Bachelor's Thesis

The Effects of a 30-hour workweek on Finnish Standard of Living

Lappeenranta–Lahti University of Technology LUT

Bachelor's Programme in Business Analytics

Bachelor's thesis

2022

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ABSTRACT

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Title: The Effects of a 30-hour workweek on Finnish Standard of Living

Faculty: LUT School of Business and Management

Bachelor's Programme: Bachelor's Degree Programme in Business Analytics

Year: 2022

Bachelor's Thesis: Lappeenranta University of Technology, 51 pages, 10 figures, 10 tables

Examiners: Postdoctoral Researcher Roman Teplov

Key words: Shortened workweek, reduced workweek, economic growth, standard of living, labour hours, total factor productivity, level of technology, labour productivity, linear regression, Monte Carlo simulation

The objective of this bachelor's thesis was to assess the effects a shift to a shortened 30-hour workweek would have on Finnish standard of living. The research was approached with the Solow Growth model and the Cobb-Douglas production function being the theoretical foundation behind the two main research methods, linear regression, and Monte Carlo simulation. The results of the thesis indicate that shifting to a shortened workweek would most likely cause a significant decrease in Finnish standard of living, with even modest estimations exceeding historic recessions such as the 1990s depression and the Global Financial Crisis. On average, the estimated decline in living standards was approximately 19%. The Monte Carlo simulation results indicated that GDP per capita would decline by 43–68 percent, 12.5–43 percent, 0.1–12.5 percent, 0 percent, or increase by 0.1–16.3 percent with probabilities of 25%, 25%, 14.5%, 1.39%, and 34.11%, respectively. Focusing on improving labour productivity, stabilizing unemployment rate to a low level, and improving the level of technology is vital in order to enable a possible transition to a shorter workweek in the future.

TIIVISTELMÄ

Tekijä:	Akseli Nyström
Tutkielman nimi:	30-tuntisen työviikon vaikutukset suomalaisten elintasoon
Tiedekunta:	LUT-kauppakorkeakoulu
Koulutusohjelma:	Liiketoiminta-analytiikka
Vuosi:	2022
Kandidaatintutkielma:	Lappeenrannan teknillinen yliopisto, 51 sivua, 10 kuvaajaa, 10 taulukkoa
Tarkastajat:	Tutkijatohtori Roman Teplov
Hakusanat:	Lyhennetty työviikko, talouskasvu, elintaso, tehdyt työtunnit, kokonaistuottavuus, teknologian taso, työn tuottavuus, lineaarinen regressio, Monte Carlo simulaatio

Tämän kandidaatintutkielman tarkoituksena oli tarkastella lyhennettyyn 30-työviikkoon siirtymisen vaikutuksia suomalaisten materiaaliseen elintasoon. Solowin kasvumalli ja Cobb-Douglas-tuotantofunktio muodostavat työn teoreettisen viitekehyksen, joka pohjusti sekä lineaarisen regression, että Monte Carlo -simulaation implementoinnin. Tutkielman tulokset osoittavat, että lyhennettyyn työviikkoon siirtyminen johtaisi todennäköisimmin merkittävään vähennykseen suomalaisten elintasossa, ja jopa kohtuulliset arviot ylittävät aikaisemmat talouskriisit, kuten 90-luvun kriisin ja finanssikriisin. Arvioitu väheneminen elintasossa oli noin 19%. Monte Carlo-menetelmän tulokset indikoivat, että BKT väkilukua kohden vähenisi 43–68 prosenttia, 12,5–43 prosenttia, 0,1–12,5 prosenttia, 0 prosenttia, tai nousisi 0,1–16,3%, todennäköisyyksin 25%, 25%, 14,5%, 1,39% ja 34,11%. Työn tuottavuuden kohentaminen, työttömyyden vakauttaminen alhaiselle tasolle ja teknologian tason parantaminen ovat ratkaisevia tekijöitä, kun pyritään mahdollistamaan sulava siirtyminen lyhennettyyn työviikkoon tulevaisuudessa.

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1 Introduction

The purpose of this thesis is to assess the effects a shortened workweek would have on Finnish material wellbeing, what the most probable outcomes of this change would be, and what the implications of these outcomes are. The nature of the study is a sensitivity analysis performed by utilizing linear regression modelling and Monte Carlo simulation in estimating different outcomes. First, the formula for the linear regression is formed and analysed, and secondly the Monte Carlo method is performed to find a probability distribution of outcomes of a 20% decrease in labour hours. GDP per capita is used to measure changes in standard of living.

The length of a workday in Finland shifted from the amount of daylight to a standardized 10–12-hour workday, after factory work became more prevalent in the 19th century (Otava, 1981). It was standard to work on Saturdays as well, although for a shorter time; only Sundays were dedicated for leisure and rest. During the phase of independence in 1917, the Finnish parliament approved a law standardizing working hours to 8 hours a day, 48 hours a week, excluding agriculture (Parliament of Finland, 2022). Finally, the change to the modern workweek was approved in 1965 when Saturday was also recognized as a holiday, making the entire workweek 40 hours long, although in several collective bargain agreements today the workweek is set to 37.5 hours (Finlex 2022). It has been over 40 years since the standard workweek saw a significant reduction in hours, even though labour productivity grew significantly from 1960 onwards (Jalava & Pohjola 2004). The majority of labour, 70 percent, worked 35 to 40 hours a week, while 19 percent worked under 35 hours a week, in 2018 (Statistics Finland 2022a).

There has been a significant amount of conversation regarding a shortened workweek for the past few decades; most commonly a six-hour workday or a four-day workweek is outlined. The current prime minister of Finland, Sanna Marin, evoked conversation surrounding the topic in 2019 when she expressed interest towards a four-day workweek (Yle 2019). Similarly, in 2016, the Left Alliance advocated for a six-hour workday experiment, to give insight to potential future policies (Uusi Suomi 2016). In 2018 Perpetual Guardian, a company that manages wills, trusts, and estates, switched to a four-day workweek whilst keeping the monthly salary of employees on its prior level, evoking media reactions worldwide (Coote et al. 2021). The company's CEO reported "no downsides" from the initial experiment, although it is important to keep in mind the industry in question and its possible effects to the success of such a change (The Guardian 2018). Similarly, Microsoft in Japan experimented with a four-day workweek and reported a 40% increase in productivity (The Guardian 2019). Individual success stories around the globe, such as the case of Perpetual Guardian and Microsoft Japan, have elicited hope in those who advocate for a reduced time spent at work.

The conversation on a shortened workweek, although infrequent, has been relevant for some time now, especially during the 21st century. The goal of this study is to provide insight on the nature of different underlying factors regarding a shift from a 37.5-hour to a 30-hour workweek, and showcase estimations of potential changes to the living standards of Finnish residents such a shift would cause.

1.1 Prior research

There is little prior research regarding a 30-hour workweek with the estimation of its effect on economic output in mind; most studies relating to the topic focus on more precise and less broad research problems that either relate to or touch on this thesis' topic. For example, Ivancevich & Lyon, and Foster et al. focus on self-reported worker wellbeing and job satisfaction in their respective studies, while Calvasina & Boxx focus on effects on labour productivity. Possibly the most relevant research regarding this study's topic is a bachelor's thesis titled *The impact of labor productivity and working hours on Finland's economic growth* from 2019 by Joonas Knuutinen. His thesis studies how much labour productivity should increase, and how many years of labour productivity growth it would take, for a shift to a four-day workweek to be possible without compromising on living standards (GDP per capita). Knuutinen utilizes linear regression to estimate future values and draw conclusions. The theoretical framework of this study will have a similar approach to Knuutinen's thesis, and one of the two main methods in this study is also linear regression.

Experiments on shorter working hours for individuals were carried out between 1996 and 1999 in a variety of Finnish companies in the so called "6+6-experiment" (Peltola 2021). The experiments give interesting insight on microeconomic level results of a shortened workweek but do not directly provide general outcomes on a macroeconomic scale. Anthony

Lepinteur studied how reductions in weekly working time affected the wellbeing of employees in France and Portugal in his study *The shorter workweek and worker wellbeing: Evidence from Portugal and France.* Lepinteur's work touches on the topic of this study but does not include a comprehensive economic analysis. A lot of research has been done about the effects of hours worked on labour productivity such as Frank J. Poper's *A Critical Evaluation of the Empirical Evidence Underlying the Relationship Between Hours of Work and Labour Productivity,* and Lonnie Golden's *The Effects of Working Time on Productivity and Firm Performance.* It is quite well founded that the number of hours worked by an individual affect their productivity: typically, one additional hour lowers the average productivity rate, or increases the cost of one additional hour of labour in relation to output. (Shepard & Clifton 2000). Previous studies will be utilized in relevant sections throughout the study.

1.2 Research aspirations and research questions

The shortened workweek to be used in this study is a six-hour workday that adds up to 30-hours weekly, not including unpaid lunchbreaks. As the 30-hour workweek is a 20% decrease from the most common amount of work per week, 37.5 hours, this study will therefore examine the effects of a 20% decrease in the overall hours worked in Finland. The data used consists of GDP, GDP per capita, capital intensity, total labour hours, labour productivity, total factor productivity growth, and unemployment rate. The study's approach is based on mainstream economic theory.

Proponents of a labour hour reduction argue that an increase in leisure time through reducing overall working hours, leads to more fulfilled lives for people. A main motivation behind reducing labour hours is the thought that having more time to oneself could improve the mental and physical health of employees, significantly reduce burnouts, and lead to happier lives overall. There exists some evidence that working hour reduction could indeed lead to the aforementioned benefits as Berniell and Bietenbeck found a causal relationship between working time and health in 2017, which suggested that working time negatively affects the health and self-reported health of employees (Berniell & Bietenbeck 2017). Additionally, Anthony Lepinteur found in his 2019 study that reducing working hours greatly benefitted workers in France, but also highlights that this change did not come without cost as France had to cut payroll taxes to ease the implementation of the working hour reduction, resulting in a significant yearly cost for the government (Lepinteur 2019).

Some proponents of reduced working hours also argue that increased leisure time translates to increased spending, which would boost the economy, and additionally, that reducing working hours would decrease unemployment through work-sharing. Increased leisure time would lead to more time for consumption of services and commodities, but it would most likely reduce the disposable income of households, leading to less consumption. A study by Kaptneyn et al combats the notion that unemployment would be reduced by cutting working hours; the study found no empirical support for work-sharing as a means of reducing unemployment (Kaptney et al. 2004).

One possible scenario of reducing labour hours, however, is that it would lead to a boost in labour productivity, offsetting the negative effect in output the initial labour input reduction would cause, resulting in “the best of both worlds”: an increase in leisure with no significant decline in economic output and the standard of living. There is some evidence to support this notion; Holman et al., estimated that shorter working hours were an important determinant of productivity increases in multiple industries in the United States between 2000 and 2005 (Golden 2012). While the “best of both worlds” -scenario is entirely possible, there is no guarantee that any increase in labour productivity achieved by cutting hours could be sufficiently sustained in the long term. For example, Calvasina and Boxx found no labour productivity increases in their empirical study of two factories producing apparel in 1975. This study, however, is relatively old and the quality of labour, production technology and labour productivity has since changed drastically. In addition, Calvasina and Boxx studied the effects of a two-hour reduction, or a 5% decrease, which differs largely from this study’s perspective of a 20% decrease. It must be noted that not all industries are eligible to achieve increases in productivity through labour hour reductions because of the nature of work in those sectors. For example, cutting the daily hours of a process manager in a paper factory, whose job is to monitor a paper machine, will not generate significant productivity increases as the paper machine will still generate the same output per hour.

Sceptics of reducing working hours often point out that such a change would most likely lead to a sizable decline in living standards, in light of which the change would not be viable. The motivation for this thesis is indeed to provide insight that helps determine whether the trade-off between standard of living and increased leisure is sensible by estimating the change in standard of living a reduction in working hours would most likely cause. The conversation weighing out these options is more philosophical and driven by subjective preferences, therefore this thesis only aims to aid in that conversation by providing concrete numbers that estimate the decline in economic output such a reduction would result in.

The main research question was formed as such:

1. "How large of an effect would a six-hour workweek have on the material wellbeing of Finnish residents?"

The supporting research questions were formed as such:

A. "How large of an effect would reducing hours worked in the economy by 20% have on Finnish GDP per capita?"
B. "What are the probabilities of different outcomes concerning the change in Finnish GDP per capita?"
C. "What are the implications of the different outcomes?"

The hypothesis for this research is that reducing labour hours by 20% would not decrease GDP per capita by 20%: the effect is likely smaller as labour productivity is a more crucial factor in defining output levels than hours worked. Thusly it could be possible to reduce working hours today without significantly decreasing economic output, and thusly living standards, in the Finnish economy.

1.3 Delimitations

This study focuses on certain characteristics of the economy of Finland between the years 2002 – 2020. More precisely, this work will contemplate the relationships between Finland's GDP per capita, total labour hours, savings rate, labour productivity, employment rate, and capital stock. The time period chosen provides enough data through augmentation, and therefore observations, to make the models used statistically significant.

While some industries could have an easier time in retaining their output amounts on their previous levels after a reduction in labour hours, for others this could be a substantial problem for their steady output. For example, a paper factory producing only newspaper material with machines would most likely not see a significant increase in labour productivity, whereas for instance law firms and other office work environments could see a major increase in labour productivity, thus balancing the effect of the labour hour reduction. This study will not take into consideration how a decreased amount of labour hours would affect different industries unevenly.

An entire economy is a highly complicated and often unpredictable structure. When modelling such a structure, there are bound to be unexpected factors that are left outside the models, which could alter the results and conclusions significantly. The linear regression that is utilized to examine the relationship between GDP per capita, and labour hours is static and does not consider the potential shifts of other variables inside the model. Therefore, a Monte Carlo simulation is performed to assess the effects of changes in the other variables, to the estimated outcomes. However, the Monte Carlo method naturally cannot estimate the effects of variables outside of the formula.

