Evaluating Climate Policy Effectiveness: A Financial Perspective on Production vs. Consumption-Based Carbon Taxation

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Abstract

In this paper, we evaluate the effectiveness of carbon taxation in Denmark, with a specific focus on the proposed CO2-equivalent (CO2E) tax on the Danish agricultural industry. We compare the outcomes of a consumption-based tax on high CO2E-intensive food products and a production-based tax on the agricultural industry. Using an Ecological Stock-Flow-Consistent Input-Output (E-SFC-IO) model, we assess the impact of both tax scenarios on CO2E emissions, economic performance, and financial net wealth. Scenario 1 implements a consumption tax on meat and dairy products, while Scenario 2 introduces a production tax in the agricultural sector. The analysis reveals that while the production tax results in a lower GDP loss per ton of CO2E emissions reduced, it affects the financial net wealth of domestic sectors negatively, as wealth shifts toward the rest of the world through negative impacts on international trade. In contrast, the consumption tax produces more moderate emissions reductions but leaves the government with a surplus, allowing for additional policy measures. We find that a combined tax and subsidy approach on consumer products has the potential to reduce emissions with minimal effects on economic and financial outcomes. The findings highlight the importance of considering environmental, economic, and financial impacts when designing climate policies.

1. Introduction

As 2030 approaches, it is becoming increasingly clear that many countries may struggle to meet their climate goals under their current environmental regulations (ECA, 2023). In addition to national targets, larger entities such as the EU have established their own climate objectives for 2030 (European Commission, 2020). Under the 2023 revision of the EU's Effort Sharing Regulation (ESR), member states are collectively committed to reducing GHG emissions in non-ETS sectors—including agriculture, transport (excluding aviation), building heating, small industries, and waste—by 50% compared to 2005 levels by 2030. In Denmark, achieving this reduction in non-ETS sectors has proven particularly challenging, especially as the agricultural sector continues to account for an increasing share of the country's CO2-equivalent (CO2E) emissions.

To address this challenge, a Danish parliamentary expert group was tasked with identifying the most effective strategies for Denmark to meet both its national and EU climate targets. One specific request from the parliament was to compare the effects of implementing a carbon tax on consumers versus producers. In the

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expert group's final recommendations, a key focus was on reducing emissions in the Danish agricultural sector, which had largely been exempt from mitigation policies like carbon taxes and the EU-ETS program. Based on these recommendations, in June 2024, the Danish parliament reached an agreement with several interest organizations, including one representing Danish farmers, to introduce a direct CO2E tax on the agriculture industry, with implementation set for 2030 (Danish Parliament 2024). This would make Denmark the first country in the world to implement such a tax directly on CO2E emissions in the agriculture industry. In their final report (referred to as the Svarer report) three possible tax-setups are recommended - all targeting the production level of the Danish agriculture industry (Svarer et al. 2024). Their rationale for excluding a consumer tax from its final recommendations, is primarily due to the argument that a production tax will cover emissions from the production of exported goods, while also encouraging individual farmers to adopt more climate-friendly technologies, as this reduces production costs directly. While these effects will not be present with a tax on consumers, two main advantages of a consumption tax can be considered. First, a consumption tax will under the regulations of WTO most likely be enforced on both domestically and imported goods (see eg. Jakob M 2014), whereas the tax will cover a larger level of CO2E emissions for developed countries for which consumption based emissions are larger than production based emissions (see e.g. Peters et al. 2011; Peters and Hertwich 2007; Wiebe et al. 2012; Zhongxiu and Yunfeng 2014). Secondly, as a consumption tax will affect prices on domestically produced and imported products evenly, no carbon leakage effects will occur.[1] The term carbon leakage is used to describe the case in which a reduction in territorial emission leads to an increase in emissions abroad. In the case of a production tax, the higher costs in the regulated industry are pushed on to consumers, increasing imports and reducing exports thereby leading to increased production and emissions outside the regulated area (Levinson and Taylor 2008).[2] Due to the growth of emissions embodied in international trade the question raised by recent literature is whether an alternative to the production based accounting policies (PBA) should be considered, in which policies using consumption based accounting methods (CBA) seem to be the most prominent alternative (see eg. Afionis et al. 2017; Rocco et al. 2020).

A few studies have compared the effectiveness of consumption based and production based policy measures (see eg. Liu et al. 2018; Rocco et al. 2020; Sommer & Kratena 2020; Nabernegg et al. 2019) in most cases, the discussion leads to whether the carbon leakage effects associated with production based measures are large enough to favor a tax targeting consumption. In this paper, we introduce an additional implication as we look at who, in the end, is financing the policy in question– domestic households, the government, domestic firms, or the rest of the world? The focus towards the financial site of the economy, seem to be excluded in the current literature on optimal carbon mitigation policies, most likely because the financial sector is rarely included in

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[1] In some cases, this might even lead to negative carbon leakage as imports fall if final demand is reduced.

