IMPACT OF ICT ON THE PRODUCTIVITY-COMPENSATION GAP

A Study on Technology, Works, and the Role of Capital

Master Thesis
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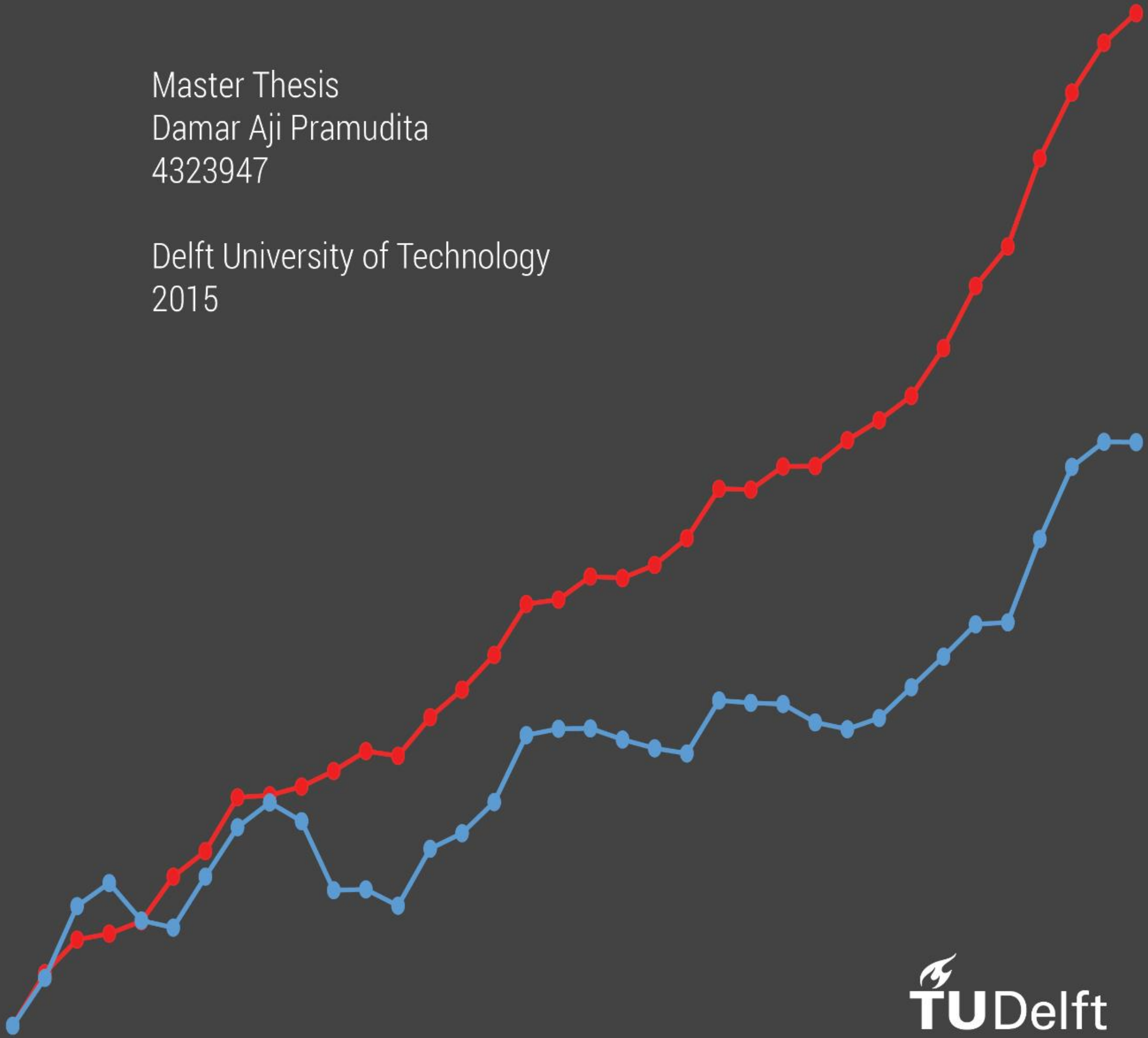

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A Study on Technology, Works, and the Role of Capital

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Damar Aji Pramudita
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EXECUTIVE SUMMARY

Researchers have observed that the growth of hourly compensation in the U.S. has lagged behind the labour productivity growth since 1970 (Fleck, Glaser, & Sprague, 2011). The disparity between productivity and compensation, which is known as the productivity-compensation gap (Mishel & Gee, 2011), suggests that workers do not benefit directly from the increase in the productivity growth.

This dynamism between labour productivity and compensation may be influenced by the use of Information and Communication Technology (ICT). By raising labour productivity, ICT saves (labour) costs - in this thesis, the money that is saved due to productivity growth, or freed by productivity growth, is called 'freed capital'. In principle, the freed capital can in turn be used to expand the production and create new jobs for those whose work is made redundant by ICT. But is this the best possible societal option for the use of the freed capital? While increasing labour productivity, ICT may also reduce work and/or alter work relationships, implying significant shifts in responsibility and hence in remuneration (Carr, 2014).

Following this, two main research questions are formulated: First, what is the impact of ICT on the productivity-compensation gap? Second, what principle that should guide the use of freed capital? In particular, could it be used to counter the impact of ICT on the productivity-compensation gap? Does a theoretical principle exist that would support such use of freed capital?

Regarding the first question, the impact of ICT on the productivity-compensation gap is assessed by investigating ICT's impact on the four critical factors of the productivity-compensation gap: output, hours worked, hourly wage rate, and intra-wage inequality. The data for the analysis are collected from the EU KLEMS and CPS database, for the U.S economy in the period 1970-2005. The analysis is done using OLS regression analysis and a two-step Prais-Winsten feasible generalized least squares (FGLS) to correct for AR(1) serial correlation.

The regression results show that ICT has a significance positive contribution to the value added of the U.S industries in the period 1970-2005. However, the impact of ICT on the hours worked of the U.S. for the same period remain inconclusive. The analysis shows a low significant positive correlation of ICT with the hours worked in some service industries, but an insignificant correlation with the hours worked in the goods producing sectors. This inconclusive result might be caused by the aggregation level of data that is used in this thesis; investigating the impact of ICT on the hours worked may require data at a more detailed level than the industry level.

Nevertheless, ICT is shown to have a significant correlation with the hourly wage rate. However, the impact of ICT on the hourly wage rate does not follow the changes in the hours worked. For instance, ICT's correlation with the hourly wage rate in the construction industry is negative, despite a positive correlation with the hours worked. Meanwhile, ICT is shown to have a positive correlation with the hourly wage rate in the manufacturing industry, in which ICT is expected to have a negative impact on the hours worked. This result shows that impact of ICT on the hourly wage rate could not be determined by its impact on the hours worked only. What other factors may explain the difference in impact of ICT on compensation between sectors? Can it be explained by differences in skill levels?

In order to answer this question, an extended analysis for intra-wage inequality is carried out. The analysis shows that ICT has a positive correlation with the wage share of both high-skill workers and in low-skill workers. On the contrary, ICT has a negative correlation with the wage share of the medium-skill workers. Thus, while ICT raises compensation for high-skilled and low-skilled workers, medium-skilled workers may end up with lower paid jobs. Nevertheless, this dynamism seems to not influence the overall intra-wage inequality in the U.S. The impact of ICT on the overall intra-wage inequality index is insignificant, which means that ICT can only explain a little part of the U.S. inequality for period 1970-2005.

In summary, the impact of ICT on the productivity-compensation gap is hard to be measured, mainly because the impact of ICT on the hours worked is still inconclusive. Nonetheless, this thesis provides two insights that shows ICT still have influences on works: first, ICT contributes to around $ 1.06 trillion (in constant 2005 US$) of the U.S. value added in period 1970-2005. This means that while, apparently, ICT does not have significant impact on the total hours worked, it still increases labour productivity (output per hour). If it is assumed that the share of total output that is distributed to workers/capital follows the actual wage share/profit share, then this thesis estimates that ICT contributes to around $330 billion of profit during the same period.

Secondly, ICT is shown to have a positive correlation with the increase of both high-skill and low-skill works, while it has an opposite effect on the medium-skill works. This means that while ICT is assumed to open up new work opportunities, it may also cause a job polarization, in which the medium-skill workers might end up competing for a lower-skill works.

Following this result, this thesis reviews various economic theories to find a principle that may guide the freed capital towards activities that may counter the impact of ICT on the productivity-compensation gap. The main questions that guide this exploratory analysis are: (1) how are values created? (2) How can the freed capital be used to realize these values? The economic theories that are explored include classical, neoclassical, Schumpeterian, and the twin value of capital perspectives.

For Adam Smith, a classical economist, values are created from the specializations in the production process, and can be equated to the wages of the labourers, the rent on the land, and the profit on the capital employed in producing and bringing the commodity to the market. Karl Marx, however, disagree with Adam Smith and argues that labour is the only source of value. However, both Smith and Marx agree that wealth creation cannot be seen independently of the evolution of society and the human being. The development of individual should also be an important goal of the economics.

On the contrary, neoclassical perspective only recognizes values as coming from utility derived from consumption. This means that all capital (including what in this thesis is called 'freed capital') must be invested in the new production activities that may increase (utility from) consumption. Under neoclassical assumptions, the pursuit of self-interest by economic actors will automatically allocate capital to investments in (expansion of) production activities. The Schumpeterian perspective, by contrast, argues that self-interest motive is not enough to direct capital towards its optimal allocation. The real value comes from entrepreneurs' idea and innovation, which is often neglected by the desire of instant profit. The direction of capital therefore should be carefully guided, since investment in innovation will require a great commitment (Mazzucato & Perez, 2014).

In summary, both neoclassical and Schumpeterian perspectives stimulate the use of capital towards the expansion of production. The labour that is obviated as the impact of technological progress is expected to be absorbed by the creation of new employment in another sectors, with the help of innovations by entrepreneurs. In contrast with the classical perspectives, in the Schumpeterian and neoclassical new growth perspectives human capital is only recognized in its potential to achieve economic growth. It is recognised, however, human knowledge contributes to technological progress and profit. Therefore, investment in new technology must also be followed by the investment in human capital, so that the workers' skills can be improved, so that they are able to race *with* the technology instead of race *against* it (Brynjolfsson & McAfee, 2011).

Wilken (1982) sees capital as originated from human inventiveness and intelligence (in German: *Geist*). Unlike the definition of human capital in Schumpeterian perspective that is recognized only for achieving economic growth, in Wilken's perspective human capacity itself has value that needs to be developed for its own sake. This perspective therefore recognize another purpose of capital outside the consumptive purposes.

By considering that consumption is not the only purpose in human life, and the development of human capacities is also a goal in itself, the twin value of capital theory recognizes two purposes of capital: (1) as the financier of the physical production activities that provide our material needs and (2) as the enabler of human capacities. Part of capital therefore can be used to the expansion of production that will provide our material needs. However, since material needs are limited, while the growth of human capacities is not, the rest of the capital should be directed towards the development of human capacities. In contrast with the concept of utility as the goal of economics, under this perspective the capital is used to achieve happiness in the Aristotelian (rather than utilitarian) sense, which may come only by exercising virtue. Following this, the basic assumption of self-interest as the driver of economic should be expanded by including the interest of others.

In conclusion, this thesis discusses various principles from the economic theories that may guide the use of freed capital. The answer to the question which principle that should guide the freed capital then will depend on which value that is important from each economic perspective. If we accept the basis of utility maximization as the value that organize economic activities, the freed capital can find its place in the expansion of production, as what neoclassical and Schumpeterian perspective prescribe. However, if we accept that human beings actually have a higher capacity than satisfaction of utility, then the freed capital should also be used for the development of human capacities and character. Just like the investment in innovation that need a great commitment, the investment in the development of human capacities and character will also need one, even greater.

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1.INTRODUCTION

1.1 Background

In general, productivity describes the relationship between the output produced and a particular input, for example land, labour, and capital. The rise in productivity provides the basis for raising the living standards within an economy, because the capital freed in the process of productivity growth can be used to either expand the economy's production base (and thereby the number of goods available to people) or to finance other fields in society (such as education, science, art). Increase in labour productivity implies that the same amount of labour can be used to produce more goods, or same amount of goods can be produced with less labour; this gain is known as the productivity dividend (Naastepad & Houghton Budd, 2015). The productivity dividend frees up some labour, thus allow people to pursue other aims in life. However, within the socio-economic constellation typical for most countries today, labour-saving technology may reduce works overall and/or the compensation it receives.

One of the technology that can transform the labour demand and compensation is Information and Communication Technology (ICT). Carlota Perez (2002) categorizes ICT as a technological revolution, a technology that massively transforms the way to do things in the whole industries and increase productivity. The flip side of increases in labour productivity, however, is the obviation of labour. In The End of Work, Jeremy Rifkin (1995) argued that worldwide unemployment would increase as information technology eliminated tens of millions of jobs in the manufacturing, agricultural and service sectors. Correspondingly, researchers have observed that since 1970 the growth of hourly compensation in the U.S., both in nominal and real terms, has lagged behind the labour productivity growth (Fleck et al., 2011). This disparity between productivity and compensation, which is known as the productivity-compensation gap (Mishel & Gee, 2011), suggests that workers do not benefit directly from the increase in the productivity growth.

At the same time, increase in labour productivity implies that fewer workers are needed to produce the goods. The increase in the labour productivity, therefore, may free capital that was previously use to pay the labour. In this thesis, following Wilken (1982), the capital that is freed from the production process as a result of increase in labour productivity is called as the *freed capital*. The question posed in this thesis is, how can we use the freed capital for the benefit of workers whose jobs/and or compensation may be diminished by the use of labour-saving technology? Before answering this question, first it is important to understand the relationship between labour productivity, wage, and working hours; and how technology might alter them.

The wage share (φ) is the share of wage income in total income:

$$\varphi = \frac{y^w}{y} = \frac{w.h}{y} \quad \textbf{(1.1)}$$

where y stands for total value added in real term, y^w denotes the real wage income, w is the real wage per hour worked, and h is the number of hours worked.

Labour productivity (λ) represents the amount of goods that are produced by one unit of labour, for example, one hour of work ($\lambda = y/h$). The relationship between wage share and labour productivity is shown in equation 1.2:

$$\varphi = \frac{w.h}{y} = \frac{w}{\lambda} \quad \textbf{(1.2)}$$

Therefore, when wage growth is lagging behind the labour productivity growth, the wage share is decreasing.

Equation 1.2 shows that wage share is affected by three variables, which are workers' real wage (w), workers' working hours (h), and total amount of output produced (y). Change in wage share therefore can be decomposed into changes in these three factors, as shown in equation 1.3:

$$\frac{\Delta\varphi}{\varphi} = \frac{\Delta w}{w} + \frac{\Delta h}{h} - \frac{\Delta y}{y} \quad \textbf{(1.3)}$$

This equation shows that a decline in wage share can be accounted by (a) an increase in output, (b) a decline in working hours, and/or (c) a decline in real wage. The dynamic between these three variables can be brought about by the use of labour-saving technology. For example, when the labour-saving technology is broadly used in an industry we expect that same number of workers can be used to produce more output. As result, wage share can decline because the growth of output exceeded the growth of workers' wage and working hours. Alternatively, same amount of output can be produced using fewer workers. In this case, wage share declines by a decrease in working hours. Finally, technological unemployment can put downward pressure on wages.

One of the technologies that can bring such dynamism in the wage share is ICT. Jobs automation brought about by the use of computer-controlled equipment allows companies to automate jobs and operate with a smaller number of workers, which can lead to technological unemployment. Frey and Osborne (2013) estimated that 47 per cent of total U.S. employment is in the high risk category of being automated.

In the recent literature, the dynamism of productivity growth and the compensation of labour has been analysed by Lawrence Mishel (2011) who has estimated the 'productivity-compensation gap' – the divergence of pay and productivity – for the U.S.A.. We can understand the relation between wage share and the productivity-compensation gap by looking at the definition of the productivity-compensation gap in Mishel (2011)'s study. Briefly, if ICT decreases the wage share, it will increase the productivity-compensation gap.

Using Mishel's notation, the productivity-compensation gap is defined as the ratio between labour productivity ($Y/(P_Y.h)$) and labourers' median real wage (W_{med}/P_C), and is described in equation 1.4:

$$\frac{Y/(P_Y.h)}{W_{med}/P_C} = \frac{Y}{(C_{ave}.h)} \times \frac{P_C}{P_Y} \times \frac{C_{ave}}{C_{med}} \times \frac{C_{med}}{W_{med}} \qquad \textbf{(1.4)}$$

where Y is nominal GDP, C_{ave} is the average nominal compensation[1], C_{med} is the nominal median compensation, W_{med} is the nominal median wage, P_Y is the GDP deflator, P_C is the consumer price index, and h is the total number of hours worked.

The right-hand side of equation 1.4 shows that the productivity-compensation gap can be decomposed into two main components, which are the wage share (φ) and the intra-wage inequality.

$$\frac{Y}{(C_{ave}.h)} \times \frac{P_C}{P_Y} = \frac{y}{w.h} = \frac{1}{\varphi} \qquad \textbf{(1.5)}$$

$$\frac{C_{ave}}{C_{med}} = Intra - Wage\ Inequality \qquad \textbf{(1.6)}$$

Eqs. 1.5 and 1.6 make clear that, within this model, income inequality has two aspects: the *functional distribution of income* (between profits and wages, or the profit share and the wage share), and the distribution of wage income between (high and low) wages (i.e. the distribution of income *within* the wage share). The wage share, in turn, consist of two main components: labour

[1] Mishel (2011) separates the definition of compensation and wage. Compensation is the sum of wages and total benefits, which include social insurance, health insurance, and pensions. The ratio between the compensation and wage is defined as the benefit ratio.

productivity, and the wage rate (see eq. 1.2). Therefore, the impact of ICT on the productivity-compensation gap can be investigated by analysing its impact on its four critical components: (a) output, (b) the number of hours worked, (c) the hourly wage rate, and (d) intra-wage inequality.

All four elements – output, hours worked, the wage rate, and intra-wage inequality – are likely to be affected by the use of technology. Sanders (2004) proposed the Skill-Biased Technical change hypothesis which says that technology increases demand for high-skilled workers while reducing demand for low-skilled workers. A study by Autor, Levy, and Murnane (2003) explained the relationship in more detail, by showing that ICT affects the demand of work based on the tasks' complexity. This condition leads to wage inequality between high-skill workers who do more complex works and low-skill workers who do less complex works.

Against this background, this thesis focuses on a double impact of Information and Communications Technology (ICT). On the one hand, by raising productivity in the economy, ICT frees capital which, in principle, can be used for the benefit of those whose work is made redundant by ICT. On the other hand, ICT may reduce work and/or alter work relationships, implying significant shifts in responsibility and hence in remuneration (Carr, 2014). It may even alter the human being, in particular the human mind, affecting human productivity (Head, 2014). Crucial, therefore, is the question what will be the role of the capital freed by the use of ICT. It may end up in part with workers, either directly (as wage income) or indirectly, for instance in the form of improved welfare services (e.g. for those whose labour becomes redundant as a result of productivity growth), free education, or funding of processes of generation of new knowledge (the scientific discovery process) or other creative processes.

This thesis will update the study of productivity-compensation gap by investigating the impact of ICT. The analysis will focus on the impact of ICT on the output, hours worked, hourly wage rate, and the intra-wage inequality in different sectors and types of occupation. This analysis will enable us to see the dynamism introduced by ICT on works. It can be used to distinguish the type of occupations that are obviated by the use of ICT and the type of occupations that get benefit from it. The result of this study can be used as the basis for discussion how to spend the freed capital. What approach should be undertaken, especially for workers who lost their jobs or whose compensation declined because of the use of ICT.

Conventional (neoclassical) economic theory might justify increases in the productivity-compensation gap as the inevitable consequence of choosing capital over labour. For instance, recently, neoclassical economists have acknowledged the possibility of 'long-term misery' as a result of unconstrained technological progress (Benzell, Kotlikoff, LaGarda, & Sachs, 2015;

Sachs & Kotlikoff, 2012). According to Sachs and Kotlikoff (2012), when technology increases the productivity of machines, the remuneration of machines in income will rise. Assuming, in neoclassical fashion, that all labour will remain fully employed, the result will be a decline in the wage rate of low-skilled workers. However, the 'long-term misery' that Sachs and Kotlikoff (2012) and Benzell *et al.* (2015) refer to is not this deterioration of the position of low-skilled workers, but the possibility that, as a result of the decline in low-skilled income, savings may decline and hence (on neoclassical assumptions of saving-determined investment) long-run output and consumption may fall (especially the consumption of high-skilled workers). Heterodox economists, on the other hand, tend to be concerned with the decline in the compensation of low-skilled workers relative to high-skilled workers. A problem with both sets of theories (neoclassical and heterodox) is that they relate capital to material welfare, or consumption, ignoring other purposes that capital may serve. This makes the discussion for allocating the freed capital rather limited. Neither ask what could be the significance of the obviation of labour in the economy by technology. For instance, could it signify a transition from a society that is mainly concerned with economic growth to a society that is, in terms of Keynes (1930), waking up to 'the real values of life' (Naastepad & Houghton Budd, 2015; Naastepad & Mulder, 2015)?

This thesis will also consider an alternative theory of the use of capital. The twin value of capital theory proposed by Houghton Budd (2011) suggests that capital could serve a dual purpose, as the financier of physical production *and* an enabler of human capacities (Naastepad & Houghton Budd, 2015). This perspective would enable us to study how to distribute the freed capital from the use of ICT more equally, whether by reducing the productivity-compensation gap, or by ensuring that the freed capital that does not accrue to wage increases is used for social benefit.

