The Importance of Wooden Biomass in the Transition to a Bioeconomy in Latvia

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Abstract

The EU Green Deal advocates decarbonising the EU's energy sector, largely by transitioning to renewable sources. Latvia aims to increase the share of renewable energy production in total energy production to 50% by 2030 (it was 39% in 2017), prioritising biomass from forests and wood for bioenergy. This paper evaluates increasing the tax on non-biobased energy use alongside implementing a subsidy for biobased energy use, particularly from wood biomass, to promote the substitution of the first by the latter as a step towards climate neutrality and energy self-sufficiency. Furthermore, it examines technological advancements in the bioenergy sector as an alternative instrument. Using an applied general equilibrium model and 2015 supply and use data, the study allows for substitution between domestic and imported inputs and between the non-biobased and biobased energy product. Given Latvia's heavy reliance on imported fossil fuels, these measures could lead to a 58% increase in bioenergy production compared to 2015, reducing CO_2 emissions by 0.3 – 1.7%, and reducing non-biobased energy imports by 2.5-4.2%.

Keywords: biobased energy, non-biobased energy, product tax, subsidy

JEL codes: C68, E17, Q23

1. Introduction

The transition from a fossil-based economy to a biobased economy is considered a priority to mitigate the effects of climate change in the European Union (EU). The EU Green Deal states that the EU has to become climate neutral by 2050 (EC b, n.d.). This requires the EU to reduce net greenhouse gas (GHG) emissions to zero. Carbon dioxide (CO_2) remains the main greenhouse gas emitted through human activities, and most CO_2 emissions come from the energy sector: electricity, heating, and transport. Therefore, one of the main actions proposed in the Green Deal is to decarbonise the EU's energy sector, largely through the transition of the generation of power from fossil-based to renewable sources. The Latvian government follows this action with the intention to increase the production of energy from renewable sources to 50% of the total energy production in 2030 (it was 39% in 2017). To achieve this goal, an emphasis will be placed on sourcing biomass from the forest and wood industry to be used for the production of biobased energy (EM, 2019). The reason for this focus is that the production and use of other renewable energy products are small. For example, in 2015 91.7% of the use of renewable energy was from biomass from forests and wood, for hydropower, this was 7.7% and for wind 0.6%.

As a reaction to the Russian invasion of Ukraine, the European Commission introduced the REPowerEU plan in March 2022 outlining measures to drastically reduce Russian gas imports and achieve independence from Russian fossil fuels before the end of the decade. The key elements in this plan are diversifying supplies, reducing demand, and increasing the production of green energy in the EU. This is expected to accelerate the green transition by reducing GHG emissions, reducing dependency on imported fossil fuels, and protecting the EU against price hikes on the energy market (EU Commission, 2022).

Economic instruments like taxes on fossil fuels and subsidies on biobased energy production or use can contribute to achieving the goals of the Green Deal and the REPowerEU plan. Since fossil fuels are non-renewable and GHG emissions are harmful to the environment, a product tax can help in reducing its demand and supply, as it increases the net price demanders pay and decreases the price suppliers receive. Product subsidies for biobased energy have the opposite effect. Moreover, product taxes and subsidies can stimulate the development and use of more sustainable technologies (Wolfson & Koopmans, 1996).

A tax on fossil energy can - in addition to the reduction in emissions – lead to an increase in welfare if it reduces the tax distortions caused by other taxes ("second best effect"). If this happens, then we speak of a 'double dividend' (see De Mooij, 2002 and Goulder, 1995). A potential double dividend can be an extra incentive to introduce a tax on fossil energy use.

In Latvia, the forest sector is one of the cornerstones of the economy. Forestry, wood processing and furniture manufacturing contributed 5.1% to GDP, 5.4% to total employment and 20.7% to exports in 2018 (AM - Ministry of Agriculture, 2022). Furthermore, the forest area covers 52% of the country's territory and this is expanding. It has doubled since 1935 due to farm abandonment that resulted in the conversion of cropland fields into young forests (Fonji & Taff, 2014). The increase in forest area is expected to continue because of purposeful afforestation, as well as through the continued natural overgrowth of forest on non-agricultural lands. Moreover, wooden biomass is increasing annually due to more sustainable forest management in recent decades (Lazdiņš et al., 2019). This opens possibilities for further increase in the use of wooden biomass in the production of biobased energy.

The aim of this paper is to investigate the potential of taxes, subsidies, and technological change to increase the share of biobased energy production in Latvia. More specifically, it assesses the effect of an increase in the tax on non-biobased energy use and the implementation of a subsidy on biobased energy use, especially from wooden biomass, to facilitate the substitution of the first for the latter as a step in the transition of Latvia's economy towards climate neutrality and self-sufficiency of energy. Moreover, the paper assesses the effects of technological change in the industry producing biobased energy. Such a technological change in the production of biobased energy is instrumental for a successful transition of the energy sector. To this end, the

EU and the Latvian government will stimulate technological change as part of the Green Deal using € 4.4 billion from EU funds for Latvia between 2021 and 2027 (FM, n.d.).

The paper uses an applied general equilibrium (AGE) model based on the model developed by Komen and Peerlings (1999) to achieve the aim. Their model included greenhouse gas emissions and policy scenarios to reduce these emissions. However, it did not distinguish between non-biobased and biobased energy, nor did it include biomass. Especially in the 1980s and 1990s AGE models were used to assess different policy issues, e.g., agricultural policy reform, environmental taxation, etc. (for an overview, see Bergman, 1990; Gunning & Keyzer, 1995; Robinson, 1989). Policy issues simulated with AGE models reflect relatively large shocks to an economy, as AGE models explicitly model the economy as a whole. Calculating the effects of large shocks cannot be done using a partial equilibrium model given that these models assume too many variables (e.g. wages, interest, etc.) exogenous. The transition towards climate neutrality and energy self-sufficiency can be considered as a large shock to the Latvian economy. Data come from the supply and use tables for 2015 and national accounting data from the Latvian Central Statistics Bureau (CSB). It is assumed that a nested production structure allows for explicit imperfect substitution between domestic and imported inputs in energy production to account for Latvia's current dependence on imported fossil fuels. By increasing the use of (domestically produced) wooden biomass in the energy sector through a tax on the use of non-biobased products and a subsidy on the use of the biobased products, the amount of CO_2 emissions from fossil energy and the dependence on fossil energy imports are expected to reduce. The technological change is expected to lead to similar effects. To the best of our knowledge, this is the first application of an AGE model to Latvia and the first AGE analysis to investigate the effects of the Green Deal.

The remainder of the paper is structured as follows. Section 2 describes the energy and forestry sectors and policies of Latvia. Section 3 presents the AGE model. The data are described in

Section 4. Section 5 presents and discusses the results of the model. Section 6 concludes and provides a general discussion.

2. Energy and forestry sectors, and policies

Latvia is highly dependent on imports of fossil fuels. Table 1 shows that oil products and natural gas are not produced in the country. Electricity is produced mostly domestically, partly from fossil fuels and partly from renewable energy sources.

