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A web-based microsimulation tool to assess the impact of the minimum wage on the gender pay gap and selected indicators in Estonia

Master's thesis

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Tallinn 2021

TALLINNA TEHNIKAÜLIKOOL
Infotehnoloogia teaduskond

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Veebiliidesega simulatsioonivahend töötasu alammäära mõju hindamiseks soolisele palgalõhele ja valitud näitajatele Eestis

magistritöö

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Tallinn 2021

Author's declaration of originality

I hereby certify that I am the sole author of this thesis. All the used materials, references to the literature and the work of others have been referred to. This thesis has not been presented for examination anywhere else.

Author: Kristine Leetberg

Abstract

This thesis aims to help the process of policy-making in Estonia by providing a tool to the broader public to predict the effects of policy changes. A public web interface for the European Union tax-benefit microsimulation tool EUROMOD is developed, which allows to run simulations on hypothetical new minimum wage scenarios in Estonia and displays the predicted change in the gender pay gap and selected social indicators. The application provides a base for building tools for simulations of other types of policy reforms as well in the future.

In addition to the web interface, the social effects of raising the minimum wage are also assessed in this work. The microsimulation model is used to create hypothetical scenarios where the minimum wage value is modified to a new level based on the reference values proposed by the European Commission. The results show an association between the gender pay gap and the minimum wage in Estonia: the higher the minimum wage, the lower the gender pay gap. A notable decrease can also be seen in poverty and inequality indices, most notably in the in-work poverty rate. Based on the results, it can be concluded that an adequate level of the minimum wage is an essential contributor to lowering the gender pay gap, poverty and inequality.

The thesis is in English and contains 74 pages of text, 7 chapters, 34 figures, 9 tables.

Annotatsioon

Selle lõputöö eesmärk on aidata kaasa poliitika kujundamise protsessile Eestis, pakkudes laiemale avalikkusele tööriista, mis võimaldab prognoosida poliitiliste muudatuste mõju. Tööriist, mida selles lõputöös tutvustatakse, on avalik veebiliides Euroopa Liidu maksude ja toetuste mikrosimulatsioonivahendi EUROMOD jaoks. Veebiliides võimaldab simuleerida hüpoteetilisi uusi miinimumpalga stsenaariume Eestis ning kuvab sotsiaalsete näitajate prognoositavat muutust. Lisaks loob rakendus põhja ka muud tüüpi poliitiliste reformide simulatsioonide loomiseks tulevikus. Sedalaadi avalik tööriist on nõutud, kuna see võib kaasa aidata uute maksu- ja toetusreformide otsustusprotsessi muutmisele argumendipõhisemaks.

Veebiliidesele lisaks hinnatakse selles töös ka miinimumpalga tõstmise sotsiaalseid mõjusid. Mikrosimulatsiooni mudelit kasutatakse hüpoteetiliste stsenaariumide loomiseks, viies igas stsenaariumis miinimumpalga väärtuse uuele tasemele, tuginedes Euroopa Komisjoni pakutud kontrollväärtustele. Tulemused näitavad seost soolise palgalõhe ja miinimumpalga vahel Eestis: mida kõrgem on miinimumpalk, seda väiksem on sooline palgalõhe. Märkimisväärset langust võib täheldada ka vaesuse ja ebavõrdsuse näitajates, eriti palgavaesuse määras. Tulemuste põhjal võib järeldada, et miinimumpalga piisav tase aitab oluliselt kaasa soolise palgalõhe, samuti vaesuse ja ebavõrdsuse vähendamisele.

Lõputöö on kirjutatud inglise keeles ning sisaldab teksti 74 leheküljel, 7 peatükki, 34 joonist, 9 tabelit.

List of abbreviations and terms

EFTA	European Free Trade Association
EU	The European Union
EU-SILC	EU Survey of Income and Living Conditions
ESU	Estonian Social Survey
IA	Department of Computer Systems
JRC	Joint Research Centre, European Commission
MEFISTO	Belgian web interface for EUROMOD
OECD	Organisation for Economic Co-operation and Development
REGE	Research project "Reducing the gender wage gap"
SES	European Union Structure of Earnings Survey
SIC	Social Insurance Contributions
SORESI	Austrian web interface for EUROMOD
UI	User interface
UK	United Kingdom

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1 Introduction

For the year 2020, Statistics Estonia reported the gender pay gap in Estonia to be 15.6%. This means that women earn an average of 15.6% less than men for the same amount of work. However, change can be seen over time, as this number has been falling every year [1]. Regardless of this trend, the unequal pay difference between men and women remains one of the highest in Europe [2]. For more than ten years, the European Commission has acknowledged that inequality of this kind is harmful, and they have been looking for political measures which could help with the closing of the gap. In order to fulfill that goal, the "Reducing the Gender wage gap" (REGE) research project [3] was ordered from the Estonian Ministry of Social Affairs. The project aims to provide solutions for more effective monitoring and evaluation of the pay gap, highlighting appropriate parameters and measures to analyze income inequality. This thesis is part of this project, with the main focus on assessing whether raising the minimum wage in Estonia could positively impact reducing the gender pay gap.

The reason behind simulating minimum wage reforms stems from a proposal for the directive on adequate minimum wages in the European Union that the European Commission sent out to the member states at the end of 2020 [4]. In the directive, the recommended reference values for the minimum wages for countries like Estonia are either 60% of the median salary or 50% of the average wage. In contrast, in 2020, the minimum wage in Estonia only responded to 41.07% of the average wage or 46.9% of the median wage. This thesis aims to assess the effects of raising the minimum wage to the reference levels on social and poverty indices. A strong focus will be placed on assessing whether an increase in the minimum wage would reduce the gender pay gap in Estonia.

Microsimulation tools provide a way to assess the possible effects of tax and policy reforms on a population and make evidence-based decisions in policymaking. EUROMOD is a static microsimulation tool for the European Union, which provides a powerful engine for such experiments [5]. To assess the social effects of raising the minimum wage, the Estonian tax-benefit model of EUROMOD is used to simulate alternative scenarios with modified minimum wage values according to the levels proposed by the European Commission. The input data in EUROMOD is based on Estonian national registries, containing data about the whole population of Estonia for the years 2018 and 2019. The input datasets are altered to represent new minimum wage scenarios and are then fed into EUROMOD to obtain an output dataset, which can be used to measure inequality indices.

Similar simulations could also prove helpful to policymakers in their decision-making process outside of the academic context. However, the capabilities of EUROMOD often remain unreachable to the general public in Estonia because of limited access to data and a steep learning curve. Therefore, in addition to running microsimulations, this thesis also begins the efforts of bringing the engine closer to the public by building an openly available web interface for EUROMOD. The first version of the web interface provides functionality for changing the minimum wage and observing the predicted changes such reform would bring to Estonia's gender pay gap and other social indices.

The research questions of this thesis are the following:

1. Would raising the national minimum wage potentially help reduce the gender pay gap in Estonia?
2. What effect would raising the minimum wage in Estonia have on poverty?
3. Is it possible to create a software solution, which would allow using EUROMOD and its accompanying instruments via a public web interface so that the user could perform analysis of the impact of policy reforms without direct access to static data?

The process of finding answers to the research questions consisted of four blocks and is visualized in Figure 1.

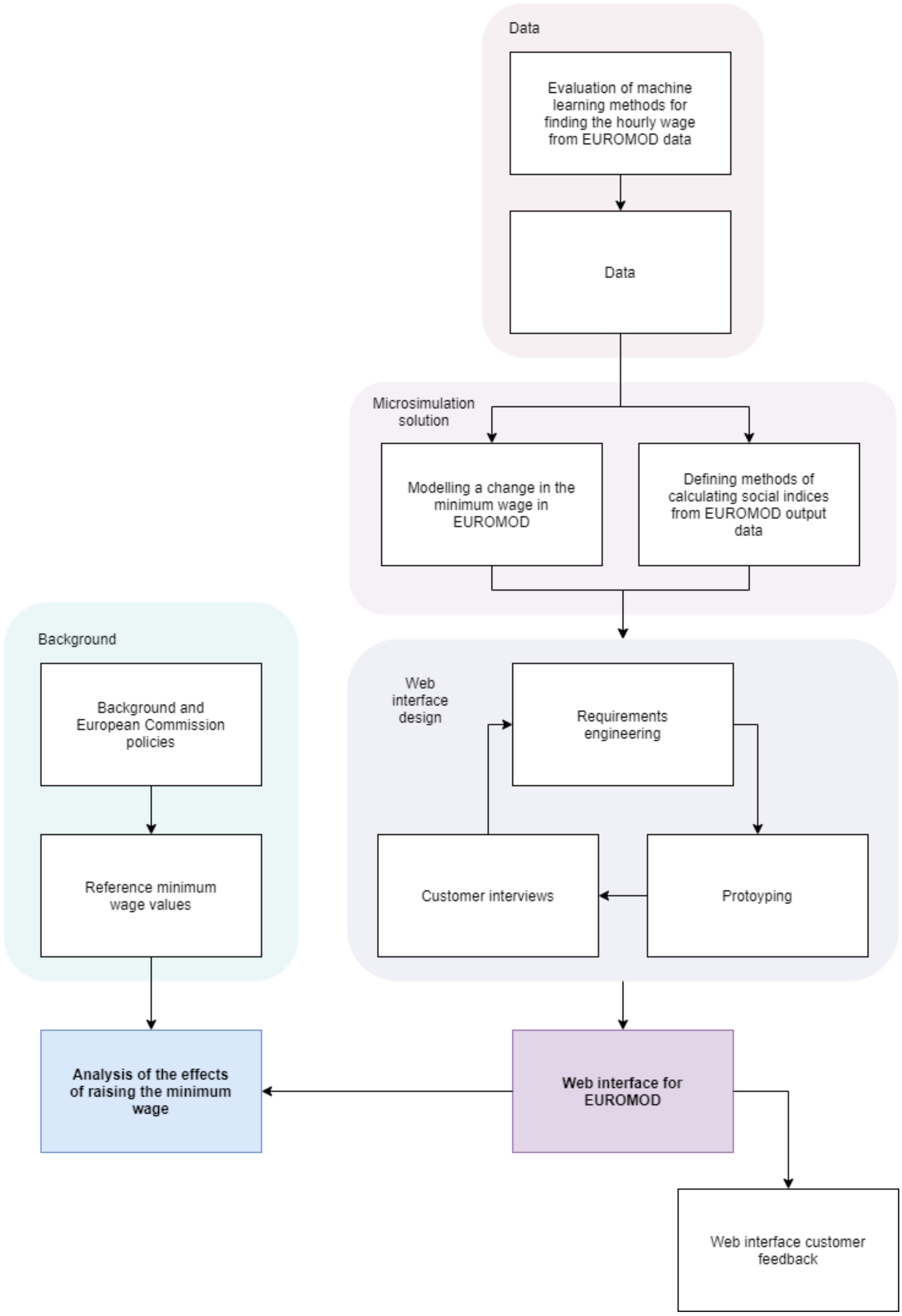


Figure 1. Process of writing the thesis

This thesis is divided into four main sections. Chapter 2 gives an overview of the background for this work, including both the social aspects and the technical background, and introduces previous work on related topics. Chapter 3 describes the data that will be used for the microsimulations. What is more, Chapter 3 compares and investigates methods to add hourly wages to the data, which are not collected as part of the initial dataset but are necessary for the gender pay gap calculations. Chapter 4 explains the process and the methods used for running the microsimulations in EUROMOD. Chapter 5 demonstrates the design and development process of the web interface for EUROMOD. Chapter 6 then builds on the previous chapters and uses the reference minimum wage values proposed by the European Commission to run microsimulations and analyze the results. The analysis breaks down the predicted effects of increasing the minimum wage in Estonia to these values on the gender pay gap and selected indicators.

2 Background

This chapter gives an overview of the gender pay gap, the current situation and trends in Estonia, and explains the motivation behind this thesis.

2.1 Social Background

A significant gender pay gap and a relatively low minimum wage are both relevant topics of discussion in Estonia. This chapter describes both of those aspects in more detail.

2.1.1 The gender pay gap

The unadjusted gender pay gap is measured by subtracting the average gross hourly salary of working men from working women's average gross hourly salary. To express the pay gap in percentages, the result is then divided by the gross hourly salary of men. Bonus payments and surcharges are not considered in the calculations. In the European Union (EU) in 2018, a notable gender pay gap existed in all member states, averaging at 14.1% [2]. This means that women earned on average only 85.9% of what men earned for each hour of equal work. This is a substantial gap, as the unearned money for women will accumulate during years worked and strongly affect how much women can save and invest for the future and how much benefits they are eligible for (e.g., child benefits, pensions). As seen in Figure 2, the gender pay gap reported by Eurostat for Estonia in 2018 was 21.8%, which was also the highest among all the countries observed. However, the same statistic reported by Statistics Estonia was lower, namely at 18.0% [1]. The reason behind this difference lies in the underlying sample used for the calculations. While Statistics Estonia includes all employed individuals in the calculations, Eurostat leaves out establishments with less than ten employees, employers in the fishing, forestry, and agriculture industries, and employees in public administration national defense [6].

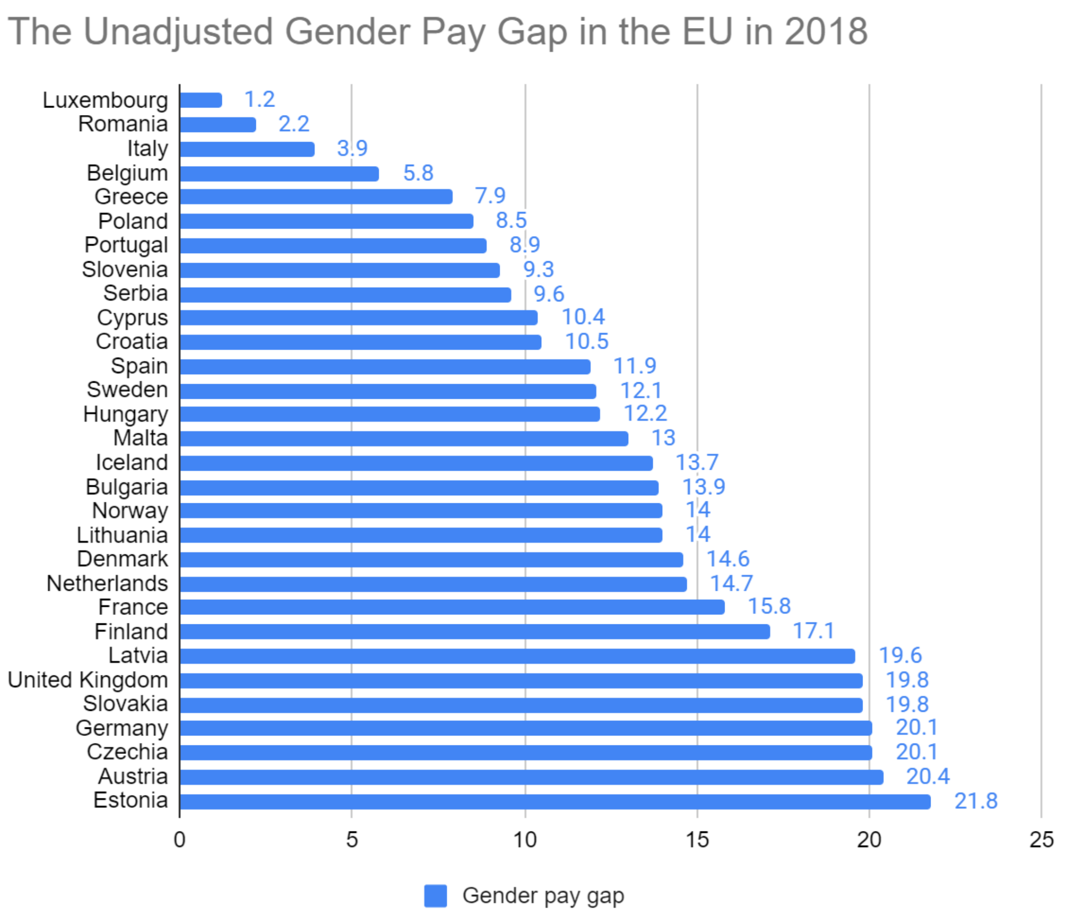


Figure 2. Gender pay gap in 2018 in the Member States of the EU, by country in %. [2]

To evaluate measures that could help in reducing the gender pay gap, it is essential to understand the origins of the phenomenon. Research trying to explain the gender pay gap is plentiful and generally divides the gap into explained and unexplained portions. The latest research in Estonia, conducted within the REGE project (Reducing the gender wage gap), managed to explain around 40% of the wage gap [7], which is more than twice higher than what was explained before [8].

The most common factors used to explain the emergence of the gender pay gap are the following:

Human capital

The concept of human capital in the workforce is best known by the definition given by Gary Becker in 1964 [9], where he explains how a person's value to the employer is affected by their education, experience in the field, and other similar investments to their human capital. This suggests that the more a person has spent time on training, experience, or improving other necessary skills, the higher their human capital value and value to the company.

Historically women's engagement in the workforce has been different than men's. While men have primarily had the opportunity to enjoy an uninterrupted career with little turnover and breaks, allowing them to advance quicker in career seniority, women have been carrying the caretaker role in the family. Caring for children and the elderly has driven women to either work part-time or switch careers to fit their schedule. Not to mention, women are more likely to take extended breaks from work to care for newborns. Blau and Kahn conclude in their research in 1997 [10] that these breaks strongly affect an individual's contributions to their human capital value and explain a big part of the wage gap between men and women, as lower human capital leads to lower career positions and lower pay.

Gender segregation

Gender segregation in the work field consists of two categories. Firstly, segregation is observed as the gathering of men and women to different areas of employment (horizontal segregation). Secondly, segregation in the work field is also regarded as the gathering of men and women to different levels of employee rankings (vertical segregation). For example, in Estonia, many working women are medical and educational professionals, while working men are not. Similarly, a large portion of working men is employed in construction, while women are not.

An exhaustive study analyzing the gender pay gap in Estonia and its reasons [8] concluded that the most significant part of the explained pay gap is gender segregation in the labor market. As described earlier, the gender pay gap is calculated as the difference in the averages of hourly pay for men and women. This means that if men and women work in different fields, the gender pay gap may be significant even when equal pay is given for equal work.

Company profile

As all companies and workplaces are different, so is the gender pay gap different in every company. The research in Estonia in 2019 [7] suggests that establishments with an overall higher average hourly wage have a more significant gender pay gap than those with a lower average hourly salary. Also, an interesting observation was that a larger wage gap occurs within companies in foreign ownership (where the gap was 40% bigger than the one in domestic private companies) and in companies that employed a more significant proportion of women than men. What is more, the gender pay gap was the lowest in local government agencies.

Gender-based discrimination

The theory of gender-based discrimination, posed by Becker already in 1957 [11], suggests that some employers carry prejudices against certain types of people and therefore do not wish to either employ them or pay them equally. For example, suppose an employer has concluded from their experience that women perform less productive than men. In that case, they might pay a lower wage to women, regardless of their actual contribution to the company [12].

All in all, when analyzing the gender pay gap as a social phenomenon, the reasons can be divided into three levels based on the multilayer premise introduced in [13]:

- Micro-level, where an individual interprets the orders and policies coming from the macro-level and either ignores them or subjects to them.
- Meso-level, which refers to the organizations, bringing together the policies from the macro-level and the individual preferences of the micro-level.
- Macro-level, which comprises the ruling value systems and the formal and non-formal rules and norms based on those systems. The macro-level regulates the lower levels.

This thesis will focus on the macro-level, basing the analysis on individual and household data. By simulating a policy change on the macro-level, we will assess and measure its impact on the individuals on the micro-level.

One of the goals of this thesis is to bring EUROMOD [5] closer to Estonian policy makers, so that decisions for new policies could be supported by simulations. EUROMOD's powerful user interface currently has many capabilities. The add-on Statistics Presenter tool inside EUROMOD allows for example users to see an overview of inequality indices in the simulated population. However, one social measure not included in the overview, is the gender pay gap. As the gender pay gap is a high priority topic in Estonia, the author decided to focus on this measure when building out the first version of the EUROMOD web interface.

2.1.2 Existing policies

As the existence of the gender pay gap is not a recent issue, authorities have implemented quite a few recommendations or policies to reduce the gender pay gap together with overall inequality in society. In this thesis, the author will evaluate whether increasing the minimum wage in Estonia could reduce the gender pay gap. The following gives an overview of policies that have already been implemented to target the gender pay gap.

Policies posed by the European Union

Even though trends in the gender pay gap in the European Union (EU) show a decrease over time, the International Labor Organization estimated in 2016 that at the rate of the current trends, the gender pay gap would only close entirely in 70 years [14]. The European Commission acknowledges that the pay gap is an issue and has compiled action plans and recommendations for the member states of the union to accelerate the closing of the gap. These plans primarily consist of non-legislative recommendations and initiatives to the states. However, the EU Action Plan 2017-2019 on tackling the gender pay gap also resulted in two legislative actions [15]. Firstly, in June 2018, the European Commission adopted the recommendation on standards of equality bodies, which was intended to help aid victims of discrimination and find support. Secondly, in 2019, in order to tackle the issue of an unfairly large part of the care responsibilities falling on women, the European Parliament and Council adopted the directive on work-life balance for parents and caregivers, which promotes equal sharing of care work between caregivers, by setting in place minimum standards for family leaves and work arrangements for new parents.

The European Commission continues to propose ways to reduce the gender pay gap. One of the causes of the gender pay gap, which the commission is tackling, is the lack of wage transparency. In 2014, the European Commission adopted a Recommendation on strengthening the equality between men and women [16]. The document emphasizes the importance of the transparency of wages. It provides guidelines to assure it, as women may often not be aware that they are discriminated against at the workplace since the salaries are kept secret. Furthermore, in 2020, the head of the European Parliament, Ursula von der Leyen, gathered feedback on the initiative to introduce binding pay transparency measures [17]. The proposal has not yet been officiated in the commission at the time of writing this thesis.

Policies in Estonia

Estonia has dealt with the gender pay gap issue more thoroughly since the 2000s. One of the most meaningful first steps was carrying out an analysis of the wage gap in 2009-2010 [8]. Political measures were proposed and analyzed against the gender pay gap within the work [18]. The authors suggested, for example, the following actions:

- Increasing knowledge of gender equality laws and the rights accompanying them
- Increasing men's part in parental leave and altering the parental leave system to be more flexible, allowing better possibilities of merging work and childcare
- Promoting part-time work for new parents to lessen career breaks
- Using in-service training and media campaigns to encourage the choice of atypical careers
- Increasing worker's knowledge of average salaries in different positions

Within the ten years that have passed from the analysis, Estonia has come a long way in including equality principles in legislative measures. The action plan of the Estonian government for the years 2015-2019 already included points to work out measures to improve gender equality and fight the gender pay gap [19]. Those measures included gathering better statistics about the state of the gender pay gap in the country and improving the gender equality law. In the action plan for the years 2019-2023, the Estonian government set reducing the gender pay gap to at least 18.5% by the year 2023 as one of their primary economic goals. The analysis and proposals to reach that goal are planned to be worked out in February 2022 [20].

2.1.3 Minimum wage

The legally set lowest value that an employer can pay to their employees is called a minimum wage. The first minimum wages were set already at the end of the 19th century in New Zealand and Australia [21], and by now, minimum wages exist in many countries. In the European Union (EU), by the year 2019, 22 member states had a minimum wage established [22].

The minimum wage in Estonia

The minimum wage was first introduced in Estonia in 1996 and has been steadily rising ever since, except for the financial crisis in 2008-2010 and after the coronavirus pandemic in 2021, when the minimum wage did not change [23]. Starting from the 1st of January 2020, the minimum wage in Estonia is 3.84€ hourly and 584€ monthly for full-time employees, with specific higher minimum wages set in certain sectors (e.g., teachers, cultural workers, firefighters). It is also essential to consider that in the year 2018, a progressive income tax was introduced in Estonia [24], which resulted in a substantial increase in the annual basic exemption for people earning the minimum wage. More precisely, for workers earning the national minimum wage, the non-taxable amount rose from 2160€ per year to 6000€ per year. However, the minimum wage's relation to the average salary has shown far less growth, only crossing the 40% margin in 2020, as seen from Figure 3.

Figure 3. Progression of the average, minimum and median wages from 2005 to 2020 in Estonia, according to Statistics Estonia [25].

Choosing appropriate levels for the minimum wage

At the time of writing this thesis, the minimum wage in Estonia is set in the following manner: the representatives of trade unions and employers conclude an agreement as a result of a discussion, under which the government will establish a regulation for setting the minimum wage for both hourly and monthly levels. In case a new minimum wage is agreed upon, it will be put into force on the 1st of January. In the end of 2020, the European Commission sent out a proposal to the member states for the directive on adequate minimum wages in the European Union [26]. According to the directive both Estonia as well as other member states would be subject to additional regulations of the national minimum wage. The directive divides member states into two categories based on the way the minimum wage is agreed upon:

- the countries where minimum wages are set in collective agreements and
- the countries where minimum wages are set on a legal basis

In the current proposal, Estonia is classified as the country where minimum wage is set on a legal basis. For such countries, the directive sets that when setting the minimum wage, the country must take into account:

- purchasing power,
- the general level and growth of gross wages,
- labor productivity

What is more, the country must choose and take into account reference values to the minimum wage, and the European Commission recommends 60% of the median wage and 50% of the average wage as such reference values [26].

