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Article

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Research paper

How does carbon tax affect social welfare and emission reduction in Finland?

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ABSTRACT

Environmental concerns related to fossil fuels utilization has developed different energy/environmental policy tools that Carbon tax is one of the important ones. There are huge debates among different political parties related to the positive and negative effects of the carbon tax on the energy and environmental policies of the countries. However, carbon tax not only can have effects on the utilization and consumption of energy sources portfolios, but it may also have negative or positive effects on the economy, industry, and social welfare of the countries that should be identified and analyzed, in particular for countries with high energy-intensive industries such as Finland. The purpose of this research is to answer the question: “How does Carbon Tax affect social welfare and emission reduction in Finland?” We use the computable general equilibrium model to analyze the impact of the carbon tax on social welfare and the rate of emission reduction. Considering the fact that Finland has several years of carbon tax policy application background, evaluation of the impact of this policy on Finland's social-environmental structure is very valuable for other countries, especially newcomers. Our results show that despite carbon tax policy in Finland has been successful in the reduction of carbon dioxide emissions, however, it has negative effects on the social welfare of Finns. Therefore, an optimum level of the carbon price is recommended for future policy revision

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1. Introduction

Energy policies are one of the main tasks of governments. They implement energy policy tools to achieve their environmental, economic, and social targets (Aslani et al., 2014). Wide range of researches has been conducted to assess various energy policy methods and tools. Many of these researches classify policy tools into five categories: financial and economic, business, management and government, energy regulation, and finally research and development (Aslani and Wong, 2014). The noted tools have been used by IEA member countries to achieve the stated energy policy goals, which, of course, have diverse effects on energy and fuel resources of these countries. The carbon tax is recognized as one of the most important energy policy instruments in the economic and financial sector. Since the implementation of a policy can have a very constructive or devastating effect on society. Therefore, analyzing the effects of carbon tax policy application on pioneer countries could lead to a reduction of the costs and prevention of potential destructive impacts in newcomer countries.

The current work is to analyze the effects of carbon taxation on social welfare and environmental indicators in one of the pioneers in the carbon tax policy-Finland. To achieve the purpose, GTAP 9, General Equilibrium model is used. Afterward, by using the GTAP-E versions of the model released in 2016, the impact of the carbon tax on social welfare and the number of carbon reductions are investigated. Finally, the results are discussed which will reveal the effects of carbon tax policy on social welfare and the environment.

2. Background

2.1. The overview of carbon tax

Carbon taxes were one of the first policy tools that were used to prevent climate change by reducing the emission. The first carbon taxes were focused on the energy sector and were applied indirectly in fuel pricing, which was high or low based on the ratio of carbon in the fuel. Nordic carbon taxes that have been adopted since 1990, continue to operate today and have undergone a number of reforms at different times (Aslani et al., 2013b). The reason for these reforms is the fact that countries have set their taxes based on their experiences and policy developments. Since late 2000, there has been a growing interest in the

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implementation of carbon taxes. Following the adoption of the Swiss carbon tax in 2008, some other European countries also began developing and adopting carbon taxes with other developed countries such as Australia and Japan. In early 2010, for the first time, carbon taxes on the emerging market were approved and implemented by South Africa, Mexico, and later Chile and India to achieve climate policy goals. The global ambitions to tackle climate change followed by the revival of carbon taxes is growing. The past trends have led to the adoption of the Paris agreement in December 2015, which was implemented in November 2016. In the Paris agreement, more than 150 countries have nationally determined contributions (NDC) to mitigate climate change. The experience of carbon taxes in the past years has provided a diverse and rich source for the development and implementation of this policy. These experiences have shown that carbon tax is a tool that can be adapted to a wide range of national and political goals (Sumner et al., 2009).

Energy and Environmental taxes can be expressed as Energy taxes, Transport taxes, Emissions taxes, and Resource taxes (Anon., 2017). Finland was the first country to use carbon taxes as a tool to reduce climate change. The carbon tax was implemented in Finland in January 1990, where only 0.3 percent of global greenhouse gasses were emitted. Initially, this tax was based on the carbon amount of fossil fuels, and when it first began, it was 1.12 euros per ton of carbon dioxide equivalent (Aslani et al., 2013a). In 2010, Finland's greenhouse gas emissions were ranked 59th among all countries. The Finland carbon tax law was amended in 1997 and 2011, and in 2013 the tax was a combination of the carbon tax and energy tax, costing €18.05 per ton of carbon dioxide (Anon., 2018). In 2018, Finland changed the carbon tax to \$ 77 per ton of carbon dioxide equivalent (The World Bank, 2018).