2 Theoretical framework

Main points of the theoretical framework, which this study is based on, will be introduced in this section. In addition, relevant concepts and theories regarding economic growth and its main components are explained briefly. This section will go over the basics of economic growth and its measurement, the Cobb-Douglas production function, concept of labour productivity, and the effect of hours worked, unemployment rate, and capital intensity on economic growth.

2.1 Economic growth indicators

Economic growth represents the increase or decrease in the total amount of goods and services, or aggregate output, in an economy from one time period to another, and it is most commonly measured with the growth of either gross domestic product (GDP) or gross domestic product per capita. Simply put, economic growth can be achieved by increasing the factors of production capital (K) and Labour (L), though these factors are not the only nor the most important aspects responsible for economic growth, especially in developed countries; long term growth is attributed to improvements in technology in these countries (Pohjola 2014, 156). GPD is calculated as the total market value of all final goods and services produced in an economy within a certain time period and it is typically considered to be the best measure to evaluate how well an economy is performing (Mankiw 2002, 16). Because of the use of market prices in calculating the GDP, the effect of general price rises via inflation are removed to portray the *real* growth in value added, which is a better metric when compared to nominal GDP, as real GDP more accurately represents the state of total production. If the European Central Bank, for example, managed to maintain its goal of 2% yearly inflation rate for the entire eurozone, this would cause an additional 2% boost in nominal GDPs in European countries despite no such additional actual increase in output (European Central Bank 2022). GDP can be viewed in two ways: as the total income of everyone living and interacting within an economy, and as the total expenditure on all goods and services within an economy (Mankiw 2002, 16).

GDP per capita is calculated by simply performing a division between GDP and population, and it is commonly used to represent the progress in living standards, although it does not measure multiple factors affecting wellbeing such as leisure, the state of the environment, life expectancy, and the level of education (Pohjola 2014, 150). Growth of real GDP per capita takes into account the population size of an economy and resembles the improvements in the *average* standard of living of people within an economy. This makes it a better indicator for overall material wellbeing as well as for cross-country examination. GDP per capita does not, however, consider income inequality, or how goods and services are distributed in the economy: growth in GDP per capita does not necessarily mean that everyone is better off, but that the amount of goods and services has increased when accounting for population size (Arminen 2022). Often when making cross-country comparisons a purchasing-power parity method (PPP) is utilized to make the different countries or economic zones comparable: purchasing-power parity considers the differences in price levels, or the *purchasing power* of a country’s currency, and ensures true comparability between countries compared (Mankiw 2002, 138-141). This thesis will focus on Finland only, thus the concept of purchasing-power parity is not needed.

A multitude of other progress and wellbeing indicators have been created to complement the traditional GDP metrics, such as the Human Development Indicator (HDI) and the Genuine Progress Indicator (GPI), that account for wellbeing factors beyond GDP by additionally examining for example life expectancy, level of education, environmental sustainability, and several social aspects. For the purposes of this thesis GDP and GDP per capita are more suitable as the purpose is to focus completely on finding the effects a decrease in workweek hours would have on the average material wellbeing, disregarding aspects such as environmental sustainability and the level of education.

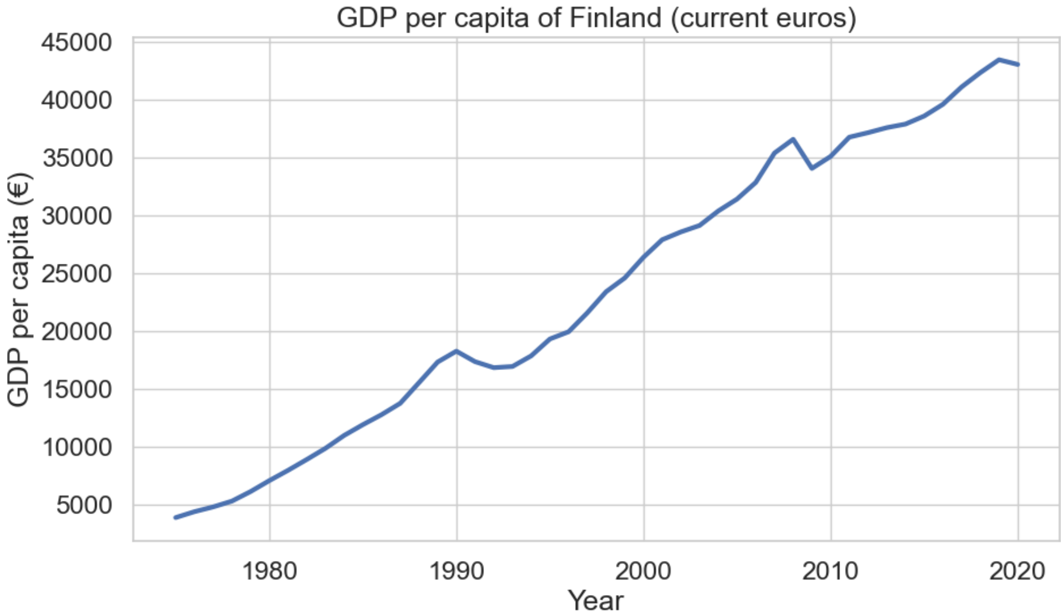


Figure 1: Nominal GDP per capita of Finland (1976 - 2020)

Figure 2: Real GDP per capita of Finland (1976 - 2020)

Above are two figures describing GDP per capita from 1976 onwards at market prices in current euros (figure 1) and in 2010 euros (figure 2), that simultaneously highlight the differences between nominal (non-inflation adjusted) and real (inflation-adjusted) GDPs. Both figures display a rather sizeable growth in GDP per capita, especially when considering that this progress has been achieved in fewer than 50 years. Despite some number of declines in GDP per capita caused mostly economic crises, the overall trend clearly indicates how Finland's living standards have improved over time. As can be observed from the differences between figures 1 and 2, nominal GDP tends to understate the output levels of previous years and overstate current ones, since it does not consider how inflation affects the numbers. For example, figure 1 indicates that after decline during the financial crisis of 2008, GDP per capita has surpassed the previous peak in 2008, although this is clearly not the case. Figure 2 reveals that the true 2008 level of GDP per capita was not reached until 2019 and that the 2008 level has not been surpassed as of 2020. During 2022, the inflation rate in Finland has risen considerably as it reached 5.7 % in April, and 7.1 % in May (Kuokkanen 2022). Inflation rate remained mostly stable during the entire 2010s but has now reached somewhat alarming levels that have not been experienced since the early 1990s depression (Statistics Finland 2022e). Although the recent developments in the general increase of prices do not fall under the review period of this study, various past decades included in this study's timeframe have experienced substantial amounts of inflation. Inflation rate of Finland was well above the European Central Bank's target amount of 2 % during approximately half of the 1990s, and the entirety of the 1980s, where inflation reached over 10 % in some instances. Nominal GDP is not a great indicator for economic wellbeing, because it does not accurately reflect how well an economy can satisfy the needs of its people, therefore inflation adjusted GDP and GDP per capita will be utilized in this thesis in an effort to provide accurate and reliable results (Statistics Finland 2022e).

2.2 Sources of economic growth according to the Solow-Swan model

The Solow-Swan model, commonly referred to as the Solow Growth Model, is a theory for long-term economic growth that aims to explain economic growth (production) via capital accumulation, increases in productivity, and labour force (population) size growth, and discover the underlying causes explaining the differences between countries in GDP per capita (Solow 1956). The Solow-Swann model is macroeconomic and dynamic by nature, as the model can describe economic growth over time, in contrast to a single static point in time (Mankiw 2002, 180). The Solow Growth model is often specified to be of Cobb-Douglas type, functioning as a simple representation of complex economies, which works as a starting point for more detailed models and theories. The model was first introduced by Robert Solow and Trevor Swan in 1956 in two separate academic articles, and later expanded upon by Robert Solow. (Acemoglu 2009)

Capital stock is one of the key factors determining an economy's level of output and increases in this factor can lead to economic growth. The changes in capital stock over time can be attributed to two reasons in particular: investment and depreciation of capital. Investment signifies contributions towards new equipment, machinery, structures, and inventory, and it raises the size of capital stock. Depreciation of capital refers to the wearing out of previously acquired capital, which, on the other hand, decreases the size of capital stock. As the size of the capital stock increases, so does the amount of economic output, but also the amount of capital depreciation. The steady-state level of capital refers to the situation where the size of capital stock does not change as investment and capital depreciation balance each other out. An economy at the steady state will stay there, and an economy not at the steady state will tend to move towards that state. If an economy has a higher than the steady state of capital, new investment is less than capital depreciation, therefore the capital stock will slowly decrease approaching the steady state level. Similarly, when an economy has a lower than steady state of capital, new investment exceeds the amount of depreciation, thus the capital stock will rise and approach the steady state level. The golden rule of capital is the level of capital stock, which maximizes consumption in a steady-state, and it is achieved at the level where the marginal product of capital (MPK) equals the depreciation rate of capital (δ) (Mankiw 2002, 192-194). Capital stock has proven to be difficult to reliably measure because of varying assumptions about capital depreciation rates, and methods to aggregate different types of capital (Sargent & Rodriguez 2000). (Mankiw 2002, 184-186)

The Solow model suggests that an economy's rate of savings determines the size of its capital stock, and therefore its level of output: if the savings rate is high, the economy will have a larger capital stock and a larger level of output. To simplify, the higher the rate of saving, the higher the level of output. Although, after the period of rapid growth caused by an increase in savings, a new steady state growth level is reached. A high savings rate can provide quite a high steady-state level of production, but it cannot create constant long-term economic growth: an increase in savings rate expands growth only until a new steady state level is reached. (Mankiw 2002, 204-205; 189-190)

Population growth, or more specifically growth in the size of the labour force, is another key factor alongside capital stock in determining the level of production in an economy. Much like capital stock, population growth cannot explain long-run developments in the standard of living but can explain a portion of growth in total output. Investment efforts increase the steady-state capital intensity, which refers to the amount of capital per worker (K/L), but contrariwise, labour force growth and capital depreciation reduce capital intensity. A reduced level of capital intensity leads to a lower level of output per worker; thus, the Solow model proposes that higher levels of population growth lead to lower levels of GDP per capita. (Mankiw 2002, 201-202)

Technological progress is the main factor explaining long run economic growth. The level of technology is an exogenous variable in the Solow model, and it is often called the "Solow residual". The Solow residual encompasses all factors of growth that are not explainable by the increase in inputs of labour and capital, and it represents the change in technology (Kyläheiko 2020). Once the steady state of growth is reached, the growth in output per worker relies solely on technological developments, therefore it is the only factor that can account for continuous rise in living standards (Mankiw 2002, 210). Technological progress will be discussed further in chapters 2.3 and 2.4. The Solow residual can be estimated by calculating total factor productivity (TFP) with the Cobb-Douglas function.

In its basic form, the Solow model can be written as:

$$Y = A * F * (K, L) \tag{1}$$

A certain level of output (Y) is achieved by labour input (L) and capital input (K). How the rate of output of products depend on capital and labour inputs does not change, therefore the model is fixed (F), with the level of technology (A) defining the ratio of output achieved with labour and capital.

The Solow model can be expanded upon as such according to Kyläheiko:

$$Q(t) = A * F[K(t), H(t), L(t)] \quad (2)$$

Where: Q(t) = Production at time t

A = The level of Technology

K(t) = Physical Capital at time t

H(t) = Immaterial (Human) Capital

L(t) = Labour Input at time t

To reach per capita level, a division with L(t) is performed on both sides of the formula:

$$Q(t)/L(t) = A * F[K(t)/L(t), H(t)/L(t), 1] \quad (3)$$

By marking the per capita units with small letters, the formula representing standard of living q finally becomes:

$$q = A * F * (k, h) \quad (4)$$

From the derived formula it can be examined that standard of living, or more accurately GDP per capita, increases when technology (A) improves, when the quality of labour improves (H/L), and when capital intensity increases (K/L). Both capital intensity and human capital are subject to the law of diminishing marginal benefits, making technological progress the only viable source of long -run economic growth (Kyläheiko 2020). Diminishing marginal benefits suggest that one additional unit of input increases output by a lesser amount every time, as the total amount of inputs increases. The Cobb-Douglas function, that will be introduced in the next section, is often utilized to derive total factor productivity (TFP), which can be loosely interpreted as a value representing the level of technology (A). In empirics, human capital is often regarded to be a part of technological progress and is measured by proxy with total factor productivity (TFP), therefore in this thesis human capital is not a separate explanatory variable of interest.

