002 | | 0.0993 |
| | | (0.0914) | | (0.1209) | | 0.2393 |
| $d07w$ | | −0.2997** | | 0.0893 | | 0.0085 |
| | | (0.01176) | | (0.0907) | | (0.1825) |
| $d73s$ | | 0.0062 | | −0.0052 | | 0.0097 |
| | | (0.0049) | | (0.0081) | | (0.0140) |
| $d07s$ | | 0.0715** | | 0.0292 | | −0.0178 |
| | | (0.0293) | | (0.0224) | | 0.1098 |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Speed of adj, $\varphi$ | −0.4320*** | 0.4319*** | | | | |
| | (0.0778) | (0.0844) | | | | |
| Log likelihood | 426.2998 | 481.2157 | | | | |
| Observations | 606 | 606 | 622 | 622 | 619 | 622 |
| Periods | 53 | 53 | 53 | 53 | 53 | 53 |
| Cross-sections | 14 | 14 | 14 | 14 | 14 | 14 |

Note: the wage variable is not adjusted by productivity. The careful reader notices the lack of any measure of goodness of fit and the like. We should exercise extreme caution in using these measures because all of them would be computed using the original and not transformed data. For what concerns the choice of leads and lags, we adopted the Schwarz-Bayesian criterion. We control the short-run dynamics with equipment and structures in every regression; additionally we choose the *pooled* panel method for each specification but in Model VI, where we opted for the *grouped* to avoid cross-section dropouts. Star significance: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table D.11. Estimation results

| Dependent variable: R&D | PMG | | FOLS | | DOLS | |
|---|---|---|---|---|---|---|
| | Model I | Model II | Model III | Model IV | Model V | Model VI |
| $w_{adj}$ | 0.2624 | 1.1128*** | 0.5202*** | 0.4709* | 0.3226 | 3.4086* |
| | (0.2264) | (0.3331) | (1.0264) | (0.2802) | (0.2530) | (1.9437) |
| $s$ | 1.0232*** | 0.9458*** | 1.0264*** | 0.9599*** | 1.0244*** | 1.4508*** |
| | (0.0305) | (0.0391) | (0.0350) | (0.0433) | (0.0000) | (0.2138) |
| $d73w_{adj}$ | | 0.0436 | | 0.4807** | | −3.1643 |
| | | (0.2769) | | (0.2291) | | (1.9565) |
| $d07w_{adj}$ | | 0.5039** | | 0.3711*** | | 1.1510* |
| | | (0.2553) | | (0.1452) | | (0.6234) |
| $d73s$ | | 0.0227 | | 0.0582* | | −0.4852** |
| | | (0.0377) | | (0.0321) | | (0.2197) |
| $d07s$ | | 0.0915*** | | 0.0787*** | | 0.1170 |
| | | (0.0331) | | (0.0221) | | (0.0800) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Speed of adj, $\varphi$ | −0.4150*** | −0.4182*** | | | | |
| | (0.0986) | (0.1006) | | | | |
| Log likelihood | 382.8508 | 433.3805 | | | | |
| Observations | 606 | 606 | 622 | 622 | 616 | 622 |
| Periods | 53 | 53 | 53 | 53 | 53 | 53 |
| Cross-sections | 14 | 14 | 14 | 14 | 14 | 14 |

Note: the wage variable is adjusted by productivity. The careful reader notices the lack of any measure of goodness of fit and the like. We should exercise extreme caution in using these measures because all of them would be computed using the original and not transformed data. For what concerns the choice of leads and lags, we adopted the Schwarz-Bayesian criterion. We control the short-run dynamics with equipment and structures in every regression; additionally we choose the *pooled* panel method for each specification but in Model VI, where we opted for the *grouped* to avoid cross-section dropouts. Star significance: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table D.12. Estimation results: robustness check

|  | R&D - effr | | R&D - bplr | |
|---|---|---|---|---|
|  | Statistics | (Weighted) Statistic | Statistics | (Weighted) Statistic |
| Panel v-stat | −1.5239 | −1.6006 | −1.9609 | −1.9631 |
| Panel $\varrho$-stat | 0.2014 | 0.2013 | 1.7243 | 1.7355 |
| Panel PP-stat | −0.6616 | −0.7286 | 1.2104 | 1.1888 |
| Panel ADF-stat | −0.5265 | −0.3897 | 1.5646 | 1.7473 |
| Group $\varrho$-stat | 1.7623 | | 3.0944 | |
| Group PP-stat | 0.0297 | | 2.1218 | |
| Group ADF-stat | 0.1082 | | 2.5287 | |

Note: results refer to Pedroni residual cointegration tests where the null hypothesis is of no cointegration; we assume no deterministic trend and we adopt the Schwarz-Bayesian criterion to select the best lag length. Star significance: $^{***}p < 0.01$, $^{**}p < 0.05$ and $^{*}p < 0.1$.

Table D.13. R&D and interest rates: Pedroni panel cointegration tests
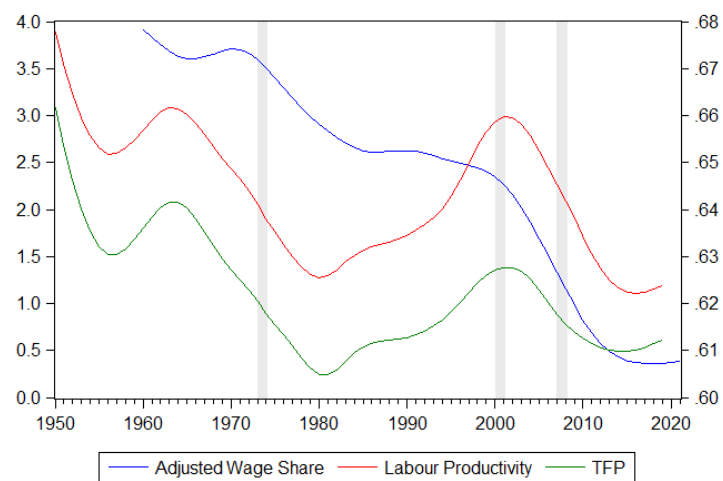
Note: left axis refers to productivity growth rates, right axis to the wage share; shaded areas indicate major crises; we reported results of the HP-filter trend component of real time series so to focus on the long-run component. Source: author's calculations on Ameco and BLS data.