For side information, it is important to mention that according to the published position of the government to the directive, Estonia has asked to be classified as a country where the minimum wage is set in collective agreements [27]. For countries where the minimum wage is not set on a legal basis, but rather in collective agreements, the European Commission's directive does not set any adequate wage criteria or detailed wage protection rules [26].

The minimum wage in the EU

As of the year 2019, 22 of the member states of the EU had established a minimum wage, which ranged from a little under two Euros hourly in Bulgaria up to over 12 Euros in Luxembourg [22]. However, it is clear that a cross-country comparison of minimum wages cannot just compare the numeric size of the minimum wage, as the standards of living vary across Europe. The European Commission has opted for using the Kaitz index for this purpose, as it is simple to use and simple to communicate [22]. The Kaitz index represents the ratio of the minimum wage to the median wage in the country. Figure 4 presents the Kaitz indices for member states of the EU for the year 2018. As seen from the figure, the Kaitz index for Estonia is 43, which is well below the proposed ideal of 60, as well as below the current average in the EU.

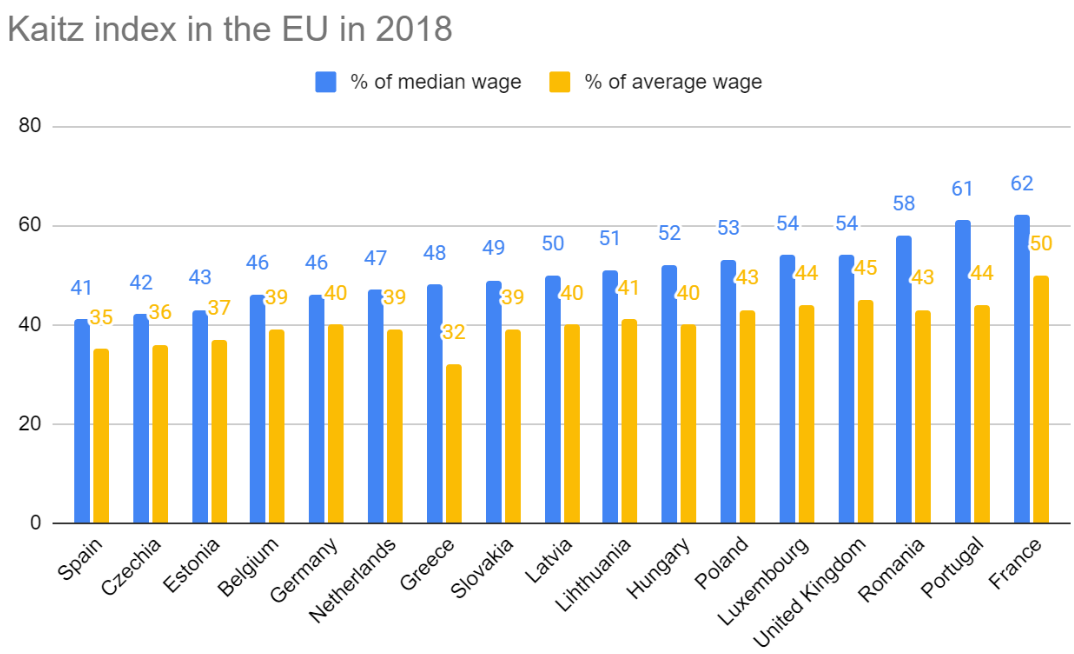


Figure 4. Kaitz index in the EU Member States in 2018. Source: OECD Earnings Database (2018)

Minimum wage earners by gender

This thesis will investigate whether raising the minimum wage in Estonia could contribute to closing the gender pay gap. In the analysis of political measures against the gender pay gap in 2010 [18], the authors also mentioned that increasing the minimum wage in Estonia could help reduce the gender pay gap. The reasoning behind it was that women rather than men more often earn minimum wage. The authors bring out that, as shown in [8], women tend to segregate to fields in which minimum wage is more often paid, which is the reason behind women being more susceptible to the rate of minimum wage. Even though this might still be true, the data from the European Union Statistics on Income and Living Situation (EU-SILC) 2017 shows that an equal amount of men and women earn the minimum wage in Estonia [22].

2.2 Technical Background

This chapter gives an overview of microsimulation, which is the technique used to create the hypothetical scenarios and run the analysis in this thesis. The specific microsimulation tool used throughout the work, EUROMOD [5], is also introduced.

2.2.1 Microsimulation

In social sciences, microsimulation refers to a computer program, which allows to mimic the operation of government policies on individual members of a population. The individual ("micro") might refer to people or households, for example. For each individual observed in a survey, the microsimulation engine simulates outcomes of interest, such as applicable benefits or taxes, by applying the rules specified in the program on the individual data. Microsimulation tools can be either dynamic, meaning that they allow us to observe changes over time, by applying economic and demographic processes on the data, or static, meaning that they simulate "overnight" effects and focus on detailed tax and benefit simulations. Microsimulation models require regular upkeep, but they provide access to a wide range of "what if" testing which may not be possible using macroeconomic models.

2.2.2 EUROMOD

EUROMOD is a static microsimulation tool for the European Union [5], which applies a user-defined set of tax and benefit policies to individual-level input data. The simulation runs on a micro-level, applying the rules on individuals and households and producing an output file holding the calculated characteristics, still at the individual level. The output file is a *.txt* file following a standard tab-separated values approach and can be further analyzed by a preferred data analysis tool. EUROMOD has been widely used and validated in numerous studies across the European Union [28]. What is more, EUROMOD is becoming more and more utilized by the European Commission, for example, in reports such as Employment and Social Developments in Europe or Tax Reforms in the EU Member States [28].

EUROMOD is most often used via its graphical user interface (GUI). A screenshot of this interface can be seen in Figure 5. Using the GUI, the user can create, edit or delete the policy parameters, create new scenarios, and run the simulations. The GUI also has some add-on features, such as the Statistics Presenter, which calculates and visualizes selected social indices based on the EUROMOD simulation results. Even though the GUI provides a great set of functionality, it can be tricky to navigate without previous training.

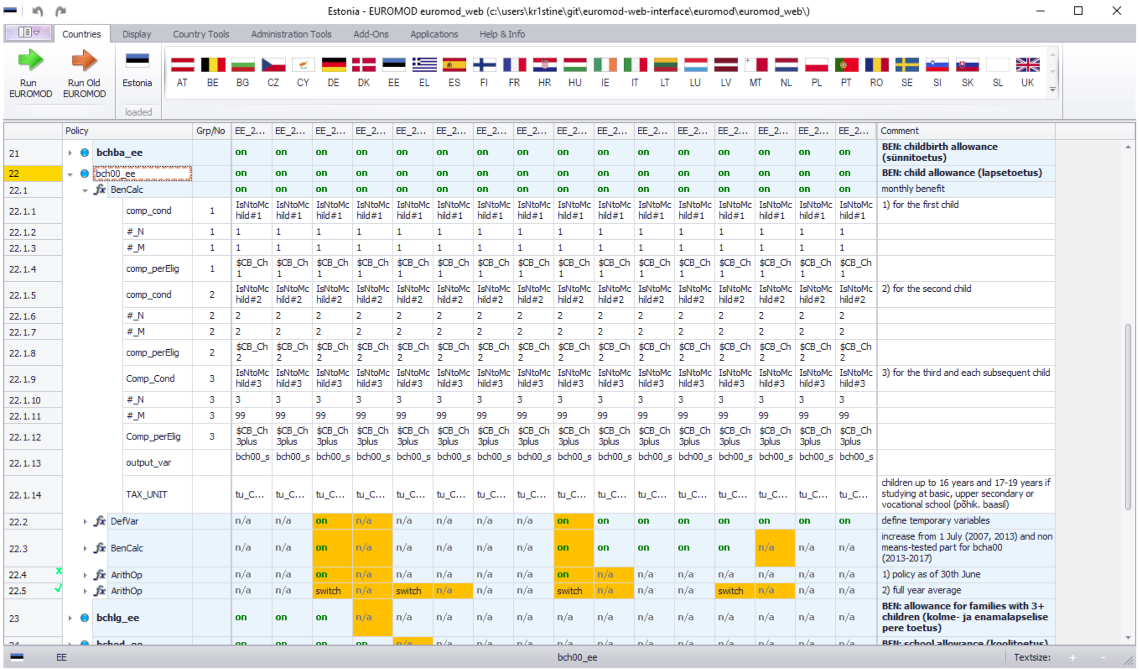


Figure 5. A view of the EUROMOD user interface

EUROMOD consists of three parts:

1. Input data – Harmonized individual-level data for the reference year
2. Tax-benefit policy rules and parameters 2005-2019
3. Software for conducting the simulations

An overview of the EUROMOD workflow is given in Figure 6.

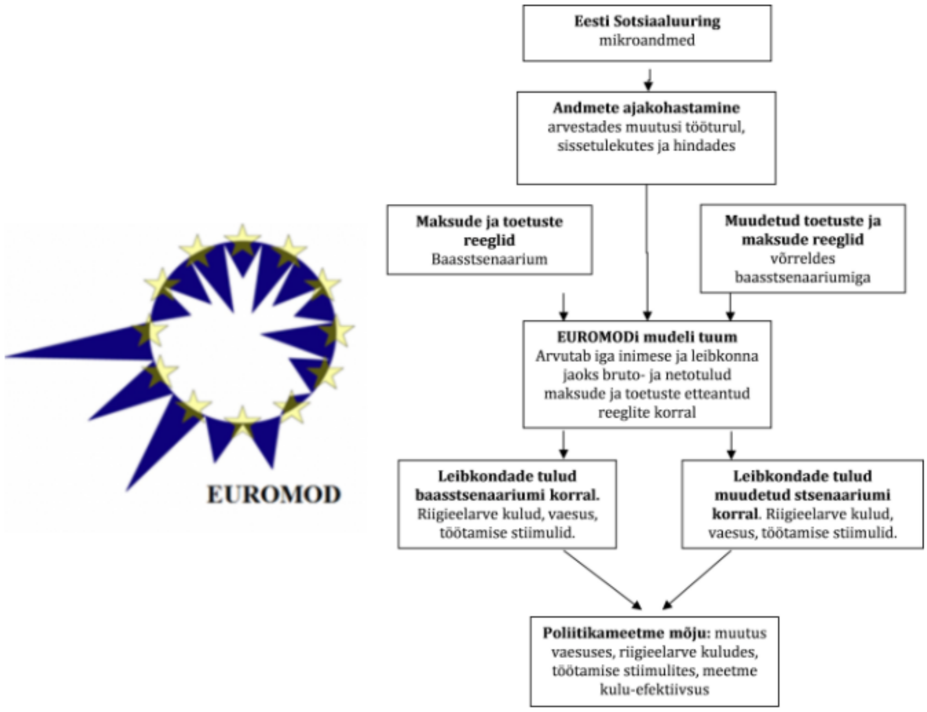


Figure 6. Euromod architecture [29]

The model is initially built by the University of Essex [5], but representative organizations in each member state maintain the country-specific rule sets. This thesis will be using the model for Estonia, which is maintained and updated yearly by PRAXIS [29]. The tax-benefit rule set defined by the representative organization for each year is called the baseline scenario. Instruments included in the Estonian baseline scenario include:

- national and local income taxes,
- employment-related social contribution,
- family benefits,
- housing benefits,
- social assistance and other income-related benefits.

EUROMOD is a well-maintained application under active development. The application itself is publicly accessible from the maintainer’s website (Centre for Microsimulation and Policy Analysis), however, it requires as input a structured dataset and an XML model, which are not included with the download. In Estonia, each year a new EUROMOD model is compiled, representing the tax and benefit policies of the previous year. Concurrently, Statistics Estonia compiles the EUROMOD input dataset as soon as all the necessary data for a year is available. Both the input dataset and the model are private and can only be accessed by authorized individuals. What is more, the EUROMOD has a rather steep learning curve, which makes it currently difficult for the public to access the capabilities of the application.

As an effort to bring EUROMOD closer and more accessible to the public, the idea was born within the REGE research group, PRAXIS, and Statistics Estonia, to build a simplified web interface for EUROMOD. The web interface would not allow access to the full capabilities of EUROMOD, but instead, would only surface a few select input and output options. Allowing policy makers access to EUROMOD's powerful engine would help them towards a more argument-based approach to policy making. The process is started within this thesis, by building a proof-of-concept application, which can later be expanded with more features. The application will allow the user to specify a minimum wage and a year for that minimum wage to be applied. EUROMOD will then be run in the background and the results will be shown to the user, based on calculations done on the EUROMOD output file.

Examples of EUROMOD web interfaces from other countries

Web interfaces allowing users to run their own microsimulations have proven to be reliable and effective in other states of the European Union. For example, Austria developed their own EUROMOD interface in 2012 called SORESI (social reform microsimulation) [30]. A view of the web application's user interface can be seen in Figure 8. SORESI was a follower of a similar Belgian model called MEFISTO (modelling and evaluating Flanders' fiscal and social tomorrow) [31]. The application surfaced the policies which were of key interest to the Austrian population: social cash benefits, social insurance contributions, and income tax. A newer version of the web interface was released in 2014. From the technical side, both SORESI and MEFISTO followed a similar architecture, presented in Figure 7.

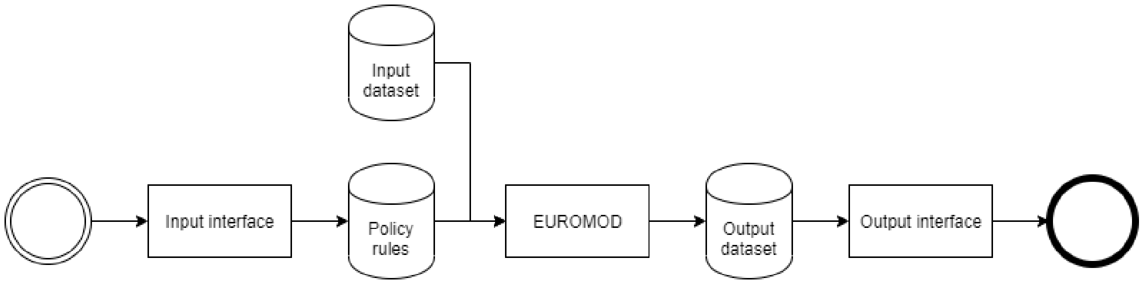


Figure 7. Process flow of SORESI and MEFISTO

One of the most recent developments in the area is the EUROMOD web interface built by the Joint Research Centre (JRC) [32]. The web application allows simulations across the member states in the EU, which makes it far more extensive than the existing local applications. The application itself has existed already for a while, however, it was made publicly available in April 2021. A view of the system can be seen in Figure 9. This is a notable step towards the EUROMOD microsimulation model becoming more accessible to the public.

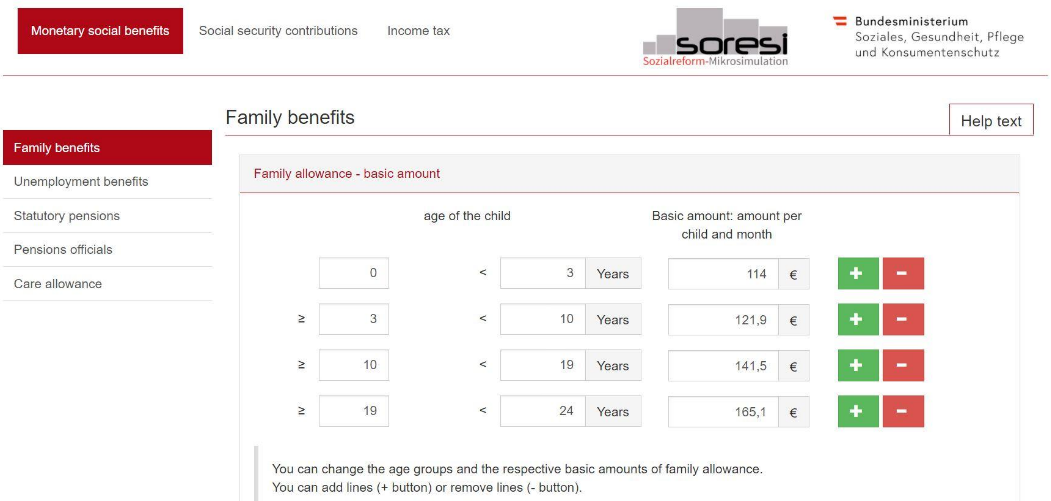


Figure 8. A view of the SORESI web interface

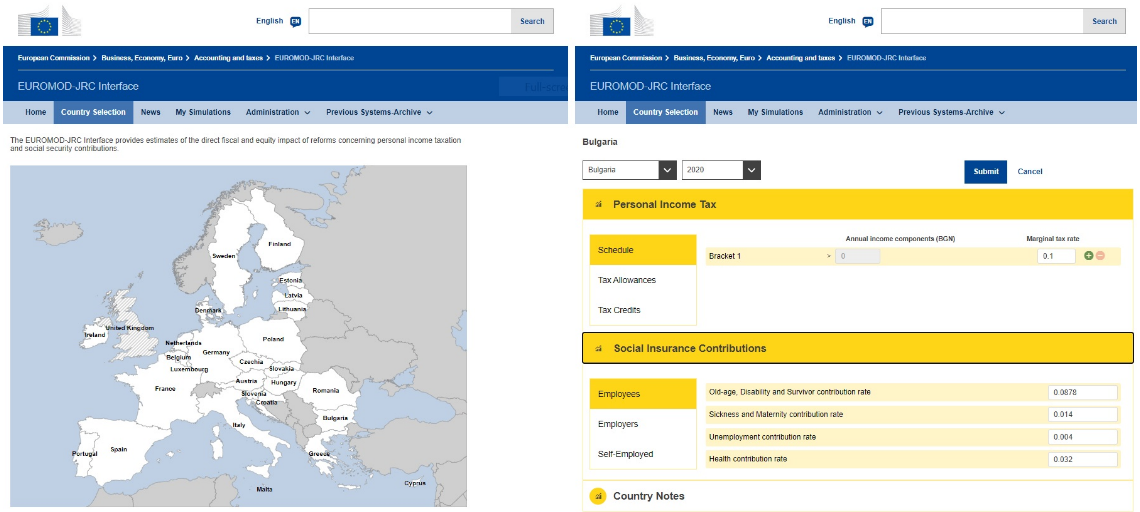


Figure 9. A view of the JRC-EUROMOD web interface

The existence of public web interfaces for EUROMOD confirms the interest and need for applications of this kind. Even though the existing applications are a great source of inspiration for the application to be built within this thesis, they cannot be used as a base. The main reason for that is their closed essence. As neither the applications nor their source code is publicly accessible, building upon them would require very tight cooperation with the owner institutions. What is more, even though the JRC-EUROMOD application allows simulations for Estonia, the application is extensive and therefore serves a much different purpose than our goal. The goal of the web interface built within this thesis is to be as user-friendly and intuitive as possible, providing only a few options for policy changes and few clear outputs.

2.2.3 Tools

For working with the EUROMOD input and output dataset, described in more detail in Chapter 3, the author uses the R programming language. This chapter introduces the tools used throughout the thesis. The tools are used for running the microsimulation, which is explained in more detail in Chapter 4, for building the web interface described in Chapter 5, and for calculating the gender pay gap and selected indicators in Chapter 6.

R and RStudio

R is a programming language and environment widely used for statistical computing and graphics [32]. The author used RStudio, an integrated development environment for R [34], to access the scripts easier. R and RStudio will be used in this thesis to prepare the input datasets for the hypothetical scenarios and the calculation and graphical visualization of the gender pay gap and inequality indices from the EUROMOD simulation output datasets.

R Shiny

R Shiny is a web application framework for R, intended to build standalone apps. RShiny will be used in this thesis to build the web interface for EUROMOD. The packages used in the application are the following:

- **xml2** - Xml2 is an R package that provides functionality for reading and manipulating XML files.
- **plotly** - Plotly is an R package for drawing charts
- **shinyBS** - ShinyBS is an R package intended to be used together with R Shiny. The package provides some additional visual elements adopted from the Bootstrap style framework to use inside the application.
- **shiny.i18n** - Shiny.i18n is an R package that provides functionality for R Shiny apps to support multiple languages.

2.3 Related work

Macedonia, 2008 - In 2008, no minimum wage was yet set in Macedonia. Angel-Urdinola posed a hypothesis in their research that companies might be paying less to their low-skilled female workers than they do to low-skilled male workers and that applying a minimum wage policy would significantly improve the condition of working women [35]. Their research concluded that a relatively high minimum wage (close to the median salary) would be necessary to get a significant decrease (up to 23%) of the gender pay gap. However, the author warns that a minimum wage that high may likely hurt employment rates, as they were already relatively low and unemployment rates were high.

The United Kingdom, 2012 – The research by Dickens and Manning in 2012 on data from the United States and the United Kingdom presents a new model for explaining the impact of minimum wage on wage distribution [36]. The authors then use the newly created model to study the effect that UK minimum wage has on society and concludes that while it does not have a noticeable impact on employment, it can be linked to the decline in the wage gap in the bottom half of the wage distribution. Most importantly, in 1998-2010, the minimum wage has reduced wage inequality among young workers. What is more, the paper presents evidence on spillover effects of the minimum wage, saying that it reaches up to 40% above the minimum wage.

France, 2016 – The study by Aeberhardt et al. does not look into the effect minimum wage can have on the gender pay gap [37]. However, it is still essential for the context of this thesis, as they discuss the spillover effects of increasing the minimum wage had on the people of France in the early 2000s. Even though the spillover effects were considerable and overall a positive impact on the wellbeing of low-earning workers, the result was lower for women than it was for men.

The United Kingdom, 2017 - Based on measures suggested by Atkinson in 2015, Atkinson et al. use EUROMOD in their study to assess the first-order effects of several tax policy measures on income inequality [38]. Through simulations and analysis, the authors conclude that progressive income tax or raising the child benefits would help substantially reduce the gender pay gap. However, interestingly, they note that increasing the Minimum Wage in the UK did not show any effect on the gender pay gap. This contradicts our hypothesis in this thesis, however, the authors also bring out that the reason why the Minimum Wage would not have an impact on poverty is related to the distribution of Minimum Wage recipients in the UK. More precisely, people receiving the Minimum Wage are spread across the income distribution instead of being closely gathered to the bottom. What is more, for most recipients, the gain from the higher minimum wage would be drawn back by loss in means-tested benefits.

Estonia, 2018 – Ferraro, Meriküll, and Staehr focus their 2018 study solely on the impact of the minimum wage on the gender pay gap and overall wage distribution in Estonia [39]. Analyzing data from 2001-2014, they uncover that the minimum wage has contributed considerably to lowering the wage inequality. Moreover, the research looks into the spillover effects the raises in the minimum wages have had. The estimated impact turns out to be that each 1€ increase of the minimum wage results in an 0.11€ rise in the average salary of a full-time worker. In the context of this thesis, it is also important to mention that the spillover effect appeared to be more prominent among women than it was among men.

Poland, 2018 – Majchrowska and Strawinski researched whether the increase in the minimum wage in 2008-2009 in Poland had a detectable effect on the gender pay gap [40]. The authors conclude that increases in the minimum wage have the most considerable impact on groups of people for whom the minimum wage is binding, i.e., people who work as low-skilled employees or just starting on the labor market. Coincidentally, the most significant decreases in the gender pay gap were observed in these groups. From the age perspective, they report that changes in the minimum wage have the most important influence on young workers and a much lower influence on middle-aged or older workers. However, the authors bring to attention that with the increase of the minimum wage, the effect of potentially lower employment levels must be considered.

The European Union, 2020 - At the end of 2020, the Joint Research Centre, European Commission, investigated the effects of raising the minimum wage in each European Union country [41]. Similar to the research at hand, they used EUROMOD to simulate the change and observed changes in social indices in the output data. Interestingly, the simulations showed a drop of 2%-6% in the gender pay gap for Estonia, and an even more significant impact appeared on poverty measures.

As seen from previous studies on whether a rise in the minimum wage could reduce the gender pay gap, the results vary. It is evident that the answer to the question relies heavily on the observed country, precisely the current level of minimum wage and how men and women are distributed in the workforce. The main concerns which stem from research that policymakers should consider before raising the minimum wage are

- How high is non-compliance in the country? Is non-compliance higher for women than for men?
- Will the spillover effect be higher for men than it will be for women?
- How will the employment rates change following the increase of the minimum wage? Will employment rates fall faster for women than for men?

The thesis at hand will focus strictly on the “overnight” effects of raising the minimum wage and will not try to answer any further questions. These questions, however, are definitely an exciting topic for upcoming research.

3 Data

In order to run the microsimulations on the hypothetical minimum wage scenarios, a harmonized dataset needs to be provided for EUROMOD to use. This chapter describes the underlying dataset in Chapter 3.1. The dataset does not, however, contain collected information on hourly wages, which are necessary for calculating the gender pay gap. To address this issue, the author compares three methods for predicting the hourly wages in Chapter 3.2.