1.2 Research Objective

Based on the problem discussed above, this research has two objectives:

1) Investigate how ICT influences the productivity-compensation gap, and how it frees capital that was previously spent on wages (the freed capital);
2) Reviews the principles from economic theories that may guide the allocation of the freed capital toward activities that will counter the impact of ICT on the productivity-compensation gap.

1.3 Research Framework

The research framework provides the steps that need to be taken to achieve the research objective. The objective of this research will be achieved through the following sub-objectives:

1) Conducting literature review to build a conceptual model which can be used to (a) analyse the influence of ICT on the productivity-compensation gap, and (b) provide insight into how the freed capital can be used to counter the impact of ICT on productivity-compensation gap.
2) Confront the conceptual model with empirical data to know how ICT is influencing the productivity-compensation gap in the U.S.
3) Provide reviews how the freed capital could be allocated more effectively to purposes which will counter the impact of ICT on the productivity-compensation gap, by comparing the empirical analysis and a review of relevant suggestions made in the literature.

1.4 Research Question

There are two main questions that will guide the research towards its objective:

1) **What is the impact of ICT on the productivity-compensation gap?**
2) **What principle that should guide the use of freed capital?**

These questions can be answered by first understanding the way ICT influences the productivity-compensation gap and frees capital. Therefore, several sub-questions is defined to help answering the main research question. These sub-questions are also designed to meet the sub-objectives defined in the research framework.

1) How does ICT contribute to the productivity-compensation gap?
   More specifically, the impact of ICT on the four critical factors of the productivity-compensation gap will be investigated.
   a) How does ICT influence output?
   b) How does ICT influence the number of hours worked?
   c) How does ICT influence the hourly wage rate?
   d) How does ICT influence the intra-wage inequality?
2) What socially agreed and/or scientifically acknowledged principle that should guide the use of freed capital?

To answer this question, we will explore the role of capital in several economic theories. According to these theories, how is capital generated, which purpose(s) does it serve and why?

a) What is the role of capital according to neoclassical theory?
b) What is the role of capital according to Schumpeterian theory?
c) What is the role of capital in society according to the twin value perspective on capital?

1.5 Research Overview

In **Chapter 2** the channels through which ICT is expected to influence the productivity-compensation gap will be discussed. The research background in the previous section provides the initial conceptual model as shown in figure 1.

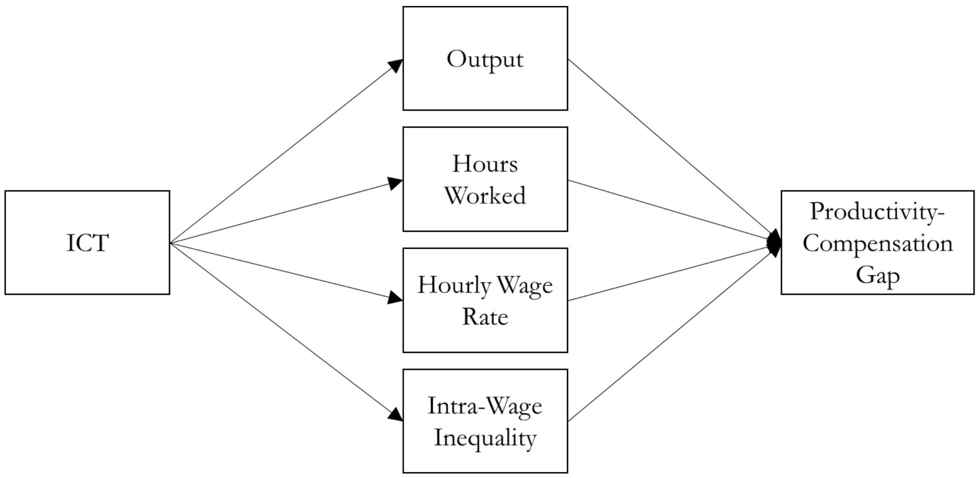

Figure 1. Conceptual Model

The use of ICT is expected to increase the labour productivity, but at the same time might decrease labourer's wage share by altering labour wage and working hours by replacing labour with machines. Furthermore, it might also alter the wage distribution between high-skill and low-skill workers and increase the intra-wage inequality. These variables will be the main focus of empirical analysis in this thesis.

Chapter 3 will discuss the use of productivity dividend from the perspective of different economic theories. The main idea that will be explored in this chapter is for what purposes – according to existing theoretical perspectives – the productivity dividend is to be used. These ideas will guide the analysis of the empirical findings that will be presented in the fourth chapter.

The empirical analysis in **chapter 4** will use data from United States economy which will be collected from two main sources, EU KLEMS database and Current Population Survey (CPS) database. Several regression analysis tests will be done to investigate the relationship between ICT and the four critical factors of the productivity-compensation gap.

C**hapter 5** will discuss the channels through which capital is allocated in theory and in practice, such as self-interest in neoclassical theory, and conscious direction of capital towards entrepreneurial ideas in Schumpeterian theory. Furthermore, the allocation of capital as guided by twin value of capital perspective is also discussed.

Finally, a conclusion will be given in the **chapter 6**.

2. IMPACT OF ICT ON PRODUCTIVITY-COMPENSATION GAP

2.1 Productivity-Compensation Gap

An increase in the productivity-compensation gap can be caused by four factors: (a) an increase in output (at constant hours), (b) a decline in the number of hours (at constant output), (c) a decline in the wage rate, and (d) a change in intra-wage inequality. A rise in the productivity-compensation gap implies that more output can be produced with less labour. As a result, the production needs less costs of labour and frees some capital.

Some researchers have already observed that labour income in the United States has lagged behind the increase in labour productivity (Fleck et al., 2011; Mishel & Gee, 2011). However, other researchers noted that the gap might be exaggerated, because the growth of productivity and the growth of workers' compensation have been adjusted using different price deflators (Baker, 2007; Feldstein, 2008; Sherk, 2007). Therefore, to understand the implication of the productivity-compensation gap we need to first understand how the productivity-compensation gap can be measured.

Before we start, note that the productivity-compensation gap literature is not explicitly concerned with the number of hours worked. It focuses on labour productivity, and does not distinguish between increases in labour productivity at constant hours or work and increases in productivity at rising or declining hours. Apparently, this literature is interested more in questions of distribution (taking hours of work as given) than in how much work is or could be created. Whether this reflects the (neoclassical) idea that the total amount of work is given by 'the market' is an open question. We shall come back to the question of hours of work in Chapter 5.

Pessoa and Van Reenen (2012) distinguish two methods of measuring the productivity-compensation gap, i.e. 'net decoupling' method and 'gross decoupling' method. The net decoupling method measures the difference between labour productivity (GDP per hour) and *average* compensation; both are adjusted using the GDP deflator. Dissimilarly, the gross decoupling method measures the difference between labour productivity (GDP per hour) and *median* wages, by using different adjustments: GDP deflator for the labour productivity and Consumer Price Index for the wages.

Here we can note two differences between the gross decoupling and the net decoupling. First, in the comparison with the labour productivity, the gross decoupling measurement uses average compensation while the net decoupling measurement uses median wage. Please note that Pessoa and Van Reenen (2012) also distinguish between compensation and wage. Labour compensation is the total of wages and other benefits received by workers, such as social insurance, health insurance, and pensions. Second, the gross decoupling measurement uses a same price deflator for adjusting labour productivity and compensation, while the net decoupling measurement uses different price deflators (GDP deflator and CPI).

By looking at these two definitions we can see why there might be two different interpretations of the increase in the productivity-compensation gap. Pessoa and Van Reenen (2012) noted that since 1972 there has been small net decoupling (13%) in the U.S. compared to the gross decoupling (about 80%). This implies that, on average, the labour compensation has grown fairly well with the labour productivity. However, if we investigate more closely, the rise in compensation does not occur homogenously in all workers. Some workers in the top of wage distribution experienced much higher growth than the other workers, which causes an increase in the average wage while the median wage stays constant. This also implies that the intra-wage inequality is increasing, which also an important driver of the rise in the (gross) productivity-compensation gap.

Mishel (2011) decomposes the productivity-compensation gap into four components and made a clear distinction between the gross decoupling and the net decoupling. These four components are nominal wage share (which is also the definition of the net decoupling), labour's terms of trade (the ratio between the GDP deflator index and the CPI), intra-wage inequality, and the benefits ratio (the ration between the median compensation and the median wage). The decomposition is described in Equation 2.1 as follows:

$$\underbrace{\frac{Y/(P_Y.h)}{W_{med}/P_C}}_{\textbf{Gross Decoupling}} = \underbrace{\frac{Y}{(C_{ave}.h)}}_{\textbf{Net Decoupling}} \times \underbrace{\frac{P_C}{P_Y}}_{\textbf{Terms Of Trade}} \times \underbrace{\frac{C_{ave}}{C_{med}}}_{\textbf{Intra-Wage Inequality}} \times \underbrace{\frac{C_{med}}{W_{med}}}_{\textbf{Benefit Ratio}} \qquad \textbf{(2.1)}$$

Equation 2.1 shows the difference between the gross decoupling measurement and the net decoupling measurement. Please note that Mishel's definition of the productivity-compensation gap in the left-hand side of equation 1 is the same as Pessoa and Van Reenen's definition of gross decoupling, while the first component on the right-hand side is the net decoupling.

Gross decoupling measures the ratio of labour productivity, or the nominal GDP (Y) per hour (h), which is adjusted using the GDP deflator (P_Y), and the median wage (W_{med}), which is adjusted using the CPI (P_C). In a different manner, the net decoupling measures the ratio of labour productivity and average compensation (C_{ave}) which are both adjusted using the same index.

The difference between the gross decoupling and the net decoupling, therefore, can be accounted to the labour's term of trade, intra-wage inequality, and benefit ratio. Labour's term of trade is the ratio between GDP deflator (P_Y) index and CPI (P_C). Intra-wage inequality is measured by dividing average compensation (C_{ave}) with median compensation (C_{med}). Finally, the benefit ratio measures the difference between compensation (C_{med}) and wage (W_{med}).

The distinction between the net decoupling and the gross decoupling allow us to understand the implication of the productivity-compensation gap. The net decoupling shows how well the average workers benefit from the productivity increase, in terms of average compensation they received. The gross decoupling shows more dynamism, by taking into account the distribution of labour compensation within the population.

Table 1.1. The Decomposition of the Productivity-Compensation Gap in the U.S., 1973-2011

Contribution to the productivity-compensation gap

	1973-1979	1979-1995	1995-2000	2000-2011	1973-2011
Net Decoupling	0.03	0.23	-0.39	0.69	0.25
Terms of Trade	0.46	0.51	0.63	0.24	0.44
Wage Inequality	0.02	0.72	0.96	0.59	0.61
Benefit Ratio	0.82	-0.02	-0.37	0.31	0.16
Gross Decoupling	1.34	1.44	0.83	1.82	1.45

Contribution to the productivity-compensation gap (per cent of the gap)

	1973-1979	1979-1995	1995-2000	2000-2011	1973-2011
Net Decoupling	2.1	15.6	-47.0	37.6	16.9
Terms of Trade	34.4	35.2	74.8	12.9	29.9
Wage Inequality	1.9	50.3	114.9	32.0	41.9
Benefit Ratio	61.6	-1.4	-43.6	16.8	11.1
Gross Decoupling	100	100	100	100	100

Furthermore, Mishel analyzed the contribution of each components to the productivity-compensation gap, as shown in table 1.1.

Some implications of the study by Mishel and Gee (2011) are the following. First, the factor which has contributed most to the continually rising productivity-compensation gap between 1973-2011 is not a decline in the average wage rate, but an increase in intra-wage inequality. The increase in intra-wage inequality, measured as the ratio between average compensation and median compensation, implies that the income grows more at the top-half of income distribution than the bottom-half of distribution.

Secondly, compared to the median compensation, average income has tracked relatively well with the productivity. There is even a period (1995-2000) where average compensation is increasing more than the productivity, even though it fell considerably in the next period. Missing in this analysis is the dynamic between two components of the net decoupling, wage and employment, and whether the change in the average wage rate is affected by the composition of the employment. A study by Blum (2008) shows that since 1979 U.S. employment is shifting from the manufacturing sectors to services, wholesale trade, and retail trade sectors. This means that manufacturing sectors might obviate a lot of labour, but at the same time new jobs are created in the service sectors. However, part of the growth of employment and wage in the service sectors is in the low-skill service occupations (Autor & Dorn, 2013). This implies a job polarization, in which the employment and income move away from the middle of distribution towards the top and bottom of distribution (Van Reenen, 2011). This may be an explanation for the continual increase in intra-wage inequality, as measured in Equation 2.1.

Next we might ask, what is the possible explanation for this dynamism in the productivity-compensation gap? Several researches already pointed to the automation brought about by ICT as the force behind this process (Autor & Dorn, 2013; Van Reenen, 2011). Several researchers, however, disagree and demand to stop blame the robot as the reason behind the wage inequality (Mishel, Shierholz, & Schmitt, 2013). Therefore, it will be interesting to investigate the impact of ICT on the productivity-compensation gap by thoroughly observing its influence on the components of the productivity-compensation gap, as described in Equation 2.1

Furthermore, the way ICT dynamically influences the components of the productivity-compensation gap is understood by considering ICT as one of the technological revolutions that can change the techno-economic paradigm, or the best practice that guides the economic actors in utilizing the technology (Perez, 2002). We ask, therefore, which techno-economic paradigm ICT creates, and how it can explain the dynamism of the productivity-compensation gap. In the end, we will also ask whether it is possible to expand the techno-economic paradigm to counter the negative effect of the productivity-compensation gap.

This thesis will therefore focus on the impact of ICT on the productivity-compensation gap by tracking four major components of the productivity-compensation gap: the output, the hours worked, the hourly wage rate, and the intra-wage inequality. The decision to focus in these four major components is because it seems to be more closely related to the techno-economic paradigm of ICT than the two other factors (the benefit ratio and the terms of trade). However, there is a possibility that the rise in benefit ratio and labour's terms of trade is also related to the increase investment of IT, therefore it will be discussed briefly in this chapter. Nevertheless, it will not be the main focus of this thesis, and will not be discussed further in the empirical analysis chapter.

Finally, this thesis will also investigate the other implication of the productivity compensation gap: the freed capital. Increase in labour productivity frees capital that was used to pay compensation. What will be the justified use of this capital, to counter the effect of the productivity-compensation gap?

2.2 ICT: The Fifth Technological Revolution

Perez (2002) defines technological revolution as powerful and dynamic technology which is capable of bringing about an upheaval in the whole economy and of propelling a long-term upsurge of development. It will bring about the conception of a set of generic tools – hard, soft, and ideological – which together modifies the best-practice that guides entrepreneurs, managers, innovators, investors, and consumers, both in their individual decisions and in their interactions. This best-practice model, which represents the most effective way of applying a particular technological revolution, is called a techno-economic paradigm. It is an 'economic' best practice because each technological transformation brings a major shift in the relative price structure that guides economic agents towards the intensive use of the more powerful new inputs and technologies. It is a 'paradigm' because it defines the model and the territory for 'normal' innovative practice, promising success to those that follow the principles incarnate in the core industries of the revolution.

Perez further argues that the economic growth since the end of eighteen century has gone through five stages that can be associated with five technological revolutions: The Industrial Revolution, The Age of Steam and Railways, The Age of Steel and Electricity, The Age of the Automobile and Mass Production, and finally, The Information Age. The latest technological revolution is brought about by the advance in Information and Communication Technology (ICT), marked by the announcement of Intel microprocessor in 1971. Each of the technological revolution brings about a techno-economic paradigm which will modernize the existing industries and activities, and constitutes a great surge of development in two distinct periods. The first period is the installation period, when the new technologies irrupt, setting up new infrastructures, and spreading new ways of doing things in industries. At the beginning of the period, the technology adoption is small because the economic actors are still bounded by the paradigm of the old technology. However, in the end of the period the new technology will have overcome the resistance and being ready to serve the economy as the new engine of growth. The second period is called the deployment period, when the paradigm brought about by the technological revolutions is adopted widely across the whole economies and brings higher level of productivity. This massive economic transformation also needs changes in the socio-institutional framework, which will direct the use of the technology and the distribution of its benefit to the society.

Looking at the advance of ICT, we can argue that ICT has passed the installation period. Various studies have identified ICT as the source of productivity (Cardona, Kretschmer, & Strobel, 2013). However, the techno-economic paradigm of ICT might also change the way labour are structured. The impact of ICT on the productivity and on the employment, especially the skills, wage, and rate of employment, is discussed in a study by Brynjolfsson and McAfee (2011). The central concern on this study is the ability of computers (which are a combination of hardware, software, and telecommunication network) to replace the human being in wide range of tasks. As a result, labour productivity may increase because the same number of output can now be produced with fewer workers. At the same time, the number of tasks that can be replaced by automation is widening (Frey & Osborne, 2013).

In summary, the use of ICT can increase productivity and creates wealth on one side, but may destroy jobs on the other side. The discussion of how ICT influences the productivity (by increasing the output and/or reducing the working hours) and influences the workers' wage (which together will increase the productivity-compensation gap) will be presented in the next section.

2.3 Impact of ICT on the Labour Productivity and Employment

Several studies have already indicated positive contribution of ICT to productivity growth (Cardona et al., 2013). The contribution of ICT to the productivity growth may come from two sources. First, the growth is due to the technological progress in ICT producing sectors, such as the sales of computers and semi-conductors. Second, the growth is also due to the intensive use of ICT in the other sectors, such as wholesale and retail trade, finance, insurance and business services. The United States has experienced increase of labour productivity growth in both ICT-producing and ICT-using industries, with the ICT-using sector accounting for the growth in the second half of the 1990s (Pilat, Lee, & Van Ark, 2002). The impact of ICT on the productivity growth is also related to the nature of ICT as General Purpose Technology (GPT). GPTs are characterized by their (potential) pervasive use in a wide range of sectors, and their role as enablers of other technology which opens up new opportunities (Bresnahan & Trajtenberg, 1995). This way, GPT's impact on the productivity growth might not appear in the early period of its arrival, because of diffusion lags between the arrival of technology and its application found within the industrial sector (David, 1990).

The rise of productivity in relation to ICT thus does not come immediately. The puzzling relation between the use of ICT and the productivity is stated by Robert Solow, which is also known as the "productivity paradox" (Brynjolfsson, 1992) : "We see the computers everywhere but in the productivity statistics". Brynjolfsson (1992) states several possible causes of the productivity paradox. First, the effect of investment in ICT to the output is hard to be measured. The benefits from ICT often comes in intangible forms, such as quality improvement, customer service improvement, and increase in speed and responsiveness. Second reason for the productivity paradox is that the benefit from ICT may take several years to show up. This is because firms and individual users of ICT may require some experience before becoming proficient. Finally, the productivity paradox can be caused by the mismanagement of ICT. Firms are keep investing in the ICT but do not properly adjust the organization to make better use of the ICT.

In conclusion, productivity cannot be increased by investment in ICT alone. It also requires complementary changes that need time to be implemented, such as changes in business process and organization structure. Therefore, the benefit of investment in IT may also need additional time before it arises (Brynjolfsson & Hitt, 2003).

According to Breshanan & Trajtenberg (1995), the era of GPT will eventually be followed with improvement of GPT efficiency (Bresnahan & Trajtenberg, 1995). This would appear in decline of prices, an increase in quality, or both (Jovanovic, 2005). As the GPT becomes more mature, its diffusion in industries will be more widespread and will help to spawn more innovation. Firms are able to have better performance by incorporating ICT in their production process, for example by automating business process to handle larger volumes of transaction (Pilat et al., 2002).

At the same time, however, there is also a growing literature on possible negative productivity effects of ICT by the way it changes the production process. Autor, Levy, and Murnane (2003) argue that computer capital can substitute workers that perform cognitive and manual tasks which can be accomplished by following explicit rules. On the contrary, it will complement workers that performs non-routine problem-solving and complex communication tasks. The term 'routine' refers to whether an occupation can be expressed in specific rules, and does not necessarily related with the skills needed to do the jobs. For instance, a managerial works that need a complex decision making process is considered as non-routine, but so does a low-skill occupation such as security guard, that has to determine quickly whether a person is a potential burglar or a worker staying up late (Levy & Murnane, 2004). The implication of this phenomenon is clear: apart from the high-skill works, the low-skill service occupations that needs relatively complex decision making process may also grow. This will result in job polarization, and is already apparent not only in U.S (Autor & Dorn, 2013; Katz & Margo, 2013; Van Reenen, 2011) but also U.K (Goos & Manning, 2007).

Nevertheless, in general, ICT is believed to increase the productivity. ICT's impact on productivity has been estimated with the help of log-linearizing Cobb-Douglas production function as below (Brynjolfsson & Hitt, 2003; Cardona et al., 2013):

$$lnQ_{it} = \beta_1 lnC_{it} + \beta_2 lnK_{it} + \beta_3 lnL_{it} + controls + \epsilon_{it} \quad \textbf{(2.2)}$$

Where Q represents value added of a firm or industry (or GDP for country studies); C is ICT capital; K is non-ICT capital; and L is labour input. The index i stands for the observational unit (could be a country, an industry, or a firm, depending on level of aggregation), while t represents the time period. The impact of ICT to output is represented by the variable β_1, which is defined as the output elasticity of ICT. In the usual modified Cobb-Douglas specification, this effect β_1 is measured as a percentage change, meaning that β_1 indicates how much output would increase if ICT investment were raised by one per cent (Cardona et al., 2013).

