How and under what conditions would technological revolution create overall societal benefit?

ICT, productivity, and capital: lessons from economic theories and perspectives

Januardy Djong

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Author:	Januardy Djong
Student number:	4292219
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University:	Delft University of Technology
Master programme:	Engineering and Policy Analysis
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Graduation Committee

Chairman: Prof.dr. Cees van Beers
TU Delft
Professor of Innovation Management
Section Technology, Strategy and Entrepreneurship
Technology, Policy and Management
c.p.vanbeers@tudelft.nl

First supervisor: Dr. C.W.M. (Ro) Naastepad
TU Delft
Professor of Innovation Management
Section Economics of Innovation
Technology, Policy and Management
c.w.m.naastepad@tudelft.nl

Second supervisor: Prof.dr. W.M. (Martin) de Jong
TU Delft
Professor of Urban and infrastructure development in China
Section Policy, Organisation, Law & Gaming
Technology, Policy and Management
w.m.dejong@tudelft.nl

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Abstract

With the advent of smart machines, ICT revolution is moving towards a relatively unknown territory. Economic theories play important role in shaping the direction and effect of this technological change to the lives of everyone. The acceleration of unemployment and dualism which the ICT revolution is expected to create has raised concerns regarding the social benefit of technological progress, and raises the question whether existing theoretical frameworks are adequate to deal with the societal consequences of technological revolution. The objective of this thesis is therefore to explore how and under what conditions technological revolution would create overall societal benefit.

This study explores and analyzes five economic perspectives: neoclassical, (Neo)-Schumpeterian, Marxian, (Post)-Keynesian, and Aristotelian economics to understand the impact of technological revolution to productivity growth its economic consequences. Empirical study is also conducted to estimate the impact of ICT revolution from 1970 to 2007 in seven advanced economies: Denmark, Finland, Sweden, Germany, The Netherlands, The U.K., and The U.S.

The various economic perspectives explored in this thesis seem to agree that technological revolution could give rise to savings (neoclassical), profits (Schumpeter), or surplus value (Marx). The empirical observation examines the impact of ICT to productivity growth in the seven advanced economies. This gain in productivity gives rise to productivity dividend, either in the form of more goods produced or reduced working hours. The econometric analysis of panel data from EU KLEMS database from 1990 to 2007 suggests that this productivity dividend, if expressed in money terms, is estimated to contribute U.S.$ 5.4 trillion (in 2007 value) as profit before taxes. The empirical result, however, does not satisfactorily answer whether the use of this productivity dividend has led to societal benefit, prompting further theoretical work.

The result of further theoretical work on capital allocation suggests that standard economic framework found in the neoclassical theory prescribed capital allocation to maximize financial returns due to its tendency to focus social benefit solely on the basis of material gains. Schumpeterian perspective which encourages entrepreneurship also tends to emphasize on the accumulation of material wealth by the entrepreneurs. On the other hand, perspectives from Marx, Keynes, and Aristotelian economics adduce to the notion of social benefit by incorporating people's immaterial needs. Importantly, the assertion that human's material needs are limited makes possible the existence of freed capital – the capital arising from that is no longer needed to finance human beings' material needs. This thesis argues that freed capital has its very origin in the human capacity, following Wilken (1992). The counterpart of this freed capital is proposed to be the immaterial needs of human beings, which include the need to develop human capacity. For the next step, it is recommended to dissect further the ethical foundations of these economic theories to strengthen the case for capital allocation that they prescribe.

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Chapter 1
Introduction

The prospect of far better lives depends on how the gains are produced and distributed
Martin Wolf, Enslave the Robots and Free the Poor

1.1. Robots and the rich

The busiest and by far the most productive worker in Amazon, one of the biggest online retailer, during the profitable holiday season of 2014 is called Kiva. She is in charge of moving goods from shelves to the shipping points in Amazon warehouses. Kiva is, of course, not human but a box robot whose appearance is far from resembling a human being. There is not one but 15,000 Kivas employed by the company. Kiva is just one example of many other applications of robots made possible by the development in smart machines.

Smart machines can be thought of as a part of the evolving trend in information & communication technology (ICT). Started in 1971 with the introduction of Intel microprocessor, ICT technology has spawned numerous innovations such as personal computer, the Internet, and smart machines like Kiva. From an economic perspective, the implication of such technological progress has been the increase of labor productivity, that is, the output per hour worked. As the consequence, real GDP has been increasing faster than the increase in total number of hours worked. Figure 1 depicts the trend of real GDP growth compared to total hours worked for the past four decades which confirms the faster rate of real GDP growth in seven OECD countries. Similar trend can be observed if other OECD members are included.

The increased intelligence of machines, made possible by sophisticated codes, opens up applications in tasks which previously could only be done by human beings. This includes complex tasks such as driving a vehicle or even assisting a surgery. Not surprisingly, concerns have been voiced by many on the dire possibility of smart machines driving human beings out of work. The most telling one is the paper by Frey and Osborne (2013) predicting that 47% of jobs in the US today are at risk of being replaced by computers. Ryan Avent (The Economist, 2014) argues that the skilled and

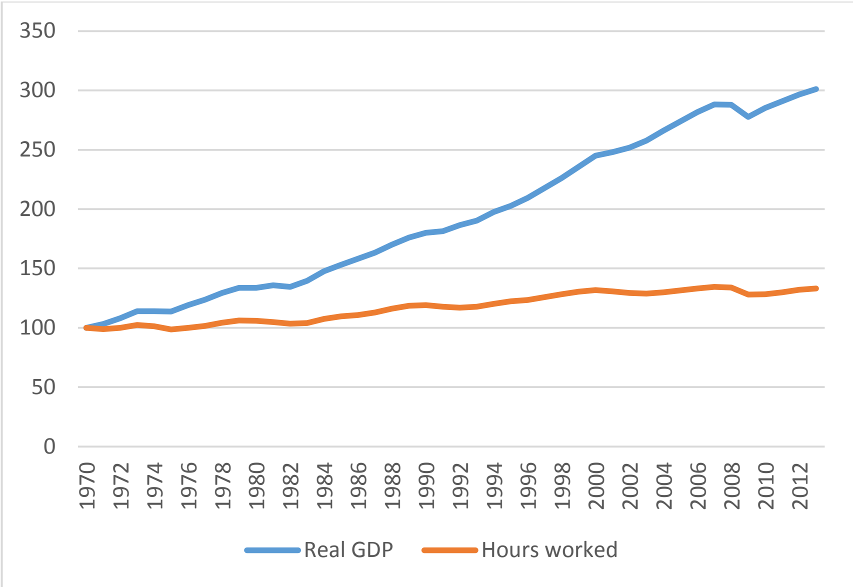

Figure 1: Real GDP and total hours worked in the US, the UK, two continental Europe countries (Germany and the Netherlands) and three Nordic countries (Denmark, Finland, Sweden). Index, 1970=100. Source: OECD.

wealthy few stand to benefit most from this ongoing technological change. While admitting the possibility of massive job loss, Brynjolfsson and McAfee (2014) are nevertheless optimistic on the economic prospects of what they call the second machine age. They argue that demand for other type of jobs will simply appear. However, as the debate is raging regarding the fate of workers, one group seems to be less disturbed than the others: the owners of financial capital.

Indeed, the rising prominence of finance and the rich is another dominant trend today. As made clear in a report by Bain & Company (2012), the world is already 'awash in money'. Total financial assets as of 2010 amount to $600 trillion, almost ten times the world GDP. By 2020, world GDP is projected to grow by $27 trillion while total financial assets is expected to increase by a staggering $300 trillion. This amount of wealth, however, seems to be concentrated amongst a handful of elites, the 1% of population (Palma, 2009).

Could it be that the same group of the wealthy few mentioned by Avent are the ones currently controlling the bulk of existing financial capital? Indeed, they seem to belong to the same group of capitalists – the owners of capital. As pointed out by Brynjolfsson and McAfee (2014), smart machines can result in the decoupling of growth in productivity from jobs and income. In other words, additional goods and services can be provided without incurring additional cost of human labor. Consequently, profit accumulated as financial capital can be concentrated to a small number of people.

Are the rise of smart machines and the growth of excessive liquidity related? More importantly, how can this situation lead to better lives for everyone and not only just a small section of the population? This introductory chapter provides the background for researching the aforementioned situation and formulates the research problem. Section 1.2 presents the theoretical background of the research. Section 1.3 briefly describes the research approach leading to the objective and research questions in section 1.4 and 1.5 respectively. Finally, section 1.6 provides an overview of the whole thesis.

1.2. Theoretical background: the economics of technological change

Economists have long acknowledged the importance of technological change in propelling economic growth. In this thesis, the main area of interest is major technological change driven by general purpose technologies (GPTs). GPTs can be loosely defined as techniques that find applications in a wide range of sectors across the economy (Dudley, 2010, p. 23). The pervasive use of a GPT in various application sectors might give rise to radical change throughout the whole economy as well as society at large. Perez (2002, pp. 8-11) calls such breakthrough in GPT a technological revolution, with ICT revolution as the latest one, marked by the introduction of Intel microprocessor in 1971. The characterization of microprocessor as the GPT that sparks ICT revolution has also found support from many other scholars such as David (1990), Brynjolfsson (1993), Bresnahan and Trajtenberg (1995), Jovanovic and Rousseau (2005).

How can we relate technological revolutions with the formation of financial capital so as to link ICT revolution and the rise of smart machines with the growth of excessive liquidity? There are, among others, three noteworthy perspectives in the economics literature related to the relationship between technological revolutions and capital: the neoclassical, Marxist, and neo-Schumpeterian perspectives.

Neoclassical economists often use the concept of General Purpose Technology (GPT) to examine technological revolution. Driven to maximize profit, economic agents are motivated to innovate and adopt GPT in various application sectors (Bresnahan and Trajtenberg, 1995). Wide adoption of GPT gives rise to general productivity growth. Theoretically, productivity growth could mean less labor is needed to produce the same output. This obviation of labor therefore reduces cost and frees capital. Following Say's law, this approach also presumes that the financial capital freed by productivity growth will be reinvested in the economy (where supply will create its own demand). This is in line with the argument of Brynjolfsson and McAfee (2014) that demand for new jobs will be created as the result of ICT revolution. However, this 'trickle down' concept of the economy has come to be increasingly questioned after the Great Recession. Palma (2009) observes that while total financial asset keeps on increasing in the past four decades, private investment has been stagnant, raising doubt regarding the assertion that today's 'excess liquidity' (resulting, at least in part, from technological revolution) is required for and will be reinvested.

Within the neo-Schumpeterian perspective, Perez (2002), while acknowledging the growth potential of technological revolutions, highlights the possibility of speculative behavior arising at certain phases during the revolution. When the technological revolution reaches maturity, investors become disillusioned with the diminishing return of investment in the technology. Financial capital becomes ‘idle money’ searching for profit by going into stock market and other financial innovations in an increasingly speculative manner. This is also one kind of financial capital formation, arising indirectly as a consequence of technological revolution. Perez (2002, 2009) shows how this has occurred several times in a cyclical manner, drawing examples from the Great Depression, the dot com bubble, and the Great Recession. However, to Perez, cyclical boom and bust periods are part of the unavoidable adjustment needed during the transitional period of each successive technological revolution. This is comparable to saying that crisis is inevitable. But as seen in the aftermath of the Great Depression and the Great Recession, most of the victims of these crises are often not the wealthy class but workers and the poor.

Marxists view technological revolution as ‘capital’s means to its end’, which, in the Marxist perspective, is accumulation of surplus value (Smith, 2009). Surplus value is created through the ‘realization’ of capital, which is, selling goods produced with certain amount of money invested (M) to get more monetary returns (M’). Within this perspective, technology is no longer simply the means of production. Instead, it becomes a tool to repress labor[1] and lower wages, thereby increasing the generation of surplus value. This is because, in the Marxian view, the source of surplus value can only come from the exploitation of labor, paying them less than the value augmented by them to the output (Wilken, 1992, p. 2). This argument, however, has often been contested. Pack (2010), for instance, argues that in a fully automated society, surplus value can still be created through exchanges. If this is so, then the appropriation of profit by the owners of capital cannot be invalidated via this argument.

This brief overview provides the basic idea regarding how the three perspectives view the formation of value and capital following technological change. All three perspectives seem to agree that technological change could lead to the formation of financial capital through the obviation of labor. However, how can capital that is formed, either directly or indirectly through technological revolution, be used to benefit everyone instead of just a wealthy few? Neoclassical economists assume that it will benefit everyone (through Say’s law and ‘trickle-down’ effect) while Marxists argue that it will dispossess labor of surplus value rightfully belongs to them. Furthermore, neo-Schumpeterians argue that speculative behavior could arise from the excess financial capital, leading to economic crisis. This is also a possibility admitted by Marxists (for example, see Smith, 2009) although while Marxists aim to replace it, the neo-Schumpeterians see it as an inevitable part of the cycle of technological revolution. ‘Crisis’, on the other hand, is not part of the neoclassical vocabulary. In conclusion, there does not seem to be agreement among these three perspectives on the appropriate allocation of financial capital freed by technological revolution. This thesis attempts to address this issue through the approach elaborated as follows.

[1] Labour here originally is in the context of physical labour. However, nowadays it is increasingly true also for routine mental labour that can be replaced by computer.

1.3. Research approach

In his book *The Enigma of Capital,* Harvey (2010) sees the Great Recession from a Marxian perspective. Harvey (*ibid.*, p. 123) further introduces a framework to analyze capital accumulation and social change within society which consists of interrelating elements that include mental conceptions, technologies, production and reproduction processes, social relations, relations with nature, and institutional arrangement. This framework will be used as a starting point of this thesis. Chapter 2 explains in greater detail the framework and how it is relevant for our purposes.

This thesis focuses on the sphere of mental conceptions and its relation to the sphere of technologies. Mental conceptions here in general refer to our cultural norms, belief systems, and knowledge structure. Stemming from the human mind, these influence the way we conduct our activities, including the development and use of technologies as well as the accumulation of capital. Since mental conceptions can be broad, this thesis further focuses on economic theories as the form of mental conceptions. For instance, mental conceptions in the form of economic theory, for Harvey, manifests itself in the need for perpetual compound growth (*ibid.*, p.27) which motivates the ever increasing use of technologies to realize more profit.

The approach taken in this thesis is as follows. This thesis analyzes and compares five economic theories or perspectives regarding: (1) the relationship between technological revolution and capital and (2) the use or destination of capital formed during technological revolution. From these perspectives, socially agreed and scientifically founded criteria are then established to inform the allocation of capital formed during technological revolution. More specifically, the approach can be divided into several steps.

First, mental conceptions are explored by analyzing economic theories on technological revolutions. The three perspectives described in section 1.2 will be analyzed in greater detail. In addition, there are two strands of theories that have not explicitly dealt with the impact of technological progress *per se* but have made contributions towards the issue of capital allocation. These are the perspectives from Keynesian and Aristotelian economics. Therefore, there are five strands of economic theories to be explored and compared. Second, empirical study regarding capital formation and allocation from different countries (from the Anglo-Saxon world, Germany, the Netherland, and Nordic countries) during the course of ICT revolution is conducted. Third, the five economic perspectives are revisited to analyze how they can inform the conditions for technological revolutions to bring societal benefit. Fourth, drawing from the theoretical and empirical study, implications can be drawn to inform policymaking on the issue of managing the economic consequences of technological revolution.

1.4. Research objective

With the advent of smart machines, ICT revolution is moving towards a relatively unknown territory. Economic theories play important role in shaping the direction and effect of this technological change to the lives of everyone. The acceleration of unemployment and dualism which the ICT revolution is expected to create has raised concerns regarding the social benefit of technological progress, and raises the question whether existing theoretical frameworks are adequate to deal with the societal consequences of technological revolution, in particular breakthroughs in GPTs (dr. Naastepad, Mar 2015, written communication). The objective of this thesis is therefore to explore how and under what conditions technological revolution would create overall societal benefit.

1.5. Research questions

Drawing from the research objective, the main research question to be answered is:

How and under what conditions would technological revolution create overall societal benefit?

The main question shall be answered by looking at the period of ICT revolution in several developed countries, including the US, the UK, Germany, the Netherlands, and Nordic countries, from the 1970s until today. The choice is based on the extensive degree of penetration of ICT in these countries which makes available more data required to do the study. Moreover, answering the main research question will also entail answering several sub-questions formulated as follows:

1. What do existing economic theories say about technological revolution and its relation to the formation and allocation of financial capital?
2. What can historical data from the U.S., the U.K., Germany, and the group of Nordic countries tell us about the relation between ICT revolution and the formation and allocation of financial capital?
3. Are existing theoretical frameworks adequate to deal with the societal consequences of technological revolution?
4. Which existing or novel mental conceptions could help formulate explicit criteria for better alignment of financial capital with societal benefit?
5. What policy implications can be drawn from the analysis under questions 3 and 4 in the context of the ICT revolution?

1.6. Structure of the thesis

This thesis is structured as follows. Chapter 2 introduces the framework used in this thesis. Chapter 3 describes the notion of technological revolution and reviews five economic theories related to technological revolution and the formation and allocation of financial capital. Chapter 4 describes the socio-economic impact of ICT revolution to several countries: US, UK, Germany, The Netherlands, Denmark, Finland, and Sweden. Chapter 5 aims at finding criteria for societal benefit by looking deeper into the five economic perspectives in Chapter 3. Finally, Chapter 6 discusses contributions, policy implications, limitations, and areas for future research.

Chapter 2

Seven activity spheres of capitalism: a starting point

One general law, leading to the advancement of all organic beings, namely, multiply, vary, let the strongest live and the weakest die
Charles Darwin, The Origin of Species

Technological revolution is not a limited phenomenon. It has a wide reaching impact to the society at large. The rise of smart machines, for instance, does not just change the way production and distribution are organized, but it also influences the livelihood of workers, the relationship with nature, and consequently social relations and our institutions. It is therefore useful to view technological revolution within the context of the whole social processes involved. This chapter presents a framework as a starting point of this study to analyze technological revolution as a part of a wider social processes in the society. Section 2.1 explains the framework, which is used by David Harvey (2010) to propose his co-evolutionary theory of social change. Section 2.2 then explores how the framework is relevant for this thesis.

2.1. The seven 'activity spheres' of capitalism

In his book *The Enigma of Capital,* Harvey proposes a general theory of social change which addresses how the process of capital accumulation works in the context of human activities as the participating agents. Harvey recognizes the danger of reducing the paradigm of capitalism throughout human history (at least since 1750) to merely a question about capital. Instead, a complex evolutionary mechanism might be at work, one which he draws parallel to Darwin's principles of natural evolution. This 'general law' describes how human activities through capitalism have shaped the world and evolve it: a co-evolutionary theory of social change. This theory is explained using a framework which distinguished seven main activities that drive social change in a capitalist society. According to Harvey, during the process of accumulation, capital circulates through seven interrelated 'activity spheres' (*ibid.*, p. 121), which are:

1. technologies and organizational forms;
2. social relations;
3. institutional and administrative arrangements;
4. production and labor processes;
5. relations to nature;
6. the reproduction of daily life and the species, specifically through activities such as consumption and sexual relations;
7. mental conceptions of the world which include but not limited to cultural norms, belief systems, and knowledge structures.

At the center of the seven activity spheres is the process of capital accumulation. Within a capitalist society, human being is perceived as *Homo economicus*, striving to maximize profit. This is the core assumption when the framework is put to use to analyze capital accumulation. As a rule of thumb, all spheres are dependent of the others and none dominates others. However, the framework is not deterministic since changes in one sphere can be contingent, such as how technological change can occur 'accidentally' (think, for example, the accidental discovery of penicillin by Alexander Fleming). One illustration to see how it works, taking technologies as the focus, is best given by Harvey (*ibid.*, p. 121) as follows.

> "One crucial 'activity sphere' concerns the production of new technological and organisational forms. Changes in this sphere have profound effects on social relations as well as on the relation to nature. But we also know that both social relations and the relation to nature are changing in ways that are in no way determined by technologies and organisational forms. Situations arise, furthermore, in which scarcities of labour supply or in nature put strong pressures to come up with new technologies and organisational forms."