Table 1. Energy production, imports, exports and domestic consumption in Latvia, 2020

Product	Production	Imports	Exports	Domestic consumption
Oil products, thousand Euro[1]	-	726.56	145.64	542.4
Natural gas, million Euro	-	433.74	0.00	433.74
Electricity, million Euro	181.86	137.71	84.02	235.55

[1]: Production plus imports does not add up to domestic consumption and exports because of changes in stocks and statistical issues.

Source: CSB, 2021a, 2021b, 2021c

To meet the objectives set by the EU in the Green Deal and international commitments (see Table 2), the Latvian government drafted the *National Energy and Climate Plan 2021 – 2030*. The long-term goal of the plan is to promote the development of a climate-neutral economy in a sustainable, competitive, cost-effective, secure, and market-based way by improving energy security and public welfare. To achieve this goal, it is necessary: '1) *To promote the efficient use of resources, as well as their self-sufficiency and diversity; 2) To ensure a significant reduction in the consumption of resources, in particular fossil and unsustainable resources,* *and a simultaneous transition to sustainable, renewable and innovative use of resources, ensuring equal access to energy for all sections of society; 3) To stimulate research and innovation that contributes to the development of a sustainable energy sector and the mitigation of climate change'* (EM - Ministry of Economics, 2019).

Table 2. EU and Latvia`s energy policy indicators and targets

Indicator/target	**EU's target, 2030**	**Latvia's actual value in 2017**	**Latvia's target, 2030**	**Latvia's target, 2050**
Reducing GHG emissions (% to 1990) (LULUCF* excluded)	-40	-57	-65	Climate neutrality (irreducible GHG emissions are compensated by LULUCF sector)
Reducing GHG emissions (% to 1990) (LULUCF included)	-	-	-38	
Energy produced from RES**, share of gross final consumption (%)	32	39	50	-
Share of imports in gross domestic energy consumption (%)	-	44.1	30-40	-

* Land Use, Land Use Change and Forestry

** Renewable energy sources

Source: EM, 2019

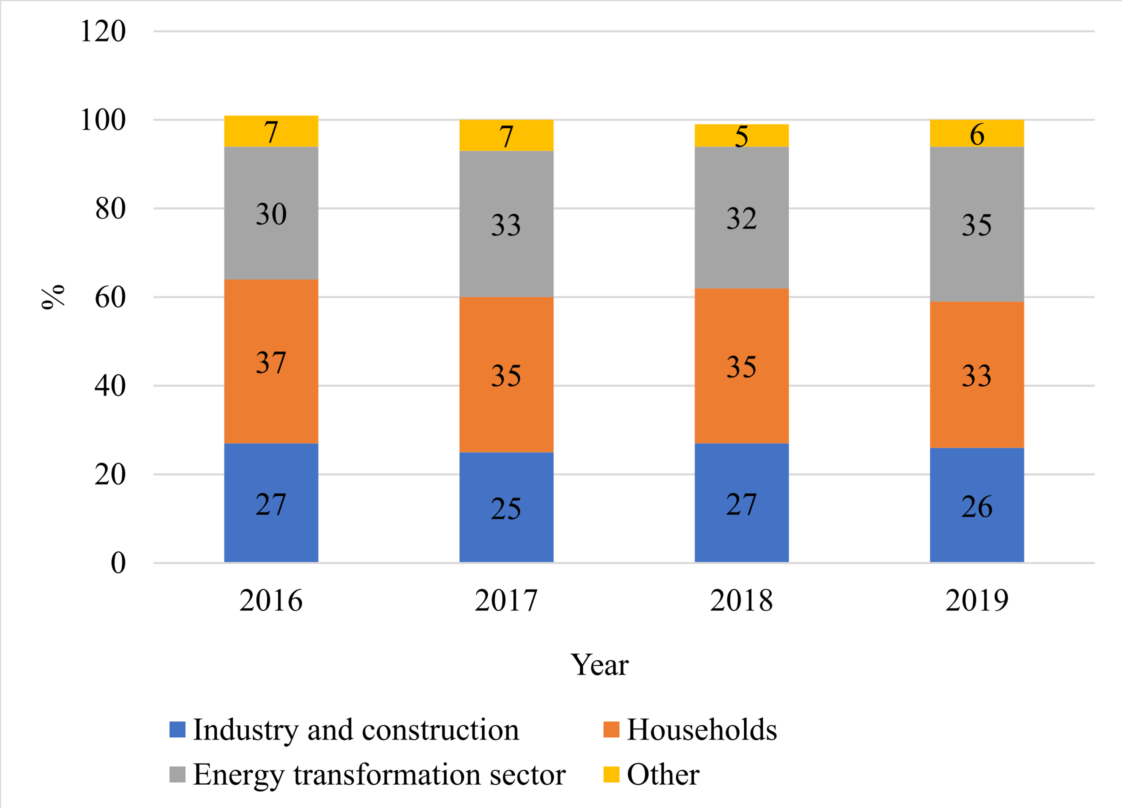
One of the goals of the *National Energy and Climate Plan* is to increase the share of renewable energy sources in Latvia. The plan includes the so-called 'tax greening' ("polluter pays principle"), where the focus is on taxes such as excise, value added, vehicle, electricity, and natural resource taxes. However, to our knowledge, these have not been implemented by the beginning of 2025.

The transition from a fossil-based economy to a biobased economy is especially relevant for the forest sector in Latvia. The forest sector is expected to contribute to this transition through the replacement of fossil fuels and non-renewable products with forestry-based products (Kröger & Raitio, 2017). In addition to being used in the production of traditional wood-based products, such as furniture, wooden biomass is increasingly being used in energy generation and in the production of textiles, bioplastics, chemicals, and intelligent packaging, and is also contributing to the construction sector (Hetemäki et al., 2017; Hurmekoski et al., 2018).

One fifth of the forest stands in Latvia is in the age of mature and old-growth (CSB, 2021d). The CO_2 sequestration capacity of old trees is relatively low, hindering the fulfilment of the Green Deal targets making them a potential feedstock to produce biobased energy.

According to data from the EU Bioeconomy Monitoring System Dashboard (EC, n.d.), 58.5% of wooden biomass in Latvia is used in the production of bioenergy and 41.5% is used as materials in manufacturing in 2015. The largest share of wooden biomass in energy production was taken by firewood (30% of the total consumption of energy sources) in 2018, followed by briquettes, pellets, wood scraps, and wood chips. The largest consumers of wooden biomass are households followed by the energy transformation sector (Figure 1).