However, increase in productivity does not necessarily mean that output is increased; it is also possible that industries need less labour to produce a given amount of output. A study by Acemoglu, Autor, Dorn, Hanson, and Price (2014) indicates that the rise of productivity in the IT-intensive manufacturing industry in the U.S. is caused more by a rapid decline in employment than by an increase in output. This result might confirm the view that the advance of ICT allows the machines to take over works from human employees (Brynjolfsson & McAfee, 2011). Moreover, the number of jobs that can be taken over by the machines are increasing, not only the physical works in the manufacturing sectors but also the mental works in service sectors, such as paralegals, bank tellers, and insurance appraisers (Frey & Osborne, 2013). This means that the reduction of working hours might also happen outside the manufacturing industries.

The wider application of computerization in the service sectors, including health care, financial services, human resource management, and customer relations management is investigated recently by Simon Head (2014). These sectors, which is originally characterized by a complex relationship between human agents are now being automated away by standardizing the processes and translating them into specific rules (thus transforming part of the works into 'routine' activities), and let them be performed by computers to increase workers' productivity. This practice, however, in the end may reduce human's judgment by offload the decision making process to the machines. The applications are wide in practice, from deciding to hire future employees, estimating the credit worthiness of a potential borrower in a financial intermediary, or judging the necessity of a doctors' treatment to their patients (Head, 2014). The result of this practice is a degeneration effect, in which we may trust the decision of the machines so much, that we sacrifice our capability to think and judge (Carr, 2014).

The trend and possibility of computerization in the service sectors can be investigated by looking at the nature of human interaction in different kinds of service industries. Lakshmanan (1989) categorizes the service sectors into three categories based on the degree of producers-consumers interaction:

1. Service dispensing activities.

   This category is characterized by a minimal customer involvement. The service provider is less involved in the production and more in dispensing them. The customer needs are well defined, thus the activities can be standardized easily. As a result, many works in the industries of this category can also be automated like in the goods production sectors. The examples of services industry in this category are retail, wholesale, and telecommunications.

2. Task-interactive services.

   This category is characterized by a moderate to high degree of uncertainty. The technologies to solve the problems are known, but the uniqueness of the client needs requires additional process of information before the service can be delivered. The dominant use of ICT in this category is not to automate the tasks, but to complement the information processing activities. This category includes accounting, engineering and architectural firms, advertising, financial, legal and marketing services.

3. Personal interactive services.

   The interaction between the producers and the consumers of this type of services are dynamic and complex. The consumers might unaware of their problems and solutions, so the service providers have to interact with the consumers to first collect the clients' requirement before delivering the services. For instance, a doctor needs to examine his patients before he can decide the correct treatment. Another examples of such services in this category are psychological consulting, welfare agencies, education, etc.

Therefore, the possibility of automation in the service industry is most likely to happen in the 'service dispensing activities'. As a result, the number of working hours in this sectors may also collapse just as the working hours in the goods production sectors. Therefore, the workers may need to find another jobs in the other sectors. However, as the capability of computers also increases over time, it is possible that the number of works in the task-interactive and personal interactive services will also collapse. Consequently, the obviated workers may need to find works in other fields, or the unemployment will increase.

2.4 Impact of ICT on the Wage Rate and Wage Inequality

ICT capabilities to replace several kinds of work may transform the demand for specific labours and also influence the compensation that is received by the workers. A decline the relative price of production goods, including the ICT, may increase the incentives of the firms owner to replace human workers with machines, which will decline the labour share of income (Karabarbounis & Neiman, 2014).

The impact of ICT on the workers' compensation can be related to the degree of substitution and complementarity between ICT and the type of occupations performed by the workers. There are two possible explanations of how ICT might influence the wage of workers. First is the skill-biased technical change hypothesis, which states that technology increases the demand for high-skill workers while reducing the demand for low-skill workers (Sanders, 2004). The second explanation is the task-biased technical change hypothesis, which states that ICT influence the labour demand based on the degree of routine tasks performed, rather than the skill level that is needed to perform the job (Autor et al., 2003). In the latter hypothesis, the demand and wages of some low-skill occupations that involves many non-routine tasks may also increase, because it is hard to be automated, thus is not obviated by the use of ICT. In both cases, the unbalance effect of ICT to workers' wage will create a polarization between the workers, and increase the wage inequality.

The wage inequality can actually be explained by various reasons beside the bias of technology. For instance, Acemoglu (2002) identified three main reasons for it. First, changes in the labour market institutions, such as reducing power of the labour market unions, causes the decline in the wages of labour in manufacturing sectors and increasing the wage inequality. Second, international trade with the less-developed countries which supply cheaper low-skill workers can push the wage of low-skill workers in the United States down. Third, the change in the wage structure is caused by an organizational change within the firms, which affected the way firms and workers match. However, he argues that these three factors only have limited direct effect to the wage structure. Instead, he suggests that the direct effect on the wage inequality comes from the technical change which is influenced by the interaction of these three factors.

There are two conclusions of Acemoglu's paper, which may explain how the technical change affected the wage inequality. First, the technical change in the US is skill-biased: it affected the demand in the labour market, which favours high-skill workers and increase the gap between the wage of high-skill and low-skill workers. Second, the increased supply of high-skill labour is also induced the development of new skill-complementary technology. In other words, the skill-biased technical change has a positive feedback to the technology development itself.

However, a study by Bernardo S. Blum (2008) shows that the skill biased technical change might not provide full explanation about the effect of technology on the wage inequality. He argued that in the period of 1970-1996 the effect of skill-biased technical change is relatively small, and further argued that the main driver behind the increase in the wage premium is the changes in the sectoral composition of the economy. He based this on the fact that in the late 1970s there was rise in the service sectors relative to the other sectors, coincidently at the time when the wage gap starts to increase. There was capital reallocation from the manufacturing sectors to the service, retail, and wholesale trade sectors, which he claimed to be accounted for about 60% of the widening of the wage premium observed between 1970 and 1996. However, Blum did not collaborate further to explain the driver behind such changes.

The changes in the economy sectoral composition, as explained by Blum (2008), might be explained by the tasks-biased technical change hypothesis. The hypothesis states that the use of ICT is complementary to a non-routine task (which is larger in the service sectors), while substitutes the routine task (which is dominant in the manufacturing sectors). This hypothesis is first proposed by Autor, Levy, and Murnane (2003), who argue that a rapid adoption of computer technology changes the tasks performed by workers at their jobs and ultimately the demand for human skills.

Furthermore, Autor, Levy, and Murnane divide the jobs into two main categories, based on their dominant tasks: routine and non-routine. Next, they divide them into five sub-categories: (1) routine manual; (2) routine cognitive; (3) non-routine cognitive; (4) non-routine interpersonal; and (5) non-routine manual. Their study reveals three patterns which support their task-biased technical change hypothesis. First, the demand for routine cognitive tasks (such as bookkeeping and clerical work) and routine manual tasks (such as repetitive production proves) is declining from 1980, indicated that this type of tasks is substitutable with the use of computer. Second, the demand for labours that perform the non-routine cognitive and the non-routine interpersonal tasks is constantly increasing. This type of tasks requires problem-solving, intuition, persuasion, and creativity. These occupations are typically done by the high-skill workers, so they may get benefit by the use of ICT. Finally, the demand for non-routine manual tasks (such as drivers, or room cleaning) which are typically done by low-skilled labour seems to have not impacted by the use of ICT. The long-standing decline in this type of jobs, which is evident since 1960s, is decelerated after 1990, indicated that the use of ICT may shift the labour demand from the jobs involving routine tasks into the jobs with non-routine manual tasks.

Autor later updated his study in 2013, and the result still shows that demand for jobs with routine tasks still continue to decline while decline for jobs with non-routine manual tasks keeps decelerating. However, this updated study also shows that the demand for the non-routine cognitive analytical and the interpersonal jobs start stagnating, which indicates that ICT might be able to replace the non-routine occupations as well (Autor & Price, 2013).

The evidence for the task-biased technical change is also apparent in a study by Van Reenen (2011), which shows that the distribution of jobs is becoming more polarized with jobs in the middle third of the wage distribution shrinking and those in the bottom and the top third rising. The demand for the middle-skill workers fell more rapidly in industries with greater ICT capital intensity, while the demand for the low-skill workers remain unaffected. This study is also consistent with the study by Blum (2008), and may explain the shifts in labour market toward the service industry, which is dominated by non-routine tasks. In summary, the tasks-biased technical change hypothesis is more convincing in explaining the impact of ICT to wage inequality than the skill-biased technical change hypothesis. The way ICT influences the labour demand of a job will depend on the extent it can be replaced by ICT, instead of the skill of workers that is performing the job.

2.5 Chapter Conclusion

The impact of ICT on the productivity-compensation gap might be a reflection of the current techno-economic paradigm. The paradigm brings the best-practice for arranging the production factors, which results in the increase in labour productivity. When labour productivity increase, two options may be undertaken. First is to produce the same number of output with fewer hours of labour. Second is to produce more output at the same hours of labour. Under current techno-economic paradigm, the gain resulted from the increase in labour productivity – which one may called the productivity dividend –will most likely be transformed into another works (Naastepad & Mulder, 2015). Following this paradigm, the gain resulted from the increase in labour productivity – which one may called the productivity dividend – will be transformed into another works. At the same time, however, the technological revolution rearranges the works needed in the production process. Consequently, workers' choice of occupations and their compensation may also be compromised. The next challenge, therefore, is whether this paradigm can be expanding by re-evaluate our definition of 'economic' value, and whether there are another uses of the productivity dividend.

While ICT has been considered to play an important role in creating more output, the absolute impact on the society as a whole is rarely discussed– that is, the technological mass-unemployment and marginalization that may take place if we only recognize the role of technology, workers, and capital to maximize profit. If, within the current techno-economic paradigm, an increase in the service sectors, including the low-skill service sectors, is considered as the 'best-practice' arrangement of the production factors, does it mean that it is also the best possible societal option? Are other techno-economic paradigms thinkable and possible in practice? This might require a widening of our understanding of the purpose of the economy and of economic actors. Can the capital that is freed by the technological revolution be used to support new purposes in life of those whose labour has become redundant? Surely, such questions will take us beyond the current techno-economic paradigm. Conventional and novel thinking regarding the purpose of freed capital will be reviewed in the next section.

3. PRODUCTIVITY DIVIDEND AND THE THEORY OF VALUE

This chapter will discuss possible uses of the productivity dividend by reviewing perspectives on value in different economic theories. Two questions will be addressed as a starting point. First, what do we value? Second, how is value created? For the purpose of this thesis, regarding the second question we will also be mainly concerned with the question: what is the role of technology in the value creation? A final question then will be addressed: what will be the significance of the productivity dividend to realize this value? Most economic perspectives have focused on the creation of goods that are valuable to the extent that they meet consumption needs. Any productivity dividend arising in the economic process is then used to increase this value unceasingly. However, according to some thinkers, there are limits to the material existence needs. Therefore one may ask, is there another counterpart of that portion of the productivity dividend that is not required for meeting material existence needs? The answer can only be found by revisiting our conception of value, which will be the main focus of this chapter.

3.1 Classical (Cost-of-Production) The Theory of Value

For Adam Smith (as well as other classical economists such as David Ricardo) the economic problem was to increase the 'wealth of nations'. Smith's main concern was to understand the nature and causes of national wealth. In analysing how wealth is created, Adam Smith takes a historical view. Adam Smith (1776) distinguishes three historical modes of production and three corresponding ways in which value is created (Tsoulfidis, 2010).

In a primitive society, where there is neither capital nor labour employed to produce goods, everyone produces his goods for his own consumption. The surplus of goods that is not consumed then can be exchanged for other goods from another producers, who also have surplus. The relative prices of goods under this condition therefore are equal to the quantities of labour that are spent in their production. This condition can be expressed formally as below:

$$\frac{P_1}{P_2} = \frac{L_1}{L_2}$$

where P_1 and P_2 are the prices of good 1 and good 2, and L_1 and L_2 are the labour quantities that are needed in their production. For instance, if the production of good 1 needs one hour of work while good 2 needs two hours of work, then the price of good 2 will be twice that of good 1. This view that puts labour quantity as the source of value is known as the labour theory of value. However, this first view is relevant only for societies in which everyone produces his own goods, which differs from the modern production method, in which outside workers are employed in the production activities and need to be paid. To understand how the value is created in such condition, we need to look at Smith's second and third views of the theory of value.

Smith's second mode of production and value creation relates to societies where one can employ workers to produce goods (Tsoulfidis, 2010). In this society, the value of goods is equal to the amount of labour needed to produce the goods. This theory is known as the labour-commanded theory of value. This second view, similar with the first one, also equates the value of a commodity to the labour quantities needed in its production. However, in the further stages of development, the production also involves other factors, in particular land and capital, hence the value of a commodity does not entirely accrue to the workers.

Smith's theory of value for the third stage of economic development equates the value of a commodity to three components: the wages of the labourers, the rent on the land, and the profit on the capital employed in producing and bringing the commodity to the market (Tsoulfidis, 2010). At this more advanced stages of development, labour is no longer homogeneous, but specialised in different tasks. The sum of the three components – land, labour and capital − constitutes a 'natural price'. The actual price of a commodity, however, is called a market price and might be above, below, or exactly the same with its natural price.

Thus, for Adam Smith, the source of economic value in modern society is specialisation – between human beings, and between human beings and machines. Specialisation is aided by technological progress, in terms of ever-improving machine technology as well as in terms of ever cleverer organisation of work. For Adam Smith, however, the creation of wealth is part and parcel of a historical evolution of modes of production and the human being. Although in *The Wealth of Nations* Smith is mainly concerned with the creation of economic wealth, *The Theory of*

Moral Sentiments places wealth creation within a larger context of (the evolution of) morality (Bharadwaj, 1989).

Karl Marx disagrees with Smith's third mode of production and acknowledges the labour theory of value instead. He argues that labour is the actual source of value, and value can be equated with the quantity of labour employed in producing the commodities. Profit, or the surplus value, is created by taking aside a portion of the commodities' value which truly belong to the workers.

Following Aristotle, who distinguished *use value* and *exchange value*, Marx (1867) constructed a dual nature of labour that is contained in the commodities. First, the concrete character of labour, which creates the *use value* of a commodity, or a value that gives useful properties to satisfy human needs. Second, the abstract character of labour, that is a labour without specific characteristic, that creates the actual value of a commodity. This value is realized in money form through an exchange and constitutes the *exchange value*.

The value of a commodity is also equal to the quantity of the labour time that is spent in its production, or what Marx defined as the socially necessary labour time. This socially necessary labour time tends to be decrease with the use of technology. Consequently, the firm's owner can produce more output with the same amount of working time. The difference between the actual hours worked and the socially necessary labour time is called surplus labour time, and its money expression is called the surplus value. This surplus value is then claimed by the capitalists as a contribution of the capital they own. To Marx, however, capital is also the result of the past labour, thus the capitalist has no justified claim to the surplus value.

Furthermore, Marx criticizes the nature of capitalist production for its orientation towards extraction of the maximum profit in the production activities. The technology plays role in this mode of production for reducing the socially necessary labour time and extracting more surplus value, or profit. Furthermore, Marx sees that there is a tendency for this rate of profit to fall. This tendency therefore will lead to an effort to increase the rate of profit by any means, including more exploitation of workers in the production process. In Marx perspective, therefore, technology may lead to alienation of the workers.

In summary, for Karl Marx, labour (the number of labour hours) is the source of value, and surplus value is created by exploitation of the workers. For Marx, similar with Adam Smith, wealth creation cannot be seen independently of the evolution of society and the human being. A single-minded focus on wealth creation can cause 'alienation' and hamper healthy human development. The way the capitalist system organizes labour makes people work for money and themselves, rather than for one's own and the others' development. Although Marx is often associated with the overthrow of capitalism and the establishment of the socialist state, the primary thing for Marx appears to be the unfolding and development of the individual, which Marx, however, could not envision as part of a capitalist system.

3.2 Neoclassical Perspective

In contrast with the classical (cost-of-production) theory of value, the neoclassical perspective sees value as a result of exchange. The price is not determined by the sum of its cost of production, but it is determined in the market, as an equilibrium between the supply and demand. In other words, from this perspective values of a good is measured as its capability to satisfy our wants or utility. Consequently, the productivity dividend will more likely be used to expand the production.

In contrast with Marx, however, neoclassical perspective assumes that the distribution of income reflects the marginal productivity of each production factors. The capital, therefore, may receive compensation for their contribution in the production. Consequently, the capital owners can also have claims to the profit. The advance of technology can cut the cost of production and creating more profit that initially go to the shareholders. Under the perfect competition, the profit will be passed on to the consumers via lower output prices. The result is the so-called 'consumer surplus', which is a monetary gain obtained by consumers because they will be able to purchase a product for a price that is less than the highest price that they would be willing to pay. In neoclassical assumption, therefore, the productivity dividend will be used to expand our consumption, assuming that it will give the most social utility. In oligopolistic conditions, however, the profit often stays within firms and ends up in financial markets (Palma, 2009).

Despite the assumption of a perfect market, neoclassical economists believe that in reality the market is imperfect, and might not be able to bring the balance by the disruption of technology. They may have concerns about how the smart machines reduce the workers' income, especially the income of the low-skill workers, and in turn lower their savings (Sachs & Kotlikoff, 2012). Since from the neoclassical 'loanable funds' perspective[2] savings are the source of finance of the machines, a reduction in savings will reduce the investment in machines and therefore slows the economic growth. The solution for this, therefore, is to shift some incomes from the machines and the high-skill workers towards the low-skill workers so they can be saved and reinvested in the future period, and keep the economy grows (Benzell et al., 2015; Sachs & Kotlikoff, 2012).

[2] In the neoclassical model, the source of finance for investment is savings (rather than credit created by banks, as it is in a modern bank-based economy).

Furthermore, Benzell et al. (2015) in their study discuss the economics of human replacement, which illustrates the possibilities when some occupations are taken over by some machines. Their prediction can be seen as an extreme version of the task-biased technical change hypothesis (Autor et al., 2003) in which the smart-machines are replacing the routine occupations, thus totally obviates the need of human labour in the goods production. As a result, human workers will be working non-routine occupations in the service sectors. Jobs polarization will occur, in which the high-tech workers will be working as programmers who write codes for the smart-machines, while the low-tech workers will be working in the other service sectors[3].

When the goods production become more dependent towards the smart-machines, high-tech workers will have increasing compensation, as more high-tech workers are attracted towards the code-writing occupation. The wage of low-tech workers will rise or fall, depending on the complementary level between the high-tech workers and low-tech workers in the service sector. However, when the code become more efficient, the demand for high-tech workers in code-writing occupation will also decreases. As a result, the high-tech workers will have to find jobs in the services sectors, and their compensation will fall. The cut in workers income will lead to reduction in savings which, on neoclassical assumption of saving-determined investment, reduces investment in the capital stock. As a result, the output will decline in the long-run and lead to long-term misery (Sachs & Kotlikoff, 2012).

The solutions to this problem therefore is by shifting some incomes of the high-tech workers to the low-tech workers. This approach will keep the capital stocks from falling and reducing the output in the long-run.

While this view recognizes the problem for declining workers income because of the use of ICT, it only has concerns with how it might lead to the decline in the investment of capital in the future generations. The productivity dividend is used to expanding the production, not necessarily to find a new purpose for the potentially obviated workers. It is assumed that by expanding the production, the workers will eventually find a new job, for instance in a low-skill service works which currently cannot be substituted by the machines. These jobs might offer lower wages, but the distribution of income policy will keep the economic growth stable and improve the utility of all workers in the long run.

To sum up, from the neoclassical perspective, the capital is seen as a tool to achieve economic growth, thus it does not give insight how it can be used to find the new purposes for the

[3] The terms high-tech and low-tech refers to the ability of workers related to the smart machines, not necessarily the degree of education. High-skill workers are programmer, analytical people, while low-skill workers are the mental workers that use their 'right brain', such as lawyer, painter, etc.

obviated workers. This is because in the neoclassical perspective, value is found only in consumption. Therefore, the role of workers in the economy, along with the capital, is limited only as the production factors. Neoclassical economics does not have a view on the end or purpose of a human life other than consumption. The human being is a utility maximizer and utility is measured in terms of consumption. Therefore, both capital and labour will be allocated towards the production activity which can bring maximum utility in society. This perspective makes the discussion for the role of capital to help human beings expand their capacities rather limited from the neoclassical perspective. Moreover, the neoclassical perspective often assumes the technological progress as determined exogenously. It does not considers the source of technological progress, which can be thought as the product of human creativity and knowledge. As a result, the role of capital for funding the source of technological progress, the knowledge accumulation, is often neglected. In response to this, several researchers have tried to endogenize the process of technical change and emphasize the importance of allocating the capital to the knowledge generation process, such as research and development, education, and entrepreneurship (Acemoglu, 1998; Romer, 1990). However, in these models, knowledge serves only utility maximisation. The idea of knowledge as the source of technological progress will be discussed further in the next section.

3.3 Schumpeterian Perspective

One of the critiques of the neoclassical perspective is that it treats technological progress as exogenous, or being determined outside the system. It ignores the contribution of human knowledge to the technological progress. The importance of knowledge in the technological progress is later stressed by several researchers, such as Romer (1990) and Lucas (1993). Lucas argues that physical capital accumulation plays an essential but decidedly subsidiary role. The main engine of growth is the accumulation of knowledge, and it takes place in schools, in research organizations, and in the course of producing goods and engaging in trades. The knowledge accumulation will have positive effect on the productivity both by the creation of new technology and the adoption of new technology (Zeira, 2007). In this literature, 'knowledge' is called 'human capital'. However, isn't all capital (embodied) human knowledge? We will take up this point in Section 3.4.