Other examples can be drawn by invoking other spheres, such as how technologies influence consumption which affect population growth and dynamics. These activities take place within the institutional and administrative structures which in turn can adapt due to forces from other spheres.

The last, yet perhaps the most interesting sphere is the mental conceptions of the world, which are ever presence in various forms, influencing decision making in other spheres, yet are constantly changing and often contested. Harvey, in using the framework to analyze the Great Recession, highlights particularly the knowledge structure of economics which he regards as dysfunctional (*ibid.*, p. 239). People, however, act based on this flawed knowledge structure informed by the trusted experts, as Harvey puts it (*ibid*, p. 121):

> "People act, furthermore, on their expectations, their beliefs and their understandings of the world. Social systems depend on trust in experts, adequate knowledge and information on the part of those making decisions, acceptance as to reasonable social arrangements (of hierarchies or of egalitarianism), as well as constructions of ethical and moral standards."

Here, it is evident that Harvey puts great emphasis on knowledge structure as part of mental conceptions of the world, at least in the context of discussing the great economic crisis of the century.

This framework of seven activity spheres has also received some criticisms. Hartman (2011), for instance, feels that the framework is too abstract. Indeed, the application of the framework can be open to wide interpretation, especially when interpreting the sphere of mental conceptions. While other spheres largely describe human beings' physical activities that can be relatively easily defined, Harvey's definition of mental conceptions is perhaps too wide. Harvey's emphasis on economics as the underlying mental conception is not fully justified. This prompts Christophers (2011) to argue that the framework lacks details and sophistication when compared to Harvey's previous works. This might be because Harvey wrote this book with popular audience in mind; this framework helps the audience to better see the structure of Harvey's analysis on capitalism. In the end, the framework feels underdeveloped and underutilized in the sense that Harvey's historical-geographic analysis of capitalism within the book can do just fine without the applying this framework.

2.2. The activity spheres as a starting point

Despite the argument that the framework is underdeveloped, what makes Harvey's seven spheres a suitable starting point for this research is its consideration for structure by dividing the profit seeking activities of *Homo economicus* into seven distinct spheres. Capital formation and accumulation process arising from technology is not a bilateral process. It encompasses more than just the technology itself, but also social processes influencing and influenced by the revolution. Having such structure enables the understanding technological revolution and the process of capital accumulation within a broader context.

The framework also allows for flexibility to focus on interaction amongst a subset of elements. As Harvey himself points out, there is no dominant sphere, yet interaction between any two spheres can affect the flow of capital. Studying technological revolution and capital accumulation by picturing things in this framework enables setting the boundaries for this research by focusing on a subset of activity spheres while allowing for further extension into other realm of activities. Specifically, this thesis focuses on the influence of mental conceptions of the world to the activity sphere of technologies and organizational forms.

While spheres other than mental conceptions will undoubtedly interact with the technologies sphere, they are not analyzed in detail in this thesis. Instead, the allocation of capital resulting from the activity within the sphere of technologies will be discussed by involving other spheres. For instance, the sphere of institutional arrangement is often originates from the mental conceptions. This might be related with technology directly through innovation policies informed by economic theories of technological change. This is in line with the argument made earlier that mental conceptions can be the appropriate starting point in prescribing real change.

Furthermore, while initially used to analyze the process of capital accumulation, Harvey suggests that the framework can also be used outside the context of capitalism (*ibid*., p. 228). Specifically, he suggests a political movement that starts around the change in mental conceptions, although he admits that such political movement can start anywhere[2]. This opens up the possibilities to use the framework in different ways, for example by replacing the presumed *Homo economicus* as the agents of activity with other conception of human beings. Harvey does not seem to believe in the assumption of *Homo economicus* himself as he writes about the need for “mental conceptions that focus on self-realization” (*ibid.,* p. 231).

This mental conception about human beings (whether we are indeed *homo economicus*) is in turn a fundamental part of economic theories. Neoclassical economics, for instance, relies on the assumption of *Homo economicus* in its very core. This has a far-reaching implications in the theory’s prescription of profit maximization and capital allocation. Therefore, in studying mental conceptions, it is important to also examine this assumption.

Finally, it is also interesting to note that the framework, whilst inclusive of mental conceptions, is in itself a form of mental conception. It is by no means a product of natural law, despite the parallel with Darwin’s theory of evolution (indeed, even Darwin’s theory is subject to long history of contentions). A shift in how we view the world might add, reduce, or combine elements of Harvey’s seven spheres. However, it does not mean that the usefulness of this framework is reduced, especially as the lens through which the world is viewed throughout this thesis.

[2] As a Marxist, Harvey naturally points to communism as the end goal of the mental conception shift, although he is cautious not to use the term due to its historical undertone.

Chapter 3
Technological revolution and the freeing of capital

The participants' view of the world is always partial and distorted
George Soros, General Theory of Reflexivity

The purpose of this chapter is to first define some concepts related to technological change, revolution, and freed capital. This is presented in section 3.1 and 3.2. Next, several economic theories linking technological change or revolution to the formation and allocation of free capital are presented in section 3.3.

3.1. Preliminary concepts: technology, technological change, innovation and technological revolution

The concept of technology commonly used by economists is the embodiment of knowledge in physical or tangible tool (Link & Siegel, 2003). Following the framework introduced in Chapter 2, organizational forms can also be included into the definition of technology for our purpose. This is because organizational forms, for instance the division of labor, are also the representation of knowledge (Lipsey & Carlaw, 2000) although it is disembodied from physical equipment.

Technological/technical change is often understood as the improvement to physical tools (embodied technical change) or organizational forms (disembodied technical change). This improvement is the result of innovation process. It is the creation of new knowledge (Landry, Amara, & Lamari, 2000) or the utilization of existing knowledge in a novel way (Schumpeter, 1928, p. 378).

Two kinds of innovation can be distinguished: incremental and radical innovation (Henderson & Clark, 1990). Incremental innovation often refers to minor progress in the technologies. However, incremental innovation can be accumulated to increase the stock of embedded knowledge. Radical innovation, on the other hand, refers to a technological breakthrough that disrupts the whole industries by making old technologies obsolete.

Technological revolution often relies on the birth of radical innovation. Bresnahan & Trajtenberg (1995) argues about the role of radical innovation as a single technological 'prime mover' they call general purpose technology (GPT). GPT can disrupt the whole industries by replacing old technologies with new ones and resulting in numerous new applications. The diffusion of GPT throughout the industries is the key feature of a technological revolution. Perez (2002, p. 8) defines technological revolution as 'interrelated constellation of technical innovation' that includes a crucial 'all-pervasive low-cost input'. The low-cost input in this sense is the GPT that furthermore shifts the best-practice for all industries, leading industries to adopt the GPT into their production and distribution processes. This becomes the new norm across the economy, Perez (*ibid.*) therefore concludes that the term 'technological revolution' is suitable for such paradigm change.

In conclusion, technological change can arise from incremental or radical innovation. When a radical innovation (a GPT) finds applications in the whole industries, it gives rise to a series of related incremental and radical innovations that characterize a technological revolution.

3.2. Productivity dividend, freed capital, and excess liquidity

In the economic literature, technological change is seen as the key to economic growth by generating productivity growth (Bresnahan & Trajtenberg, 1995; Miller & Atkinson, 2014). If productivity is defined as the ratio between output and input, when productivity increases, less input is needed to produce the same amount of output. Most often, this reduction comes from the reduction in labor input as technological progress which drives productivity is usually labor-saving (Lipsey & Carlaw, 2000). Alternatively, as productivity increases, the same amount of labor can be used to produce more goods. Naastepad & Houghton Budd (2015) call this gain, of either more free time (due to less labor input) or more goods, *productivity dividend*.

The obviation of labor through productivity growth, however, not only free people from their economic activities. In addition, money that previously spent on paying wages also becomes free to be used for other purposes. Money capital formed in this way can be called *freed capital.*

To further clarify the concept of freed capital, it is useful to look at several sources of money capital. In *Liberation of Capital*, Wilken (1982, pp. 220-221) distinguishes six sources of money capital:

1. the formation of 'true profit' resulting from the sphere of production, this is the money capital that arise out of consciousness of the human minds;
2. voluntary saving, when people choose to save their income to be used as capital later on instead of spending it for consumption;
3. credit creation by banks;
4. forced savings due to pricing policy, for example in the case of monopoly;

5. the formation of capital through the withholding of necessary income formation, for instance the repression of wages through paying labor less;
6. formation of capital through speculative means, resulting from asset prices inflation for instance.

Based on this distinction of the origin of money capital, freed capital as understood here is equivalent to the first source of money capital according to Wilken. Importantly, freed capital must exist independently, that is to say, capital arising from other sources is not free in this definition. Hence freed capital is different from voluntary savings whereby capital is formed through savings in consumption. Additionally, credit from banks originates in money capital to fund production, the capital is hence tied to specific use proposed when the credit is requested.

Forced saving and wage repression can cause the redistribution of income from consumers and workers to the producers. This redistributed income then can become money capital to those who appropriate it. Nevertheless, this is not freed capital as it is actually needed in the spheres of production and consumption although indeed, it can be difficult to distinguish true profit and profit resulting from forced savings or wage repression. Lastly, the formation of capital through speculation does not have its root in productivity growth *per se* although it can be influenced by technological revolution, as evident from the dot com bubble prior to stock market crash in the year 2000.

Finally, in the introductory chapter, observation is made on the phenomenon of 'excess liquidity'. This excess liquidity reflects the amount of financial capital that is not needed to finance the physical economy or the activities within the sphere of production. This excess liquidity is different from freed capital in the sense that excess liquidity can be formed by any of the six sources mentioned by Wilken.

3.3. The formation and allocation of capital resulting from technological revolution

This section elaborates on how technological change and revolution can lead to productivity growth and productivity dividend and importantly how this capital is allocated according to different economic perspectives. There are five perspectives within the economic literature to be briefly discussed here. The first three perspectives are commonly discussed when studying technological change: the neoclassical growth theory, the (neo)-Schumpeterian perspective, the Marxian perspective. In addition, two other – Keynesian and Aristotelian views – are also discussed. Although the literature within these two perspectives do not focus a lot on the issue of technological change, valuable insights can be drawn from these theories.

3.3.1. Neoclassical growth theory and the allocation of capital

Neoclassical growth theory offers a way to explain and measure the impact of technological change to economic growth within the context of an aggregate production function. The production function links aggregate output of the economy to two inputs: capital and labor. If Y, K, and L represents economic output, capital, and labor inputs respectively, then the production function can be written in Hicks-neutral form as

$$(1) \qquad Y = A\, f(K,L),$$

where the factor A is the total factor productivity (TFP) which measures 'technical change'; it is a generic shorthand for "*any kind of shift* in the production function" (Solow, 1957, original emphasis).

By assuming perfect competition and constant return to scale, the growth of output can be expressed as the sum of weighted growth of inputs and TFP growth[3]:

$$(2) \qquad \mathrm{d}\, ln\, Y = w_K \mathrm{d}\, ln\, K + w_L \mathrm{d}\, ln\, L + \mathrm{d}\, ln\, A,$$

where w_K is capital's share of income, w_L is labor's share of income, $w_K + w_L = 1$, and d is the first derivative. Following Jorgenson & Stiroh (2000), equation (2) can be expressed in terms of average labor productivity (ALP) defined as $y = Y/H$, whereby H is the aggregate number of hours worked. Let k be the ratio of capital inputs to hours worked, or $k = K/H$[4]. The growth of ALP can be written as:

$$(3) \qquad \mathrm{d}\, ln\, y = w_K \mathrm{d}\, ln\, k + w_L (\mathrm{d}\, ln\, L - \mathrm{d}\, ln\, H) + \mathrm{d}\, ln\, A.$$

ALP growth is therefore the sum of three effects: the growth of capital services per worker ('capital deepening'), improvement of labor quality defined as the difference between the growth of labor input (in money terms) and growth of hours worked, and the growth of TFP (Jorgenson & Stiroh, 2000).

One drawback of this framework is in the assumptions used to derive the weight of capital and labor contributions. The growth accounting framework can be misleading if the factor market for labor and capital are not perfect. In other words, the price paid for labor and capital might not truly reflect their contributions. Furthermore, equation (3) also shows that the impact of technological change is captured only by TFP growth. However, measuring the economic impact of technological change through TFP has been subject to debate. In particular, scholars have been arguing about what TFP actually measures. Lipsey & Carlaw (2000), for instance, show that it is possible to have technological change with zero TFP growth. As Griliches (1995) argues, TFP at best only measures the free-lunch associated with returns above the costs of R&D.

It is nevertheless important to note that from equation (3), TFP is not the only useful measure of technological revolution. Instead, the growth of capital inputs which utilize the GPT can also reflect the contribution of technological revolution to the economy. Empirical evidence of this can be found

[3] This is the growth accounting framework. Note that the weight w_K and w_L here are derived from the neoclassical assumptions.

[4] Note that L is not equal to H, but L measures labor input in terms of money spent paying labor. This definition is different from the conventional formulation whereby L is regarded as labor input in terms of number of hours worked. This follows Jorgenson & Stiroh (2000).

in the literature. Fernald and Ramnath (2004), for instance, find that the sources of ALP growth in the US since the mid-1990's are: (1) TFP growth in sectors producing ICT goods and (2) ICT capital deepening in aggregate, thus arguing for the influence of ICT revolution.

Labor productivity growth has since been the focus in the growth model since it is seen as the key issue to drive long-run growth (Jorgenson & Stiroh, 2000). This is because technological progress tends to save labor (Lipsey & Carlaw, 2000). The impact of this obviation of labor is therefore reduction in cost of production. As the result, output price falls and the benefit of productivity growth is passed on to consumers, raising their real income. As the real income increases, consumers can either consume more or save more (voluntary saving). The savings would theoretically be reinvested and thus bring about more consumption in the future. This is the neoclassical story.

Hence, in the neoclassical framework, productivity growth naturally results in increased consumption. Increasing consumption, from a utilitarian perspective would imply the increase of living standards. This is the motivation behind the obsession with long-term growth in mainstream economics[5]. On the one hand, this would mean consumers should aim to maximize their utilities through consumption. On the other hand, producers should be guided by profit maximization, that is, choosing to allocate capital whereby *financial returns* are maximized. This is reflected, among others, in Milton Friedman's (1970) influential essay about the social responsibility of firms, which is to maximize the shareholders' profits.

Sachs & Kotlikoff (2012) argue that smart machines become more productive (due to technological change), the cost of these machines per unit output falls. Consequently, wages of low-skilled workers is reduced at a new, lower equilibrium as capital-labor substitution occurs. Surplus resulting from this replacement of workers with smart machines instead increases income for high-skilled workers who create and maintain the machines. Their analysis further points to the possibility that productivity gain is consumed by high-skilled workers who do not use it to invest in productive capacity (due to inadequate saving rate). Should this happen, they predict the reduction of consumption in the future as the stock of productive capital is reduced. Benzell et al. (2015), building on this work by Sachs & Kotlikoff, propose transfer mechanism that ensures part of the income of the high-skilled workers who benefit from technological revolution is turned into savings that can be used for investment instead of for consumption.

3.3.2. (Neo)-Schumpeterian perspective: the long waves of technological revolution

Schumpeter's idea on the impact of technological revolution is focused on the dis-equilibrating effect of innovation. For Schumpeter, innovation comes from the ingenuity of entrepreneur's mind. This creates temporary monopoly that enables entrepreneurs to obtain profit from their innovations

[5] This choice is perhaps understandable since in the nineteenth century, when neoclassical theory was being developed, average living standards was low (Houghton Budd, Naastepad & van Beers, 2015).

(Cantwell, 2000). In this context, entrepreneurial profit is neither rent, wage, nor return to capital (Schumpeter, [1934] 2008, p. 153).

Technological revolution is a crucial part of economic development in this perspective. Radical innovation renders old technology obsolete, a process known as ‘creative destruction’. It does not happen overnight but in the long run, occurring as a ‘long wave’. Economic development in a capitalist economy depends on the succession of creative destructions and long waves (Perez, 2002).

Figure 2 distinguishes the phases within one long wave of technological revolution. Within each phase, innovations and therefore entrepreneurial profit can be found albeit at varying degrees. This is depicted by the S-shape curve of the long wave. What interesting is that capital allocation differs depending on the phase of the long wave.

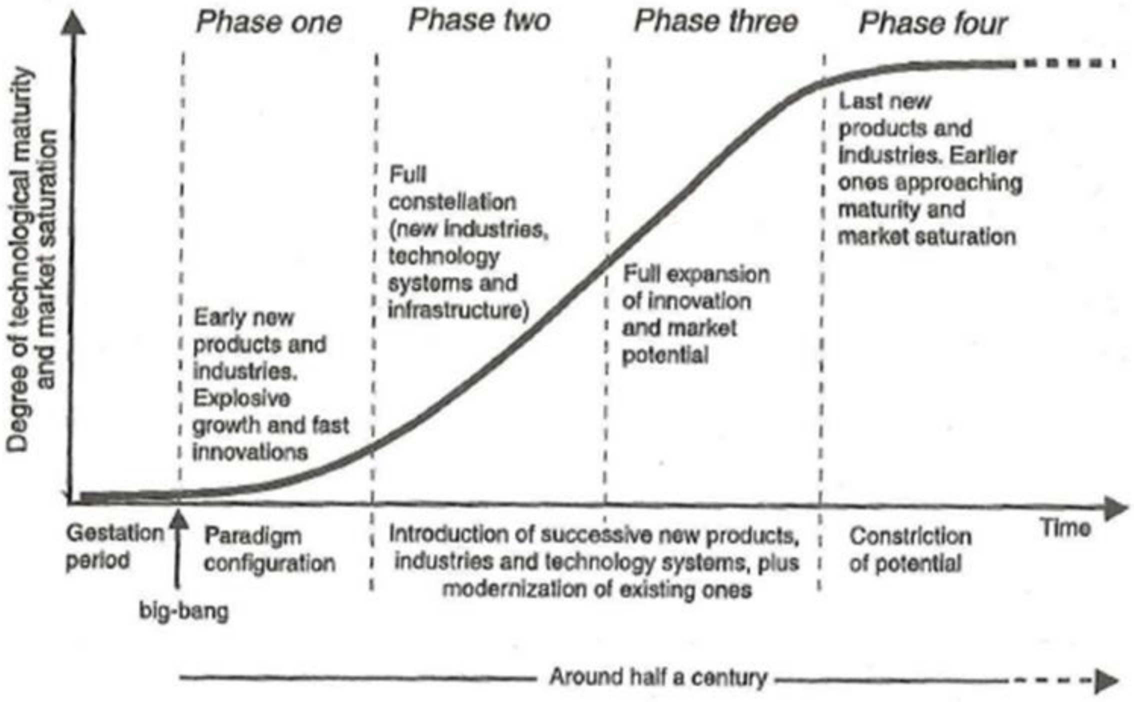

Figure 2: The four phases of technological revolution (Perez, 2002)

Right after the introduction of a GPT (*big-bang*), the economy enters phase one, ‘irruption’. In this phase, old industries have reached the point of market saturation combined with cost pressure. Moreover, production processes seem to have reached the limits in terms of improvements. This pushes the old firms to invest in new technologies to improve their processes using ‘idle’ money in their hands (Perez, 2002, p. 94). This ‘idle’ money is hoarded by the old firms, whom at the point of saturation invest the money to the new radical innovation in the hope of rejuvenating their business processes. It is worthy to note that this phase often coincides with high unemployment and stagnation, for instance the stagflation occurred in the early 1970s which marked the start of ICT revolution

Upon finding that investment in new technology yields good return, ‘idle’ money increasingly rushes to finance new innovations in the hope of high return. However, as the technology is yet to reach maturity, there is actually limited profitable investment available. This is the character of phase two, ‘frenzy’. Owners of idle money nevertheless believe that their investments are profitable. In the 1990s, this can be seen in the phenomenon of Internet mania prior to the dot-com crash. In this phase also financial innovations flourish as financial institutions find new ways to create new instruments, learning from financing of the technological revolution (Perez, 2002, p. 134). Consequently, ‘frenzy’ is marked with asset inflation, widening gap between rich and poor, the decoupling of financial and real economy, and eventually economic crisis. Perez (2009) argues that while the dot-com crash was due to Internet mania, the financial crisis of 2008 was caused by financial innovations, both parts of the second phase in the long wave of ICT revolution.