Figure 1. Wooden Biomass Consumption in Energy Production in Latvia 2016 – 2019 (%)



Source: AM, 2022

3. Model

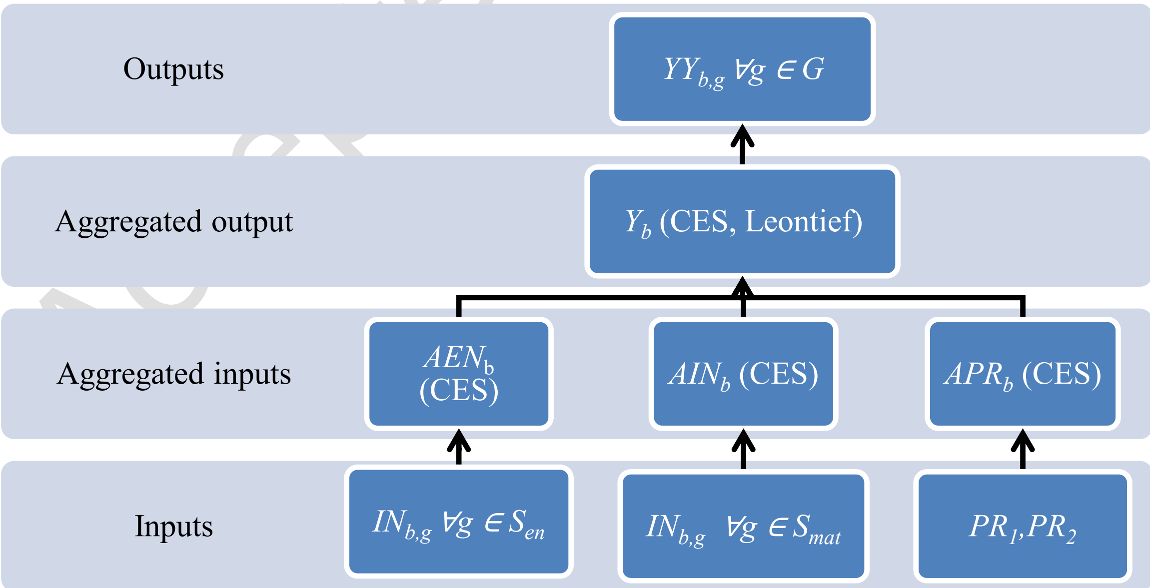
This section describes the AGE model developed and applied in this paper. The model is based on the model of Komen and Peerlings (1999). Their model included greenhouse gas emissions and policy scenarios to reduce these emissions. However, it did not distinguish between non-biobased and biobased energy. We present the model in Section 3.1 and discuss the modelling of taxes, subsidies, and technological change in section 3.2. A full description can be found in Appendix A.

3.1 General description

An AGE model describes an economy as a whole and is therefore useful to analyse large shocks to the economy that affect, through market linkages, all the economy's actors (i.e. industries, households, government). It mainly consists of demand and supply functions of commodities and factor inputs, and income formation and distribution equations (Dervis et al., 1982). The developed model contains 60 commodities and 60 industries including both a non-biobased and biobased energy commodity and industry. However, one industry can produce more than one commodity, and one commodity can be produced by more than one industry. Industries are assumed to minimise costs as they face a constant returns to scale nested Constant Elasticity of Substitution (CES) production function (see, e.g. Arrow et al., 1961; Sato, 1967).

Figure 2 shows that for industry b, the intermediate energy intermediate inputs ($IN_{b,g}$ $\forall g \in S_{en}$), material intermediate inputs ($IN_{b,g}$ $\forall g \in S_{mat}$) and primary inputs (PR_1, PR_2) are aggregated into 3 aggregate inputs respectively. This is done using 3 CES functions, each with their own substitution elasticity. The aggregate inputs are then aggregated into an aggregate output (Y_b) using a CES function with again its own substitution elasticity. The aggregated output is then divided into different outputs ($YY_{b,g}$) using a Leontief transformation function (i.e., using fixed ratios).

Figure 2. Production of industry b



Where:

$IN_{b,g}$ $\forall g \in S_{en}$: use of energy commodity g as an intermediate input in industry b. Commodities are in the set S_{en} of energy intermediate inputs.

$IN_{b,g}$ $\forall g \in S_{mat}$: use of commodity g as an intermediate input in industry b. Commodities are in the set S_{mat} of non-energy intermediate inputs.

PR_1, PR_2: labour (j=1) and capital (j=2) used in industry b.

AEN_b, $AINb$, and APR_b: aggregate energy, aggregate intermediate and aggregate primary input use, respectively, in industry b.

Y_b: aggregate output in industry b.

$YY_{b,g}$: output g of industry b.

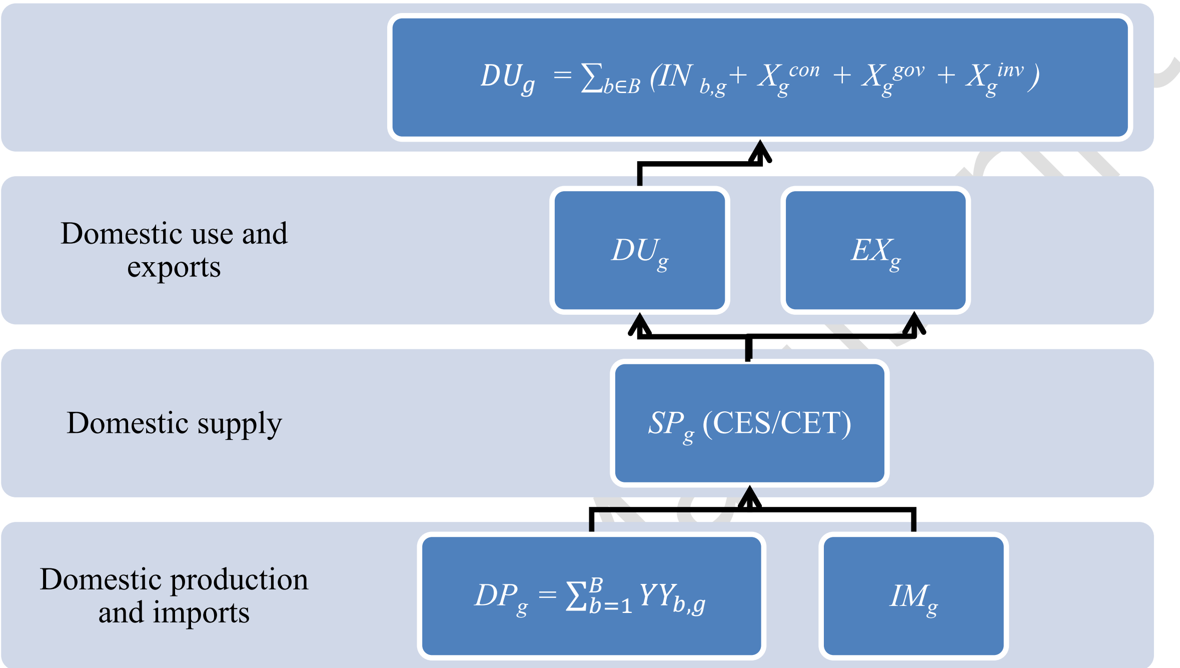
Source: Authors` elaboration

At the highest level, outputs are produced by an aggregate energy input, an aggregate intermediate input, and an aggregate factor input. At the lowest level, the aggregate energy input is composed of a biobased and a non-biobased energy input. The aggregate intermediate input is composed of 58 non-energy intermediate inputs. The aggregate factor input is composed of labour and capital. Cost minimisation leads to the demand for energy intermediate inputs, non-energy intermediate inputs, labour and capital.

Figure 3 shows that in the next step of the model, the outputs produced by different industries are aggregated commodity by commodity. Aggregation gives domestic production (DP_g) of a commodity g. Domestic production competes with imports of the same commodity (IM_g). This competition can be seen as an aggregation into total supply (SP_g) using a CES production function. The total supply is then disaggregated using a CET transformation function into domestic use (DU_g) and exports (EX_g). CES production and CET transformation functions imply that with profit maximisation relative prices determine demand and supply, respectively.