The idea of knowledge and creativity as the engine of growth can be tracked back to Joseph Schumpeter (1942) who introduce the term of 'creative destruction'. In this process, the accumulation of knowledge contributes to economic growth through new innovation which obsolete the old skills, goods, markets, and manufacturing processes (Aghion & Howitt, 1990).

Rather than the optimal allocation of the production factors, this perspective emphasize the importance of ideas, innovations, and entrepreneurships as the engine of growth. Therefore, the capital should not only be invested in the production of goods that uses mature technology but should also be directed towards research activities for a new technology opportunity. However, the investment in new technology might not give profit immediately, thus it requires a long time commitment (Mazzucato & Perez, 2014).

Guided by the same motive of material progress, Schumpeterian perspective will also use the productivity dividend to expand the production. However, this perspective highlights the importance of idea and creativity as the source of value. From a Schumpeterian perspective, therefore, the allocation of capital should not be guided by profit maximization only, as novel technology might not promise immediate profit. Thus, investments need a long-term commitment to take the risk (Mazzucato & Perez, 2014). This perspective also stress the importance of human knowledge and creativity as the driver of change. Innovations will open up new works through the entrepreneurship. This can be described as the process of creative destruction: technological revolution, such as ICT, obviates labour but opens up new opportunities, and the people whose work is obviated by technological revolution may find new jobs in the new settings.

However, the process of creative destruction implies that the technical change may affect the division of rewards, both between capital and labour and between high-skill and low-skill workers (Brynjolfsson & McAfee, 2011). The general purpose nature of the GPT allows ICT to be used in a wide range of sectors in the economy. As a result, its impact can be seen on nearly every occupations and industries. It is not only affecting the methods of production but also changing the relationship between labour and organization (McConnell, 1996).

Furthermore, if the current techno-economic paradigm is understand as the only way guiding the use of workers, the production may keep expanding without considering the social impact. First, more works will be obviated, not only the low-skill works but also the high-skill ones (Frey & Osborne, 2013). Second, it can also impact the human mind, for instance, imposing the de-skilling of workers (Carr, 2014; Head, 2014).

Even though the neoclassical perspective and the Schumpeterian perspective have different idea for the use for capital, both are geared towards the same value: economic growth. Both put economic growth as the goal of economic activities, and discuss the best way to reach the goal. Schumpeterian perspective and neoclassical new growth theory acknowledge the close relationship between human capacities and capital. Schumpeterian and neoclassical new growth theory, however, only recognise human knowledge – or, more generally, human capacities − in the context of improving material production activities, such as reducing cost and creating additional growth. The role of human beings is limited to their contribution to the particular techno-economic paradigm as it is currently understood. The people whose work is obviated by the techno-economic paradigm (i.e. people who cannot find their use in the production activities which follows the 'best-practice') will have to face unemployment. Within the prevailing techno-economic paradigm, this unemployment is explained with reference to qualities (or lack thereof) of workers, such as their skill levels. From a different perspective, however, the unemployment resulting from the obviation of labour by technology can be understood as the inability of the prevailing culture to find purposes in life outside the material realm. This is a consequence of the materialist conception of progress professed by conventional economic theories (Naastepad & Mulder, 2015). What may be required is to set a broader goal for human life than the normative foundation of conventional economic theories, which is utility maximization.

3.4 Twin Value of Capital

In Economic Possibilities for Our Grandchildren, Keynes (1930) challenges the purpose of economics to provide beyond material needs. He assumes that in one hundred years, the rise in living standard will increase eightfold, and that human will only need to work only fifteen hours a week to produce goods needed to live. The next problem that humanity will face is "how to occupy the leisure, which science have won for them, to live wisely and agreeably and well" (Keynes, 1930).

On one hand, we may already in track with what Keynes has predicted: the world income per capita has increased fourfold since 1930 (Maddison, 2003; Skidelsky & Skidelsky, 2012). On the other hand, Keynes was wrong to assume that the increase in the income per capita will free up some works that enable people to the pursuit other goal in life. People choose to trade the leisure for higher income, and the working hours does not decreased dramatically as what Keynes has predicted (Skidelsky, 2010).

Keynes therefore may have mistaken that the rise in living standards will encourage people to pursue other goal beyond satisfaction of material needs. The mainstream economic perspective allows wealth to be accumulated without ends. In Aristotelian view, however, wealth is seen as means to achieve something better that can lead to a good life (Skidelsky & Skidelsky, 2012). In this perspective, wealth is still needed to sustain life. However, material needs are limited; the real purpose of human beings is happiness, which for Aristotle comes from exercising virtue, not by pursuing pleasure. Our desires then need to be transformed to be virtuous, through knowledge and the incorporation of character (Naastepad & Houghton Budd, 2015). Economics, therefore, should serve additional goal: generating capital that will enable people to realise their life purpose and be able to do so using character (Naastepad & Houghton Budd, 2015).

The justification for the purpose of capital to develop human capacities may not be immediately clear if the neoclassical assumption of marginal productivity is accepted. However, the link may be established if we examined various channel through which capital is formed. Wilken (1982) distinguished six sources of capital formation: (1) the capital formation in the production sphere, resulted from the increase in productivity; (2) the capital formation in the consumption sphere, resulted from the voluntary savings by the consumers; (3) the capital formation in the financial sphere, resulted from the creation of money by the commercial bank; (4) the capital formation through a pricing policy, which force consumers to spend a larger portion of their income in the same product (forced savings); (5) the capital formation through withholding of a necessary income formation, for example by paying inadequate wages to the workers; and (6) the capital formation through the sale of factitious goods such as land or property, and also other deals linked with the speculative accumulation of financial capital. Out of this six sources, the first three sources are genuinely justified because it conform to economic necessity; the other three were unjustified. The three justified source, in turn, can be linked to human creativity and inventiveness, or in general, human capacities (Houghton Budd & Naastepad, 2015).

The twin value of capital theory recognizes two purposes of capital: (1) financing the production of goods required to sustain livelihood, and (2) serving the building of character (in the Aristotelian sense) and the realisation by each individual of his or her life purpose (using character) (Naastepad & Houghton Budd, 2015). The innovation that is created from the human creativities is not limited only to improve the material needs, but also to improve the non-material needs. The obviation of labour by ICT, which replaces routine work in the production economy, allows people to pursue mental work, which relies on the intellectual rather than physical action. These works, however, should not only be pursued towards the narrow motive of utility maximization, but should also allow the fulfilment of higher goals through the development of higher capacities − including morality, creativity, and character, or a self-actualization that includes responsibility for others.

In contrast with the Schumpeterian perspective, the twin value of capital perspective recognize the development of human capacities as both the source and the destination of capital. In this perspective, therefore, the development of human capacity is encouraged for its own sake, not only as it potential to achieve economic growth. Within this perspective, the productivity dividend may not all be transformed into work for the sake of generating more output. Instead, the dividend should make ways for people to pursue another activities that can develop their capacities. The role of economic here is to generate goods and services that is needed to sustain a life. However, this perspective sees that there is a limit in the material needed to sustain the life, thus the economic growth could not be the end goal that is pursued unceasingly. The profit, or capital, that is generated in the economic sphere should be set aside to develop human capacities, which in this perspective is recognized as the original source of capital.

3.5 Chapter Conclusion

The automation introduced by the advance of ICT can replace routine jobs and obviates the need for human workers in the routine occupations. This process also frees money or capital that was previously used to pay compensations for the workers. Can this capital be guided towards activities that will find new purposes for the people whose work is obviated by technology?

The neoclassical perspective does not provide insights that can guide the capital towards this purpose. Instead, the role of capital is realized only as a production factor. Within this perspective, new jobs can be created and full employment can be achieved by allocating capital towards expanding production. However, since production is increasingly jobless (as a result of ICT), this strategy appears to be running against self-created limits. The Schumpeterian perspective guides the use of capital towards entrepreneurial ideas. Innovation by entrepreneurs will create new work, both in the research fields and in innovating businesses. However, here, too, the problem of jobless growth makes itself felt. Moreover, the materialistic motive behind these two perspectives tends to neglect the impact of ICT on society.

The twin value of capital recognises two purposes of capital, as the financier of physical production and as enabler of human capacity. Within this perspective, capital would be allocated not only towards materialistic purpose but also for the development of human character and capabilities, which will enable individuals to realize their life purpose, which in this perspective goes beyond utility maximisation. The relationship between the development of desired human qualities and the financial markets has not been systematically investigated. However, unless moral qualities and creative capacities are financed, they cannot unfold (Naastepad & Houghton Budd, 2015). Just as the investment in new technology opportunity that needs a long-term commitment, the investment in the character development also needs one, even greater.

4. EMPIRICAL ANALYSIS

This chapter investigates the impact of ICT on the critical factors of the productivity-compensation gap in the U.S., which are output, hours worked, hourly wage rate, and intra-wage inequality. There are two main sources of the data that is used for the analysis. The first source is the EU KLEMS database, which contains the aggregated data of ICT and non-ICT capital service, working hours, and labour compensation. The second source is the Current Population Survey (CPS) database, which is a monthly survey of households conducted by the Bureau of Labor Statistics. It contains individuals' labour characteristics information of the United States, including types of industry, occupation types, hours worked, and hourly wage rate. First, the treatment for the data and the research methodology will be explained. After that, the impact of ICT on the productivity-compensation gap will be discussed.

4.1 Data Collection

4.1.1 EU KLEMS Database

EU KLEMS database contains measures of economic growth, productivity, employment creation, capital formation and technological change at the industry level for 25 European countries, Japan, and the U.S. for the period from 1970 onwards (O'Mahony & Timmer, 2009). The industry aggregation in EU KLEMS database follows the International Standard Industrial Classification of All Economic Activities (ISIC). The latest version of ISIC is ISIC v.4, which is valid starting from 2008. However, this thesis utilize the data from EU KLEMS in March 2008 release, which provides the most extended ranges of variables from the period 1970 to 2005, but still uses the ISIC v.3 classification. The analysis in this thesis is done at the industry level, which follow the ISIC v.3 classification, as can be seen in table 4.1.

EU KLEMS database measures capital and labour inputs as capital service and labour service. The capital service is defined as a flow of productive services from the cumulative stock of past investments. Conceptually, capital services reflect a quantity, or physical concept, not to price concept of capital. For example, service flows of an office building are the protection against rain, the comfort and storage services that the building provides to personnel during a given period (Schreyer, 2004).

Table 4.1 EU KLEMS Industry Categories

Industry Code	Industry Categories
A	Agriculture, hunting and forestry
B	Fishing
C	Mining and quarrying
D	Manufacturing
E	Electricity, gas and water supply
F	Construction
G	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods
H	Hotels and restaurants
I	Transport, storage and communications
J	Financial intermediation
K	Real estate, renting and business activities
L	Public administration and defence; compulsory social security
M	Education
N	Health and social work
O	Other community, social and personal service activities
P	Private households with employed persons
Q	Extra-territorial organizations and bodies

However, the data for ICT capital service in the EU KLEMS database are not completely available for all industries. The ICT capital service data in industry P and Q are missing, while the ICT capital service data for industry A and B are only available collectively, not separately. Therefore, in this thesis, the analysis is done by dropping the industry P and Q, and combining the industry A and B.

The measures of input in the EU KLEMS database covers several categories: capital (K), labour (L), energy (E), material (M) and service inputs (S). Two output measurements are provide: gross output and value added. The gross output represents the market value of all goods and services that are produced, while the value added is the gross output minus the intermediate inputs, which are the E, M, S inputs. In other words, the value added represents the output in relation with the capital and labour input only. Since this thesis mainly focuses on the relation between ICT capitals and labour, it will use value added as the measurement of the output.

EU KLEMS categorized assets into several categories as seen in table 4.2, and make distinction between ICT and Non-ICT assets, which constitute the ICT and Non-ICT capital stock. Out of these assets types, three types of assets are considered as ICT assets: Computing equipment (IT), Communications equipment (CT), and Software (Soft).

Table 4.2 Assets Category in the EU KLEMS Database

Assets Type	**Code**
Total investment	GFCF
Total tangible assets	GFCFT
Total construction	Con
Residential structures	Rstruc
Total non-residential investment	OCon
Non-residential structures	NRStruc
Infrastructure	Infra
Machinery and equipment	MaEq
Transport equipment	TraEq
Machinery and other equipment	Mach
Computing equipment	IT
Communications equipment	CT
Other machinery and equipment	OMach
Other tangible assets	OGFCFT
Products of agriculture and forestry	Agri
Other products	Oth
Total Intangibles	GFCFI
Software	Soft
Other intangibles	OGFCFI

The capital services is estimated from the capital stocks of particular assets (Timmer et al., 2007). The capital stock $A_{k,t}$ of a particular asset k at a given time t is given as follows:

$$A_{k,t} = \sum_{\tau=0}^{\infty}(1-\delta_k)^{\tau} I_{k,t-\tau} = (1-\delta_k)A_{k,t-1} + I_{k,t} \tag{4.1}$$

where δ_k is the depreciation rate of asset k and $I_{k,t}$ is the investment of asset k at period t. It is further assumed that the flow of capital service of each type of assets is proportional to its capital stock, independent of time. Hence the corresponding index of capital input K is a translog quantity index of individual assets in a particular industry, and is shown in equation 4.2:

$$\Delta lnK_t = \sum_{l} \bar{v}_{k,t} \Delta lnA_{k,t} \tag{4.2}$$

$\bar{v}_{k,t}$ is the weight of the capital assets, which is determined by its shares of value in total capital compensation, as defined in equation 4.3 and 4.4 below:

$$v_{k,t} = \frac{P_{kt}^{K} A_{kt}}{\sum_l P_{kt}^{K} A_{kt}} \quad \textbf{(4.3)}$$

$$\bar{v}_{k,t} = \frac{v_{k,t} - v_{k,t-1}}{2} \quad \textbf{(4.4)}$$

where P_{kt}^{K} is the price of capital service from asset type k.

Similarly, EU KLEMS measure labour input as services that are delivered by a unit of labour, not only as the number of employees or hours worked. It takes into account the heterogeneity of the labour forces, such as high-skill and low-skill workers, in analyzing the contribution of labour to output growth. It is assumed that the flow of labour service for each labour type is proportional to hours worked, and that workers receive compensation that is equal to their marginal productivity. Therefore, the labour service inputs L at a time t is measured as in equation 4.5 below:

$$\Delta lnL_t = \sum_l \bar{v}_{l,t} \Delta lnH_{l,t} \quad \textbf{(4.5)}$$

where $H_{l,t}$ is hours worked by labour of type l at time t. It is assumed that the labour service is proportional to the hours worked which is weighted by the shares of compensation of labour type l in all labour types. The weight of each labour type $\bar{v}_{l,t}$ is calculated as shown in equation 4.6 and 4.7 below:

$$v_{l,t} = \frac{P_{lt}^{L} H_{lt}}{\sum_l P_{lt}^{L} H_{lt}} \quad \textbf{(4.6)}$$

$$\bar{v}_{l,t} = \frac{v_{l,t} - v_{l,t-1}}{2} \quad \textbf{(4.7)}$$

where P_{lt}^{L} is the price of one hour work of labour type l.

4.1.2 CPS Database

The EU KLEMS database does not provide detailed information for the hourly wage of each individuals and their type of occupations. Consequently, the analysis for calculating the intra-wage inequality is not possible by only using the data from the EU KLEMS database. Therefore, this thesis utilizes another datasets from the CPS database. CPS is a monthly survey of households in the U.S. which is conducted by the Bureau of Labor Statistics. It contains information of the labour characteristics of the U.S., which includes industry types, occupation types, hours worked, and hourly wage rate.

The CPS data for this thesis are collected from The Center for Economic and Policy Research (CEPR) website. The CEPR's version of the CPS data are the consistent, user-friendly versions of the CPS (Center for Economic and Policy Research, 2015). Specifically, this thesis uses the CPS Outgoing Rotation Group (ORG) data, which provides the information of usual weekly earnings and weekly hours of the U.S. workers. The ORG data that are collected from the CEPR website has already been adjusted to provide a consistent and robust hourly wage series, by using several treatments as described below (Schmitt, 2002):

1. Adjustment for the top-coded individuals

   The original CPS data are top-coded for the workers who have a very high earnings to ensure anonymity. For instance, a worker who had a weekly earnings more than $999 in the period of 1989-1997 is reported to have $999 weekly earnings. This approach may lower the mean and variance of the wage data relative to the true mean and variance. To treat this issue, the mean of earnings above the top-code are estimated and are assigned to all top-coded observations. The estimation is based on the assumption that the weekly earnings distribution will follow a log-normal distribution. Using this assumption, the mean for the earnings above the top-code can be estimated.

2. Trimming of outliers

   The data are trimmed for workers with very high and very low hourly wages to eliminate the problematic outliers. The CEPR version trims the data for workers with hourly wage less than $0.5 and higher than $200 (in constant 1989 dollars).

3. Imputation for workers with imprecise weekly hours

   Started from 1994, CPS allows workers to report their usual weekly hours as 'hours vary'. This creates problem for calculating the hourly wage, because it is estimated from the usual weekly earnings divided by the usual weekly hours. Therefore, the weekly hours for this condition are estimated using an ordinary least square regressions method. The usual weekly hours is estimated as a function of the respondent's age, race, education level, marital status, and immigration and naturalization status. The coefficient of this regression is then used to estimate the weekly hours for workers whose weekly hours are reported as 'hours vary'.

Finally, for the analysis in this thesis, the CPS data need to be categorized based on its skill groups and occupation type, to investigate how intra-wage inequality differs over the time and occupations, and how it can be explained by the skill-biased or the task-biased technical change hypothesis.

The task-biased technical change hypothesis claims that the demand for occupations are influenced by the degree of its substitution and complementarity with ICT. Therefore, the grouping for the occupations also needs to be based on such criteria. Autor and Dorn (Autor & Dorn, 2013) create a summary measure of Routine Task Intensity (RTI) index by occupations, using the task requirements from the fourth edition of the U.S. Department of Labor's Dictionary of Occupational Titles (DOT). The index is rising in the importance of routine tasks and declining in the importance of manual and abstract tasks. Since according to the task-biased technical change the routine occupations are more likely to be replaced by ICT, the shares of occupations with high RTI index is most likely to drop with the increase use of ICT.

The grouping for occupations in this thesis follows the classification criteria by Autor and Dorn (Autor & Dorn, 2013), which are made available to public in David Dorn's website page (http://www.ddorn.net/data.htm). Dorn also aggregate three versions of the CPS occupation codes (1980, 1990, and 2000) into a balanced panel of occupations (Dorn, 2009). The occupation groups and corresponding RTI index is shown in table 4.3 below.

Table 4.3 Workers' Occupation Groups and the corresponding RTI index

Code	Occupation Types	RTI Index
OCC1	Management/Professional/Technical/Financial Sales/Public Security Occupations	–
OCC2	Administrative Support and Retail Sales Occupations	+
OCC3	Low-skill Services Occupations	–
OCC4	Precision Production and Craft Occupations	+
OCC5	Machine Operators, Assemblers and Inspectors	+
OCC6	Transportation/Construction/Mechanics/Mining/Agricultural Occupations	–

Table 4.4 Workers' Skill Groups and the corresponding education level

EU KLEMS Skill Groups	CEPR Education Level
Low-skill	Lower than high school
Medium-skill	High school
Medium-skill	Some years of college
High-skill	College graduate
High-skill	Advance

Additionally, the data are also categorized based on the workers' skill groups. CEPR database provides five levels of workers' education. These levels of education is then used to define the workers skill group as defined by the EU KLEMS database, and is shown in table 4.4 above.

Finally, the CPS data is aggregated with the data of ICT capital service from the EU KLEMS data based on the industry in which the workers works. One problem for this aggregation is that the CPS database uses different industry classification with the EU KLEMS database, and there is no one-to-one mapping for the detailed industry codes between two databases can be found. By considering the time limitation in working this thesis, the analysis for the intra-wage inequality in this thesis is conducted based on three major industry aggregation, which are (1) Agriculture, hunting, forestry, and fishing; (2) Mining and manufacturing; and (3) Services industry. The aggregation from the EU KLEMS industries to these major industry groups used in this thesis is shown in table 4.5 below.

Table 4.5 Aggregation of EU KLEMS industry codes into three major groups

Major Industry Groups	EU KLEMS Code	EU KLEMS Industry Name
Agriculture, hunting, forestry, and fishing	A	Agriculture, hunting and forestry
	B	Fishing
Mining and manufacturing	C	Mining and quarrying
	D	Manufacturing
Service Industry	E	Electricity, gas and water supply
	F	Construction
	G	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods
	H	Hotels and restaurants
	I	Transport, storage and communications
	J	Financial intermediation
	K	Real estate, renting and business activities
	L	Public administration and defence; compulsory social security
	M	Education
	N	Health and social work
	O	Other community, social and personal service activities
	P	Private households with employed persons
	Q	Extra-territorial organizations and bodies

4.2 Descriptive Statistic

4.2.1 ICT Intensity

There are several ways to measure ICT intensity, such as the share of ICT capital stock in total capital stock, the ratio of ICT capital to output, or the ration of ICT capital to number of workers (Stiroh, 2001). The ICT intensity measurement in this thesis follows Stiroh (2001), which is described as the share of ICT capital services in total capital services and identifies how industries allocate their resources towards ICT assets. The number differs across industries, which ranges from 0.93% in the agriculture, hunting, forestry, and fishing industry to 33% in the transport, storage, and communications industry in 2005. However, all U.S. industries have been increasing their expense in ICT capital relative to the non-ICT capital for the period of 1970 to 2005, as is apparent in table 4.6 and figure 4.1 below.