2.3 Cobb-Douglas function and the level of technology

The Cobb-Douglas function is a widely used production function that mainly attempts to explain the relationship between two variables, and how they affect the total production of an economy. Many economists regard the Cobb-Douglas function as an adequate approximation of how an economy creates outputs with labour and capital: it is a good fit for modelling GDP as a function of the two main inputs; labour and capital. The function can be utilized to portray the level of technology of an economy but can also be applied to examine the other variables in the function. The Cobb-Douglas production function was first created by the cooperation between Paul Douglas and Charles Cobb, in 1928. Technology is, in its essence, innovation through individual ideas that combine resources, knowledge and know-how in a unique way, creating something socially significant (Pohjola 2014 ,162). (Mankiw 2002, 71)

The Cobb-Douglas function can be written as such:

$$Y(t) = AK(t)^\alpha L(t)^{(1-\alpha)}, \quad 0 < \alpha < 1 \tag{5}$$

Or in a simpler way, as a single good with two factors:

$$Y = AK^\alpha * L^{(1-\alpha)} \tag{6}$$

Where:	Y =	Total production
	A =	Total factor productivity (parameter measuring the level of technology)
	L =	Labour input
	K =	Capital stock
	α =	Capital’s share of income
	β =	Labour’s share of income

From the last formula, it can be seen that economic output is determined by capital and labour input, with their exponents of output elasticities, respectively. The output elasticities determine how large of an effect the increases in capital or labour would have on total production. An increase in capital stock raises the marginal product of labour (MPL) and reduces the marginal product of capital (MPK). Likewise, an increase in the amount of labour raises the marginal product of capital and lowers the marginal rate of labour. When total factor productivity (A) increases, the marginal rate of both labour and capital increase. The

Cobb-Douglas production function is consistent with United States data between 1960 and 2000. During this time period the share of income for labour has been around 0.7, and correspondingly the share of income for labour has been around 0.3. (Mankiw 2002, 71-73)

The Cobb-Douglas function can be useful in estimating the level of technology of a certain production unit through calculating total factor productivity (TFP). TFP measures all increases (decreases) in output that cannot be explained by the increases (decreases) of capital and labour input. The remaining effect is thought to represent, among other unmeasurable variables, technological progress. TFP is a significant factor affecting economic growth and its fluctuations, and it is a key variable explaining differences in GDP per capita across countries. Utilizing TFP as a measure of technological progress enabled researchers to build endogenous models, which could further explain how different underlying variables affect developments in TFP, and thus the main factor explaining long-run growth. TFP can be calculated with the following formula according to Sargent and Rodriguez (2000):

$$TFP = LP - \alpha * \mathrm{K/L} \tag{7}$$

Where:	TFP =	Total factor productivity
	LP =	Labour productivity
	K/L =	Capital intensity
	α =	Capital's share of income

Neoclassical economic theory declares that in the long run TFP explains growth in labour productivity as well as growth in capital intensity (Sargent & Rodriguez 2000). Statisticians tend to prefer the term "multifactor productivity" (MFP) over TFP as some inputs are not always included, such as energy, measurement errors, and externalities (Statistics Finland 2022d). Despite different terminology used, they represent the same variable (Comin 2006).

2.4 Labour productivity

Labour productivity is defined as a ratio between the volume of outputs and the volume of labour inputs; it measures what amount of output can be achieved with a single unit of labour

(Pohjola 2014, 71). Labour productivity (Q/L) is calculated by either gross domestic product per hour worked, or gross domestic product per the number of employees, although GDP per hour worked captures labour input use better than output per worker (OECD 2017). Labour productivity typically exhibits a diminishing marginal productivity: as the amount labour input increases, the marginal utility of each additional input decreases (Pohjola 2014, 72). This thought process is easy to follow: As a labourer's input (labour hours) increases, so does their level of fatigue, thus making each additional labour input less productive than the previous one. There are differences in the decreases in marginal labour productivity across industries, however generally all industries display a decreasing marginal labour productivity. The most frequently used productivity measures are labour and capital productivity, and multifactor productivity (MFP), among which value-added of labour productivity is the single most frequently calculated productivity statistic (OECD 2002). Multifactor productivity is often referred to as total factor productivity (TFP) between economists.

The standard of living of Finland (GDP per capita) was about 12 times larger in the beginning of the 21st century when compared to the beginning of the 20th century. The underlying change leading to this colossal increase in living standards is explained by labour productivity having grown 14 times higher during the prior time period mentioned, signifying that on average, a single 21st century worker produces 14 times more output per hour when compared to an early 20th century worker. Labour productivity in Finland has continued to increase from the year 2000 onwards up until the financial crisis of 2008, after which growth of productivity has slowed down and on certain years completely stagnated, as can be observed from figure 3. The development of labour productivity growth resembles quite closely that of the progress of GDP per capita (figure 1), which is unsurprising considering that the main factor for long-run real economic growth is improvements in labour productivity. (Jalava & Pohjola 2004).

Figure 3: Growth of labour productivity in Finland, index: 2015 = 100 (value added)

The sources for labour productivity growth are improvements in technology (A), increases in capital intensity (K/L), and improvements in human capital of labourers (H/L). Human capital is the stock of skills labourers possess, this includes for example worker know-how, health, education, and knowledge, which all aid in production processes and are an important source for increased productivity (Goldin 2016). The better the skills and knowledge are of a worker regarding their job description, the more efficient their labour is. Capital intensity translates to investments in machinery, infrastructure, production processes, and tools, which subsequently increases labour productivity: workers are able to produce more output per unit of labour as the amount of aiding production tools per worker increase, thus increasing productivity. The single most important factor for labour productivity growth is technical development since productivity growth will eventually halt if no improvements in the level of technology are achieved. Investments in physical capital (Kp) and human capital (Kh) are futile if the level of technology does not improve, according to production theory, because of the diminishing marginal productivity. The law of diminishing marginal utility in this scenario states that as capital intensity increases, so does labour productivity but at a diminishing rate, therefore meaningful long-term productivity growth is possible only through technological developments. A classic example of improvements in technology would be the production of books. Before the invention of the printing press, a scribe would have to copy texts by hand, which could take up to a year depending on the length (Horn & Born 1986). The invention of the printing press would then come to increase labour productivity by colossally reducing the amount of time required to reproduce texts. (Pohjola 2014, 159-160)

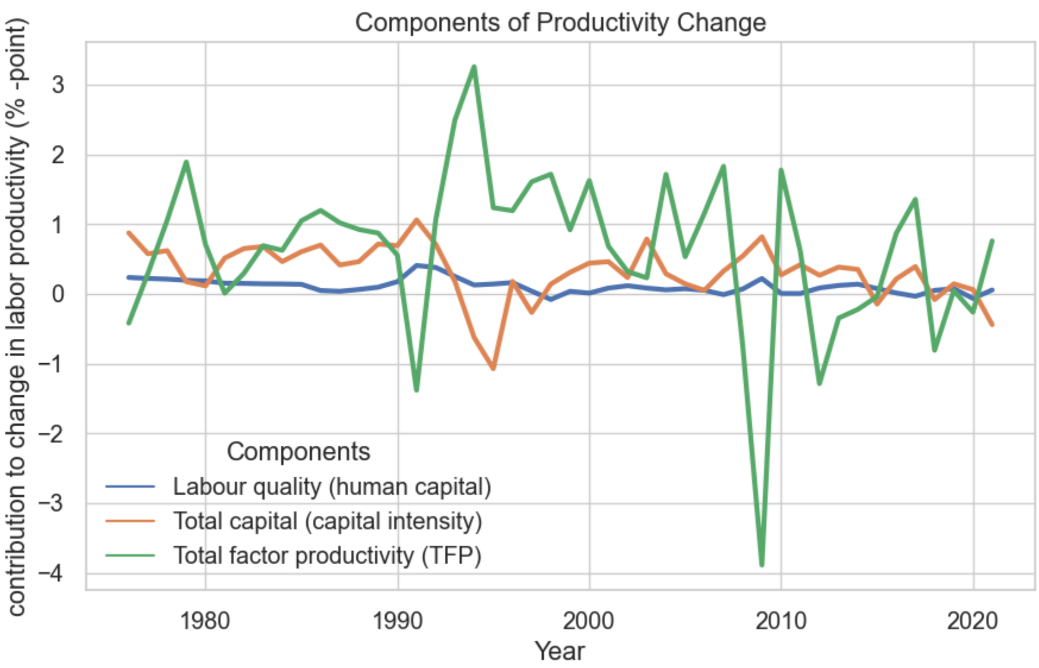


Figure 4: Labour quality, Total capital, and TFP contributions to growth in labour productivity in Finland

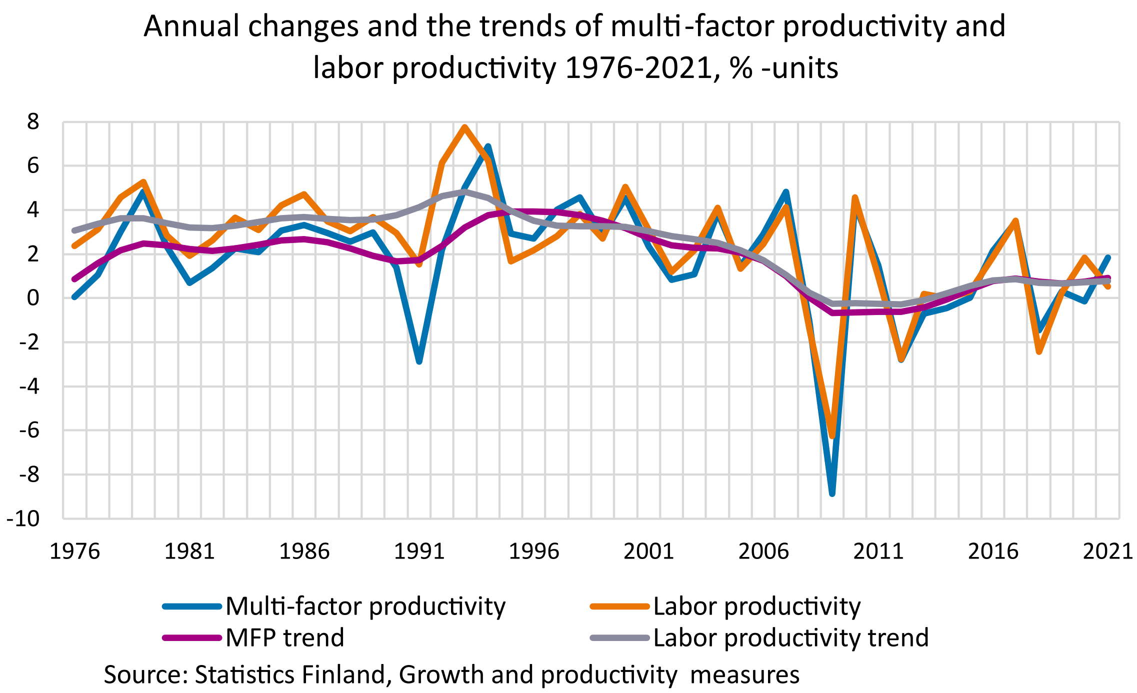


Figure 5: Growth of total factor productivity and labour productivity in Finland

It is evident, from figure 4, that the most crucial factor affecting labour productivity out of the three factors discussed is improvements in technology, which is represented by total factor productivity (TFP). Total factor productivity provides the largest boosts to labour productivity growth but also the biggest declines. Human capital, represented by labour quality, has the smallest effect on labour productivity growth, after capital intensity, represented by total capital contribution. The largest falls in TFP over the time period were caused by the early 1990s depression in Finland, and the Global Financial Crisis of 2008. Figure 5 shows that there is indeed heavy correlation between total factor productivity (TFP), which is referred to as multi-factor productivity in the figure (MFP), and labour productivity: TFP and labour productivity seem to follow each other quite closely. This supports the notion that technical development, or TFP, is the single most important component of amelioration in labour productivity. From the trendline it can be noted that the growth rate of labour productivity had declined from the somewhat steady level of 3 per cent to a stagnating 0 per cent in the early 2010s. In 2021 labour productivity grew 0,5 per cent with TFP having the largest positive effect on the improvement (Statistics Finland 2022b).

“Productivity isn’t everything, but in the long run it is almost everything. A country’s ability to improve its standard of living over time depends almost entirely on its ability to raise its output per worker”, Paul Krugman, the 2008 winner of the Nobel Memorial Prize in Economic Sciences, exclaimed in his 1997 book ‘The Age of Diminished Expectations’. Krugman’s statement is accurate despite sounding somewhat absolute: increases in labour productivity through technological progress have historically been the single most important factor in improvements of GDP per capita (Roubini & Backus 1998). In addition, according to neoclassical economic theory, long-term economic growth is achieved only through growth in productivity of labour (Statistics Finland 2022c). It is clear that, both theoretically and empirically, technological progress is the main underlying factor defining the level of productivity, and therefore long-run economic growth (Chien 2015).

2.5 Total labour hours and unemployment rate

Total labour hours are among the two main economic inputs, labour and capital, that determine a portion of the economic output. Labour hours suffer from diminishing marginal benefits: each additional unit of work is less efficient, or produces less output, than the previous unit. The former implies two things: one, that attempting to achieve consistent economic growth through increases in labour hours is not sustainable in the long run, and two, that decreases in labour hours do not cause catastrophic declines in output of capital intensive and technologically developed industries.

Unemployment is both a short-range cyclical, and a long-term structural issue in an economy, and it typically reduces living standards of the unemployed individuals (Mankiw 2002, 155). Unemployment does, however, have a ‘natural rate’, which is the steady state rate that depends on the rates of job separation and finding (Mankiw 2002, 175). Unemployment that occurs during an economy’s period of normal inflation levels and natural long range GDP growth, is called structural unemployment; it does not vary according to cyclical changes in the performance of the economy. Short-term cyclical unemployment is temporary, and it is caused by changes in demand of labour driven by economic cycles. Unemployment decreases the use of available resources for production, increases public costs and decreases public income through taxes, posing an important issue for governments to manage. Additionally, it causes rises in societal inequality, as less-skilled, young, and senior workers are more likely to experience unemployment, although unemployment is typically much higher for younger than older workers (Mankiw 2002, 175). Unemployment rate is measured as the ratio between 15- to 74-year-old unemployed individuals and the active workforce, expressed as a percentage (Statistics Finland 2022f). (Pohjola 2014, 173-175)

Unemployment rate correlates heavily with total labour hours, since typically the bigger the size of the active workforce the larger the amount of labour hours in an economy. As can be seen from figure 6, total labour hours and unemployment rate seem to, quite logically, exhibit an inversely proportional relationship: as unemployment rate increases, total labour hours decrease, and vice versa. This inverse relationship might translate to high correlation between these variables, and multicollinearity issues in the upcoming regression modelling. Comparing figure 6 and figure 2, it can be noted that although total labour hours suffered an immense fall in 1995, GDP per capita did not suffer as sizeable of a decline. This supports the previously established notion that total hours worked in an economy, although important, is not the most crucial variable in determining the standard of living of an economy.