Figure D.1. US adjusted wage share and productivity growth rates, 1950-2018
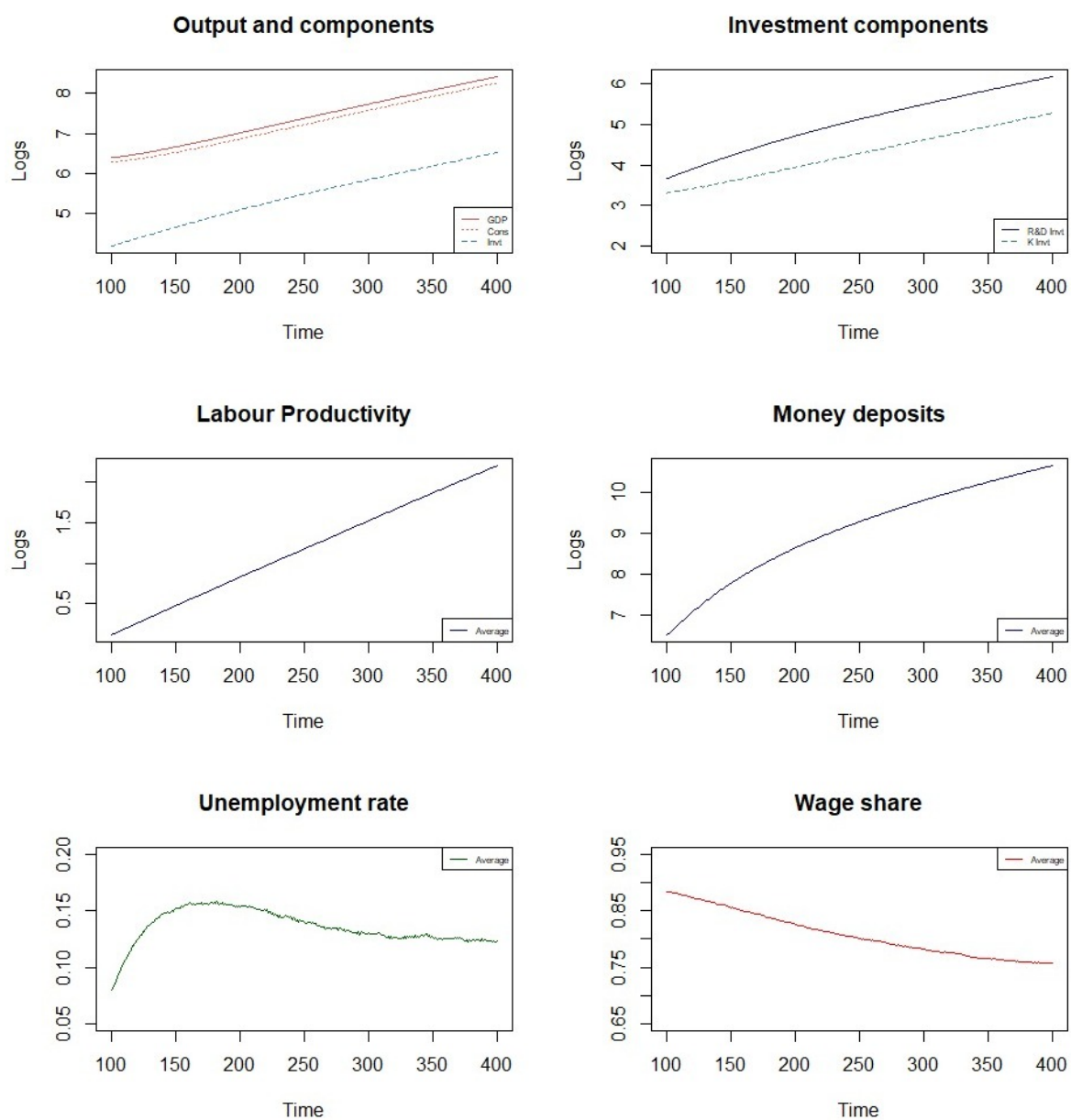
Figure D.2. Baseline model: levels in log terms
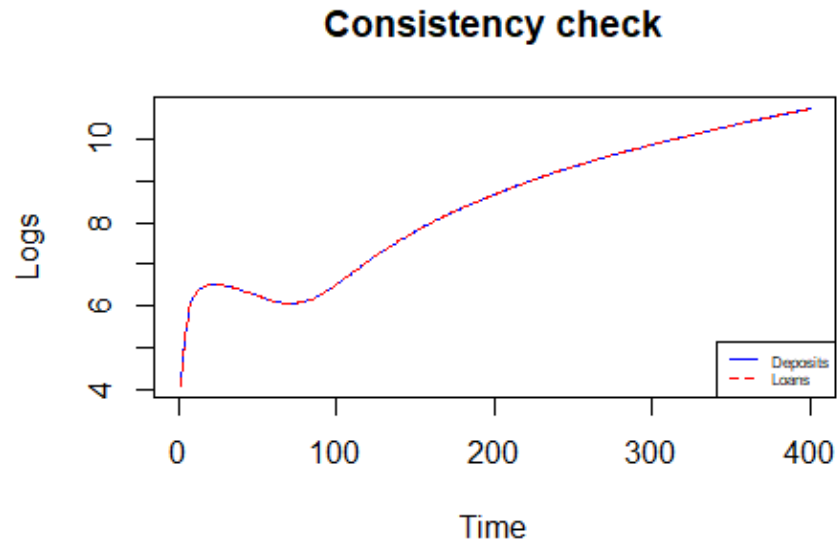
Figure D.3. Stock-flow consistency check on selected simulation
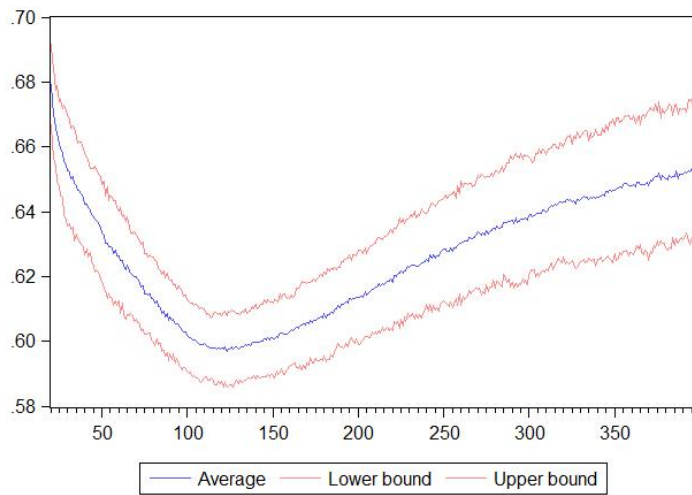


Note: bounds are the confidence interval at 95% level; average and bounds are computed across Monte Carlo runs.