In 2016, worldwide revenue of over \$ 28.3 billion has been collected in governments and sectors that have implemented carbon finance policies. It is clear from available figures that 27 percent of this revenue is spent on green subsidies in sectors such as renewable energy and energy efficiency, 26 percent is spent on government funds, and 36 percent is dedicated to fiscal frameworks such as income tax cuts, subsidies and financial incentives for taxpayers such as companies and individuals. In 2013, with a revenue of \$ 800 million in carbon taxes, Finland did not allocate any amount to green subsidies, and spent half of the proceeds on the state-owned fund, and spent the other half on revenues, such as income tax cuts (Carl and Fedor, 2016). A documentary entitled "National Energy and Climate Strategy" has recently been released, which will enable Finland to systematically achieve an 80–95 percent reduction of greenhouse gas emissions by 2050 (which is the target set by the European Union for the Finnish government). Another critical goal of this document is to reduce the level of greenhouse gas emission to at least 40 percent of the 1990 level (Ministry of Economic Affairs and Employment, 2017).

There are different approaches among governments for the use of carbon tax incomes. One of these approaches is applying the tax-shifting packages. In this approach, to avoid increasing tax pressure on different classes of society, other types of taxes such as income taxes are reduced. This will only lead to a change in the behavior of producers and consumers and will increase the cost of goods that damage the environment during the production or consumption process. On the other hand, by reducing income taxes, new job opportunities will be created. The Finnish government has chosen this approach for carbon tax revenues, and revenue that collected through a carbon tax is distributed in the state budget of Finland, and the income tax is reduced to compensate for the increase in taxes (Mao, 2018).

2.2. Literature review

A review of a variety of emission reduction tools to mitigate the impact of climate change has been a heated debate over the past decades. The vast majority of researchers believe that the most powerful means to reduce emissions is the carbon tax (Nordhaus, 2006; Wei et al., 2015). In these years, the effectiveness and impact of this policy tool have been studied by many researchers in many respects. They evaluate the effects of different carbon tax ranges on welfare, the environment, the electricity market, renewable energy development, and many other indicators. But the results of these researches are in many cases contradictory (Wier et al., 2005; Fullerton and Heutel, 2007; Robinson et al., 2011; Zhixin and Ya, 2011; Fang et al., 2013; Renner, 2014; Liu and Lu, 2015; Chen et al., 2015; Goulder, 2013). In this study, we are looking for researches which investigate the impact of carbon taxes on environmental and social welfare.

In 2004, the Swedish Environmental Protection Agency conducted a study based on a computable general equilibrium model for a variety of green taxes, including carbon taxes. The results of this study claimed that green taxes would not increase government revenue and reduce unemployment at the community level, nor will the amount of environmental damage reduction be noticeable (Swedish Environmental Protection Agency, 2004). When Uri and Boyd used the computable general equilibrium model, they discovered that by increasing the price of energy in Mexico, energy consumption and environmental harms will be reduced, while the government will face rising incomes (Uri and Boyd, 1997). In 2013, Oueslati conducted a study on the long-term and short-term effects of environmental taxes on the economy. Results indicated that although these types of taxes had a positive impact on social welfare and economic growth in long-term, the short-term effects were adverse (Oueslati, 2013). In the same year, D'Haultfoeuille et al. did a similar study for France, and they claim that short and long-term effects of such policies on this country would be harmful (d'Haultfoeuille et al., 2013).

Similarly, Bae and Shortle, with a computable general equilibrium model, explored the welfare effects of environmental taxes in the form of small-open economies for Pennsylvania. They examined the possible implications of replacing carbon taxes with current taxes and conclude that environmental taxes will increase prosperity (Bae and Shortle, 2005). Chen and Nie concluded in their study that a low carbon tax would increase the social welfare index, but with increasing carbon tax rates, the trend would be reversed and the welfare index would decrease in the region. Finally, they stated the critical issue to examine the impact of carbon taxes on the welfare index is checking how carbon tax revenue is consumed. Because this will ultimately determine how the carbon tax will affect social welfare (Chen and Nie, 2016), some researchers believe that global warming will accelerate as carbon tax increases. They believe that resource owners will be expanding their energy extraction in the short term due to fears of future increases in carbon taxes. This phenomenon, known as the Green Paradox, was reviewed in 2011 by Edenhofer and Kalkuhl. In this study, it was proved that the green paradox would not occur until the carbon tax growth rate is lower than the growth rate of the effective interest rates of resource owners (Edenhofer and Kalkuhl, 2011). Saveyn and Regemorter also reviewed the environmental policies of Belgium using a regional general equilibrium model. They realized that implementing these regional policies would be in the interest of the economy and environment of Belgium (Saveyn and Van Regemorter, 2007). In 2017, Wesseh et al. published their study on the effects of carbon taxes. They believed that carbon taxes in both low-income and high-income countries would have the same impact on emission reduction. But concerning welfare,

they said that the effect of carbon taxes on low-income regions would be negative, in contrast to high-income regions (which will experience positive impacts) (Wesseh et al., 2017). Given the controversy among researchers, collecting more up-to-date data and using real models will make the results in the studied area more realistic.

2.3. Energy economic models

In order to model the impact of carbon tax policies on different sectors, economic models should be reviewed. Since the signing of the Kyoto Protocol, the literature on economic modeling of climate change and carbon pricing has become widespread. In 2003, Springer compiled the available models for reviewing the topics listed below (Carlos Ludeña and Miguel, 2012). (See Fig. 1.)