3.1 Datasets

There are two datasets used in this thesis, both provided by Statistics Estonia. This chapter describes the structure and collection method of these datasets.

The Estonian registry-based EUROMOD input data set

EUROMOD requires a country-specific harmonized input dataset to operate. The components and working principles of EUROMOD are discussed in more detail in Chapter 2.2.2. For Estonia, for each calendar year, there are two primary input datasets composed for EUROMOD:

1. The dataset based on the European Union Survey of Income and Living Conditions (EU-SILC)

   The main benefit for this dataset is that it can be used in comparative cross-country studies, as comparable data is also available for other member states
2. The dataset based on the Estonian Social Survey (ESU) and other national registries

   This dataset is specific to Estonia and represents a much more extensive selection of individuals for Estonia.

In this thesis, the focus is solely on Estonia. For that reason, the author opted for using the second option, which is the register-based dataset, often also referred to as registry data in the community.

The input dataset mentioned above is composed yearly by Statistic Estonia from data from the Estonian Social Survey (ESU) and national registries (Population Register, Employment Register, Parent-Children Register, Tax Declaration Register, Disability Register). The data is gathered from the registries and harmonized to represent all required variables and fit a valid EUROMOD input file structure. The resulting data contains cumulative yearly wage information for individuals, which has been adjusted to reflect the average monthly wage of that person by dividing the total employment earnings by the number of months worked in the reference year. Neither the number of hours worked or the official hourly pay is reflected in the survey. Therefore hourly wages are imputed based on the monthly salary and whether the individual worked part-time or full-time.

At the moment of writing, the latest Estonian registry-based input data available for EUROMOD is 2019. The author will use both the 2018 and 2019 data for the simulations. The 2018 Estonian registry-based EUROMOD input data set consists of 1324820 observations and 152 variables. The 2019 Estonian registry-based EUROMOD input data set consists of 1328976 observations and 155 variables

The 2018 Structure of Earnings Survey (SES)

Every four years, the Member States of the European Union (EU), as well as the candidate states and states part of the European Free Trade Association (EFTA), are asked to conduct the Structure of Earnings Survey (SES) [6]. The SES is intended to gather comparable information about the state's wage structure, mainly focusing on businesses outside of the public sector that employ more than ten employees. However, companies that fall outside of this category may also fill out the survey voluntarily. As the resulting data is profound and uniform across all states, it is used as an input in policy creation as well as by researchers in the EU. The SES has been conducted since 2002, with limited data available for 1995.

The reason why the SES is an important source of data for the question of the gender pay gap is that it contains accurate wage information, such as the real working hours, hourly pay, and bonus payments, together with the characteristics of the people (sex, age, education) and the characteristics of the employers (economic sector, size). The data is made available approximately two years after the survey took place, therefore at the time of writing, the latest available data is from the SES 2018. The Estonian SES dataset available for 2018 consists of a total of 158500 observations and 82 variables.

3.2 Predicting the hourly wage

The gender pay gap is calculated from the difference of hourly gross wages of men and women. EUROMOD input dataset, however, contains:

- the average monthly earnings of individuals (calculated by dividing the total yearly earnings, which also contains bonus payments together with the base pay, by the number of months worked)
- the number of months worked full-time
- the number of months worked part-time
- imputed hourly wage

The imputed hourly wages in the dataset can be prone to errors, since there is no information on the real working hours of individuals. The hourly wages are imputed based on the following formula:

$$hourly\ wage = \frac{gross\ monthly\ pay}{\frac{months\ worked\ full\ time\ +0.5\cdot\ months\ worked\ part\ time}{months\ worked} \cdot 168} \qquad (1)$$

As the imputed hourly wage might not always be correct, the author will compare the accuracy of the imputed hourly wages with two machine learning methods: decision tree and linear regression, to see if there is perhaps a way to derive more precise hourly wages from the data.

The machine learning methods and the accuracy evaluation will be based on the Structure of Earnings Survey (SES), which is conducted every four years on a sample of employers. The SES is special as it holds detailed and reliable information on each individual's working hours and hourly wage, making a distinction between the base pay and total pay including bonuses and overtime. The SES is conducted every four years and the latest available data is from 2018. The 2018 SES consists of 158500 weighted observations and 82 variables. For each method in this chapter, the author will find the gender pay gap from the imputed hourly wages and compare it with the gender pay gap from the SES data to assess the accuracy of the method. For more objective results, the individuals whose hourly wage classified as an outlier in the data (a total of 135 observations), were removed from the dataset.

Kuldkepp recently conducted a similar analysis in [42], where the working hours were predicted based on combined Estonian registry-data, in order to calculate the gender pay gap. The experiment here builds on this work, adding to it by predicting the hourly wage instead of the working hours. What is more, the dataset used in this chapter contains additional variables, which might affect results.

To assess the precision of each method, two characteristics are measured:

The average difference between the real and predicted hourly wages, calculated by the formula:

$$Avg\ error = \frac{\sum_{i=1}^{n} \left| predicted\ houtly\ wage - real\ hourly\ wage \right|}{n} \quad (2)$$

The gender pay gap from the predicted wages, calculated based on the following formula:

$$\frac{gross\ hourly\ pay\ of\ men - gross\ hourly\ pay\ of\ women}{gross\ hourly\ pay\ of\ men} \cdot 100 \quad (3)$$

3.2.1 Imputing the hourly wage based on mean working time values

The EUROMOD input dataset is based on the Estonian Social Survey (ESU) and other national registries, such as the Tax Declaration Registry, which contain only cumulative wage information for each individual. The values available from the registries are: cumulative yearly earnings, number of months worked full-time, number of months worked part-time. From these values, an estimated hourly wage is imputed for each individual during the creation of the EUROMOD input dataset. The formula for calculating the estimated hourly wage is shown in Formula 1.

Comparing the imputed hourly wage values to the actual values available in the Structure of Earnings Survey (SES) allows evaluating the precision of this method. After combining the EUROMOD input data set with the SES data, the dataset consisted of 155621 rows.

The average error between the imputed and SES hourly wages was 0.95€.

The gender pay gap was

- from the SES data: 21.9%
- from the imputed wages: 21.83%

3.2.2 Building a decision tree to classify individuals based on hourly wages

A decision tree is a classification methodology often used in machine learning problems to divide elements in a dataset into two or more classes. The process consists of a set of hierarchical decisions, also called split criteria, which are laid out in a tree-like structure. The inner nodes in the tree are the decisions, and each decision splits the data into two or more parts by the value of a condition on the feature variables of the data. The outer leaves of the tree represent the classes where the decision tree estimates the data point to belong [43].

The algorithm for building the decision tree starts by creating a root node and then uses the Gini Index to find the next best split criterion on each iteration. The formula for the Gini Index G(S)

$$G(v_i) = 1 - \sum_{j=1}^{k} p_j^2 \quad (4)$$

where $v_i \dots v_r$ are the r possible values of a feature variable and p_j is the set of data points containing the value v_i and belonging to the class $j \in \{1 \dots k\}$ [43].

In order to use the decision tree in finding the hourly wages, the individuals will be divided into ten buckets based on their hourly wage. The ranges for the buckets are selected based on the deciles of the hourly wages. The ten buckets are presented in Table 1.

Table 1. Hourly wage buckets for the decision tree algorithm

Nr	Range
1	1.20€ - 3.41€
2	3.42€ - 4.21€
3	4.22€ - 4.98€
4	4.99€ - 5.77€
5	5.78€ - 6.51€
6	6.52€ - 7.31€
7	7.32€ - 8.30€
8	8.31€ - 9.71€
9	9.72€ - 12.20€
10	12.21€ - 32.40€

The dataset was split into a train set of 120000 observations and a test set of 31308 observations. The decision tree created from the train set is shown in Figure 10.

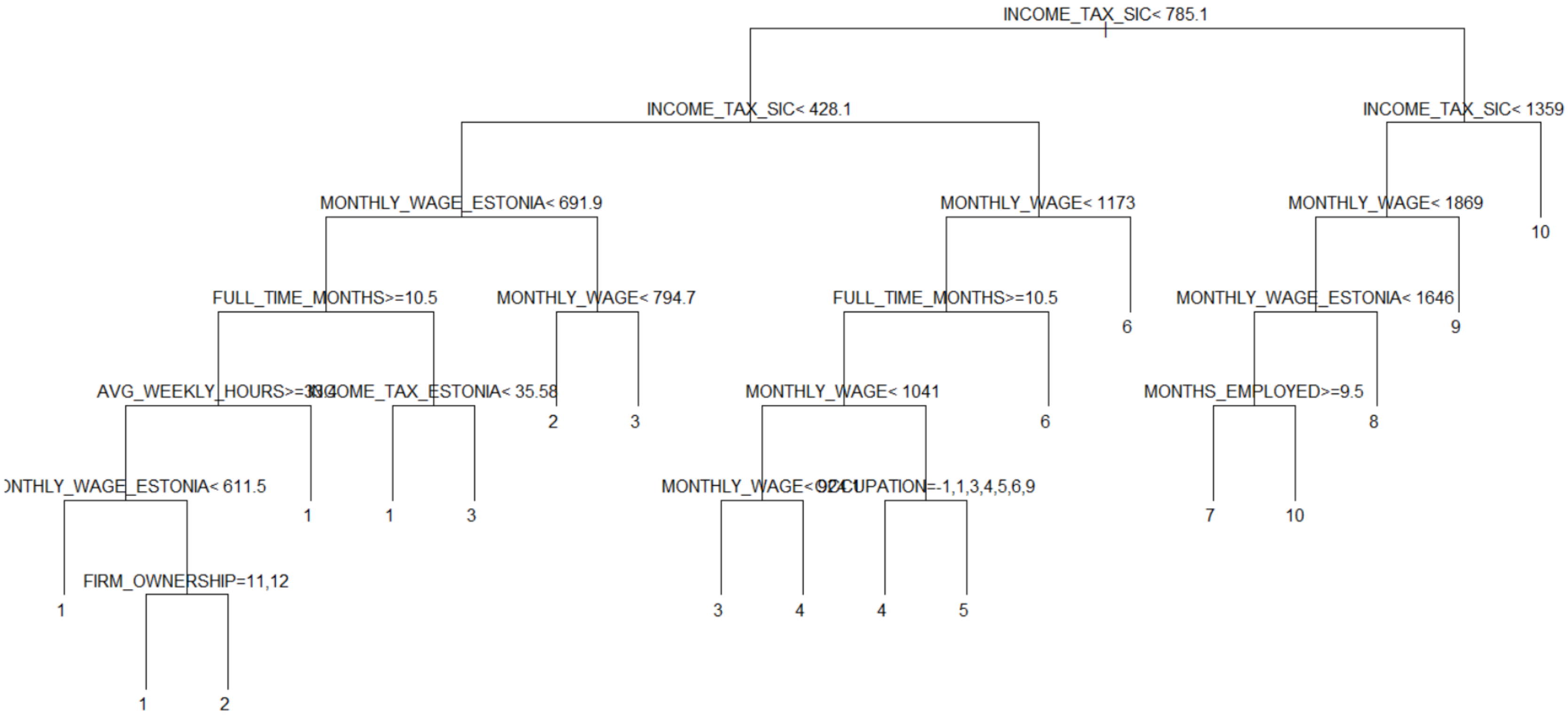


Figure 10. Decision tree predicting the hourly wage range of individuals based on EUROMOD input data.

To see how the decision tree performs, the test set was used. The confusion matrix for the predictions is shown in Table 2.

Table 2. Confusion matrix of the decision tree test set classifications

	1	2	3	4	5	6	7	8	9	10
1	**1790**	782	374	263	139	109	77	48	41	18
2	461	**1049**	492	179	87	73	27	18	15	4
3	413	939	**1222**	716	387	293	164	106	67	35
4	106	225	605	**923**	517	220	99	53	26	13
5	19	29	83	250	**324**	187	75	37	10	5
6	86	107	200	550	1047	**1572**	993	475	194	89
7	22	34	48	95	205	497	**826**	585	175	48
8	16	15	24	46	94	224	463	**869**	459	83
9	19	21	27	39	65	152	318	780	**1444**	465
10	19	18	8	29	36	85	131	179	666	**2472**

The accuracy for the decision tree is found using Formula 5 [43], where *k*represents a bucket in the value to be estimated.

$$Accuracy = \frac{\sum_k tk}{\sum_k tk + fk} \quad (5)$$

Based on the confusion matrix shown in Table 3, the accuracy of the decision tree classifications is 0.4.

For each class k, the precision, recall, and F-score were calculated using the following formulae [43]:

$$Recall = \frac{tp}{tp + fn} \quad (6)$$

$$Precision = \frac{tp}{tp + fp} \quad (7)$$

$$F = 2 \cdot \frac{Precision \cdot Recall}{Precision + Recall} \quad (8)$$

The results of the accuracy measures for each class are shown in Table 3.

Table 3. Recall, Precision, and F-score values for each bucket in the decision tree classification.

Bucket	**Recall**	**Precision**	**F-score**
1	0.49	0.61	0.54
2	0.44	0.33	0.37
3	0.28	0.40	0.33
4	0.33	0.30	0.31
5	0.32	0.11	0.17
6	0.30	0.46	0.36
7	0.33	0.26	0.29
8	0.38	0.28	0.32
9	0.43	0.47	0.45
10	0.68	0.76	0.72

Each individual was then assigned the average wage of their predicted bucket. Based on those values the average error between the predicted and SES hourly wages was 2.3€.
The gender pay gap was

- from the SES data: 21.9%
- from the decision tree predicted wages: 23.7%

3.2.3 Building a linear regression model to predict hourly wages

When predicting the hourly wage using linear regression, the dependent variable was set to the hourly wage from SES, and independent variables were:

- Gender
- Occupation
- Ownership of firm
- Social and income tax paid
- Monthly gross wage
- Monthly gross wage from Estonia
- Months in full-time employment

- Months in part-time employment
- Months in employment
- Average weekly working hours
- Age
- Disability level
- Current education status
- Highest education status
- Ability to work
- Is responsible in household
- Is in institutional household
- Marital status
- Region
- Is civil servant
- Firm size
- Industry
- Is self-employed

The residual standard error of the model was 3.11 and the multiple R-squared value 0.69. The variables with the best predicting power were:

- Social and income tax paid
- Monthly gross wage
- Monthly gross wage from Estonia
- Months in full-time employment
- Months in employment
- Average weekly hours
- Occupation

The average error between the predicted and SES hourly wages was 1.9€.
The gender pay gap was:

- from the SES data: 21.9%
- from the values fitted by the linear regression model: 19.92%

3.2.4 Conclusion

In this chapter, the author compared three methods for assigning a hourly wage value to individuals based on available characteristics in the EUROMOD input data set. For each method, the average error in the predicted hourly wage was calculated. Based on this measure, the first option, where the wages were imputed based on mean working hours, proved to give the best result with only a 0.95€ average error. The gender pay gap was also calculated in each scenario from the predicted hourly wage values. The results proved to be similar to Kuldkepp [42], who predicted the working hours in order to calculate the gender pay gap. The comparison in [42] between using mean values, linear regression, and neural networks to predict working hours, concluded that the most precise method for the gender pay gap was using the mean wage values, where the gender pay gap only differed by 0.2 percentage points. This aligns with the result here, as the imputed wage showed a difference of 0.07 points from the reference gender pay gap.

When comparing the gender pay gap values to the value in the original SES data, it can be concluded that once again, the first option, where the hourly wages were imputed, gives the closest answer, with the predicted value of 21.83% being only 0.07 percentage points or 3.2% different from the reference value of 21.9%. Therefore, the imputed hourly wages will be used throughout the rest of this thesis for calculating the gender pay gap.

4 Microsimulation

The goal of this thesis is to assess the effects increasing the minimum wage would have on the gender pay gap and other selected indicators in Estonia. The method at the core of the evaluation is microsimulation, which was explained in Chapter 2.2.1. This chapter explains the process needed to do the experiments. The steps of the complete microsimulation process are the following:

1. Identifying minimum wage earners and modifying the wages of the minimum wage earners to the new level

   In order to simulate a scenario with a higher minimum wage level, the wages of eligible people must be set to the new level. Chapter 4.1 describes the process of how the eligible individuals are identified and how the data is modified.

2. Running a tax-benefit microsimulation in EUROMOD

   Chapter 4.2 describes the process of running a microsimulation in EUROMOD with the modified input data. The parameters which were modified in the EUROMOD policy system are also described.

3. Assessing the inequality measures based on the output microdata

   Chapter 4.3 describes the formulae and process of calculating the gender pay gap and inequality measures from the EUROMOD output data.

A visual representation of the process of running a hypothetical minimum wage scenario microsimulation with EUROMOD is shown in Figure 11.

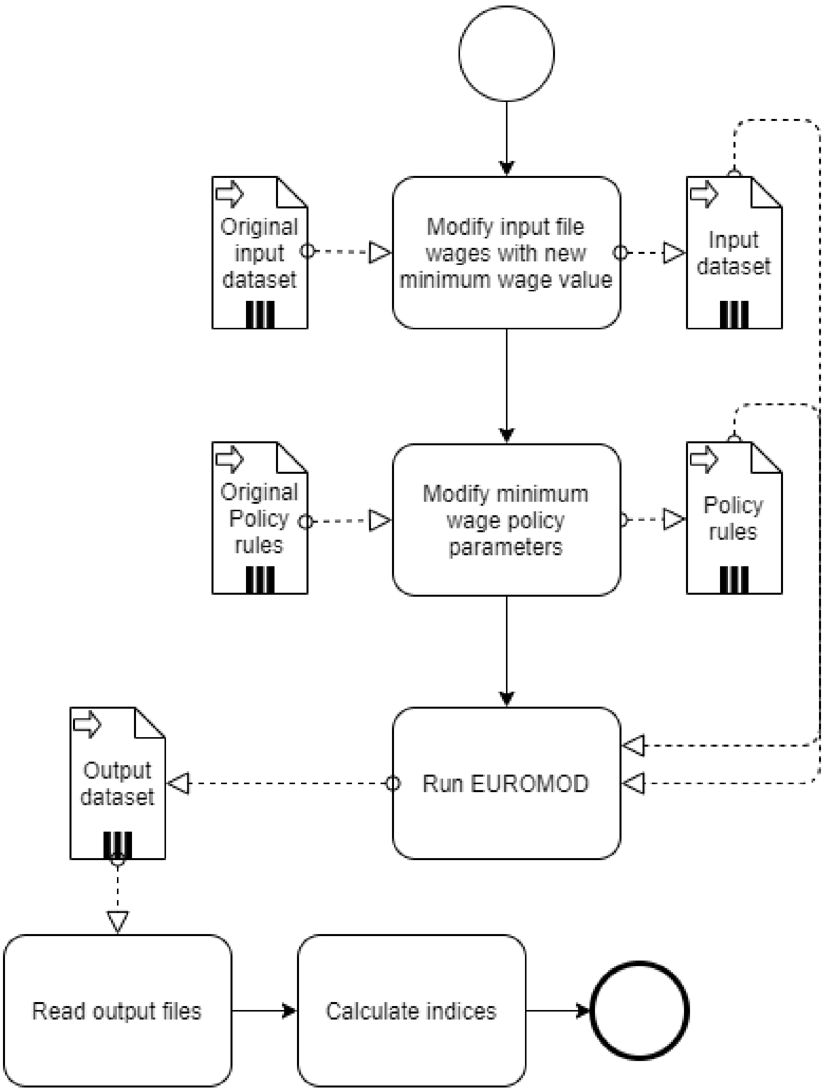


Figure 11. Process flow of running a modified minimum wage scenario microsimulation

4.1 Identifying minimum wage earners

There is no specific data on who earns the minimum wage and who does not. Therefore, identifying the minimum wage earners has to be based solely on the salary number. In this thesis, the author will first identify minimum wage earners based on monthly wages. The reasons behind preferring monthly wages over hourly wages for the identification are the following:

- Estonian registry data contains data on the monthly wage and does not contain precise information on either the hourly wage or the hours worked, which means that the hourly wages are imputed.

- Estonian registry data contains information on the workload, which makes it possible to distinguish full-time and part-time employees.
- The Estonian tax system encourages full-time positions over part-time positions. Since 2013, the Minister of Finance established the minimum liability of social tax [24], per which an employer is required to pay social tax (33% [23]) as if the employee worked a full-time position, regardless of whether they are working full-time or part-time.
- The data also confirm the last point. According to the EUROMOD input data sets:
    - In 2018, out of 701 473 employed individuals, 598 027 worked full-time.
    - In 2019, out of 708 061 employed individuals, 689 904 worked full-time.

In this thesis, subjects to the new minimum wages are defined as those employees, whose full-time monthly wage lies between 80% of the actual minimum wage and 105% of the new minimum wage. The reason for using a range is to account for minor reporting and rounding errors. The limits of 80% and 105% were chosen following the example of the Joint Research Centre [41]. The monthly and hourly wages of those individuals are then modified to correspond to the new minimum wage of the scenario. The new dataset can then be used in the next steps of the simulation.

4.2 Running tax-benefit simulations on the modified data

This thesis aims to evaluate the changes in the gender pay gap and the overall inequality measures caused by the difference in the minimum wage. In order to adequately measure that, it is crucial to account for the tax and benefit changes which may occur when one's income changes. For simulating the applicable taxes and benefits for each individual, EUROMOD will be used. The architecture and behavior of EUROMOD are explained in more detail in Chapter 2.2.2.

For both the year 2018 and 2019, the author ran EUROMOD simulations for both the base scenario and all the hypothetical scenarios, where the wages were modified in the input data. What is more, for the hypothetical scenarios, some constant system variables, which are in their essence tied to the minimum wage level, had to be changed in the EUROMOD policy set. The changed parameters are listed in Table 4.

Table 4. Modified policy parameters in EUROMOD

EUROMOD variable name	Variable description	New value
$AvWage	The average wage	Calculated mean of the new modified wages
$MinWage	The minimum wage	New minimum wage value
$SAPE_IncLim	Support for pensioners living alone: income limit	New minimum wage value

To ensure reasonable comparability, the base scenario data was also modified by the same principles as the hypothetical scenario input data, with the reference minimum wage being the proper minimum wage of that year.

Some benefits in Estonia are also tied to the minimum wage level of the year before. In order to therefore see the possible full effects the change of minimum wage would have, in Chapter 6.4, a second set of all the 2019 scenarios was executed, where in addition to the previous variables, also the following constants in EUROMOD were modified to consider the corresponding 2018 scenario minimum wage value. The additional modified parameters are listed in Table 5.

Table 5. Modified policy parameters in EUROMOD for the two-year scenario

EUROMOD variable name	Variable description	New value
$MinWage_lag1	The minimum wage of the previous year	Corresponding 2018 scenario minimum wage value
$SIC_MinBase	Social Insurance Contributions (SIC) minimum base	New minimum wage value
$PB_MinAmount	Maternity pay minimum amount	New minimum wage value

4.3 Measuring the gender pay gap and selected indicators from the EUROMOD output data

EUROMOD is a microsimulation tool, which means that its output is a dataset the same length as the input dataset, with modified and added values. EUROMOD does not calculate social indices itself, but they rather have to be calculated using a data analysis software. In this thesis, the author uses the R programming language described in Chapter 2.2.3 for the analysis. The code for the functions can be found in the following Git repository: https://github.com/kr1stine/minimum-wage-functions/.

In this chapter, the formulae which were used on the output data to find social indices are described. The poverty and inequality indicators follow the Eurostat guidelines for calculating Laeken indicators.

The gender pay gap

To monitor the gender pay gap in unadjusted form, the European Union uses the indicator published by Eurostat each year for every member state. The gender pay gap indicates the difference in pay between men and women. Eurostat calculates the indicator based on the gross hourly pay, and it shows how many percent the gross hourly pay of women is lower than the gross hourly pay of men [44]. To calculate the indicator, the following formula is used:

$$\frac{gross\ hourly\ pay\ of\ men - gross\ hourly\ pay\ of\ women}{gross\ hourly\ pay\ of\ men} \cdot 100 \qquad (9)$$

Equivalised disposable income

Except for the gender pay gap, all social indicators measured in this paper use individuals' equivalised disposable income as their basis of calculation. The equivalised disposable income is calculated by finding the sum of a household's members' disposable income and dividing it by the total consumption weight of the household, also called equivalised household size. We calculate the equivalised size of the household using modified OECD scales, where the first adult of the household is given a weight of 1, all other individuals over the age of 14 the weight of 0.5, and everyone under the age of 14 the weight of 0.3 [45].

EUROMOD calculates the initial disposable income for each individual, which the author then uses as a base to find the equivalised disposable income. For each individual, EUROMOD calculates their disposable income by adding together income sources and benefits and subtracting applicable taxes. The structure of benefits added and taxes deducted to find the disposable income value is shown in Appendix 2.