[2] For a more detailed analysis of possible carbon leakage effects in the Danish economy see Thomsen 2024 and Kruse-Andersen et al. 2021.

environmentally specified CGE models (Liu et al. 2017). On the other hand, Stock Flow Consistent models explicitly incorporate the financial sector. This explicit inclusion of banks and other financial institutions allows for loans to companies, the government, and households, just like it opens up questions related to allocation of wealth among different financial assets and across sectors (see eg. Godley & Lavoie 2006; Lavoie and Godley 2001). In recent literature, the combination of Stock Flow Consistent models with environmentally-extended input-output analysis has shown promising signs for integrating concerns about ecological impacts and the financial sector (Hardt & O'Niell 2017). The purpose of this paper is to evaluate and compare the effects of a production tax in the Danish agricultural industry with a consumption tax on high CO2E intensity food products. We combine environmentally-extended input-output analysis and stock-flow consistent modelling by using an Empirical Ecological Stock-Flow-Consistent Input-Output model (ESFC-IO) for Denmark (see Thomsen et al. 2024 for a detailed presentation of the model). Besides from using environmental and economic measures, the combination of stock-flow consistent models with environmentally-extended input-output analysis, allow us to focus on reallocation of wealth when evaluating climate policies. Our analysis will bring about several contributions: i) it allows us a more holistic evaluation of the consumption and production tax including the development of financial net wealth for the different sectors, both in the Danish economy and for the rest of the world. ii) our framework diverges from the popular supply-driven models by adopting a purely demand-driven set-up, which arguably is better suited for analyzing a consumption tax on households as it directly affects final demand. iii) we contribute to the sparse but emerging literature on empirical SFC-IO models, applying such a model to estimate the reduction potential of both production and consumption based policies in the Danish economy

2. Literature review

One of the most widely discussed policy measures for mitigating climate change is carbon pricing (Rosenbloom et al. 2020). The two primary approaches to carbon pricing are carbon taxation and cap-and-trade systems. In the typical framework, carbon taxation involves imposing a tax on CO2-equivalent (CO2E) emissions, often estimated through energy consumption, while cap-and-trade systems establish a fixed limit on the quantity of emissions allowed (Stern and Stiglitz 2017). In the current literature, carbon mitigation policies are usually evaluated within the framework of Computational General Equilibrium models (CGE) in which Babatunde et al. (2017) provides a review of the application using this framework. Models within this framework are often built around a general set-up presented by the GTAP-E model (see eg. Burniaux & Truong (2002); McDougall & Golub (2007); Truong & Kemfert (2007)), which is an energy-environmental version of the GTAP-model (using the GTAP-database originally presented by Hertel & Tsigas (1997)). Kruse-Andersen and Sørensen (2022) use a modified version of the GTAP-E model to study the optimal carbon tax policy in EU frontrunner countries. Their results suggests that in the case of Denmark, the carbon price should be 33% higher in the EU-ETS (Emission Trading System) sectors compared to EU-non-ETS sectors. According to

Kruse-Andersen & Sørensen (2022) this can be achieved by implementing an additional carbon tax on production in the EU-ETS sectors if the price of allowances is not high enough. In general, the most efficient mitigation policies suggested by the CGE literature is related to production based accounting. This also aligns with the accounting principle in place by the UNFCCC which requires all parties to report GHG emissions applying a production-based principle, as specified by the guidelines for National Greenhouse Gas Inventories by the Intergovernmental Panel on Climate Change (Eggleston et al. 2006).

As an alternative to the production based accounting, several studies calculate consumption-based emissions using the Multi-Regional Input-Output (MRIO) method (see e.g. Peters et al., 2011; Peters and Hertwich, 2008; Wiebe et al., 2012; Zhongxiu and Yunfeng, 2014). In general, these studies find that developed countries are net importers of GHG emissions linked to international trade with developing countries. Therefore, relying on a consumption based accounting method will impose a stronger responsibility towards developed countries, and thereby force them to take on a larger responsibility for the green transition (Kander et al., 2015; Peters and Hertwich, 2008; Steininger et al., 2014, 2016). Finally, the main argument in favor of consumption based mitigation policies are due to the avoidant of carbon leakage.