Table 4.6 ICT intensity of the U.S. industries in 1970 and 2005

Code	Industry Categories	ICT Intensity (%)	
		1970	2005
A+B	Agriculture, hunting, forestry, and fishing	0.00	0.93
C	Mining and quarrying	0.01	2.05
D	Manufacturing	0.07	10.43
E	Electricity, gas and water supply	0.04	5.92
F	Construction	0.02	8.13
G	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	0.06	24.14
H	Hotels and restaurants	0.02	11.71
I	Transport, storage and communications	8.61	33.26
J	Financial intermediation	0.04	11.88
K	Real estate, renting and business activities	0.09	12.20
L	Public administration and defence; compulsory social security	0.38	12.21
M	Education	0.39	12.35
N	Health and social work	0.03	11.92
O	Other community, social and personal service activities	0.56	15.65

As shown in the figure 4.1, all industries have become more ICT intensive during the period of 1970 to 2005. This is shown by the increase of the of the ICT capital service growth index, which is calculated by taking the natural logarithmic of the ICT intensity of an industry in the particular year relative to the ICT intensity of that industry in 1970.

The industry of transport, storage, and communication (industry I) are the most ICT intensive industry in the U.S for period 1970-2005. However, during the same period other industries has increased their ICT capital service at a faster rate than the transport, storage, and communication industry. Accordingly, as apparent in the figure 4.1, the transport, storage, and communication industry become the industry with the slowest ICT intensity growth rate for period 1970-2005. Overall, figure 4.1 shows the pervasiveness of ICT in all industries of the U.S.

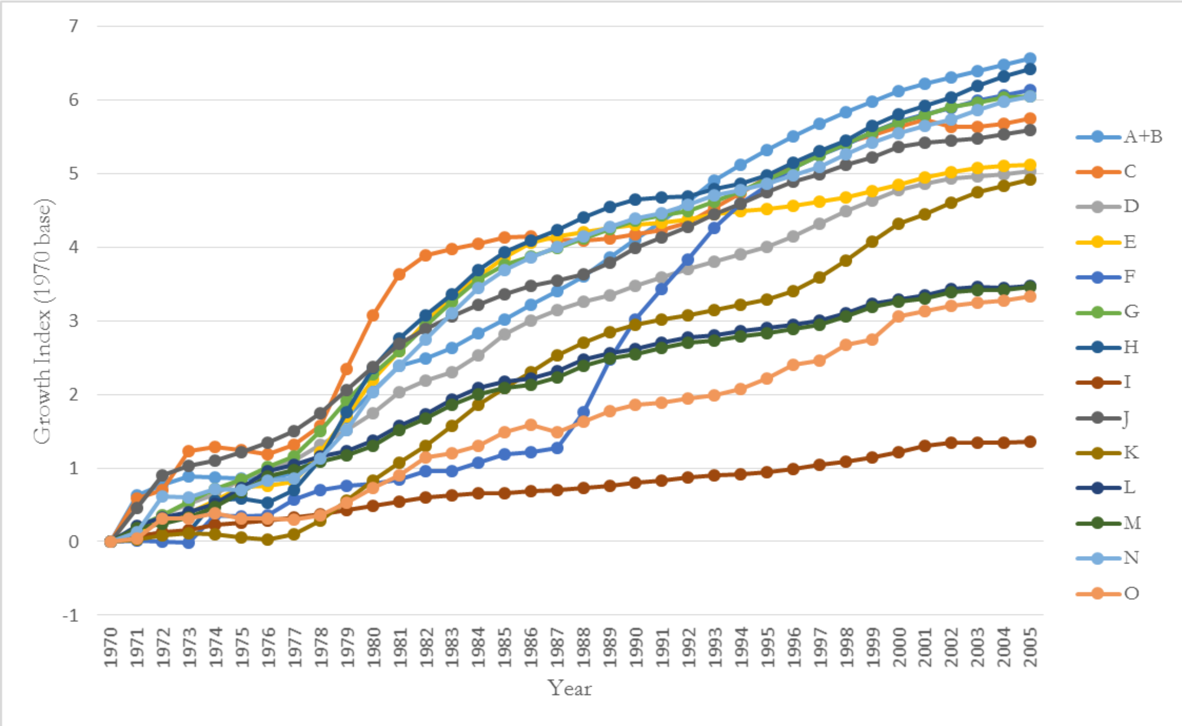

Figure 4.1 The growth of ICT intensity in the U.S. industries from 1970 to 2005

4.2.2 Output, Hours Worked, and Hourly Wage Rate

Table 4.7 shows the change of output, hours worked, and the hourly wage rate of the U.S. industries in 1970 and 2005. The output (value added) are adjusted using the Price Index provided in the EU KLEMS database. Hourly wages data are calculated as the total compensation received by workers in the industry divided by the total hours worked, and are adjusted using CPI retrieved from the Bureau of Labor Statistic website.

As apparent in table 4.7, all industries experience an increase in the value added in the period of 1970 to 2005. However, not all industries experience an increase in the hours worked for the same period. The manufacturing industry (D) and the agriculture, hunting, forestry, and fishing industry (A+B) experience a decrease in the number of hours worked. Meanwhile, all service industries (E to O) shows an increase in the hours worked, with the biggest growth comes from the real estate, renting and business activities industry (K).

Table 4.7 The Annual Growth Rate of Output, Hours Worked, and Hourly Wage Rate in the U.S from period 1970-2005

Industry	Output (in 2005 billion U.S. dollars)			Hours Worked (in billion hours)			Hourly Wage Rate (in 2005 U.S. dollars)		
	1970	2005	Annual Growth Rate	1970	2005	Annual Growth Rate	1970	2005	Annual Growth Rate
A+B	60.29	224.22	4.28%	10.14	7.83	-0.71%	8.18	12.39	1.43%
C	188.15	183.76	0.21%	1.31	1.34	0.34%	33.91	28.18	-0.39%
D	633.97	1931.40	3.35%	37.52	29.80	-0.58%	24.43	39.86	1.44%
E	173.67	255.28	1.30%	1.35	1.34	0.03%	25.46	53.70	2.26%
F	503.94	588.98	0.65%	8.38	18.03	2.36%	34.70	24.45	-0.90%
G	291.64	1351.13	4.53%	28.76	41.83	1.10%	18.54	23.27	0.69%
H	162.76	275.25	1.56%	6.21	14.82	2.54%	13.68	13.33	-0.04%
I	154.45	616.01	4.08%	7.77	11.81	1.25%	26.20	26.59	0.11%
J	156.82	849.89	5.01%	5.71	11.61	2.07%	24.05	36.39	1.39%
K	801.94	2915.63	3.77%	8.18	34.50	4.25%	28.10	35.69	0.73%
L	721.03	1103.37	1.26%	18.46	19.70	0.20%	21.93	40.03	1.76%
M	291.69	689.79	2.52%	8.21	17.74	2.23%	28.05	32.47	0.44%
N	321.49	927.95	3.09%	7.85	22.67	3.09%	18.99	32.87	1.62%
O	121.94	419.17	3.65%	7.51	18.31	2.60%	13.82	19.10	1.00%

However, an increase in the hours worked does not always followed with the increase in the hourly wages. The mining and quarrying industry (C), construction (F), and hotels and restaurants (H) experience a decrease in the hourly wages while they employ more workers. On the other hand, the hourly wages in the agriculture and manufacturing industry grows in the period of 1970 to 2005, despite the decrease in the hours worked.

4.2.3 Intra-Wage Inequality

Mishel (2011) uses a simple approach to measure the intra-wage inequality, which is by dividing the average hourly wage with the median hourly wage. However, other measures of the intra-wage inequality are exist, such as Gini coefficient and Theil index. The most popular option is Gini coefficient; it is derived from the Lorenz curve, which sorts the population from poorest to richest, and shows the cumulative proportion of the population on the horizontal axis and the cumulative proportion of expenditure (or income) on the vertical axis. However, it cannot easily be decomposed to separate the sources of inequality. For instance, it is not immediately clear from the Gini coefficient whether the inequality within a country is caused by the inequality between provinces of the country.

The analysis of the intra-wage inequality distribution between groups within a population can be done using Theil index method (Conceicao & Galbraith, 1998). The criterion for grouping could be any a series of exogenous factors (for instance, the provinces within a country or industries within a country) according to which we have an interest in grouping individuals for analytical purposes (Conceicao & Ferreira, 2000). For this thesis, the grouping is based on the workers' skill groups and the occupation types, to investigate the skill-biased and the task-biased technical change hypothesis.

Table 4.8 Shares of US employment based on the skill groups and the occupation groups in 1985 and 2000

	Shares of employment by the skill groups					
	1985			2000		
Occupation Groups	High-Skill	Medium-Skill	Low-Skill	High-Skill	Medium-Skill	Low-Skill
OCC1	53.2%	43.8%	3.0%	56.0%	42.5%	1.5%
OCC2	12.7%	77.6%	9.7%	14.8%	76.4%	8.8%
OCC3	4.7%	60.6%	34.7%	5.9%	67.3%	26.8%
OCC4	7.3%	72.1%	20.6%	8.0%	77.1%	14.9%
OCC5	2.8%	64.4%	32.8%	4.6%	73.2%	22.2%
OCC6	3.9%	66.9%	29.2%	5.0%	73.9%	21.1%
Total Employment	21.6%	61.5%	16.9%	27.0%	61.5%	11.4%

The relationship between the workers' skill group and the occupation types is shown in table 4.8. The table shows the distribution of employee in the U.S. based on the occupation groups and the skill groups in 1985 and 2000. The table shows that the occupation group OCC1 is dominated by the high-skill workers, while the rest of occupation types is dominated by the medium-skill workers. Low-skill workers occupies smallest share in all occupation groups, but the share is the biggest in the occupation type OCC3.

Next, the Theil index is calculated by comparing the shares of wage for each group with its shares of employment. In the Theil index measurement, the total inequality can be decomposed into two main components, the inequality within-group and the inequality between groups, as is shown in equation 4.8 below:

$$T_{total} = \underbrace{\sum_{C=1}^{m} \frac{W_C}{W} T_C}_{\text{Theil Index Within-Group}} + \underbrace{\sum_{C=1}^{m} \frac{W_C}{W} log \frac{\left({W_C}/{W} \right)}{\left({N_C}/{N} \right)}}_{\text{Theil Index Between-Groups}} \qquad \textbf{(4.8)}$$

where W_C is the total wage of workers in group C, W is the total wage of workers in all groups, N_C is the total number of workers in group C, and N is the total number of workers in all groups. T_C is the Theil index inequality within-groups C, and is calculated as shown in equation 4.9 below:

$$T_C = \sum_{i=1}^{N} \frac{W_i}{W_C} log \frac{(W_i)}{\left({W_C}/{N_C}\right)} \quad \textbf{(4.9)}$$

where W_i is the wage of individual in group C.

The sub-component 'Theil index between-groups' in equation 4.8 represents the wage inequality between the groups. The interesting part of this sub-component is that it also shows how much the wage distribution differs between the groups. Each group's contributions to the index is calculated by comparing the average wage of each group to the average wage of total population. A positive value then shows that a group's average wage is greater than the average wage of total population. On the contrary, a negative value shows that a group's average wage is less than the average wage of total population. Figure 4.2 shows the changes of the Theil index between skill groups in the U.S from period 1979 to 2010.

Figure 4.2 shows that the high-skill workers' average wages are higher than the average wages of total population, while the medium-skill and the low-skill average wages are lower than the average wages of the total population. However, the trend shows that the low-skill workers' contribution to the Theil index is getting less negative over time, while the middle-skill workers' contribution is getting more negative each year. This indicates that the wage share of the medium-skill workers is becoming compares to the other skill-groups. The dynamism of the Theil's contribution shown in figure 4.2 may indicate a job polarization, in which the shares of employment moves away from the medium-skill groups towards the high-skill and low-skill groups.

Meanwhile, a more dynamic pattern is shown in the Theil index decomposition between occupation types, as shown in Figure 4.3. The occupation group OCC1, which is dominated by high-skill workers, gets the biggest wage share compared to the other groups. On the other hand, the low-skill service occupation group OCC3 shows almost no changes. The most changes comes from the occupation group OCC4 and OCC6 that have positive contribution on the Theil index in the beginning of the period but turns to negative in the end of the period. Overall, figure 4.3 shows that the wage inequality between occupation groups in the U.S. is growing, with only OCC1 group that has a positive contribution to the Theil Index.

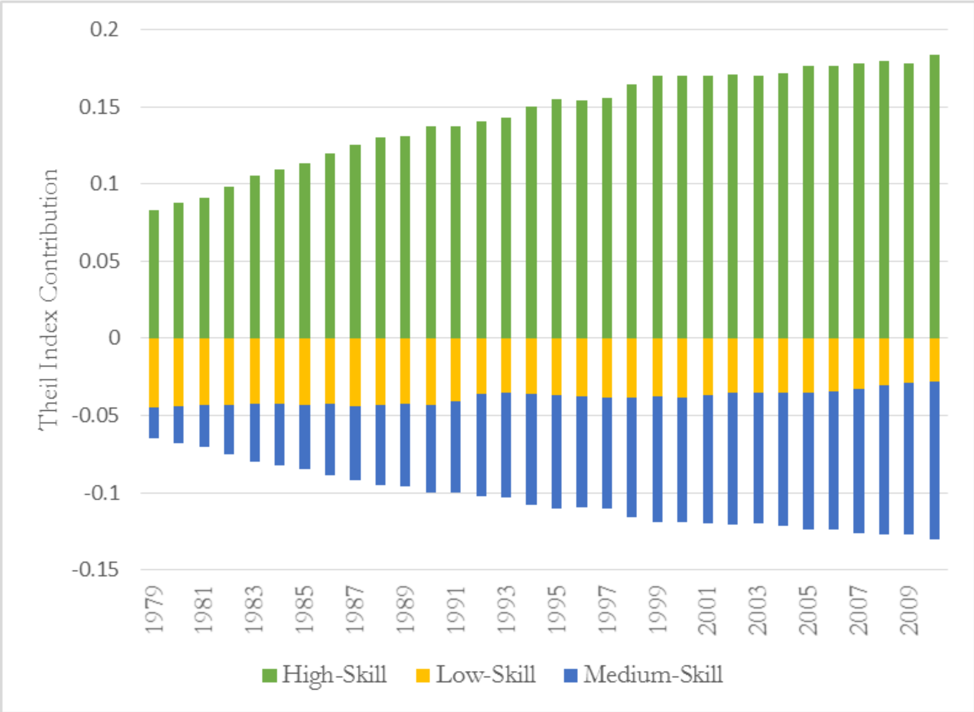

Figure 4.2 Changes of the Theil Index between Skill Groups in the U.S from 1979-2010

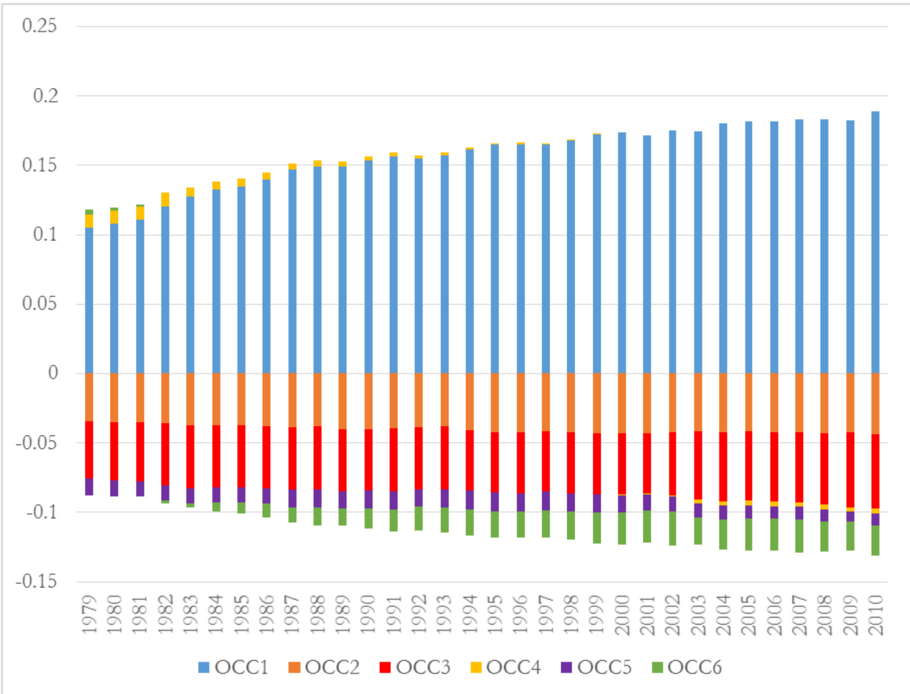

Figure 4.3 Changes of the Theil Index between Occupation Groups in the U.S from 1979-2010

4.3 Regression Analysis Results

This thesis focuses on the impact of ICT on the four components of the productivity-compensation gap: output, hours worked, hourly wage, and intra-wage inequality. Several regression analysis is done separately to investigate the association between ICT as the independent variable and the four components of the productivity-compensation gap as the dependent variable: (a) output, (b) the number of hours worked, (c) the hourly wage rate, and (d) intra-wage inequality.

The regression analysis is done using R, a language and environment for statistical computing and graphic. There are two methods of regression analysis that are done in this thesis, the Ordinary Least Square (OLS) regression and a two-step Prais-Winsten feasible generalized least squares (FGLS) to correct for AR(1) serial correlation. For each OLS regression, a Durbin-Watson (DW) test is conducted first, to test a null hypothesis that the residuals from an OLS regression are not autocorrelated, against an alternative hypothesis that the residuals follow an AR1 process. As a rule of thumb, a value of DW near 2 indicates non-autocorrelation, a value towards 0 indicates a positive correlation, and a value towards 4 indicates a negative correlation. To have a valid interpretation of the DW test, however, a critical values need to be calculated, which depends on the sample size and the number of regressors. The table that provides lower and upper bound of the critical values to accept/reject the null hypothesis of the DW test is provided in the Appendix. If the value of the DW test is lower than the lower bound, the null hypothesis is rejected; if the value of the DW test is higher than the upper bound, the null hypothesis is accepted. If the value is between the lower and upper bound, the result is inconclusive.

Generally, almost all regression equations in this thesis generate a low value from the DW test, indicating a positive autocorrelation. For all of the regression test that indicates an autocorrelation, a two-step Prais-Winsten FGLS procedure is done. One exception is for the regression between ICT intensity and the (Mishel) intra-wage inequality index, which return a value higher than the upper bound for the corresponding sample size and number of regressor, thus the null hypothesis is accepted. Consequently, it is assumed that there is no autocorrelation for the residual of the regression equation, thus only the OLS procedure is taken.

The detailed procedure and the results of the regression analysis is discussed in the sub-sections 4.3.1-4.3.4.

4.3.1 ICT and Output

The impact of ICT on the output is estimated with a regression equation based on the Cobb-Douglas production function, as shown in equation 4.10 below.

$$ln(Y_{it}) = \alpha + \beta_1 ln(K_{it}) + \beta_2 ln(C_{it}) + \beta_3 ln(L_{it}) + \delta_t + \varepsilon \quad \textbf{(4.10)}$$

where Y_{it} is the value added, K_{it} is the ICT capital service, C_{it} is the non-ICT capital service, and L_{it} is the labour service of industry i at time t in U.S., from the period of 1970 to 2005. The variable δ_t denotes the time fixed effect, and ε is the error term. An alternative to estimate the production function in industry aggregation is to also include industry fixed effect that allows each industry to have a unique intercept, to account for unobserved heterogeneity. However, to the extent that the unobservable factors vary and are correlated with particular inputs, those coefficients will be biased (McGuckin & Stiroh, 2002). For this reason, the industry fixed effect are excluded, and only time fixed effect is included in the regression equation.

All data for this analysis (value added, ICT capital service, non-ICT capital service, and labour service) are collected from the EU KLEMS database. The results of the regression analysis are summarized in table 4.9 below.

Table 4.9 The regression analysis result of equation 4.10. The number in parentheses denotes the standard error

Independent Variable Coefficient	**Dependent Variable: Value Added**	
	OLS	**FGLS**
Intercept (α)	4.616*** (0.333)	6.458*** (0.519)
ICT Capital Service (β_1)	0.075*** (0.013)	0.05*** (0.014)
Non ICT Capital Service (β_2)	0.383*** (0.027)	0.237*** (0.032)
Labour Service (β_3)	0.361*** (0.023)	0.36*** (0.055)
R-squared	0.704	0.984
No. of Observation	504	504
Time Period	1970-2005	1970-2005
DW Test	0.0474	-

$^{+}$, *, **, *** Significant at the 10%, 5%, 1%, and 0.1% respectively

Both OLS and FGLS tests shows that ICT capital service has a positive correlation with the output, although FGLS procedure shows a lower β_1 coefficient. This result is also consistent with other studies that concludes that ICT has a positive contribution on the output of the U.S economy. However, the coefficient values might be vary between studies. For instance, a study by Stiroh (2001) provides a coefficient value of 0.05. However, the study uses gross output as the dependent variable, and includes the intermediate inputs as the dependent variable. Another study by McGuckin and Stiroh (2002) shows a higher coefficient (0.14), but this study uses capital stocks as the estimators instead of capital service. In summary, the result in the table 4.9 shows that ICT has a positive contribution to the increase of output in the U.S. from the period 1970-2005.

4.3.2 ICT and Hours Worked

The impact of ICT on the hours worked is estimated by doing a regression analysis between the ICT intensity as the independent variable and the natural-logarithmic of hours worked as the dependent variable. The measurement of ICT intensity in this thesis follows the study by Stiroh (2001), which defines ICT intensity as the ratio between the ICT capital service and the total capital service. The ICT intensity then enters the regression analysis as the normalized value, which are calculated by subtracting the original value with the mean and divided by the standard deviation.