Figure D.4. Aggregate capacity utilisation rate
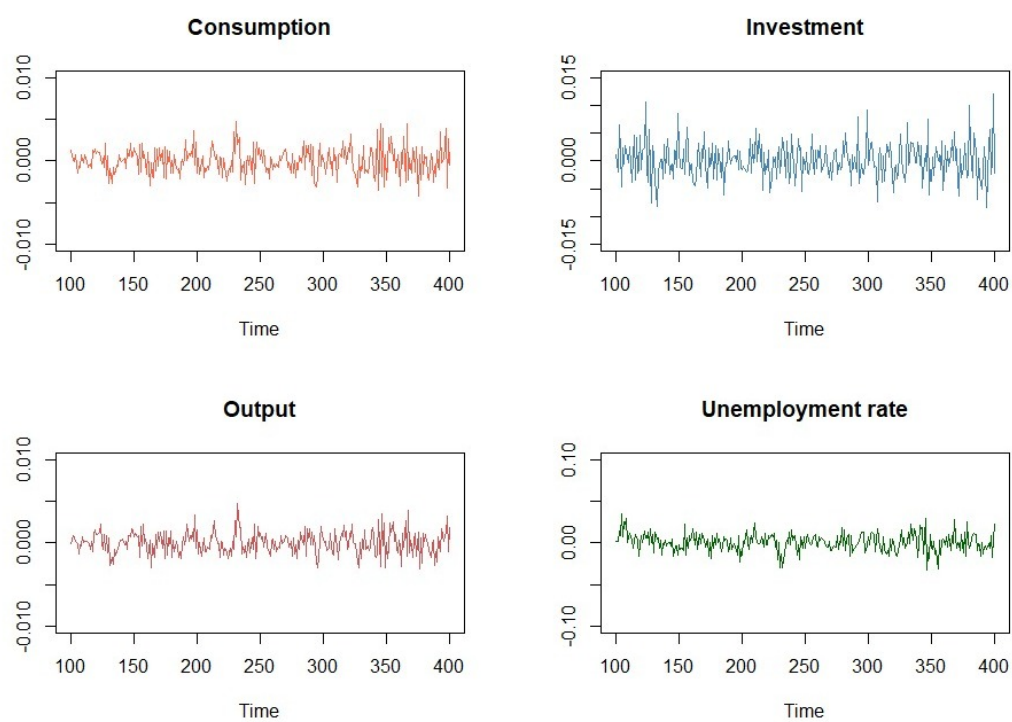
Figure D.5. Cyclical components of simulated time series for some aggregate variables
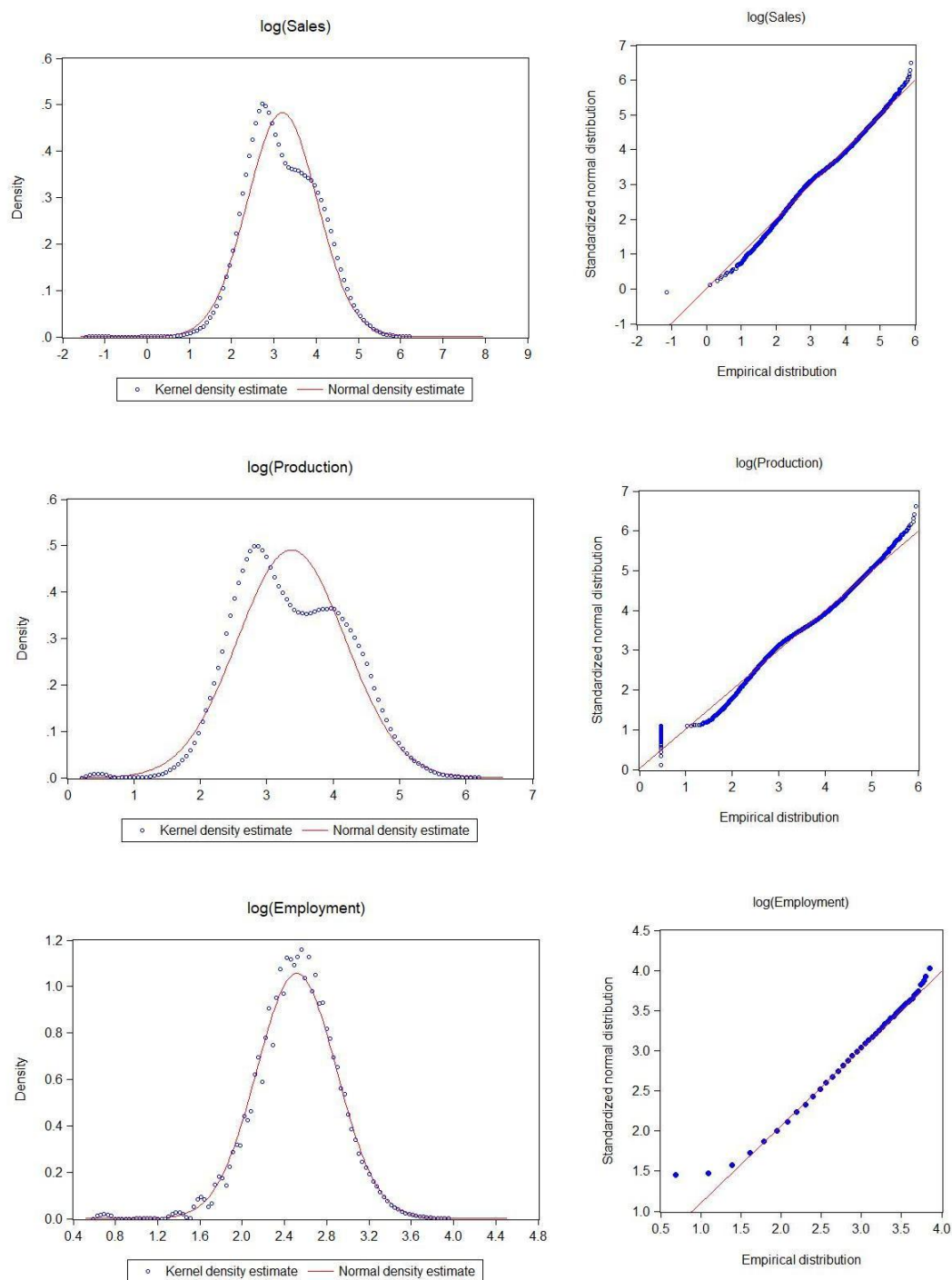
Note: sales refer to shipments of consumption good, while production is about shipments of consumption and investment goods.

Figure D.6. Firm size distribution
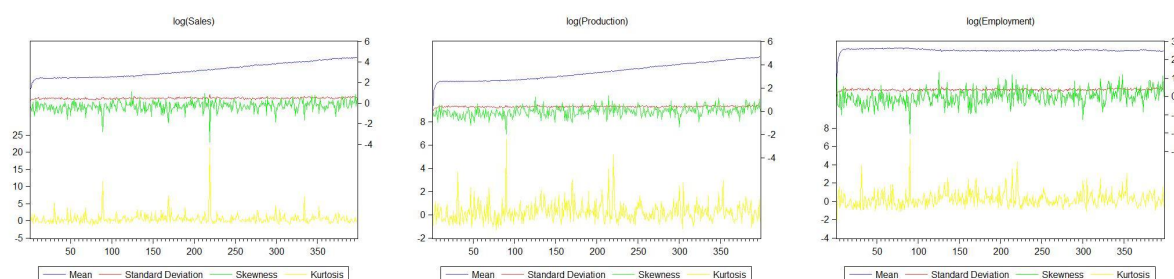
Note:  sales refer to shipments of consumption good, while production is about shipments of consumption and investment goods.