Domestic use equals the sum of intermediate demand ($\sum_{b \in B} IN_{b,g}$), private household demand (X_g^{con}), public household demand (X_g^{gov}) and investment demand (X_g^{inv}).

Figure 3. Supply and use of commodity g



Where:

DP_g : domestic production of commodity g.

IM_g : imports of commodity g.

SP_g : total supply of the commodity g.

DU_g : domestic use of the commodity g.

EX_g : exports of commodity g.

$IN_{b,g}$: intermediate input demand of commodity g in industry b.

X_g^{con}: private household demand of commodity g.

X_g^{gov}: public household demand of commodity g.

X_g^{con}: investment demand of commodity g.

Source: Authors` elaboration

The model includes one private household that supplies labour and capital to the industries and receives income in return. Capital and labour are assumed to be imperfectly mobile between industries. We also assume one aggregated public household (i.e., government). Consumption of commodity g by the private and public household follows from maximising a CES direct utility function given an income constraint. The CES utility function used implies an income elasticity of one. In addition, as a consumer, the public household imposes taxes and redistributes income. A fixed share of both private and public household income is saved. Savings together with the (minus) surplus on the balance of trade equal investment. Investment demand is modelled using a Leontief production function implying that the demand for an individual commodity is proportional to total investment (Komen & Peerlings, 2001).

The model also includes greenhouse gas emissions that are proportionally linked to the production of an industry (Y_b).

3.2 Taxes, subsidies, and technological change

All transactions in the model can be potentially taxed or subsidised. Taxes can be divided into product and non-product taxes (including subsidies). The latter are levied on income, the first on transactions of commodities. Product taxes drive a price wedge between the demand and the supply price. In the model, we use ad valorem taxes on demand (see Equation 1).

$$P_{demand} = (1 + tax_{rate})P_{supply} \qquad (1)$$

A tax increases the price demanders must pay and decreases the price suppliers receive; a subsidy does the opposite.

This paper also examines the effects of Hicks neutral technological change in the biobased energy industry. Hicks neutral technological change implies that with the same level and ratio between (all) inputs, more biobased energy can be produced. Equation 2 shows a CES input demand function. In the case of a Hicks neutral technological change, the exogenous scale parameter Γ increases. We include the Hicks neutral technological change in the aggregate demand functions (see Figure 2) of the biobased energy industry. Hicks neutral technological change implies that input demand (x_n) and cost of production decrease given a level of output *ceteris paribus*. However, in the AGE model, the *ceteris paribus* assumption does not hold, as Hicks neutral technological change lowers the price of wooden biomass as less is needed to produce biobased energy, making it more attractive to demand. Therefore, technological change in the production of biobased energy leads to an increase in the demand for wooden biomass and a lower price for biobased energy. In addition, the lower price of biobased energy leads, because of substitution, to a reduction in the demand for non-biobased energy by all demanders. The degree of substitution between biobased energy and non-biobased energy depends on the degree of substitution (i.e. substitution elasticity) between both in the different industries.

$$x_n(..) = y.\Gamma^{-1}.\alpha_n^{\sigma}.w_n^{-\sigma}.(\sum_{n=1}^{N}\alpha_n^{\sigma}.w_n^{1-\sigma})^{\frac{\sigma}{1-\sigma}} \qquad n = 1,..,N \qquad (2)$$

where: x_n - conditional demand for input n, y - output, $w_n -$ price of input n, σ- substitution elasticity, Γ - scale parameter and α_n - distribution coefficient of input n.

4. Data

The model uses the supply and use tables (SUT) at the basic prices from Latvia`s Central Statistical Bureau for 2015 (CSB Latvia, 2016). A supply table shows in its columns the supply of commodities by the different industries and by imports in an economy for a given period. A use table shows in its columns the use of commodities by type of use. Therefore, the use table reveals in its columns the input structure of each industry and the demand for individual commodities by the different final demand categories (Eurostat, 2008). Due to a lack of data, some industries and commodities are aggregated. The data set used in modelling contains 60 commodities and 60 industries (see Appendices B and C).

Furthermore, we use Latvia's 'energy SUT' in terajoules from Eurostat's 2015 Physical Energy Flow accounts (Eurostat, 2021) with energy commodities supplied/used by industries to split commodity ***Electricity, gas, steam and air-conditioning*** of the SUT in non-biobased and biobased ***Electricity, gas, steam and air-conditioning,*** respectively. We consider energy commodities wood, wood waste and other solid biomass, liquid fuels, and biogas as biobased energy commodities. Other energy commodities are fossil-based or renewable energy sources that are not biobased. This implies, for example, that electricity and heat are non-biobased energy products, but they can be produced using both the biobased and non-biobased product. The two energy commodities are used to calculate the shares of biobased and non-biobased energy commodities in the commodity and industry '***Electricity, gas, steam and air-conditioning***' in the SUT, respectively. According to the data of Physical Energy Flow accounts, 7.47% of the total energy supplied and 5.88% of the total energy used comes from biobased energy commodities.

5. Scenarios and Results

5.1 Scenarios

In the Base scenario, the model calculates back the actual situation of the Latvian economy in 2015. This includes a product tax of 17% for all energy commodities – biobased and non-biobased – since all energy producers pay the tax.

Scenario I

In Scenario I, we introduce an arbitrary 25% tax on non-biobased energy demand and a subsidy of 10% for biobased energy demand replacing the 17% tax on both products in the Base scenario (see Equation 1 and equations A.29-A.33 in Appendix A).

Scenario II

In Scenario II, a 25% Hicks neutral technological change in the biobased energy production industry is introduced in the Base scenario, where the scale parameter Γ in eq. (2) is increased by 25%. This scenario reflects the technological change in new technologies producing biobased energy that is partially stimulated by government investment from EU funds. The 25% is selected because it leads to a similar increase in the production of biobased energy as in Scenario 1.

5.2 Results

Table 3 shows the outcomes of both scenarios. It is important to note that all price changes are relative to the price numeraire chosen, which is the exchange rate in our case.

Scenario I

Table 3 shows that due to the switch to the subsidy (10%) on biobased energy, its production increases with 57.8%. Table 3 also shows that due to the tax (25%) on non-biobased energy, the price of non-biobased energy increases for buyers (8.3%). Moreover, production in the non-biobased energy industry decreases (-6.0%). This leads to a reduction in the value added (-2.9%) of this industry. Non-biobased energy is substituted by biobased energy in all industries where the degree of substitution depends on the substitution elasticity between non-biobased and biobased energy. In the model, we assume that this substitution elasticity is large ($\sigma = 1.5$), implying that the degree of substitution is large (see Appendix D). In all industries, we see therefore a reduction in the demand of non-biobased energy and an increase in the use of biobased energy. Overall, the use of energy falls between 1-3% (a reduction of *AENb;* see Figure 2). The increase in biobased energy production (57.8%) leads to a reduction in imports of biobased energy products (i.e. natural gas and oil) of 4.2%, making Latvia less dependent on energy imports. However, the subsidy on non-biobased energy increases the imports of this product (64.4%). However, these imports are still very small. Table 3 shows a 1.7% reduction in CO_2 emissions assuming CO_2 emissions from the biobased energy product to be zero (i.e. being climate neutral). The reduction largely follows from the reduced use of non-biobased energy products (5.7%). Despite this reduction, the target of 50% energy from biobased sources is not reached.