As have been discussed in the chapter 2, the use of ICT may have a different impact on the hours worked in the different industries because of the different industry characteristics. For instance, the goods producing industry, such as manufacturing industry, might use ICT for automation and replacing human workers. As a result, the impact of ICT on the hours worked in the goods producing industry may be negative. However, the use of ICT in the service industry is mainly complementary to the workers, which is to process the information for the service delivery. With the exception of the service dispensing activities (such as ATM or a self-service cashier), the actual service delivery might still need human workers, thus the use of ICT might have no impact, or even positive impact, on the hours worked in the service industry. For this reason, it is important to separate the effect of ICT on the hours worked of each industry, by including an interaction effect on the regression equation.

The impact of ICT on the hours worked thus is estimated by the equation 4.11 below:

$$ln(H_{it}) = \alpha + \beta_1 IT_{it} + \beta_2 IT_{it} \cdot IND + \delta_t + \varepsilon \tag{4.11}$$

where H_{it} is the hours worked and IT_{it} is the normalized value of ICT intensity in industry I at period t. The interaction effect of ICT intensity in the different industry is expressed by $IT_{it} \cdot IND$, with industry A+B serves as the base industry for comparison. This means that the variable $\beta_1$will represent the coefficient value of the ICT intensity for industry A+B, while the coefficient value of other industries are represented by the sum of variable β_1 and β_2. Finally, the variables δ_t denotes the time fixed effect, and ε is the error term.

The data of hours worked and ICT intensity is collected from the EU KLEMS database. The result of the regression is shown in table 4.10 below.

Table 4.10 The regression analysis result of equation 4.11. The number in parentheses denotes the standard error

Independent Variables Coefficient	**Dependent Variable: Hours Worked**	
	OLS	**FGLS**
Intercept (α)	5.295 (0.495)***	8.668 (0.302)***
ICT Intensity (β_1)	-4.993 (0.705)***	-0.569 (0.457)
Inter-Industry Interaction Effect (β_2)		
C	2.044 (0.537)***	0.527 (0.664)
D	4.508 (0.663)***	0.44 (0.451)
E	4.225 (0.636)***	0.492 (0.491)
F	5.004 (0.651)***	0.985 (0.484)*
G	4.909 (0.686)***	0.631 (0.46)
H	4.995 (0.662)***	0.822 (0.49) +
I	4.933 (0.686)***	0.661 (0.456)
J	4.939 (0.668)***	0.82 (0.485) +
K	5.268 (0.665)***	0.974 (0.498) +
L	4.688 (0.669)***	0.607 (0.462)
M	4.983 (0.669)***	0.898 (0.468) +
N	5.066 (0.664)***	0.911 (0.49) +
O	5.08 (0.675)***	0.814 (0.464) +
R-squared	0.9891	0.9936
No. of observation	504	504
Time Period	1970-2005	1970-2005
DW test	0.2115	-

+, *, **, *** Significant at the 10%, 5%, 1%, and 0.1% respectively

Table 4.10 shows that the two tests using OLS and FGLS procedure provide different results for the variable β_1 and β_2. The OLS procedure shows that both coefficient β_1 and β_2 have significant values for all industries, while the FGLS procedure shows a significance result only for industry F, H, J, K, and M to O. Furthermore, only the result of industry F has a significant level less than 5%.

The result is rather puzzling, considering that the discussion in the chapter 2 indicates that ICT may replace workers in the goods producing industry and the service dispensing activities. The insignificant level for the coefficient value in the goods producing industries therefore may be caused by the choice of aggregation level of the statistical analysis. This thesis uses the measurement of ICT intensity at the industry level, while in practice the ICT intensity might be vary within an industry. An analysis at a firm level therefore might provide a more detailed result of the impact of ICT on the hours worked, and to see how much works are obviated and/or created by ICT.

Nevertheless, if the results in the table 4.10 is taken to estimate the impact of ICT on the hours worked, we will end up with a result as presented in table 4.11. The numbers are calculated by adding the variable β_1 and β_2 for each industry, and assuming the insignificant coefficient to have no effect on the hours worked (meaning that β_1 or β_2 is written as zero for insignificant result). The numbers represent how much hours worked will be increased/decreased in logarithmic level by an increase of ICT intensity by one standard deviation (around six percentage points).

Table 4.11 The relationship between ICT intensity with the hours worked

Industry Codes	**Coefficient value of ICT Intensity ($\boldsymbol{\beta_1} + \boldsymbol{\beta_2}$)**	
	OLS	**FGLS**
A+B	-4.992648	0
C	-2.948648	0
D	-0.484984	0
E	-0.767194	0
F	0.01086	0.985
G	-0.084052	0
H	0.002417	0.822
I	-0.060053	0
J	-0.053994	0.82
K	0.274958	0.974
L	-0.304495	0
M	-0.010007	0.898
N	0.073422	0.911
O	0.087295	0.814

Looking at coefficient values in table 4.11, the relationship between ICT intensity and the hours worked of the non-service industries (industry A+B, C, and D) are insignificant. As discussed before, this result is unexpected, because the use of ICT in these industry may enable automation that can reduce the needs for human workers. A possibility to explain this result, as discussed above, is related with the aggregation level of data used. Another possibility is that the decrease of hours worked in the goods producing industry is may also be caused by other reason than an increase in ICT capital service, for instance an offshoring practice. In this case, ICT may still play an important role in the decrease of the hours worked, because it can be used to increase the tradability of service to other country (Welsum & Reif, 2005). However, its impact on the hours worked might not be directly related with the ICT capital service as is used in this thesis. Therefore, to investigate a more accurate impact of ICT on the hours worked, another proxy of ICT intensity that specify its use in the industry might be needed.

4.3.3 ICT and Wage Rate

Similar with the previous section, the impact of ICT on the hourly wage rate is estimated through a regression equation with the ICT intensity as the independent variable and natural logarithm of hourly wage rate as the dependent variable. The hourly wage rate is calculated as total labour compensation divided by total hours worked. The ICT intensity is calculated by dividing ICT capital service with total capital service. The ICT intensity enters the regression as normalized value, which is calculated by subtracting the original value with the mean and divided by the standard deviation. The regression equation for the analysis is shown in equation 4.12 below:

$$ln(W_{it}) = \alpha + \beta_1 IT_{it} + \beta_2 IT_{it} \cdot IND + \delta_t + \varepsilon \quad \textbf{(4.12)}$$

where W_{it} is the hourly wage rate, IT_{it} is the normalized value of ICT intensity, and $IT_{it} \cdot IND$ is the interaction effect of ICT intensity in different industry, with industry A+B as the base. This means that the variable $\beta_1$will represent the coefficient value of the ICT intensity for industry A+B, while the coefficient value of other industries are represented by the sum of variable β_1 and β_2. Finally, the variables δ_t denotes the time fixed effect, and ε is the error term.

All data for this analysis are collected from the EU KLEMS database. The result for the regression analysis is summarized in table 4.12, while table 4.13 shows the total impact of ICT on the hourly wage rate (which is the sum of the variable β_1 and β_2).

The results show that the use of ICT can be correlated with the increase the average hourly wage rate in most of industries. However, the use of ICT has negative impact to the hourly wage rate in the mining and quarrying industry (C), the construction industry (F), and the transport, storage, and communication industry (I). Furthermore, the results also show that the wage rate might not be directly influenced by the change of number of hours worked in the industry. For instance, the construction industry (F) experience a decrease in the hourly wage while experience an increase in the number of hours worked.

Table 4.12 The regression analysis result of equation 4.12. The number in parentheses denotes the standard error

Independent Variables Coefficient	Dependent Variable: Hourly Wage Rate	
	OLS	**FGLS**
Intercept (α)	4.509 (0.373)***	4.161 (0.557)***
ICT Intensity (β_1)	3.426 (0.531)***	2.812 (0.839)***
Inter-Industry Interaction Effect (β_2)		
C	-4.426 (0.405)***	-3.619 (0.935)***
D	-3.281 (0.5)***	-2.601 (0.841)**
E	-3.034 (0.479)***	-2.261 (0.85)**
F	-3.768 (0.491)***	-3.047 (0.861)***
G	-3.407 (0.517)***	-2.768 (0.84)**
H	-3.504 (0.499)***	-2.802 (0.85)**
I	-3.491 (0.517)***	-2.837 (0.84)***
J	-3.254 (0.504)***	-2.607 (0.814)**
K	-3.267 (0.501)***	-2.647 (0.83)**
L	-3.25 (0.504)***	-2.57 (0.841)**
M	-3.406 (0.504)***	-2.743 (0.836)**
N	-3.187 (0.5)***	-2.564 (0.829)**
O	-3.333 (0.508)***	-2.702 (0.834)**
R-squared	0.9663	0.9676
No. of observation	504	504
Time Period	1970-2005	1970-2005
DW Test	0.3298	

+, *, **, *** Significant at the 10%, 5%, 1%, and 0.1% respectively

Table 4.13 The relationship between ICT intensity with the hourly wage rate

Industry Codes	Coefficient value of ICT Intensity ($\beta_1 + \beta_2$)	
	OLS	**FGLS**
A+B	3.425818	2.8118
C	-1.00002	-0.8076
D	0.145031	0.2107
E	0.392226	0.551
F	-0.34176	-0.2351
G	0.018759	0.0443
H	-0.07778	0.0095
I	-0.06516	-0.0254
J	0.172086	0.2045
K	0.159007	0.1651
L	0.176048	0.2415
M	0.020164	0.0689
N	0.238861	0.2481
O	0.09241	0.1102

The dissimilar results between the hours worked and the hourly wage rate might be explained by the skill-biased and the task-biased technological change of the ICT. Both hypothesis propose that the demand for the workers will be influenced by the workers' degree of substitution with the ICT. This means that the works that are being replaced or added in the industry will depend on the typical tasks in such industry. Accordingly, the impact of ICT on the average wage rate for a specific industry will depend on the type of works that is replaced or created by ICT. An industry that was dominated by low-skill labours may experience an increase in the average wage rate when the low-skill labour are replaced by machines. Likewise, an industry which utilize more low-skill labour using ICT may experience a decrease in the average wage rate while employing more workers. Following this, it will be interesting to investigate the impact of ICT on the wage of the workers in more detail. This analysis is done in the next section, by looking at the wage share between the workers' skill groups and occupation groups.

4.3.4 ICT and Intra-Wage Inequality

The impact of ICT on the intra-wage inequality is measured by doing a regression test with the ICT intensity as the independent variable and the wage inequality index as the dependent variable. Theil T index is chosen in addition to Mishel's wage inequality index, because the Theil index allows decomposition to observe both the inequality within groups and between groups. The impact of ICT on the wage inequality as proposed by the skill-biased technical change or the task-biased technical change can be observed by first dividing the data into several groups, based on the workers' skill or the occupation types. Next, the regression analysis is done following equation 4.13:

$$WI_{it} = \alpha + \beta_1 IT_{it} + \gamma_i + \delta_t + \varepsilon \qquad \textbf{(4.13)}$$

where WI is the wage inequality index and IT is the normalized value of ICT intensity. It is assumed that the effect of ICT on the wage inequality is homogenous across the industries, thus there will be no interaction effect. Variables γ and δ denotes the industry and time fixed effect respectively, and ε is the error term. The data for calculating the wage inequality is collected from the CEPR database, while the ICT intensity data is collected from the EU KLEMS database. The aggregation of CEPR data and the EU KLEMS data is done at the major industry level, as was shown in table 4.5.

The regression analysis is done in two categories, to test both the skill-biased technical change hypothesis and the task-biased technical change hypothesis. In the first analysis, the Theil index is calculated by grouping the data based on the workers' education to test the skill-biased technical change hypothesis. In the second analysis, the Theil index is calculated by grouping the data based on the workers' occupation to test the task-biased technical change. The regression analysis then done twice for each category, to check the impact of ICT on the wage inequality within groups and between groups.

In total, the regression analysis is repeated five times with five different dependent variables: (1) Mishel's wage inequality index (Average to Median wage ratio), (2) Theil within occupation groups, (3) Theil between occupation groups, (4) Theil within skill groups, and (5) Theil between skill groups. The DW test for regression equation using Mishel's index of wage inequality shows that there is no evidence of autocorrelation, therefore the analysis for Mishel's index of wage inequality is done by only using the OLS method. The rest of the tests use both OLS and FGLS procedures, since the DW test shows an evidence of autocorrelation. The results are summarized in table 4.14 below:

Table 4.14 The relationship between ICT intensity with the intra-wage inequality

	Dependent Variable: Wage Inequality Index					
	Mishel		**Theil Within Occupation Groups**		**Theil Between Occupation Groups**	
	OLS	**FGLS**	**OLS**	**FGLS**	**OLS**	**FGLS**
Intercept (α)	1.177*** (0.018)	-	0.113*** (0.01)	0.128*** (0.008)	0.028*** (0.003)	0.038*** (0.003)
ICT Intensity (β_1)	<0.001 (0.007)	-	-0.003 (0.004)	0.008 (0.005)	0.008*** (0.001)	0.008*** (0.001)
R-squared	0.6712	-	0.6571	0.2313	0.8438	0.167
Observation	81	-	81	81	81	81
Time Period	1979-2010	-	1979-2010	1979-2010	1979-2010	1979-2010
DW Test	1.5939		1.1198		0.8958	

	Dependent Variable: Wage Inequality Index			
	Theil Within Skill Groups		**Theil Between Skill Groups**	
	OLS	**FGLS**	**OLS**	**FGLS**
Intercept (α)	0.124*** (0.008)	0.131*** (0.006)	0.018*** (0.002)	0.034*** (0.003)
ICT Intensity (β_1)	0.001 (0.003)	0.006^{+} (0.004)	0.004*** (0.001)	0.009*** (0.001)
R-squared	0.8159	0.3412	0.92	-0.017
Observation	81	81	81	81
Time Period	1979-2010	1979-2010	1979-2010	1979-2010
DW Test	1.1357		0.898	

$^{+}$, *, **, *** Significant at the 10%, 5%, 1%, and 0.1% respectively

The results show that ICT has positive significant impact on the wage inequality *between* groups, but insignificant impact on the wage inequality *within* groups. These results thus are still consistent with both the skill-biased and the task-biased technical change hypothesis, that ICT may have different influence on the wage of the workers depend on the workers' skill and/or type of occupations. However, the results also shows that the wage inequality between the skill groups or the occupation groups explain only a small part of total wage inequality in the U.S. Another part of the wage inequality comes from the wage inequality within groups, meaning that workers with same type of occupations or education level can receive a different level of income.

Moreover, the impact of ICT on the wage-inequality within groups is shown to be insignificant. This means that ICT can only explain small part of the wage inequality in the U.S., while the rest of the intra-wage inequality might be caused by another sources. This is also shown by the insignificant and weak coefficient value of ICT intensity to the Mishel's index of wage inequality. Nevertheless, the impact of ICT on the wage inequality between skill and occupation groups is significant, thus it is still interesting to see how ICT influence the distribution of wages between different occupations and skill groups.

The impact of ICT on the wage distribution between the occupation groups and the skill groups can be investigated by looking at each group's contribution to the Theil index, and regress it with the ICT intensity. Following from equation 4.9, the contribution of each group to the Theil index is calculated as:

$$T_{contrib} = \frac{W_C}{W} log \frac{\left({}^{W_C}/_{W}\right)}{\left({}^{N_C}/_{N}\right)} \qquad \textbf{(4.14)}$$

Where W_C and N_C represent the wage and population of group C, while W and N are the wage and total population

The data were divided into 6 occupation groups and 3 skill groups, thus the regression analysis is done nine times in total, to see the correlation between the ICT intensity with each group's contribution to the Theil index. The result is summarized in table 4.15 in the next page.

The first insight that we can take from the result in the table 4.15 is that the use of ICT positively impact the Theil's contribution of the high-skill workers and the occupation type that is typically done by the high-skill workers, which is the Managerial and Professional Specialty Occupations (OCC1). This result is consistent with both of the skill-biased technical change and task-biased technical change.

Table 4.15 The relationship between ICT intensity with each group's contribution to the Theil index

Independent Variables Coefficient	Dependent variable: Group's contribution to the Theil Index Between Occupation Groups					
	OCC1		OCC2		OCC3	
	OLS	FGLS	OLS	FGLS	OLS	FGLS
Intercept (α)	0.076*** (0.007)	0.124*** (0.011)	0.013*** (0.003)	-0.014 (0.015)	0.015** (0.005)	-0.018** (0.006)
ICT Intensity (β_1)	0.019*** (0.003)	0.023*** (0.005)	0.001 (0.001)	-0.001 (0.002)	0.009*** (0.002)	-0.005* (0.002)
R-squared	0.959	0.1613	0.9829	0.0105	0.9252	0.0385
Observation	81	81	81	81	81	81
Time Period	1979-2010	1979-2010	1979-2010	1979-2010	1979-2010	1979-2010
DW Test	0.9061		1.189		0.4529	

Independent Variables Coefficient	Dependent variable: Group's contribution to the Theil Index Between Occupation Groups					
	OCC4		OCC5		OCC6	
	OLS	FGLS	OLS	FGLS	OLS	FGLS
Intercept (α)	0.005 (0.003)	0.001 (0.002)	0.003* (0.001)	0.308 (0.437)	-0.085*** (0.005)	-0.031*** (0.008)
ICT Intensity (β_1)	-0.002. (0.001)	-0.004** (0.001)	<0.001 (<0.001)	0.001 (0.002)	-0.019*** (0.002)	<0.001 (0.003)
R-squared	0.35	0.0548	0.35	0.0548	0.9476	0.0548
Observation	81	81	81	81	81	81
Time Period	1979-2010	1979-2010	1979-2010	1979-2010	1979-2010	1979-2010
DW Test	0.2537		0.8634		0.748	

Independent Variables Coefficient	Dependent variable: Group's contribution to the Theil Index Between Skill Groups					
	High-Skill		Medium-Skill		Low-Skill	
	OLS	FGLS	OLS	FGLS	OLS	FGLS
Intercept (α)	0.017*** (0.002)	0.114*** (0.008)	0.013* (0.006)	-0.025 (0.017)	-0.056*** (0.004)	-0.053*** (0.007)
ICT Intensity (β_1)	0.04*** (0.003)	0.028*** (0.004)	-0.024*** (0.002)	-0.019*** (0.004)	0.011*** (0.001)	0.005+ (0.002)
R-squared	0.9499	0.1587	0.9554	0.0206	0.9052	0.2067
Observation	81	81	81	81	81	81
Time Period	1979-2010	1979-2010	1979-2010	1979-2010	1979-2010	1979-2010
DW Test	0.9404		1.0101		0.9766	

+, *, **, *** Significant at the 10%, 5%, 1%, and 0.1% respectively

However, the use of ICT also shows significant positive impact to the Theil's contribution of the low-skill workers. On the contrary, The Theil's contribution of the middle-skill workers is shown to be negatively affected by the ICT. This result is not consistent with the skill-biased technical change hypothesis, which states that demand for workers with higher skills is rising relatively with the lower skilled workers. Therefore, this result may be more consistent with the task-biased hypothesis, in which ICT influences jobs based on the tasks that the workers performed, not based on the skill level of the workers. From this perspective, the shares of medium workers may be decreased because ICT may replace the routine works they typically performed; on the other hand, the shares of the low-skill workers are increasing because they typically perform the non-routine manual tasks (Van Reenen, 2011).

Nevertheless, the results in table 4.15 may not completely explain the task-biased hypothesis. While ICT shows a positive correlation with non-routine occupation OCC1 and a negative correlation with the routine occupation OCC4, it shows insignificant correlations with the occupation groups OCC2, OCC5, and OCC6. Moreover, the FGLS result shows a negative correlation of ICT with the low-skill service occupation group (OCC3), whereas ICT is expected to increase the share of the occupation group. One of the possible reasons that explain this result is that the classification of the occupation groups used in this thesis might not fully represent the possibility of their replacement by ICT. Therefore, further studies might also consider to use another classification, such as by Frey and Osborne (2013), to know in more detail which occupations that may have been impacted the most by ICT.

4.4 Impact of ICT on The Productivity-Compensation Gap

The impact of ICT on the productivity-compensation gap is finalized by taking all coefficients from the FGLS regression analysis (or OLS regression analysis for the case of the intra-wage inequality) in the section 4.3 to estimate the total contribution of ICT on the four components of the gap. The relationship between the four components and the productivity-compensation gap is shown in equation 2.1. However, the analysis in this thesis exclude the benefit ratio factor and incorporate the trade factor into the net decoupling measurement. Thus the equation 2.1 can be rewritten as below:

$$\underbrace{\frac{Y/P_Y}{(W_{med}/P_C).h}}_{\text{Gross Decoupling}} = \underbrace{\frac{Y/P_Y}{(W_{ave}/P_C).h}}_{\text{Net Decoupling}} \times \underbrace{\frac{W_{ave}}{W_{med}}}_{\text{Intra-Wage Inequality}} \qquad \textbf{(4.15)}$$

where Y is the output, h is the hours worked, W_{ave} is the average wage, W_{med} is the median wage, P_Y is the GDP deflator, and P_C is the Consumer Price Index (CPI).

4.4.1 Output

The contribution of ICT on the output is estimated by taking the β_1 coefficient from the table 4.9, and multiplying it with the actual ICT capital service growth (in natural logarithmic form) in the U.S. from the period 1970-2005. The result is the growth of value added (in natural logarithmic form) since 1970 that is contributed by ICT. Converting the result to a level will give us the contribution of ICT on the output. Based on this calculation, it is estimated that ICT contributes to around $1.06 trillion (in constant 2005 US$) to value added of the U.S. for period 1970-2005.