Some recent literature compares production-based and consumption-based policies, assessing whether carbon leakage effects make consumption-based taxation more preferable. Rocco et al. (2020) assess the effectiveness of production based and consumption based emission accounting methods (PBA and CBA) at an EU level. They utilize the World Trade Model with Bilateral Trades (WTMBT) finding that environmental policies within the consumption based paradigm seems to be the most efficient in reducing global carbon emissions, as carbon leakage effects are avoided. Using an environmentally extended input-output model, Liu et al. (2018) evaluate the optimal mitigation strategy between production-based accounting (PBA) and consumption-based accounting (CBA). Their findings suggest that within the Canadian economy, PBA tends to be more effective for primary sectors, while CBA is more suitable for sectors located at the downstream end of the industrial chain. Nabernegg et al. (2019) integrate a computable general equilibrium (CGE) framework with a multi-regional input-output (MRIO) model, enabling the calculation of consumption-based emissions alongside conducting climate policy simulations within the CGE framework. This approach allows for an evaluation of how national policies affect both production- and consumption-based emissions. Their findings indicate that policies primarily aimed at reducing direct household emissions are the most effective in lowering both consumption- and production-based emissions. On the other hand, Sommer and Kratena (2020) analyze the impacts of production-based and consumption-based taxes using a Dynamic New Keynesian model. Their findings show no evidence that the consumption-based approach should be favored, even though it results in negative carbon leakage. Similarly, Franzen and Mader (2018) advise against shifting away from production-based policies, as their fixed effects panel regression analysis for the period 1997-2011 finds no significant carbon leakage from developed to developing countries.

The debate between consumption-based and production-based policies has intensified in recent years, with ongoing discussions of their respective advantages and disadvantages. Notably, the financial sector has been largely absent from this debate, as computable general equilibrium (CGE) and input-output frameworks typically omit financial components (see, e.g., Liu et al., 2017). Attempts to integrate environmental and financial dimensions into the CGE framework have faced criticism for relying on assumptions that appear disconnected from observed economic realities. In contrast, macro-econometric models grounded in non-equilibrium economic theory tend to address the financial sector in a manner more consistent with real-world conditions (Pollitt & Mercure, 2018). One type of macro-econometric model is the Stock-Flow-Consistent model, developed in the tradition of Wynne Godley. These models adopt a fundamentally different approach from CGE models by incorporating a consistent accounting of all monetary, financial, and physical stocks and flows, within a post-Keynesian theoretical framework. Unlike CGE models, SFC models place the financial sector at the core, recognizing its critical role as a provider and creator of credit for the broader economy (Godley & Lavoie, 2006; Lavoie & Godley, 2001). An increasing number of studies (e.g., Berg et al 2015; Naqvi 2015; Jackson & Jackson 2021; Dunz et al. 2021) have integrated input-output models into the Stock-Flow-Consistent framework (SFC-IO) to better capture the complexity of economic production. In parallel, environmental input-output (EIO) analysis has been widely used to explore how demand feedbacks across the economy influence industry output and associated environmental impacts (Hardt & O'Neill, 2017). The integration of SFC and EIO frameworks, termed E-SFC-IO, is a relatively recent development that combines the SFC framework's comprehensive view of economic and financial dynamics with the environmentally extended IO system's capacity to address climate-related challenges. To further enhance their relevance for studying the green transition, country-specific models have been developed (e.g., Valdecantos, 2021; Thomsen et al., 2024).

The literature review highlights that current evaluations of climate mitigation policies often overlook the financial sector. To address this gap, the following section introduces the model used in this paper, which incorporates both environmental and financial aspects through an extended Ecological Stock-Flow-Consistent Input-Output (E-SFC-IO) framework.

3. Model description

In this paper, we use an extended version of the Ecological Stock-Flow-Consistent Input-Output (E-SFC-IO) model developed by Thomsen et al. (2024). To specifically address the agricultural sector and food consumption, we have modified the industry aggregation compared to the original model. In our version, the food production industry is subdivided into meat production, dairy production, bread production, and the production of other food items. This refined aggregation allows for a more detailed analysis of the impacts of consumption and production taxes within these specific industries.[3] To investigate the substitution of consumption between different products, the model incorporates a detailed description of household consumption and consumer prices for each product type. These features enable us to analyze and compare the effects of a production tax on the agricultural industry and a consumption tax on specific food products with high CO2E intensities.

The estimation of the structural equations of the model is based on an annual databank from 1995-2020, while the model is simulated for the period of 1998-2020, to capture the short to medium term effects of the policies. The model is fully demand-driven in the sense that supply adjusts to demand changes. However, supply does affect demand through price changes, as higher costs within an industry increase the producer prices. These higher costs of productions are then passed through intermediate sales and all the way to consumer prices, which affects the aggregate demand. Ecological aspects are incorporated into the model through an environmentally extended input-output system. In this system, energy supply and usage are assumed to have a linear relationship with both industrial production and household consumption. The model distinguishes between two types of CO2E emissions: energy-related emissions, which depend linearly on energy usage and are calculated using industry-specific emission coefficients, and energy-unrelated emissions, which depend linearly on both industry output and household consumption. This framework enables a detailed analysis of the environmental impacts associated with production and consumption.

As we will focus on the research-specific elements of the model in the following sections, readers are referred to Thomsen et al. (2024) for a more detailed description of the model as a whole.