In this research, considering the previous studies and the capabilities of the general equilibrium models, this model is chosen. General equilibrium models are the branch of the top-down models because they use general economic data in all sectors of the economy (Carlos Ludeña and Miguel, 2012). In general equilibrium models, the indirect effects of economic policies such as pricing policies, taxes, and subsidies are assessed and estimated. In these models, relations between all sectors and economic variables are considered as economic factors in the form of financial interactions. So that direct and indirect effects of policies and shocks are taken into account. It should be kept in mind that in these models, most variables are considered as endogenous. These models simulate the flow of economic activity by considering three categories of important economic agents, including households (consumers), firms (producers), and government (taxes and subsidies), the interaction of these brokers in the form of markets. In general equilibrium models, not only the variables are modeled endogenously, but also mathematical relations will be realistic. In general equilibrium analyzes, the behavior of several brokers is simulated simultaneously.

Today, computable general equilibrium (CGE) models are one of the standard tools for empirical analysis. These models are used as a tool for analyzing the welfare and the distributive effects of policies. Because they have a theoretical basis based on the microeconomics and these models examine the behavior of the agents endogenously (Burfisher, 0000).

The study of welfare effects and income distribution of policies is one of the most attractive subjects to be considered by general equilibrium models. We have used a general equilibrium model called the Global Trade Analysis Project (GTAP) in this study. Among the general equilibrium models, multi-regional models provide a suitable platform for global trade research and among the multi-regional general equilibrium models, the GTAP model has extensive facilities for global trade studies. Most importantly, this model has the potential for international studies related to energy and climate change.

2.3.1. GTAP-E model

The GTAP-E general equilibrium model is a developed format based on the GTAP equilibrium model. This developed model includes many economic parameters such as world trade behaviors, savings, and global investment. This model improved the GTAP base model, by reforming the energy demand behavior which includes energy-stock, fuel replacements, and carbon trade. Noted points demonstrate the up-down energy modeling in the GTAP model which also includes a detailed description of the economy in macro scale. The GTAP-E general equilibrium model is a multi-regional and multi-sectoral model and is an extended version of the GTAP equilibrium model. Burniaux and Truong extended the model in 2002 from the Hertel and Tsigas GTAP models.

The model has improved the GTAP base by utilizing an energy demand modification that involves replacing capital-energy, fuel alternatives, carbon dioxide calculations, carbon taxes, and emissions trading. Because of this approach, this model is often used to analyze climate change policies (Peterson, 2007).

For the GTAP-E model, a production structure with different elasticity substitution exists in different layers as Figs. 2 and 3. Each sub-layer in the production structure represents the potential of substitution between inputs. Each group entry at below layers is made up of goods, and in the higher layers of the production structure, products are produced using inputs of non-energy intermediate goods and primary compounding agents. Typically, the elasticity substitution (σ) between non-energy interface inputs and the main production factors is zero, which has a Leontief production function. This means using fixed inputs in each unit of output. The constant elasticity substitution (σ_{VAE}) exists between the primary production factors such as land, labor, and natural resources, which has a constant elasticity substitution production function. In the energy-capital components, there are three possibilities for replacing fuel: 1. the electric and the non-electric branches have an elasticity substitution (σ_{ENER}) equal to one and the Cobb Douglas production function, 2. The coal and the Non-Coal Coal branches have a constant elasticity substitution (σ_{NELY}), 3. The choice between oil, gas and petroleum products with elasticity substitution (σ_{NCOLE}) equal to one and the Cobb Douglas production function (Burniaux and Truong, 2002). For example, when coal is more expensive than non-coal fuels, manufacturers can go for oil, gas or petroleum products. According to Burniaux and Truong, the advantage of this system is the possibility of a replacement between fuels and energy and capital, which is dependent on the value of elasticity substitution.

In the GTAP-E model, the carbon dioxide emissions in region “r” with energy “e” are calculated as follows in Eq. (1).

$$CO2(r, e) = \left[\frac{C(e)}{V(e)} \right] \left[\frac{V(e)}{Q(e)} \right] \times \left\{ \sum_{j \in prod_comm} [QFD(e, j, r) + QFM(e, j, r)] + QPD(e, r) + QPM(e, r) + QGD(e, r) + QGM(e, r) \right\} \quad (1)$$

CO2 is defined as million tonnes (MT); (C/V) is the amount of carbon dioxide emitted per million tons of oil equivalent; (V/Q) million tons of oil equivalent per unit of energy carrier; QFD and QFM are intermediate inputs that are domestic and imported; QPD and QPM are the levels of domestic and imported energy that are purchased by private households; QGD and QGM are the levels of domestic and imported energy that are purchased by the government. As a result, (V/Q)(C/V) converts physical quantities of energy into carbon dioxide emission levels (Peterson, 2007; Burniaux and Truong, 2002).