Economic crash at the end of frenzy period leads to the turning point in which rethinking and rationalization happen. This marks the beginning of phase three, ‘synergy’. During synergy, real and financial economy recouple. Moreover, the nature of the technology igniting the revolution has been understood better. This leads to full expansion of innovation and the allocation of capital for productive innovations. An example of this phase is the Golden Age after the Second World War. Finally, as the revolution enters the fourth phase, ‘maturity’, productivity starts to be stagnant again with new investment becoming less and less effective and profitable. The economy enters gestation period waiting for the next technological revolution to emerge.

One problem with this approach is the difficulty in proving the existence of long waves (Kuznets, 1940). Furthermore, most of the events in the long wave can only be identified and reconstructed in hindsight. At the present, people are faced with uncertainty and risk with regards to capital allocation. As the result. the phases in the long wave appears to be unavoidable part of the capitalist system. The solution proposed by the neo-Schumpeterian is the pro-active role of state in guiding investment (for instance see Mazzucato, 2013; Perez & Mazzucato, 2014) instead of fixing the problem caused by financial innovation.

3.3.3. Marxian perspective: relative surplus value and the tendency for the rate of profit to fall

The Marxian law of value is derived from the socially necessary labor time to produce a commodity required for the reproduction of daily life (Tsoulfidis, 2010, p. 92). This socially necessary labor time works to regulate prices and profit. ‘Surplus value’ can only arise if labor works longer than what is necessary to produce goods required for the reproduction of daily. This is the ‘absolute surplus value’ in Marxian terms.

However, it is in theory possible to create surplus value without extending the boundary of the working day by increasing labor productivity. This is done by “revolutionizing the technical and social conditions of the process and consequently the mode of production itself” (Marx, *Capital vol. I,* p. 432). In other words, technological progress is the key to enhance surplus value. This is what Marx calls relative surplus value (*ibid.*). It is in fact consistent with the neoclassical analysis of productivity growth. But the aim of capitalist production is not to reduce working hours for all (*ibid.*, p. 438).

Instead, capitalists aim to maximize profit by appropriating the surplus value, thus resulting in reduction of working hours only for those displaced by technology (in other words, unemployment).

It is also interesting to note that for Marx, capital used as production input is dead labor. This is because the intrinsic value of capital comes from the embodiment of labor time required to make the physical capital. Dead labor competes with living labor, even replacing them and therefore denies them subsistence wage. Marx famously compares this dead labor to the vampire, that is the vampire-motive of capital.

Hence, surplus value in Marxian analysis is always appropriated by the capitalists. Marxian surplus value is different from freed capital. Marx did not see money capital as formed through the profit from the saving of labor wages (Wilken, 1992, p. 234). For Marx, surplus value is entirely a form of labor exploitation. This exploitation of labor represses wages, making it more difficult for workers to meet their subsistence.

However, the capitalist system which creates relative surplus value by making labor redundant would soon run into a problem of the falling rate of profit as average variable cost (labor cost) is lowered at the expense of increasing fixed cost (Shaikh, 1992). To show this, let *s* be the surplus value, *C* represents total capital, *v* reflects the amount of variable cost, and let *l* be the total value of living labor, that is the combination of variable cost and surplus value, *v*+*s*. Then the rate of profit *r*, defined as the ratio of surplus value to total capital invested, can be written as:

$$r = \frac{s}{C} = \frac{s}{l} \cdot \frac{l}{C} = \frac{s}{v+s} \cdot \frac{l}{C} = \frac{1}{1+\frac{1}{s/v}} \cdot \frac{l}{C}. \tag{4}$$

Notice that if the ratio *s/v* and *l*/*C* are functions of time with positive first and second derivatives, then as *s/v* increases, the first term on the right hand side increasingly approaches unity. The rate of profit is therefore increasingly dominated by the second term, *l/C*, which necessarily falls as capital deepening occurs. Shaikh (1992) argues that this phenomenon would eventually lead to stagnation and economic crisis, similar with the case of neo-Schumpeterian maturity phase. This is Marx’s theory of falling profit, or tendency for the rate of profit to fall (TRPF).

TRPF is in the core of Marxian argument regarding the contradiction within the capitalist mode of production. For Marxists, capital would attempt to circumvent this limitation through the process of accumulation by dispossession (Harvey, 2010). Innovation, including but not limited to technological progress[6], could be used as the means to dispossess labor by replacing and therefore denying them subsistence. In other words, due to TRPF, labor exploitation and wage repression are the inevitable consequences of capitalism.

While neoclassical economics see increased savings from productivity growth as naturally being transformed into physical capital, Marxian analysis also points to the possibility for financial capital to live a life of its own. This is Harvey’s (2010) argument as the root cause of the Great Recession. The conventional Marxist transformation problem explains the use of money to purchase commodities that

[6] For instance, offshoring of production can be seen as an ‘innovative’ way to circumvent this limits of capital.

are utilized to produce goods. These goods then can be sold for more money (the M-C-M' transformation).However, as financial innovation evolves, this transformation increasingly becomes M-M', the use of money to obtain more money (see also Arrighi, 1994). Harvey contends that this shift of transformation paradigm is rooted in the emergence of neoliberalism that established the 'state-finance nexus', giving power to financial institutions (Harvey, 2010., p. 56-57). The emergence of neoliberalism, in turn, was triggered by stagflation during the 1970s which in Marxian analysis was caused by TRPF.

Comparison can also be drawn with neo-Schumpeterian perspective. TRPF and the maturity phase exhibit similar properties in the tendency to cause stagnation. However, neo-Schumpeterians argue that the financial crisis of 2008 was caused by the irrationality of frenzy phase. Marxists, on the other hand, argue for the crisis as the result of the 'state-finance nexus' design that encouraged the transformation of M-M'. This mode of transformation can lead to the problem of under-consumption, either due to speculation that increase prices and therefore cost of living or unemployment and wage repression of labor.

Yet, TRPF has long been a subject of debate. Okishio (1961), for example, argues that TRPF cannot occur if profit maximizing firms only choose 'viable technical changes', which refer to technological progress that earns supernormal profits. But even if Okishio's analysis is true, it would still depend on the existence of viable technical changes, which, as the neo-Schumpeterian analysis shows us, cannot always be achieved as the nature of the technology in a technological revolution requires some time before it reaches maturity.

The solution for Marxists is ultimately can only come via supplanting capitalism. This needs to be done by "seizing state power, radically transforming and reworking the constitutional and institutional framework that currently supports private property, the market system and endless capital accumulation." (Harvey, 2010, p. 256).

3.3.4. (Post)-Keynesian critique: effective demand and humanity's permanent problem

Literature on technological revolution within the Keynesian tradition is very limited. One paper by Cesaratto *et al.* (2003) is particularly interesting because it explicitly links technological change with the Keynesian approach to effective demand. In this paper, they criticize neoclassical optimism on "trickle-down" effect of technological revolution and neo-Schumpeterian view that investment would be stimulated by new technologies.

Their arguments are as follows. First, new technologies may induce investment, but some of the induced investment would be 'misdirected investment' (Keynes, 1936, p. 321) that increases aggregate demand temporarily but not its growth rate. This is similar to the neo-Schumpeterian frenzy phase, but it could happen at any stage of the technological revolution. Second, when the technological progress is labor-saving, innovation will negatively influence autonomous consumption absent real wage growth or availability of consumer credit[7].

Technological change alone is therefore not sufficient to explain long-run economic growth, instead it can be the source of persistent unemployment irrespective of market failures. Expansionary macroeconomic policies to induce aggregate demand is also required (Cesaratto *et al.*, 2003). This expansionary policies, in the context of Keynesian demand-driven model, concern primarily with investment demand required for full employment.

This demand-side approach hence offers a different perspective in looking at the allocation of freed capital. On the other hand, a neo-Schumpeterian might argue that stagflation in the early 1970s proved that expansionary policies alone are not enough to prevent runaway inflation and persistent unemployment. Nevertheless, the neo-Schumpeterian perspective actually agrees instead of contradicting this view of demand-driven model if we look at their proposal of the entrepreneurial state that pro-actively guides investment.

But a more fundamental critique of technological revolution comes from Keynes himself, in his little essay *Economic possibilities for our grandchildren* (Keynes, 1930). At first, Keynes warned about the danger of technological unemployment. But in an optimistic turn, he was convinced that technological progress can free humanity from the economic problem, that is to fulfill the material needs of human beings. Indeed, the *economic problem* for Keynes is "the struggle for subsistence" (*ibid.*). Keynes further states that this struggle for subsistence does not only belong to the human race but to the entire "biological kingdom". This is in contrast with conventional understanding of *economic problem* as the problem of allocating scarce resources. For instance, Robbins (1935, p. 15) argues that the economics science concerns with "relationship between ends and scarce means which have alternative uses".

As we get so well versed in pursuing material existence for our economic problem, we are clueless on what to do should the economic problem is no longer:

> "Thus for the first time since his creation man will be faced with his real, his permanent problem—how to use his freedom from pressing economic cares, how to occupy the leisure, which science and compound interest will have won for him, to live wisely and agreeably and well." (*ibid.* p. 367)

If during Keynes's time of writing this essay back in 1930, "the time for all this is not yet", we might not have to wait much longer. The rise of smart machines, with its potential to displace 47% of jobs today, would get us sooner rather than later. It is therefore probably the time to consider what Keynes have not fully answered almost a hundred years ago for he was occupied with the economic problem, the solution to humanity's permanent problem.

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[7] To be clear, Cesaratto *et al.* do not think that consumer credit is a 'good' solution other than just to temporarily patch up problems with weak demand, But as other post-Keynesians like Palley (2012) or even Marxist like Harvey (2010) argue, this has happened with the recent easy credit bubble leading to the financial crisis in 2008. It is therefore a solution that could backfire, but a solution notwithstanding.

3.3.5. Aristotelian perspective on capital and its allocation

In volume I of *Politics*, Aristotle distinguishes use value and exchange value. For Aristotle, a good can be said to have a use value but can also be exchanged for other good, as he puts it:

> "Of everything which we possess there are two uses: both belong to the thing as such, but not in the same manner, for one is the proper, and the other the improper or secondary use of it. For example, a shoe is used for wear, and is used for exchange; both are uses of the shoe. He who gives a shoe in exchange for money or food to him who wants one, does indeed use the shoe as a shoe, but this is not its proper or primary purpose, for a shoe is not made to be an object of barter." (*Politics* vol. I, Chapter IX)

When money becomes the unit of exchange, it follows that wealth accumulation is necessary in the 'art of managing a household'; that is to provide subsistence for the household. However, Aristotle contends that material needs are limited (Pack, 2010, p. 25). On the contrary, wealth accumulation can become unlimited as one becomes absorbed in 'the art of wealth-getting' that is not natural:

> "Hence some persons are led to believe that getting wealth is the object of household management, and the whole idea of their lives is that they ought either to increase their money without limit, or at any rate not to lose it. The origin of this disposition in men is that they are intent upon living only, and not upon living well; and, as their desires are unlimited they also desire that the means of gratifying them should be without limit." (*ibid.*)

Material needs are limited because those needs are only prerequisites, a means to an end. According to Aristotle, human beings' purpose, or *telos*, is happiness (*eudaimonia*). Happiness is not only derived from fulfilling pleasure but from the exercising of virtue (*arete*) (Naastepad & Houghton Budd, 2015). Virtue by itself is not easy to define as it involves being the best that human beings can be, both with regards to the individuals and the community (Giovanola & Fermani, 2012; Solomon, 2004). The inclusion of community implies that in this framework, human beings are not only self-interested but also 'other-interested'. Furthermore, virtues do not come as a given nor as a universal thing in human beings (Van Staveren, 2001, p. 153). To become virtuous requires the development of the mind and of character (Pack, 2010, p. 31-32).

The limitedness of material needs and the characterization of human beings as both self- and other-interested contrast Aristotelian approach with neoclassical approach. As mentioned in subsection 3.3.1, the neoclassical perspective emphasizes on human being's maximization of utility and profit, both of which are material needs. The neoclassical perspective is rooted in the assumption of human beings as *Homo economicus* who attempt to maximize utility and profit due to their self-interested nature. If Aristotelian perspective is adopted, the assumption of *Homo economicus* hence has to be dropped. Hence, human beings are no longer only self-interested and strive for not only material needs but also immaterial needs.

The Aristotelian perspective can be extended to the understanding of capital and its allocation, if capital is assumed to be similar to wealth[8]. Houghton Budd (2011, pp.144-145) argues that surplus

[8] In Aristotle's time, the understanding of wealth might be different from today and the concept of capital was not used yet.

could arise from human economic activity, and that this surplus is "over and above the needs of those party to it". This surplus therefore is no longer needed for subsistence and can be used to finance people's aspiration, that is of a goal higher than mere material things. Linking this to the Aristotelian perspective, the allocation of freed capital, as the result of productivity growth, can therefore be used to finance the development of the mind and character. Consequently, using this surplus, human capacities are 'capitalized'; we might call this mental capital.

It is important to note that the understanding of capacities as mental capital is different from the neoclassical notion of human capital (Lucas, 1988). In the neoclassical approach, human capital is seen as a factor of production, a means for expanding production[9]; what human beings strive for is the pleasure derived from consuming more goods. Instead, mental capital is something that human beings also strive for.

The idea that human beings strive for more than just material subsistence can also be found in other perspectives discussed previously. In Keynes's *Economic possibilities*, it is made clear that for Keynes, the economic problem, that is the struggle for material subsistence, once solved would left mankind with his real and permanent problem. This real, permanent problem can be interpreted as the pursuit of immaterial purposes instead of the pursuit of material gains. Marx, according to Fromm (1961), saw the world history as the proof of human development through labor and creativity human beings:

> "The whole of what is called world history is nothing but the creation of man by human labor, and the emergence of nature for man; he therefore has the evident and irrefutable proof of his self-creation, of his own origins." (Marx, quoted in Fromm, 1961)

Marx had therefore seen the value in the activity of creation other than to satisfy material needs.

Additionally, Schumpeter, in his analysis of the role of the entrepreneur, came to the conclusion that the ultimate motive that drives the entrepreneur is not merely profit but also:

> "…the joy of creating, of getting things done, or simply of exercising one's energy and ingenuity" (Schumpeter, [1911] 2008, p. 93)

But eventually Schumpeter, as with the neoclassical economics, failed to see the alternative to capital allocation other than in the sphere of production. Hence, is it possible for Aristotelian economics to adduce the conception of capital and go beyond the context of physical needs? The purpose of this thesis, eventually, is to learn from these economic theories, coming from these great thinkers, on how technological revolution would create societal benefit.

[9] This human capital is reflected in equation (3) as labor quality, the difference between growth of labor services and growth of hours worked.

Chapter 4

On the impact of ICT revolution to productivity growth and the freeing of capital

We have all this money, we have all these people, why aren't we doing more stuff?
Larry Page on Google 'moon-shot' projects

4.1. Introduction

The previous chapter presented economic perspectives on technological change and the allocation of capital freed by it. This chapter attempts to examine empirically the impact of ICT as a technological revolution on macroeconomic performance, particularly productivity growth. First, ICT will be defined and its qualification as a technological revolution to be assessed based on Perez (2002). Second, the contribution of ICT capital deepening to productivity growth is to be examined. Third, we take a first tentative step towards estimating the capital that is freed from the economic process by ICT. Finally, the allocation of this 'freed capital' will be explored.

This chapter focuses on empirical observations in seven countries: the U.S., the U.K., Germany, the Netherlands, Denmark, Sweden, and Finland. The first reason for this choice is practical, namely, the availability of data for the countries since relatively early stage of ICT revolution. Second, ICT revolution does not occur simultaneously in the whole world, but its diffusion is uneven and involves often significant time-lag (Perez, 2002). Third, contrasting the countries would be interesting, especially since the countries adopt different mix of economic perspectives. The U.S. and the U.K. for instance are where neoclassical perspective being adopted at a relatively pure form (Naastepad & Houghton Budd, 2015) when compared to continental Europe model (represented by Germany and the Netherlands) and the Nordic model.

The data used in this chapter comes from various publicly available sources, among others the EU KLEMS database, OECD, and the World Bank. This chapter mainly makes use of descriptive statistics. Some calculations are on occasions performed on the raw data to better represent the data as needed for our purpose.

4.2. Defining ICT and ICT revolution

4.2.1. What is ICT?

When talking about ICT, one generally needs to go back only as far as the introduction of Intel's first microprocessor, the Intel 4004, first introduced in the spring of 1971. The event marks the beginning of ICT era that would subsequently find applications in industries, households, and governments. Perez (2002) refers to the event as the big-bang of ICT revolution. Over time, the microprocessor technology is adopted into various technologies that forms ICT.

There is, however, no uniform definition of ICT that can pinpoint exactly the boundaries of what constitute information & communication technologies. OECD defines ICT based on its primary function to process, transmit, and display information and communication electronically (OECD, 2013). To measure ICT investment, ICT is further decomposed into three components: information technology (IT) equipment which consists of computers and other related hardware, communication equipment, and software. Economists have commonly taken practical stance in defining ICT, based on the availability of data. McGuckin & Stiroh (2002), Stiroh (2002), O'Mahony & Vecchi (2005) for instance have considered the total investment in computer hardware, software, and communication devices. Oliner & Sichel (2000), on the other hand, focus specifically on IT hardware and software in their study.

The EU KLEMS database follows closely the definition of ICT proposed by OECD. In EU KLEMS, the measurement of ICT investment is divided into computing equipment, communication equipment, and software (O'Mahony & Timmer, 2009). Since this thesis makes use of EU KLEMS database, ICT as understood here therefore follows the categories proposed in EU KLEMS.

Finally, it is interesting to note that the role of ICT examined by the database such as EU KLEMS or OECD focuses on ICT capital as a factor of production. However, the use of ICT in daily life, outside of the sphere of production, might also have an impact to productivity. For instance, with the ubiquity of smartphones and social media, one could easily imagine how people can become occupied with their online 'activities' that result in productivity reduction. However, empirical evidence has been ambivalent in this rather new field with some studies find positive impact while some other report negative impact (Aguenza et al., 2012). Moreover, this aspect of ICT impact to productivity has not shown up in the database used in this thesis since the usage of personal ICT equipment within the working environment is not considered.

4.2.2. The progress of ICT revolution

What measure can be used to determine whether ICT has indeed become technological revolution? As mentioned in section 3.1, Perez's (2002) defines technological revolution as 'interrelated constellation of technical innovation' that includes a crucial 'all-pervasive low-cost input'. The development of various technologies within ICT described in previous section (computing equipment, software, and communication devices) can be considered 'interrelated' since they are all made possible by the invention of microprocessor and they complement each other (hardware needs software to run, communication devices essentially combine hardware and software capabilities to perform their function). Hence, two other criteria need to be evaluated: the price of ICT input and the pervasiveness of ICT across various sectors in the economy. In particular, seeing the pervasiveness of ICT might be an indication of whether ICT has become 'the new norm' across the economy, thus befitting the characterization of technological revolution by Perez. Figure 3 shows the price index of computing equipment, communication devices, and software in our seven countries of interest.