Figure D.7. Moments of firm size distribution
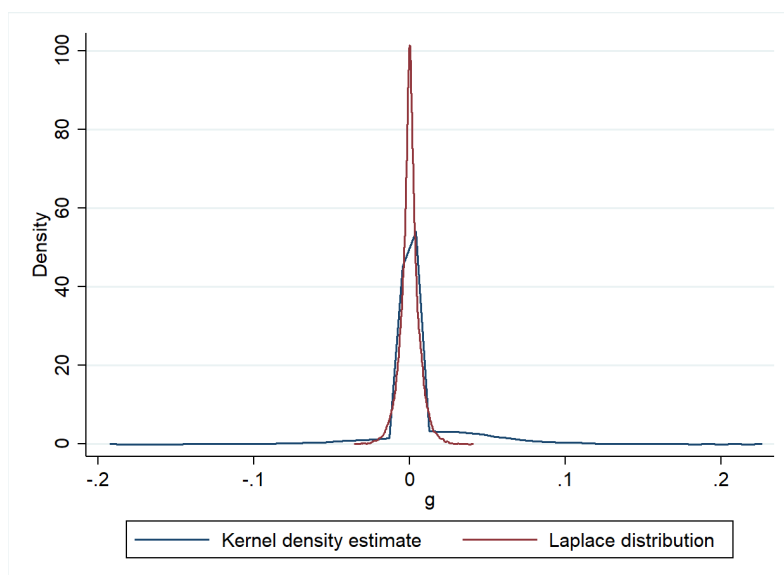


Note: estimates refer to productivity changes at firm level.

Figure D.8. Productivity growth distribution
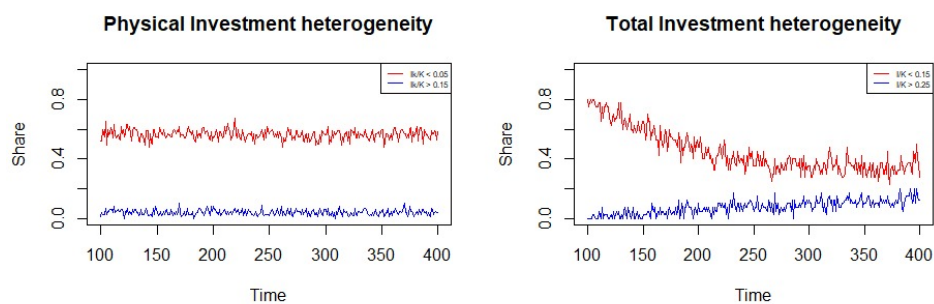


Figure D.9. Investment heterogeneity
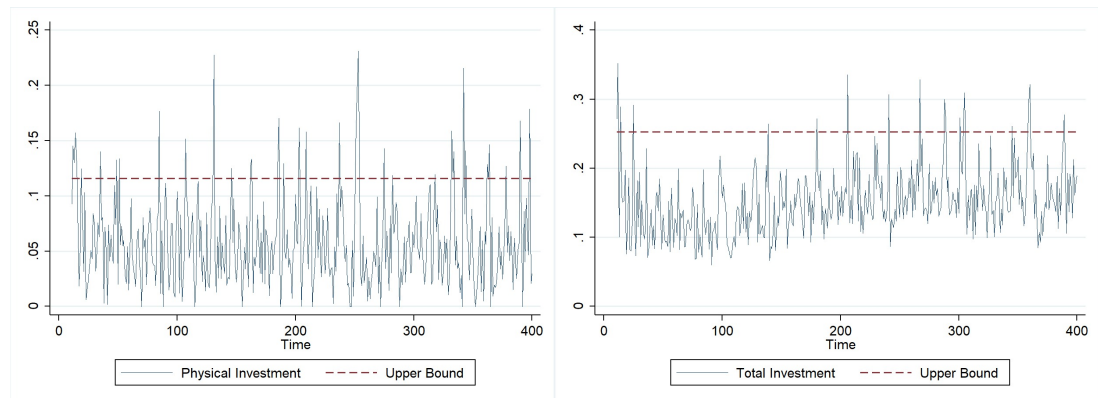
Note: investment patterns from a selected firm; the upper bound is determined as median value plus one standard deviation.