Overall, there is a welfare gain (63.5 million euros) in Scenario I, where we measured welfare as private, public, and investment demand changes in prices of the base year. The welfare gain results from a reduction in already existing distortions by introducing the subsidy for biobased products (replacing the 17% tax) and increasing the tax on non-biobased products (from 17% to 25%). Therefore, there is a double dividend. However, whether the double dividend exists depends on the level of tax and subsidy. Sensitivity analyses show that larger taxes and subsidies create welfare losses and that especially the subsidy helps to reduce already existing distortions. Table 3 shows that the increase in tax revenue from the product-related tax on non-biobased energy production (117.4 million euro) is larger than the cost of the switch from the tax to the subsidy for the biobased product (45.6 million euro).

Scenario II

Table 3 shows that Hicks neutral technological change of 25% (Scenario II) results in a reduction in the price of biobased energy (-28.1%) and therefore, an increase in production (57.9%) and value added (10.3%) in the biobased energy industry. This leads to a substitution away from non-biobased energy and a reduction in the production (-1.2%) and value added (-

0.8%) in the non-biobased energy industry. Also, in this scenario, import of the biobased energy product fall (-2.5%). The lower price of the biobased energy product decreases imports of the biobased energy product (-12.4%). Again, imports are very small. Compared to Scenario I, the reduction in CO_2 emissions is smaller (0.3% versus 1.7%) because the price and production of non-biobased products changes less, and therefore, less substitution takes place. The welfare increase is similar to the welfare increase in Scenario I (61.9 million euros). This welfare gain results from the fact that fewer inputs are needed in the production of biobased energy. This shows the attractiveness of technological change. However, in this scenario, technological change is 'free', and this is, of course, not true.

Overall, one can conclude that the effects for the Latvian economy are not large. Important reasons for this are the fact that the biobased energy industry is small and even a large growth in production (57.8% and 57.9% in Scenario I and II respectively) does not create a substantial change. Another reason is that in the AGE model factor inputs are mobile between industries making that labour and capital moving out of industries affected negatively by the scenarios can be used elsewhere in the economy leading there to higher production and value added. Finally, the AGE model allows for substitution because of relative price change, again smoothing the effect for the economy as a whole.

Table 3. Scenario results compared to initial values (i.e., Base scenario)

	Initial values	Scenario I: Tax and subsidy (% change)	Scenario II: Technological change (% change)
Production* and value added in million euro of the base year**			
Production of non-biobased energy industry (Y_b)	1,766.3	-6.0	-1.2

Production of biobased energy industry (Y_b)	110.3	57.8	57.9
Forestry production (Y_b)	938.9	-0.3	-0.1
Value added in non-biobased energy industry (APR_b)	663.6	-2.9	-0.8
Value added in biobased energy industry (APR_b)	34.2	27.7	10.3
Value added in forestry (APR_b)	352.8	-0.2	-0.1
Prices (index, so no unit)			
Price of non-biobased energy production (price of DP_g)	1.00	1.2	-0.8
Price of biobased energy production (price of DP_g)	1.00	9.4	-28.1
Price of non-biobased energy demand (price of DU_g)	1.17	8.3	-0.8
Price of biobased energy demand (price of DU_g)	1.17	-16.1	-28.8
CO_2 emissions[***] in 1000 tons			
CO_2 emissions in non-biobased energy industry	1,757,841	-6.0	-1.2
Total CO_2 emissions	6,937,629	-1.7	-0.3
Tax revenue in million euro (nominal)		(M euro)	(M euro)
Product tax paid on non-biobased energy product	293.7	411.1	287.7
Product tax paid on biobased product	23.7	-21.9	24.5
Welfare in million euro of the base year		(M euro)	(M euro)
Laspeyers index		63.5	61.9

* Note: quantities are expressed in million euros for the base year 2015. This implies that initial supply prices (indices) are equal to 1; the initial price for energy demanders is equal to 1.17 due to the 17% tax on energy demand.

** Value added equals the value of capital and labour.

*** Excluding CO_2 emissions from biobased energy commodities that are assumed to be climate neutral.

Source: Authors` elaboration

6. Conclusions and Discussion

This paper aims to assess the effect of a tax on non-biobased energy demand and a subsidy on biobased energy demand replacing a lower tax on both to facilitate the substitution of the first for the latter as a step in the transition of Latvia's economy towards climate neutrality and energy self-sufficiency. Furthermore, the effects of Hicks neutral technological change in the biobased energy industry are examined. The paper uses an applied general equilibrium (AGE) model to assess the effects of a tax, subsidy, and technological change given the expected economy-wide effects and interest in national emissions and welfare.

The paper finds that a tax in combination with the subsidy indeed has the expected effects. The Green Deal proposed decarbonisation of the economy by transitioning from fossil-based to renewable sources in energy production. Latvia aims to increase the share of renewable energy production in total energy production to 50% by 2030 (it was 39% in 2017), focussing on the use of wooden biomass in energy production. According to the results of the model, the supply of the biobased energy commodity has increased by 57.8%. However, measures are insufficient to deliver the target, climate neutrality, and energy self-sufficiency. However, there is an overall welfare gain in both Scenario I and Scenario II. So, Scenario I reduces existing distortions in Latvia's economy (i.e., double dividend). Scenario II (technological change in the biobased energy industry) leads to a similar increase in the production and use of biobased energy. Because in Scenario II the prices of non-biobased energy are affected less than in Scenario I, it`s production and use fall less leading to a lower reduction in CO_2 emissions. Although the welfare gain is similar to the gain in Scenario I, Scenario II ignores the costs of technological change and does not explicitly include the incentives needed to implement it.

To our knowledge, there are no prior studies on the use of wooden biomass for bioenergy production in Latvia. While there are studies of the AGE model on energy taxes, they are not recent. For example, Komen and Peerlings (1999) analysed the effect of an energy tax on small users in the Netherlands using 1990 data. They only find a double dividend in the case of small tax rates. Goulder (1995) discusses the double dividend in more detail, coming to the same conclusion. Welfare effects found by Komen and Peerlings (1999) are also small, like in our case. This is largely due to the substitution possibilities economy-wide and fixed endowments of labour and capital in combination with factor mobility in the models used.

This study has three main caveats. First, Latvia devised an action plan in 2019, and is currently undergoing upgrading procedure, although the exact measures are largely unknown. Therefore, it is not possible to calculate the effects of actual policies. This research can contribute to the formulation of such policies. Second, data on energy use and supply are largely aggregated and had to be disaggregated for this study. This involved arbitrary choices. This emphasises the importance of data collection. Related to this, in the base year there is hardly and use of other renewable energy sources than biomass from forests and wood. Wind and solar energy are negligible, although there is some hydropower. It is to be expected that the share of wind and solar energy will grow, requiring that in future research they must be considered separate energy products. Finally, an AGE model is a powerful tool to analyse the economy-wide effects of policies but also comes at a price. For example, the level of aggregation is high, for example, it distinguishes not between, e.g. electricity and heat production. Despite these caveats, this study contributes to the discussion of the transition of the Latvia`s economy towards climate neutrality and energy self-sufficiency.