4.4.2 Hours Worked

Since the regression result shows a low and insignificant results for the hours worked of some industries in the U.S, empirically estimating the exact impact of ICT on the total hours worked may need a further research. As discussed in section 4.3.2, the impact of ICT on the hours worked is hard to be examined at the industry level. Accordingly, in the calculation that follows in section 4.4.5, it is assumed that ICT does not have impact on the hours worked.

4.4.3 Hourly Wage Rate

Estimating the effect of ICT on the wage rate can be done by taking the β_1 coefficients of each industry in table 4.13, multiply them with the change of ICT intensity during the period of 1970-2005, and transform the result to a level form. The results are summarized in table 4.16 below.

Table 4.16 Impact of ICT on the Hourly Wage Rate

Industry	**Change of Hourly Wage Rate, 1970-2005 (in 2005 US$)**
A+B	4.424467
C	-8.0822
D	10.61631
E	18.03538
F	-9.38086
G	3.574802
H	0.253631
I	-2.57587
J	11.82639
K	11.00526
L	13.24746
M	4.095046
N	11.9344
O	4.373885

4.4.4 Intra-Wage Inequality

The result of regression analysis on section 4.3.4 provides that ICT have insignificant correlation with the Mishel's index of wage inequality. However, an extended analysis shows that ICT contributes to the change of Theil index between the skill groups and the occupation groups. The Theil index contribution of the high-skill workers and the low-skill workers is shown to be positively correlated with ICT, while the Theil index contribution of the medium-skill workers is shown to be negatively correlated with ICT. Since the Theil index contribution reflects the average wages of each group compares to the average wage of total population, it can be said that ICT still have impact on works and the wage distribution, and accordingly, on the intra-wage inequality. However, its impact on the Mishel's measurement of intra-wage inequality might not be observable at the industry level.

4.4.5 Gross Decoupling and Net Decoupling

Refer to the equation 4.15, the net decoupling part of the productivity-compensation gap has three components: output, hours worked, and hourly wage rate. The impact of ICT on the net decoupling of the U.S for the period 1970-2005 thus can be estimated by calculating to what extent this three major components has changed by the change of ICT capital service during those period.

Essentially, the net decoupling is a comparison between the labour productivity ($(Y/P_Y)/h$) and the average wage (W_{ave}/P_C). Therefore, the change of the net decoupling may be calculated by comparing how much labour productivity has grown by the use of ICT to how much real wage has grown by the use of ICT. However, since the impact of ICT on the hours worked is inconclusive, the exact impact could not be estimated.

If, instead, it is assumed that ICT does not impact the hours worked at all, then by taking the ICT's contribution on the output as is calculated in section 4.4.1, we may estimate that ICT contributes to the increase of labour productivity by \$5.15 per hour worked for the period 1970-2005. This number is calculated by dividing the ICT's contribution on output for period 1970-2005 with the average hours worked in the same period. Accordingly, by weighting the increase of the hourly wage rate in table 4.16 with the average shares of hours worked of each industry, we may estimate that in the same period, ICT contributes to the increase of hourly wage rate by \$5.78. This means that, if it is assumed that ICT has no impact on the hours worked, ICT may actually contribute to the decrease of U.S. net decoupling during the period 1970-2005. However, since the impact of ICT on the hours worked is inconclusive, this number should not be taken as the exact impact of ICT on the net decoupling. Instead, another research will be needed to estimate the impact of ICT on the net decoupling.

Finally, the gross decoupling can calculated by multiplying the net decoupling component with the intra-wage inequality. Since the analysis in section 4.3.4 shows insignificant correlation of ICT and the intra-wage inequality, accordingly, it is also assumed that ICT also does not have significant impact on the gross decoupling.

In summary, this thesis was not available to empirically estimate the impact of ICT on the productivity-compensation gap. This result is mainly caused by the inconclusive impact of ICT on the hours worked for the observed period. However, this thesis shows that ICT has impact on the output and the wage distribution between workers at a different skill level, which are an important factors that may influence the productivity-compensation gap. For this reason, further studies may focus on how ICT may influence the hours worked, by also taking into account the different skill level of the workers. With this additional approach, the exact impact of ICT on the productivity-compensation gap may be estimated.

4.4.6 Freed Capital

This thesis has discussed the concept of the freed capital, which is the amount of capital that is freed from the production activities as a result of the increased of labour productivity. However, since the impact of ICT on the hours worked are unknown, the estimation of the freed capital is also hard to do. If the impact of ICT on the hours worked are ignored, as discussed in the section 4.4.5, then it can be said that for the period of 1970-2005 ICT contributes to both the increase of labour productivity and hourly wage. In the other words, the capital that is contributed by ICT goes directly to the workers; all the additional number of output per hour are followed by the increase of hourly wage. This is indeed a puzzling result, considering that the workers' actual wage share are decreasing, or the net decoupling are increasing (refer to the table 1.1).

One possible reason for this result is because the analysis is done using the data at industry level; the hourly wage rate is calculated as the total number of compensation divided by the total hours worked of an industry. Consequently, the hourly wage rate is assumed to be equal for all workers and the impact of ICT is assumed to be homogenous towards the workers in the particular industry. The result in the section 4.3.4, however, shows that ICT may have different impact for workers in the different skill groups and types of occupation. This shows that estimating the impact of ICT on the hours worked and the wage rate may require a further study. The impact of

ICT on the hours worked and the hourly wage rate may not be observable at the industry level only, but have to be done at a more detailed aggregation level, and by taking the type of occupations and the workers' skill level into account.

Alternatively, if it is assumed that the share of total output that is distributed to the workers follows the actual wage share, then it may be estimated that out of $1.06 trillion value added that is contributed by ICT (as is calculated in section 4.4.1), $735 billion will be distributed to the workers. This number is calculated by first determining the average wage share from period 1970-2005, which is around 69 per cent, and then multiply it with the total output that is contributed by ICT. Accordingly, using this assumption, the share of profit that is contributed by ICT is estimated to be $330 billion. However, this number also could not be immediately claimed as the freed capital, as it does not account for the source of capital. Wilken (1982) argued that capital may also come from unjustified sources, such as by paying an adequate wages. Meanwhile, it is not clear whether the current wage share of the U.S. represent a justified distribution of income.

In summary, further study will be needed to empirically estimate the amount of freed capital. This is because the estimation of the freed capital will need the separation of the justified and unjustified source of capital.

Nevertheless, this thesis already shows that ICT contributes to the increase of output and labour productivity. Additionally, it may also influence the wage distribution between the type of occupations and the skill level of workers. Thus, it is still important to discuss the purpose and the allocation of the freed capital, which will be the main focus of the next chapter.

4.5 Chapter Conclusion

This chapter investigates the impact of ICT on the productivity-compensation gap by observing its impact on four critical components: output, hours worked, hourly wage rate, and intra-wage inequality. The results show that ICT have a significant correlation with the output and the hourly wage rate of the U.S for period 1970-2005. However, its impact on the hours worked and the wage inequality are inconclusive. ICT shows a positive correlation with the hours worked in several service sectors (industry F, H, J, K, M, N, O), but it shows an insignificant correlation with the hours worked in the other industries. This result makes the exact impact of ICT on the hours worked hard to be concluded. At the same time, the analysis also shows an insignificant correlation of ICT with Mishel's intra-wage inequality index, which makes the total impact of ICT on the productivity-compensation gap hard to be measured.

However, this does not necessarily mean that ICT has no impact on works; while its impact on the total number of works is inconclusive, ICT shows a negative significant correlation with the share of medium skill-works. Meanwhile, it shows a positive correlation with the share of both high-skill and low-skill workers. This means that while ICT may contribute to the creation of new works (especially in the service sectors), it may not always provide a better works. For this reason, this thesis argues that analysing the impact of ICT on works (and also the compensation) may need further studies, by using a data at lower level, for instance, at the firm level. Additionally, it will be interesting to also analyse the impact of ICT on hours worked and the hourly wage rate based on the types of occupations or the skill level of the workers, not only based on the types of industries.

Nonetheless, this chapter provides two insights that may lead us to the discussion in the next chapter. First, ICT is shown to have positive correlation with the output of the U.S. in the period of 1970-2005. Based on the regression result, it is estimated that ICT contributes to around $ 1.06 trillion (in constant 2005 US$) to value added of the U.S. for period 1970-2005. If it is assumed that the share of total output that is distributed to workers/capital follows the actual wage share/profit share, then we can estimate that ICT contributes to around $330 billion of profit during the same period.

Second, ICT is shown to have a positive correlation with the increase of both high-skill and low-skill works, while it has an opposite effect on the medium-skill works. This means that while ICT is assumed to open up new work opportunities, it may also cause a job polarization, in which the medium-skill workers might end up competing for a lower-skill works.

These results therefore lead us to the next question: what principle that should guide the use of capital or profit that is contributed by ICT? The mainstream economic theories only recognize value from consumption, thus the capital end up reinvested in another sectors. However, at the same time, ICT may revolutionize the way we do production, and influence the types of occupations that are left for the workers. The high-skill workers that lose their jobs may be able to find another jobs, but the less fortunate one might have to find even worse jobs. Expanding the production to create more jobs thus might be less useful, as it might follow the same trajectory. What can be the alternative uses for the capital and labour? This question will be the main topic of the next chapter.

5. USING THE FREED CAPITAL

5.1 ICT and The Productivity-Compensation Gap

The analysis in chapter 4 shows us some findings that related to the productivity-compensation gap. First, ICT contributes to the increase of U.S. output for period 1970-2005, thus contributes to the profit of around $330 billion in the same period. Second, the total hours worked seems to have not changed much because of ICT. However, ICT seems to affect job polarization, in which the share of medium-skill works are shifted towards the share of both higher and lower-skill works. This means that while, in total, the number of works available to people are almost the same, the quality of works might be differ.

Intuitively, one may relate this condition with the Schumpeterian term 'creative destruction'. The technological progress might obsolete the old production process and replace it with a new, more efficient one. As the consequence, some works may be obviated, but at the same time new innovations will open up new opportunities, and creates new jobs. The works that are lost in the process can be compensated by reinvesting in new technology and expanding the production to open up new works. However, the result in chapter 4 shows that ICT may also contributes to the creation of low-skill works.

On one hand, we may argue that ICT actually facilitates the low-skill workers to provide their service more effectively. ICT may be able to do so by reducing the coordination costs between the potential buyers and the service providers (Christiaanse & Kumar, 2000). One example is Uber, a transportation network companies that allowing someone with a car to be hired as a personal driver. The success of Uber's business model is later copied by other companies to expand the model to deliver more personal service, such as food delivery, doing laundries, house cleaning, or a simple house work like changing a light bulb (CBS News, 2015). On the other hand, we may ask whether this is the only possibility for the obviated workers - by absorbing them back in the production activities, regardless of the significance of the works and the demand they serve. This view might find its justification if the purpose of economics is to only maximize our utility. However, if we accept that the economy has a twofold task and, correspondingly, capital actually has a dual value - as a provider of the physical production and as an enabler of human capacities -we will see that the expansion of production will only provide a partial solution.

This chapter aims to answer a crucial question regarding the productivity-compensation gap: what principle that should guide the use of freed capital towards activities that may counter the impact of ICT on the productivity-compensation gap? This question can be answered by exploring the significance of capital and labour in economic theories. Accordingly, two additional questions are formulated. First, what is the role of the capital that is freed from the increased of labour productivity, as a result of the technical change? Second, what is the significance of the labours obviated by the technological revolution? The answer for these two questions will be discussed in the next sections.

5.2 The Capital Formation and The Role of Capital

Defining the purpose of the freed capital requires us to go back to the discussion in the chapter 3 about the source of value from various economic theory. Marx argues that labour is the origin of value, thus the profit created in the production process are belong to the workers. Neoclassical perspective, on the other hand, argues that value is created as a result of the exchange in the market, not in the production process. The distribution of income to all of the production factors, therefore, may follow their marginal productivity. Meanwhile, Schumpeterian perspective recognizes idea and human creativity as the source of value in the production process. The entrepreneurs - as the ones who create the new values – will also have a rightful claim for the profit.

Alternatively, the ownership of the capital can be determined by looking at its origin. The distinction of capital formation by Wilken (1982) which is discussed in the sub-chapter 3.4 views the profit in the production sphere as a result of the increase in productivity by the development of labour-saving technology. This type of capital arises from human intellectual and creativity which creates the technology, and differs from labour activity (à la Marx) as well as from the entrepreneurial spirit that organizes production (à la Schumpeter) and the investment capital that finances the means of production (Wilken, 1982). This perspective, therefore, attach the ownership of the freed capital to human capacities, and prescribes the use of the freed capital towards the development of human capacities.

Taking the result in the chapter 4, for instance, the amount of profit that is contributed by the use of ICT in the U.S. for period 2005 can be estimated to be around $ 330 billion. This number is calculated by taking the contribution of ICT on output for year 2005 ($1.06 trillion) and multiplied it by the profit share of the year (around 31 per cent). This number of profit contributed by ICT, however, cannot be immediately claimed as the freed capital. As have been discussed in the chapter 3, capital may also be raised from several possibilities, for instance an increase in prices without additional increase in the quality of the products, or a decrease in wages due to underpayment of labour. These sources are not originated from the human capacity, thus cannot be included as the freed capital.

It is therefore difficult to separate the freed capital from the total of profit reported, for instance from the total of profit reported in the EU KLEMS database. In chapter 4, it is shown that while ICT has a positive contribution to the output, it also contributes to the increase of wage inequality. This means that some of the capital that is contributed by ICT may also come from an unjustified source according to Wilken (1982), which is a withholding of necessary income formation by paying inadequate wages. Whether this is actually the case, however, depends on one's judgement of how much income is necessary or justified – on which different economic perspectives have different ideas.

In summary, to empirically estimate the exact amount of the freed capital as is contributed by ICT is a complicated matter. Nevertheless, a discussion for the role of the freed capital to counter the impact of ICT on the productivity-compensation gap remains relevant. This thesis has shown that current techno-economic paradigm may have several drawbacks for workers. ICT may obviate some labour and free some capital, but how can this freed capital be used to open up new opportunities for the workers whose labour is obviated? The answer for this question will depend on our understanding of value. Which value or values does capital serve? The next section reviews different economic perspectives for their view on the value(s) that capital serves.

5.3 Current Use of The Capital

The neoclassical perspective puts emphasis on consumption as the source of value (utility); the goal of economics and the economy is economic growth, which makes possible the growth of consumption. The rational expectation of the economic actors, each of which aims to maximize their own utility, is expected to create an equilibrium that will produce maximum social utility and redistribute them for the social benefit. On reality, however, the capital is often used to pursue instant profit, without being spend on the actual productive activities that is expected to drive economic growth. For instance, the executives of high-tech corporations often spend the companies' cash for the stock buyback rather than investing in the development of new technology, because it is expected to raise the company's stock price (Lazonick, 2013). Since these executives are also the shareholders of the companies, the buyback will maximize their own value, but creating no additional value for the companies. Wilken (1982) would categorize this kind of profit as unjustified, as it is coming from a speculative activities, and would not recognize it as the true use of the freed capital.

The Schumpeterian perspective is built under the same viewpoint; capital is seen as a tool to achieve economic growth. However, it recognizes innovative ideas as the *source* of value. The (neoclassical) pursuit of self-interest does not automatically channel capital to ideas. Accordingly, the direction of capital cannot be left to the self-interest, but it needs to be guided towards those potential ideas that can become the new engine of the economic growth. For example, instead of spending the cash to repurchase the stocks, a good executive should actively looking for potential innovation that can deliver better goods or service and create a high-quality jobs (Lazonick, 2013). The role of capital from the Schumpeterian perspective, therefore, is to embrace these innovative ideas and enable them to be a new engine for the economic growth.

The growth driven by the innovative ideas and the technological progress that arises from them, however, is not always translated to the overall improvement of human skills and capacities. In the current techno-economic paradigm, in which technology is used as a tool to achieve as much profit as possible, it may create a set of 'winners' and 'losers' between people who can take benefit on the technology and those who cannot (Brynjolfsson & McAfee, 2011). Following this, some studies often stress the importance of complementing the investment in ICT capital with the investment in human capital. Brynjolfsson, Hitt, and Yang (2002) suggest that to realize the potential benefits of computerization, investments in intangible assets such as workers knowledge and organizational structures is also needed. In other words, the solution is to make human workers and institutions to race with machines, not against them (Brynjolfsson & McAfee, 2011).

In summary, both neoclassical and Schumpeterian perspective perceive value in the expansion of production, and prescribe the use of capital for expanding the production. The benefit of the freed capital can be dispersed towards the society (including the workers whose labours are obviated) through several channels. First, it may initially end up in the forms of profit of the firms or the entrepreneurs. This profit, however, has a tendency to fall, because the competitions between the firms will impose a price reduction. In this case, the freed capital will be transferred to the consumers through a reduction in price which allows them to do more savings. Alternatively, the freed capital can be channelled to raise the workers' compensation. In this case, the workers will also be allowed to save more. Accordingly, the freed capital –either in forms of the entrepreneurs' profit, or consumers' savings– can be reinvested into a new productive activities that will reemploy the obviated workers.

Wilken, however, points this method as an unpredictable and 'chancy' way to balance the economy (Wilken, 1982). The rise in real income - as a result of lower prices or a higher income- may raise the consumption demand of the goods disproportionately. In other words, one cannot predict which particular goods which demand will rise. Accordingly, the occupations that are created to fulfil this additional demand may also go disproportionately. David Graeber (2013), for instance, questions the necessity of the personal service occupations (for instance the late-night food delivery) that rise only because everyone else is spending so much of their time working. The rise in the low-skill service occupations, as is shown in chapter 4 therefore may lead us to the same conclusion as Wilken (1982): an attempt to direct the freed capital towards material consumption guided by the self-interest may eventually end in a socially imbalance result.

The social imbalance may happen if the capital is appropriated by individuals and be used to maximize the utility of only those individuals (Wilken, 1982). The investment will be directed towards the most profitable opportunity from the shareholders' perspective, but might be economically and socially unnecessary. On the other hand, the development of the human capacity that is socially necessary, as it is the actual source of the progress, might be neglected for its unprofitable nature. This disproportionate use of capital will in turn generated a disproportionate demand, and will lead to a disproportionate capital formation.

Wilken (1982) emphasises human inventiveness or intelligence (in German: *Geist*) as the source of all capital (physical and financial) and argues that a way to balance the disproportion is by channelling the freed capital to foster its actual source: the human creativity or mental capacity. Please note that the definition of the human capacity in this context is different from the definition of 'human capital' as it is understood in the Schumpeterian perspective. The Schumpeterian perspective recognize the value of the human capital as its ability to satisfy our material needs. In Wilken's perspective, human capacity itself has value that needs to be developed for its own sake. This means that the effort to counter the productivity-compensation gap should not be focusing only on providing workers with technology related skills *only*, but also on developing human capacities.

5.4 Human Capacities as The Source and The Destination of Capital

In his book Economics of Good and Evil, Tomas Sedláček (2011) emphasises the need to expand the purpose of economics beyond the maximization of utility. From this perspective, the capital is seen as a mean to serve a higher purpose, not only to satisfy the pleasure. Surely, one function of economics is to organize production of goods that fulfil our material needs, but this kind of needs will have a certain limit. As Amartya Sen (2001) said, as living standards increase, the source of happiness increasingly lies in the satisfaction of immaterial rather than material needs. Beyond this limit, therefore, there should be no need to accumulate capital to fulfil our material needs. Nevertheless, in the current economic perspective there is no link between capital and the fulfilment of human immaterial needs.

Wilken (1982) defines threefold divisions of social organism that has to work mutually to achieve a social harmony. This three spheres are (1) cultural sphere, which is related with the development of human capacities; (2) political sphere, which is related with the arrangement of social life according to justice; and (3) economic sphere, which is to provide the material goods needed to sustain life. In reality, however, this three spheres may be developed exclusively. The economic sphere, for instance, is developed towards the fulfilment of only material needs as it ends goal. On the other hand, several authors has already emphasised the importance of development of human capacities (Nussbaum, 2011; Sen, 2000; Skidelsky & Skidelsky, 2012) which, in Wilken's division, would be part of the cultural sphere. However, what is missing from Sen's, Nussbaum's and the two Skidelkys' analysis is the link between the three spheres. Capacities can be used and developed only to the extent that the economy frees capital from production and makes it available for this purpose.

In the previous section, it has been argued how the development of economics that only values material consumption may be ended in a socially imbalance result. In the light of the three spheres as described by Wilken, we may see that the development of economic sphere based on the materialistic obsession may in turn block the development of other two sphere. Under such paradigm, the use of ICT may also lead to the underdevelopment of human capacities and immaterial needs in the cultural sphere. Skidelsky and Skidelsky (2012), for instance, argues that despite the world income per capita has increased fourfold since 1930, the development of what they call 'basic goods' – goods that are needed to achieve a good life[4] – has not improved significantly.

Despite the importance of human capacity development and the tendency of current techno-economic paradigm to hinder its development, conventional economic theories has limited perspective to justify the use of capital for such purpose. This is because in the conventional economic theories values is often seen as coming out of the consumption, thus capital has no basis to be directed towards the development of human capacities. Wilken's analysis of the capital formation, however, makes clear that the capital that is formed in the economic sphere originates in human capacities and creativity formed in the cultural sphere, and is organized by rules and law developed in the political sphere. Accordingly, the direction of capital from the economic sphere to the cultural sphere − after the economy's first purpose (to produce the material goods needed to sustain life) has been met − can be aided by changes in the political or legal sphere. This will enable capital to serve a dual purpose: as the provider of our material needs and immaterial needs (Naastepad & Houghton Budd, 2015). Surely, the capital is needed to fund the physical production, but once it reaches the limit of material needs, the rest of it should flow towards the development and fulfilment of our immaterial needs and the development of our capacities.