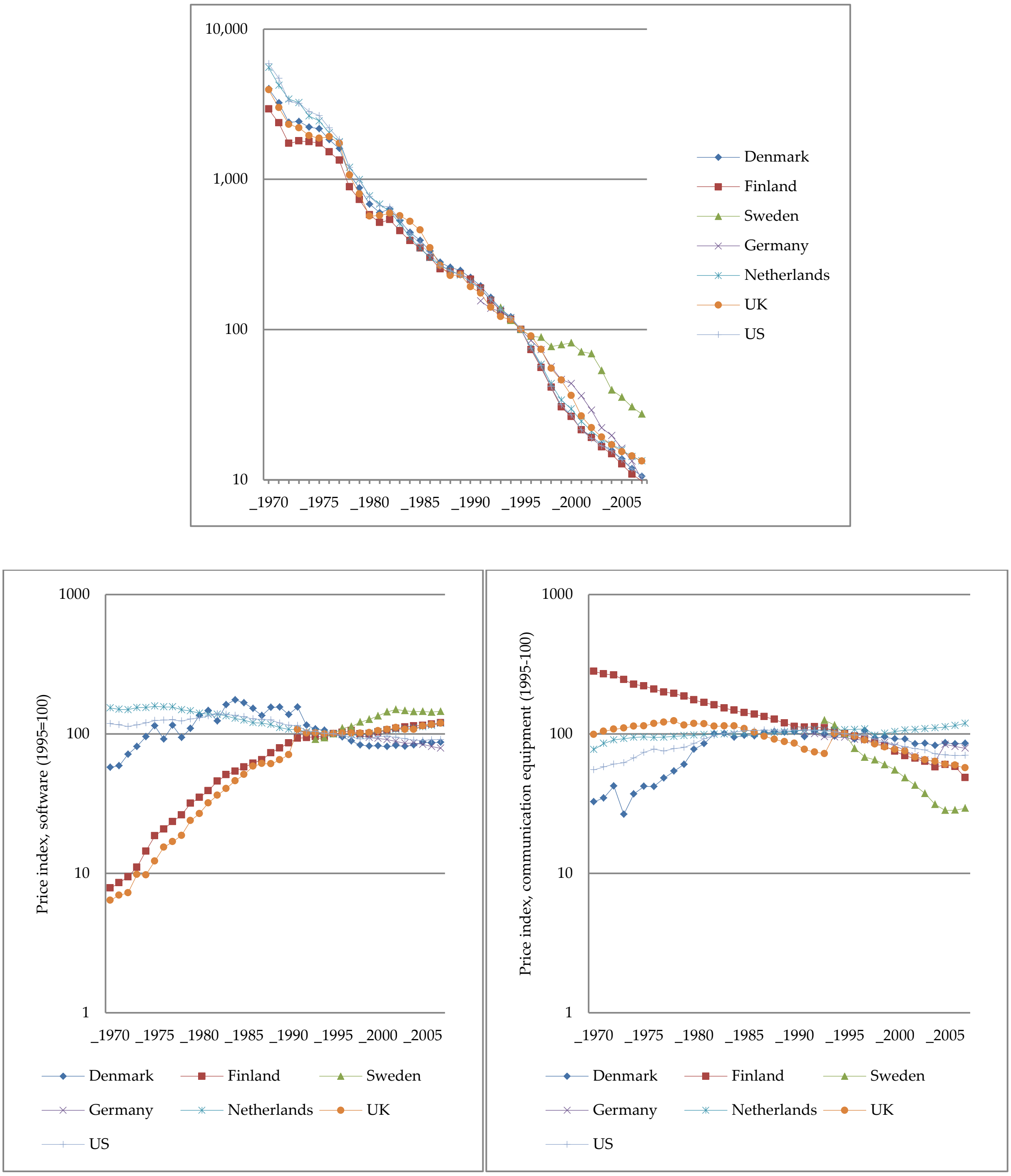

Figure 3: Computing equipment price index (top), software price index (bottom-left), and communication equipment price index (bottom-right), logarithmic scale (1995 = 100). Source: EU KLEMS database

The price of computing equipment is shown to follow exponential decline during the last four decades. The trend is found to be similar in all seven countries with slight deviation in Sweden during the late 1990s. However, communication equipment and software have not followed the similar path as computing equipment, Moreover, the trend has been different across the seven countries of interest.

The top-left, top-right, and bottom-left panels of Figure 4 depicts the trend of investment in ICT including computing equipment, communication equipment, and software respectively as input for all sectors tracked by the EU KLEMS database. The chart shows exponentially increasing usage of ICT capital in the last four decades, reflecting ICT capital deepening. The bottom-right panel of Figure 3 on the other hand shows that the growth of non-ICT capital formation has been relatively linear across all seven countries. This could imply that the rate of diffusion of ICT capital is much faster than non-ICT capital. Moreover, it could also reflect the pervasive usage of ICT capital across industries, thereby multiplying its growth when compared to non-ICT capital.

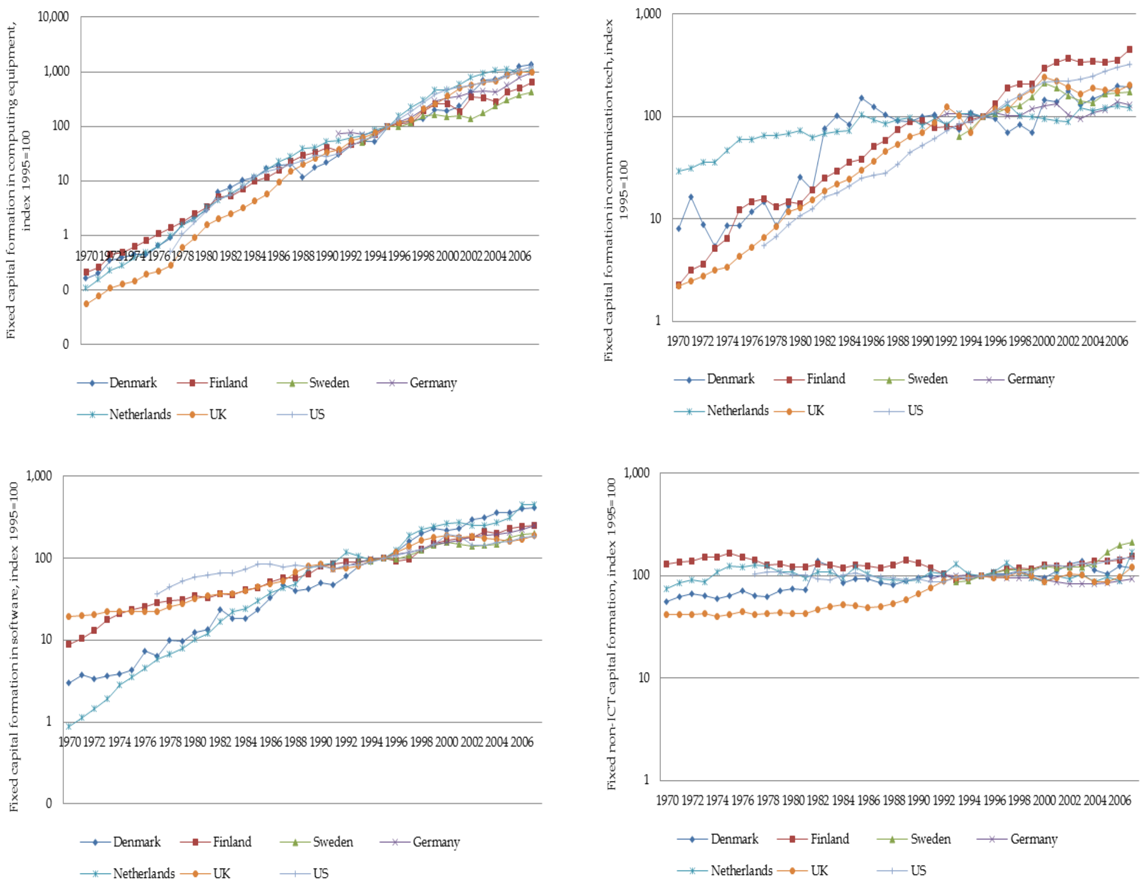

Figure 4: Fixed capital formation in computing equipment (top-left), communication equipment (top-right), software (bottom-left), and non-ICT capital (bottom-right), volume index (1995 = 100). All charts shown in log scale. Source: EU KLEMS.

The bottom-right panel of Figure 4 on the other hand shows that the growth of non-ICT capital formation has been relatively linear across all seven countries. This could imply that the rate of diffusion of ICT capital is much faster than non-ICT capital. Moreover, it could also reflect the pervasive usage of ICT capital across industries, thereby multiplying its growth when compared to non-ICT capital.

The trends of price index and ICT capital formation index also show that the seven countries of this study experience more or less similar development in ICT. However, this is largely related to only computing equipment. To declare that ICT as a technological revolution from this perspective therefore would not be accurate since such strong trend of cost reduction and pervasiveness have not been observed for software and communication devices, two other technologies included in the three categories of ICT as defined in subsection 4.2.1. One possible explanation for this is that ICT revolution is still ongoing. This is also suggested by Perez (2002), arguing that we have yet to reach the 'synergy' phase whereby full expansion of ICT can be observed. Towards the Internet and machine intelligence era, software and communication equipment would become increasingly prominent. A better picture of ICT revolution can therefore be obtained only if there have been adequate data to observe price decline and pervasiveness for these two technologies. Therefore, as far as the data available in the EU KLEMS can inform us, ICT is at best in the process of becoming a technological revolution. This observation is important because it might considerably weaken the observed impact of ICT to productivity growth. Subsequent discussion on ICT and productivity growth should then be taken bearing in mind this limitation.

4.3. Contribution of ICT to productivity growth

Figure 5 shows the trend in GDP per capita growth in the seven countries. Over the four decades, there is no significant gap in GDP per capita growth observed, except for Finland's extreme trough and peak in the 1990s (reflecting a crisis following the collapse of its major trade partner, the U.S.S.R.). The declining trend post 2008 financial crisis shows the severity of the financial crisis affecting everyone. But other than that, GDP per capita has not been diverging since the early onset of ICT revolution. How much has ICT influenced the productivity growth for these countries?

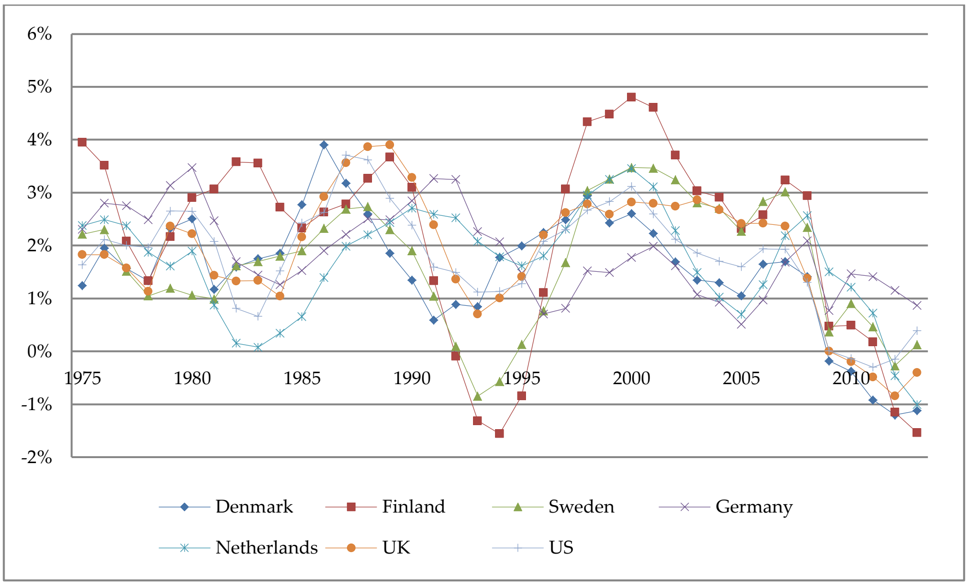

Figure 5: GDP per capita growth, 5-year moving average. Source: World Bank and author's calculation.

This section attempts to provide an estimate of ICT contribution to productivity growth in the seven countries studied. Since this topic has been widely studied, a brief overview of previous results (albeit with focus in the U.S.) is first presented. The empirical approach and data issue is then discussed before the result is presented.

4.3.1. Results from previous studies

There are typically two approaches in estimating the impact of ICT to productivity growth: using the growth accounting framework or econometric estimation. Both approaches normally start with a production function (Cobb-Douglas or otherwise).

Using Cobb-Douglas production function as the baseline and a growth accounting framework, the contribution of ICT to productivity growth can be estimated by extending equation (3) shown in Chapter 3, decomposing capital input into ICT capital and non-ICT capital:

$$(4) \qquad \mathrm{d}\, ln\, y = w_{KIT} \mathrm{d}\, ln\, k_{ICT} + w_{KNIT} \mathrm{d}\, ln\, k_{NICT} + w_L(\mathrm{d}\, ln\, L - \mathrm{d}\, ln\, H) + \mathrm{d}\, ln\, A.$$

Similar to equation (3), d denotes the first difference, y denotes output per hour worked (i.e. labor productivity), k_{ICT} stands for ICT capital per hour worked, k_{NICT} for non-ICT capital, and the difference between labor input L and number of hours worked H denotes the labor input only for the contribution of changes in labor quality. The total factor productivity term A can further be decomposed into TFP growth in ICT producing sector and otherwise (see for example Oliner & Sichel, 2000). Note that the only difference betwwen equation (3) and (4) is only the decomposition of k into k_{ICT} and k_{NICT}.

For our purpose, the impact of ICT to TFP growth will be ignored since studies have not shown conclusive results of this impact outside the U.S. (Cardona et al., 2013). The important things to note from equation (4) are the coefficients w_{KIT}, w_{NKIT}, and w_L derived from the share of compensation received by each factor. Growth accounting approach assumes that the weighted share of actual remuneration of each production factor – as reflected by w_{KIT}, w_{NKIT}, and w_L - reflects the marginal productivity of each factor. This stems from the neoclassical assumptions of perfect competition and constant return to scale. The weakness of this approach, however, is the reliance with these neoclassical assumptions. For instance, if perfect competition does not hold, each factor's share of compensation would fail to reflect its marginal productivity; that is the change of output due to the change of one unit of the particular input. As the result, the elasticity of each factor to productivity growth obtained from this approach would be misleading. However, in the growth accounting framework, these neoclassical assumptions are not tested to see whether or not they align to reality. In other words, growth accounting approach has no empirical basis.

The EU KLEMS database includes the estimation of ICT contribution from a growth accounting approach. The result is presented in Table 1, accounting only for the impact of ICT capital deepening. On average, the contribution of ICT in Europe, except for Denmark, is lower on average than in the US. This is pretty consistent with the result of most studies that have demonstrated lower impact of ICT in Europe than in the US (Timmer et al., 2003). Since only the impact of ICT capital deepening is accounted for, however, this result is lower than other studies that also include the impact of ICT to TFP growth. Van Ark et al. (2003) and Van Ark & Inklaar (2005) , for instance, estimate the contribution of ICT to labor productivity growth in Europe to be around 17-45% in the period of 1990-

2005. In the U.S., Jorgenson (2001) and Jorgenson et al. (2008) estimate even higher number of 36-73% in the period of 1990-2005.

Table 1: contribution of ICT capital deepening to average labor productivity. Source: EU KLEMS database and author's calculation.

Country	**Year**	**Contribution of ICT capital deepening (in % of average labor productivity growth)**
Denmark	1981-2007	48.61%
Finland	1971-2007	13.26%
Sweden	1994-2007	19.05%
Germany	1992-2007	20.08%
The Netherlands	1980-2007	25.76%
UK	1971-2007	27.16%
US	1978-2007	33.78%

The second common approach makes use of linear regression models to estimate the impact of ICT. This approach also often starts with a Cobb-Douglas production function as the basis. The regression equation is derived by log-linearizing the aggregate production function. Alternatively, the production function can be expressed in terms of growth rates (first difference) or log first difference. For instance, in terms of log-linearized production function, the regression equation can be written as:

$$lny_{i,t} = \alpha + \beta_1 \ln k_{i,t}^{ICT} + \beta_2 \ln k_{i,t}^{NICT} + \beta_3 \ln l_{i,t} + controls + \varepsilon_{i,t} . \quad (5)$$

The index *i* denotes the observational unit. Depending on the level of aggregation, it is either a country, an industry, or a firm. The index *t* stands for the time period. The control variables most commonly used are time dummies or dummy variables representing the observational unit (i.e. industry dummies, country dummies, etc.). The coefficients β_1, β_2, and β_3 represent the elasticity of each factor to productivity. The interpretation of β_1, for instance, is the increase of 1% in ICT capital investment is expected to increase productivity by β_1%.

The advantage of using such econometric approach is that it does not require the assumptions postulated by neoclassical theory as in the growth accounting framework. Instead, these coefficients are estimated by testing its statistical significance. The drawback, however, is that it is prone with the problem of endogeneity. Investment in capital can be said as influencing productivity, but likewise, increase in productivity and output might also increases the investment in capital (Cardona et al., 2013). As the result, this approach yields a better measure of correlation than growth accounting (because it is empirically estimated). However, regarding the causality between ICT capital and productivity growth, both approaches remain inconclusive.

Results of econometric approach from various studies have commonly found significant relationship between ICT capital deepening and productivity growth. McGuckin & Stiroh (2002) find the coefficient β_1 to be 0.17 in the US between 1980 to 1996. O'Mahony & Vecchi (2005) find similar result in the case of the US (0.18) but significantly lower in the UK (-0.013) between 1976 to 2000. However, the result of some econometric studies have failed to find significant result on the impact of ICT capital to TFP growth, or the spillover effect. Stiroh (2002), for instance, finds that ICT capital deepening inversely influenced TFP growth (-0.07) in the U.S. between 1984-1999. Interestingly, in general, econometric studies find much lower (and often statistically insignificant) effects than the growth accounting approach.

4.3.2. Empirical approach and data issue

The empirical strategy adopted here is similar to the one used in McGuckin & Stiroh (2002). The aggregation is on the industry level, hence the coefficients will be estimated for each country separately. This industry-level aggregation is taken instead of country-level one following McGuckin & Stiroh (2002, p. 57) who find that country-level aggregation leads to biased results that are potentially misleading. Starting with a Cobb-Douglas production function, the regression equation used is akin to equation (5). However, in this case, the effect of labor quality is omitted due to data limitation (same omission is made in McGuckin & Stiroh, 2002). The regression equation is therefore reduced to:

$$(6) \qquad ln y_{i,t} = \alpha + \beta_1 \ln k_{i,t}^{ICT} + \beta_2 \ln k_{i,t}^{NICT} + controls + \varepsilon_{i,t}.$$

The regression technique to be used is a simple pooled ordinary least squares (OLS) regression. The control variables to be used are time dummies to capture the effect of common productivity shocks over time (O'Mahony & Vecchi, 2005). These common shocks shift the regression line but does not change the impact of ICT capital. If it is not included, the coefficients can therefore be distorted.

Industry dummies are not included in the regression equation used here. Inclusion of industry dummies to the OLS regression on top of the time dummies, commonly termed 2-way fixed effects (FE) model in panel data analysis, should theoretically account for the unobserved heterogeneity across industries. This can be important because ICT use is typically concentrated within a group of industries (usually services industries). McGuckin & Stiroh (2002) cast doubt on the 2-way FE models, arguing that such models tend to bias down the result due to the loss of variance on the right hand side of the equation.

Besides the issue of unobserved heterogeneity, there could also be multicollinearity problem in the regression model. This is because the independent variables are likely to be correlated. The investment in ICT capital could be influenced by the investment in non-ICT capital, and vice versa. Increased in non-ICT capital could reduce the investment in ICT capital, for instance.

It is also important to note another drawback of this regression model, which is the issue of endogeneity. Researchers have attempted to solve this problem but no solution seems to be agreeable to all despite the complexity of techniques involved. O'Mahony & Vecchi (2005), for instance, propose to use dynamic panel data estimation. Despite its complexity, the results of dynamic panel data does not differ much with simple pooled OLS for the US case (0.18 vs. 0.17). It is therefore inconclusive if more complex methods can actually solve the problem of endogeneity. Furthermore, it could be the case that endogeneity is perhaps not a significant problem in measuring the impact of ICT to productivity. Nevertheless, one observation from O'Mahony & Vecchi might not be enough to conclusively state that endogeneity is not a problem and further research is required on this matter. Simple pooled OLS regression is therefore chosen, bearing in mind the problem of endogeneity and unobserved heterogeneity that might affect the quality of the result.