3.1. Household consumption

For the consumption function, we assume a standard Keynesian framework in which real consumption (c_t^{tot}) is determined by real disposable income (yd_t^H) in the short run, and by both real disposable income and real financial net wealth (fnw_{t-1}^H) in the long run. The estimates align with our expectations, indicating positive effects of disposable income and financial net wealth on consumption.

$$\ln\Delta(c_t^{tot}) = 0.38^{***}\, ln\Delta yd_t^H - 0.38^{***}\, ln\, c_{t-1}^{tot} + 0.36^{***} \ln yd_{t-1}^H + 0.03 \ln fnw_{t-1}^H - 0.003^{**}\, Time$$

(Equation 1.)

Where real disposable income and real financial net wealth can be written as:

$$yd_t^H = YD_t^H / ppcon_t^{tax}$$

(Equation 2.)

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[3] In the appendix Table A1 the nine industries are presented, together with key statistics of each industry.

$$fnw_t^H = FNW_t^H / ppcon_t^{tax} \qquad \text{(Equation 3.)}$$

The price index used in equations 2-3 is described in connection with the calculation of price indices in equation 12. For now, we proceed by describing the two substitution effects associated with households' final consumption.

Substitution between products

In the model, households consumption basket consists of seven types of consumption goods, bread (c_t^{110}), meat (c_t^{120}), fish (c_t^{130}), dairy (c_t^{140}), fruits and vegetables (c_t^{160}), other food products (c_t^{180}), and finally industry specific products (c_t^{spec}). The industry specific products are simply the type of products (other than the bread, meat, fish, dairy, and fruits & vegetable) provided by each industry *n*. The superscripts are solely for identification purposes, matching the notation used by Statistics Denmark. For a general representation, we replace the superscript by p (where $p = 1,2, 3, 4, 5, 6, 7$) representing the seven product types. The amount spent on a good type (p) is calculated as:

$$c_t^p = \gamma_t^{c^p} * c_t^{tot} \qquad \text{(Equation 4.)}$$

Where $\gamma_t^{c^p}$ is the (time varying) fraction of a good type (p) in the total consumption; we endogenize this share using a nested structure with constant elasticity of substitution based on relative prices. First, consumers choose between food products and industry specific products, afterwards they make a choice amongst the six food products. We present this nested structure in equation 5-11.

$$\gamma_t^{c^{spec}} = \theta^{spec} * \left(\frac{ppcon_t^{oth,tax}}{ppcon_t^{tax}}\right)^{\sigma^{nest1}} \qquad \text{(Equation 5.)}$$

$$\gamma_t^{c^{110}} = \theta^{110} * \left(\frac{ppcon_t^{110,tax}}{ppcon_t^{food,tax}}\right)^{\sigma^{nest2}} * \left(\frac{ppcon_t^{food,tax}}{ppcon_t^{tax}}\right)^{\sigma^{nest1}} \qquad \text{(Equation 6.)}$$

$$\gamma_t^{c^{120}} = \theta^{120} * \left(\frac{ppcon_t^{120,tax}}{ppcon_t^{food,tax}}\right)^{\sigma^{nest2}} * \left(\frac{ppcon_t^{food,tax}}{ppcon_t^{tax}}\right)^{\sigma^{nest1}} \qquad \text{(Equation 7.)}$$

$$\gamma_t^{c^{130}} = \theta^{130} * \left(\frac{ppcon_t^{130,tax}}{ppcon_t^{food,tax}}\right)^{\sigma^{nest2}} * \left(\frac{ppcon_t^{food,tax}}{ppcon_t^{tax}}\right)^{\sigma^{nest1}} \qquad \text{(Equation 8.)}$$

$$\gamma_t^{c^{140}} = \theta^{140} * \left(\frac{ppcon_t^{140,tax}}{ppcon_t^{food,tax}}\right)^{\sigma^{nest2}} * \left(\frac{ppcon_t^{food,tax}}{ppcon_t^{tax}}\right)^{\sigma^{nest1}} \qquad \text{(Equation 9.)}$$

$$\gamma_t^{c^{160}} = \theta^{160} * \left(\frac{ppcon_t^{160,tax}}{ppcon_t^{food,tax}}\right)^{\sigma^{nest2}} * \left(\frac{ppcon_t^{food,tax}}{ppcon_t^{tax}}\right)^{\sigma^{nest1}} \qquad \text{(Equation 10.)}$$

$$\gamma_t^{c^{180}} = \theta^{180} * \left(\frac{ppcon_t^{180,tax}}{ppcon_t^{food,tax}}\right)^{\sigma^{nest2}} * \left(\frac{ppcon_t^{food,tax}}{ppcon_t^{tax}}\right)^{\sigma^{nest1}} \qquad \text{(Equation 11.)}$$

Several parameters go into the equations above. Starting with σ^{nest2} and σ^{nest1} these represent the elasticity of substitution in the two nests. We set $\sigma^{nest2} = 1.1$ and $\sigma^{nest1} = 0.3$ matching the parameters used by GreenREFORM. For example, in the second nest, if the price of meat products ($ppcon_t^{120,tax}$) increase by 1 percent relative to other food products ($ppcon_t^{food,tax}$), the share of meat consumption to total consumption ($\gamma_t^{c^{120}}$) falls by 1.1 percent. Lastly, the parameters $\theta_t^{spec}, \theta^{110}, \theta^{120}, \theta^{130}, \theta^{140}, \theta^{160}$, and θ^{180} are calibrated to match the starting value of each corresponding share.