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Appendices

Appendix A Model description

Demand and supply equations

Aggregate output in industry b (Y_b) is composed of a hypothetical aggregate energy input (AEN_b), aggregate intermediate input (AIN_b) and aggregate factor input (APR_b) according a CES production function with constant returns to scale (see glossary at the end of this Appendix for overview of variables, coefficients and sets). Intermediate inputs g in industry b ($IN_{b,g}$) are transformed into an aggregate energy and aggregate intermediate input according to the CES production functions with constant returns to scale. Labor ($PR_{b,1}$) and capital ($PR_{b,2}$) in industry b are transformed into the aggregate factor input, using a CES production function with constant returns to scale. Cost minimization yields CES demand functions for the aggregate energy (A.1), aggregate intermediate (A.2), aggregate factor (A.3), energy (A.4), intermediate (A.5) and factor inputs (A.6):

$$AEN_b = f^{CES}_{AEN_b}(Y_b, WAEN_b, WAIN_b, WAPR_b) \qquad \forall b \in B \qquad \text{(A.1)}$$

$$AIN_b = f^{CES}_{AIN_b}(Y_b, WAEN_b, WAIN_b, WAPR_b) \qquad \forall b \in B \qquad \text{(A.2)}$$

$$APR_b = f^{CES}_{APR_b}(Y_b, WAEN_b, WAIN_b, WAPR_b) \qquad \forall b \in B \qquad \text{(A.3)}$$

$$IN_{b,g} = f^{CES}_{EN_{b,g}}(AEN_b, \boldsymbol{WIN_g}) \qquad \forall b \in B, \forall g \in S_{en} \qquad \text{(A.4)}$$

$$IN_{b,g} = f^{CES}_{IN_{b,g}}(AIN_b, \boldsymbol{WIN_g}) \qquad \forall b \in B, \forall g \in S_{mat} \qquad \text{(A.5)}$$

$$PR_{b,j} = f^{CES}_{PR_{b,j}}(APR_b, \boldsymbol{WPR_{b,j}}) \qquad \forall b \in B, \forall j \in J \qquad (A.6)$$

Supply of output g by industry b ($YY_{b,g}$) is proportional to the aggregate output (Y_b) by industry b (A.7). Aggregation of outputs over industries gives domestic production (DP_g) of commodity g (A.8):

$$YY_{b,g} = \delta^Y_{b,g} \times Y_b \quad \sum_{g \in G} \delta^Y_{b,g} = 1 \qquad \forall b \in B, \forall g \in G \qquad (A.7)$$

$$DP_g = \sum_{b=1}^{B} YY_{b,g} \qquad \forall g \in G \qquad (A.8)$$

Domestic production (DP_g) and imports (IM_g) are aggregated into total supply of commodity g (SP_g) using a CES production function with constant returns to scale. This implies that the Armington assumption is adopted (see Dervis et al., 1982, p.221). The total supply is then divided into domestic use (DU_g) and exports (EX_g) using a CET product transformation function with constant returns to scale. Cost minimization yields CES demand equations for domestic production (A.9) and imports (A.10) and revenue maximization yields CET supply equations for domestic use (A.11) and exports (A.12):

$$DP_g = f^{CES}_{DP_g}(SP_g, WDP_g, WIM_g) \qquad \forall g \in G \qquad (A.9)$$

$$IM_g = f^{CES}_{IM_g}(SP_g, WDP_g, WIM_g) \qquad \forall g \in G \qquad (A.10)$$

$$DU_g = f^{CET}_{DU_g}(SP_g, WDU_g, WEX_g) \qquad \forall g \in G \qquad (A.11)$$

$$EX_g = f^{CET}_{EX_g}(SP_g, WDU_g, WEX_g) \qquad \forall g \in G \qquad (A.12)$$

Total labour (j=1) and total capital (j=2) available in the economy (TPR_j) are divided into supply of labour ($PR_{b,1}$) and capital ($PR_{b,2}$) by industry using CET product transformation functions with constant returns to scale. Revenue maximisation yields supply functions for labor and capital, respectively (A.13):

$$PR_{b,j} = f^{CET}_{pr_{b,j}}(\overline{TPR_j}, \boldsymbol{WPR_{b,j}}) \qquad \forall b \in B, \forall j \in J \qquad \text{(A.13)}$$

Maximization of the CES utility functions yields CES demand equations for the private household (A.14) and public household (A.15):

$$CON_g = f^{CES}_{con_g}(EXP^{con}, \boldsymbol{WCON_g}) \qquad \forall g \in G \qquad \text{(A.14)}$$

$$GOV_g = f^{CES}_{gov_g}(EXP^{gov}, \boldsymbol{WGOV_g}) \qquad \forall g \in G \qquad \text{(A.15)}$$

The demand for investment goods (X^{inv}_g) is given by (A.16):

$$INV_g = \delta^{inv}_g \times INV \quad \textstyle\sum_{g \in g} \delta^{inv}_g = 1 \qquad \forall g \in G \qquad \text{(A.16)}$$

Zero-profit conditions

The value of the disaggregated outputs by industry is equal to the value of the aggregate output produced by industry (A.17). The value of aggregate output equals the value of the aggregate energy input, aggregate intermediate input and aggregate factor input (A.18):

$$\textstyle\sum_{g \in G} WDP_g \, Y_{b,g} = WY_b \times Y_b \qquad \forall b \in B \qquad \text{(A.17)}$$

$$WY_bY_b = WAEN_b \times AEN_b + WAIN_b \times AIN_b + WAPR_b \times APR_b \qquad \forall b \in B \qquad (A.18)$$

The value of the aggregate energy input is equal to the value of the energy inputs by industry (A.19). The value of the aggregate intermediate input equals the value of the intermediate inputs by industry (A.20). The value of the aggregate factor input equals the value of labour and capital by industry (A.21):

$$WAEN_b \times AEN_b = \sum_{g \in S_{en}} WIN_{b,g} \times IN_{b,g} \qquad \forall b \in B \qquad (A.19)$$

$$WAIN_b \times AIN_b = \sum_{g \in S_{mat}} WIN_{b,g} \times IN_{b,g} \qquad \forall b \in B \qquad (A.20)$$

$$WNAPR_b \times APR_b = \sum_{j=1}^{2} WPR_{b,j} \times PR_{b,j} \qquad \forall b \in B \qquad (A.21)$$

The value of total supply (SP_g) equals the sum of the value of domestic production and imports (A.22) and the sum of the value of domestic use and exports by commodity (A.23):

$$WSP_g \times SP_g = WDP_g \times DP_g + WIM_g \times IM_g \qquad \forall g \in G \qquad (A.22)$$

$$WSP_g \times SP_g = WDU_g \times DU_g + WEX_g \times EX_g \qquad \forall g \in G \qquad (A.23)$$

The value of the supply of labour and capital equals the value of the total availability of labour and capital, respectively (A.24).