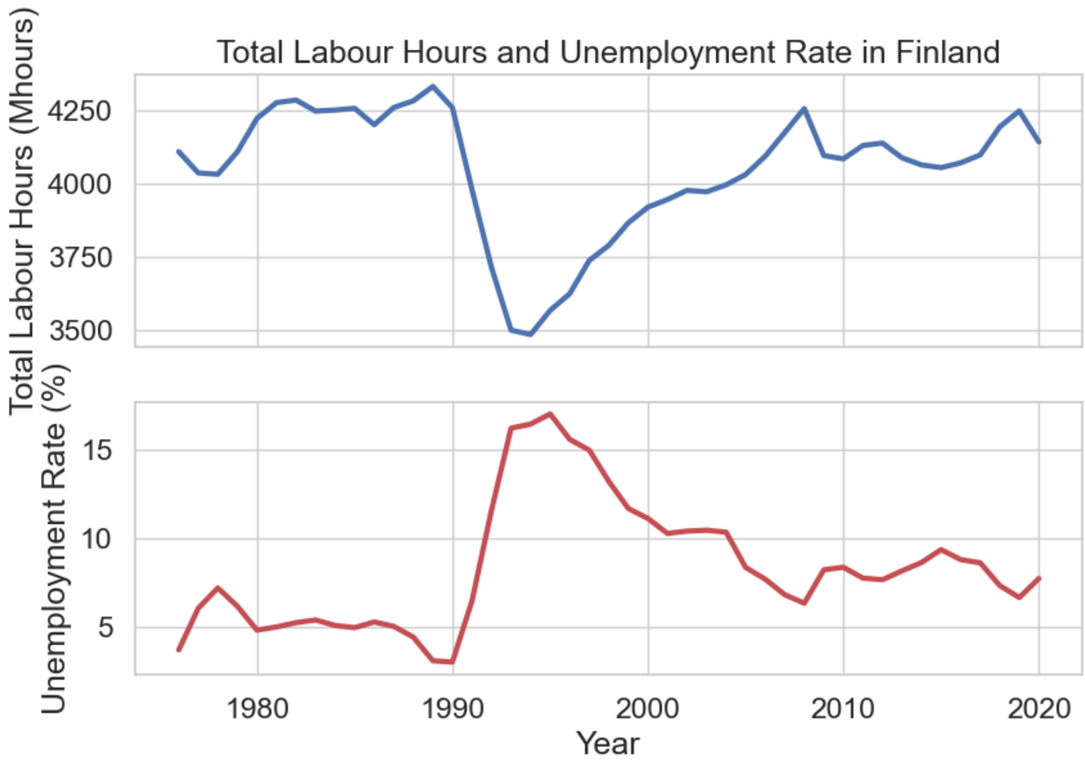


Figure 6: Total labour hours and unemployment rate in Finland (1976-2020)

2.6 Framework application

The theoretical framework introduced in chapter 2 was applied to determine the starting point in choosing the explanatory variables used in the linear regression analysis, and in further methods. The Solow Growth Model provides the study with a framework with which to examine GDP per capita and further analyse the effects of labour hours. To summarize, the Solow Growth Model determines that economic growth can be explained through capital accumulation, active labour force, and labour productivity. In essence, the explanatory variables have been chosen according to the Solow Growth Model: the capital intensity variable relates to capital accumulation, total labour hours and unemployment rate relate to active labour force, the Solow residual representing the level of technology has been included by utilizing Total factor productivity growth (TFPG), and labour productivity has been included as such.

The level of technology is imperative in determining labour productivity; thus, the Cobb-Douglas production function was included in the theoretical framework to provide a proper understanding of how total factor productivity (TFP) represents the level of technology, and how it is calculated, and to justify its usage. The Solow growth model and the Cobb-Douglas function together provide the theoretical framework and starting point for the regression modelling, and thusly the Monte Carlo simulation.

3 Research material, methods, and progression

The study is conducted using quantitative statistical methods applied on data compiled from Statistics Finland's database, which is a Finnish government agency tasked to produce information and statistics for the benefit of the public, and government policy. In this section, the research tools, materials, and methods are presented, in addition to the two main research methods. The two methods, OLS linear regression and Monte Carlo simulation, will first be briefly introduced, followed by the analysis.

3.1 Research tools

Python programming language was used in Visual Studio Code environment, to perform the initial gathering of the data. The subsequent data processing, including joining the data, validating the integrity of the data, and building the initial and final regression models, as well as performing the Monte Carlo simulation was also done in Visual Studio Code. Illustrative graphs, tables and figures were created in Visual Studio Code and Microsoft Excel.

3.2 Compiling the data

The data utilized in this study consists of GDP per capita (Y), total labour hours (Lh), labour productivity (Lp), unemployment rate (UR), capital intensity (K/Lh), and total factor productivity growth (TFPG). GDP per capita is expressed in millions of 2010 euros to properly take into account the effects of inflation on the time-series data. Labour productivity (Lp) was calculated as a division between total labour hours (Lh) and GDP in 2010 euros. Both GDP and total labour hours is measured in millions of 2010 units, thus a simple division generates the labour productivity (Lp) variable ready for modelling. Capital intensity (K/Lh) was generated by performing a division between net stock of total non-financial assets in 2010 euros and labour hours (Lh). Unemployment rate (UR), which represents the ratio between the unemployed to the active labour force from ages 15 to 74, was retrieved directly from Statistic Finland's database. Total factor productivity growth (TFPG) displays the growth in productivity not explained by inputs capital and labour, and it is interpreted as the improvement in the level of technology in this study.

The original time series data had yearly observations between the years 1976 and 2020, consisting of 45 individual data points for each of the variables. To increase the size of the dataset and improve reliability of results, a data augmentation technique using averages to generate more data points was utilized: biannual observations were created by averaging between yearly data points. For example, to derive an observation for labour hours 1st of May 1999, the data for 1999 (3867 Mhours) and 2000 (3920.5 Mhours) was averaged between providing a new data point (3893.75 Mhours). The new data added is technically synthetic data, however these added data points are reasonable as it can be argued that the new data points were simply measured from a different point in time. For example, GDP per capita was 24 087€ in 1995, and 24 489€ in 1996, thus between 1995 and 1996 GDP per capita has necessarily shifted through the average amount of 24 288€ between these years. After augmenting the data, observations increased to 89 for each variable.

During the relatively wide time frame of the data, Finland experienced many recessions such as the early 1990s depression and the financial crisis of 2008. In order to maximize the accuracy of the linear regression model and further analysis, the years 1991-1993 and the years 2009-2010 were considered outlier observations and consequently removed, leaving the dataset with 79 observations for each variable.

Table 1: Descriptive statistics

	GDP per capita (Y)	Labour hours (Lh)	Labour productivity (Lp)	Capital intensity (K/Lh)	Unemployment rate (UR)	TFP growth (TFPG)
Mean	28122,5	4074,4	36,0	117,0	8,1	1,9
Standard deviation	6893,4	197,0	10,3	28,3	3,5	1,9
Min	16629,0	3483,9	19,1	66,4	3,1	-5,0
Median	28327,0	4110,4	38,2	126,1	7,7	2,2
Max	37330,0	4334,3	48,9	158,6	17,0	6,9

3.3 OLS Linear regression

Ordinary least squares (OLS) linear regression is a statistical model where the dependent variable y is explained by known independent variables $X_1, X_2, \ldots, X_n$, and by the unknown random error term, which represents the portion of the model that is not explainable with the chosen explanatory variable(s) (Hill et al. 2012, 46). The purpose of OLS regression is to fit a line to the data values as well as possible, and this is achieved through minimizing the sum of the squares of the vertical distances from each data point to the fitted line (Hill et al. 2012, 51). Ordinary least squares linear regression is one of the most used multivariate modelling techniques and it has been known for almost 200 years (Chumney et al. 2006, 94).

The simple linear regression equation goes as follows:

$$Y = \beta 0 + \beta 1x1 + \beta 2x2 + \beta 3x3 + \ldots + \beta nxn + e \qquad (8)$$

Where: Y = The dependent variable

X = An explanatory variable

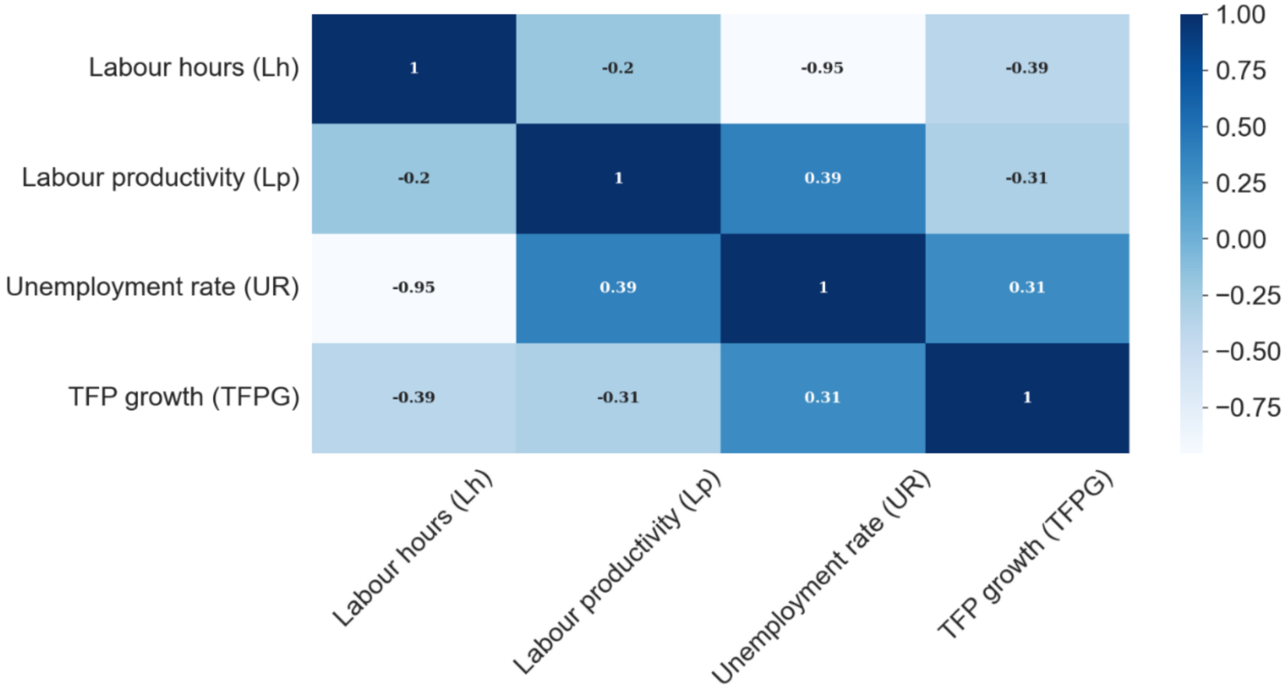
β = Parameter, where β_0 is the intercept term

e = The error term

It was evident from the initial model building that capital intensity (K/Lh) seemed to exhibit an inversely proportional relationship to GDP per capita, according to the coefficient of the first regression model. Increases in capital intensity decreased the value of GDP per capita, and vice versa. Although the p-value for capital intensity was statistically significant, the coefficient and implications of the variable go against the theoretical framework specified in chapter 2.2 and well-established modern economic theory. In addition, removing the capital intensity variable from the model decreases the symmetric mean absolute percentage error of the final predictive regression model, and does not significantly lower the goodness of fit of the model. The purpose of this study is to particularly examine the effects of hours worked on Finnish standard of living, and for the above reasons capital intensity was removed from further analysis.

A dataset experiences multicollinearity when chosen variables shift together in systematic ways making it unsure that we can extract useful insight of the different variables individually (Hill et al. 2012, 240). Multicollinearity tends to cause large shifts in the regression model with even relatively small changes in the base data; it can cause an ill-conditioned OLS estimator, and thusly incorrect inference. Multicollinearity does not, however, affect the overall performance of the model. The main goal in this thesis is to examine the effects of a single variable, labour hours, on the economy in addition to the entire model, therefore multicollinearity issues must be examined rigorously. (Belsley 2006)

Table 2: Correlation matrix of explanatory variables



The correlation matrix in table 4 indicates that most of the variables experience only mild, unproblematic correlation whereas unemployment rate (UR) and labour hours (Lh) experience a high-level opposite direction correlation of -0.95. Labour hours tend to diminish when unemployment rate increases and vice versa, which can be examined from figure 6, thus a high correlation between these variables is expected. The variance inflator factor (VIF) corroborates the findings from the correlation matrix above: the VIF -values for labour hours, unemployment rate, labour productivity, and TFP growth are 18.1, 20.8, 2.3, and 1.5, respectively. By a commonly used rule of thumb, a VIF -value that exceeds 10 is thought to cause issues in the model (Kaakinen & Ellonen 2022). In addition to causing a multicollinearity issue, the null hypothesis of the coefficient having a value of 0, cannot confidently be rejected in the case of unemployment rate. Unemployment rate variable is statistically insignificant on a 95% confidence interval as the p-value for the variable in the initial testing was 0.114. By removing unemployment rate from the model, all multicollinearity issues lacquer. The new VIF -values for labour hours, labour productivity and TFP growth are 1.4, 1.3, and 1.4 respectively. Lh can be thought to encompass the information inside unemployment rate, thus removing unemployment from the model more than likely does not significantly decrease valuable information in the dataset. The final remaining explanatory variables in the model are thusly labour productivity (Lp), labour hours (Lh), and TFP growth (TFPG), after removing unemployment rate to avoid overfitting and multicollinearity problems in the model.

The trained model was built after the evaluation and refinement of the data was performed, and the final explanatory variables chosen. The main purpose of the trained model was to verify accuracy of the coefficient estimations, and find a fitting formula for the regression equation, which can subsequently be utilized in the Monte Carlo method. The dataset was first split into a training dataset and a testing dataset, where the training set encompassed 80% of the data and the testing data the remaining 20%. The data for each group was randomly sampled.