Gini coefficient

The Gini coefficient describes the inequality within the distribution of income in a population. The higher the Gini coefficient, the higher the inequality. The Gini coefficient is defined as the relationship of cumulative shares of the population indexed in non-decreasing order by their equivalised disposable income, to the cumulative share of the total equivalised disposable income received by them. For a population with values $y_i, i = 1 \text{to} n$, that are indexed in non-decreasing order $y_i \leq y_i + 1$, the Gini index can be defined as shown in Formula 10 [46].

$$Gini := \frac{2\sum_{i=1}^{n} iy_i}{n\sum_{i=1}^{n} y_i} - \frac{n+1}{n} \tag{10}$$

D5/D1 ratio

D5/D1 ratio measures inequality in a population. It is found as the ratio between the median and lowest 10% wage earners (50% decile and 10% decile) [46].

At-risk-of-poverty rate

To find the ratio of the population at risk at poverty, we first need to define the at-risk-at-poverty threshold. In Estonia, as well as in other European Union member states, the at-risk-at-poverty threshold is defined as 60% of the national median equivalised disposable income [45]. The ratio of people whose equivalised disposable income falls under the at-risk-at-poverty threshold, is called the at-risk-at-poverty rate. The mathematical notation of the at-risk-of-poverty-rate is shown in Formula 11.

$$ARPR := P\left(x < 0.6 \cdot q_{0.5}\right) \cdot 100 \tag{11}$$

where $q_{0.5} := F^{-1}(0.5)$ denotes the population 50% quantile and F is the distribution function of the equivalised disposable income on the population level.

In-work poverty

In-work poverty is a measure closely tied to the at-risk-of-poverty rate and threshold. In-work poverty measures the proportion of working individuals whose equivalised disposable income is under the at-risk-of-poverty threshold. In other words, it depicts the amount of people who are at risk of poverty regardless that they are employed.

Extreme poverty

Extreme poverty, also referred to as absolute poverty, measures the proportion of individuals whose equivalised disposable income stays below the extreme poverty line [45]. The extreme poverty line in Estonia is the estimated subsistence level, which expresses the financial cost of meeting minimum needs. The calculation of the subsistence level takes into account expenses on food, accommodation, and individual expenses not related to food. The subsistence level does not include expenses on alcohol, tobacco, holiday travel, eating out, staying at hotels or buying personal means of transportation.

This chapter described the steps the author is taking to run the microsimulations and assess effects of raising the minimum wage in Estonia. The steps will be followed both when building the EUROMOD web interface, described in Chapter 5, as well as when analyzing the effects on the complete dataset, described in Chapter 6.

5 Web Interface for EUROMOD

As a part of this thesis, a web interface for EUROMOD was developed. This chapter presents the motivation of the project, as well as the included requirements and the architecture of the system. The goal was to provide a public, user-friendly web application on the Statistics Estonia website, which would allow the user to specify a hypothetical minimum wage value, would then run EUROMOD on the background, calculate social indices based on the results, and display the results to the user.

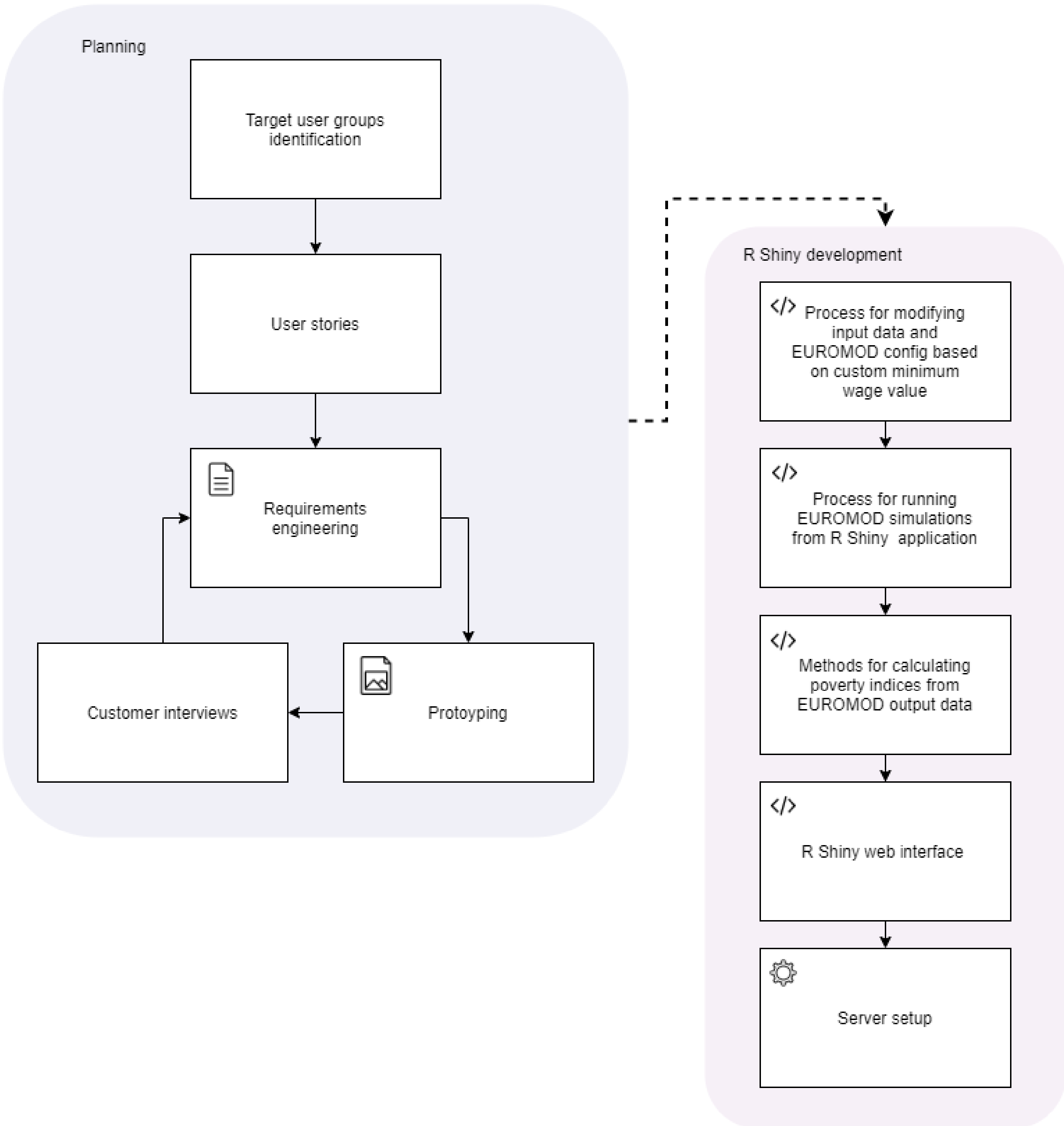


Figure 12. Development process of the EUROMOD web interface

One of the main goals of the application was user-friendliness. Existing microsimulation solutions tend to come with a learning curve or restricted access, and therefore the goal for our application was to make it as intuitive and straightforward as possible. Therefore, a substantial part of the development process was dedicated to planning and user research. Several prototypes were created, and user interviews were conducted to figure out the requirements. The development process of the application is shown in Figure 12. The complete source code and development process can be seen at https://github.com/kr1stine/euromod-web-interface.

5.1 Requirements specification

This chapter describes the process of requirements engineering for the EUROMOD web interface. User stories, prototyping, and the list of functional and non-functional requirements are covered in this chapter.

5.1.1 User stories

The goal of the web application is to allow the user to experiment with different levels of the minimum wage and observe the predicted effect on the gender pay gap as well as other social indicators. Within the experts in the REGE research group, the following target user personas were defined:

- Representatives of trade unions
- Officials at the Ministry of Social Affairs
- Economic journalists
- People with an interest in social sciences

Stemming from the user personas and the goal of the application, the following user stories were defined:

1. As an **economic journalist**, I want to see the predictable change in the gender pay gap, so that I could use it as a source of proof when writing articles about the minimum wage.
2. As an **economic journalist**, I want to be able to set the minimum wage level myself, so that I can find the most interesting levels to write about.

3. As an **official at the ministry of social affairs**, I want to see clearly the year, input data specifications, and formulas used for the calculations, so that I can use the application in detailed assessments.
4. As an **official at the ministry of social affairs**, I want to see the predictable change in overall poverty indicators, so that I can use this when proposing new minimum wage levels and measures to reduce poverty.
5. As an **official at the ministry of social affairs**, I want to see the predictable change in in-work poverty, so that I can better scour ways to reduce in-work poverty, which is an issue in Estonia.
6. As an o**fficial at the ministry of social affairs**, I want to see the predictable change in the received taxes, so that I can better select balanced measures to propose to my superiors.
7. As **a person interested in social sciences**, I want to see the predictable change in poverty for target households, so that I can see the effect it would have on the people around me.
8. As **a person interested in social sciences**, I want to be able to view the application in English, in case Estonian is not my native language.

The user stories serve as a starting point in planning the application, and are used as a basis for prototyping. The resulting prototypes are shown in the following chapter.

5.1.2 Prototype validation

Based on the user stories described in the chapter above, the author composed a paper prototype of the system. As one of the goals for the application was intuitiveness and user-friendliness, the design was kept as simple as possible. What is more, as the application will be added on the Statistics Estonia website, the design was kept in line with other applications already on the platform. Some examples of other applications on the Statistics Estonia website are the Labor policy indicators application [47] and the Occupational monthly salaries application [48]. This will help assure that the users are familiar with the design and onboard seamlessly. The prototype was then evaluated by conducting interviews with the representatives of the target user groups. Three rounds of prototypes were created, each improved based on the user feedback. The first two rounds of prototypes can be found in Appendix 3, and the final prototypes can be seen in Figure 13, Figure 14, and Figure 15.

During the interviews, the user was asked to conduct the following tasks on the paper prototype:

1. How would the gender pay gap be affected, if the minimum wage was increased up to €750?
2. In the same scenario, in which household would we see the largest impact on absolute poverty?
3. In the same scenario, how much would the state's expenses on benefits rise?

After the tasks, the users were asked to give feedback in free form. All in all, the feedback from the user interviews was positive. The users found the application helpful and necessary and had no issues in completing the tasks. The summary of the feedback from the conducted interviews is presented below.

Interviewee 1, economic journalist:

- The title should be more precise about what the application does
- It is crucial that the application be as easy as possible so that the user would comprehend at first glance why they need the application.
- The terms used in the application are too scientific for the average person
- Each indicator could be accompanied by an information icon, which would show more explanations when hovering on
- The impact on the gender pay gap and the impact on the poverty indices seem to be geared towards separate target groups and could therefore be separated into individual applications.
- The value of the taxes and benefits portion is questionable

Interviewee 2, official at the Ministry of Social Affairs:

- The minimum wage input field should specify that "gross"
- Instead of displaying the change in percentages, real values should be shown
- Would love to see specific wage-related taxes and benefits

- The household most affected by the minimum wage should be shown (single man, single woman, single parent, couple with children, couple without children)
- In-work poverty would be more useful to see instead of absolute poverty

Interviewee 3, social scientist:

- It is important to stress that the impact displayed is the “overnight effect”
- As EUROMOD is a static model, then effect over multiple years can be very prone to errors
- The results could be shown with confidence limits
- Instead of displaying the change in percentages, real values should be shown
- The application should support multiple languages
- Under taxes and benefits, the percentage change should stay, social tax, income tax and subsistence benefit should be individually shown

From the feedback from the user interviews, an updated prototype was created, which can be seen in Figure 13, Figure 14, and Figure 15. In addition to the prototype, the list of functional and non-functional requirements was composed, which will serve as a reference for developing the application.

5.1.3 Functional and non-functional requirements

Combining the initial user stories with the feedback from the user interviews, the following requirements were defined for the system:

Functional requirements

1. Numerical input field for the minimum wage
2. Selection for the year the change is applied to
3. A validation that the minimum wage must not be lower than the actual minimum wage that year
4. The gender pay gap for the working population
5. The disposable income gap for the working population
6. The absolute poverty rate for the entire population
7. The relative poverty rate for the entire population
8. Absolute poverty rate by households

9. Relative poverty rate by households
10. In-work poverty rate
11. Estimate change in social tax
12. Estimated change in income tax
13. Estimated change in labor tax combined
14. Estimated change in subsistence benefit
15. Estimated change in benefits combined
16. Estimated change in expenses to the employers in the public sector
17. Estimated change in expenses to the employers in the private sector
18. Tooltips with exact formulas for each displayed value
19. Specifications and assumptions clearly displayed

Non-functional requirements

1. The application supports multiple languages (Estonian and English being the first to be implemented) and has a language selection in the UI.
2. The application supports the latest versions of all the most popular internet browsers (Google Chrome, Mozilla Firefox, Safari, Microsoft Edge)
3. The application can be used in parallel by at least 10 users
4. The application loads first, and each simulation takes less than 20 seconds
5. The application is listed under the Statistics Estonia website

The requirements defined above serve as a reference point for developing the application. Together with the requirements, the final paper prototype, which was composed from the user feedback, was also used as a reference point for the development. The final paper prototype can be seen in Figure 13, Figure 14 and Figure 15.

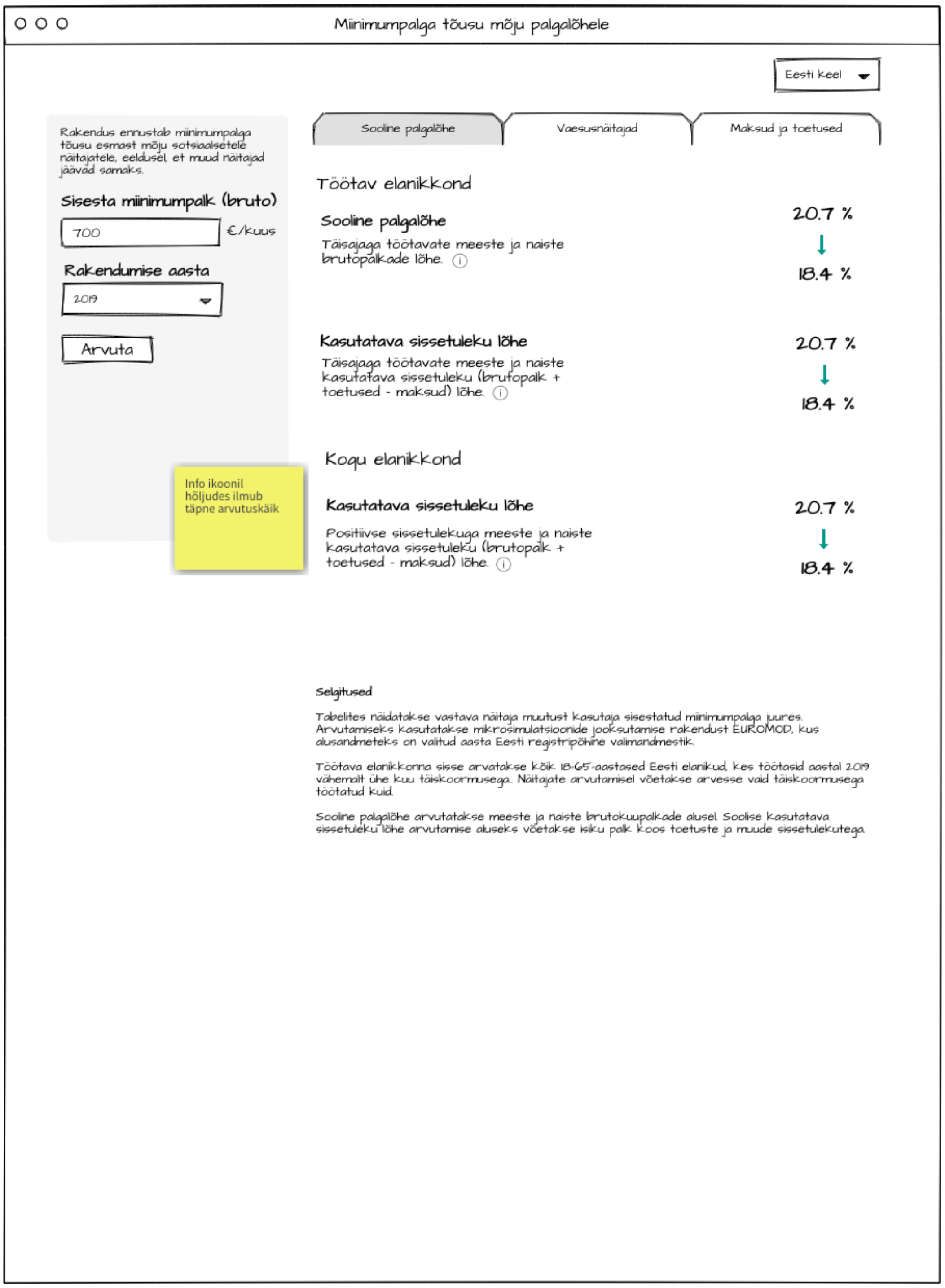


Figure 13. Paper prototype for the EUROMOD web interface, the gender pay gap tab

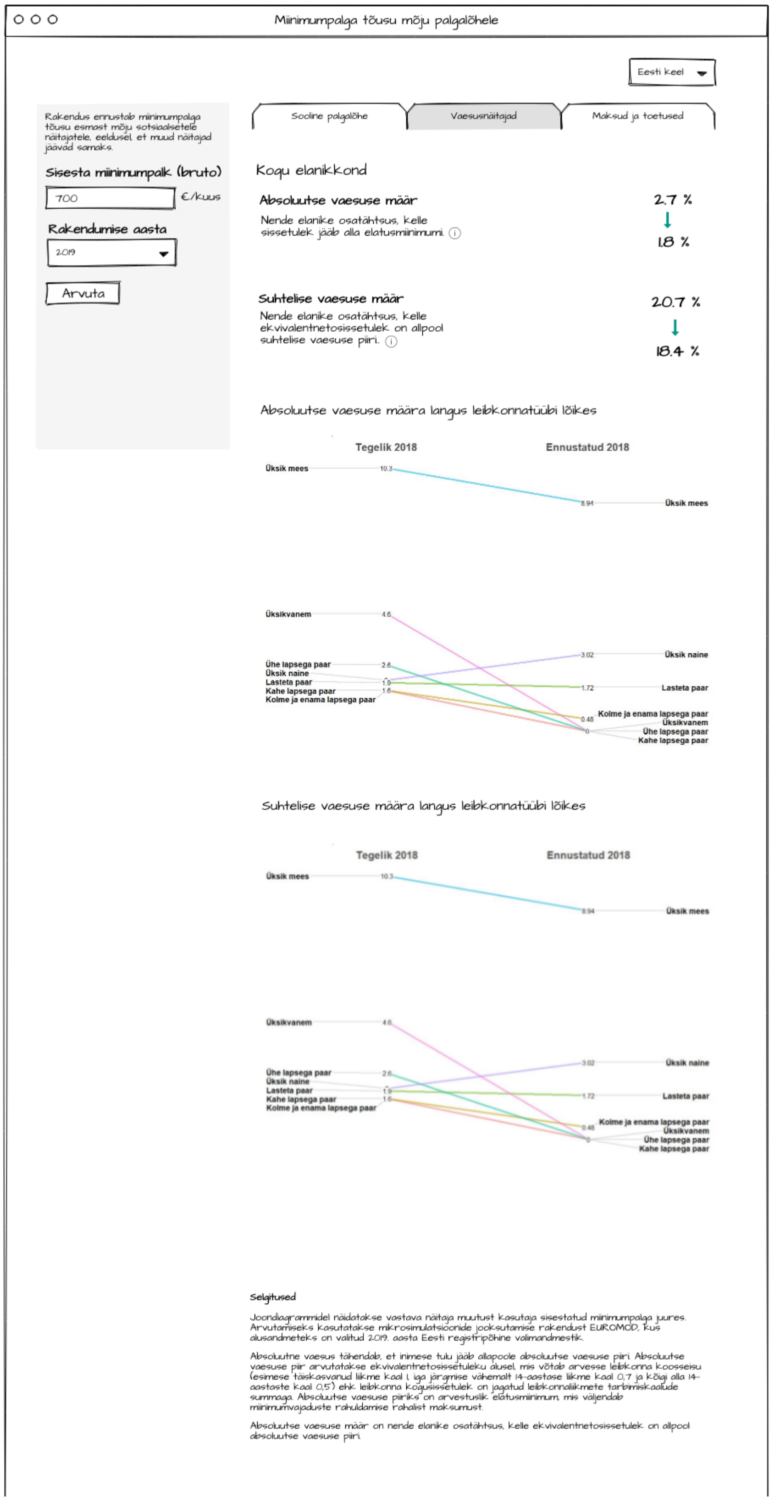


Figure 14. Paper prototype for the EUROMOD web interface, the poverty tab

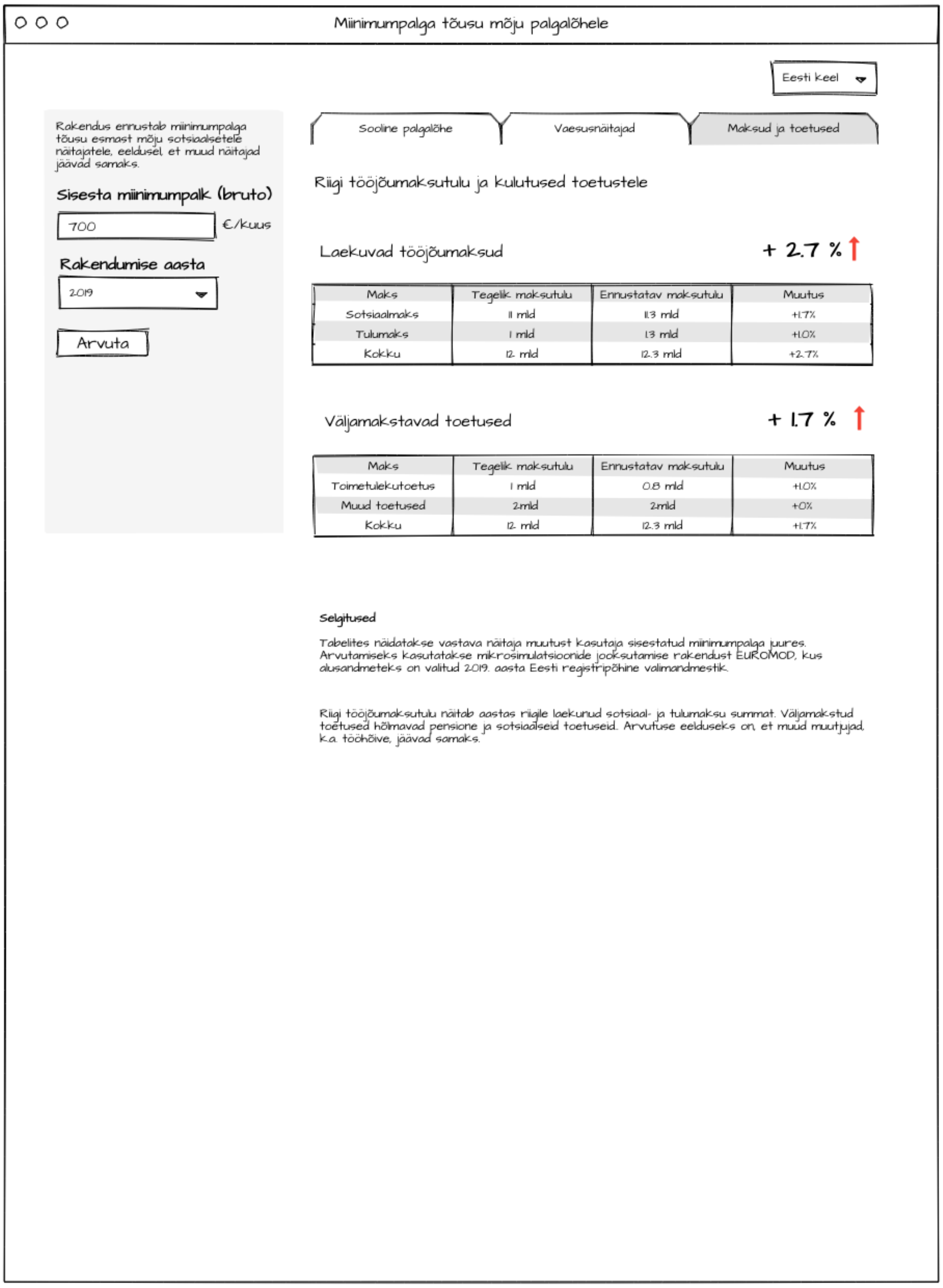


Figure 15. Paper prototype for the EUROMOD web interface, the taxes and benefits tab

5.2 Implementation

This chapter gives an overview of the architecture and the development process of the EUROMOD web interface. The requirements for the application, as well as the visual structure of the application were described in the chapter above.

Version control system

The author used GitHub for version control and issue management during the development process. All issues were categorized into milestones and labeled by their type (enhancement, technical task, UI task). Each feature was developed in a separate feature branch and merged to the master branch when ready. The complete source code and development process can be seen at https://github.com/kr1stine/euromod-web-interface.