Figure D.10. Investment lumpiness
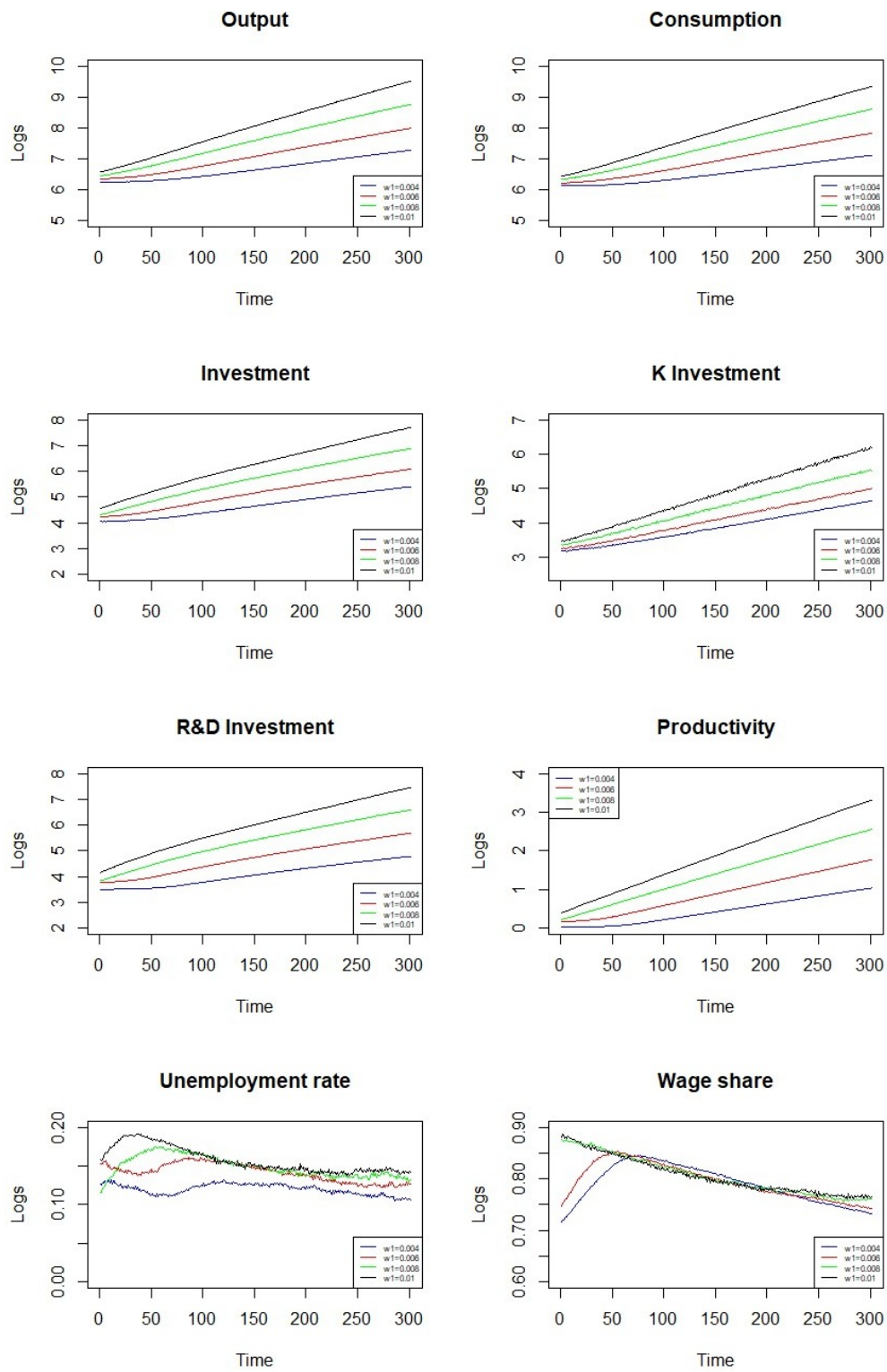
Figure D.11. Experiments on income distribution
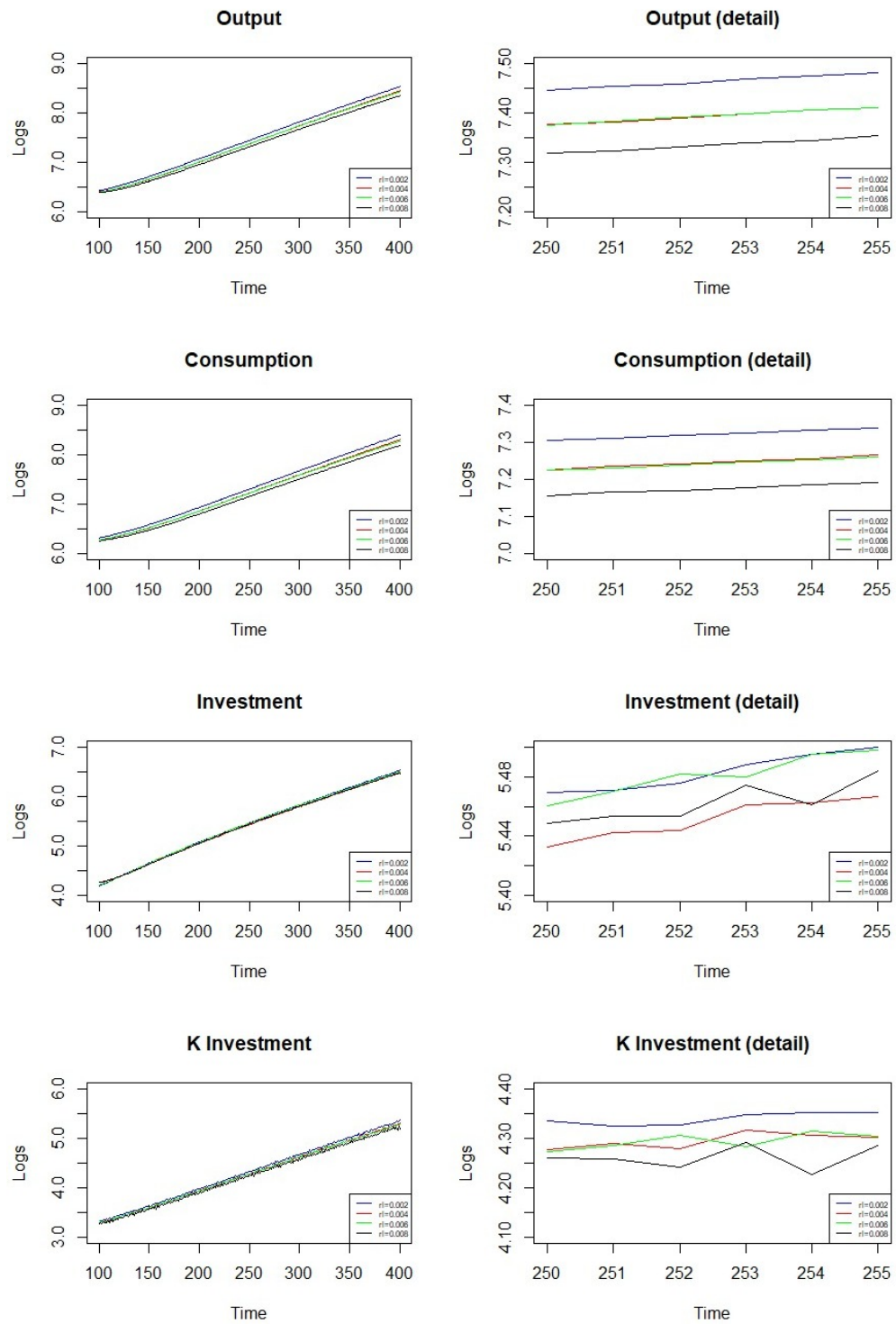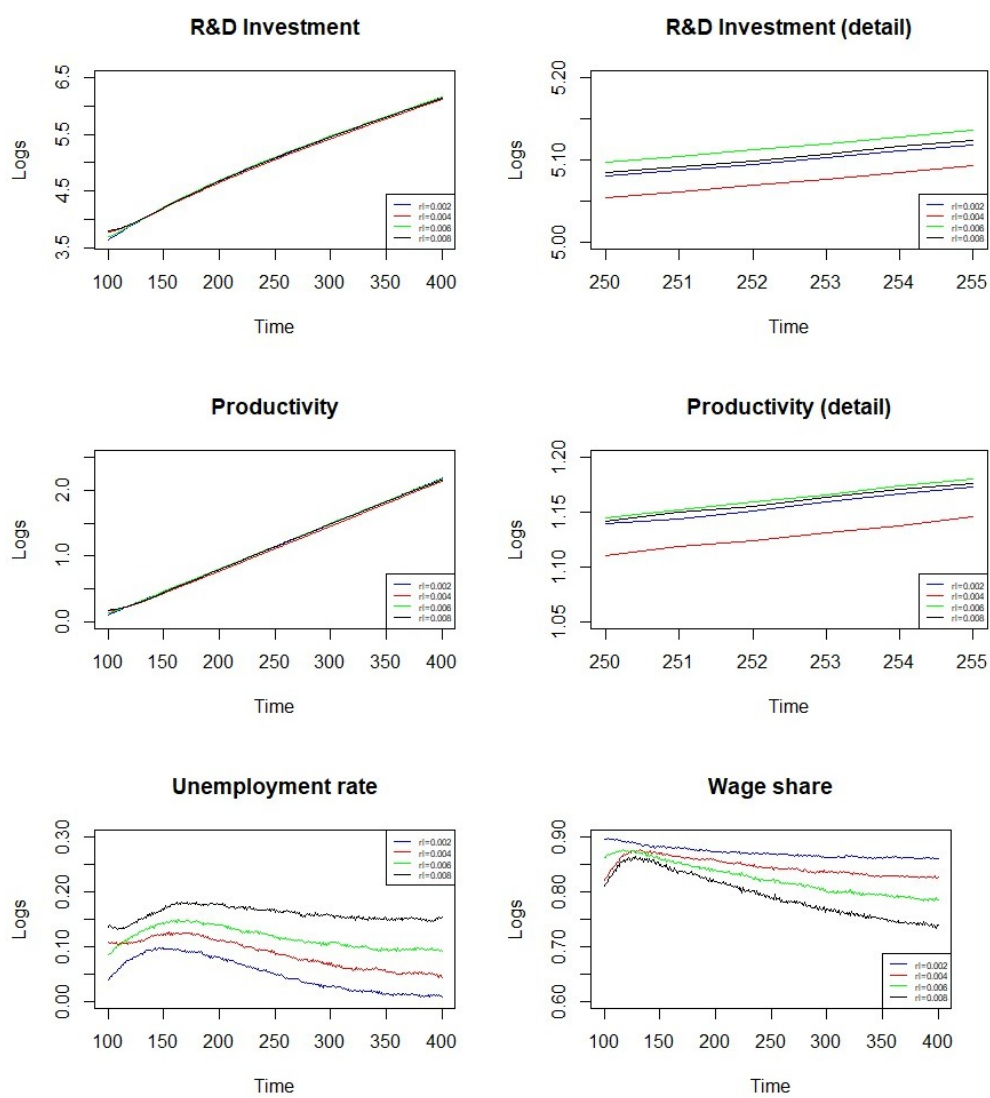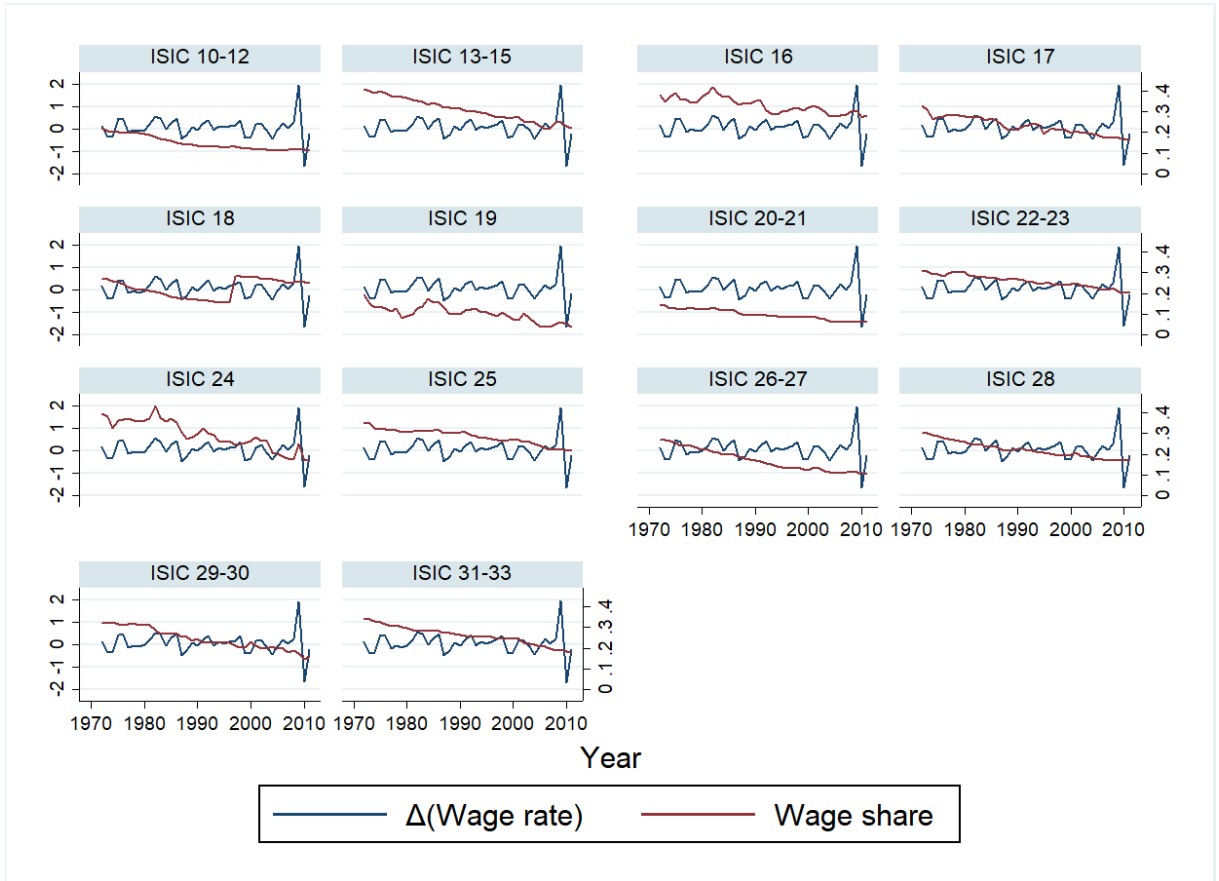
Figure D.12. Experiments on the interest rate