Table 3: Regression model indicators

R-squared	0.997
Adjusted R-squared	0.997
F-statistic	0.0000
Durbin-Watson	0.182

Table 4: Explanatory variables

	Coefficient	Standard error	P-value
Constant	-21443. 76913365585	1212.932	0.000
Lh	6.0914445	0.271	0.000
Lp	684.46092502	5.009	0.000
TFPG	68.41205596	28.556	0.032

Tables 3 and 4 demonstrate the results of the regression. The entirety of the model is statistically significant on the applied 95% confidence interval as F-statistic, the p-value for the goodness of the model fit, is comfortably below 0.05. The coefficient of determination, R-squared, indicates that the regression model explains 99.7% of the variation of dependent variable Y, GDP per capita. The adjusted R-squared, which takes into account the number of estimated variables and the sample size, indicates an identical goodness-of-fit. The

Durbin-Watson test will be explored more thoroughly moving forward, although it is good to already remark that the result indicates significant autocorrelation in the data. The null hypothesis can be rejected regarding all chosen explanatory variables, making their coefficients differ statistically significantly from an effect of 0. The standard errors in the model, which indicate how much the estimations vary depending on different samples of the same data, are relatively small for all other variables apart from TFP growth. Standard errors can be considered a metric of accuracy for the coefficients; therefore, it must be conceded that TFP growth might not produce accurate estimates. The coefficients of each explanatory variable estimate the increase of dependent variable Y when an explanatory variable increases by one unit. The coefficients of the regression results construct the final regression equation:

$$Y = -21443.77 + 6.0914 * \mathrm{Lh} + 684.4609 * \mathrm{Lp} + 68.4121 * \mathrm{TFPG} \qquad (9)$$

The equation indicates how much GDP per capita (Y) would be affected by changes in the coefficient variables. For example, a one-unit positive change in labour productivity (Lp) is estimated to grow Y by approximately 684.5 2010 euros. Labour productivity has distinctly the largest effect on GDP per capita, which is consistent with contemporary economic theory. On the other hand, a million hour increase in hours worked (Lh) is estimated to increase Y by roughly 6.1 2010 euros. Finally, a one percentage point increase in TFP growth (TFPG) is estimated to increase Y by 68.4 2010 euros.

The first five predicted and true values of GDP per capita (Y) and their relative difference have been compiled in Table 5. The predicted values are quite close to the true values, with the highest difference between all true and predicted values compared being 2.28 %. For example, the regression formula provides a value of 36915.4 when estimating the level of Y for 2020. This differs from the true value for Y in 2020, which was 36263, by only 1.8%. The relatively small difference between the predictions and true values indicates a well behaving predictive model with accurate forecasts.

Table 5: First five predicted and actual values of Y

Predicted values for Y	**Actual values of Y**	**Difference (%)**	**Year**
32447.76	32840.5	1.20	6/2004
24823.48	25159.5	1.34	6/1990
23442.38	23201	1.03	12/1994
35003.64	34900	0.30	6/2013
31028.27	31459.5	1.38	6/2002

The mean absolute percentage error (MAPE) and the symmetric mean absolute percentage error (SMAPE) measures were used to examine the prediction accuracy of the previously formed linear model. Mean absolute percentage error (MAPE) is the most widely used measure of forecast accuracy in businesses and organizations that measures the accuracy in percentage, and it is especially effective when the dependent variable's value is on the positive and remains comfortably distant from 0 (Tofallis 2015; Myttenaere et al. 2016). The dependent variable in this thesis ranges between 16629 and 37330, thus the values do not induce issues for the MAPE equation.

The MAPE method is asymmetric by nature, meaning that it puts more weight on negative errors in predictions than on positive ones, therefore MAPE favours models that provide predictions under the true values. SMAPE is designed to address the asymmetricity problem of MAPE, and thusly does not favour negative errors nor positive errors in prediction. Both methods were applied to test the prediction accuracy of the formed regression model. (Lewinson 2020)

The MAPE and SMAPE equations are defined as follows:

$$MAPE = \frac{\sum \frac{|T-P|}{T} * 100\%}{N} \quad (10)$$

$$SMAPE = \frac{100\%}{N} * \sum_{t=1}^{N} [\frac{|P_t - T_t|}{(|T_t| + |P_t|) / 2}] \quad (11)$$

Where: T = True values of Y

P = Predicted values of Y

N = Number of observations

Table 6: Results of MAPE and SMAPE measures

MAPE	1.230 %
SMAPE	1.233 %

The results of both MAPE and SMAPE indicate minimal error between predicted and true values. According to these accuracy measures applied, the forecast provided by the regression model differs from true values by only 1.2 %, which indicates highly accurate predicted values by the regression equation. Such a low prediction error percentage is ideal when drawing conclusions from the model and using the model for further data analysis methods.

3.4 Verifying integrity of data

The remaining aspects of data integrity verification are examined in this section. Multicollinearity issues were already covered in chapter 3.3, and it resulted in completely removing an explanatory variable from the regression model. The data is examined for heteroskedasticity and autocorrelation issues in this section.

3.4.1 Heteroskedasticity

Heteroskedasticity is a phenomenon where a sequence of variables does not possess matching finite variances, and standard errors are not constant over time, resulting in inefficient estimates for parameters and therefore possible incorrect conclusions (White 1980). Plausible causes for heteroskedasticity are outlier observations, skewness of the distribution of variables and training over time (Turppura 2022). The Breusch–Pagan test is commonly utilized in determining heteroskedasticity in a linear regression model. The null hypothesis states that the linear regression variables are homoscedastic, and it is rejected if the test delivers a p-value below the chosen confidence interval. The p-value from the Breusch-Pagan test applied on this study's linear model returns a value below the chosen confidence interval of 95%, meaning that the null hypothesis is rejected and thusly there is heteroskedasticity in the model. The returned value is approximately 0000.1, which is significantly below the threshold of 0.05. Despite breaking one of the assumptions behind the OLS regression, heteroskedasticity does not cause the estimates of OLS to be biased, however the standard errors of the individual variables' coefficients could be significantly biased. This study focuses more on the predicting power of the linear model, therefore heteroskedasticity does not pose a sepulchral issue. (Breusch & Pagan 1979)

3.4.2 Autocorrelation

Autocorrelation in a dataset indicates that observations from a previous period affect the next in a meaningful way, causing unreliable standard errors for estimated coefficients, much like in the case of heteroskedasticity and multicollinearity (Turppura 2022). Figure 7 is a first order lagged scatter plot, illustrating a clear structural pattern in the data. The data appears to be positively autocorrelated, indicating that an increase in the value of a variable during a previous time period leads to a relative increase in the next period.

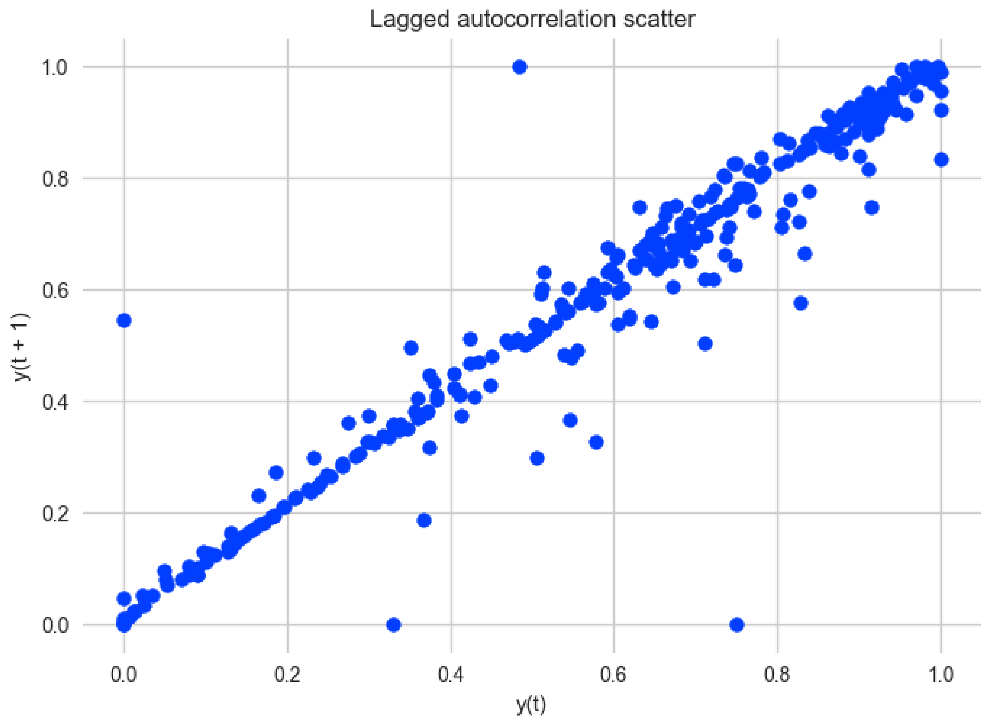


Figure 7: Lagplot to examine autocorrelation

Durbin-Watson test was used to confirm whether autocorrelation exists within the dataset, and the returned value of approximately 0.18 of said test indicates positive autocorrelation in the data. This is not surprising considering the relatively wide time period and the nature of the economic data used in this thesis. It is quite intuitive, that for example labour productivity data points are affected by previous data points, as the source for labour productivity is mainly the level of technology, and a previously achieved level of technology naturally affects its future levels. Correlation between a variable's data points is quite typical in a long-range time-series data, and it may lead to incorrect standard errors (Turppura 2022).

3.5 Monte Carlo method

To simplify, Monte Carlo method, or Monte Carlo simulation, means the repeated generation of random values with certain probabilities or weights, which correspond to a real-world variable probabilities and values. The goal is to extract insight about one or multiple variables by observing many realizations of it or them. The algorithm is instructed to sample values from a certain distribution with certain predefined probabilities. After defining the sample values and their respective probabilities, the Monte Carlo simulation can be repeated as many times as is seen fit; typically, the more the better, although computing power must be considered. (Kroese et al. 2014)

Monte Carlo simulation is a crucial part of the complete analysis. The regression results can be analysed independently, and conclusions can be draw. Nonetheless, the regression equation is static and does not consider possible and probable simultaneous shifts in the explanatory variables. When analysing how a 20% decrease in labour hours (Lh) would affect output in the year 2020, static values for labour productivity (Lp) and TFP growth (TFPG) must be assumed to perform the analysis. This is of course useful on its own, but a simulation that takes into account possible simultaneous shifts provides more reasonable and rigorous outcomes, from which to draw more reliable and accurate conclusions.

In this study, the sample values were formed from the original data of labour hours (Lh), labour productivity (Lp), and TFP growth (TFPG), by creating 15 value bins with equal ranges, and calculating their mean values inside each bin, respectively. The bins for Lp were created from data where the original Lh values were reduced by 20% to represent an economy-wide switch to a 30-hour workweek. The bins were assigned a sampling probability corresponding to the number of observations in each bin. For example, 15 bins were created for Lp, with the bin value limits ranging from 19 to 49, thusly each bin has a range of 2 integers. Table 7 shows the logic behind the bins and their probabilities: for example, the probability of bin 19-21, with a mean value of 19.78, to be sampled on a single run in the Monte Carlo simulation is 7.59%. The probability of a value getting sampled comes from the count of observations (6) in the bin 19-21 divided by all observations (79).

The explanatory variables are not completely independent as there exists correlation between them. Taking into account the correlation between the sample values could further increase the accuracy of the simulation. For example, sampling a certain value from labour productivity would translate to a higher probability for a certain value of TFP growth, as their correlation coefficient exceeds 0. Nevertheless, the correlation between all the explanatory variables is relatively weak in the data; below 0.4 and using the previously established method is more straightforward. Correlation does not necessarily correspond to a causal relationship: although the matrix indicates some correlation between the explanatory variables, this might not be the case with all variables in actuality. For example, correlation between labour hours and productivity is somewhat contested, as was examined in chapter 1.1, thus using the correlation between these factors in sampling could skew the end results of the simulation. Additionally, this study does not differentiate between industries and using a single correlation coefficient across all industries in sampling would not accurately represent the conditions of them all in aggregate as the relationships of the explanatory variables differ from industry to industry. The correlation between Lp and TFPG is clearer; one of the main drivers for labour productivity increases is in fact technological improvements, which was examined in chapter 2.4. In this regard it could be beneficial to consider their correlation in sampling, however the correlation remains relatively low in the data (0.31). After abandoning using the correlation in sampling for labour hours, it was also abandoned for other variables, because the correlation remained relatively low between all variables, and because it is not justifiable to use correlations in sampling for some but not all variables.

Table 7: Means, probabilities, and counts of first Lp bins

Bin mean	Probability (%)	Count
19.78	7.59	6
21.94	10.13	8
24.10	6.33	5
25.998880	5.06	4

After defining the sample values (mean of each variable's bin), and their corresponding probabilities, defined by the number of observations in each bin, the simulation could be performed utilizing the coefficients and constant from the regression equation (equation 9). The coefficients and constant will remain the same throughout the simulation, but the sample values for Lh, Lp, and TFPG will vary across the entire time period (1976-2020) according to the probabilities of different bins and their values, changing the outcome of each run. The end results will be compared to the actual GDP per capita distribution. The simulation was run 100 000 times to create a significant distribution of outcomes.

4 Findings and interpretation

The purpose of this study was to find the relationship between labour hours and standard of living, or GDP per capita more precisely. The goal was to estimate how much a shift from a 37.5-hour workweek to a 30-hour workweek would affect the living standards of Finland. Findings of both the linear regression and the Monte Carlo simulation are presented individually in this section. Overall, the results of both research methods suggest that a shift to a shortened workweek, or a 20% decrease in hours worked in particular, would reduce the level of GDP per capita, as was expected.