The data used for this regression is taken from output and input data provided in the EU KLEMS database for the seven countries of this study. The EU KLEMS database used spans from 1970 to 2007 and was released in March 2011. The industry classification is based on the International Standard Industrial Classification of All Economic Activities (ISIC) Revision 3.1, a system used by the United Nations. There are 72 industries included which are grouped into 17 categories.

Table 2 shows these classifications.

Table 2: ISIC Rev. 3.1 top level industry classifications. Source: United Nations, 2002.

Code	Industry group
A and B	AGRICULTURE, HUNTING, FORESTRY AND FISHING
C	MINING AND QUARRYING
D	TOTAL MANUFACTURING
E	ELECTRICITY, GAS AND WATER SUPPLY
F	CONSTRUCTION
G	WHOLESALE AND RETAIL TRADE
H	HOTELS AND RESTAURANTS
I	TRANSPORT AND STORAGE AND COMMUNICATION
J	FINANCIAL INTERMEDIATION
K	REAL ESTATE, RENTING AND BUSINESS ACTIVITIES
L	PUBLIC ADMIN AND DEFENCE; COMPULSORY SOCIAL SECURITY
M	EDUCATION
N	HEALTH AND SOCIAL WORK
O	OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES
P	PRIVATE HOUSEHOLDS WITH EMPLOYED PERSONS
Q	EXTRA-TERRITORIAL ORGANIZATIONS AND BODIES

In this thesis, the regression analysis will be conducted by pooling the data from 15 of the 17 categories, from A to O. Industry group P and Q are omitted due to the incompleteness of data.

Moreover, these two industries do not add substantially to the aggregate. Industry groups A and B are combined together in the database.

The productivity independent variable y is obtained from the gross value per hour worked in constant 1995 price. Hence, this estimate ignores the influence of intermediate inputs. Furthermore, the measure of ICT and non-ICT capital used are based on fixed capital formation in constant 1995 prices, a proxy for capital investment. O'Mahony & Vecchi (2005) argue for the use of capital services instead, which are derived based on capital investment weighted by the user cost of capital. The user cost of capital, sometimes referred to as the rental price, reflects the marginal productivity of the capital based on its share of total capital compensation. This leads to a similar problem with the growth accounting framework whereby it is necessary to assume that the share of capital compensation actually reflects its marginal productivity. The measure of fixed capital formation does not require such assumption and hence is chosen for this study.

4.3.3. Estimation results

Table 3 reports estimates of the pooled OLS regression according to equation (5), performed for the seven countries. All countries exhibit positive and significant coefficients of β_1 and β_2. This means that the increase in investment of both ICT and non-ICT capital have positive impact to productivity growth. The adjusted-R^2 are quite high for all countries, ranging between 60%-80%, indicating that the regression model could explain the variance pretty well.

Table 3: Pooled OLS regression results for seven countries. All coefficients are significant at the 1% level. Standard errors are in parentheses.

Country	**Year**	$\boldsymbol{\beta_1(lnk^{ICT})}$	$\boldsymbol{\beta_2(lnk^{NICT})}$	**Adjusted-R^2**
Denmark	1970-2007	0.26 (0.024)	0.22 (0.019)	0.60
Finland	1987-2007	0.30 (0.018)	0.22 (0.018)	0.77
Sweden	1993-2007	0.16 (0.019)	0.36 (0.028)	0.68
Germany	1991-2007	0.28 (0.02)	0.25 (0.02)	0.81
Netherlands	1980-2007	0.13 (0.025)	0.51 (0.027)	0.71
UK	1970-2007	0.13 (0.012)	0.32 (0.015)	0.69
US	1977-2007	0.15 (0.014)	0.29 (0.019)	0.68

Going deeper into the coefficient of ICT capital, one can observe that the result for the U.S. is 0.15. This is lower but still consistent with the results by McGuckin & Stiroh (2002) and O'Mahony &

Vecchi (2005). The Nordic countries and Germany exhibit rather high coefficient for ICT capital. The result for Finland and Germany are quite surprising since these countries are found to have higher ICT impact than Denmark which has higher ICT penetration. One possible explanation for the higher coefficients found in Finland and Germany is that these countries were using ICT capital in a more productive way. Hence, while Finland and Germany have relatively low ICT capital formation compared to Denmark, the trend of productivity growth observed is relatively similar.

Other possible explanation could be due to the fact that the observation for Denmark has started from the year 1970 while for Finland and Germany, the observations start from the late 1980s. In the nascent period of ICT revolution, productivity gain might suffer due to the time lag required for learning and adapting to the new technology (this is the productivity paradox, see David, 1990). Thus, the low productivity gain contributed by ICT in the 1970s is reflected in Denmark's result. This might also explain the relatively low results for the Netherlands and the U.S.

The result for UK is also unexpected since it is positive (0.13), in co.ntrast with the result of -0.013 obtained by O'Mahony & Vecchi (2005). One explanation could be the time period of study. Their study spans from the year 1976 to 2000. More recent progress post-2000 might have helped the result obtained in this study.

Other explanation could be due to the fact that this study makes use of ICT capital formation as the proxy of ICT investment. O'Mahony & Vecchi use ICT capital services instead. Depending on the share of ICT capital compensation in the country, capital services could paint very different picture compared to simply measuring investment in ICT capital. Nevertheless, the difference between the result in this study and the result obtained by O'Mahony & Vecchi is relatively not large although the sign is changed.

Yet another explanation could be the difference of regression technique adopted. As mentioned. O'Mahony & Vecchi opt for the more sophisticated dynamic panel data analysis. However, this ecxplanation might not be very convincing since we only observe small difference in the result for the U.S.

Commenting on the overall impact of ICT capital, it would appear that the contribution of ICT during the past few decades have been around one-quarter or less in these advanced countries with relatively high penetration of ICT. If this is already the full extent of ICT revolution, then the impact to productivity growth does not seem to add up to its label as a revolution. However, the analysis from section 4.2 suggested that we might not have observed the full impact of ICT revolution yet, especially as the development in communication and software technologies have yet to reach the level of computing equipment. Furthermore, these two other technologies could have bigger impact to productivity as by nature they might allow for more automation. Indeed, smart machines can only happen with extensive application and development in communication technologies and software.

4.4. Productivity dividend and the freeing of capital due to ICT revolution and its allocation

4.4.1. How much productivity dividend and freed capital has been contributed by ICT revolution?

Following the estimate on the impact of ICT to productivity, a question might arise about to what extent ICT revolution has contributed to the freeing of capital and creation of excess liquidity. The answer to this is not straightforward, and to this author's knowledge, there has been no existing study attempting to answer such question. But can it actually be measured, or at least estimated?

The estimate in section 4.3 has provided us with a proxy on how much ICT capital deepening has contributed to productivity growth. This contribution can be calculated in money term, therefore estimating the productivity dividend resulting from ICT capital. From here, things get a bit more complicated. This dividend can be distributed in various ways, but in general there might be three main conduits: as wages, profits, or taxes. As wages, the dividend might be a part of necessary income formation. As taxes, the dividend can be used to finance public expenditure whose contribution to social benefit is open to debate. As profits, this dividend might be used to expand production (in practice, it is often distributed to shareholders, on the assumption that they will use it for productive investment in the real economy). Regarding the distribution of the dividend between profits and wages, we have a problem. Thinking in neoclassical framework, we should try to assess the contribution of each factor to productivity growth. However, how to measure this? Neoclassical economists typically take the *actual* remuneration of labour and capital and argue that, under the familiar set of restrictive assumptions, this will reflect their relative contributions. Thus we end up in a tautology. From an Aristotelian perspective, we might question the neoclassical meritocratic idea that 'factor incomes' should reflect the contribution of each 'factor of production' to total output, and propose instead a division based on needs. For the purpose of this chapter, however, we will not try to resolve this issue.

The important point is that to the extent that the productivity dividend is necessary to improve or expand production in order to meet material needs, one cannot speak of freed capital; capital that is needed for meeting the material needs of people is not free. Some of the dividend, however, could be 'freed capital', that is, capital that it is no longer needed for the purpose of fulfilling basic needs (because living standards are high enough). The question posed in this thesis[10] is whether today's phenomenon of 'excess liquidity' reflects freed capital that (as yet) has failed to find a counterpart. The major concern in this chapter is whether it would be possible to arrive at an estimate of capital freed by ICT revolution.

[10] Following Naastepad and Houghton Budd 2015.

The procedure for estimating productivity dividend for the seven countries being studied as the result of ICT capital deepening is as follows. The data used for the estimation is based on value-added data from the EU KLEMS database for the 15 group of industries included in the econometric estimation. The increase (or decrease) of aggregate value-added per hour worked is the difference between the value-added per hour for the current year and for the previous year. Multiplying with the number of hours worked in the current year gives us an estimate of total productivity dividend for the current year. The contribution of ICT can be computed in two ways. First, using the growth accounting result from the EU KLEMS database, the contribution of ICT is its percentage contribution to productivity growth. Taking the case of Denmark, this means roughly half of the productivity dividend comes from ICT capital deepening. Second, the econometric estimation result allows us to estimate the contribution of ICT capital. Taking log-difference of the current and previous year ICT capital formation and multiplying it with the coefficient β_1 gives us the contribution of ICT to productivity increase. Transforming it from log form to level form and multiplying by the number of hours worked in the current year then gives us the contribution of ICT to productivity dividend in money term.

Table 4 presents the result for both growth accounting and econometric estimation. The result is the sum of ICT contribution to productivity dividend throughout the years studied, expressed in constant 1995 prices in local currency. The first observation can be made from the result is the estimations from growth accounting are almost always higher than the econometric estimates, except for Finland case. However, the differences are still within the same magnitude. The result in Table 4 certainly cannot be taken as hard facts. This is because there are numerous problems with the estimation of ICT contribution itself, both from growth accounting and econometric perspectives, as elaborated in section 4.3.

Table 4: Total contribution of ICT capital deepening, figures are in local currency unit at 1995 constant prices.

Country	**Year**	**Growth accounting estimate**	**Econometric estimate**
Denmark	1970-2007	DKK 8.2 Trillion	DKK 0.16 Trillion
Finland	1987-2007	EUR 0.15 Trillion	EUR 0.16 Trillion
Sweden	1993-2007	SEK 1.2 Trillion	SEK 0.1 Trillion
Germany	1991-2007	EUR 1.4 Trillion	EUR 0.93 Trillion
Netherlands	1980-2007	EUR 0.16 Trillion	EUR 0.28 Trillion
UK	1970-2007	GBP 2.9 Trillion	GBP 1.7 Trillion
US	1977-2007	US$ 18.5 Trillion	US$ 7.2 Trillion

Despite the shortcomings of the results presented in Table 4, a first attempt can be made to see the potential impact of ICT to excess liquidity. To this end, we rely on Kaldor's (1957) 'stylized fact' of a roughly constant wage share; according to Kaldor (1957), over a very long period of time, the ratio of wages to profits is roughly constant at 2:1. This stylized fact will be used to solve the problem raised above (of dividing the productivity dividend over profits and wages). That is, in contrast to actual trends (of stagnating wages, especially in the U.S.), it is assumed that wage earners have a justified claim to two thirds of the productivity dividend and profit earners can claim one third. Taking the example of the U.S., this would mean that, of the productivity dividend worth U.S.$ 7.2 trillion (taking the more conservative estimate given by econometric approach given in Table 4), U.S.$ 2.4 trillion would accrue to profits (before taxes) since 1977 in the U.S.

If a rather blunt assumption is made, namely that the estimation of profit share based on Kaldor's stylized fact reflects the true profit contributed by ICT, then capital freed by ICT would amount to the U.S.$ 2.4 trillion computed, minus taxes (as mentioned in section 3.2, freed capital in this thesis is understood as the true profit from the production sphere, following Wilken 1992). However, this assumption has no empirical basis. Kaldor's stylized fact merely observes the distribution of profit and wage over time, mainly based on data from the U.S. and the U.K. The stylized fact therefore cannot show whether the share of profit is true profit according to Wilken or the share of profit is also formed through other source, e.g. through forced saving or the withholding of necessary income formation. To know precisely the amount of freed capital contributed by ICT would require observing these other sources of capital formation. This would require extensive research and not all required information might be available (for instance, defining 'necessary income formation' could perhaps require many assumptions to be made). Hence, in this thesis, due to time constraint, it is not possible to arrive at a reliable estimate of capital freed by ICT, but only the estimation of profit contributed by ICT capital.

Even so, how does this estimated profit compare to reality? In particular, how would it relate to estimates of excess liquidity? As a reality check, one might look at the number for estimated excess liquidity. The estimates for excess liquidity itself is full of problems. The number presented in the introductory chapter of US$ 600 trillion (Bain & Company, 2012) refers to the total notional value of financial assets. Naastepad & Houghton Budd (2015) give an estimate of financial assets based on the data from the Bank for International Settlements (BIS) which points to around U.S.$ 21 trillion of gross market value. Not all of this is excess liquidity, however, since part of it is still supporting the physical base of the economy. One conservative estimate can be found in Pozsar (2011, Figure 6) who uses global institutional cash pool as a proxy. This is because institutional cash pools have been increasingly used for financial investments (Naastepad & Houghton Budd, 2015). Figure 6 depicts this estimation, showing the rise of global institutional cash pools from around US$ 100 billion in 1990 to nearly U.S.$ 3.8 trillion in 2007.

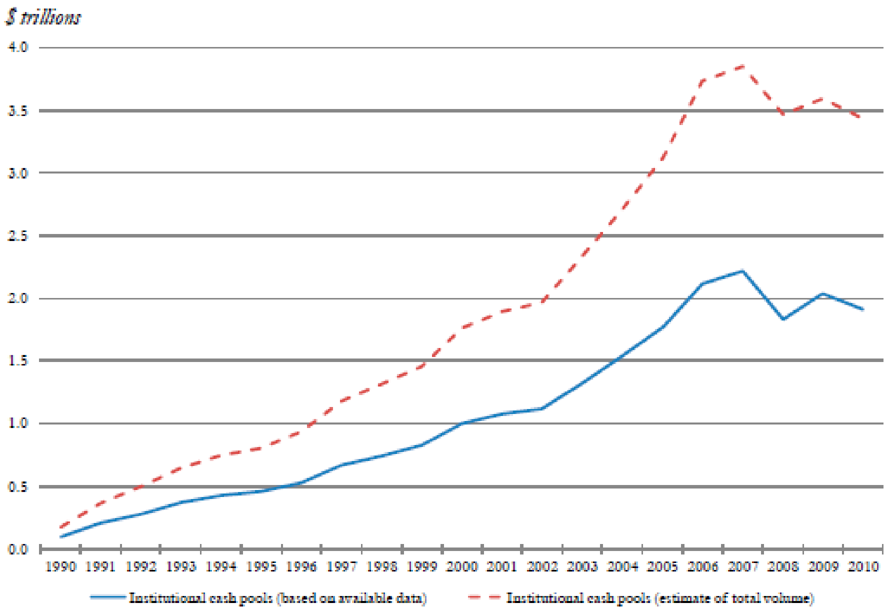

Figure 6: The secular rise of institutional cash pools. Source: Pozsar, 2011

Table 5: Profit estimation in equivalent 2007 U.S.$, year 1990-2007 unless otherwise stated. Source: Author's calculation, World Bank exchange rate database, EU KLEMS database price index

Country	**Year**	**Profit estimation** (in 2007 Trillion U.S.$ equivalent)
Denmark	1990-2007	0.02
Finland	1990-2007	0.10
Sweden	1993-2007	0.01
Germany	1991-2007	0.27
Netherlands	1990-2007	1.28
UK	1990-2007	1.70
US	1990-2007	2.04
Total		5.42

To compare the amount of global institutional cash pools with our estimated profit presented in Table 4, the profit estimation needs to be recalculated to start only from the year 1990. In this way, we will compare the sum of estimated profit with the increase of global institutional cash pools within the same time frame, that is from 1990 to 2007. This estimation is presented in Table 5. The profit share of ICT contribution in the US, if calculated from 1990 only, is US$ 1.6 trillion in 1995 price. That is around U.S.$ 2 trillion in 2007 current price (based on value-added price index in EU KLEMS database), from the U.S. alone. Including the other six countries, using the exchange rate data from the World Bank for the year 2007, adds around US$ 3.4 trillion in 2007 price leading to a total of US$ 5.4 trillion. Globally, the number could be bigger. Certainly not all of this money went to the institutional cash pools although a part of it might, together with the contribution from non-ICT capital and the residual. However, the estimate of profit given here seems to be in the same magnitude with the estimate of excess liquidity by Pozsar, therefore supports the estimation of productivity dividend and profit done in this chapter.

Furthermore, there might be reason to believe that ICT will have increasing impact to productivity dividend. In section 4.2, the argument is made about how ICT might not reach its full potential as a technological revolution yet, as seen from the price trend and investment trend in communication technologies and software. If the unfolding of ICT revolution happens as Brynjolfsson & McAffee (2014) predict, ICT would then be the dominant force in driving productivity gain. This invites the question, what do we do with the dividend resulting from productivity growth? Before attempting to answer this question in Chapter 5, there are two noteworthy trends about the direction of capital allocation in the past few decades; one related to the trend in wages formation and another in the phenomenon of financialization.

4.4.2. On wage share and distribution

This subsection focuses on observing the trend of wage and profit share in the seven countries of our study during the period of ICT revolution. The aim is to give us some ideas regarding how productivity dividend has been distributed in reality. This also helps check the validity of Kaldor's stylized fact on wage share. Furthermore, wage distribution is also looked at, importantly to see whether Marxian hypothesis regarding wage repression is still relevant today.

One channel to allocate productivity dividend is to increase real wages. This way of allocation does not only support subsistence for persons, but also increase their ability to finance their aspirations. The core of Marxian critique of capitalism and technological progress is the possibility of wage repression it can bring. Post-Keynesian analysis also argues that wage repression is one of the cause of the Great Recession, rooted from the error of neoliberal policy.

Figure 7 shows that wage share has been declining almost uniformly in the seven countries, violating Kaldor's stylized fact that stipulates constant labor and capital share over the long run (Kaldor, 1957). On the other hand, capital compensation therefore has been increasing the past four decades. The cause could be capital deepening and the obviation of labor, although Marxists would argue that due to the tendency of the rate of profit to fall, this could not happen. Hence, from a Marxian perspective, the cause is likely wage repression. Either way, the decline in wage share could imply the decrease of persons' ability to meet subsistence and pursue aspirations.

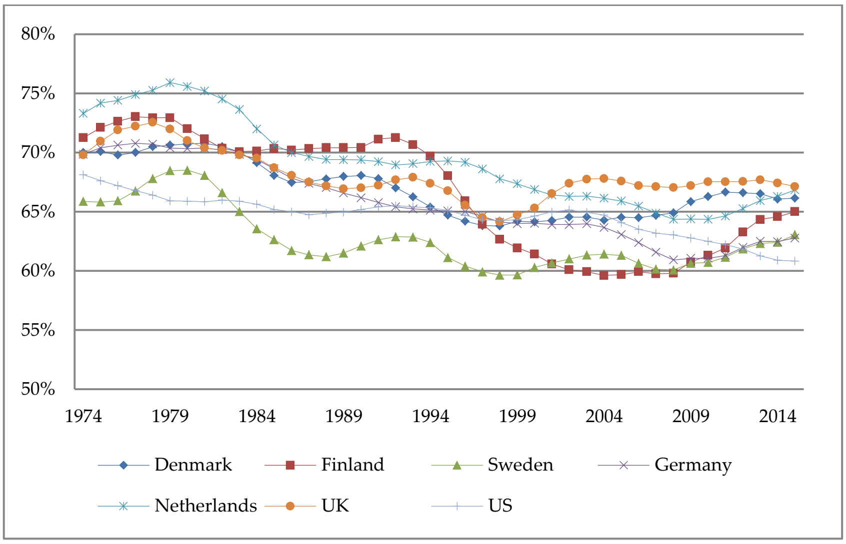

Figure 7: Adjusted wage share, compensation of employee, as percentage of GDP, 5-year moving average. Source: European Commission Annual Macroeconomic Database.