5.2.1 Architecture

The EUROMOD web interface developed in this thesis will be embedded into the Statistics Estonia website. The website of Statistics Estonia offers both in-house visualizations of their statistics, as well as several external applications which have been embedded into the website. Some examples of such external applications are the Labor policy indicators application [47] and the Occupational monthly salaries application [48]. The EUROMOD web interface will be added to the website as another external application, and therefore, the design and technology stack will follow already existing applications. At the time of writing, the application is not yet deployed, as the process of setting up servers with the help of the Information Technology Center of the Ministry of Finance (RMIT) is currently ongoing. The application is scheduled to be publicly available by the end of 2021.

The architecture of the system can be seen in Figure 16. At the core of the system, there is an R Shiny server, which requires a Linux environment to run on. EUROMOD, however, runs on a Windows environment. What is more, each EUROMOD run takes around 15 seconds, which means that the application is blocked for other calculations for this time. To accommodate these conditions, the application is served from a Linux server, inside of which n Windows virtual machines are running and hosting EUROMOD. R Shiny server and the Windows machines will communicate via an SSH connection. To make the application scalable, each user process runs on its own thread on the R Shiny server, which will allocate one of the Windows machines. To begin with, considering the size of the target group, $n = 10$ machines are set up, which can be increased in case the interest to the application proves to be higher. If there happen to be more than n concurrent users, the rest of the users will have to wait until the previous calculations are finished.

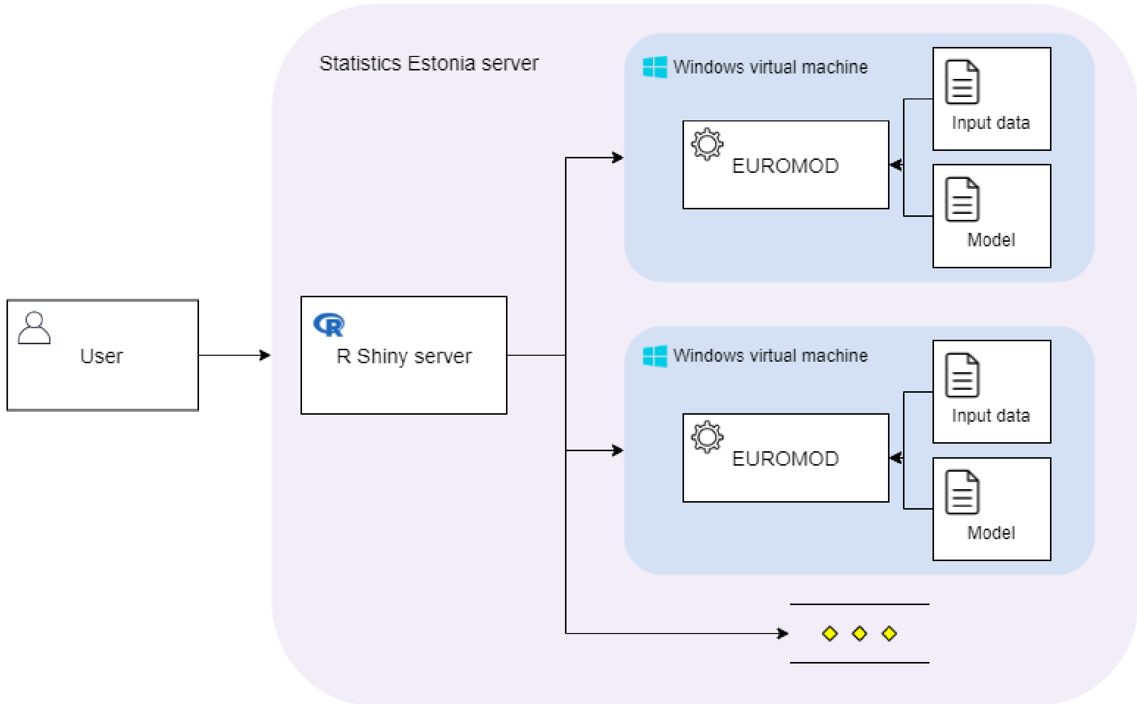


Figure 16. Architecture of the EUROMOD web interface

The application uses the registry-based EUROMOD input dataset described in Chapter 3.1. The input dataset contains information on the whole population of Estonia, however, in order to correspond with the non-functional requirements of the system, a stratified sample of the dataset with 14869 observations is used instead of the entire dataset. The reason behind it is to keep the application runtime low. Using the sample, the application took on average 12.5 seconds to load, while with the complete dataset, the runtime would be more than 10 minutes.

5.2.2 Process Flow

Figure 17 depicts the flow in which the minimum wage and year entered by the user are processed. In order to run the EUROMOD simulations with the correct parameters, both the input dataset and the policy rules need to be modified before they can be entered into the simulation application. For that purpose, a copy of the originals is kept of both, which the application uses as a base to create new files on each run. After EUROMOD has finished, the application reads the output file and uses the data to calculate all of the social measures which are then rendered and displayed to the user.

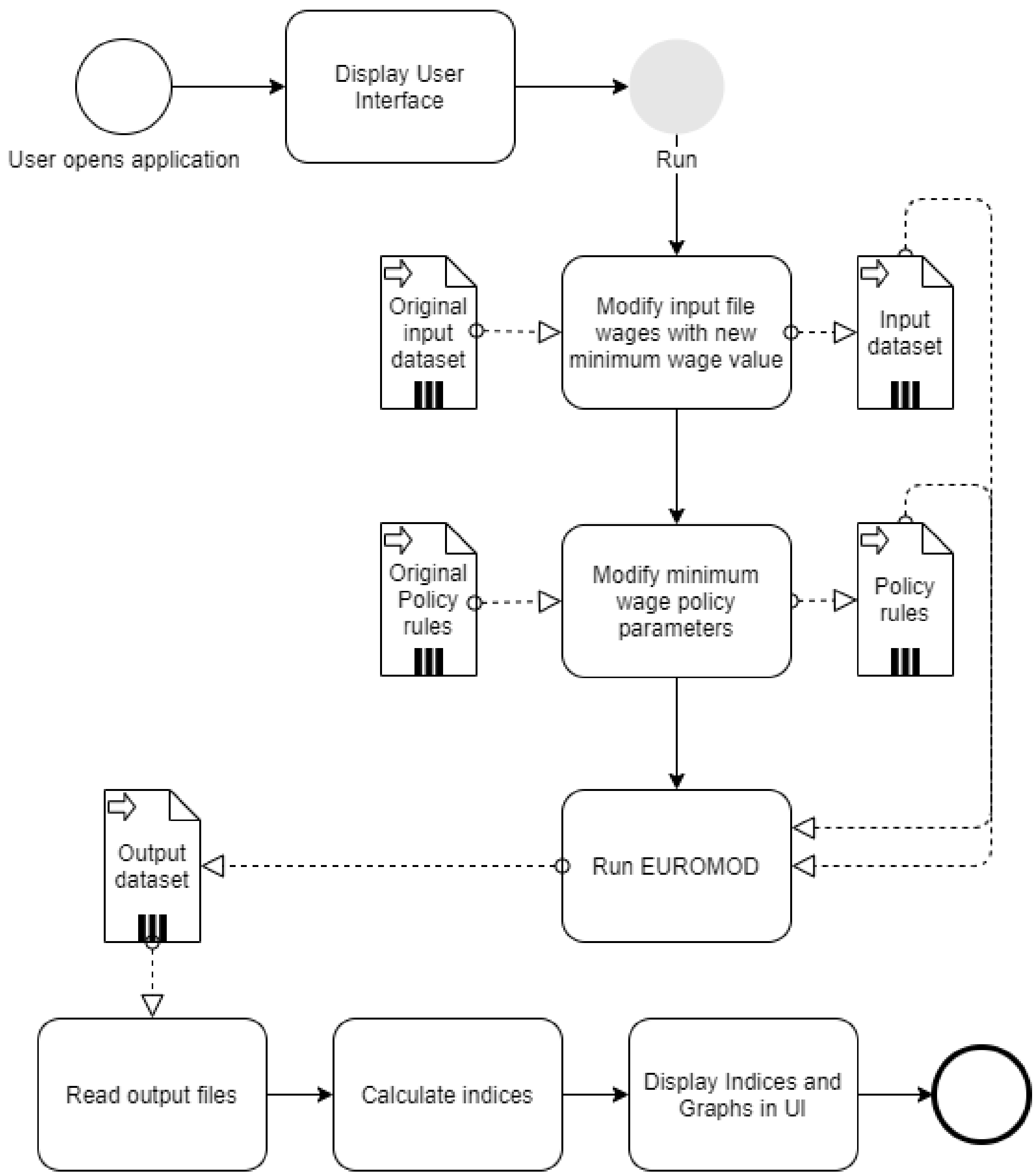


Figure 17. Process Flow of the EUROMOD web interface

5.2.3 Application views

The EUROMOD web interface was built as an R Shiny application and will be served from the Statistics Estonia server as part of the Statistics Estonia website. The view of the application is divided into a side container, where the user inputs are located, and a main container, where the simulation results are displayed. The results are divided into three tabs for better readability.

The tabs are:

- The gender pay gap displaying changes in the gender pay gap, the gender gap in disposable income for the working population, and the gender gap in disposable income for the whole population.
- The poverty tab displaying changes in the in-work poverty rate, the at-risk-of-poverty rate, the extreme poverty rate, as well as the change in the at-risk-of-poverty and extreme rates for the most affected household types.
- The taxes and benefits tab displaying changes in the labour taxes receivable and benefits to be paid, showing detailed values for the social tax, income tax, and the subsistence benefit.

Figure 18, Figure 19, and Figure 20 show screenshots of the tab contents.

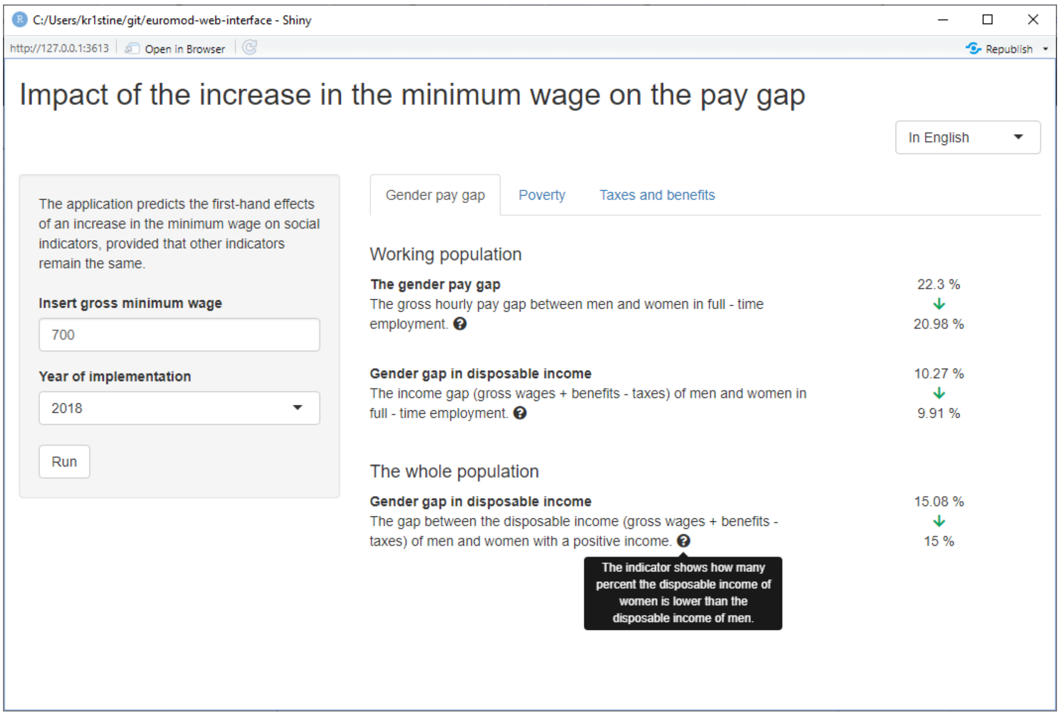


Figure 18. View of the EUROMOD web interface: the gender pay gap tab

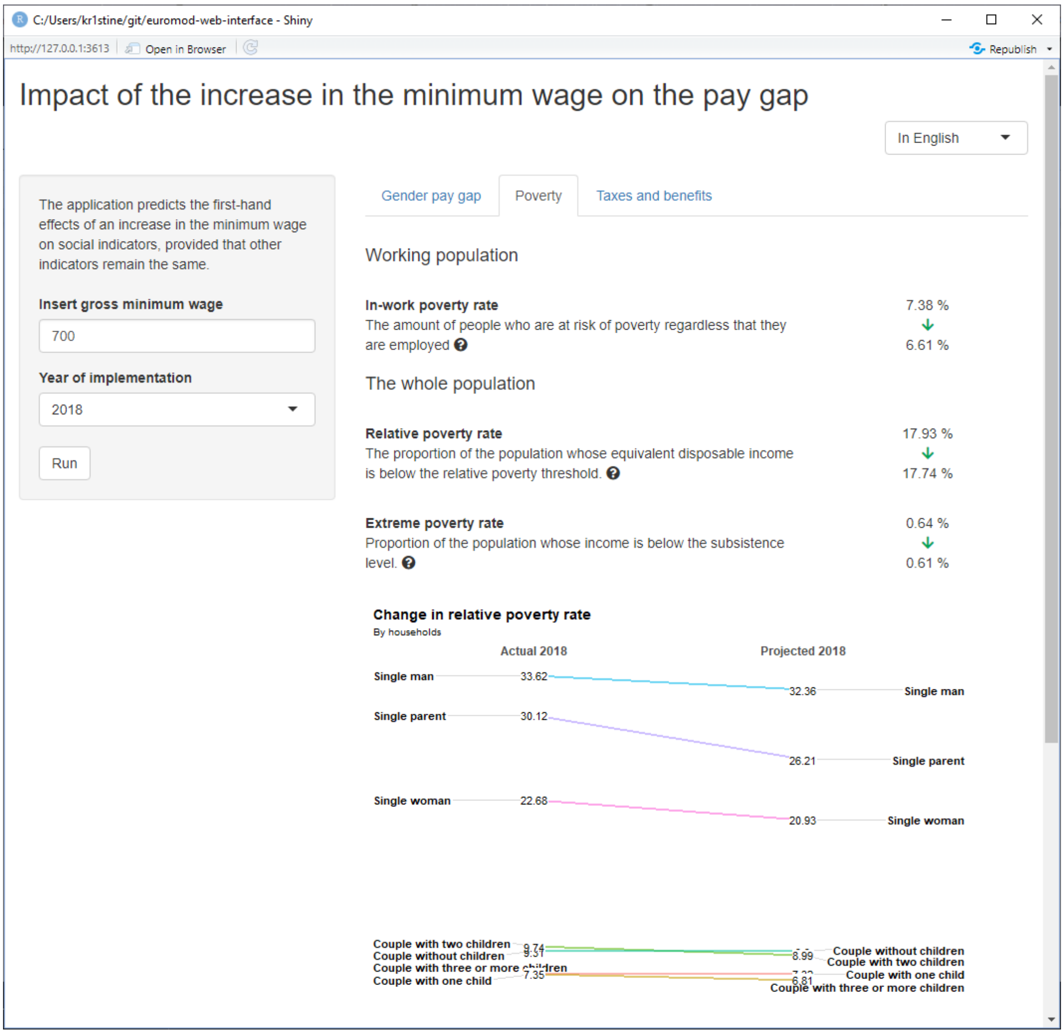


Figure 19. View of the EUROMOD web interface: the poverty tab

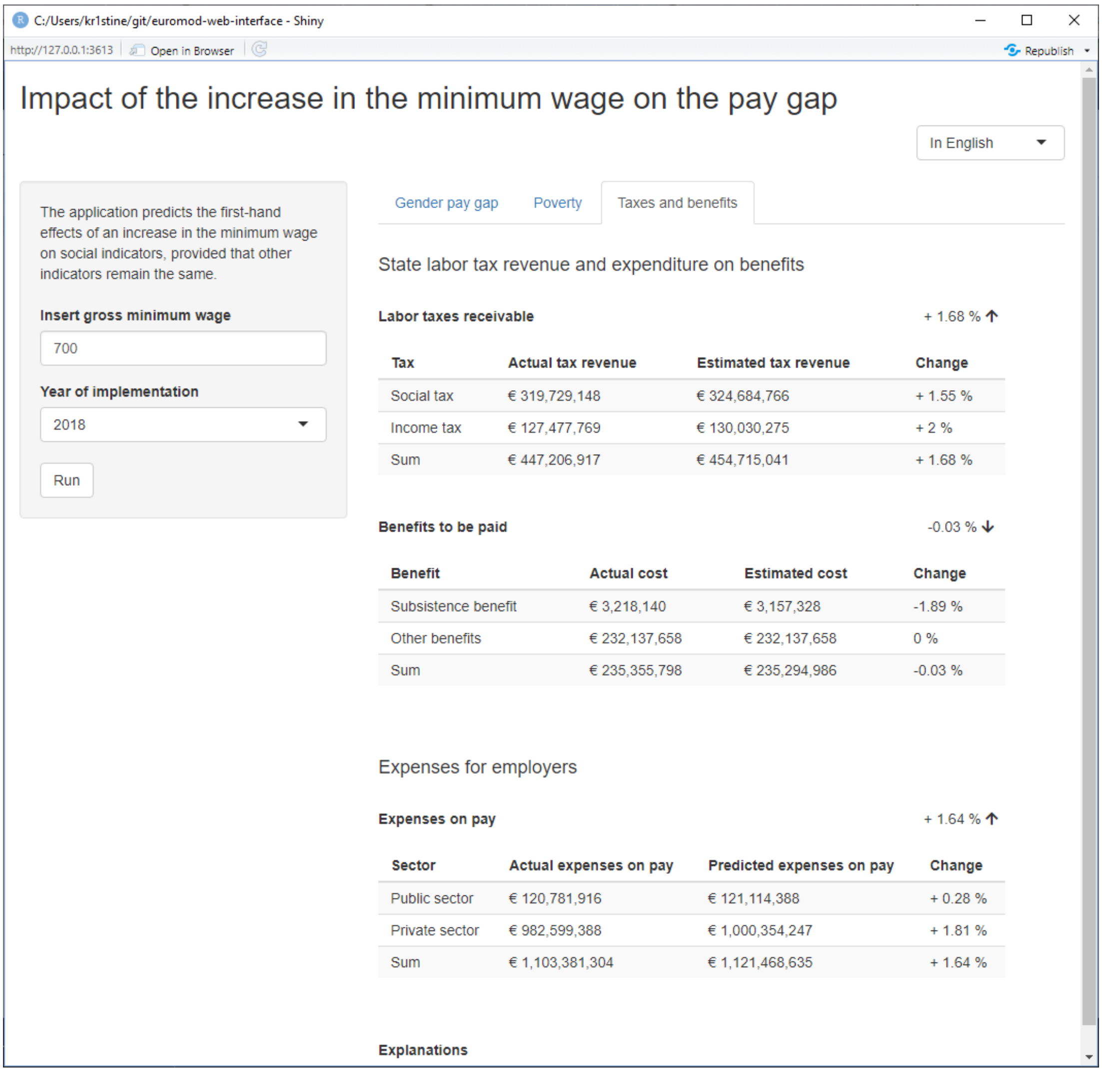


Figure 20. View of the EUROMOD web interface: the taxes and benefits tab

5.3 User feedback

In order to collect feedback for the EUROMOD web interface, a presentation of the application to representatives of target groups was held. The presentation was held on the 4th of May 2021 and had 10 participants, including representatives from five Estonian trade unions and the Estonian Trade Union Confederation. The goal of the presentation was to gather feedback on the existing solution and find out what other features the target users would be interested in.

The presentation turned out to be a success, as the participants were very involved, and the overall feedback was positive. The representatives of the trade unions recognized that when a new minimum wage level is considered, there is currently no way to assess the possible social impact of the policy change. Assessments on the state's expenses and proceeds can be requested from the Ministry of Finance. However, the impact on poverty or the gender pay gap is not measured. Therefore, the trade unions were interested in having such a tool at hand to use as a basis of arguments during discussions on the minimum wage level.

As a result of the session, several valuable specific feedback points were also given. Firstly, the participants agreed that the application should present the formulae for the social indicators and the nature of the underlying data more prominently. Secondly, it would interest the users to see the gender pay gap and other measures in the context of sectors or qualifications. This could provide a more detailed overview of who is most impacted by the change.

The user feedback gathered from the presentation session gives significant input in the further development of the application. The recommended fixes can be implemented to the web interface immediately, and once the application is live, it will be sent to the participants for another round of feedback. What is more, some trade unions are interested in linking the application on their website, and this opportunity will be provided for them once the application is live. It is reassuring to see that there is interest in the application, and similar discussions should be held when adding functionality for additional policy measures to the system.

5.4 Next development steps

The EUROMOD web interface developed within this thesis provides the first version of an openly accessible, user-friendly microsimulation solution for Estonia. As seen from the user feedback, the application is already valuable to target groups. The next step in the development process is setting up the application on the Statistics Estonia website. For that purpose, discussions are currently ongoing with the Information Technology Center of the Ministry of Finance (RMIT), who will provide the servers. The application is expected to be available to the public by the end of 2021.

It is important to note that the application provides a basis for many future additions. The code can be extended to accommodate other policy measure changes, in addition to the minimum wage, or to show more output values. What is more, the application could be used as a base for developing detached EUROMOD web interfaces geared explicitly to other tax or benefit areas. The author is hopeful that the system will prove useful and help make the policymaking process in Estonia more argument-based.

6 Analysis of the effects of increasing the minimum wage in Estonia

The web application introduced in Chapter 5 allows the public to run microsimulations on minimum wage changes. To work out the application, it is vital to know the trends in the effects of a minimum wage increase. This chapter aims to analyze the effects of raising the minimum wage in Estonia on the gender pay gap and selected social indices. Using the reference minimum wage values proposed by the European Commission and the methods introduced in Chapter 4, the hypothetical scenarios are simulated. Unlike the web application, the simulations here use the whole dataset described in Chapter 3.1, representing the entire population of Estonia, instead of a sample.

Chapter 6.1 describes the process of selecting the hypothetical minimum wage values to be further analyzed for the years 2018 and 2019. Chapter 6.2 presents the results of applying the minimum wage modifications on the data per the method described in Chapter 4.1. Chapter 6.3 presents results of the simulations by showing the predicted values of social indicators. The formulae for the indicators were described in Chapter 4.3. Chapter 6.4 explores an additional set of scenarios for the year 2019. In those scenarios, the policy parameters for the minimum wage of the year before were also altered. Chapter 6.5 discusses the results of the simulations.

6.1 Selecting new levels for the minimum wage

As described in Chapter 2.1.3, the European Commission recommends 60% of the median wage and 50% of the average wage as reference values for setting the minimum wage. In contrast, currently, the Estonian minimum wage corresponds to only 41.07% of the average salary or 46.9% of the median wage. Considering these proposals, the author has chosen to evaluate the impacts of bringing the national minimum wage in Estonia to the levels presented in Table 6 for the year 2018 and to the levels shown in

Table 7 for 2019. The new values represented in the tables are based on the average and median wage values of 2018 and 2019.

Table 6. Minimum wage levels to be simulated in the hypothetical scenarios for 2018

Nr	Reference condition	New monthly min. wage	New hourly min. wage	Change to min. wage
1	45% of the average wage	589.50€	3.50€	+ 17.9%
2	50% of the average wage	655.00€	3.90€	+ 31.0%
3	55% of the average wage	720.50€	4.23€	+ 44.1%
4	55% of the median wage	551.10€	3.28€	+ 10.2%
5	60% of the median wage	601.20€	3.58€	+ 20.2%
6	65% of the median wage	651.30€	3.88€	+ 30.3%

Table 7. Minimum wage levels to be simulated in the hypothetical scenarios for 2019

Nr	Reference condition	New monthly min. wage	New hourly min. wage	Change to min. wage
1	45% of the average wage	633.15€	3.77€	+ 17.25%
2	50% of the average wage	703.50€	4.19€	+ 30.28%
3	55% of the average wage	773.85€	4.61€	+ 43.31%
4	55% of the median wage	605.00€	3.60€	+ 12.04%
5	60% of the median wage	660.00€	3.93€	+ 22.22%
6	65% of the median wage	715.00€	4.26€	+ 32.41%

6.2 Identifying minimum wage earners

Before running tax-benefit simulations in EUROMOD and analyzing the results, input datasets were created for each hypothetical scenario. In this thesis, the author created six hypothetical scenarios for both 2018 and 2019. For each scenario, eligible minimum wage earners were filtered from full-time employees and their wage values modified in respect to the scenario at hand, as described in more detail in Chapter 4.1. The initial 2018 EUROMOD input data set consisted of 1324820 rows and 152 variables, out of which 598027 were full-time employees. The number of individuals affected by the minimum wage change in each scenario is presented in Table 8.

Table 8. Individuals affected in the hypothetical scenarios for 2018

Nr	Reference condition	New monthly min. wage	Individuals affected
1	45% of the average wage	589.50€	84556
2	50% of the average wage	655.00€	108948
3	55% of the average wage	720.50€	133061
4	55% of the median wage	551.10€	69316
5	60% of the median wage	601.20€	88993
6	65% of the median wage	651.30€	107681

The initial 2019 EUROMOD input data set consisted of 1328976 rows and 155 variables, out of which 689904 were full-time employees. The number of individuals affected by the minimum wage change in each scenario is presented in Table 9.