Equation 5-11 requires nine price indices: seven defined for each of the seven product types p, along with two aggregate price indices—one for food products ($ppcon_t^{food,tax}$) and another for all consumption products ($ppcon_t^{tax}$).[4] In Equation 12, the subscript p is used for each of the seven product types, while the two aggregate price indices follow a similar method, with p corresponding to multiple products.

$$ppcon_t^{p,tax} = \left(\frac{C_t^p}{\sum_{n=1}^{9} \frac{C_{dom,t}^{n\,p}}{py_t^n} + \sum_{n=1}^{9} \frac{C_{im,t}^{n\,p}}{pm_t^n} + \frac{C_{im,t}^{un\,p}}{pm_t^{un}}}\right) * \left(1 + tax_{rate,t}^p\right) \qquad \text{(Equation 12.)}$$

Thereby each price index, is a function of the underlying producer price indexes for the nine domestic industries (py_t^n), as well as the ten foreign price indexes (pm_t^n, pm_t^{un}). Since consumers face prices inclusive of taxes, we multiply by the average tax rate for a given product ($tax_{rate,t}^p$). The average tax-rate is modelled as follows:

$$tax_{rate,t}^p = \frac{\left(C_{imd,t}^p + C_{ctax,t}^p + C_{VAT,t}^p\right)}{C_t^p} \qquad \text{(Equation 13a.)}$$

Where $C_{imd,t}^p$ defines import duties, $C_{ctax,t}^p$ defines commodity taxes, and $C_{VAT,t}^p$ defines value added taxes all associated with consumption of product type p.

Substitution between domestic and foreign products

Once we find the amount spent by households on the consumption of good type p (e.g., meat), we can calculate what proportion of this good is provided by domestic producers and what proportion is provided by

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[4] We include these tax rates within the consumer price indexes, as these rates are included within the final price paid by the consumer. Also, this allows us to implement carbon taxes on the consumers for different product types for future analysis.

foreign producers. We can calculate the value of domestic products ($c^{p}_{dom,t}$) and imported products ($c^{p}_{im,t}$) used in consumption as follows.

$$c^{p}_{dom,t} = (1 - \phi^{p}_{c,t}) * c^{p}_{t} \qquad \text{(Equation 14.)}$$

$$c^{p}_{im,t} = (\phi^{p}_{c,t}) * c^{p}_{t} \qquad \text{(Equation 15.)}$$

where $\left(1 - \phi^{p}_{c,t}\right)$ is the time varying fraction of the good produced by domestic producers whereas $\phi^{p}_{c,t}$ is the fraction of the good provided by foreign producers, i.e., it is the proportion that is imported. In the next section, we endogenize $\phi^{p}_{c,t}$ as a function of the real exchange rate. After determining the share of domestic and foreign producers of a good type (*p*), we disaggregate domestic and foreign production into the corresponding *n* industries (where *n=1,2, 3,…,9*). We use time-varying shares as follows:

$$c^{n\,p}_{dom,t} = \lambda^{n\,p}_{dom,t} * c^{p}_{dom,t} \qquad \text{(Equation 16.)}$$

$$c^{n\,p}_{im,t} = \lambda^{n\,p}_{im,t} * c^{p}_{im,t} \qquad \text{(Equation 17a.)}$$

$$c^{un\,p}_{im,t} = \lambda^{un\,p}_{im,t} * c^{p}_{im,t} \qquad \text{(Equation 17b.)}$$

where $c^{p,n}_{dom,t}$ is the amount of consumption of a good type (*p*) provided by the domestic industry *n*, $c^{p,n}_{im,t}$ is the amount imported from abroad, i.e., it is provided by foreign industry *n* and $c^{un\,p}_{im,t}$ refers to unspecified imports, which cannot be attributed to one of the nine industries.[5] Here, $\lambda^{p,n}_{dom,t}$, $\lambda^{p,n}_{im,t}$, and $\lambda^{un\,p}_{im,t}$ represent the exogenous share of each domestic and foreign industry (both specified and unspecified) in the supply of good (*p*).