Wage share is only half of the story. It is indeed possible that wage share is declining while the real wage is still increasing if productivity grows at a faster rate[11]. Figure 7 is therefore interesting to give a better picture on wage. The six panels show how average income for top 1% and bottom 90% earners in six of the advanced economies has evolved since 1970. Consistent with Post-Keynesian argument, in the US and the UK, income for the bottom 90% has been declining or stagnating at best. However, in Germany the bottom 90% has been experiencing decline in income over the last decade. Even in Sweden where bottom 90% income is still increasing, the rich already overtook the rest in terms of income growth. Only in Denmark and Netherlands the bottom 90% still experience income growth faster than the rich, although in the Netherlands, the data has not been updated since 2000 so changes might already occurred today.

This observation is important for at least two reasons. First, compared to the rich, it is harder for the middle class and below to finance their aspirations (referring to subsection 3.3.5) or sometimes even to meet subsistence. Growing income for the bottom 90% indicates that their ability to finance those aspirations could be increasing. On the other hand, declining income for the bottom 90% might indicate that wage repression, as warned by the Marxists, is actually happening.

Second, as Palma (2009) points out, the increase in income of the rich tends to go hand in hand with financial deepening. But as the next section will show, financial deepening happens in the seven counties, including in Denmark and the Netherlands where the income of the rich has stagnated. Hence, the problem of financialization does not originate solely from the rich. Part of the increased income of the middle class might go to fiduciary institutions such as investment or pension funds, increasing savings.

[11] This can be seen from the relationship between profit share (ϕ), real wage per hour worked (w), and productivity (λ) where $\phi = 1 - w\lambda^{-1}$. See Storm & Naastepad (2012, p. 14).

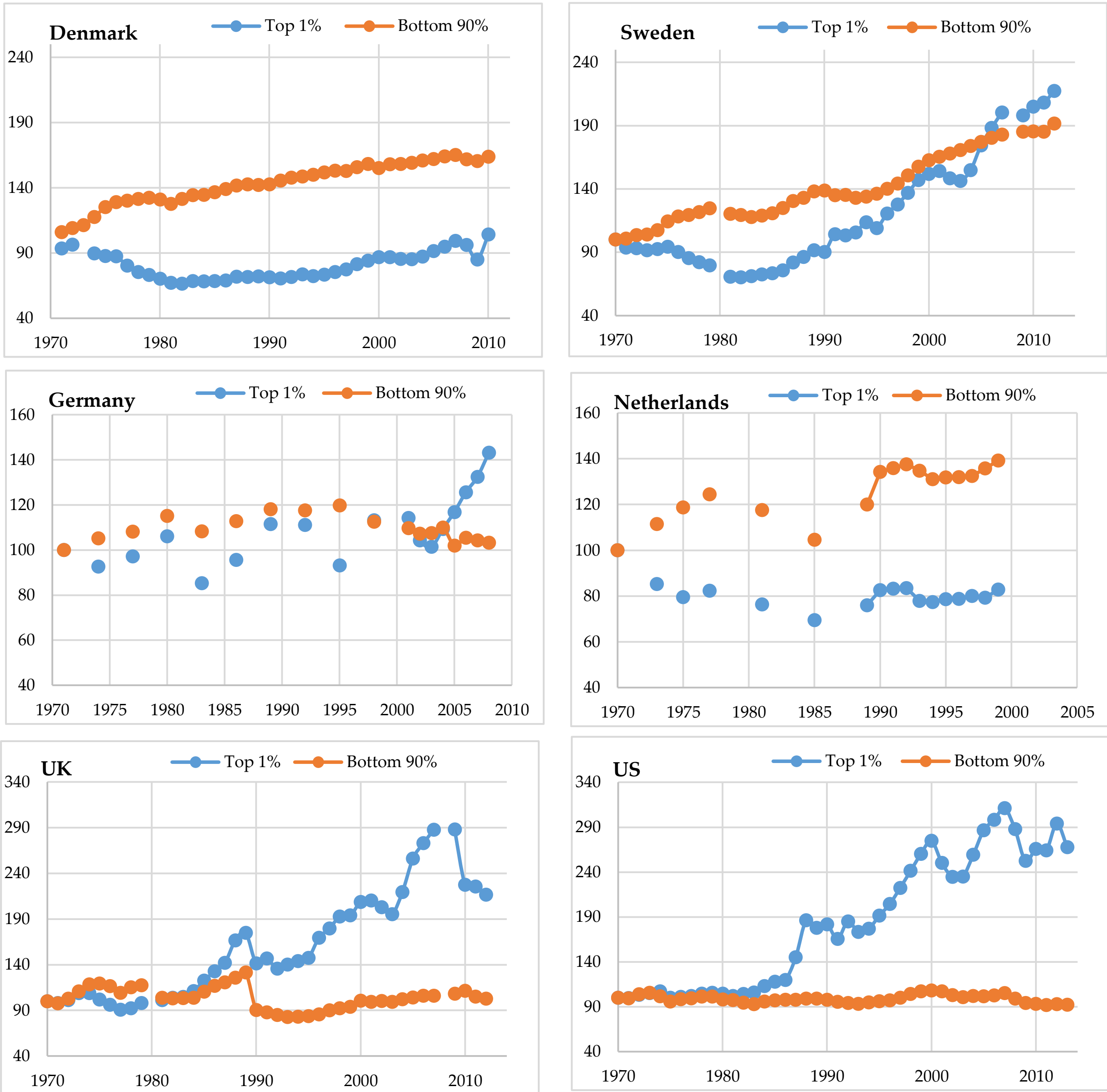

Figure 7: Average income for the Top 1% and Bottom 90%, index, 1970 = 100. Excluding capital gain. Data for Finland not available. Source: The World Top Incomes Database, Alvaredo, Atkinson, Piketty, and Saez and author's calculation. See: http://topincomes.parisschoolofeconomics.eu/.

Figure 8 further supports this through depiction of household net saving as percentage of GDP in the seven countries. In the UK and the US, net saving has been declining, implying that it is getting harder for the bottom 90% whose wage has stagnated to save. On the other hand, net saving has been on the rise in the Nordic countries and the Netherlands since the late 1980s, only to drop post financial crisis. It appears that although income has been on the rise for the bottom 90%, much of this income becomes savings that got affected during the financial crisis.

Figure 8: Household net saving as percentage of GDP, 5-year moving average. Source: OECD National Accounts.

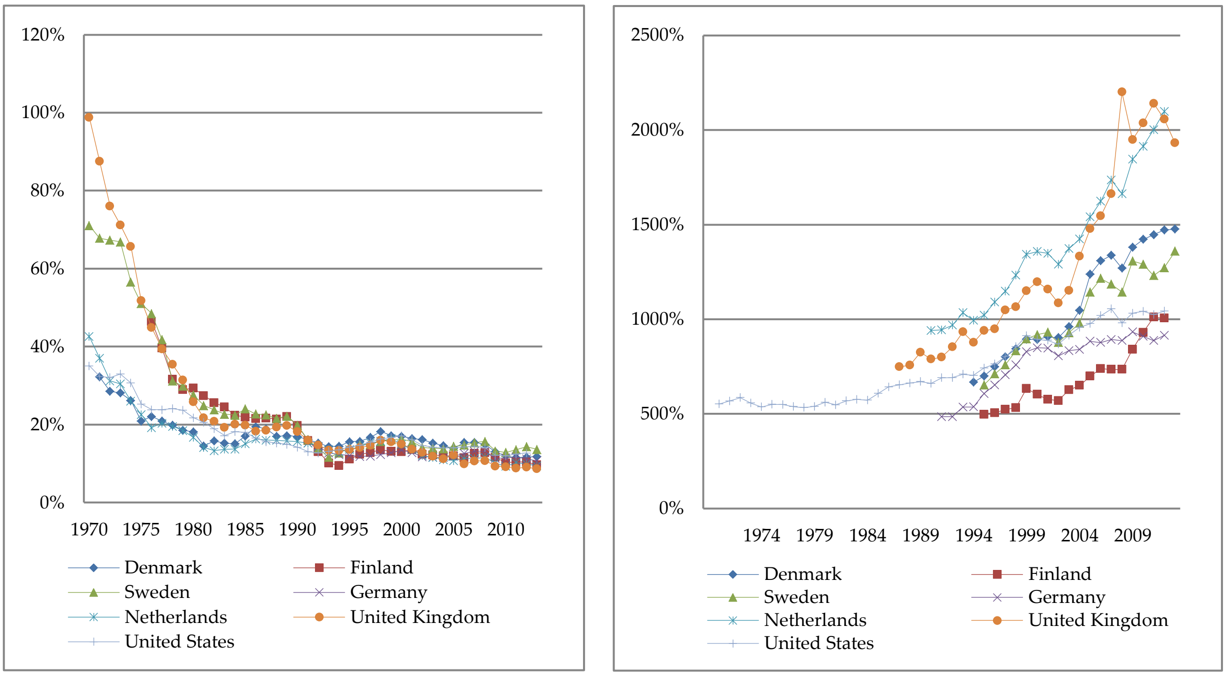

Figure 9: Private investment as percentage of GDP (left) and total financial asset in all sector (right). Source: OECD statistical database and author's calculation.

4.4.3. On financialization

The second trend on capital allocation concerns the speculative use of capital towards the formation of financial asset. Palma (2009) shows how financial deepening occur in the US by observing stagnating private investment compared to increasing financial asset in the period of neoliberalization (that is since Reagan's administration). Figure 9 compares the similar observation in other European countries as well, and the result aligns with Palma's observation. The left panel shows that private investment in all countries observed has been declining exponentially even since 1970 and stagnating, even slightly declining, since mid-1980s. The right panel on the contrary shows exponential increase of total financial assets since the 1980s. Both charts are in percentage with respect to GDP.

Directly comparing the two graphs, however, is misleading because annual private investment shown is in fact the *flow* of investment while total financial asset reflects the *stock* of asset. But Palma's conclusion is not wrong if we examine the shape of the curves. In the 1970s, the period of stagflation caused private investment to decline significantly, but there has been no sharp increase in the stock of financial asset as well. Since the 1980s, private investment have been declining linearly. It can be inferred therefore that the stock of capital resulted from the investment has been increasing at a decreasing rate. This is in contrast with the stock of financial asset that is clearly shown to be increasing at an increasing rate, implying increasing flow of financial asset formation.

This observation therefore supports the hypothesis that capital has been increasingly allocated towards the formation of financial asset rather than productive capital. Perez (2009) argues that this phenomenon is caused by the availability of financial innovation, more so after the dot-com IPO boom in the late 1990s, and the lack of viable investment that can match investors' expectation set by the previous dot-com bubble. Palley (2007) on the other hand points to easy access to financial market and the result of neoliberal policy error. Indeed, easy access to financial market and the burgeoning of financial innovation might be mutually reinforcing. Furthermore, financial innovation is also supported by policies that set free the financial market, especially in the case of the shadow banking system. Viewed in this way, neo-Schumpeterian and Post-Keynesian diagnosis of the financial crisis seem to be compatible and even complementary.

4.5. Concluding remarks

To sum up, several remarks can be drawn from the discussion in this chapter. First, empirical estimation of ICT contribution to productivity in section 4.3 corroborates economic perspectives laid out in Chapter 3 that technological revolution would result in productivity growth. Moreover, some of these economic theories suggest that technological revolution could generates savings (neoclassical), profits (Schumpeter), or surplus value (Marx). This is reflected in the estimation of productivity dividend conducted in section 4.4. Depending on the position we take, the estimated profit portion of this productivity dividend can be seen as savings, profits, or surplus value.

Second, the direction of capital allocation observed in the seven countries have indicated the tendency of wage stagnation for the bottom 90% and increased financialization. Analysis conducted in subsection 4.4.2 indicates that Marxian analysis presented in Chapter 3 on wage repression might, to a certain extent, help explain the. Meanwhile, ICT revolution is still unfolding and can potentially reach bigger impact than it already does today. Hence, the increase in financialization could possibly be explained by the neo-Schumpeterian theory of phases in technological revolution, particularly the argument that ICT revolution is still in the 'frenzy' phase whereby capital allocation is increasingly driven towards speculation (following Perez, 2002)

The empirical result, however, is not able to tell the extent to which capital is allocated as prescribed by Aristotelian perspective in subsection 3.3.5. This would require further research, in particular to generate the appropriate measurement. Furthermore, this chapter does not satisfactorily answer whether the use of this productivity dividend has led to societal benefit. To do so, further theoretical work is needed, to first define societal benefit before suggesting how technological revolution would be able to create overall societal benefit. This will be the concern of the next chapter.

Chapter 5

Linking technological revolution and the allocation of productivity dividend to societal benefit

All men by nature desire to know
Aristotle, Metaphysics

5.1. Introduction

Empirical observation presented in Chapter 4 shows that ICT probably has not reached its full potential as a technological revolution. Nevertheless, it has already some impact to productivity growth. Should ICT revolution continues to unfold as predicted by scholars such as Perez (2002, 2009) or Brynjolfsson & McAfee (2014), this impact to productivity growth would increase and could become the dominant factor. Productivity and GDP growth over the long run, however, has been accompanied with declining private investment in the seven countries studied, as shown in subsection 4.4.3. At the same time, the stock of financial asset has been increasing at an increasing rate. On the other hand, wage share have been declining with widening income gap between the top 1% earners and the bottom 90%, except in Denmark and the Netherlands as shown in subsection 4.4.2.

These observations point to the increasing allocation of capital, some of which originated from the productivity dividend contributed by ICT as computed in subsection 4.4.1, into speculative purposes via the use of financial assets. This has been argued as the cause of 2008 financial crisis (for instance Palley, 2012). A question therefore arises regarding how this productivity dividend arising from technological revolution can be allocated for purposes that lead to overall societal benefit.

This chapter attempts to answer the conditions under which productivity growth resulting from technological revolution can be linked with overall societal benefit by taking lessons from various economic perspectives presented in Chapter 3. First, social benefit and the conditions leading to it are defined as how different economic perspectives see it. Then, lessons are drawn from these insights, including the insights mainly from Chapter 3 to examine the link between social benefit and technological revolution.

5.2. Perspectives on societal/social benefit

Before setting out to explore the conditions and criteria for societal benefit, a question must be asked: what is societal benefit? To answer this question, it is useful to look once more at the economic perspectives introduced in Chapter 3, expanding it further to link productivity growth with social benefit.

5.2.1. Neoclassical perspective on social benefit

First of all, let us consider the neoclassical position regarding societal benefit. How can neoclassical perspective about productivity growth be linked to social benefit? As mentioned in section 3.3.1, productivity growth that obviates labor can theoretically reduce output prices under perfect competition. This benefit is then passed on to the consumers.

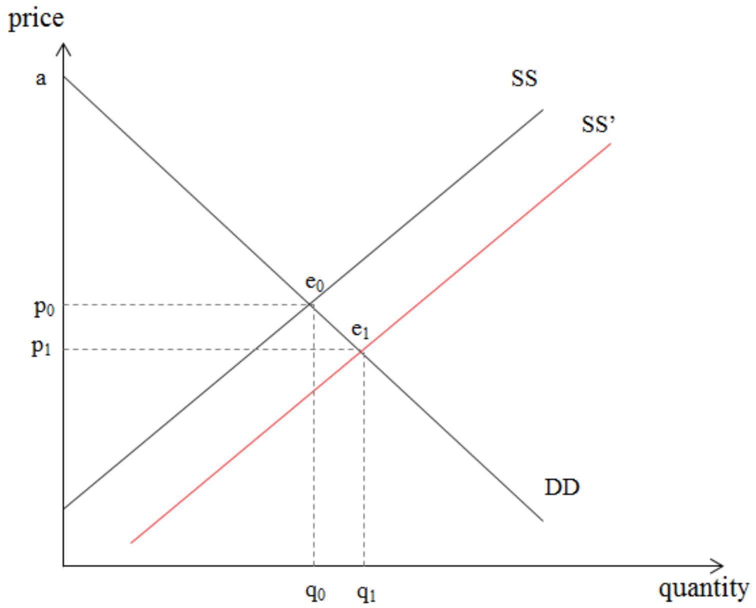

Figure 10: Consumer and producer surplus

To better illustrate this, a simple example can be used. Figure 10 shows a hypothetical market for a single good under perfect competition. The market is initially at equilibrium point e_0, where supply curve SS and demand curve DD meet. At the equilibrium, the quantity produced is q_0 at the price of p_0. The consumer surplus seen as the triangular area between DD and SS curves to the left of equilibrium e_0 and above p_0. The producer surplus seen as the triangular area between DD and SS curves to the left of equilibrium e_0 and below p_0. This area can be seen as surplus in money terms: for the consumers it represents the money that would otherwise be spent on purchasing the goods at higher price (their willingness to pay) while for producers it represents the benefit they gain for selling the goods at the price higher than they are willing to sell.

Due to technological shock, productivity increases in the production of this good, leading to expansion of production. Under the assumption of perfect competition, SS curve shifts to the right, represented by the SS' curve. The new equilibrium is the point e_1, with higher quantity being produced at q_1 and lower price of p_1. As the result, consumer surplus increases, as shown by larger triangular area below the DD curve. This means consumers now have more money; the result of more savings made possible by productivity growth. This extra money can be spent in other markets, increasing demand for other goods. Alternatively, if the money is not used to spend more in other markets, it increases the supply of savings, assuming the existence of loanable funds market, which increases liquidity (for instance, see Bernanke 2005 on global saving glut).

Societal benefit, in this framework, is therefore the sum of producers and consumers surplus that need to be maximized. Capital should be allocated for purposes that maximize these surpluses. According to conventional neoclassical theory, this mechanism is ensured as long as firms strive to maximize financial returns.

This framework has been a subject of contention due to the need for restrictive assumptions (among others about perfect competition and constant return to scale) for the theory to work, and these assumptions seem to appear out of theoretical necessity rather than reflecting reality (Kaldor, 1972, p. 1238-1239). Moreover, neoclassical economics disregard entirely the issue of distribution, by simply assuming that wealth that is concentrated to those on the left side of the equilibrium point (that is people who enjoy the surplus) would 'trickle-down' (Houghton Budd, Naastepad, & van Beers, 2015). However, there has been no conclusive evidence that trickle-down actually occurs (Basu & Mallick, 2007).

5.2.2. Schumpeter's and Schumpeterian view

Schumpeter's emphasis, in his works, had been on the role of entrepreneurs as the disequilibrating force in the economy through innovation. Entrepreneurs create temporary monopoly in the economy and thus obtain profit from this monopoly position. It seems that in his view, economic development through entrepreneurial actions is aligned with social benefit. In particular, 'redirection' of wealth and income from the wealthy to the less wealthy due to entrepreneurial activities that gain profits because it will be the economically less advantaged, and not the wealthy, who would be driven to take entrepreneurial actions in order to increase their wealth (McDaniel, 2011).

From this viewpoint, the redirection of wealth is a dynamic process that happens *naturally* as human beings strive to increase their material well-being. Entrepreneurship, in turn, flourishes when individuals are given the freedom to pursue economic activities (Nyström , 2008). Nevertheless, Schumpeter himself did not seem to think that 'rational bureaucracy' is less capable than free market competition to spur entrepreneurship (Gintis, 1991). But the viability of market or state to support entrepreneurship is not the main point of the discussion here.