Table 9. Individuals affected in the hypothetical scenarios for 2019

Nr	Reference condition	New monthly min. wage	Individuals affected
1	45% of the average wage	633.15€	102457
2	50% of the average wage	703.50€	131108
3	55% of the average wage	773.85€	158975
4	55% of the median wage	605.00€	90183
5	60% of the median wage	660.00€	113284
6	65% of the median wage	715.00€	135748

These modified files were then used to run microsimulations in EUROMOD as described in Chapter 4.2. The output files from EUROMOD are used for the calculations in Chapter 6.3.

6.3 Measuring social indicators from the EUROMOD output data

This chapter presents the results of measuring the indicators described in Chapter 4.3 from the EUROMOD output data. For each indicator, a trend graph and a description of the results are included.

6.3.1 Gender pay gap

Figure 21 and Figure 22 show the predicted change in the gender gay gap as the minimum wage increases. It is clear from the visuals that the gender pay gap is negatively correlated to the minimum wage, meaning that when the minimum wage increases, the gender pay gap decreases. The scenario with the highest minimum wage in both cases was Scenario 3 (minimum wage tied to 55% of the average wage). In that scenario, the gender pay gap showed a decrease of 3.35% in 2018 and 4.29% in 2019. This confirms the hypothesis that women are more likely to gain from the rise of the minimum wage, since occupations where the minimum wage is paid are dominated by women.

Figure 21. The predicted change in the gender pay gap in the 2018 hypothetical scenarios as the minimum wage increases

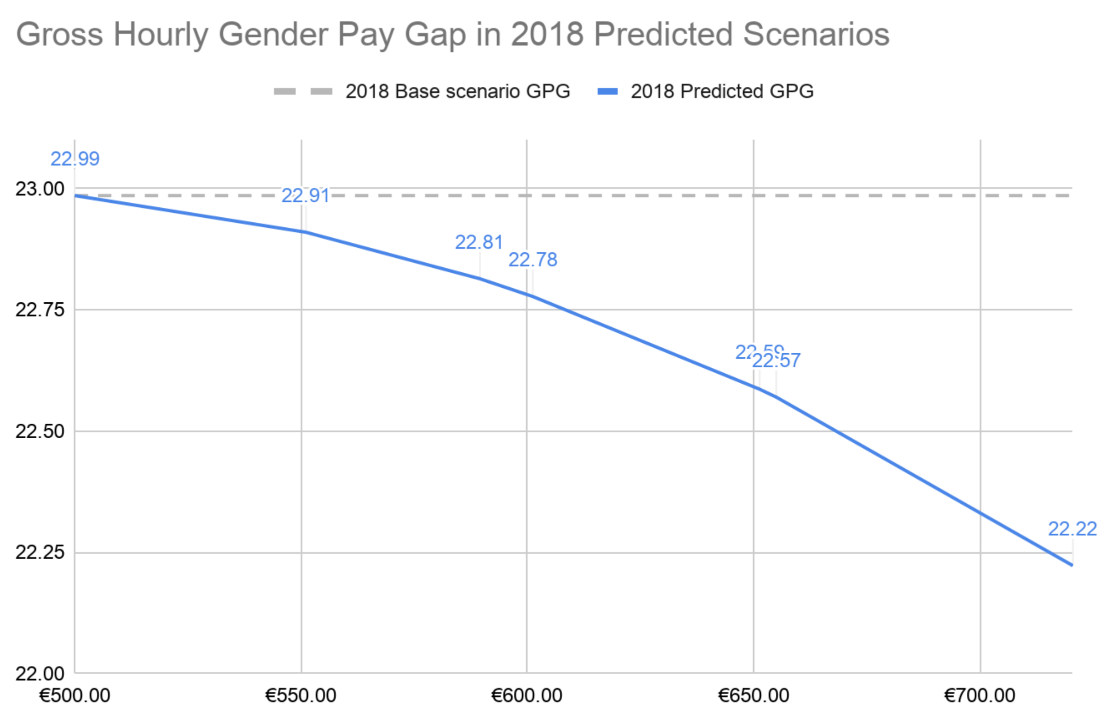
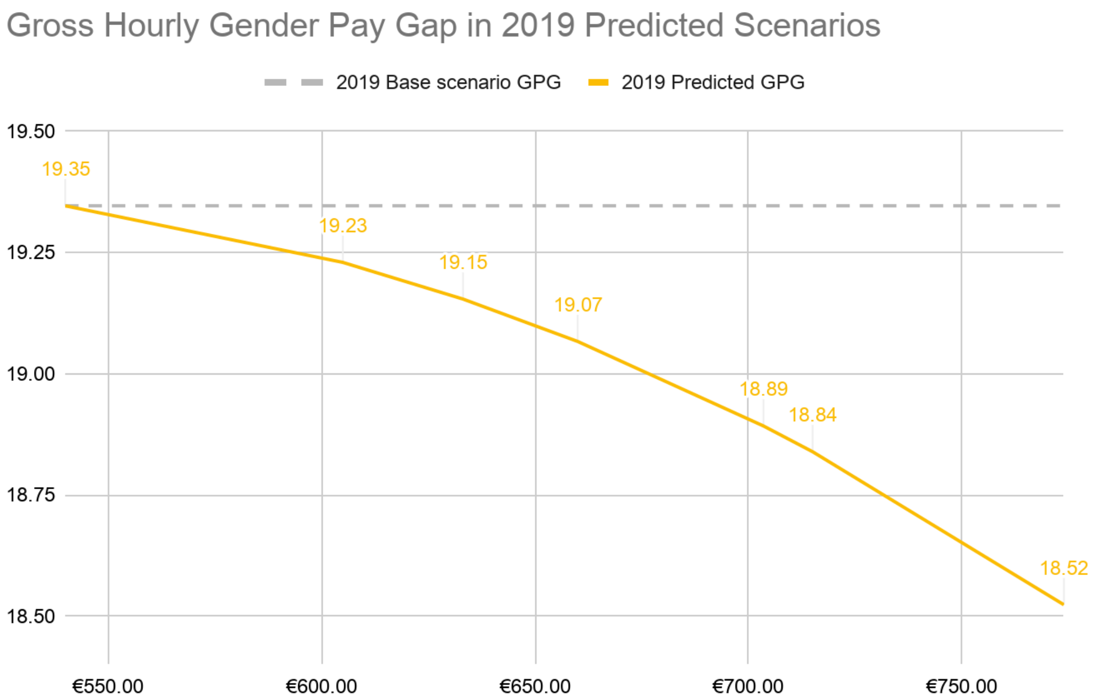


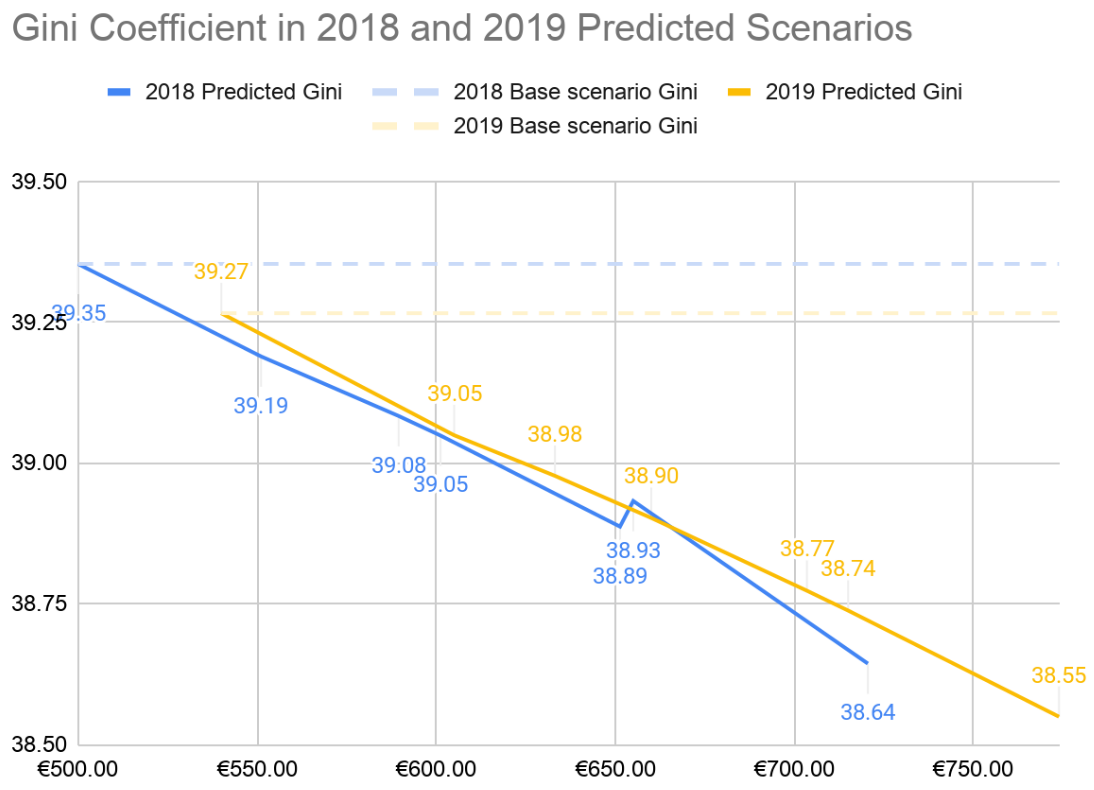
Figure 22. The predicted change in the gender pay gap in the 2018 hypothetical scenarios as the minimum wage increases



6.3.2 Gini coefficient

Figure 23 shows a linear decrease in the Gini coefficient as the minimum wage increases in both the 2018 and 2019 scenarios. As seen from Figure 23, the results are very similar for both years, and even a small increase in the minimum wage provides a noticeable impact to the measure.

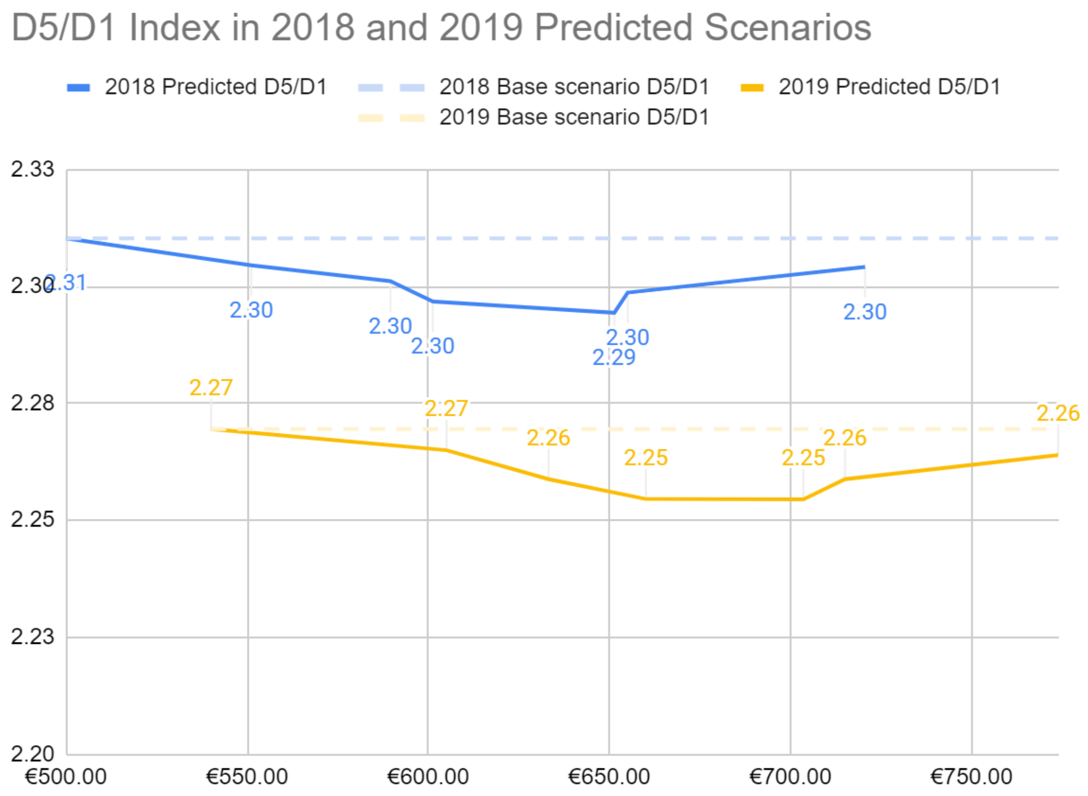
Figure 23. The predicted change in the Gini coefficient in the 2018 and 2019 hypothetical scenarios as the minimum wage increases



6.3.3 D5/D1 Index

Figure 24 shows the change in the D5/D1 index in both the 2018 and 2019 scenarios. It is interesting to observe that even though a small rise in the minimum wage lowers the index, a more substantial increase starts to bring it back up. This can be expected, as the minimum wage gets closer to the median wage. It is important to keep in mind here that this simulation only looked at the "overnight" effects on the policy change. It has been shown in previous research [49] that raising the level of the minimum wage has notable spillover effects, which can reach up to the median wage level. This means that when the minimum wage level rises, the wages of those slightly above the minimum wage level also rise.

Figure 24. The predicted change in the D5/D1 index in the 2018 and 2019 hypothetical scenarios as the minimum wage increases



6.3.4 At-risk-of-poverty rate

Figure 25 and Figure 26 show the predicted change in the at-risk-of-poverty threshold and the at-risk-of-poverty rate as the minimum wage increases. It can be observed that even though a small increase in the minimum wage can bring the poverty rate down, it soon stabilizes and stays on the same level. This is likely because even though there are households with minimum-wage earners that are getting out of poverty, the increase in the minimum wage likely does not have the same effect on pensioners. In Estonia, the average national old-age pension is very close to the at-risk-of-poverty threshold. Therefore, it must be considered that as the poverty threshold goes up, more pensioners might be falling under that threshold.

Figure 25. The predicted change in the at-risk-of-poverty rate and threshold in the 2018 hypothetical scenarios as the minimum wage increases

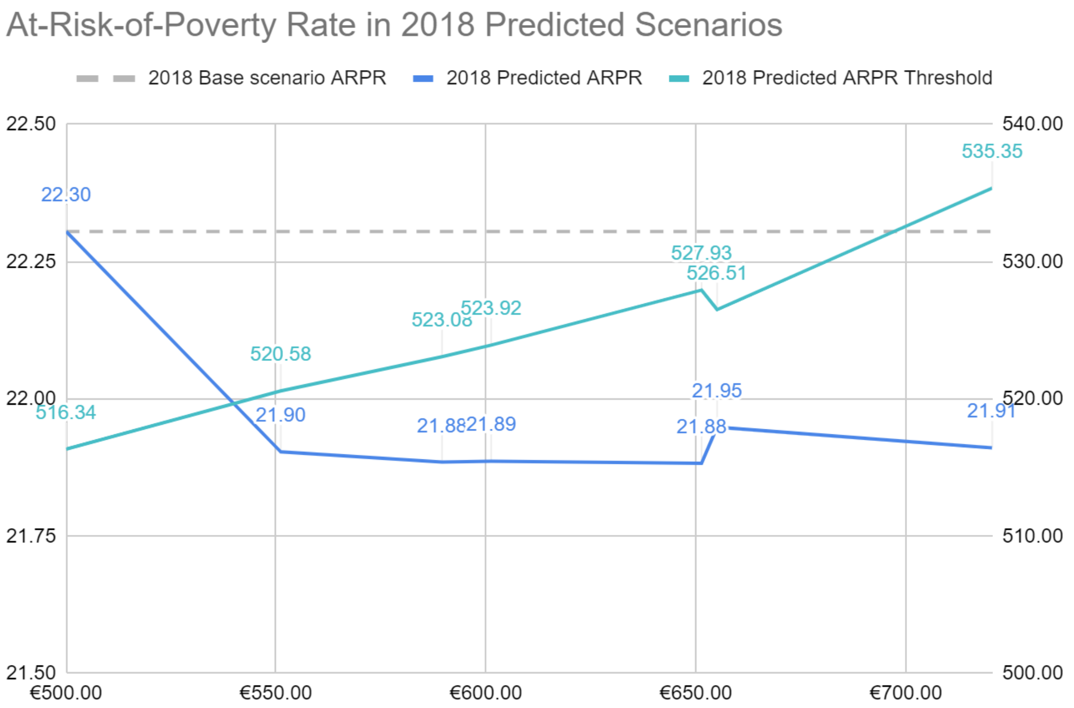
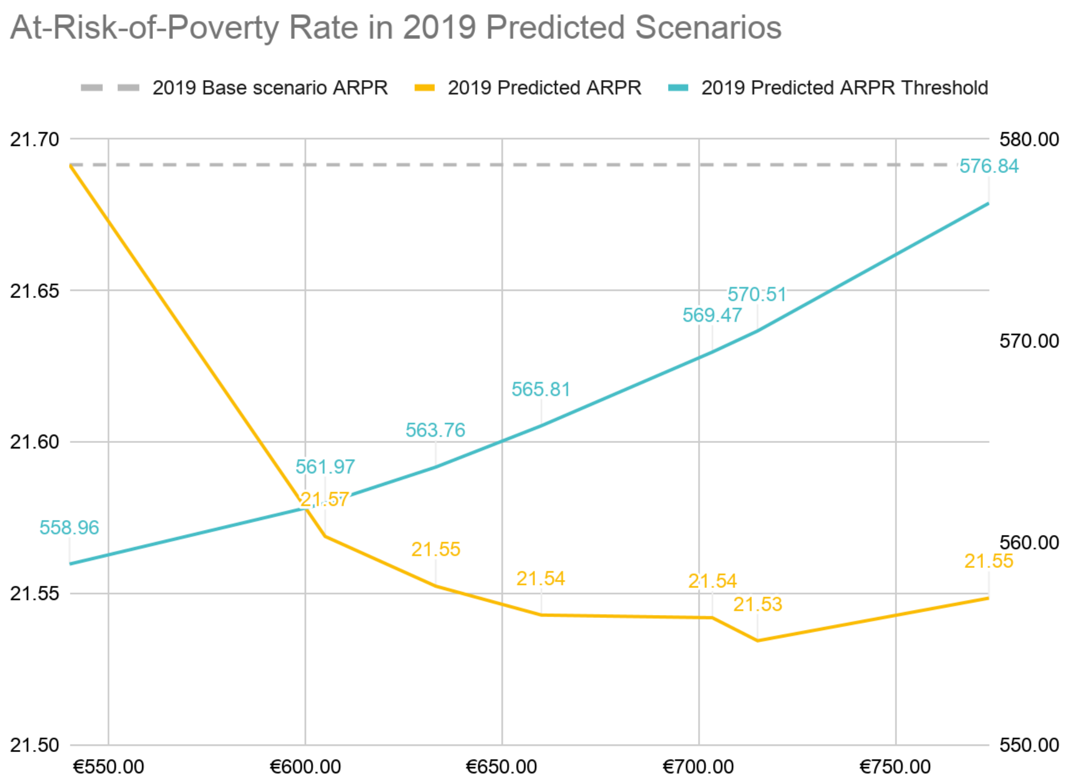


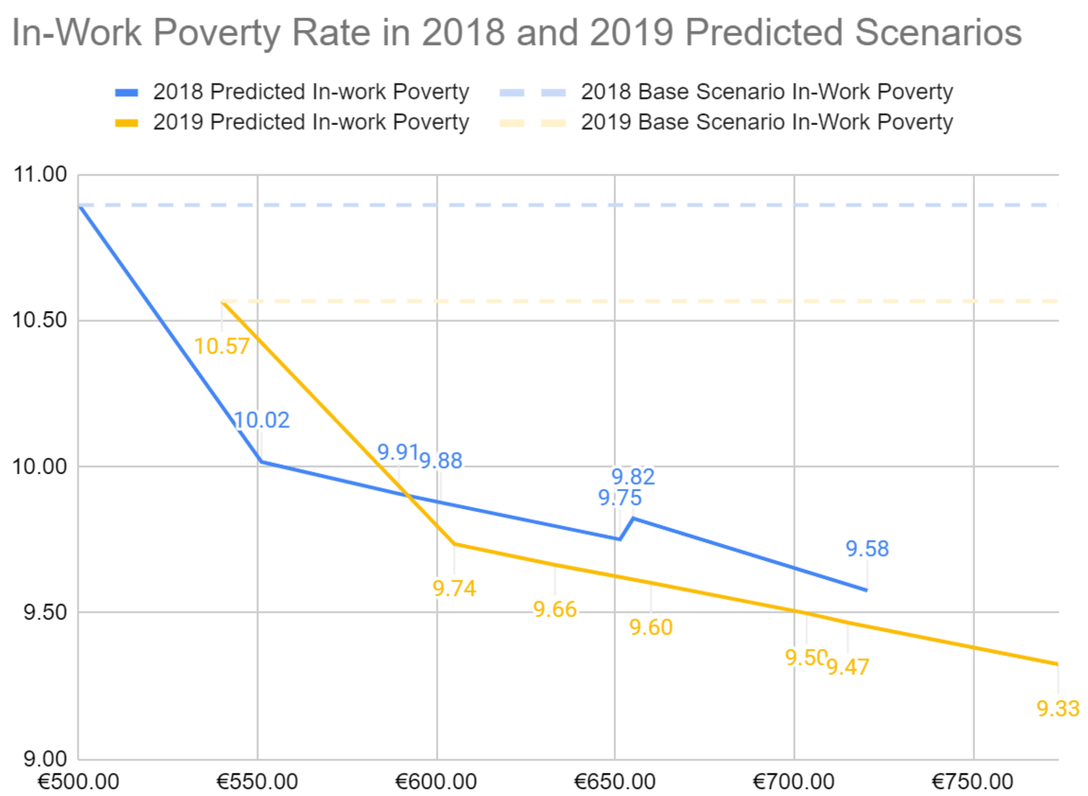
Figure 26. The predicted change in the at-risk-of-poverty rate and threshold in the 2019 hypothetical scenarios as the minimum wage increases



6.3.5 In-work poverty

Figure 27 shows the predicted change in the in-work poverty rate as the minimum wage increases in both the 2018 and 2019 scenarios. As the at-risk-of-poverty rate takes into account the entire population, including pensioners and unemployed individuals, the in-work poverty rate is a better indicator on the direct beneficiaries of the minimum wage increase. In Estonia, there is still a large portion of people whose income falls under the poverty line, regardless that they are employed. Figure 27 shows that we can predict an up to 12.9% decrease in the 2018 scenarios and 11.7% decrease in the 2019 scenarios for the in-work poverty rate when raising the minimum wage. Further research should be done on how this could affect individuals' work incentives.

Figure 27. The predicted change in the in-work poverty rate in the 2018 and 2019 hypothetical scenarios as the minimum wage increases



6.3.4 Extreme poverty

Figure 28 and Figure 29 show the change in the extreme poverty rate when the minimum wage increases in the 2018 and 2019 scenarios. The extreme poverty line is calculated and set for each year and therefore does not change dynamically when the minimum wage changes. The extreme poverty rate in Estonia is considered to be rather low, thanks to already existing minimum wage levels and subsistence benefits. However, as seen from the figures, an increase in the minimum wage could help further lower the level by up to 1.5% in the 2018 scenarios and up to 1.08% in the 2019 scenarios.