We can now define nominal consumption (both for domestic and imported products) using price indices for each domestic (py^{n}_{t}) and foreign (pm^{n}_{t}, pm^{un}_{t}) industry:

$$C^{n\,p}_{dom,t} = c^{n\,p}_{dom,t} * py^{n}_{t} \qquad \text{(Equation 18.)}$$

$$C^{n\,p}_{im,t} = c^{n\,p}_{im,t} * pm^{n}_{t} \qquad \text{(Equation 19a.)}$$

$$C^{un\,p}_{im,t} = c^{un\,p}_{im,t} * pm^{un}_{t} \qquad \text{(Equation 19b.)}$$

From equations 16-19, we disaggregate consumption into the seven product types *p,* across the nine industries *n*, distinguishing between domestically and foreign-produced goods, and at both nominal and real levels. However, this does not yet account for import duties ($C^{tot}_{imd,t}$), commodity taxes ($C^{tot}_{ct,t}$), and value added taxes

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[5] A share of imported consumption cannot be associated with an industry whereas these are classified as unspecified imports. We calculate unspecified imports as follows: $c^{p}_{uim,t} = \lambda^{p}_{uim,t} * c^{p}_{im,t}$. A similar equation is used for the other final demand components where some imports are also unspecified.

($C^{tot}_{vat,t}$). To include these taxes, we use product specific tax rates based on total nominal consumption for each product p:

$$C^{tot}_{imd,t} = \sum_{p=1}^{7} tax^{imd,p}_{rate} * C^{p}_{im,t} \qquad \text{(Equation 20.)}$$

$$C^{tot}_{ct,t} = \sum_{p=1}^{7} tax^{ct,p}_{rate} * C^{p}_{dom,t} \qquad \text{(Equation 21.)}$$

$$C^{tot}_{vat,t} = \sum_{p=1}^{7} tax^{vat,p}_{rate} * C^{p}_{dom,t} \qquad \text{(Equation 22.)}$$

Finally, we can calculate total consumption in nominal values:

$$PCON_t = \sum_{n=1}^{9}\sum_{p=1}^{7} C^{n\,p}_{dom,t} + \sum_{n=1}^{9}\sum_{p=1}^{7} C^{n\,p}_{im,t} + C^{un\,p}_{im,t} + C^{tot}_{imd,t} + C^{tot}_{ct,t} + C^{tot}_{vat,t} \qquad \text{(Equation 23a.)}$$

Summing up the modelling of final consumption, three overall effects should be highlighted. I) The income effect, for which increases in the average consumer price ($ppcon^{tax}_{t}$) will reduce the purchasing power of real disposable income and wealth, reducing total real consumption. II) substitution between products, in which relative price changes between product types will leave the households to substitute to relative cheaper products based on the nested structure presented in equation 5-11. III) Substitution between domestic and imported products, for which changes in the real exchange rate will result in substitution between domestically and foreign produced products.

3.2. International trade

As highlighted in the literature, a major drawback of production-based environmental regulations is their potential negative impact on international trade. As the implementation of a production tax can lead to higher domestic prices, which reduce the competitiveness of domestic firms. This loss of competitiveness can worsen the trade balance for the Danish economy, with the resulting financial burden falling on domestic sectors. Additionally, diminished competitiveness may drive consumers to substitute Danish products with those from abroad, potentially resulting in carbon leakage. Therefore, capturing the dynamics of international trade within the model is crucial for evaluating the effects of a production tax. Especially as the agricultural industry in Denmark delivers a large share of inputs used in the food production industries, for which export shares are relatively high (see Appendix Table 2).

Export

We determine the total exports for each of the nine industries using an Armington-type approach by modeling the market share for each domestic industries exports $\left(\frac{x^n_t}{m^{n*}_t}\right)$, where $m^{n*}_t$is the global demand (or imports) for the type of goods produced by industry *n* at a global level, and x^n_t is the exports of industry *n* at a domestic level.[6] The export share for each industry is then modeled as a function of relative prices (real exchange rate) and can be written as follows:

$$\ln\left(\frac{x_t^n}{m_t^{n*}}\right) = \alpha_0^n + \alpha_1^n * \ln(rer_{t-1}^n) + adj_{x,t}^n \qquad \text{(Equation 24.)}$$

Where α_1^n captures the export elasticities to movements in the real exchange rate rer_t^n. Real exchange rate for each industry is a proxy for international competitiveness, defined as follows:

$$rer_t^n = xr_t * \frac{py_t^n}{pm_t^n} \qquad \text{(Equation 25.)}$$

where py_t^n is the domestic price of industry *n*, pm_t^n is the price of imports of industry *n*, and xr_t is the exogenous nominal exchange rate. To find the export elasticities (represented by α_1^n), we use estimates found by Kronborg, Poulsen, and Kastrup (2020) who derive export elasticities using the BACI-dataset for the Danish economy. As the BACI-dataset does not include exports for all industries, we use an average export elasticity for the Danish economy in the mining and energy production industries. All export elasticities are presented in the appendix Table A2.