4.1 Linear regression

The coefficients for labour hours (Lh), labour productivity (Lp), and total factor productivity growth (TFPG) provided by the trained regression model (equation 10) all encompass a positive linear relationship with GDP per capita (Y). Lp has the largest affect by far, and clearly explains most of the growth in Y out of the three explanatory variables. This is in line with contemporary economic theory. The coefficient for labour hours (Lh), 6.0914, suggests that an increase (decrease) of 1 million hours in labour time would increase (decrease) GDP per capita by approximately 6.1 deflated 2010 euros. The effect of Lh on Y might seem trivial at first glance, but for example, if hours worked in 2020 were reduced by 20%, it would cause a reduction of about 5049 euros in GDP per capita that year. The new value for GDP per capita after such a reduction in labour hours would be approximately 31214.1, which is a 13.92% decrease from the original value 36263.

When making comparisons between the effects of the different regression coefficients, it is important to use standardized coefficients, because they take into account the unit of measurement and thusly accurately represent the comparable effect of each explanatory variable, respectively. The min-max-standardized coefficients are presented in table 8. The standardized coefficients confirm that Lp has the largest effect on Y, followed by Lh and lastly TFPG. Notably, the gap between coefficients Lp and Lh has significantly reduced, which indicates a more shared roles in explaining output Y. The effect of Lh is highlighted in the standardized coefficients because of the large values of the original data compared to the other two explanatory variables. Additionally, the significance of TFPG has greatly diminished compared to the other two variables. Overall, the standardized coefficients confirm that Lp has clearly the largest effect.

Table 8: Standardized regression coefficients

	Standardized coefficient
Constant	-0.1984685547013788
Lh	0.2502374
Lp	0.98385368
TFPG	0.03928711

The percentage decrease a 20% reduction in labour hours caused was calculated for each year to get a more comprehensive view of the effects of this type of a change. Some descriptive statistics of these calculations are compiled in table 8.

Table 9: Descriptive statistics of outcomes from a 20% decrease in hours worked

	Actual Y	**New Y after a 20% reduction in labour hours**	**Percent decrease from Actual to new Y (%)**
Mean	28120	23156	18.9
Median	28327	23663	16.5
Max	37330	32142	30.1
Min	16629	11621	13.7
Standard deviation	6894.8	6906.5	5.3

As is evident from table 8, the effects of a 20% decrease in labour hours varies largely from year to year: the largest decrease in Y was 30.1 % in the year 1976, and the lowest decrease in Y was 13.7% in the year 2007. The calculated decrease for each year tends to exhibit smaller percentages from 1976 towards more recent years. The proportional difference between estimated and actual GDP per capita diminished through the 1990s and 2000s, as labour productivity increased significantly, up until roughly 2010 when labour productivity growth began to stagnate. Figure 8 also suggests that the reason for the labour hour reduction having an overall smaller impact in later years is due to increased labour productivity, which takes a certain amount of importance or weight from labour input in defining output, and thusly GDP per capita. The mean value suggests that on average, a 20% reduction in hours worked would result in a 18.9% decrease in the level of GDP per capita. As a comparison, during one of the worst economic crises in Finland, the early 1990s depression, Finnish GDP per capita saw a cumulative decline of 11.3% between 1990-1993. Even the lowest reduction from the dataset, 13.7%, exceeds the former percentage. A more recent reference would be the Global Financial Crisis of 2008, when Finnish GDP per capita experienced an 8.5% decline in 2009. Some of the decline in these two crises is attributable to population growth, however. Population size grew by about 80 thousand people between 1990 and 1991, and by about 25 thousand people in 2009 (World Bank 2022). An increase in population size naturally reduces the level of GDP per capita even if real GDP remains constant. Some amount of the decline in GDP per capita was caused by population growth during the aforementioned time periods, although it did not have a substantial effect, thus the comparisons made work well in providing reference points. If this study was conducted with only more recent data, the effect of the labour hour reduction would most likely be below the average estimate of 18.9% provided by the regression in this wider dataset. (Statistics Finland 2022g)

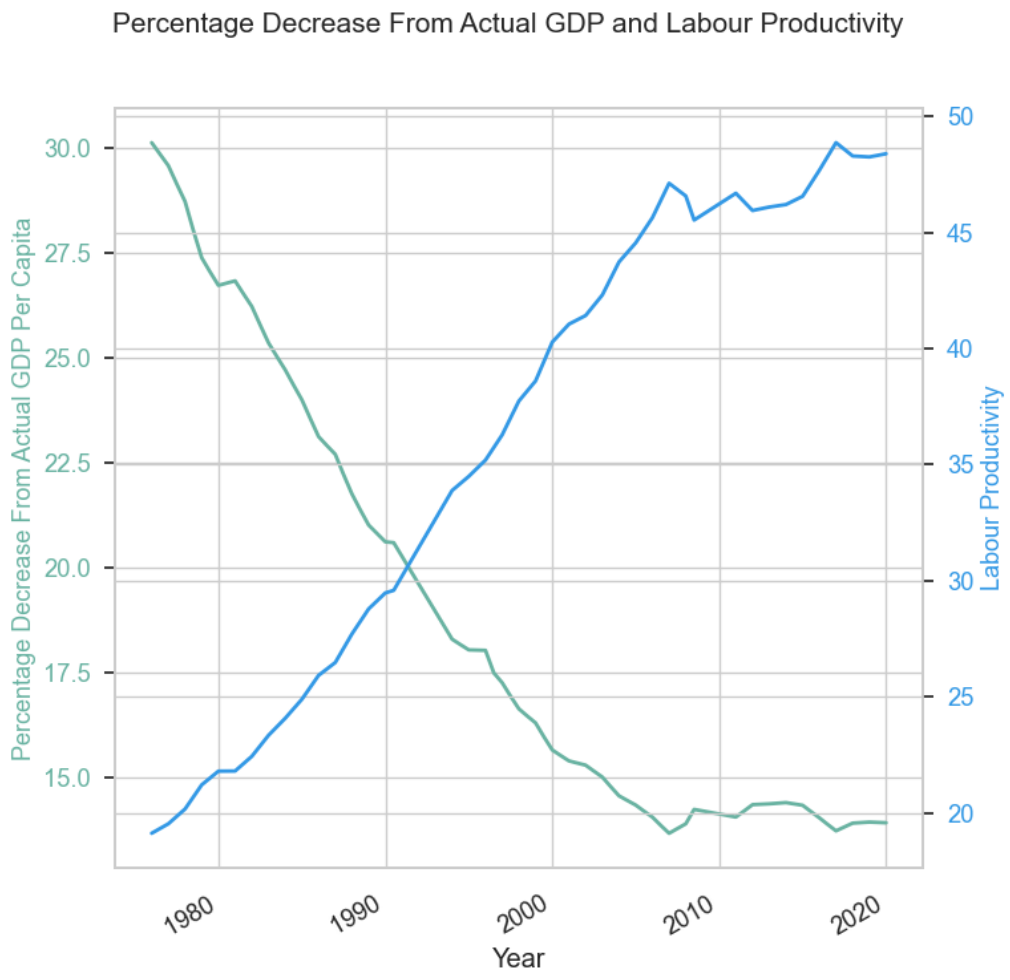


Figure 8:Subplot of percentage decrease from actual GDP and labour productivity

As discussed in chapter 1.2, decreasing labour hours could increase labour productivity and therefore offset some or all reductions in GDP per capita that cutting labour hours would cause. Workers would be less fatigued, and consequently would be able to perform their duties better and more efficiently. This would vary largely between industries, however. So called white-collar workers likely have the largest potential for achieving the same amount of output with fewer working hours, on the contrary so called blue-collar workers would likely struggle more with achieving the same output with decreased working time. Potential labour productivity increases through fewer working hours were not considered in the regression model as the data utilized does not differentiate between industries.

The analysis through the regression model only is static and assumes that all else stays equal when calculating the decrease in GDP per capita. This is not realistic as in addition to labour hours both labour productivity and TFP growth shifted largely from year to year. Thus, the Monte Carlo simulation is applied in the following chapter to provide some additional results.

4.2 Monte Carlo simulation

The Monte Carlo simulation provided somewhat unexpected but nevertheless insightful results: the distribution derived from the simulation does not accurately represent any typical probability distribution, although it seems to somewhat exhibit a bimodal distribution with quite a large amplitude. Figure 9 is a distribution plot that displays the outcomes of the simulation with GDP per capita on the x-axis and the outcome count on the y-axis. The orange dashed line represents the mean of the simulation outcomes, and the red dashed line represents the mean of the actual GDP per capita. The mean value of actual GDP per capita (Y), instead of the latest value from 2020, must be utilized to perform a fair comparison between simulation outcomes and actual GDP per capita, as the simulation outcomes do naturally not correspond to any certain year. Similarly, the comparisons must be made between descriptive statistics, for instance mean, median, max, and min values, instead of individual reference points.

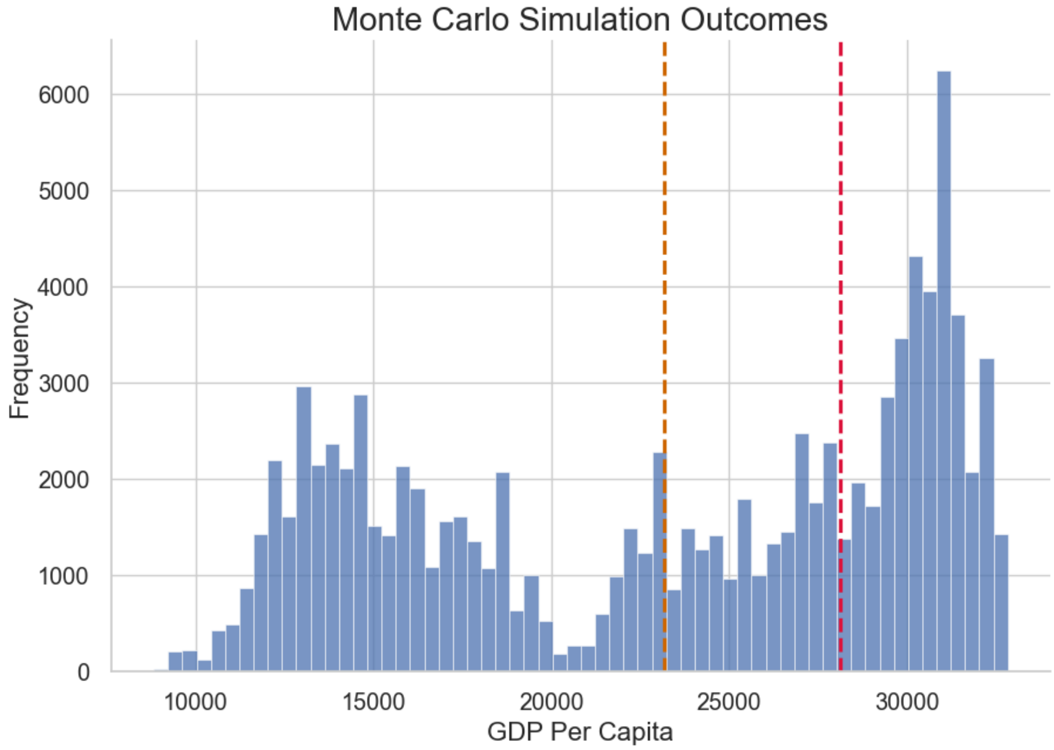


Figure 9: Monte Carlo Simulation outcomes, and averages of actual GDP (red) and simulation GDP (orange)

The large number of high-end outcomes above even the mean of actual GDP per capita (Y) push the mean of the simulation outcomes towards the right, even though a large portion of outcomes is well below the simulation mean. The difference between the average simulation outcome and the average of actual GDP per capita (Y) is 19.55 percent, indicating an average decline of 19.55% in GDP per capita (Y) if labour hours were reduced by 20%. This effect is slightly larger than that of analysing the regression model alone, which provided an average decline of 18.9%. The random sampling for the variables therefore did not decrease the effect a labour hour reduction would have on GDP overall but increased it.

Most of the simulation values for GDP per capita (Y) fall under the mean of actual GDP per capita (Y), however a large portion of the outcomes exceeds it. Notably the most common value of the outcomes, the mode, is about 31059, which is roughly 10% larger than the average for the actual Y. The mode remains well beneath the most recent (2020) level of Y 36263, although some outcomes nearly matched the 2020 level of Y as well. The vast number of values beyond the actual Y average suggest that if all the other variables remain favourable during a hypothetical shift to a shorter workweek, the standard of living might not decrease at all, but rather increase. Thusly, it is possible that living standards would be unaffected, with a bit of luck if you will, when reducing working hours. 35.5% of the outcomes either match or exceed the average of actual Y; this can be interpreted as a 35.5% probability of Y remaining the same or increasing after reducing the length of the workweek. The majority of the simulation outcomes, 64.5%, remain below the average of actual Y, however. This quite dismally indicates that there is a 64.5% chance that a reduction in labour hours would result in, more or less, a diminished level of GDP per capita, or living standards.

Figure 10 displays a boxplot of both the actual GDP per capita (Y) and the simulation outcomes with a shared x-axis. The edges of both boxes represent the upper and lower quartiles, and the whiskers represent values between 0-25% and 75-100%, respectively. The lines inside the coloured boxes represent the median value. The values of the Monte Carlo results vary slightly more widely, whereas actual Y is more tightly packed; this is due to the to the somewhat bimodal shape of the Monte Carlo distribution. Especially the bottom 25% is overrepresented when compared to the distribution of the actual GDP per capita. 50% of the values of the simulation fall between 15954.2 and 30014.7 whereas 50% of Y values fall between 22019.3 and 34882.8.