Figure 28. The predicted change in the extreme poverty rate in the 2018 hypothetical scenarios as the minimum wage increases

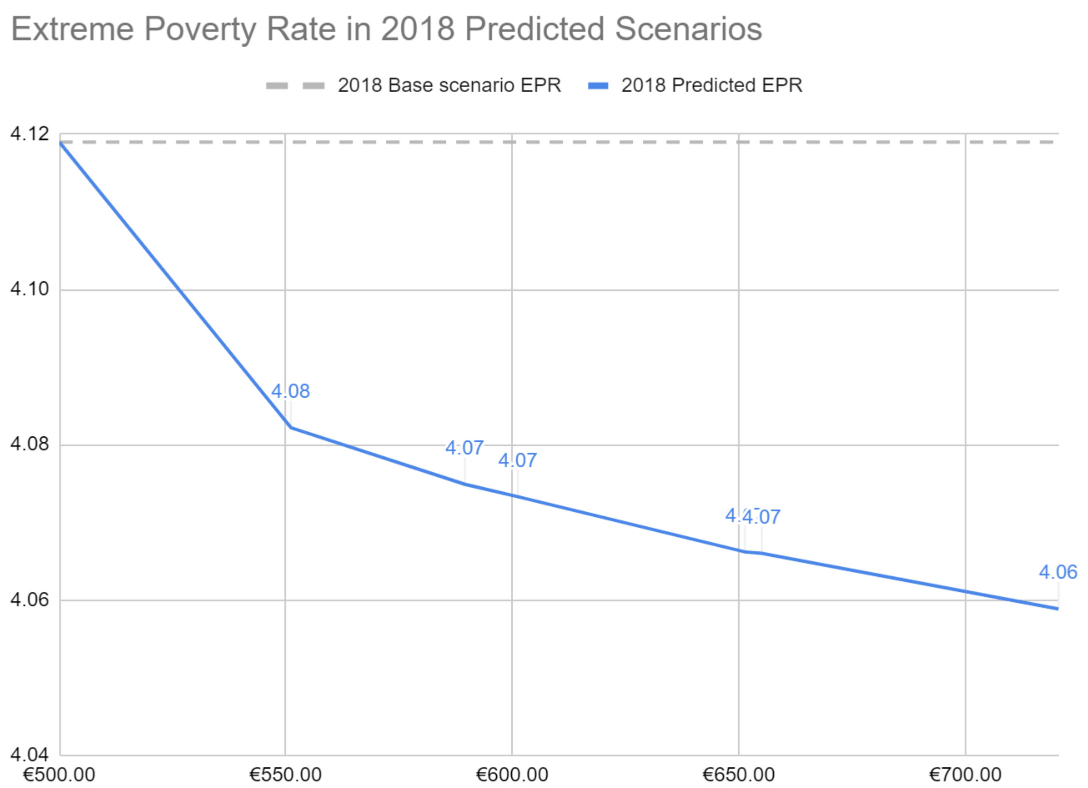
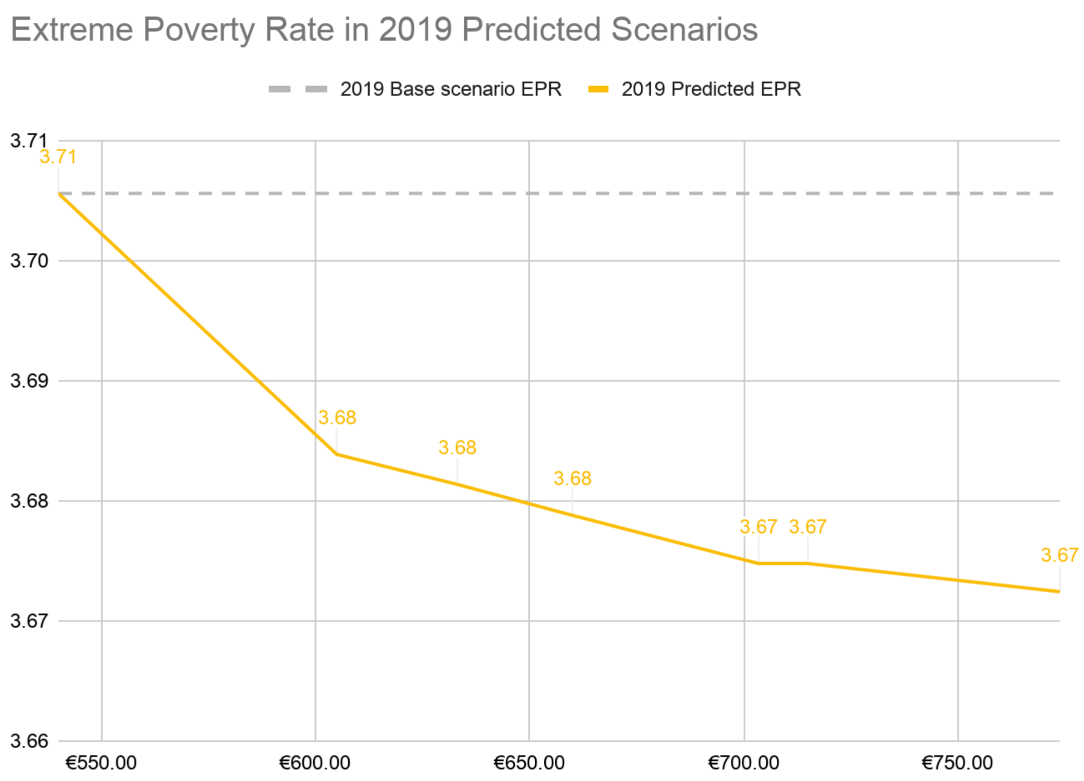


Figure 29. The predicted change in the extreme poverty rate and threshold in the 2019 hypothetical scenarios as the minimum wage increases



6.4 Results in an expanded time frame

Some benefits and thresholds in the Estonian policy system are tied to the minimum wage level of the previous year. For that reason, the author also explored the scenarios for 2019, where in addition to modifying the policies tied to the minimum wage, policies tied to the minimum wage of the previous year were also modified. As seen from the figures below, the results are rather similar with the base scenario. The poverty rates, however, are somewhat higher, which is most possibly due to higher thresholds resulting from this change.

Figure 30. The predicted change in the Gini coefficient in the 2019 hypothetical scenarios as the minimum wage increases

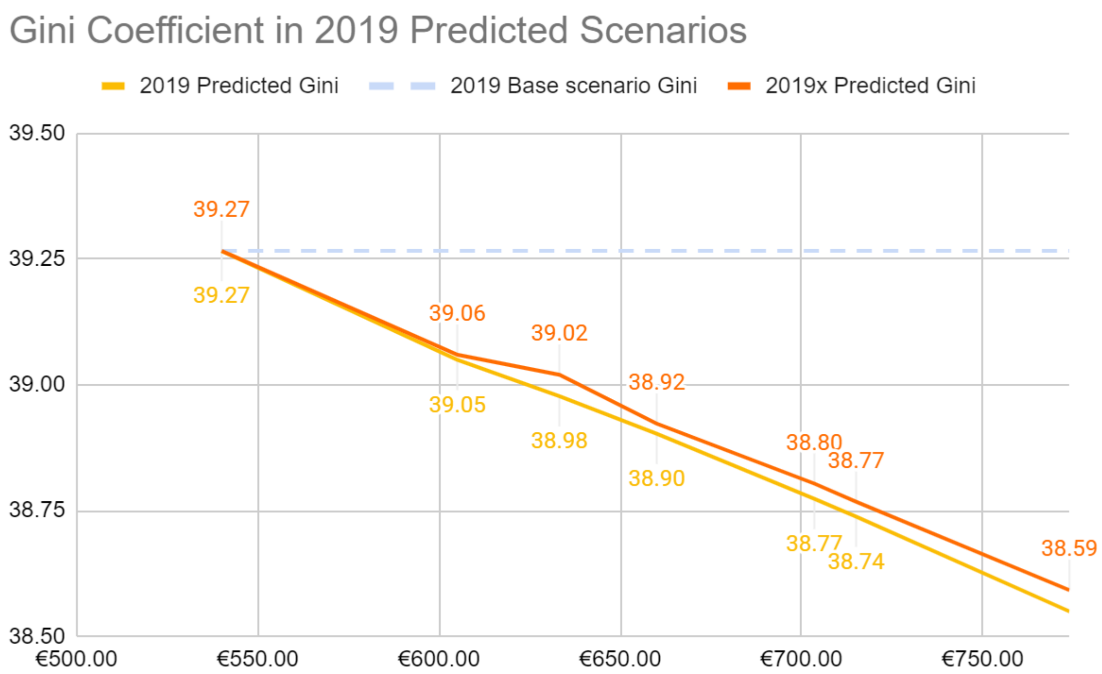


Figure 31. The predicted change in the D5/D1 index in the 2019 hypothetical scenarios as the minimum wage increases

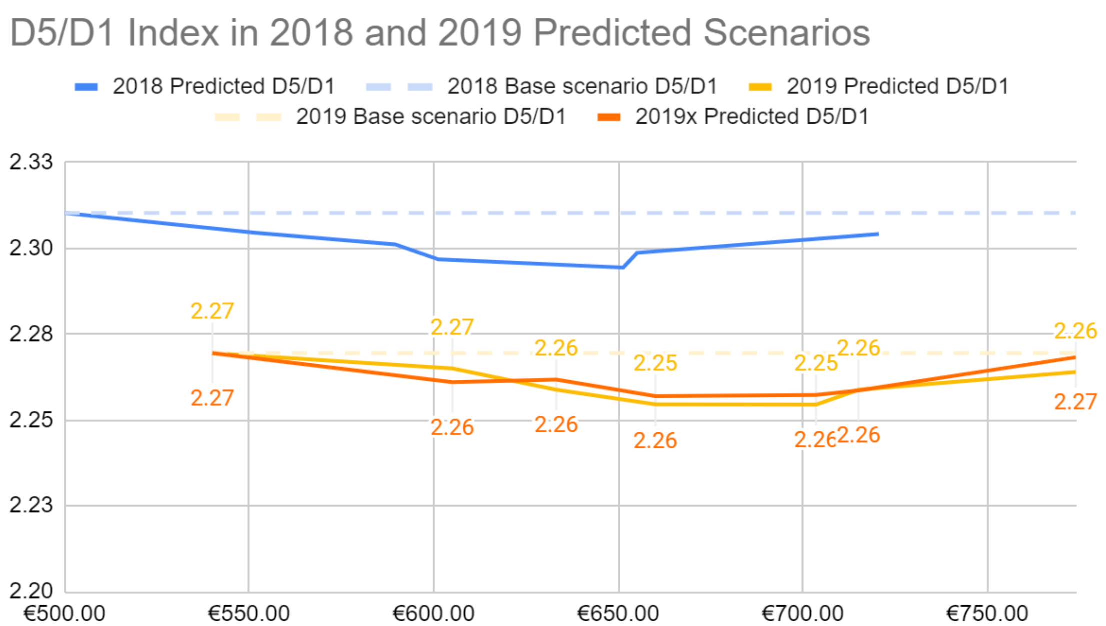


Figure 32. The predicted change in the at-risk-of-poverty rate and threshold in the 2019 hypothetical scenarios as the minimum wage increases

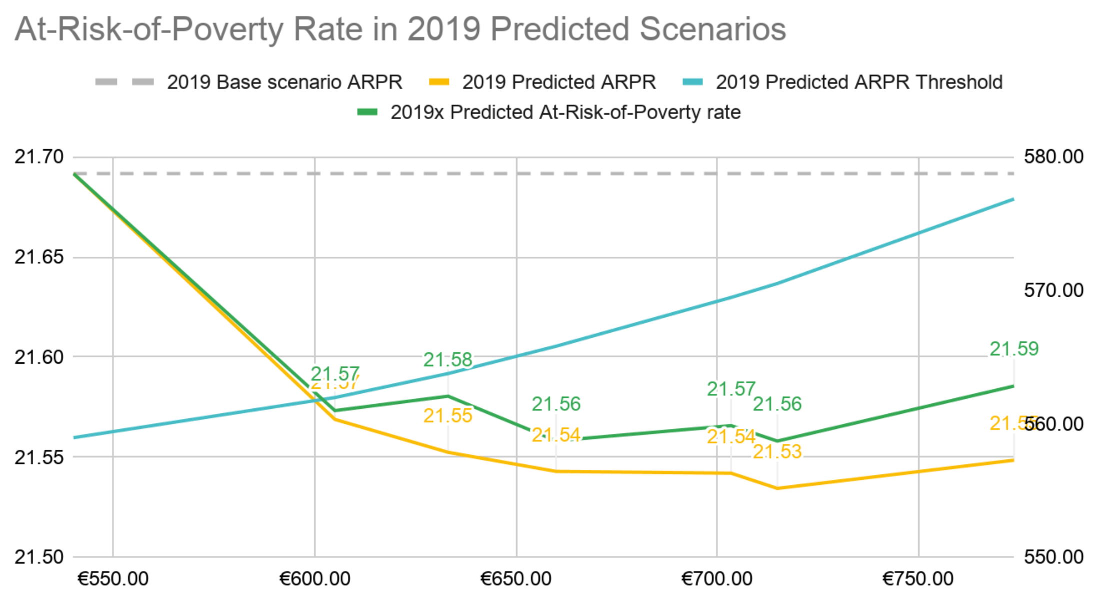


Figure 33. The predicted change in the in-work poverty rate and threshold in the 2018 and 2019 hypothetical scenarios as the minimum wage increases

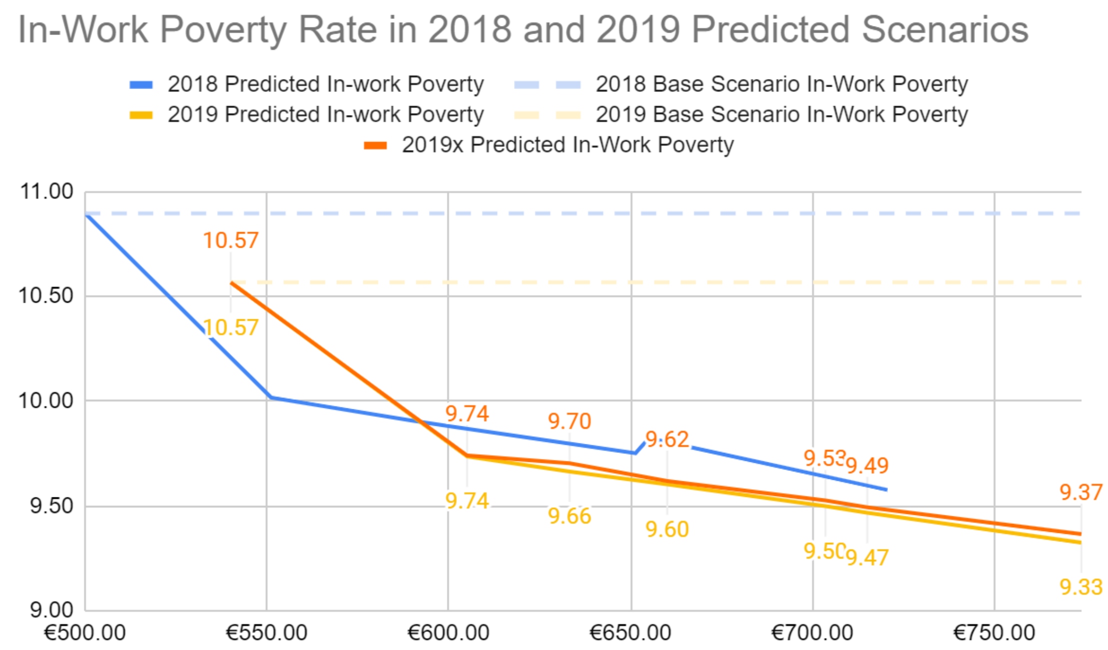
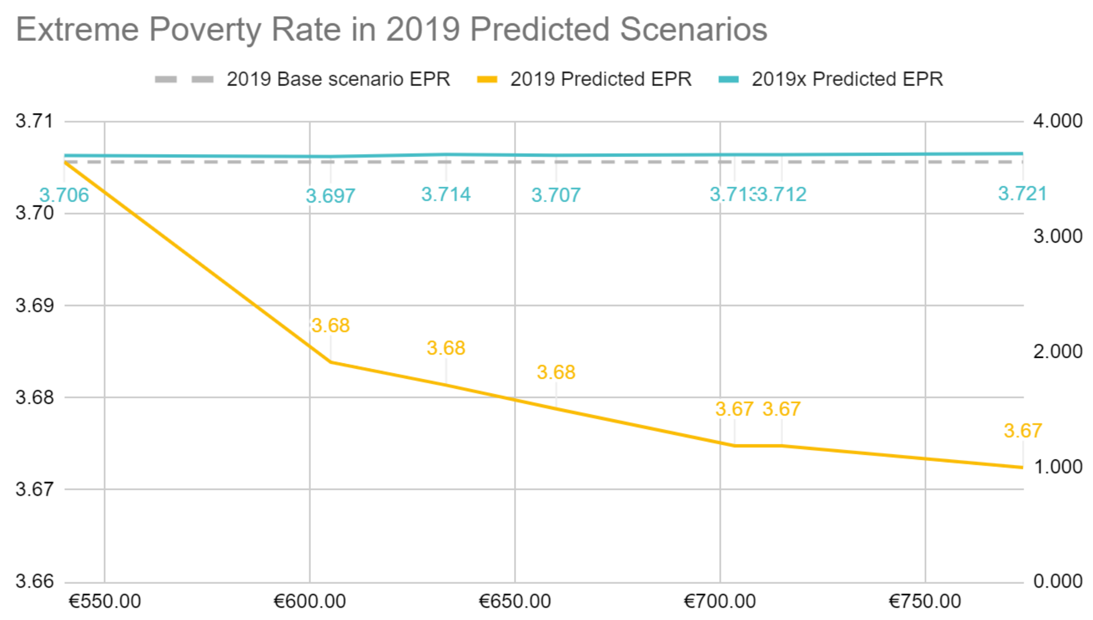


Figure 34. The predicted change in the extreme poverty rate and threshold in the 2019 hypothetical scenarios as the minimum wage increases



6.5 Discussion

One of the goals of this thesis was to evaluate how the gender pay gap might change in reaction to the change in the minimum wage. After defining scenarios for 2018 and 2019 with new minimum wage levels, simulations were run with EUROMOD and the resulting data observed. As seen from the results, the gender pay gap decreases as the minimum wage increases. This confirms the hypothesis that women are more likely to be occupying positions where the minimum wage is paid and are therefore more subjective to the changes in the value. Even though the value of the change (~0.7 percentage points) could seem minor, for the last four years, the average rate of decrease in the gender pay gap has been 1.1 percentage points in a year [2]. Considering this trend, the drop seen from the policy change can be considered significant.

The increase in the minimum wage also shows direct benefits to reduce the extreme and at-risk-at-poverty rates. A very significant decrease could be seen in the in-work poverty rate, which saw an up to 12.9% decrease in one scenario. All in all, it can be said that even though the rise in the minimum wage might result in some individuals no longer being eligible for certain benefits, the gains from the wages outweigh the losses from the benefits.

EUROMOD is a static microsimulation tool that only allows to observe the "overnight" effects on reforms and does not simulate behavioral effects. Therefore, the results from these simulations must be taken with caution, and further research must be done on the spillover effects and behavioral responses. What is more, it is essential to keep in mind other social groups, such as pensioners, whose pension is currently very close to the relative poverty threshold and who might be suspect of falling into poverty once that threshold rises.

In Chapter 6.4, the author also explored scenarios with a modified value for the previous year's minimum wage. Even though the results were not drastic, it is crucial to keep in mind that EUROMOD is only intended for static simulations and cannot show dynamic effects over a period of time. It can be expected that in reality, a high raise in the minimum wage would result in changes in the work distribution in the first year, which would influence the indices calculated here in a far greater manner than the change in benefits tied to the previous year's minimum wage value would.

7 Summary

Within this thesis, a web interface was built, which uses the EUROMOD engine to allow users to run microsimulations on hypothetical policy changes. This allows the wider public to access the possibilities offered by the tool without needing onboarding to the complete EUROMOD toolkit or access to confidential data. The web interface proved to be a good starting point for bringing the EUROMOD microsimulation tool closer to the public in Estonia. In addition, the tool presents a method of how a closed Windows software component can be used within a public web application. The EUROMOD web interface allows users to select a year and a minimum wage level and presents the predicted change in the gender pay gap, poverty measures, and taxes and benefits. As seen from the user feedback, this tool is very appreciated and should be extended in the future to allow for more policy changes. Work on the web interface continues, and the application is estimated to be publicly available by the end of 2021.

Another interest of this thesis was to examine whether raising the minimum wage could positively influence the gender pay gap. In order to do so, alternative scenarios were simulated with the EUROMOD microsimulation model, and the resulting data were analyzed. However, hourly wage values are necessary for the gender pay gap calculations. As the EUROMOD input data contains only imputed values of the hourly wages, before moving on to the simulations, the author analyzed and compared three options, the decision tree, linear regression, and the original imputation, for predicting the hourly wage based on the data. The analysis confirmed the validity of the imputed hourly wages in the original EUROMOD input dataset, as this proved to be the most accurate option of the three.

For the analysis of the impacts of a minimum wage increase in Estonia, six new potential minimum wage levels were simulated for both 2018 and 2019, two of the latest datasets. The levels were chosen based on recommended reference values proposed by the European Commission. As seen from the results, even a small change in the minimum wage already has a positive impact on lowering the gender pay gap and poverty measures in Estonia. The results of the analysis also allow us to answer the research questions raised in the beginning of this thesis.

1. Would raising the national minimum wage potentially help reduce the gender pay gap in Estonia?

   The results show an association between the gender pay gap and the minimum wage in Estonia: the higher the minimum wage, the lower the gender pay gap.

2. What effect would raising the minimum wage in Estonia have on poverty?

   A notable decrease can also be seen in poverty and inequality indices, most prominently in the in-work poverty rate.

3. Is it possible to create a software solution, which would allow using EUROMOD and its accompanying instruments via a public web interface so that the user could perform analysis of the impact of policy reforms without direct access to static data?

   Creating such a solution is possible and the architecture is described in this thesis. The application created in this thesis serves as a proof of concept for future EUROMOD web interfaces.

In conclusion, it can be seen from the results of the analysis in this thesis that an adequate level of the minimum wage is an essential contributor to lowering the gender pay gap as well as poverty and inequality. This might refer to the segregation of women to more low-earning positions, but the exact reasons behind the effect should be investigated in more detail. It is, however, also important to note that this research did not look into other effects, such as a decrease in employment levels, that such reforms might have. What is more, as seen from the user feedback to the web interface built within the thesis, there is a need for open access to microsimulation models in Estonia, and the web application was very well received. We hope that the tool and its further developments will help shape evidence-based policymaking in the future, leading to changes in Estonian social order aimed at greater social justice.

References

[1] "PA5335: Gender pay gap by economic activity (EMTAK 2008), October", Andmebaas.stat.ee, 2021. [Online]. Available: http://andmebaas.stat.ee/Index.aspx?DataSetCode=PA5335. [Accessed: 07- May- 2021].

[2] "Gender pay gap in unadjusted form - Products Datasets - Eurostat", Ec.europa.eu, 2021. [Online]. Available: https://ec.europa.eu/eurostat/web/products-datasets/product?code=tesem180. [Accessed: 07- May- 2021].

[3] "Reducing the gender wage gap", Rege.tlu.ee, 2021. [Online]. Available: http://rege.tlu.ee/projekti-tutvustus/. [Accessed: 07- May- 2021].

[4] "Press corner", European Commission - European Commission, 2021. [Online]. Available: https://ec.europa.eu/commission/presscorner/detail/en/mex_20_56. [Accessed: 07- May- 2021].

[5] Sutherland, H. and F. Figari. EUROMOD: the European Union tax-benefit microsimulation model. International Journal of Microsimulation 6(1), 4–26, 2013

[6] "Structure of Earnings Survey - Access to microdata - Eurostat", Ec.europa.eu, 2021. [Online]. Available: https://ec.europa.eu/eurostat/web/microdata/structure-of-earnings-survey. [Accessed: 07- May- 2021].

[7] K. Täht, M. Unt, E. Kuldkepp, T. Roosalu, T. Lauri, M. Klesment, M. Rokicka ja S. Nõmm. Soolise palgalõhe kirjeldamine ja seletamine. Tallinn: RASI, 2019.

[8] S. Anspal, H. Biin, E. Kallaste, M. Karu ja L. Kraut, Sooline palgalõhe. Teoreetilise ja empiirilise kirjanduse ülevaade, Estonian Center for Applied Research CENTAR, Center for Policy Studies PRAXIS, Social Ministry, Tallinn, 2009.

[9] Gary Becker, Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education, University of Chicago Press, 1993.

[10] Blau, Francine D., and Lawrence M. Kahn. Swimming Upstream: Trends in the Gender Wage Differential in the 1980s. Journal of Labor Economics, vol. 15, no. 1, 1997.

[11] Becker, G. S. The economics of discrimination. Chicago: The University of Chicago Press, 1957/1971.

[12] Wharton, A. S. The sociology of gender: an introduction to theory and research. Malden, MA: Blackwell Publishing, 20dg05.

[13] Scott, R., & Meyer, J. W. Institutional environments and organizations: structural complexity and individualism. Thousand Oaks, CA: Sage, 1994.

[14] Rubery, G, Koukiadaki, A. Closing the gender pay gap: A review of the issues, policy mechanisms and international evidence, Geneva: International Labour Office, 2016.

[15] European Commission, “Report from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions on the implementation of the EU Action Plan 2017-2019 on tackling the gender pay gap” [Online]. Available: https://ec.europa.eu/info/sites/info/files/com-2020-101_en.pdf [Accessed: 07- May- 2021].

[16] European Commission. “Commission Recommendation of 7 March 2014 on strengthening the principle of equal pay between men and women through transparency” [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014H0124 [Accessed: 07- May- 2021].

[17] European Commission. “Initiative: Gender pay gap – transparency on pay for men and women“ [Online]. Available: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12098-Strengthening-the-principle-of-equal-pay-between-men-and-women-through-pay-transparency [Accessed: 07- May- 2021].

[18] S. Anspal, T. Rõõm, P. Turk, E. Kallaste, M. Karu ja L. Kraut, „Sooline palgalõhe Eestis. Poliitikameetmete analüüs“ Estonian Center for Applied Research CENTAR, Center for Policy Studies PRAXIS, Social Ministry, Tallinn, 2010.

[19] Action Plan of the government of Estonia 2015-2019 [Online]. Available: https://www.riigiteataja.ee/aktilisa/3030/6201/5006/231klisa.pdf [Accessed: 07- May- 2021].