The twin value of capital perspective emphasises human capacities as the source and the destination of capital. Under this perspective, human capacities have values of their own, not only because of their potentials in achieving economic growth. This perspective, therefore, differs from the conventional economic perspective. Under the conventional economic perspective, the marginalisation in low-skill occupations is seen as a sign of 'skill-deficiency'. This means that there is needs to equip the workers with necessary skills in order to participate in the digital economy (Brynjolfsson & McAfee, 2011). On a broader sense, however, the marginalisation is also a sign that people are provided with limited choice to utilize their capacities; human capacities are valued only for its capability to generate profit in the physical production sphere. Consequently, under the current economic paradigm labour can only find its significance in the physical production sphere.

The twin value of capital perspective therefore expand the significance of labour outside the physical production activities. Under this perspective, people should be allowed to utilize their own capacity to fulfil their life purpose. The development of human capacities and their utilization in turn requires an expansion of the basic foundation of economics. The real purpose

[4] Skidelsky and Skidelsky (2012) have identified seven basic goods in total: health, security, respect, personality, harmony with nature, friendship, and leisure.

of human beings may only be achieved from exercising virtue, not by pursuing pleasure in the Benthamite-utilitarian sense. Economics, therefore, should serve additional goal: generating capital that will enable people to realise their life purpose and be able to do so using character (Naastepad & Houghton Budd, 2015).

5.5 Human Capacities and Character

A difference between the twin values of capital perspective and the neoclassical/Schumpeter perspectives lies in the motive of organizing the economic resources. Both neoclassical and Schumpeterian perspective emphasise utility as the driver of economic activities. Consequently, the economic resources are arranged to maximize the utility and to satisfy our *wants*. On the contrary, the twin value perspective emphasises human capacities as the end (in the sense of purpose) of economic activities. This means that the economic resources will be arranged not to satisfy our *wants*, but to provide what we actually *need* in order to realize our capacities.

Accepting human capacities as the end or, in terms of Aristotle, *telos* of economic activities leads us to also discuss the importance of character. The development of character becomes important within this perspective because character is what determines our choice of actions. In the economic system based on self-utility, humans are driven to satisfy only their pleasures. This perspective is captured in the concept of *homo economicus*, in which human beings are portrayed as rational and self-interested agents who pursue maximum utility. For Aristotle, however, pleasure and desire are a low level of capacity which is shared with the most all animals (Pack, 2010). On top of these animal-like attributes, human beings have higher capability to reason, which in turn helps them to choose the right things that will help them to actualize their capacities (Pack, 2010). The choice of actions that are taken by a person to realize values that are important to him/her will in turn form his/her character. This means that if we accept human capacities as the end of economic activities, character development will also be necessary; our actions could not be guided by the self-interest and pleasures only, but they also need to be guided by a moral sense of judgement, to determine what is right and worthy for human life.

The determination of what is right and worthy is a special human capacity that enable human beings to evaluate values that are important to them. Alisjahbana (1986) discuss this human capacity to reason and evaluate values as 'budi', which enables the human beings to create culture and live in culture[5]. The Indonesian word 'budi' to a great extent represents the German word

[5] In Indonesian language, culture is translated as 'budaya', which Alisjahbana (1986) argues comes from the combination of words 'budi' and 'daya'. 'Daya' means force or result of force, thus for Alisjahbana culture is developed as a manifestation of 'budi'.

‘Geist’, which is the source of the freed capital according to Wilken (1982). ‘Budi’ is the combination of ‘mind’ and ‘spirit’; it does not only emphasise human cognitive capacity, but also includes feeling, intuition and imagination as expressed in religious awe, aesthetic creativity and in social relationships (Alisjahbana, 1986).

Correspondingly, the concept of ‘budi’ or ‘Geist’ as the wellspring of culture (including economic thoughts, according to Wilken) perceives that human beings do not only find satisfaction by pursuing their own pleasure exclusively, but also in relation with the others. This means that satisfaction may also come from appreciating other people as individuals with their own capacities, and from assisting them in the unfolding of their capacities. Accordingly, replacing utility as the motive of economic activities with the development of human capacity will also require the development of character that expand the self-interest to include the interest of the others.

5.6 Chapter Conclusion

The discussions in the previous sections therefore provides answers to the two questions raised in the section 5.1. First, what is the role of the capital that is freed by the increase in labour productivity? A complete answer comes from the twin values of capital perspective, which prescribes that the freed capital should be used to provide both our material and immaterial needs. The material needs are limited, therefore some part of the freed capital should also flow to accomodate our immaterial needs. As discussed above, the definition of the immaterial needs is not fixed, but Skidelsky’s list of the basic goods or Sen and Nussbaum’s capability approach (Nussbaum, 2011) can be a good start. Some of the direct applications, for example, are directing the freed capital for building healthcare facilities, improving education, or supporting art and culture centre. But what may be the most important use of capital is to develop character within the economics. In the other words, expanding the self-interest as the only motive guiding the current economic paradigm to include the mutual interest of the others.

The idea to expand our current paradigm based on the self-interest to include the interests of others may in turn provide answer for the second question: what is the significance of the labours obviated by the technological revolution? A new paradigm that expand our self-interest to include the interest of the others, may allow the mutual development of economic, political, and cultural spheres. Should this new paradigm be successfully created, the significance of labour will also be recognized outside the physical production activities. Unlike the current paradigm that will leave us with ‘winners’ and ‘losers’, this new paradigm will allow every person to utilize their full capacity to work and serve each other mutually. Consequently, every person should be given access to the freed capital, in order to utilize their capacity.

Finally, this chapter is concluded by answering the second research question of this thesis. What principle that should guide the use of freed capital towards activities that may counter the impact of ICT on the productivity-compensation gap? A discussion in this chapter makes clear that the principle that may guide the use of freed capital will depend on which value that is important to us. If we accept the basis of utility maximization as the value that organize economic activities, the freed capital can find its place in the expansion of production, as what neoclassical and Schumpeterian perspective prescribe. However, if we accept that human actually have a higher capacity than satisfaction of utility, then the use of freed capital should be focused on the development of human capacity.

Surely, one might find the idea to invest in human capacities as a way to counter productivity-compensation gap to be unconvincing. Moreover, currently there may be no direct link between the development of human capacities and character and financial profit. However, if we accept that the capital is originated from human creativity and inventiveness, then directing the capital towards the development of human capacities certainly has its own justification. Just like the investment in innovation that need a great commitment, the investment in the development of human capacities and character will also need one, even greater.

6. CONCLUSION AND REFLECTION

6.1 Conclusion

This thesis aims to answer two research questions. First, what is the impact of ICT on the productivity-compensation gap? This first question is answered by first decomposing the productivity-compensation, following a study by Mishel and Gee (2011). The impact of ICT on the gap further investigated by analyzing the correlation between ICT and the four critical components of the productivity-compensation gap: output, hours worked, hourly wage rate, and intra-wage inequality. Furthermore, a second question is also asked: What principle that should guide the use of freed capital to counter the impact of ICT on the productivity-compensation gap? This question is then answered by exploring the source of values and the role of capital in four economic perspectives: classical, neoclassical, Schumpeterian, and the twin value of capital theory.

6.1.1 What is the impact of ICT on the productivity-compensation gap?

The empirical test for each component of the productivity-compensation gap is conducted using two methods, OLS regression and a two-step Prais-Winsten feasible generalized least squares (FGLS) regression to minimize the autocorrelation. The analysis utilize data from the EU KLEMS database and CPS database for the U.S. economy in period 1970-2005. The regression tests shows various results: ICT has a positive correlation with the output and the hourly wage rate, but insignificant correlation with the hours worked and Mishel's intra-wage inequality index.

Firstly, the increase of output can be correlated with the increase in ICT capital service. Both OLS and FGLS regression tests show that ICT has a positive significant contribution to the output of the U.S industries in the period 1970-2005. This result is consistent with other studies that have shown ICT have increased labour productivity in the U.S.

However, the analysis shows an inconclusive result for ICT's impact on the hours worked. ICT is found to have insignificant correlation with the hours worked in the U.S. goods production industries for period 1970-2005. The result is puzzling, considering that theoretically, ICT may replace workers in the goods producing industry and the service dispensing activities. The insignificant level for the coefficient value in the goods producing industries therefore may be caused by the choice of aggregation level of the statistical analysis. This thesis uses the measurement of ICT intensity at the industry level, while in practice the ICT intensity might be vary within an industry. An analysis at a more detailed level therefore might provide a better view on how much works are obviated and/or created by ICT. Meanwhile, the regression result shows that generally ICT has a positive correlation with the hours worked in the U.S. service sectors, even though the significant level is quite low.

Meanwhile, a different pattern is shown by the analysis of the hourly wage rate. The regression analysis shows a significant correlation of ICT with the hourly wage rate of the U.S. industries, but the sign of the coefficients does not always correspond to the changes in the hours worked. For instance, the construction industry experience a decrease in the hourly wage despite ICT is shown to positively influence the number of hours worked in this industry. Following this, the analysis is extended to investigate the impact of ICT on the wage distribution between different occupation types and workers' skill level.

The next analysis is done by investigating the impact of ICT on the Theil index and the contribution of each workers group to the Theil index, which represents how income are distributed towards workers at different skill levels or different occupations. The analysis shows that ICT has different influences on the wage distribution of workers with different skill level. ICT is found to have increased the average wage of both high-skill and low-skill workers, while decreased the average wage of medium-skill workers. However, the impact of ICT on the total intra-wage inequality is shown to be insignificant. This means that while ICT may influence the wage distribution between workers at the different skill level, it may only explain a small part of the total intra-wage inequality.

In summary, this thesis has not been able to estimate the total impact of ICT on the productivity-compensation gap of the U.S. This is mainly caused by the insignificant result of ICT's impact on the hours worked and the intra-wage inequality. However, this does not necessarily mean that ICT has no impact on works; ICT shows a negative significant correlation with the share of medium skill-works and it shows a positive correlation with the share of both high-skill and low-skill workers. This means that while ICT may contribute to the creation of new works (especially in the service sectors), it may not always provide a better works. Following this, the analysis of the impact of ICT on works (and also the workers' compensation) will require further studies by using a data at a more detailed level, for instance, at the firm level. Additionally, it will be interesting to also analyse the impact of ICT on hours worked and the hourly wage rate based on the types of occupations or the skill level of the workers, not only based on the types of industries.

Nonetheless, this thesis provides two insights that may lead us to the discussion of the freed capital. First, ICT is shown to have positive correlation with the output of the U.S. in the period of 1970-2005. Based on the regression result, it is estimated that ICT contributes to around $ 1.06 trillion (in constant 2005 US$) to value added of the U.S. for period 1970-2005. If it is assumed that the share of total output that is distributed to workers/capital follows the actual wage share/profit share, then we can estimate that ICT contributes to around $330 billion of profit during the same period. This number, however, should not be taken as the exact number of the freed capital, since it does not take the source of capital into account.

Second, ICT is shown to have a positive correlation with the increase of both high-skill and low-skill works, while it has an opposite effect on the medium-skill works. This means that while ICT is assumed to open up new work opportunities, it may also cause a job polarization, in which the medium-skill workers might end up competing for a lower-skill works.

Following these findings, this thesis sees that it is important to further discuss the purpose of capital that is freed as a result of the labour-saving technology. The principle that may guide this capital, however, will depend on how value is perceived; this is the main focus on the second part of this thesis.

6.1.2 What principle that should guide the use of freed capital to counter the impact of ICT on the productivity-compensation gap?

In order to answer this question, several economic perspectives are explored to find how values are created and how (freed) capital may contribute to the realization of those values. The economic perspectives that are explored includes the classical, neoclassical, Schumpeterian, and the twin value of capital perspectives.

Adam Smith's third mode of production equates the value of a commodity to three components: the wages of the labourers, the rent on the land, and the profit on the capital employed in producing and bringing the commodity to the market. The source of value in the modern society is specialisation aided by technological progress, between human beings and human beings and machines. Karl Marx, on the other hand, argues that labour is the rightful source of value. For

Karl Marx, machines does not produce value since it is also a creation of past labour, thus capitalist does not have right to claim for the profit. Both Adam Smith and Karl Marx, however, agree that wealth creation cannot be seen independently of the evolution of society and the human being. The (moral) development of individual is also an important factor that should be the goal of economics.

In a different manner, neoclassical perspective recognizes value of a commodity from its utility. Following this, the capital is directed towards activities that provide maximum profit for the producers. Under the perfect market, this profit will be passed on towards the consumer through a lower price, thus the profit may in turn be enjoyed by all member of societies. Schumpeterian perspective, however, argues that the direction of capital cannot be guided by the motive of profit maximization only. The innovation, which is a result of the ideas and creativity of the entrepreneurs, is an important factor that drives the economic growth. The capital, therefore, should also be guided towards generating innovations through a correct policy, since it requires a long term commitment (Mazzucato & Perez, 2014).

Both neoclassical and Schumpeterian perspectives stimulate the use of capital towards the expansion of production. The labour that is obviated as the impact of technological progress is expected to be created in another sectors. However, it must also be followed by the investment in human capital, to improve the workers' skills using the latest technology so that they are able to race *with* the technology instead of race *against* it (Brynjolfsson & McAfee, 2011).

Despite the recognition of human capital in the Schumpeterian and the new growth neoclassical perspective, the character development of individual is absent from both perspectives. Both perspectives, only see the significance of capital and human capital in the physical production activities. Meanwhile, the significance of human labour in the production may be diminished by the use of machines, which means production may require less labour. Within this setting, the workers that do not have a necessary skill to participate in the production activities may end up unemployed or are forced to find a lower paid job. Thus, the productivity-compensation gap may increase, as an effect of the increase in the intra-wage inequality.

On the other hand, the unemployment and the marginalization in low-skill jobs may also be a result of the inability of current techno-economic paradigm to recognize the significance of labour outside its materialist conception of progress (Naastepad & Mulder, 2015). Under the mainstream economic perspective, technology and capital are only recognized as tools to achieve an economic growth. Both technological progress and capital, however, is a result of human knowledge and creativity, or in a more general term: capacities. Nonetheless, under current techno-economic paradigm, the use of technology and capital may be directed away from developing human capacities.

The twin value of capital theory recognize two purposes of capital: (1) as the financer of the physical production activities that provide our material needs and (2) as the enabler of human capacities. In contrast with the concept of utility as the goal of economics, under this perspective the capital is used to achieve happiness, which may come only by exercising virtue. This in turn requires the development of human capacities which include character. This means expanding the current assumption of self-interest as the primary motive of economics to include the interest of others. Under this new paradigm, all people will be able to realize their capacities to fulfil their life purpose and serve others, and will have access to capital that is required to achieve it. Part of the capital that is not needed to fulfil our material needs, therefore, can be used towards this purpose.

6.2 Limitation and Future Research

This thesis has not been able to estimate the exact impact of ICT on the productivity-compensation gap. This is mainly caused by the insignificant result of the analysis of the hours worked and the intra-wage inequality. However, it also shows that ICT influences the distribution of works and compensation between workers at the different skill level. Therefore, more studies will be needed before the exact impact of ICT on the hours worked, and accordingly, the productivity-compensation gap, can be estimated. These studies might have to be taken at a lower level of aggregation, as apparently the impact of ICT on the hours worked may not be observable on the industry level. Additionally, it will be interesting to separate the impact of ICT on the hours worked with different skill levels or different occupations.

Moreover, this thesis only use ICT intensity as the dependent variable to investigate the change of the components of the productivity-compensation gap. However, the productivity-compensation gap might also be influenced by other factors. For instance, Van Reenen (2011) discuss that the trade with less developed countries in which the unskilled labour are relatively abundant may put pressure wages on the wages of less skilled workers in the developed countries. In this case, ICT may also have indirect effect in this, by supporting outsourcing activities. Therefore, further studies will be needed to measure the exact influence of ICT on works by taking these factors into account.

Secondly, this thesis also has limitation in aggregating the data from the EU KLEMS database and CPS database, which use different industry codes. Considering the time limitation, the aggregation of data is only possible on the three major industry level: agriculture, manufacture, and service. This approach therefore assumes a same level of ICT intensity for the industries that fall under the same category, while in reality it can be varied. A suggestion for the improvement therefore is to aggregate the data from both databases at a more detailed level. This can be done by matching the SIC codes, as are used in the CPS database, with the NACE codes, which is the basis of the EU KLEMS database.

Thirdly, this thesis only used data from the U.S economy. This choice is undertaken because this thesis also aims to have an in-depth analysis of the impact of ICT on occupations. Therefore, by considering a time limitation in finishing this thesis, the data is focused only on one country. However, it is also interesting to investigate the impact of ICT in another countries, and compare them with the findings in this thesis.

Finally, this thesis discusses the development of human capacities as the end of economics. This in turn provides the twin values of capital: as financer of the physical production and the enabler of human capacities. Following this, a question for another study may be formulated: how technology can be organized in a way that it may serve both of these values? Technology has been used to offers values that are important to the potential customers. Thus, 'values proposition' becomes an important concept in a business model. However, in the current perspectives, values is identical with the consumption, and profit becomes the main motive of the company. The discussions in this thesis, however, makes clear that there are values other than profit maximization that should guide the economic activities. Therefore, further studies might explore how technology and capital could be organized in a way that may serve both of these values.

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APPENDIX

Durbin-Watson Statistic: 1 Per Cent Significance Points of dL and dU
Source: (Savin & White, 1977)

	k'*=1		k'=2		k'=3		k'=4	
n	dL	dU	dL	dU	dL	dU	dL	dU
6	0.39	1.142	-----	-----	-----	-----	-----	-----
7	0.435	1.036	0.294	1.676	-----	-----	-----	-----
8	0.497	1.003	0.345	1.489	0.229	2.102	-----	-----
9	0.554	0.998	0.408	1.389	0.279	1.875	0.183	2.433
10	0.604	1.001	0.466	1.333	0.34	1.733	0.23	2.193
11	0.653	1.01	0.519	1.297	0.396	1.64	0.286	2.03
12	0.697	1.023	0.569	1.274	0.449	1.575	0.339	1.913
13	0.738	1.038	0.616	1.261	0.499	1.526	0.391	1.826
14	0.776	1.054	0.66	1.254	0.547	1.49	0.441	1.757
15	0.811	1.07	0.7	1.252	0.591	1.465	0.487	1.705
16	0.844	1.086	0.738	1.253	0.633	1.447	0.532	1.664
17	0.873	1.102	0.773	1.255	0.672	1.432	0.574	1.631
18	0.902	1.118	0.805	1.259	0.708	1.422	0.614	1.604
19	0.928	1.133	0.835	1.264	0.742	1.416	0.65	1.583
20	0.952	1.147	0.862	1.27	0.774	1.41	0.684	1.567
21	0.975	1.161	0.889	1.276	0.803	1.408	0.718	1.554
22	0.997	1.174	0.915	1.284	0.832	1.407	0.748	1.543
23	1.017	1.186	0.938	1.29	0.858	1.407	0.777	1.535
24	1.037	1.199	0.959	1.298	0.881	1.407	0.805	1.527
25	1.055	1.21	0.981	1.305	0.906	1.408	0.832	1.521
26	1.072	1.222	1	1.311	0.928	1.41	0.855	1.517
27	1.088	1.232	1.019	1.318	0.948	1.413	0.878	1.514
28	1.104	1.244	1.036	1.325	0.969	1.414	0.901	1.512
29	1.119	1.254	1.053	1.332	0.988	1.418	0.921	1.511
30	1.134	1.264	1.07	1.339	1.006	1.421	0.941	1.51
31	1.147	1.274	1.085	1.345	1.022	1.425	0.96	1.509
32	1.16	1.283	1.1	1.351	1.039	1.428	0.978	1.509
33	1.171	1.291	1.114	1.358	1.055	1.432	0.995	1.51
34	1.184	1.298	1.128	1.364	1.07	1.436	1.012	1.511
35	1.195	1.307	1.141	1.37	1.085	1.439	1.028	1.512
36	1.205	1.315	1.153	1.376	1.098	1.442	1.043	1.513
37	1.217	1.322	1.164	1.383	1.112	1.446	1.058	1.514
38	1.227	1.33	1.176	1.388	1.124	1.449	1.072	1.515
39	1.237	1.337	1.187	1.392	1.137	1.452	1.085	1.517
40	1.246	1.344	1.197	1.398	1.149	1.456	1.098	1.518
45	1.288	1.376	1.245	1.424	1.201	1.474	1.156	1.528
50	1.324	1.403	1.285	1.445	1.245	1.491	1.206	1.537
55	1.356	1.428	1.32	1.466	1.284	1.505	1.246	1.548
60	1.382	1.449	1.351	1.484	1.317	1.52	1.283	1.559
65	1.407	1.467	1.377	1.5	1.346	1.534	1.314	1.568
70	1.429	1.485	1.4	1.514	1.372	1.546	1.343	1.577
75	1.448	1.501	1.422	1.529	1.395	1.557	1.368	1.586
80	1.465	1.514	1.44	1.541	1.416	1.568	1.39	1.595
85	1.481	1.529	1.458	1.553	1.434	1.577	1.411	1.603
90	1.496	1.541	1.474	1.563	1.452	1.587	1.429	1.611
95	1.51	1.552	1.489	1.573	1.468	1.596	1.446	1.618
100	1.522	1.562	1.502	1.582	1.482	1.604	1.461	1.625

*k' is the number of regressors excluding the intercept