The percentage change in carbon dioxide emissions could be calculated using Eq. (2).

$$CO2(r, e)^*gco2(r, e) = \sum [EDINT(e, j, r)^*qfd(e, j, r) + EMINT^*qfm(e, j, r)] + EDHH(e, r)^*qpd(e, r) + EMHH(e, r)^*qpm(e, r) + EDGV(e, r)^*qgd(e, r) + EMGV(e, r)^*qgm(e, r) \quad (2)$$

gco2 is equal to the percentage change in carbon dioxide emissions. the amount of carbon dioxide released from domestic and imported which is consumed in intermediate energy inputs (EDINT, EMINT), by private household (EDHH, EMHH) and by government households (EDGV, EMGV); Also, qfd, qfm, qpd, qpm,

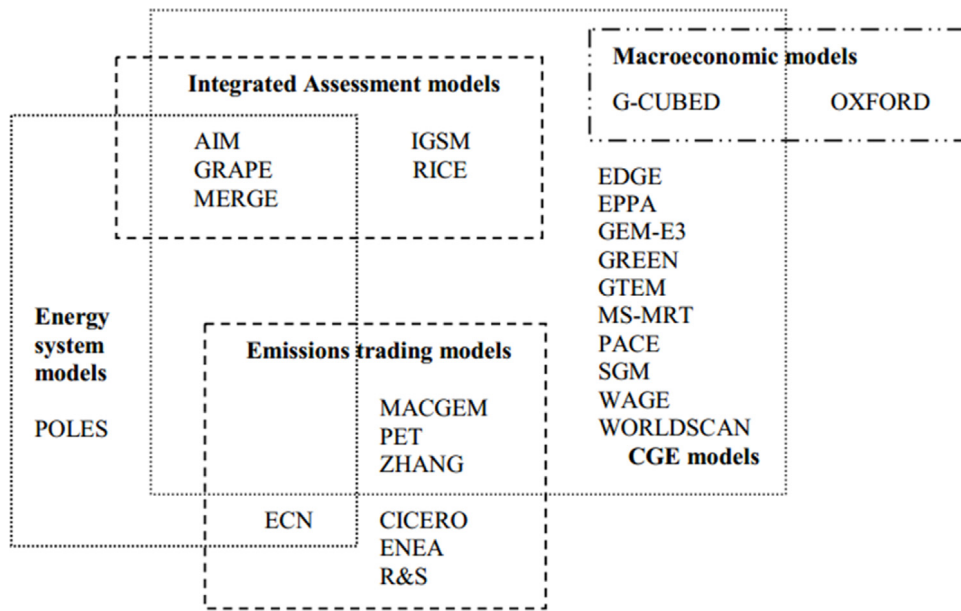


Fig. 1. Climate change and carbon pricing models (Carlos Ludeña and Miguel, 2012).

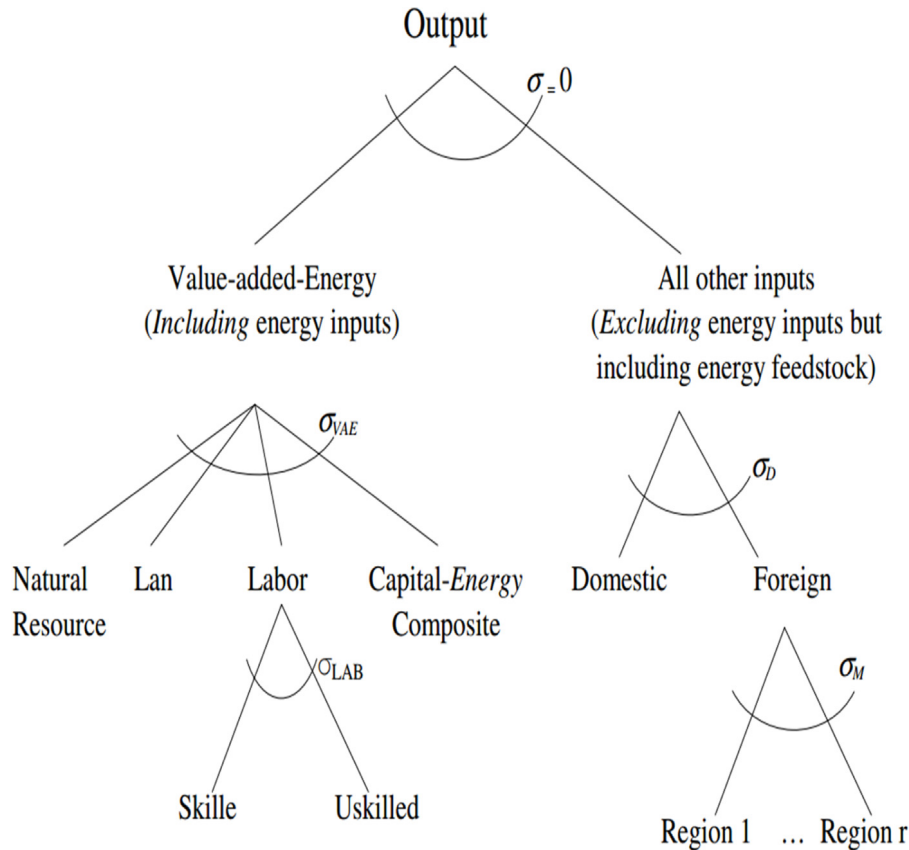


Fig. 2. Production structure in the GTAP-E model (Burniaux and Truong, 2002).