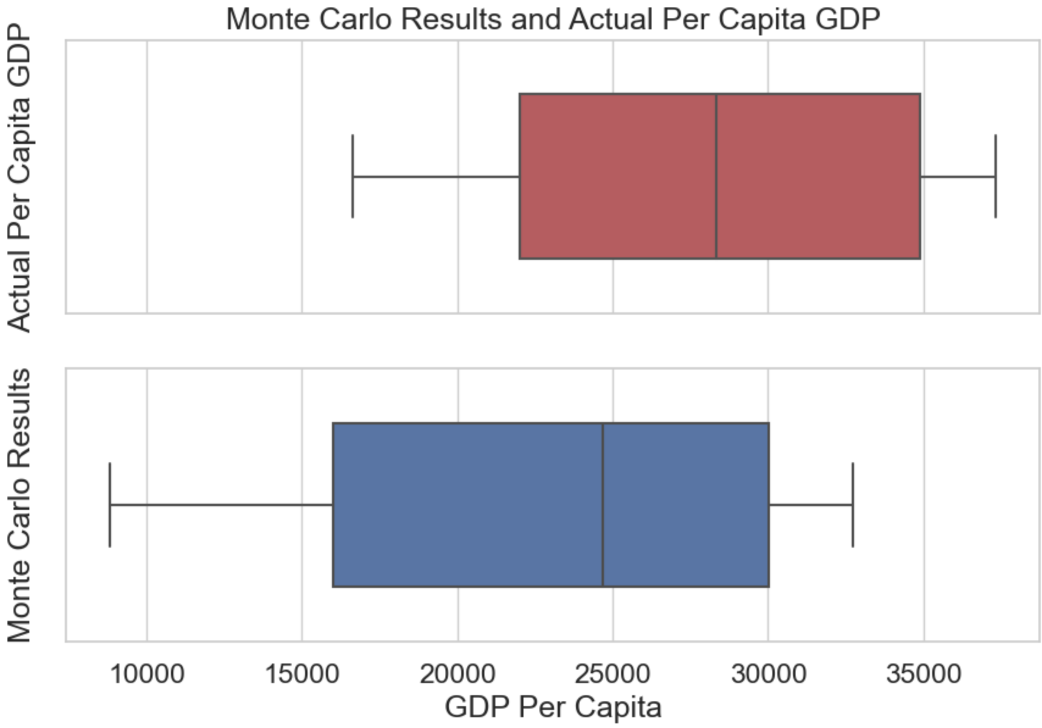


Figure 10: Boxplots of Monte Carlo results and actual per capita GDP with a shared x-axis (2010 euros)

The simulation results, and figures 9 and 10, clearly display that a systematic 20% reduction in working hours diminishes the level of GDP per capita (Y) significantly, on average. The simulation provides probabilities for different scenarios regarding the change in Y, when comparing to the mean of the true values for GDP, which can be found from table 9. The simulation suggests that there is a 25% probability for both Y diminishing either 43 to 68 percent, or 12.5 to 43 percent from the average of actual Y. There is a 14.5% probability that Y would decline by 0.1 to 12.5 percent, a 1.39% probability of it neither diminishing nor growing, and a 34.11% probability that it would instead increase by 1 to 16.3 % above the average of the actual Y. The most positive occurrence out of all the individual scenarios in table 9 is also the most likely with a 34.11 percent probability. However, there is a cumulative probability of 50% for Y to fall between 12.5 to 68 percent.

Table 10: Different outcomes for GDP per capita and their probabilities

Per capita GDP outcome	Probability	Change from mean of actual per capita GDP (2010, %)	Per capita GDP outcome in current euros (6/2022)
8827.42–15954.24	25%	68–43 (–)	11210.82–20261.89
15954.24 –24609.73	25%	43–12.5 (–)	20261.89–31254.36
24609.73 – 28119.92	14.5%	12.5–0.1 (–)	31254.36–35712.30
28119.93	1.39%	0	35712.31
28119.93–32711.46	34.11%	0.1–16.3 (+)	35712.31–41543.55

After these probabilities and value ranges have been calculated, we can determine the overall expected value for GDP per capita by using the mean values between the outcome ranges. The expected value for GDP per capita via the simulation is 22756.76 deflated 2010 euros, which would be approximately 28901.1 in current euros. This value once more signifies a large 19% drop in the level of Finnish living standards, when compared to the mean of the actual Y data, which would be 35693.63 in current euros. The difference between the max values of both the simulation and actual Y is 12.4%, and the difference between the min values of both datasets is 46.9%. Simulation outcome median is 13.2% smaller than the median of actual Y. None of the simulation outcomes reached the most recent value of Y, 36263.

The results look somewhat bleak but, in some instances, moderately hopeful for the proponents of a nationwide 30-hour workweek. The bad news is that more likely than not, GDP per capita (Y) would decrease by anywhere between 0.1 to 68 percent, although a decrease approaching even 60% is highly unlikely, with a probability of a bit over 2%. Because of the somewhat bimodal distribution of the simulation outcomes, the most probable values are either very low or surprisingly high, making any actual policy change to diminish working hours very risky with potentially high rewards, however. Despite all previously mentioned, over a third of all the simulation outcomes reached numbers above or on par with the mean of per capita GDP (Y), signifying a 35.5% probability of no compromises in living standards after shortening working hours. Additionally, there is a one in two probability that new GDP per capita, after shortening the workweek, would result in a 12.5 percent decrease in the worst-case scenario, but a 16.3 percent increase in the best-case scenario.

For some, depending on their subjective preferences, a trade-off between living standards and leisure time is attractive; these individuals would be ready to accept a certain decline in their living standards to enjoy more leisure time. With a 75% probability, GDP per capita would remain between 20262-41544 in current euros, with the larger values being more likely. This value range would put Finnish residents anywhere between 1997 and 2017 in terms of living standards.

The most favourable cases, or the smallest reductions in GDP per capita, are those in which all the sampled values, especially labour productivity, remain favourable. For there to be no dramatic drop in GDP per capita, labour productivity would have to remain high; approximately on levels 2011 and above. This is quite likely as once achieved, a certain level of productivity is typically unlikely to dramatically decline. The largest decline in recent years in labour productivity was experienced during the financial crisis, when productivity declined approximately 10%, which can be seen in figure 3 (Ministry of Finance Finland 2019, 33). For a labour hour reduction to be possible without dramatically compromising on living standards, there would be no room for large additional decreases in labour hours in addition to the initial 20%. Labour hours should preferably remain well above 3000 million hours to achieve a smooth transition and a non-dramatic decline in GDP per capita. Lastly, total factor productivity should experience steady growth or at least not decline, to be able to reduce working hours without compromising on living standards.

To summarize; to be able to cut hours without experiencing a large decline in GDP per capita, Finland would have to ensure that labour productivity remains high, TFP sustains a steady growth and does not encompass negative values, and lastly ensure that total labour hours do not decrease substantially beyond the initial 20 per cent. A high level of labour productivity is possible to sustain by investing in technology, research and both human and physical capital, for economic theory designates these factors as the source for increased productivity. The amount of labour hours in the Finnish economy is largely dictated by the level of unemployment as can be seen from figure 6. Unemployment, especially structural unemployment, should be combated to ensure that labour hours remain relatively high after a hypothetical reduction in labour hours. A favourable level of total factor productivity growth can be attempted to sustain through incentivizing technological innovation and supporting the application of new technology proven beneficial. An example of supporting application of technology would be the governments of Sipilä (2015) and Rinne-Marin (2019), which both stated implementing new technology and promoting digitalization as one of their important objectives (Prime Minister's Office 2015, 26; Prime Minister's Office 2019, 23).

As stated multiple times before, the most important factor determining GDP per capita is labour productivity. Proponents of a reduction in labour hours often point out that increased productivity could offset any initial declines in GDP per capita through fewer working hours. In regard to this study's results, labour productivity would have to increase anywhere between 13-30% in most cases to offset the negative effect on living standards caused by cutting labour hours, according to the regression results. On average, a growth of 19% would be required to offset decreases in GDP per capita, although this amount varies somewhat according to labour hours and TFP growth as well. The larger the number for both TFPG and Lh, the smaller the amount of GDP per capita needed to be offset with labour productivity. Overall, increases in labour productivity is the main factor that could enable a potential shift to a shorter workweek in the future.

5 Summary and conclusions

The objective of this bachelor's thesis was to precisely assess the effects a shift to a shortened 30-hour workweek would have on Finnish standard of living. The research was approached with the Solow Growth model and the Cobb-Douglas production function being the theoretical foundation behind the linear regression model, which enabled further analysis. In the end, the study's core data consisted of GDP per capita (Y), total factor productivity growth (TFPG), labour productivity (Lp), and total labour hours (Lh), between years 1976–2020. The conclusions were made by analysing the results of the linear regression model and the Monte Carlo method, respectively.

The results of this thesis indicate that shifting to a shortened workweek would cause a significant decrease in Finnish standard of living, with even modest estimations exceeding historic recessions such as the 1990s depression and the Global Financial Crisis. On average, the estimated decline in living standards was 19%. GDP per capita would decline with a 64.5 percent probability and remain the same or increase with a 35.5 percent probability, although both with varying degrees. According to the Monte Carlo simulation's bimodal nature, switching to a shortened workweek is a "high-risk, high-reward" type of a scenario, where the most probable individual values are either very high or quite low.

Both the regression model results, and the Monte Carlo simulation results suggest that shifting to a 30-hour workweek would result in around a 19% decline in living standards. The linear regression results saw a smaller decline in living standards when approaching more recent years, caused by the increase in labour productivity, and thusly a smaller weight for labour hours in output creation. The linear regression indicated that a shift to a shorter workweek would result in between 13.7 to 30.1 percent decline, with the average decline being 18.9 percent. Compared to the mean of actual GDP per capita, the Monte Carlo method indicated that GDP per capita would decline by 43–68 percent, 12.5–43 percent, 0.1–12.5 percent, 0 percent, or increase by 0.1–16.3 percent with probabilities of 25%, 25%, 14.5%, 1.39%, and 34.11%, respectively. Overall, the simulation provided a 75 percent probability that GDP per capita would change by -40–16%. The average decline in living standards assessed by the simulation was 19.55%, and 19.1% through calculating the expected value.

The hypothesis introduced in chapter 1.2 is mostly refuted. Although GDP per capita and labour hours did not encompass a 1:1 ratio, their respective declines were in very close proximity to each other, on average. It is possible to achieve a reduction in workhours without a dramatic decline in GDP per capita given that labour productivity, hours worked, and TFP growth remain on favourable levels. Nevertheless, the results indicate that experiencing no drop in GDP per capita would be highly unlikely, thus the hypothesis must be cautiously rejected.

Focusing on improving labour productivity, stabilizing hours worked to a high level and improving the level of technology is vital in order to enable a possible transition to a shorter workweek in the future. The above factors can be supported by incentivizing technological innovation and supporting the application of new technology, investing in research and education, combating unemployment, and increasing both human and physical capital.

6 Limitations and further research

As was examined in section 2.4, the largest factor for increasing labour productivity is the improvements in technology over time. Although labour productivity growth has stagnated since approximately the 2010s, it is highly unlikely that this productivity could fall far beneath the levels of 2010 as once achieved, the level of technology does not vary year to year in the same manner as for example labour hours. Therefore, using data from a large time frame could highlight the weight of labour hours in determining output more than is currently the case. The highest decline in productivity calculated in recent years was about 10% during the Global Financial Crisis, but the value range in this thesis' dataset is much higher than that (Ministry of Finance Finland 2019, 33). As was seen in the regression analysis, the negative effect reducing labour hours had on GDP per capita was continuously smaller towards more recent years due to productivity's increased role. This might suggest that using more recent data in performing the Monte Carlo simulation could lead to more desirable outcomes for proponents of a shortened workweek. Additionally, the sample size of this thesis was relatively small, and it had to be augmented to generate more reliable models. Increasing the sample size would provide more robust models and increase confidence in the results.

This thesis did not differentiate between industries as the goal was to provide an estimate of an aggregate effect the shortened workweek would have on living standards. Because decreasing overall working hours would most likely affect industries differently, it could be worthwhile to study industry-specific decreases in output a labour hour reduction would result in and draw conclusions separately.

There is some evidence supporting the notion that a reduction in labour hours could lead to improvements in labour productivity, and therefore offset the potential decline in output a labour hour reduction would cause, which was examined in chapter 1.2. The results of this study could have been different, whether this possibility was considered, but as no differentiation between industries was made, and as the relationship between hours worked and productivity is somewhat contested, this possibility was rejected in analysis. Interesting further insight could be provided by taking into account the potential increases to productivity through labour hour reductions.