Figure D.13. Experiments on the interest rate

Note: author's own calculations on Anberd and NBER Manufacturing Productivity databases.

Figure D.14. Wage rate and wage share across US manufacturing industries, $1972 - 2011$
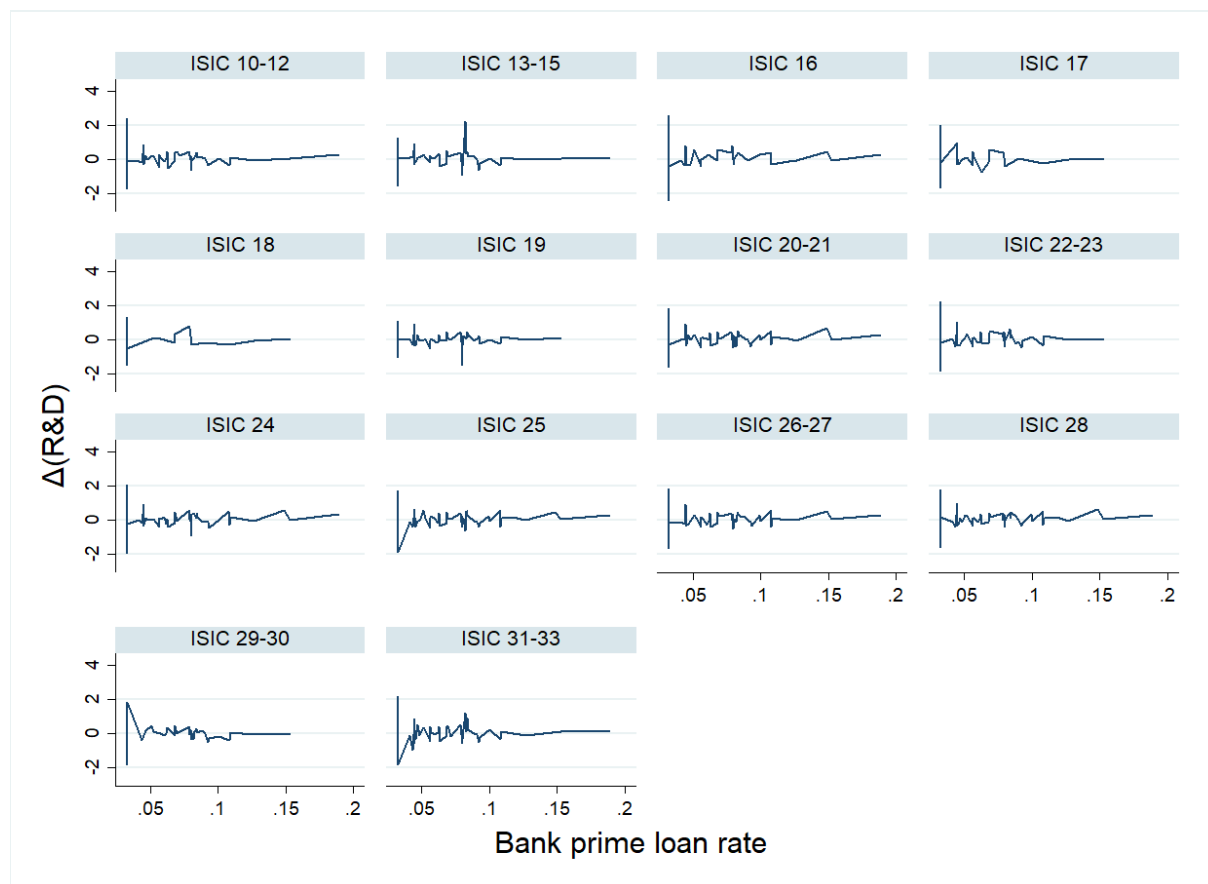
Note: author's own calculations on Anberd, NBER Manufacturing Productivity and NSF SIRD databases.