qgd , qgm are the percentage change in the use of energy carriers by companies, households and government based on the input of domestic and imported energy sources (Peterson, 2007; Burniaux and Truong, 2002). Data on the emission of greenhouse gases from fossil fuel combustion are calculated from GTAP energy data (Martini et al., 2010).

3. Methodology

For data modeling, GTAP-E database and GTAP database aggregator software are used. Later, data is transferred to the RunGTAP software. The aggregation of the required data (countries classification, economic sectors, and classification of primary production factors and the assumption of inter-section mobility) is created. Afterward, the economy closure method is selected based on

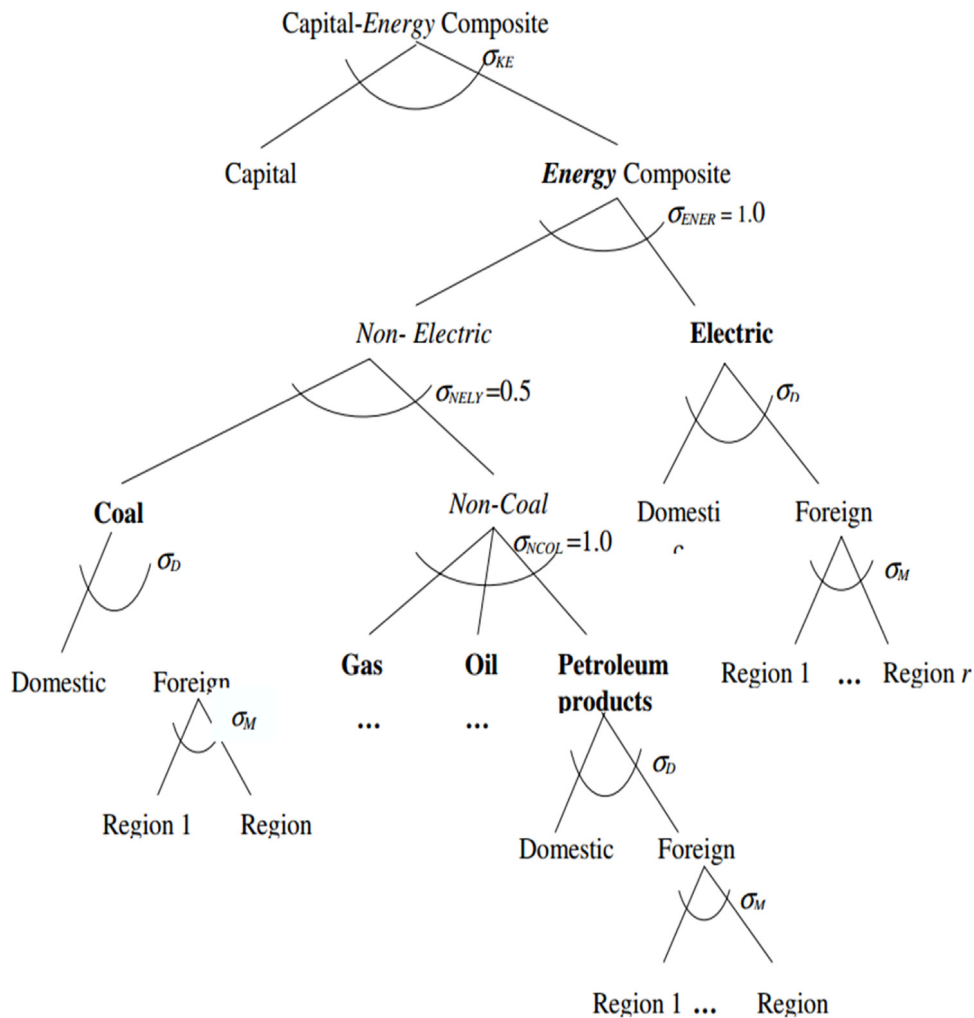


Fig. 3. Energy-Capital Composite Structure in the GTAP-E Model (Burniaux and Truong, 2002).

requirements and limitations. With regards to the economic or business policy, the political shock is simulated. Next, equilibriums are set, and the result of endogenous parameters alteration are presented. In the first step of the data aggregation, the regional aggregation is completed by the GTAPAgg software. In order to do the calculations, all 140 countries in the database are divided into ten regions (provided in Table A in Appendix 1). At this stage, Finland has been separately categorized as a case study of this study. Sweden and Denmark have also been classified separately, because of their closeness to Finland in most circumstances, so that the results can be generalized to these countries as well. In the second step of the data aggregation, a collection of 19 related industries is gathered. It should be noted that the economic sectors in this database include a group of 57 different sectors of the economy. This category is also available in Table B (presented in Appendix 1). The recommended classification includes energy carriers and different industries. Since the focus of this research is the carbon tax policies, it is tried to group similar industries in the same group. The third step will be the classification of producing factors into 5 groups of land, simple workforce, professional workforce, capital, and environment. Finally, aggregated data is transferred to RunGTAP program, and related computations are carried out. To conduct the computations related to exogenous variables, different carbon tax prices which are suggested for different scenarios are implemented. Furthermore, by applying defined political shocks changes in the endogenous parameters will be monitored.