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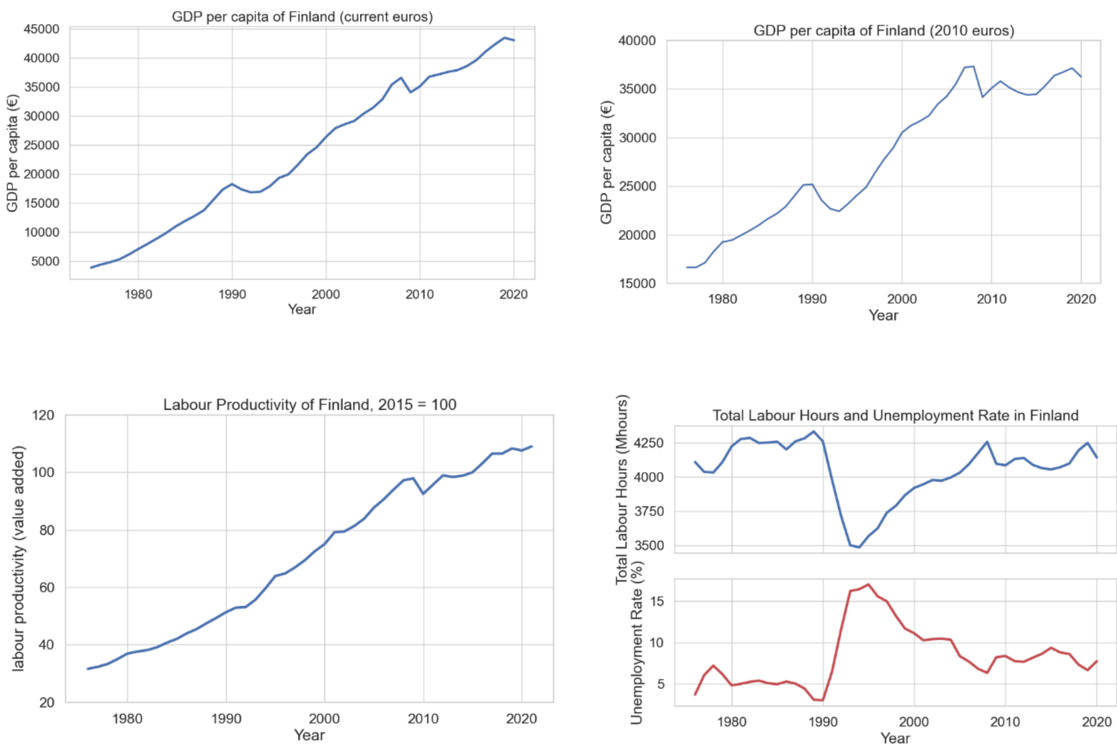
Appendices

1. Nominal and real GDP per capita of Finland, labour productivity, and unemployment rate and total labour hours of Finland



2. First and final correlation matrices

	labour_hours	labour_productivity	unemployment_rate	TFP_growth
labour_hours	1.000000000	-0.196092	-0.952662	-0.389871
labour_productivity	-0.196092	1.00000000	0.391719	-0.306643
unemployment_rate	-0.952662	0.391719	1.00000000	0.310347
TFP_growth	-0.389871	-0.306643	0.310347	1.00000000

	labour_hours	labour_productivity	TFP_growth
labour_hours	1.000000000	-0.196092	-0.389871
labour_productivity	-0.196092	1.00000000	-0.306643
TFP_growth	-0.389871	-0.306643	1.00000000

3. VIF-test printouts

	variables	VIF
0	labour_hours	18.063086
1	labour_productivity	2.318413
2	TFP_growth	1.456251
3	unemployment_rate	20.764150

	variables	VIF
0	labour_hours	1.354959
1	labour_productivity	1.268260
2	TFP_growth	1.438080

4. Linear regression

		OLS REGRESSION RESULTS				
=================	======================	======================	=============	==============	================	================
Dep.Variable:	y		R-squared:	0.997		
Model:	OLS		Adj. R-squared:	0.997		
Method:	Least Squares		F-statistic:	7484.		
No. Observations	79		Prob (F-statistic):	8.55e-93		
Df Residuals:	75		Log-Likelihood:	-584.49		
Df Model:	3		AIC:	1177.		
Covariance Type:	nonrobust		BIC:	1186.		
==============	======================	======================	=============	==============	==============	================
	coef	std err	t	p>|t|	[0.025	0.975]
Intercept	-21.44376913365585e+03	1212.932	-18.283	0.000	-2.46e+04	-1.98e+04
labour_hours	6.0914445	0.271	23.058	0.000	5.718	6.799
labour_productivity	684.46092502	5.009	136.814	0.000	675.325	695.282
TFP-growth	68.41205596	28.556	2.878	0.032	25.290	139.063
=================	======================	======================	=============	==============	================	================
Omnibus:	0.345		Durbin-Watson	0.182		
Prob(Omnibus):	0.842		Jarque-Bera (JB):	0.076		
Skew:	0.058		Prob(JB):	0.963		
Kurtosis:	3.098		Cond. No.	1.08e+05		

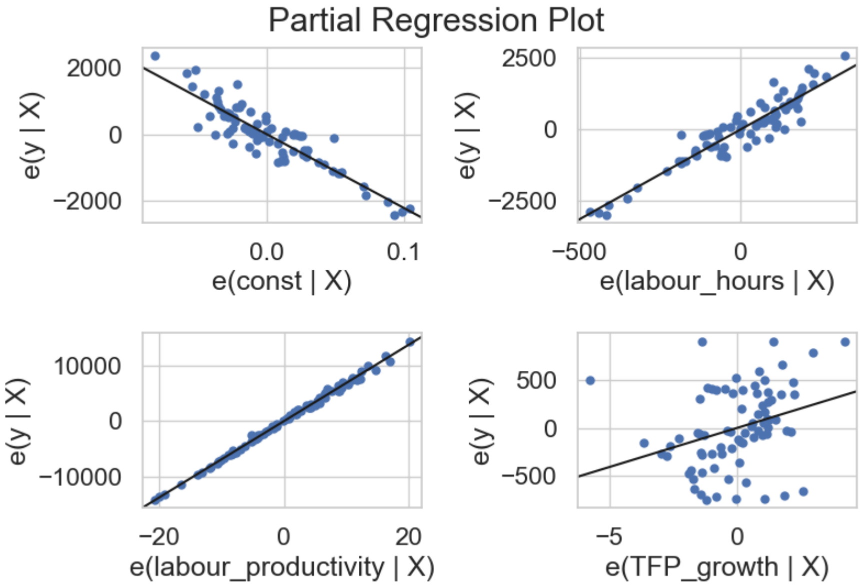
5. SMAPE and MAPE results printout

	forecast_test	test_result (%)
1	sMAPE	1.230000
2	MAPE	1.232964

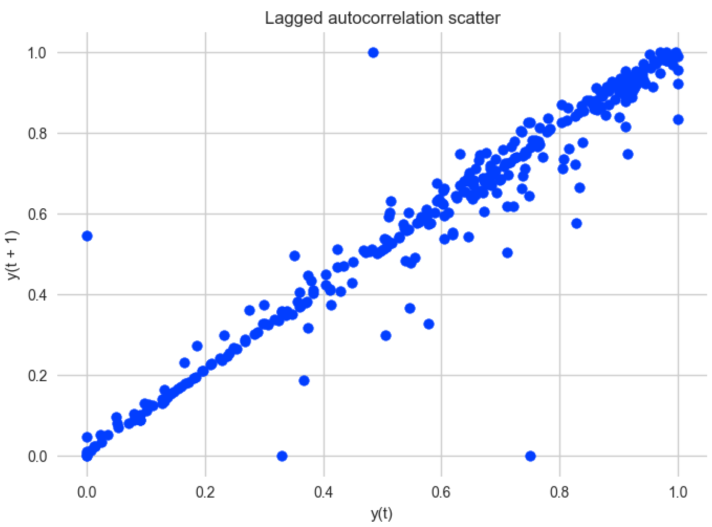
6. Breusch-Pagan test p-value

Breusch_P_result	5.379298504116317e-07

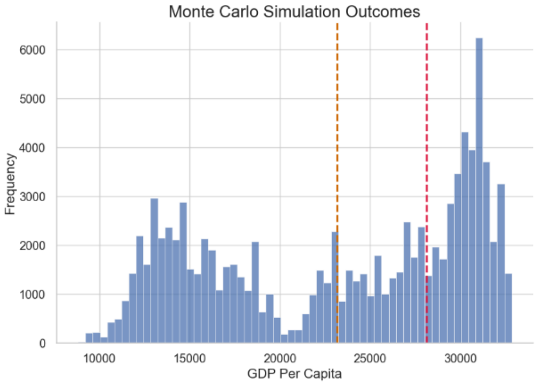
7. Partregress plot

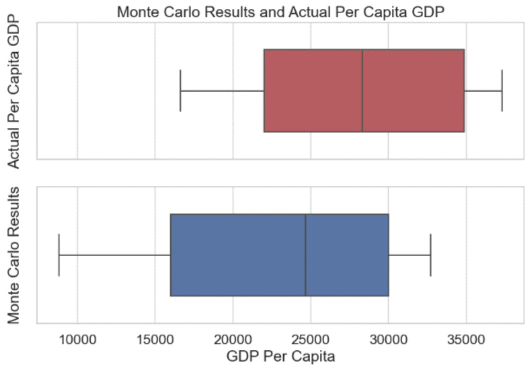


8. Lagplot of autocorrelation



9. Monte Carlo simulation plots





10. Equations 1-11

(1)	Y= A * F * (K,L)
(2)	Q(t) = A *F[K(t), H(t), L(t)]
(3)	Q(t)/L(t) = A * F[K(t)/L(t), H(t)/L(t), 1]
(4)	q = A * F * (k,h)
(5)	Y(t) = AK(t)^a * L(t)^(1 - a), 0<a<1
(6)	Y = AK^a * L^(1-a)
(7)	TFP = LP - a*K/L
(8)	$Y = B_0 + B_1x_1 + B_2x_2 + B_3x_3 + \ldots + B_nx_n + e$
(9)	Y = -21443.77 + 6.0914 * Lh + 684.4609 * Lp + 68.4121 * TFPG
(10)	MAPE = (∑[|T-P|/T] * 100%) / N
(11)	$sMAPE = 100\%/N * \sum^{N}_{t=1}[(\|P_t-T_t\| / (\|T_t\|+\|P_t\|)/2]$

11. Dataset descriptors

	year	gdp_capita	labour_hours	labour_productivity	TFP_growth
mean	1997,841772	28119,93038	4074,350633	35,95260272	1,931050633
std	13,36219896	6894,827697	197,0093131	10,32828333	1,929162678
min	1976	16629	3483,9	19,117182	-5,009
25%	1985,75	22019,25	3991,1	25,6623345	0,89225
50%	1998,5	28327	4110,4	38,173175	2,184
75%	2008,25	34882,75	4231,875	46,12525825	3,10475
max	2020	37330	4334,3	48,873088	6,879

12. Dataset matrix

	year	gdp_capita	labour_hours	labour_productivity	TFP_growth
0	1976	16629	4110,7	19,117182	0,035
1	1976,5	16633	4074,3	19,321215	0,545
2	1977	16637	4037,9	19,525248	1,055
3	1977,5	16874	4035,55	19,843949	2,0355
4	1978	17111	4033,2	20,16265	3,016
5	1978,5	17702	4071,8	20,683578	3,917
6	1979	18293	4110,4	21,204506	4,818
7	1979,5	18778	4167,5	21,4987875	3,578
8	1980	19263	4224,6	21,793069	2,338
9	1980,5	19348	4251,75	21,7964155	1,51
10	1981	19433	4278,9	21,799762	0,682
11	1981,5	19679	4283,3	22,115451	1,02
12	1982	19925	4287,7	22,43114	1,358
13	1982,5	20174,5	4268,75	22,883766	1,811
14	1983	20424	4249,8	23,336392	2,264
15	1983,5	20698,5	4251,65	23,703696	2,173
16	1984	20973	4253,5	24,071	2,082
17	1984,5	21300	4256,45	24,4807975	2,578
18	1985	21627	4259,4	24,890595	3,074
19	1985,5	21888,5	4231,2	25,405088	3,1975
20	1986	22150	4203	25,919581	3,321
21	1986,5	22514	4232,55	26,19681	3,1355
22	1987	22878	4262,1	26,474039	2,95
23	1987,5	23439,5	4273,55	27,0902285	2,757
24	1988	24001	4285	27,706418	2,564
25	1988,5	24566	4309,65	28,2454985	2,771
26	1989	25131	4334,3	28,784579	2,978
27	1989,5	25159,5	4297,9	29,12865	2,184
28	1990	25188	4261,5	29,472721	1,39
29	1990,5	24382	4121,25	29,5825045	0,749
36	1994	23201	3483,9	33,885875	6,879
37	1994,5	23644	3525,25	34,1908765	4,8965
38	1995	24087	3566,6	34,495878	2,914
39	1995,5	24288	3595,2	34,8461785	2,803
40	1996	24489	3623,8	35,196479	2,692
41	1996,5	25638	3680,8	35,740462	3,351
42	1997	26387	3737,8	36,284445	4,01
43	1997,5	27070	3763,75	37,0124495	4,299
44	1998	27753	3789,7	37,740454	4,588
45	1998,5	28327	3828,35	38,173175	3,7315
46	1999	28901	3867	38,605896	2,875

47	1999,5	29703,5	3893,75	39,441706	3,7175
48	2000	30506	3920,5	40,277516	4,56
49	2000,5	30868,5	3933,65	40,665387	3,4495
50	2001	31231	3946,8	41,053258	2,339
51	2001,5	31459,5	3962,45	41,2394065	1,582
52	2002	31688	3978,1	41,425555	0,825
53	2002,5	31967	3975,6	41,867166	0,9595
54	2003	32246	3973,1	42,308777	1,094
55	2003,5	32840,5	3985,1	43,021117	2,4885
56	2004	33435	3997,1	43,733457	3,883
57	2004,5	33841,5	4014,75	44,1445285	2,6675
58	2005	34248	4032,4	44,5556	1,452
59	2005,5	34869	4063,8	45,0975645	2,1695
60	2006	35490	4095,2	45,639529	2,887
61	2006,5	36351,5	4135,8	46,381564	3,8585
62	2007	37213	4176,4	47,123599	4,83
63	2007,5	37271,5	4217,55	46,8494225	1,865
64	2008	37330	4258,7	46,575246	-1,1
65	2008,5	35741	4178	45,5381295	-5,009
70	2011	35806	4132	46,693127	1,487
71	2011,5	35472	4136,1	46,321299	-0,651
72	2012	35138	4140,2	45,949471	-2,789
73	2012,5	34900	4114,9	46,0239335	-1,752
74	2013	34662	4089,6	46,098396	-0,715
75	2013,5	34524	4077,4	46,1521205	-0,5815
76	2014	34386	4065,2	46,205845	-0,448
77	2014,5	34423	4060,65	46,383537	-0,211
78	2015	34460	4056,1	46,561229	0,026
79	2015,5	34896,5	4064,2	47,120582	1,0915
80	2016	35333	4072,3	47,679935	2,157
81	2016,5	35854,5	4086	48,2765115	2,8025
82	2017	36376	4099,7	48,873088	3,448
83	2017,5	36556,5	4147,75	48,585574	1,0005
84	2018	36737	4195,8	48,29806	-1,447
85	2018,5	36944	4223,25	48,277997	-0,567
86	2019	37151	4250,7	48,257934	0,313
87	2019,5	36707	4197,5	48,3262985	0,086
88	2020	36263	4144,3	48,394663	-0,141