Figure D.15. R&D and labour productivity across US manufacturing industries, $1972-2011$
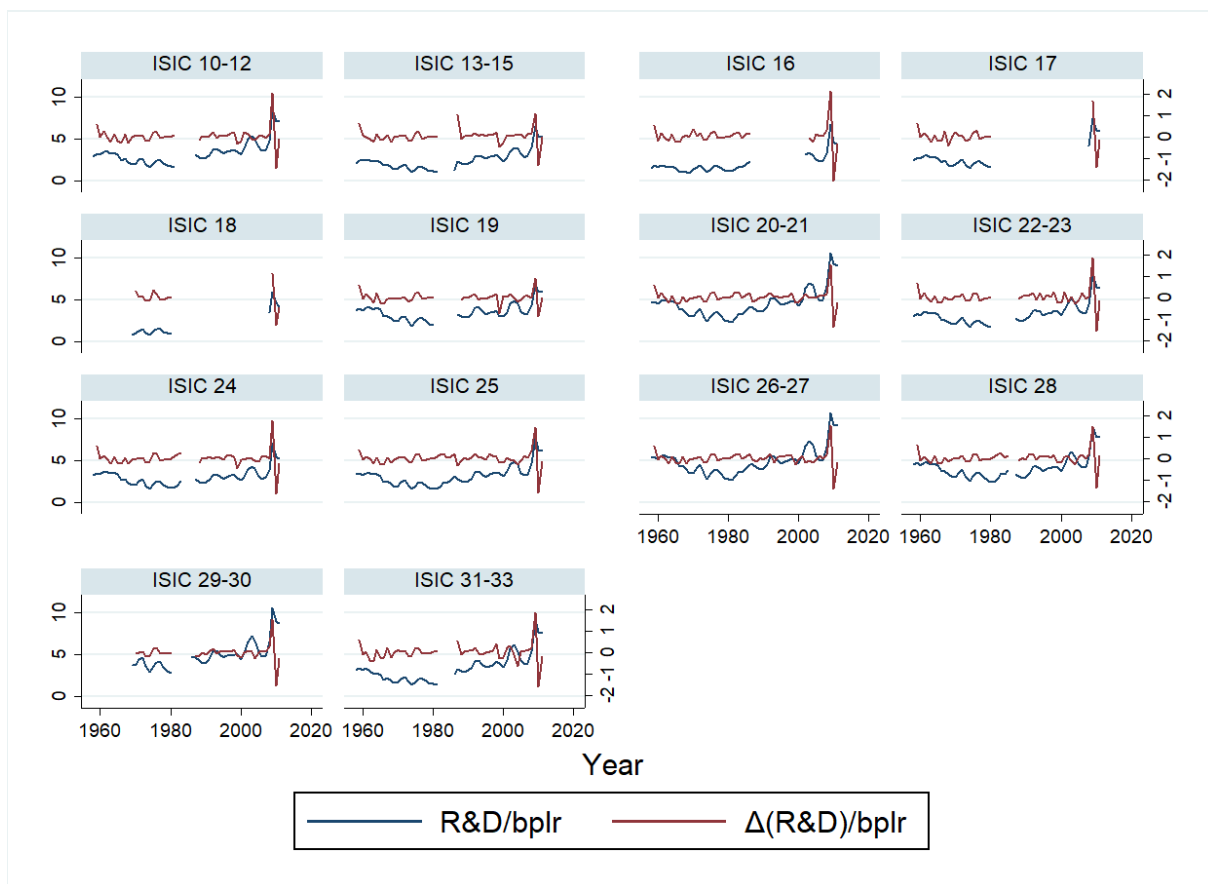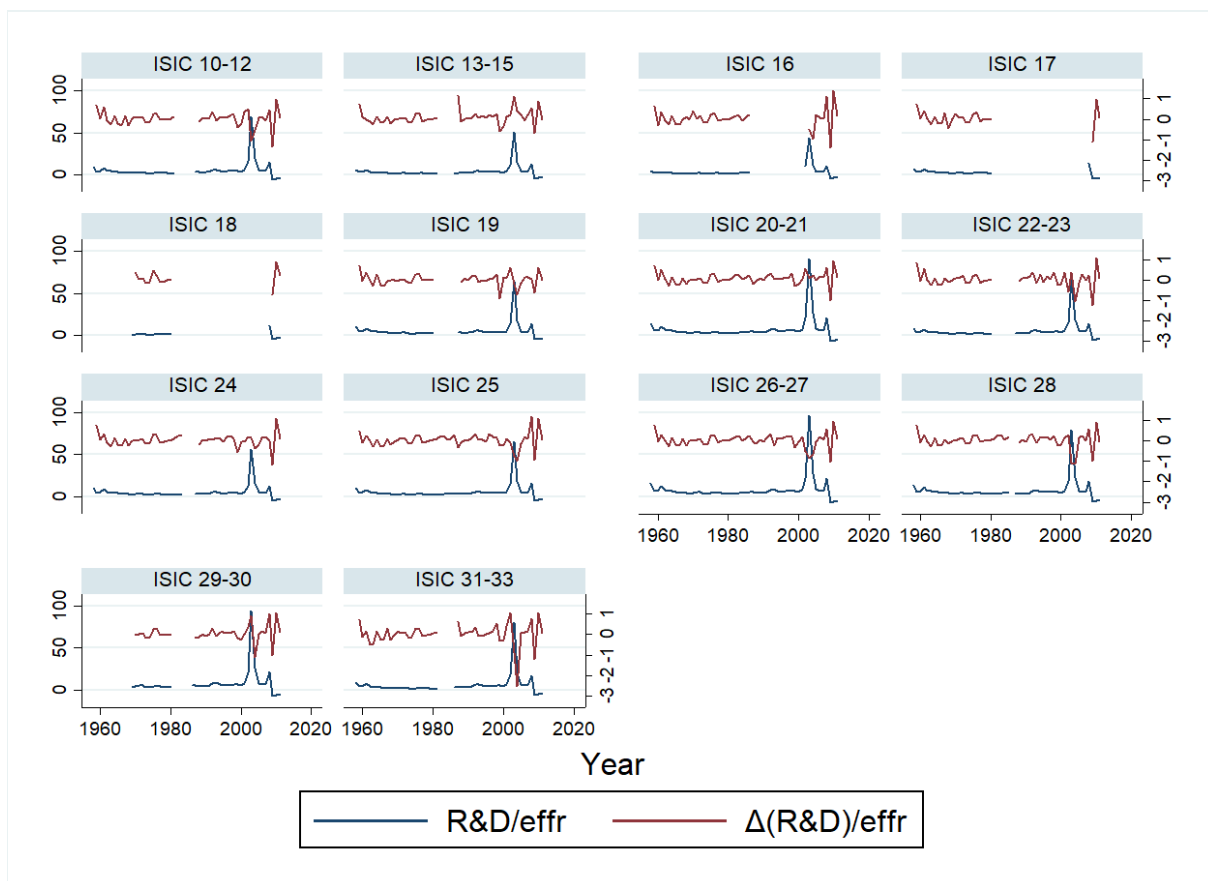
Note: author's own calculations on Anberd, FRED St. Louis and NSF SIRD databases.