The last term in equation 24 is an adjustment term ($adj_{x,t}^n$), which accounts for the effects of variables beyond the real exchange rate. The price elasticities provided by Kronborg, Poulsen, and Kastrup (2020) are derived from micro-level data aimed at establishing a causal relationship between relative prices and exports. These estimates are found to be theoretically intuitive, but poorly fitting the aggregate data. Leaving out the adjustment terms would therefore create large discrepancies compared to the observed data which could be problematic in the model simulations.

Import

To model imports, we first estimate industry-level imports used in production and then imports of final consumption products. In both cases, we calculate imports as a proportion of domestic demand, thereby assuming an elasticity of 1. This means that as domestic demand increases for either production inputs or final consumption products, imports adjust proportionally.

For products used as inputs, substitution occurs at the industry level, meaning that the same import elasticity is applied to all agricultural products, regardless of whether they are used within the agriculture industry itself or in one of the eight other industries. To estimate import elasticities for inputs used in production, we employ a straightforward approach known as the "rule of two," where the import elasticity of an industry is assumed to be half of its export elasticity. This methodology is also adopted by the GreenREFORM model (Kirk and Hansen, 2023). The rationale behind this assumption is that domestic residents tend to prefer domestically

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[6] To calculate the share of Danish exports in the global market, we use the BACI-dataset providing import and export values amongst countries in the world at a product-level.

produced goods, even when they are relatively more expensive. The functional form of this relationship can be expressed as follows:

$$\ln(\phi_{z,t}^{i\,n}) = \beta_0^{z^{i\,n}} + \beta_1^{z^n} * ln(rer_t^n) + adj_{\phi,t}^n \qquad \text{(Equation 26.)}$$

In the above equation, $\beta_0^{z^{i\,n}}$ is a constant taking the log of the starting value for the import share ($\phi_{z,t}^{i\,n}$), and $\beta_1^{z^n}$ represents the import elasticity (shown in the appendix Table A2). As for exports, we include an exogenous determined adjustment term capturing other relevant effects than the real exchange rate $\left(adj_{\phi,t}^n\right)$

We now focus on imports associated with the final demand block. Focusing on household consumption, we classified the consumer basket into domestic and imported goods using equation 14-15 in the previous section. We used the proportion of good type (*p*) in the consumer basket imported from abroad ($\phi_{c,t}^p$) and the proportion of good type (*p*) in the consumer basket domestically produced ($1 - \phi_{c,t}^p$) to make this classification. Thus, by endogenizing $\phi_{c,t}^p$, we can model the substitution effects between household consumption of domestic and foreign goods. To do so, we model $\phi_{c,t}^p$ as a function of the relative prices. We can represent this relationship as follows:

$$\ln \phi_{c,t}^p = \beta_0^{c^p} + \beta_1^{c^p} * \ln(rer_t^p) + \phi_{c,t}^{p,res} \qquad \text{(Equation 27.)}$$

The parameter $\beta_1^{c^p}$, estimated via OLS, captures the elasticity of substitution between domestic and imported goods. The estimates of the import elasticities associated with the seven product types are presented in the Appendix Table A3 where the highest elasticity is observed for meat products.

The real exchange rate rer_t^p is used as a proxy of competitiveness and is defined as follows:

$$rer_t^p = xr_t * \frac{ppcon_{dom,t}^p}{ppcon_{im,t}^p} \qquad \text{(equation 28.)}$$

Where $ppcon_{dom,t}^p$ is the price index for domestically produced products of type *p* and $ppcon_{im,t}^p$ an index of foreign produced products of type *p*. To take into account other factors not related to real exchange rate, we add in an adjustment term in the end $\phi_{c,t}^{j,res}$.

3.3. The implementation of a carbon production & consumption tax

In this section, we extend the model presented by Thomsen et al. (2024) to allow for the introduction of a consumption-based environmental tax. We achieve this by introducing a new tax variable, $C_{envT,t}^{tot}$, which determines the total environmental taxes paid on consumption. The total tax is the sum of the environmental taxes paid on each product type *p*, as shown below:

$$C_{envT,t}^{tot} = \sum_{p=1}^{7} C_{envT,t}^{p} \tag{Equation 29.}$$

The environmental taxes paid on each product type is the product of the tax-rate ($tax_{rate}^{envT,p}$) and the nominal consumption of product type p (C_t^p). In the baseline model, environmental consumption taxes are fixed to 0 for each product type:

$$C_{envT,t}^{p} = tax_{rate}^{envT,p} * C_t^p \tag{Equation 30.}$$

The environmental tax on consumption is part of the net tax revenue received by the government ($NTAX_t^{prod}$) modeled as follows:

$$NTAX_t^{prod} = CT_t^{tot} + VAT_t^{tot} + IM_t^{D,tot} + C_{envT,t}^{tot} \tag{Equation 31.}$$

Also, the environmental consumption tax should be included in the total final consumption ($PCON_t$) previously presented in equation 23a:

$$PCON_t = \sum_{n=1}^{9}\sum_{p=1}^{7} C_{dom,t}^{n\,p} + \sum_{n=1}^{9}\sum_{p=1}^{7} C_{im,t}^{n\,p} + C_{im,t}^{un\,p} + C_{imd,t}^{tot} + C_{ct,t}^{tot} + C_{vat,t}^{tot} + C_{envT,t}^{tot}$$

(Equation 23b.)