The implication of this insight is that there is no need to think about the allocation of productivity dividend or capital freed by technological revolution (then again, the conception of freed capital does not exist in Schumpeter's system). It belongs rightly to the entrepreneur who earns it through his/her efforts. Entrepreneurial activities occur because people are driven to increase their wealth (McDaniels, 2011). One question might arise: how can Schumpeter's entrepreneurs obtain the capital required for their activities? In this regard, it is worthy to note that Schumpeter put huge emphasis on the role of finance, in particular the services provided by financial intermediaries which include mobilize savings, evaluating projects, managing risk, and facilitating transactions (King & Levine, 1993). Productivity dividend can therefore be allocated to the entrepreneurs through, for instance, credit creation by the banks as financial intermediaries. In subsection 3.3.2, we elaborate Perez's (2002) view on how this role of finance could be distorted depending on the phase of technological revolution. In particular, during 'frenzy' phase in the nascent stage of a technological revolution, speculative behaviour tends to dominate. Financial intermediaries also increasingly support this speculative behaviour through financial innovations. However, as also stated in subsection 3.3.2, within the Schumpeterian perspective, this phenomenon is temporary as the technological revolution enters the 'synergy' phase.

5.2.3. Marx's view

Marx recognized that productivity growth via technological innovation leads to 'relative surplus value', as mentioned in subsection 3.3.3. However, for Marx, technological innovation comes out of necessity due to the tendency for the rate of profit to fall so that the capitalists can maintain their profit rate (West, 1968). Since technological innovation is mostly labor-saving, the result is the creation of 'the industrial reserve army'.

Marx's view is therefore different from neoclassical perspective that suggests the benefit of productivity growth gets passed down to the consumers. On the other hand, Marx is not too different than Schumpeter in his view that the rich (the capitalists) do not want change. However, Marx in this case has equated the role of the entrepreneur with the capitalists, while Schumpeter's entrepreneurs do not necessarily own the capital themselves.

Since in Marx's theoretical system there is no entrepreneurs than can redirect wealth and income, it follows that productivity growth cannot be linked with social benefit under capitalist paradigm. Workers who are displaced by machines are unable to meet their material subsistence as the result. On the other hand, workers that remain to be employed are dictated by the division of labor in the capitalists' factory, and are only 'sustaining life by stunting it' (West, 1969, p. 3-5).

Indeed, for Marx, economic activity should be in the service of human beings, in order to meet natural needs (Sayers, 2003). Hence, social benefit firstly entails the fulfilment of material needs for human beings. But it is not enough for Marx to sustain a 'stunted life' through work that is externally forced and becomes mere means to fulfilling material needs. Instead, through work, human development is something we also strive for (*ibid.*). While for Marx artistic work is the highest form of creative activity, Marx also recognizes this quality in economic work, provided that it is not dominated by immediate desire for immediate consumption. Marx distinguished the creative activities of human beings from that of animals (1975, p. 329):

> "They build nests and dwelling, like the bee, the beaver, the ant, etc. But they produce only their own immediate needs or those of their young; they produce only when immediate physical need compels them to do so, while man produces even when he is free from physical need and truly produces only in freedom from such need… hence, man also produces in accordance with the laws of beauty."

Hence, there are two facets of social benefit from this perspective: one pertaining to the fulfilment of material needs and the other pertaining to the ability to do and achieve "attractive work, the individual's self-realization" (*Grundrisse*, 1973, p. 611). While the first arises out of necessity, the second requires the freedom from the oppression of capitalism that society needs to bring back under human control.

5.2.4. Keynes's view

For Keynes, the purpose of economic life, and thus the growth of productivity and material wealth brought about by technological progress, is to enable people to lead 'the good life' (Skidelsky, 2009, p. 133). 'The good life', in this sense, is not what makes people better off but what makes them 'good' (*ibid.*). This could come, among others, from having the time for the enjoyment of beautiful objects and for friendship (Moore, 1922 as cited in Chicks, 2013). Keynes thinks that people are able to lead a 'good life' once they have achieved a required level of material needs to live comfortably.

Skidelsky (2009, p. 136-138) points out that Keynes was influenced by the philosopher G.E. Moore's utilitarianism that seeks to maximize goodness instead of pleasure. This is in contract to Benthamite utilitarianism that focuses on maximizing pleasure inherent in the neoclassical perspective. For Keynes, it is therefore necessary to distinguish what is good and what is pleasurable whereby trade-off between the two might be necessary.

It follows that there is a limit to material growth, up to the point that material needs have been fulfilled[12] (Skidelsky & Skidelsky, 2012). It is in this context social benefit in Keynes's view can be understood. When 'sufficiency of productive capital' in order to meet our material needs can be achieved, pursuit of material wealth should be supplanted with the pursuit of 'the good life' even if it leads to an economy with zero growth (Chick, 2013). As Keynes puts it in *The Economic Possibilities for our Grandchildren* (1930):

[12] If we push aside for a while the limits to growth due to natural resources endowment constraint.

> "The strenuous purposeful money-makers may carry all of us along with them into the lap of economic abundance. But it will be those peoples, who can keep alive, and cultivate into a fuller perfection, the art of life itself and do not sell themselves for the means of life, who will be able to enjoy the abundance when it comes"

5.2.5. Aristotelian perspective on social benefit

Aristotle emphasizes on the limited need of wealth although admitting its necessity (*Politics* vol. I, Chapter VIII). In section 3.3.5, we pointed out Aristotle's distinction of use value and exchange value, in which a particular good (for example a pair of shoes) has use value but can also be exchanged with other good, therefore it also has exchange value. Aristotle further points out the use of money to simplify the process of barter (*ibid.*, Chapter IX).

Pack (2010, p. 10) argues that although Aristotle suggested that things are made commensurable by money (Aristotle, *Nicomachean Ethics* Book V), he did not imply that money in itself is the source commensurability. Rather, it is human need that is the source of commensurability. This points to the necessary wealth-getting, which for Aristotle is a part of the art of managing a household (*Politics*, vol. I, Chapter IX), that is based on meeting the material needs of human beings. Aristotle distinguishes this necessary wealth-getting with the unnecessary one, the art of wealth-getting that becomes an end itself (*ibid.*).

As also pointed out in section 3.3.5, the primacy for Aristotle lies in human beings' purpose, that is happiness, by exercising virtue, bringing out the best in oneself and in the community. But this requires the development of the mind and character (Pack, 2010, p. 31-32). Hence, social benefit in Aristotelian perspective cannot be derived only from consuming more or getting more wealth. Only to the extent that material subsistence is not met, increased wealth can still be linked with social benefit.

5.2.6. Human capacity as the source and destination of capital – and implications for freedom

From the discussion in previous subsections regarding social benefit, with the risk of oversimplification, two emerging themes can be identified. The first, from neoclassical and Schumpeterian perspectives, require the increase in material wealth. The second, based on the thoughts of Marx, Keynes, and Aristotle, points to both the material and immaterial needs of human beings with. When only material wealth is considered as the criterion for social benefit, the allocation of productivity dividend resulting from technological revolution for purposes that maximize profit might be justifiable. But when immaterial needs are also considered, especially when material needs are seen to have limits, then the question of the allocation of productivity dividend remains. As stated in subsection 4.4.1, capital that is needed for meeting the material needs of people is not free since, following Wilken's (1992) distinction of the sources of capital explained in section 3.2, it arises from the withholding of necessary income formation. Aristotle, as pointed out in section 5.2.4, saw that material needs are limited. This is also aligned with Keynes's view pointed out in subsection 5.2.4 that we need a required level of material needs to live comfortably. It is also the case for Marx who saw material needs as necessary but inadequate for human beings (refer to section 5.2.3). Productivity dividend should first be spent to meet the material needs of people. What is then left of this productivity dividend, if any, is freed capital. This subsection attempts to explore the allocation of this freed capital, by first tracing its origin and then proposing its destination.

The economic perspectives presented in this thesis do not oppose the notion that innovation and technological progress could lead to the increase in material wealth through productivity gain. But where does innovation or technological progress come from? Conventional neoclassical theory does not attach importance to this question, letting technological progress to come exogenously (the so-called old growth theory, see Solow 1957). Within contemporary neoclassical tradition, in particular through the new growth theory, innovation is linked with investment in what is called 'human capital' (Lucas, 1988). One could argue, therefore, that neoclassical theory implicitly acknowledges the human mind, since what is the origin of innovation other than human ingenuity? However, within the neoclassical framework, it is treated as just a factor of production.

Schumpeter is more explicit in hailing human's ingenuity as the source of innovation. Yet, for Schumpeter, the main motivation for the entrepreneur to innovate is in order to achieve material wealth. This is despite his acknowledgment that there is an element of the '"joy of creating"' and the "exercise of ingenuity"' in one's innovative activities (Schumpeter, [1911] 2008, p. 93). Marx, on the other hand, is more sceptical about technological progress. But he himself had recognized the value of creativity in economic activities (Sayers, 2003).

The argument to be made here is that freed capital that results from technological revolution therefore also has its very origin in the human mind. Wilken (1992, p. 220) clearly sees this by pointing out the first source of capital formation as "appearing out of consciousness". In other words, human's creative capacity is the source of capital in this sense. What is the use of capital generated in this way?

When capital is released, the prescription regarding its destination can be found in different economic perspectives. Neoclassical theory suggests the destination of capital for purposes that maximize financial returns which, according to neoclassical theory, is the means or *intermediate goal* towards its *ultimate goal* of economic growth. Schumpeter recognizes the function of capital to finance the activities done by entrepreneurs through the role of bankers (King & Levine, 1993, p, 735). However, his focus is on the financing of physical capital itself with the goal of expanding material wealth.

Wilken (1992, pp. 266-267), on the other hand, argues that freed capital originates from the human mind (through the work of the *Geistesleben*) supposedly be used to fund the *Geistesleben* as well. In other words, freed capital can be used to finance the development of human's creative capacity. This is consistent with the Aristotelian perspective that prescribes the need for the development of the mind

(Pack, 2010, pp. 31-32). This therefore departs from neoclassical or Schumpeterian ideas in the sense that it is not material gain *per se* that we are striving for, but also the development of creative capacity.

Furthermore, Houghton Budd (2011), as pointed out in subsection 3.3.5, suggests that ‘surplus’ that is no longer needed for subsistence and can be used to finance people’s aspiration. This aspiration is “to ‘become something’ or to fulfill a dream, rather than spend their working lives in a job earning money for the weekend or retirement” (*ibid.*, p. 145). Human aspiration points to the need of human beings beyond material fulfillment. Naastepad & Houghton Budd (2015) argue that beyond material needs, human beings strive for “the development of higher capacities – including morality, creativity, and a self-actualization that includes responsibility for others”. From this angle, the development of creative capacity can therefore be seen as the immaterial need of human beings, something that we also strive for.

Hence, if freed capital is seen as originating from the human’s mind, then it is also possible that the capital resulting from it is used to finance the further development of human’s mind, i.e. human capacity is both the source and destination of capital. This leads to the need to expand the understanding of capital to include its role as the financier of material needs and the financier or immaterial needs: the dual role of capital (Naastepad & Houghton Budd, 2015). However, this cannot be done unless we reject the standpoint in which pleasure gained from the fulfilment of desire in the material sense is the only important thing.

Another point to be made here is related to the concept of freedom. In the neoclassical framework, the act of maximizing utilities and profits done by consumers and producers entail the exercise of choice. Choice, in turn, requires the freedom to choose. Friedman (1970), in his influential essay about the responsibility of corporations (that, is to maximize profits), argues that preventing corporations to maximize their profits would amount to violating their freedom to choose. Freedom *to* would therefore need to be supported by freedom *from,* among others from restricting government regulations.

This neoclassical argument is of course agreeable if we were to accept that societal benefit is equivalent to the fulfilment of desire in terms of material goods, that is the first kind of societal benefit described in the previous section. Implicitly, however, this neoclassical proposition has restricted the notion of freedom *to*, limited to the boundaries of material wealth. Certainly, this is rooted from the assumption of *homo economicus*. If we were to drop the assumption of *homo economicus* and accept that societal benefit concerns also about the realizations of human beings’ purpose, then this neoclassical logic would violate the very notion of freedom *to*. This is an example of how mental conceptions could shape the direction of capital allocation and the way we use technological progress.

Following the second conception of societal benefit requires an expansion of the notion of freedom. This notion of freedom therefore relies on persons to first choose what they value. It is certainly not inconceivable that a person would choose the accumulation of material wealth as their purpose. From Aristotle, however, freedom *to* is also underlined by exercising virtue.

This expanded notion of freedom *to* also needs to be supported in counterpart by the negative freedom *from*. For Friedman this kind of freedom should be interpreted as freedom *from* the preventing hurdles, regulatory or otherwise, to maximize profits. Accordingly, the second notion of freedom *from* can be seen as the freedom *from* the obstacles preventing persons to do develop their capabilities. What could be these obstacles? Following Keynes, these obstacles could be the center of the economic problem; that is the fulfilment of human beings' basic material needs. Freedom *to* therefore needs to be supported by the freedom from the obstacles to meet one's subsistence.

5.3. Two conditions for linking technological revolution with societal benefit

From this perspectives of social benefit in section 5.2, one can draw two kinds of societal benefit that can be linked with productivity growth. The first relates to the availability of goods (and services) for persons to consume. The second kind of societal benefit concerns the immaterial needs of human beings, which include human capacities. This thesis argues for the need of the following two conditions leads to be met in order to link technological revolution with societal benefit:

(1) persons are not denied the ability to meet subsistence, and

(2) persons are able to develop capacities in the way they value.

The first condition implies the role of capital as the enabler for human beings to meet their basic needs, including material needs such as food, clothing, and housing. This is the necessary, but not sufficient, condition for societal benefit. Technological progress and revolution can then directly support this first condition by reducing the cost of production.

In prescribing the reduction of costs, one might draw the connection with neoclassical logic whereby productivity growth reduces costs that are being passed down to consumers. However, within the neoclassical conception, cost reduction leads to more production and hence more consumption. On the other hand, the Aristotelian view states that that there is limit to material needs. The purpose of cost reduction is therefore to ensure that the material needs of persons can be met with less and less money.

The second condition for societal benefit is related to the use of capital to finance the development of human mind and character. One possible solution is through the reduction of working hours to enable people pursuing their aspirations without the concern of having to meet subsistence. Following Wilken (1992), freed capital hence should be allocated to develop human's mind.. As Bertrand Russell (1932) put it in his essay *In Praise of Idleness*:

> "…every person possessed of scientific curiosity will be able to indulge it, and every painter will be able to paint without starving, however excellent his pictures may be. Young writers will not be obliged to draw attention to themselves by sensational pot-boilers, with a view to acquiring the economic independence needed for monumental works, for which, when the time at last comes, they will have lost the taste and capacity. Men who, in their professional work, have become interested in some phase of economics or government, will be able to develop their ideas without the academic detachment that makes the work of university economists often seem lacking in

reality. Medical men will have the time to learn about the progress of medicine, teachers will not be exasperatedly struggling to teach by routine methods things which they learnt in their youth, which may, in the interval, have been proved to be untrue."

Finally, it might be interesting to revisit Harvey's seven activity spheres mentioned in Chapter 2, which we reproduce in Figure 11 for easy reference. The first condition suggests the use of productivity dividend to meet human beings' material needs. In the framework of Harvey, this could be seen as the allocation of capital towards the spheres of production, reproduction (that represents consumption), and relations to nature (with regards to managing the endowment of natural resources to sustain production and consumption of goods).

The second condition can be related to other spheres. Looking at Wilken's idea from Harvey's lens, human's creativity is embedded within the activities in the sphere of mental conception, which is then embodied in technological progress. In parallel, it could be said that Wilken's proposition would mean, for Harvey, the allocation of freed capital to fund activities within the sphere of mental conception. But Wilken (1992, p. 223) also mentions the possibility to spend capital in social life and in government. This would correspond to Harvey's sphere of social relations and institutional arrangements.

All these, however, requires effectively letting go of the obsession with growth in the conventional sense. Consequently, it could only happen if we accept the two roles of capital in physical economy and human capacities (Naastepad and Houghton Budd, 2015). In addition, this also requires the replacement of *homo economicus*, that always act based on personal gain, as the central agent within the seven activity spheres.

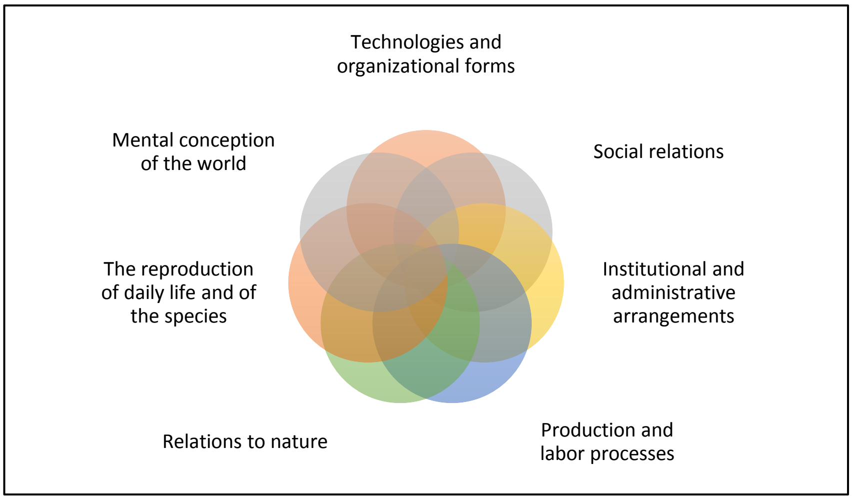

Figure 11: The seven activity spheres of Harvey (2010)

Chapter 6

Conclusions, implications, and reflections

Of course this is utopian! But so what! We cannot afford not to be
David Harvey, The Enigma of Capital

6.1. Conclusions

This thesis set out to answer the main question of "how and under what conditions would technological revolution create overall societal benefit?" To answer the question, we began with the seven activity spheres by Harvey (2010), focusing on the spheres of mental conceptions and technologies. Regarding 'mental conceptions of the world', five economic perspectives were explored for their views on the relationship between technological progress and capital, and on the role of technology and capital in society.

The various economic perspectives explored in this thesis seem to agree that technological revolution generates savings (neoclassical), profits (Schumpeter), or surplus value (Marx), and that this poses a problem before society: how to use these savings?

Neoclassical theory suggests that technological revolution leads to reduction of cost which is passed on (through lower consumer prices) to consumers, resulting in extra savings that can be made. This surplus would return to the economy for the purpose of maximizing utilities, in the form of investment in production for future consumption.

Schumpeterian perspective argues that innovation that creates technological progress results in temporary monopoly, yielding profits for the entrepreneurs. During the course of technological revolution, capital allocation could become increasingly irrational, leading to the boom and bust cycle especially in the financial sphere.

Marxists argue that technological progress creates relative surplus value appropriated by the capitalist class. The relentless competition in the capitalist system forces capitalists to use this surplus to reduce costs of production through labour-saving technological progress. This leads to the class of repressed labor who are unable to meet their subsistence, or at best are only able to lead the 'stunted life' by doing work dictated by the command of the capitalists. This is particularly apparent through the division of labor.

The Keynesian argument is that productivity growth through technological revolution alone is inadequate to sustain economic growth. Absent effective demand, capital allocation can be 'misdirected'. Furthermore, drawing from Keynes himself, there is a limit to growth of material wealth since it is but a means to enable people to pursue 'the good life'. Past a point whereby a certain level of material comfort is ensured, blind pursuit of material wealth can no longer be justified.

Aristotelian perspective also comes from the starting point that there is a limit to material needs. More than that, human beings have higher (immaterial) goals in life that can be achieved through the development of mind and character.

The empirical observation from seven advanced countries over the course of ICT revolution since 1970 revealed the potential impact of ICT to productivity growth and productivity dividend. However, ICT revolution might have not reached its full potential yet, upon which larger impact to productivity dividend can be expected. This productivity dividend can be distributed as wages, profits, or taxes. Ignoring taxes, the evidence suggests that during the past four decades wage share has been declining, implying the increasing of profit share. This gives us a clue that the allocation of productivity dividend might be increasingly skewed to profit. Seen from the perspective of Marx, this could suggest the existence of wage repression.