Figure D.16. Ratio between R&D and bank prime loan rate across US manufacturing industries, 1958 − 2011
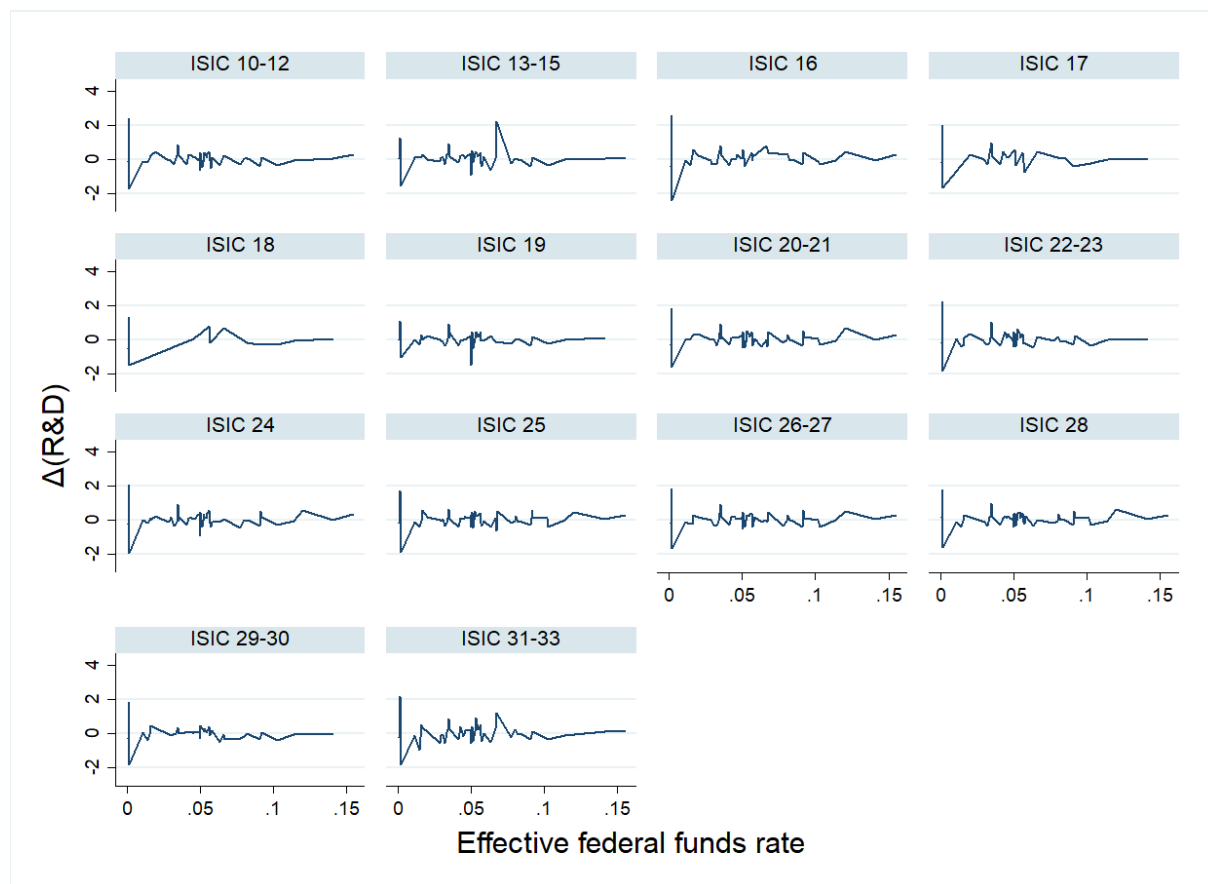
Note: author's own calculations on Anberd, FRED St. Louis and NSF SIRD databases.

Figure D.17. R&D against bank prime loan rate across US manufacturing industries, $1958 - 2011$

Note: author's own calculations on Anberd, FRED St. Louis and NSF SIRD databases.

Figure D.18. Ratio between R&D and effective federal funds rate across US manufacturing industries, $1958 - 2011$

Note: author's own calculations on Anberd, FRED St. Louis and NSF SIRD databases.

Figure D.19. R&D against effective federal funds rate across US manufacturing industries, $1958 - 2011$

## Final considerations

We reminded over and over again in this dissertation that the matter risen by Secular Stagnation theories is far from simple or solved. These pages have tried to show how that problem − as we did identify it − may turn around to, among other things, two basic words: income distribution. From this point of view, more egalitarian societies, in which the slice of the social product to profits is not so large if compared to the slice for labour, would seem better equipped to cope with the long periods of economic stagnation we have debated on thus far.

However, we would fail if we thought that the problem were economic *only*. In other words, are the prescribed policies *politically* feasible? The meltdown in 2007 and the corresponding revival of Secular Stagnationist theories occurred within strong changes in the international relationships and a more general crisis involving political and social aspects of the common life. With respect to the USA, the problem was raised by Prof. Summers during the debate with Prof. Stiglitz on the columns of Project Syndicate in 2018.[1] The diatribe focused on the ineffective and insufficient fiscal stimuli set by the American administration − as Stiglitz judged− the weak positive effect in reducing unemployment notwithstanding. Stiglitz's point was that the government did not pursue a stronger and more flexible fiscal policy. Had the latter better-structured, more designed for the poor and longer, then the recovery would not have concerned to the top 1% only, but to a bigger slice of population too. Furthermore, the fiscal stimulus should have launched a massive income re-distribution, the strenghtening of workers's bargaining power and the weakening of agglomeration market power, along with industrial policies to help American de-industrialized areas. Summers replied that, while agreeing with these policy presciptions, a stronger stimulus than what actually took place would have been *politically unfeasible*. It is all but simple therefore to find a good reply to the question above. But something must be done in the direction paved by Stiglitz; at least not to confirm the suggestion by Eco (2004) on good proposals, according to which "the simple folk always pay for all, even for those who speak in their favor".

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[1]Stiglitz (2018); Summers and Stiglitz (2018).

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