$$\sum_{B \in b}\left(WPR_{b,j} \times PR_{b,j}\right) = WTPR_j \times \overline{TPR_j} \qquad \forall j \in J \qquad (A.24)$$

The value of the demand for individual investment goods equals the expenditure on investment (A.25):

$$\sum_{g \in G}\left(WINV_g \times INV_g\right) = WINV \times INV \quad \text{(A.25)}$$

Margins

The value of demand/supply for margins per commodity (MAR_g) is assumed to form a share of the value of the different demand categories and is given by (A.26).

$$MAR_g = m_g^{sp} \times WDU_g \times DU_g + m_g^{sp} \times WEX_g \times EX_g \qquad \forall g \in G \quad \text{(A.26)}$$

The total value of the margins is zero (A.27):

$$\sum_{g \in G} MAR_g = 0 \quad \text{(A.27)}$$

Equilibrium conditions for commodities

Total domestic use equals intermediate, private household, public household and investment demand (A.28):

$$DU_g = \sum_{b \in B} IN_{b,g} + CON_g + GOV_g + INV_g \qquad \forall g \in G \quad \text{(A.28)}$$

Price equations

Indirect taxes and margins drive a wedge between the demanders' and suppliers' price of domestic use. This applies to commodities consumed by the private household (A.29), the public household (A.30), as investment commodities (A.31), as intermediate inputs (A.32) and as exports (A.33):

$$WCON_g = \left(1 + m_g^{sp} + t_g^{sp}\right) \times WDU_g \tag{A.29}$$

$$WGOV_g = \left(1 + m_g^{sp} + t_g^{sp}\right) \times WDU_g \tag{A.30}$$

$$WINV_g = \left(1 + m_g^{sp} + t_g^{sp}\right) \times WDU_g \tag{A.31}$$

$$WIN_g = \left(1 + m_g^{sp} + t_g^{sp}\right) \times WDU_g \tag{A.32}$$

$$WGEX_g = \left(1 + m_g^{sp} + t_g^{sp}\right) \times WEX_g \tag{A.33}$$

The price received for exports (A.34) and paid for imports (A.35) are equal to the world market price times the exchange rate:

$$WGEX_g = \overline{WPEX_g} \times \overline{ER} \tag{A.34}$$

$$WIM_g = \overline{WPIM_g} \times \overline{ER} \tag{A.35}$$

Non-product related taxes are levied on the total value of labour and capital used by industry (A.36):

$$WAPR_b = \left(1 + t_b^{apr}\right) \times WNAPR_b \tag{A.36}$$

Income formation and distribution

Tax revenue from product (PTX) and non-product related taxes ($NPTX$) and social contribution ($SOCCON$) is given by equations A.37, A.38 and A.39, respectively:

$$PTX = \sum_{g \in S} \left(t_g^{sp} \times WDU_g \times DU_g + t_g^{sp} \times WEX_g \times EX_g \right) \tag{A.37}$$

$$NPTX = \sum_{b \in B} \left(t_b^{apr} \times WNAPR_b \times APR_b \right) \tag{A.38}$$

$$SOCCON = r_{soccon} \times LABI \tag{A.39}$$

Labour income ($LABI$), capital income ($CAPI$) and capital depreciation (DEP) are given by equation A.40, A.41 and A.42 respectively:

$$LABI = WTPR_1 \times \overline{TPR_1} \tag{A.40}$$

$$CAPI = WTPR_2 \times \overline{TPR_2} \tag{A.41}$$

$$DEP = r_{capdep} \times CAPI \tag{A.42}$$

The income (I^{con}), expenditure EXP^{con} and savings (SAV^{con}) of the private household are given by equations A.43, A.44 and A.45 respectively:

$$I^{con} = (1 - r_{soccon}) \times LABI + (1 - r_{capdep}) \times CAPI \tag{A.43}$$

$$EXP^{con} = (1 - s^{con}) \times I^{con} \tag{A.44}$$

$$SAV^{con} = s^{con} \times I^{con} \tag{A.45}$$

The income (I^{gov}), expenditure (EXP^{gov}) and savings (SAV^{gov}) of the public household are given by equations A.46, A.47 and A.48, respectively:

$$I^{gov} = PTX + NPTX + SOCCON \tag{A.46}$$

$$EXP^{gov} = (1 - s^{gov}) \times I^{gov} \tag{A.47}$$

$$SAV^{gov} = s^{gov} \times I^{gov} \tag{A.48}$$

Total savings (A.49) equal the sum of the savings of the private household, public household and capital depreciation minus the surplus on the balance of trade (BBAR). As the balance of trade is expressed in foreign price it must be multiplied by the exchange rate (ER):

$$SAV = SAV^{con} + SAV^{gov} + DEP - BBAR \times \overline{ER} \tag{A.49}$$

The surplus on the balance of trade (A.50) equals:

$$BBAR = \sum_{g \in G} \left(\overline{WPEX}_g \times EX_g \right) - \sum_{g \in G} \left(\overline{WPIM}_g \times IM_g \right) \tag{A.50}$$

The value of investment ($INVT$) equals the value of the savings (A.51) but also the value of the investment commodities (A.52). Due to Walras' law, one equation must be dropped to keep the model identified. In the operational model this is Equation A.52.

$$INVT = SAV \tag{A.51}$$

$$INVT = WINV \times INV \tag{A.52}$$

Price numéraire

An applied general equilibrium model is homogenous of degree zero. This model selects the exchange rate as price numéraire.

Environment

CO_2, CH_4, N_2O emissions of an industry ($EMIS_b$) equals the share (amount) of emissions (δ_b^{emis}) emitted by the industry($Y_{b\ old}$).

$$\delta_b^{emis} = EMIS_{b\ old}/Y_{b\ old} \tag{A.53}$$

$$EMIS_b = \delta_b^{emis} \times Y_b \tag{A.54}$$

Welfare change

As a welfare measure, the Laspeyres index of real income change is taken. This index compares commodity bundles between two equilibria (e.g. before and after a policy change), using the prices of the initial equilibrium (A.55). This welfare measure allows for the calculation of the welfare effects of savings other than the private savings of which the underlying optimizing behaviour is not modelled explicitly (i.e., capital depreciation, government deficit and the balance of trade). Since savings are equal to investments, the bundle of investment commodities represent welfare derived from saving.

$$WELF = \sum_{g \in S}\left(WCON_g^{old} \times CON_g^{old}\right) + \sum_{g \in S}\left(WGOV_g^{old} \times GOV_g^{old}\right) + \sum_{g \in S}\left(WINV_g^{old} \times INV_g^{old}\right) - \sum_{g \in S}\left(WCON_g^{old} \times CON_g\right) - \sum_{g \in S}\left(WGOV_g^{old} \times GOV_g\right) - \sum_{g \in S}\left(WINV_g^{old} \times INV_g\right) \tag{A.55}$$

Glossary

Variables:

Quantities

Y_b	aggregate output of industry b
AEN_b	aggregate intermediate energy input in industry b
AIN_b	aggregate intermediate materials input in industry b
APR_b	aggregate factor input in industry b
$IN_{b,g}$	intermediate input g in industry b
$PR_{b,j}$	labour (j=1) and capital (j=2) in industry b
$YY_{b,g}$	output g of industry b
DP_g	domestic production of commodity g
IM_g	import of commodity g
SP_g	total supply of commodity g
DU_g	domestic use of commodity g
EX_g	export of commodity g
$\overline{TPR_j}$	labour (j=1) and capital (j=2) endowment in the economy
CON_g	consumer demand for commodity g
GOV_g	government demand for commodity g
INV_g	demand of investment good g
INV	aggregate investment good
$EMIS_b$	emissions of industry b

Prices (quantity symbols plus a W)

$WAEN_b$	price of aggregate intermediate energy input in industry b
$WAIN_b$	price of aggregate intermediate materials input in industry b

$WAPR_b$ price of aggregate factor input including tax in industry b

$WNAPR_b$ price of aggregate factor input excluding the tax in industry b

WIN_g price of intermediate input g

$WPR_{b,j}$ price of labour (j=1) or capital (j=2) used in industry b

WIM_g price of import of commodity g

$\overline{WPIM_g}$ world market price of import of commodity g

WDP_g price of domestic production of commodity g

WY_b price of aggregate output of industry b

WSP_g price of total supply of commodity g

WDU_g price of domestic use of commodity g

WEX_g price of export excluding taxes and margins of commodity g

$WGEX_g$ price of export including taxes and margins of commodity g

$\overline{WPEX_g}$ world market price of export of commodity g

$WCON_g$ price of commodity g demanded by the private household

$WGOV_g$ price of commodity g demanded by the public household

$WTPR_j$ price of labour (j=1) and capital (j=2) endowment in the economy

$WINV_g$ price of investment good g

$WINV$ price of aggregate investment good

Other

$\overline{ER}$ exchange rate

MAR_g value of demand/supply of margins by commodity g

$LABI$ labour income

$CAPI$ capital income

DEP capital depreciation

I^{con} income of private household

I^{gov} income of public household

EXP^{con} expenditure of private household

EXP^{gov} expenditure of public household

SAV^{con} expenditure of private household

SAV^{gov} expenditure of public household

SAV total savings

$BBAR$ surplus on the trade balance (in foreign prices)

DEP capital depreciation

$INVT$ value of the investment

PTX value of the product related taxes

$NPTX$ value of the non-product related taxes

$SOCCON$ social contributions

$WELF$ welfare change

Fixed coefficients

δ_b^{emis} coefficient dividing aggregate emissions by industry b

m_g^{sp} margins for commodity g

t_g^{sp} tax rate for product related taxes on commodity g

t_b^{apr} tax rate for non-product related taxes in industry b

$\delta_{b,g}^{Y}$ coefficient dividing aggregate output into outputs g in industry b

δ_g^{inv} coefficient dividing aggregate investment good into investment good g

s^{con} savings rate of the private household

s^{gov} savings rate of the public household

r_{soccon} share of labour income that goes to social contributions

r_{capdep} capital depreciation as share of capital income

Sets and subsets:

G: goods, g = 1 to 60

B: industries, b = 1 to 60

J: factors, j = 1 (labour) j = 2 (capital)

$S_{en} \subset G$: subset energy commodities: g = 24,25

$S_{mat} \subset G$: subset materials: g = 1,…,23,26,…,60

Miscellaneous

gov = public household; con = private household; inv = investment; en = energy; old = base year value; CES = Constant Elasticity Substitution; CET = Constant Elasticity of Transformation

Bold printed variables represent a vector; variables with a bar represent exogenous variables.

Appendix B Aggregation level of commodities and industries in Supply-Use tables

CPA/NACE code	**Commodity/Industry**
A01	Crop and animal production, hunting and related service activities
A02	Forestry and logging
A03	Fishing and aquaculture
B	Mining and quarrying
C10_12	Manufacture of food products, beverages and tobacco products
C13_15	Manufacture of textiles, wearing apparel and leather products

C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
C17	Manufacture of paper and paper products
C18	Printing and reproduction of recorded media
C19	Manufacture of coke and refined petroleum products
C20	Manufacture of chemicals and chemical products
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
C22	Manufacture of rubber and plastic products
C23	Manufacture of other non-metallic mineral products
C24	Manufacture of basic metals
C25	Manufacture of fabricated metal products, except machinery and equipment
C26	Manufacture of computer, electronic and optical products
C27	Manufacture of electrical equipment
C28	Manufacture of machinery and equipment n.e.c.
C29	Manufacture of motor vehicles, trailers and semi-trailers
C30	Manufacture of other transport equipment
C31_32	Manufacture of furniture; other manufacturing
C33	Repair and installation of machinery and equipment
D35-1	Biobased energy
D35-2	Non-biobased energy
E36	Water collection, treatment and supply
E37_39	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services
F	Construction

G	Wholesale and retail trade
H49	Land transport and transport via pipelines
H50_51	Water and Air transport
H52	Warehousing and support activities for transportation
H53	Postal and courier activities
I	Accommodation and food service activities
J58	Publishing activities
J59_60	Motion picture, video and television program production, sound recording and music publishing activities; programming and broadcasting activities
J61	Telecommunications
J62_63	Computer programming, consultancy and related activities; information service activities
K64	Financial service activities, except insurance and pension funding
K65	Insurance, reinsurance and pension funding, except compulsory social security
K66	Activities auxiliary to financial services and insurance activities
L68	Real estate activities
M69_70	Legal and accounting activities; activities of head offices; management consultancy activities
M71	Architectural and engineering activities; technical testing and analysis
M72	Scientific research and development
M73	Advertising and market research
M74_75	Other professional, scientific and technical activities; veterinary activities
N77	Rental and leasing activities
N78	Employment activities

N79	Travel agency, tour operator reservation service and related activities
N80_82	Security and investigation activities; services to buildings and landscape activities; office administrative, office support and other business support activities
O	Public administration and defense; compulsory social security
P	Education
Q86	Human health activities
Q87_88	Social work activities
R90_92	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities
R93	Sports activities and amusement and recreation activities
S94	Activities of membership organizations
S95	Repair of computers and personal and household goods
S96_T	Other personal service activities

Appendix C Industries ranked according to the largest shares in supply and use of biobased energy commodities

Suppliers of Energy commodities*	**Users of Energy commodities****
Forestry and logging	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
Fishing and aquaculture	Manufacture of chemicals and chemical products
Manufacture of machinery and equipment n.e.c.	Residential care activities and social work activities without accommodation

Rental and leasing activities	Sewerage, waste management, remediation activities
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	
Manufacture of chemicals and chemical products	
Manufacture of furniture; other manufacturing	
Retail trade, except of motor vehicles and motorcycles	

* 90%<

**30%<

Source: author`s calculations based on Eurostat, 2021

Appendix D Substitution (sigma) and transformation (omega) elasticities

Symbol	**Function**	**Value**
SIGMAY (B)	CES for output	0.4
SIGMAPR (B)	CES for aggregate primary input	0.4
SIGMAE (B)	CES for aggregate energy input	1.5
SIGMAX (B)	CES for aggregate intermediate input	0.4
SIGMADOMS (G)	CES for domestic supply	1.5
OMEGADOMD (G)	CET for domestic demand	-1.5