4. Policy scenarios

Based on the past research and data collection from three Finnish policymakers, five scenarios are defined to cover a broader range of carbon tax rates. The scenarios include five global rates for carbon taxes. It should be noted that until now, the \$ 150 per ton tax rate has not been adopted anywhere in the world, and only Sweden implemented the nearest rate in 2018 which was \$ 140 per ton (The World Bank, 2018). In general, with the growing rate of a carbon tax in Finland, it is estimated that Finland and its neighbors will adopt \$ 150 per ton tax in the coming years. The numerical range of scenarios will give a more realistic view of this policy impact on the decline in emissions and the changes in the welfare index in Finland.

The noted scenarios are as follows:

1. The adoption of a carbon tax rate of \$ 20 per ton of released carbon (Martini et al., 2010; Li et al., 2016; Cui and Song, 2017; Ayu, 2018)
2. The adoption of a carbon tax rate of \$ 35 per ton of released carbon (Li et al., 2016; Cui and Song, 2017; Frey, 2016)
3. The adoption of a carbon tax rate of \$ 80 per ton of released carbon (The World Bank, 2018; Martini et al., 2010; Li et al., 2016; Frey, 2016; Antimiani et al., 2015)
4. The adoption of a carbon tax rate of \$ 120 per ton of released carbon (The World Bank, 2018; Antimiani et al., 2015; Rausch and Yonezawa, 2018)

Table 1
Percentage change in the supply price of the primary production factors.

	Tax rate (\$/CO ₂ ton)				
	20\$	35\$	80\$	120\$	150\$
Primary production factors	Percentage change in the supply price of the primary production factors				
Land	−0.256	−0.448	−1.016	−1.506	−1.864
UnSkLab	−0.482	−0.829	−1.808	−2.611	−3.18
SkLab	−0.533	−0.917	−1.996	−2.881	−3.507
Capital	−0.973	−1.66	−3.559	−5.089	−6.159
NatRes	−1.868	−3.12	−6.324	−8.684	−10.246

Table 2
Welfare changes due to the implementation of carbon taxes in Finland.

Scenarios	20\$	35\$	80\$	120\$	150\$
Overall (Mill \$)	−412.965	−748.254	−1808.62	−2775.41	−3501.82
Per capita (\$)	−75.0845	−136.046	−328.84	−504.62	−636.695

5. The adoption of a carbon tax rate of \$ 150 per ton of released carbon (The World Bank, 2018; Antimiani et al., 2015; Rausch and Yonezawa, 2018)

5. Results and discussions

5.1. Impact on welfare

There are different rules for carbon taxes around the world, but carbon taxes generally apply to upstream fuel sales on coal mines, natural gas, and oil wells. Primary consumers of fuel, such as electricity services, oil, and gas refineries, and transportation face the rising cost. Which bring the shift of costs to their customers, households, and businesses, and ultimately, this heavy burden will be passed on to downstream customers. In other words, in the last layer of the effects of carbon taxes, they are the consumers who are paying a higher price for goods. Although, Finland has introduced a tax-shifting package for carbon tax revenue, and, in exchange for a decrease in people's income from carbon taxes, they reduce income taxes by a percentage. However, all these measures could only cover a little portion of the negative impact of carbon taxes on welfare in Finland.

In Table 1, the results of applying the five proposed scenarios on the price change of the primary production factors are presented. The results suggest that the factors of production have a negative percentage change, which is evidence of a reduction in labor wage and the possibility of a return on real capital.

It should be explicitly stated that the implementation of carbon taxes in Finland will reduce the level of welfare in this community. The first line of Table 2, indicates the welfare changes (what we mean by welfare change is the difference between the million dollars amount of welfare when adopting carbon tax and when the carbon tax is absent) in Finland. For example, after applying the \$ 150 carbon tax rate, Finland will encounter a welfare decline of \$ 3.5 billion. Also, in the \$ 80 scenario, which is very close to Finland's current situation, the welfare loss is about \$ 1.8 billion.

By dividing the amount of welfare change into the population of Finland, per capita, welfare changes in Finland will be calculated. The second line of Table 2 and Fig. 4 show the level of welfare change per capita in Finland based on the application of each carbon tax rate. For example, the rate of \$ 80 per ton shows a decrease of \$ 329 per person.