[20] Action Plan of the government of Estonia 2019-2023 17.11.2020 [Online]. Available: https://www.valitsus.ee/sites/default/files/content-editors/valitsus/RataseIIvalitsus/vabariigi_valitsuse_tegevusprogramm_2019-2023_esitatud_300519.pdf [Accessed: 07- May- 2021].

[21] Starr, G. „Minimum wage fixing : an international review of practices and problems (2nd impression (with corrections) ed.)“ Geneva: International Labour Office, 1993.

[22] Eurofound, “Minimum wages in 2019: Annual review” Luxembourg: Publications Office of the European Union, 2019.

[23] Estonian Tax and Customs Board [Online]. Available: https://www.emta.ee/eng/business-client/income-expenses-supply-profit/income-tax-withheld/national-minimum-wage-rates [Accessed: 07- May- 2021].

[24] Estonian Tax and Customs Board [Online]. Available: https://www.emta.ee/eng/private-client/declaration-income/tax-rates [Accessed: 07- May- 2021].

[25] Statistics Estonia, Average wage in Estonia in 2019 [Online]. Available: https://www.stat.ee/et/avasta-statistikat/valdkonnad/tooelu/palk-ja-toojoukulu/keskmine-brutokuupalk [Accessed: 07- May- 2021].

[26] The European Commission, Directive of the european parliament and of the council on adequate minimum wages in the European Union [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020PC0682&from=EN [Accessed: 07- May- 2021].

[27] The Government of Estonia, The positions of the government to EU initiatives [Online]. Available: https://www.riigikogu.ee/tegevus/dokumendiregister/dokument/5dfd1f48-08d4-4f2d-b172-92096d9f21d8 [Accessed: 07- May- 2021].

[28] Institute of Social and Economic Research, University of Essex, Publications, [Online]. Available: https://www.euromod.ac.uk/publications [Accessed: 07- May- 2021].

[29] Praxis, Developing the Estonian country component of EUROMOD [Online]. Available: http://www.praxis.ee/tood/euromodi-mudeli-eesti-osamudeli-arendamine/mis-on-euromod/ [Accessed: 07- May- 2021].

[30] Fuchs, Michael, and Katrin Gasior. "Social Reform Microsimulation (SORESI). A web-based citizens' tool to model the social impact of taxes and benefits in Austria."

[31] Decancq K., Decoster A., Spiritus K., and G. Verbist (2012) 'MEFISTO: a new micro-simulation model for Flanders', FLEMOSI Discussion Paper 14.

[32] Joint Research Centre, EUROMOD-JRC Interface [Online]. Available: https://euromod-web.jrc.ec.europa.eu/euromod-jrc-interface [Accessed: 07- May- 2021].

[32] R [Online]. Available: https://www.r-project.org/ [Accessed: 07- May- 2021].

[34] RStudio [Online]. Available: https://rstudio.com/ [Accessed: 07- May- 2021].

[35] Angel-Urdinola "Can the Introduction of a Minimum Wage in FYR Macedonia Decrease the Gender Wage Gap?", 2008.

[36] Butcher, Tim. "Minimum Wages and Wage Inequality: Some Theory and an Application to the UK." Vol. 1, 2012.

[37] Aeberhardt, Romaine, Givord, Pauline, Marbot, Claire. "Spillover effect of the Minimum Wage in France: An UnconditionalQuantile Regression" Center for Research in Economics and Statistics, 2016.

[38] Atkinson, Anthony, et al. “Reducing Poverty and Inequality through Tax-Benefit Reform and the Minimum Wage: the UK as a Case-Study.” The Journal of Economic Inequality, vol. 15, no. 4, 2017, pp. 303–323.

[39] Ferraro, Simona, et al. “Minimum Wages and the Wage Distribution in Estonia.” Applied Economics, vol. 50, no. 49, 2018, pp. 5253–5268.

[40] Majchrowska, Aleksandra, and Paweł Strawiński. “Impact of Minimum Wage Increase on Gender Wage Gap: Case of Poland.” Economic Modelling, vol. 70, 2018, pp. 174–185.

[41] European Commission, Commission staff working document impact assessment Accompanying the document Proposal for a Directive of the European Parliament and of the Council on adequate minimum wages in the European Union SWD/2020/245 final, [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD:2020:245:FIN [Accessed: 07- May- 2021].

[42] Kuldkepp, Elina, “Soolise palgalõhe modelleerimine masinõppe meetoditega”, Tallinn, 2020

[43] C. C. Aggarwal, Neural Networks and Deep Learning, New York: Springer, 2018.

[44] Eurostat, The gender pay gap [Online]. Available: https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Gender_pay_gap [Accessed: 07- May- 2021].

[45] Statistics Estonia, Suhteline vaesus [Online]. Available: https://www.stat.ee/et/avasta-statistikat/valdkonnad/heaolu/sotsiaalne-torjutus-ja-vaesus/suhteline-vaesus [Accessed: 07- May- 2021].

[46] DOC. E2/IPSE/2003: The ‘Laeken’ Indicators : Detailed Calculation Methodology. Working Group on Statistics on Income, Poverty and Social Exclusion. 28-29 April 2003, Eurostat, Luxembourg.

[47] Statistics Estonia, Ametite kuupalgad [Online]. Available: https://ametipalk.stat.ee/ [Accessed: 07- May- 2021].

[48] Statistics Estonia, Tööpoliitika näitajad [Online]. Available: https://tooturg.stat.ee/ [Accessed: 07- May- 2021].

[49] Simona Ferraro, Jaanika Meriküll & Karsten Staehr “Minimum wages and the wage distribution in Estonia”, Applied Economics, 50:49, 5253-5268, 2018

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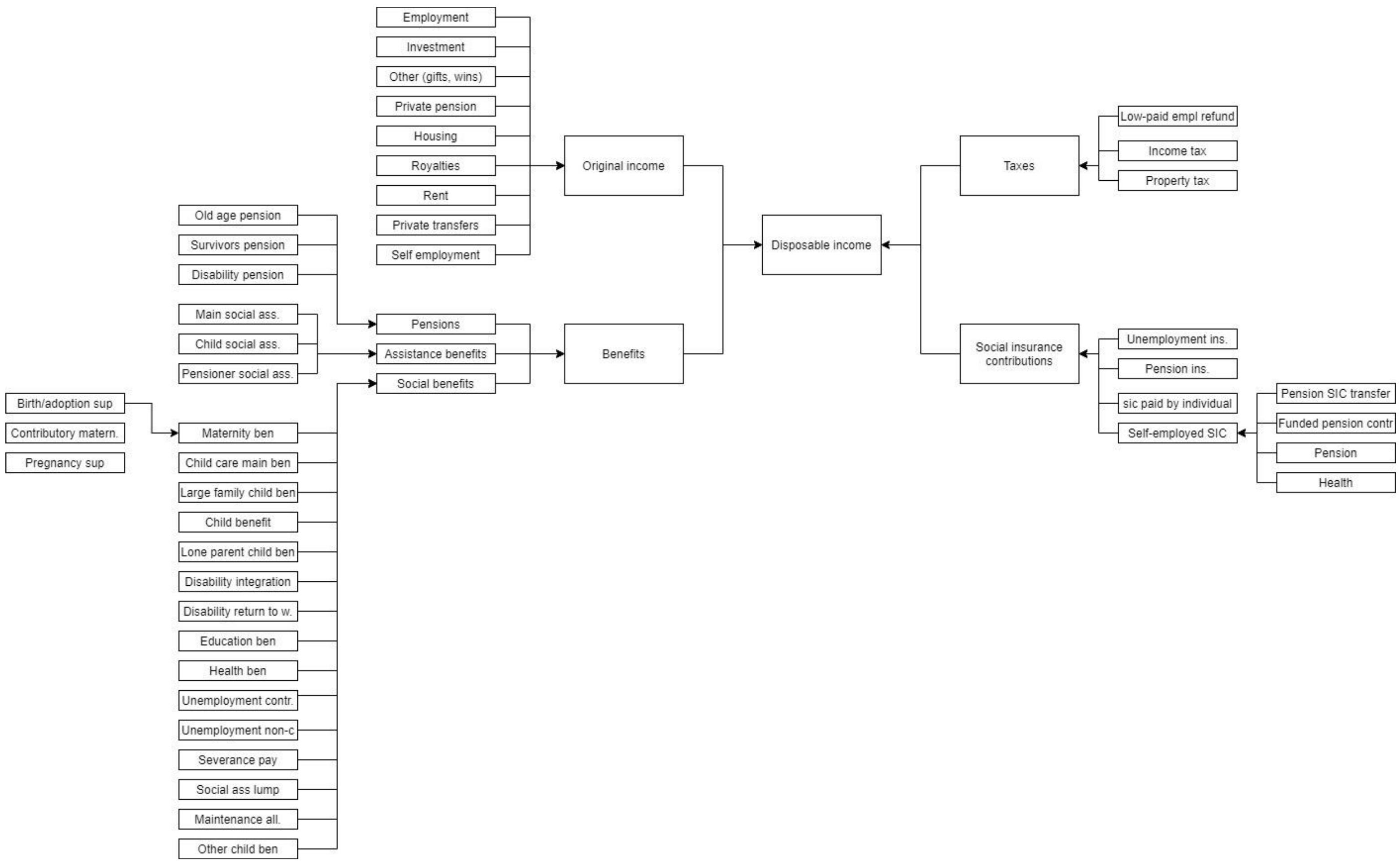
Appendix 2 – Calculation of disposable income in EUROMOD



Appendix 3 – Prototypes for the EUROMOD web interface

Version 1 of the prototype

Figure 34. Version 1 of the prototype - the gender pay gap tab

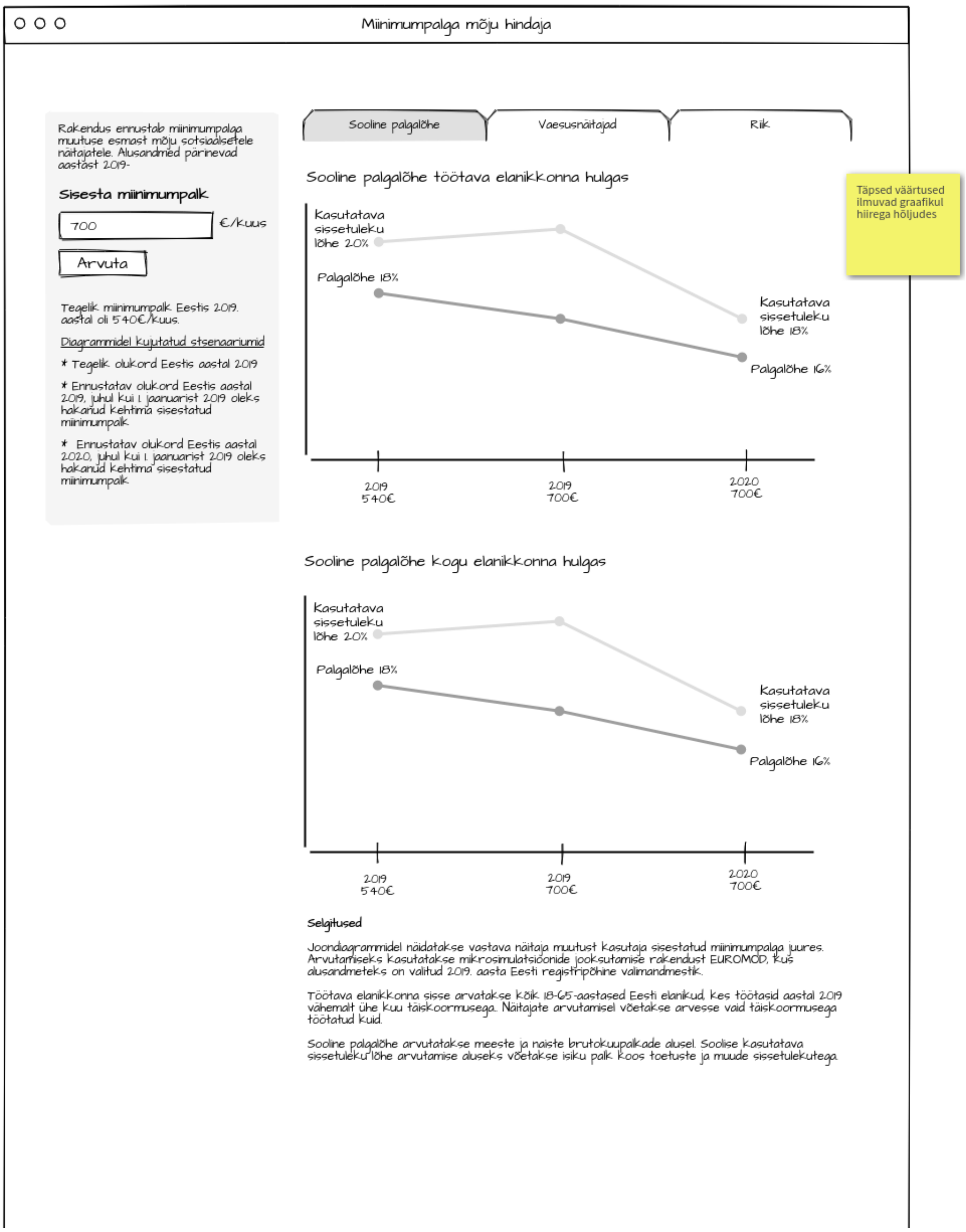


Figure 35. Version 1 of the prototype - the poverty tab

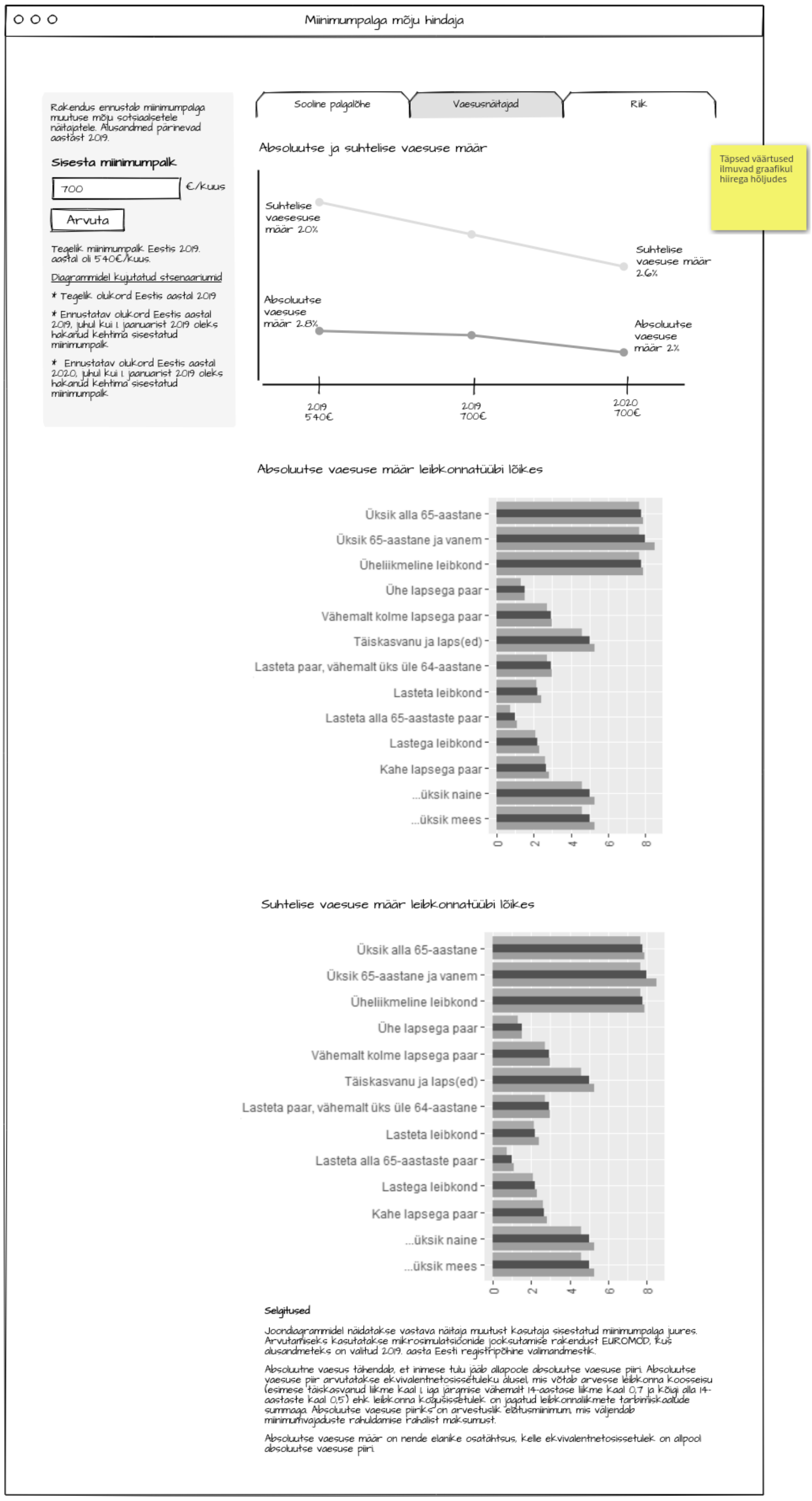
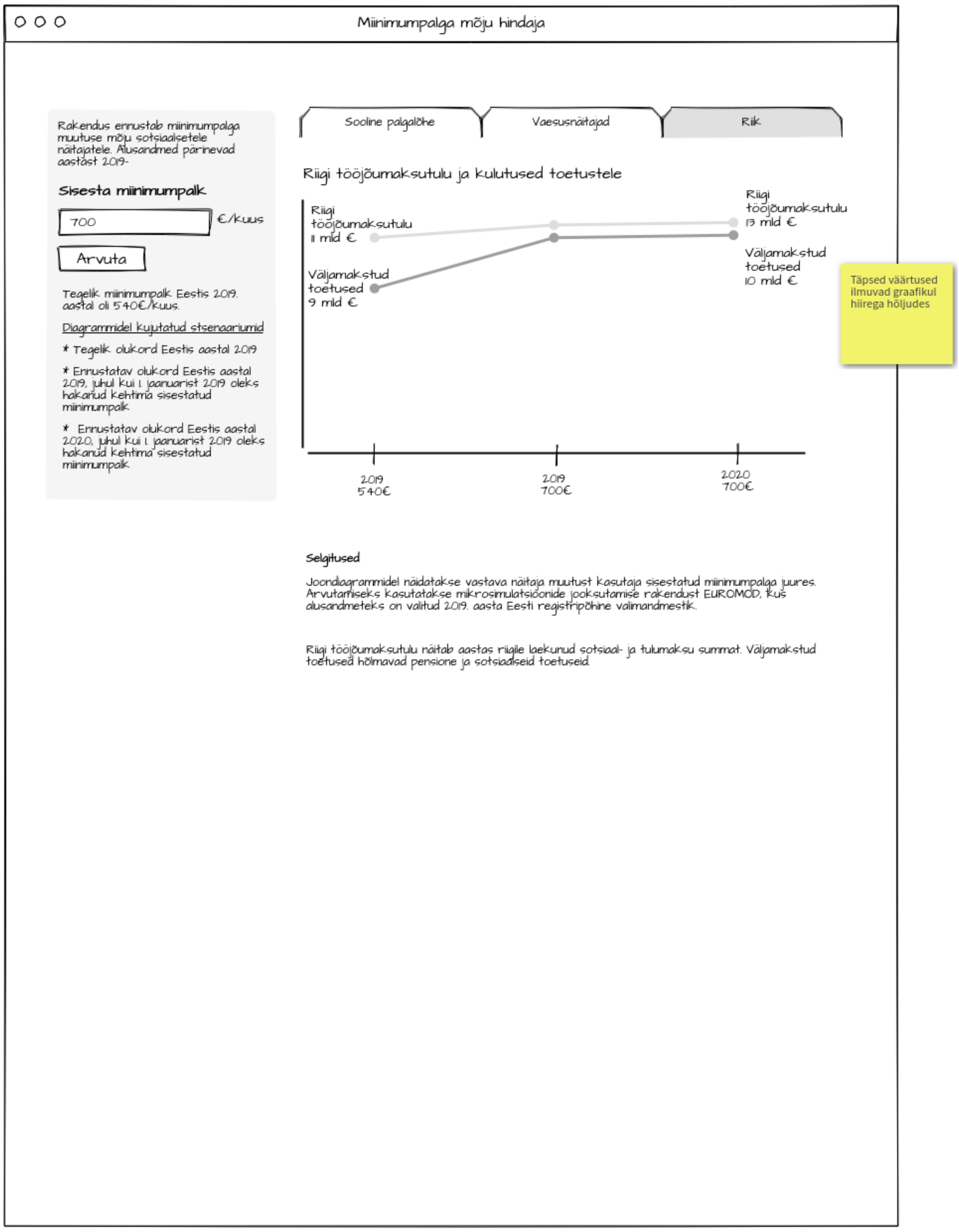


Figure 36. Version 1 of the prototype - the taxes and benefits tab



Version 2 of the prototype

Figure 37. Version 2 of the prototype - the gender pay gap tab

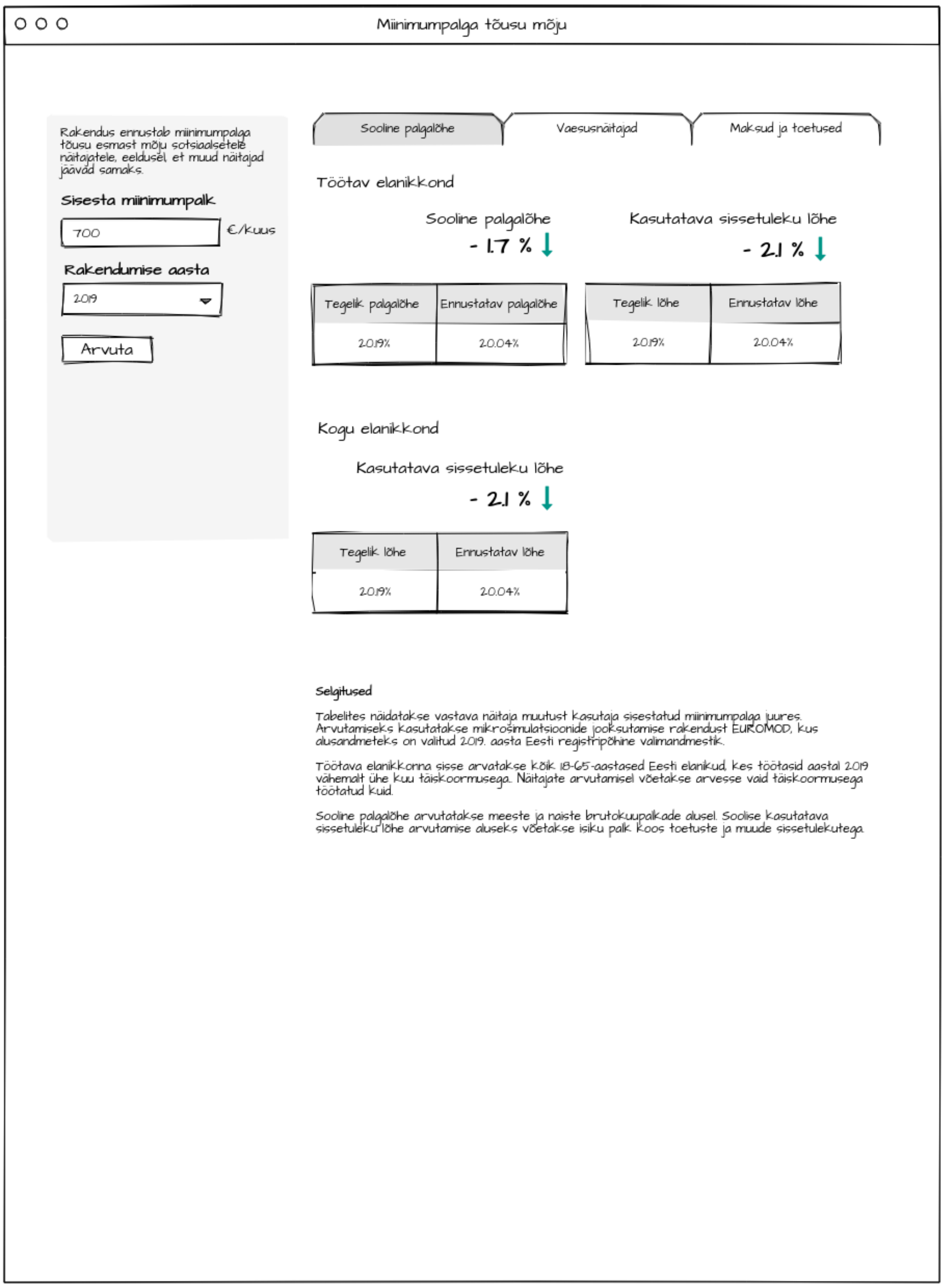


Figure 38. Version 2 of the prototype - the poverty tab

Figure 39. Version 2 of the prototype - the taxes and benefits tab