Upon seeing the potential impact of ICT revolution, its consequence to societal benefit is explored by invoking the economic theories discussed earlier. It appears that standard economic framework found in the neoclassical theory, by focusing solely on material gains, has dismissed the immaterial needs of human beings. Schumpeterian perspective, also shows the same tendency towards material wealth as its focus. Furthermore, the argument of freedom to pursue material wealth advanced by Friedman (1970) was found to be limiting the freedom of human beings.

On the other hand, perspectives from Marx, Keynes, and Aristotelian economics adduce to the notion of social benefit and freedom. by incorporating people's immaterial needs. Hence, seen from these perspectives, the fulfilment of material needs is only the first condition leading to social benefit. However, after these needs are fulfilled, social benefit requires also the fulfilment of human beings' immaterial needs.

Importantly, the assertion that human's material needs are limited makes possible the existence of freed capital – the capital that is no longer needed to finance human beings' material needs. By tracing the source of capital, the creative capacity of human beings was identified as the source of this freed capital (Wilken, 1992). The counterpart of this freed capital is proposed to be the immaterial needs of human beings. In particular, the development of human mind is seen as something worth striving for.

This thesis concluded that for technological revolution to create overall societal benefit, two conditions need to be met. The first condition relates to the fulfilment of people's material needs.

Productivity dividend arising from technological revolution hence needs to first be allocated to ensure the fulfilment of this need. What is left after this allocation is the freed capital. The second condition follows the allocation of this freed capital to finance the development of capacities, one possibility includes the development of creative capacity as proposed by Wilken.

6.2. Policy implications

The theoretical and empirical work done in this thesis can lead to several implications for policymaking. In particular, if the two conditions prescribing the fulfilment of material and material needs are pursued, policy agenda can help set into motion the mobilization of productivity dividend resulting from technological revolution. This is especially relevant today with the ongoing rise of smart machines within the ICT revolution. The policy agenda set by governments can influence the economic and cultural context within the society.

First, the need to consider both material and immaterial requires us to let go of our obsession on economic growth, which is commonly measured by Gross Domestic Product (GDP). By only measuring a country's welfare through GDP, it is implicitly assumed that human beings strive for only material wealth. Furthermore, this indicator is an aggregated one, thereby disregarding the effect of wealth distribution, making it possible that in countries with high GDP per capita, there are people struggling to meet material needs. Therefore, the context of economic policymaking need to expand from the sole focus on material wealth to include aspects of human development and reconsider the aggregation level of any measurement.

Second, the first condition proposed in Chapter 5 also suggests that productivity dividend should first be spent for meeting the subsistence of human beings which implies a division based on needs. This could be done in legal terms, by ensuring the rights of individual citizen to subsistence. The protection of this right to subsistence could be the first step to enabling citizens to pursue higher material needs. The money needed for this could come from taxation as a means of redistributing productivity dividend from technological revolution. As this thesis is being written, the government in the Dutch city of Utrecht is about to start a social experiment to provide citizens with universal basic income[13]. It will be interesting to see how this experiment pans out to evaluate the feasibility of our proposal here.

Finally, the second proposal of wealth redistribution might seem ludicrous when coming from the perspective of standard economic theory. Indeed, the two conditions for societal benefit proposed in this thesis would not be compatible with neoclassical framework. In section 2.1 of this thesis, we mentioned how Harvey criticizes the knowledge structure of economics as dysfunctional (2010, p. 239). Here, Harvey refers to the prevalence of mainstream economic theory in the world today.

[13] See http://www.independent.co.uk/news/world/europe/dutch-city-of-utrecht-to-experiment-with-a-universal-unconditional-income-10345595.html

Furthermore, the underlying assumption of *homo economicus*, suggesting that human beings are self-interested and wealth maximizers, seems to have ingrained within our culture today. This is reflected from the dominance of this idea in classrooms, from the basic economic course taught in secondary school up to many economics or business courses in colleges. Harvey recognizes this as he wonders if "the shifts in mental conceptions can change the world" (*ibid.*, p. 235). The policy implication here is that the governments, through public schools, need to reconsider the teaching of economics to allow for other economic perspectives to be heard.

6.3. Contributions and limitations

This thesis has used theoretical and empirical work to examine the impact of technological revolution to productivity growth and its relation to capital. The theoretical part has explored different economic perspectives ('mental conceptions' per Harvey) regarding how capital should be allocated. Learning from these perspectives, two conditions have been proposed as the criteria for technological revolution to create overall societal benefit. On the other hand, the empirical part contributed to the estimation of productivity dividend resulting from ICT revolution in seven developed countries and some indications towards the allocation of this productivity dividend.

There are several limitations to this research on the theoretical side. First, mental conceptions here are assumed to be economic theories, while there are other forms of mental conceptions ingrained in the society, such as sociology. Furthermore, the economic theories used are limited to the five perspectives, omitting the contributions from, among others, Adam Smith. Even so, these five perspectives are already by themselves rich and complex, which cannot be captured entirely by this thesis.

Another major limitation is that it is evident from the discussion in Chapter 5 that economics and ethics are deeply connected. However, ethical perspectives are not adequately discussed in this thesis due to time constraint. It is also apparent from the discussion in Chapter 5 that the fundamental differences in the economic theories discussed stem from the difference in ethical foundation of each perspective. It is important for the choice of mental conception to be followed to explicitly incorporate the ethical considerations for any choice.

On empirical ground, this thesis has attempted to estimate to extent of ICT's impact to productivity growth and estimate the potential amount of resulting productivity dividend. The evidence however has to be taken with a grain of salt. The major limitation is due to the shortcomings in the methodology used to estimate this productivity gain, both inherent in the growth accounting framework and the econometric method. This would also impact the quality of estimated productivity dividend.

Moreover, this research has stopped short of estimating the amount of productivity dividend that becomes freed capital and excess liquidity. This exercise would prove to be difficult due to its complexity and the lack of available data. In addition, the empirical work has been constrained to seven developed nations within the OECD. It is unclear if similar findings can be observed for the other developed or developing countries.

Finally, another limitation can be found on the lack of empirical investigation related to the allocation of capital for the purpose of developing capacities. One reason is due to the lack of reliable data in measuring this. The discussion in Chapter 4 regarding wage stagnation and financialization are only indicative of the direction of capital, but these did not prove that capital has not been allocated for the purpose of developing capacities.

6.4. Directions for future research

This thesis started with exploring different economic theories as mental conceptions to examine the formation and allocation of capital within the context of technological revolution. The next step could be to dissect further ethical foundations of these economic theories to strengthen the case for capital allocation that they prescribe.

Furthermore, it can be interesting to examine empirically the allocation of freed capital more thoroughly to assess which economic theories actually prevail in the real world. As mentioned, this could prove to be a difficult exercise. However, there are methods that might permit us to do so, for instance, the Stock-Flow Consistent (SFC) modelling approach by Godley (see for instance Lavoie & Zezza, 2012). This might be able to give us better insights on the allocation of capital and its consequences.

Another possible direction is to explore more on the potential impact of technological revolution. As shown in this thesis, ICT might not have fulfilled its promise as a technological revolution completely. However, there are other cases of technological revolution that probably has unfolded completely, for instance electricity. Therefore, examination of the impact of electricity as a technological revolution on productivity growth and the allocation of capital resulting from it might be able to paint a fuller picture of the consequences of technological revolution than ICT.

Finally, there are important questions with regards to the limit to material needs and growth. How much is enough? Future research could explore further on the economic theories prescribing the allocation of capital to immaterial needs as to give clues on how the limit can be identified. This could lead to the identification measurement criteria that could be useful to finally provide clearer insights to the problem of capital allocation.

References

Aguenza, B., Al-Kassem, A. H., & Som, A. P. M., 2012. Social Media and Productivity in the Workplace: Challenges and Constraints. *Interdisciplinary Journal of Research in Business*, 2(2), 22.

Anderson, E. S., 1991. John Stuart Mill and experiments in living. *Ethics* 102 (1):4-26.

Aristotle., Jowett, B., 1885. *The Politics of Aristotle*. Online: http://classics.mit.edu/Aristotle/politics.1.one.html

Aristotle.,Ross, W.D., 1908. *Nicomachean Ethics*. Online: http://classics.mit.edu/Aristotle/nicomachaen.5.v.html

Arrighi, G., 1994. *The long twentieth century*. London: Verso.

Avent, R., 2014. The third great wave. *The Economist.* Available at: http://www.economist.com/news/special-report/21621156-first-two-industrial-revolutions-inflicted-plenty-pain-ultimately-benefited

Bain & Company Macro Trends Group, 2010. *A world awash in money. Capital trends through 2020.* Available at: www.bain.com

Bresnahan, T.F. & Trajtenberg, M., 1995. General purpose technologies “Engines of growth”? *Journal of Econometrics*, 65: 83–108.

Brynjolfsson, E., 1993. The productivity paradox of information technology. *Commun. ACM,* 36: 66-77.

Brynjolfsson, E., McAfee, A., 2014. *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies.* New York: W. W. Norton & Company.

Cantwell, J.A., 2000. Innovation, profits and growth: Schumpeter and Penrose. University of Reading, Department of Economics.

Cardona, M., Kretschmer, T., Strobel, T., 2013. ICT and productivity: conclusions from the empirical literature. *Information Economics and Policy* 25, 109-125.

Cesaratto, S., Serrano, F., Stirati, A., 2003. Technical Change, Effective Demand and Employment. *Review of Political Economy* 15, 33-52.

Chick, V., 2013. Economics and the good life: Keynes and Schumacher. Economic Thought, 2, 33-45.

Christophers, B., 2011. Review of David Harvey’s Enigma of Capital and the Crises of Capitalism. *Progress in Human Geography*, 35: 577-580, doi:10.1177/03091325110350040202.

David, P. A., 1990. The dynamo and the computer: An historical perspective on the modern productivity paradox. *The American Economic Review,* 80(2): 355-361.

Dudley, L., 2010. General purpose technologies and the industrial revolution. *Papers on Economics and Evolution*, 1011. Available at: https://papers.econ.mpg.de/evo/discussionpapers/2010-11.pdf

Fernald, J. & Ramnath, S., 2004. The acceleration in U.S. total productivity after 1995: the role of information technology. Economic Perspectives, Federal Reserve Bank of Chicago, issue Q I, pages 52-67.

Frey, C. B., & Osborne, M. A. 2013. The future of employment: how susceptible are jobs to computerisation? Oxford University (September).

Friedman, M., 1970. The social responsibility of business is to increase its profits. *The New York Times Magazine*.

Fromm, E., 1961. *Marx’s concept of man*. New York: Frederick Ungar Publishing Co.

Gintis, H., 1991. Where did Schumpeter go wrong?. *Challenge*, 27-33.

Giovanola, B., & Fermani, A., 2012. *Leadership through the Classics*. Springer.

Griliches, S., 1995. The Discovery of the Residual. *NBER Working Paper #5348*.

Hartman, A., 2011. *David Harvey's mental conception.* Retrieved Mar 15, 2015 from Society for U.S. Intellectual history blog: http://s-usih.org/2011/09/david-harveys-mental-conceptions.html
Harvey, D., 2010. *The Enigma of Capital and the Crises of Capitalism*. Oxford: Oxford University Press.
Henderson, R., & Clark, K., 1990. Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. *Administrative Science Quarterly* 35, 1, 9-30.
Houghton Budd, C. 2011. Finance at the Threshold. Rethinking the Real and Financial Economies, Farnham: Gower.
Houghton Budd, C., C. W. M. Naastepad and C. P. van Beers. 2015. CrESSI's Common Framework, in: C. Houghton Budd, C. W. M. Naastepad and C. P. van Beers (2015), Ch. 10.
Jorgenson, D.W., & Stiroh, K.J., 2000. Raising the speed limit: US economic growth in the Information Age. *Brookings Papers on Economic Activity*, 1, 2000, 125-235.
Jorgenson, D.W., 2001. Information technology and the US economy. *American Economic Review* 91 (1), 1–32.
Jorgenson, D.W., Ho, M.S., Stiroh, K.J., 2008. A retrospective look at the US productivity growth resurgence. Journal of Economic Perspectives 22 (1), 3–24.
Jovanovic, B. & Rousseau, P.L., 2005. Chapter 18 General Purpose Technologies. *Handbook of Economic Growth*, 1, pp.1181–1224.
Kaldor, N., 1957. A Model of Economic Growth. The Economic Journal 67 (268): 591–624.
Keynes, J., 1930. Economic possibilities for our grandchildren., in: *Essays in* persuasion (1931). London: Macmillan.
Keynes, J., 1936. The general theory of employment, interest and money. New York: Harcourt, Brace.
King, R., Levine, R., 1993. Finance and Growth: Schumpeter Might Be Right. *The Quarterly Journal of Economics* 108, 717-737.
Landry, R., Amara, N., & Lamari, M., 2000. Does social capital determine innovation? To what extent? Quebec: CHSRF chair on dissemination and uptake of research.
Lipsey, R.J., & Carlaw, K., 2000. What does total factor productivity measure? *International Productivity Monitor*, 1: 31-40.
Lucas, R., 1988. On the mechanics of economic development. *Journal of Monetary Economics* 22, 3-42.
Marx, K. 1990. *Capital: A Critique of Political Economy*, Volume I, London, Penguin Classics.
Marx, K., 1975, Economic and Philosophical Manuscripts of 1844, in *Early Writings*, Harmondsworth: Penguin.
Marx, Karl 1973, *Grundrisse*, Harmondsworth: Penguin.
Mazzucato, M. & Perez, C., 2014. Innovation as Growth Policy: the challenge for Europe. *SPRU Working Paper* Series, SPRU - Science and Technology Policy Research, University of Sussex.
Mazzucato, M., 2013. *The Entrepreneurial State: debunking public vs. private sector myths*. Anthem.
McDaniel, B. A., 2011. Schumpeter's View of Market Distribution and Redirection of Income and Wealth. *Journal of Management Policy and Practice*, 12(4), 23-26.
McGuckin, R., Stiroh, K., 2002. Computers and Productivity: are Aggregation Effects Important?. *Economic Inquiry* 40, 42-59.
Miller, B. & Atkinson, R.D., 2014. Raising European productivity growth through ICT. *Information Technology & Innovation Foundation Report*. Available at: http://www2.itif.org/2014-raising-eu-productivity-growth-ict.pdf
Minsky, H.P., 1992. The Financial Instability Hypothesis. The Jerome Levy Economics Institute Working Paper, 74. Available at: www.levyinstitute.org/pubs/wp74.pdf
Naastepad, C.W.M. and C. Houghton Budd. 2015. Aristotelian economics and modern finance. A consideration of the true counterpart to today's financial markets, in: C. Houghton Budd, C. W. M. Naastepad & C. P. van Beers (2015), Ch. 6.

Nussbaum, M., 2011. *Creating capabilities*. Cambridge: Belknap Press of Harvard University Press.
Nyström, K., 2008. The institutions of economic freedom and entrepreneurship: evidence from panel data. *Public Choice*, 136(3-4), 269-282.
Okishio, N. 1961. Technical Change and the Rate of Profit. *Kobe University Economic Review*, 7, pp. 85-99.
Oliner, S., Sichel, D., 2000. The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?. *Journal of Economic Perspectives* 14, 3-22.
O'Mahony, M., Timmer, M., 2009. Output, Input and Productivity Measures at the Industry Level: The EU KLEMS Database. *The Economic Journal* 119, F374-F403.
O'Mahony, M., Vecchi, M., 2005. Quantifying the Impact of ICT Capital on Output Growth: A Heterogeneous Dynamic Panel Approach. *Economica* 72, 615-633.
Pack, S., 2010. *Aristotle, Adam Smith and Karl Marx*. Edward Elgar, Cheltenham, UK.
Palley, T., 2007. Financialization: What it is and Why it Matters. SSRN Journal.
Palley, T., 2012. *From financial crisis to stagnation*. Cambridge University Press, New York.
Palma, J.G., 2009. The revenge of the market on the rentiers. Why neo-liberal reports of the end of history turned out to be premature. *Cambridge Journal of Economics*, 33: 829–869.
Perez, C., 2002. *Technological revolutions and financial capital*. Cheltenham: E. Elgar Pub.
Perez, C., 2009. The double bubble at the turn of the century: technological roots and structural implications. *Cambridge Journal of Economics* 33, 779-805.
Pozsar, Z., 2011. Institutional Cash Pools and the Triffin Dilemma of the U.S. Banking System. *IMF Working Papers* 11, 1.
Robbins L., 1935. *An Essay on the Nature and Significance of Economic Science*. London: MacMillan and Co.
Russell, B., 1932. In praise of idleness, in: *In praise of idleness and other essays* (2004). Routledge, London.
Sachs, J. D. and Kotlikoff, L. J., 2012. Smart Machines and Long-Term Misery. *NBER Working Paper No. w18629*. Available at SSRN: http://ssrn.com/abstract=2192802
Sayers, S., 2003. Creative Activity and Alienation in Hegel and Marx. *Historical Materialism* 11, 107-128.
Schumpeter, J. A., [1908] 2010. *The Nature and Essence of Economic Theory*, English edition and New Introduction by Bruce A. McDaniel, Transaction Publishers, Rutgers:The State University, Piscatway.
Schumpeter, J.A., [1911] 2008. *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest and the Business Cycle*, translated from the German by Redvers Opie, New Brunswick (U.S.A) and London (U.K.): Transaction Publishers.
Schumpeter, J.A., 1928. The instability of capitalism. *Economic Journal*, 38: 361-86.
Sen, A., 1999. *Development as Freedom*. NY: Anchor Books.
Sen, A., 2001. *Development as freedom.* Oxford: Oxford University Press.
Shaikh, A., 1992. The falling rate of profit as the cause of long waves: Theory and empirical evidence. In Kleinknecht, A., Mandel, E., & Wallerstein, I. (Eds.), *New Findings in Long Wave Research*. London: Macmillan.
Skidelsky, R., 2009. *Keynes: The return of the master*. PublicAffairs, New York.
Skidelsky, R., Skidelsky, E., 2012. *How much is enough?.* Other Press, New York.
Smith, T., 2009. Technological change in Capitalism: some Marxian themes. *Cambridge Journal of Economics*, 34(1), pp.203–212. Available at: http://cje.oxfordjournals.org/cgi/doi/10.1093/cje/bep048 [Accessed January 30, 2015].
Solomon, R. 2004. Aristotle, Ethics and Business Organizations. *Organization Studies* 25 , 1021.
Solow, R., 1957. Technical Change and the Aggregate Production Function. *The Review of Economics and Statistics* 39, 312.
Steil, B., Victor, D., Nelson, R., 2002. Technological innovation and economic performance. University Press, Princeton.

Stiroh, K., 2002. Are ICT Spillovers Driving the New Economy?. *Rev Income Wealth* 48, 33-57.
Storm, S., Naastepad, C., 2012. *Macroeconomics beyond the NAIRU*. Harvard University Press, Cambridge, Mass.
Timmer, M.P., Ypma, G., van Ark, B., 2003. IT in the European Union: Driving Productivity Divergence?, *Research Memorandum GD-67*, Groningen Growth and Development Centre.
Tsoulfidis, L., 2010. *Competing schools of economic thought*. Springer, Berlin.
van Ark, B., Inklaar, R., 2005. Catching Up or Getting Stuck? Europe's Troubles to Exploit ICT's Productivity Potential, *Research Memorandum GD-79*, Groningen Growth and Development Centre.
van Ark, B., Melka, J., Mulder, N., Timmer, M.P., Ypma, G., 2003. *ICT Investment and Growth Accounts for the European Union*, 1980–2000.
Van Staveren, I., 2001. *The values of economics*. Routledge, London.
Viner, J., 1937. *Studies in the theory of international trade*. Harper & Bros., New York, London.
West, E. G., 1969. The political economy of alienation: Karl Marx and Adam Smith. *Oxford Economic Papers*, 1-23.
Wilken, F., 1982. *The liberation of capital*. Allen & Unwin, London.