5.2. Impact on emission reduction

Despite the economic importance of carbon taxes over the past two decades and its effect on government revenue and social

welfare changes in society, the impact of this policy shock on environmental issues remains to be seen as the most crucial outcome of the carbon tax debate because this policy shock is mainly applied to improve the environmental situation. So, at this stage, the effects of this tax on the environment will be examined. To do this, a review of the percentage change in carbon dioxide emissions in two general, which is the impact of the carbon tax on the various tax rate for overall carbon dioxide emissions in Finland, and partial levels for, different sources of energy including coal, oil, natural gas, and petroleum products are conducted. Table 3 shows this percentage change.

The percentage change of emissions on the overall level, under the \$ 150 scenario, is about 30 percent lower than non-taxed. As it is noticeable, in the \$ 80 scenario, it is also 20 percent lower than non-taxed. At partial level, coal is also at the lowest level, with a reduction of nearly 50 percent at \$ 150. Coal is known as one of the most polluting sources of fossil fuels, and this 50 percent reduction can be considered as the most significant carbon tax gain. Of course, the fact that the implementation of carbon taxes sometimes makes irreparable blows to some industries cannot be ignored. However, this tax is reasonable due to the significant environmental targets which will be achieved by shifting the energy consumption from fossil fuels to renewable energy sources. In general, it can be concluded that this tax is adequately doing its most important duty. Fig. 5 shows the percentage change in carbon dioxide emissions for both general and partial levels, including different sources of energy.

GHG reduction comes from a reduction in energy consumption. Fig. 6 shows, percentages change of energy consumption for each energy carrier after applying different scenarios in various industries. This figure examines the information on the reduction of energy consumption in each sector precisely after applying different scenarios. It is clear that carbon taxes reduce fuel consumption in various sectors of the economy for all energy carriers. As shown in this Figure, the most substantial changes in energy consumption are related to oil and coal. It should be kept in mind that all sectors will seek to reduce carbon dioxide emissions by adopting carbon taxes. This reduction for oil and coal amounts to 40 to 50 percent, which is a significant reduction in energy consumption.

6. Conclusion

With the review of past studies and combined with the results of this research, it could be concluded that the effects of carbon taxes are highly dependent on the country and the region that implements it. Although Finland was the first country to adopt carbon taxes, there was no comprehensive study on the simultaneous impact of carbon taxes on emissions reductions and welfare changes. Therefore, in this study, these cases were examined by a computable general equilibrium model. There are different rules for carbon taxes around the world, but carbon taxes generally apply to upstream fuel sales on coal mines, natural gas, and oil wells. Primary consumers of fuel, such as electricity services, oil, and gas refineries and transportation face the

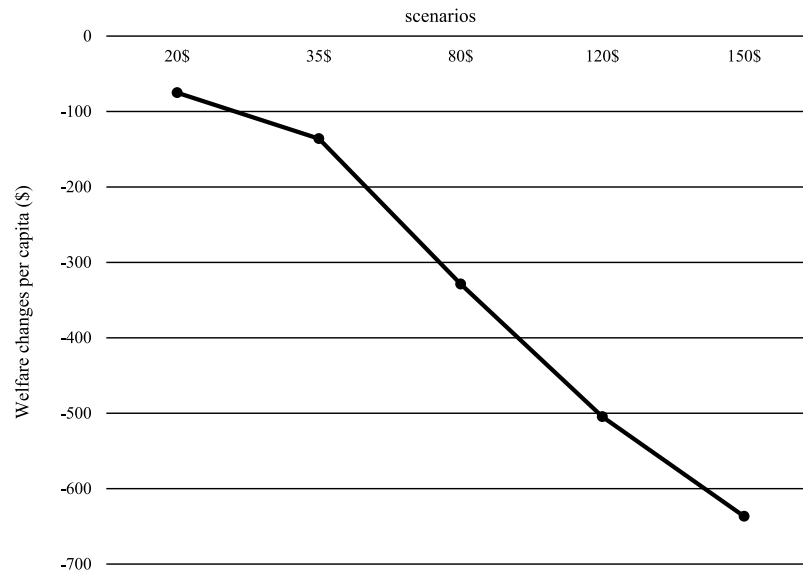


Fig. 4. Welfare changes per capita due to the implementation of carbon taxes.

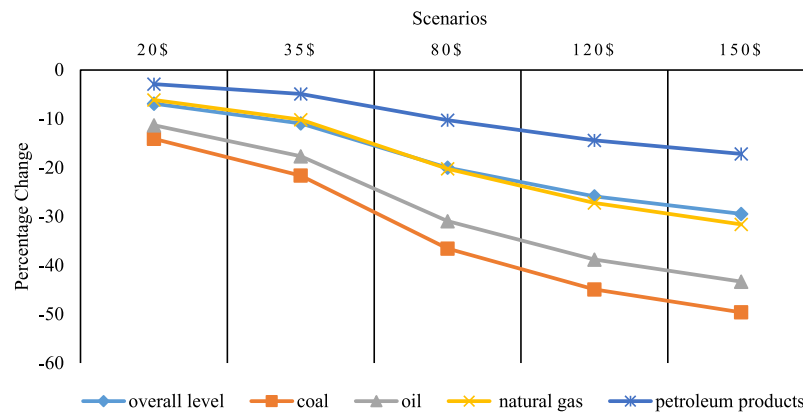


Fig. 5. Percentage change in carbon dioxide emissions.

Table 3

Percentage change in carbon dioxide emissions from different energy Source under scenarios.

Energy source	Tax rate (\$/CO ₂ ton)				
	20\$	35\$	80\$	120\$	150\$
General level	-6.906	-10.951	-20.003	-25.865	-29.465
Coal	-14.111	-21.635	-36.566	-44.937	-49.623
Oil	-11.321	-17.682	-30.958	-38.804	-43.326
Natural gas	-6.129	-10.182	-20.233	-27.231	-31.626
Petroleum products	-2.887	-4.9	-10.284	-14.41	-17.187

rising cost, which will shift costs to their customers, households, and businesses. Eventually, this heavy burden will be passed on to downstream customers. In other words, in the last layer of consumption, the consumer will pay off more for the price of the goods. Finland has introduced a tax-shifting package for carbon tax revenue, and in exchange for a decrease in people's income from carbon taxes, they reduce income taxes by a percentage. However, all these measures could only cut a little of the negative impact of carbon taxes on the welfare of Finland. Result of this research indicates that the implementation of carbon taxes reduces welfare in the Finnish community. For example, after applying the \$ 150 carbon tax rate, Finland will see a welfare decline of \$ 3.5 billion. Also, in the \$ 80 scenario, which is very close to Finland's current situation, the welfare loss is about \$ 1.8 billion. On the

other hand, Finland has sought to reduce emission in pursuit of this policy, and results will guarantee Finland's success in this regard. For example, the percentage change in emissions on the overall level, under the \$ 150 scenario, is about 30 percent lower than non-taxed and in the \$ 80 scenario, it is also 20 percent lower than non-taxed. Also, at the partial level, coal is also at the lowest level, with a reduction of nearly 50 percent at \$ 150. Coal is known as one of the most polluting sources of fossil fuels, and this 50 percent reduction can be considered the most significant carbon tax gain.

Future research can examine the effects of this policy in developing countries. Also, about the Paris agreement for countries, using other economic models to analyze the impact of carbon policy or other energy and environmental policies can be helpful.

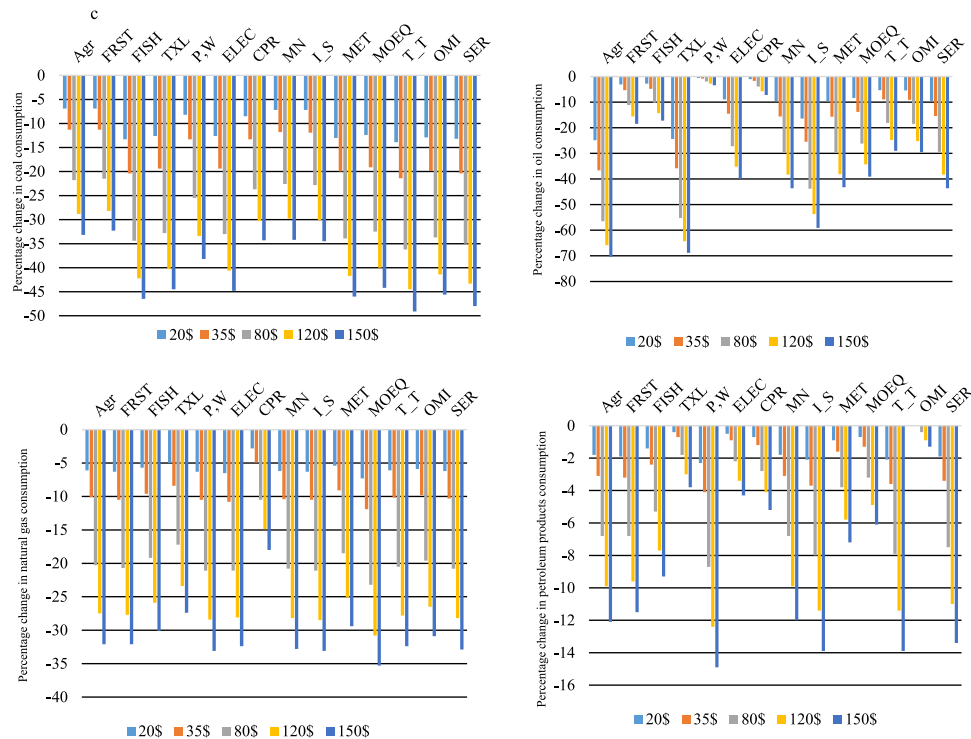


Fig. 6. Percentage change of energy consumption for each energy carriers after applying different scenarios in various industries.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at <https://doi.org/10.1016/j.egy.2020.03.001>.

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