The implementation of the carbon tax thereby increases nominal consumption, as consumers would have to pay a larger tax per money spend on products. But a reverse effect on consumption goes through the income effect, as the average consumer price index (adjusted for the tax-rate) $ppcon_t^{tax}$ lowers real disposable income and real financial net wealth (see equation 2-3). The increase in the price indices is a result of including the new environmental consumption tax in equation 13a presented earlier.

$$tax_{rate,t}^{p} = \frac{\left(C_{imd,t}^{p} + C_{ct,t}^{p} + C_{vat,t}^{p} + C_{envT,t}^{p}\right)}{C_t^p} \tag{Equation 13b}$$

Thereby, an increase in the environmental tax rate on product type p ($tax_{rate}^{envT,p}$) leads to an increase in the total level of environmental tax ($C_{envT,t}^{tot}$). This, in turn, raises overall consumption ($PCON_t$) and the net-production taxes ($NTAX_t^{prod}$), while also increasing the average tax rate ($tax_{rate,t}^{p}$). The rise in the average tax rate reduces real disposable income and real financial net wealth, as reflected in equations 2 and 3. This, in turn, reduce real consumption (c_t^{tot}) through equation 1.[7]

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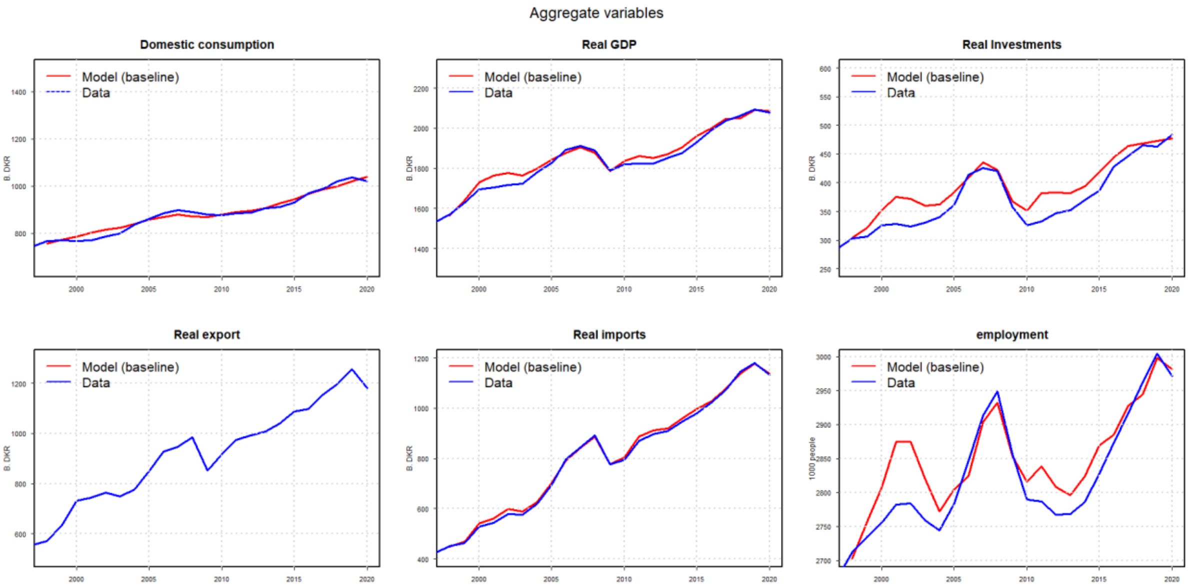
[7] As the elasticity of the aggregate price on real consumption is close to 1, an increase in the tax on consumer products will have close to no effect on the nominal value of total consumption ($PCON_t$). Similar results are found by DØRS (2023) for meat products in Denmark.

3.4. Model evaluation

In this section, we evaluate the performance of the model by comparing simulated outcomes with observed data. Figure 1 illustrates the development of real GDP (along with its components) and employment. The results show that the model successfully captures the overall trends of these key macroeconomic variables. Although there are some periods where the model diverges from the original data, particularly in terms of investments and employment, the model generally performs well in reflecting both the long-term tendencies and cyclical movements.[8]

Figure 1: Model evaluation of aggregate variables



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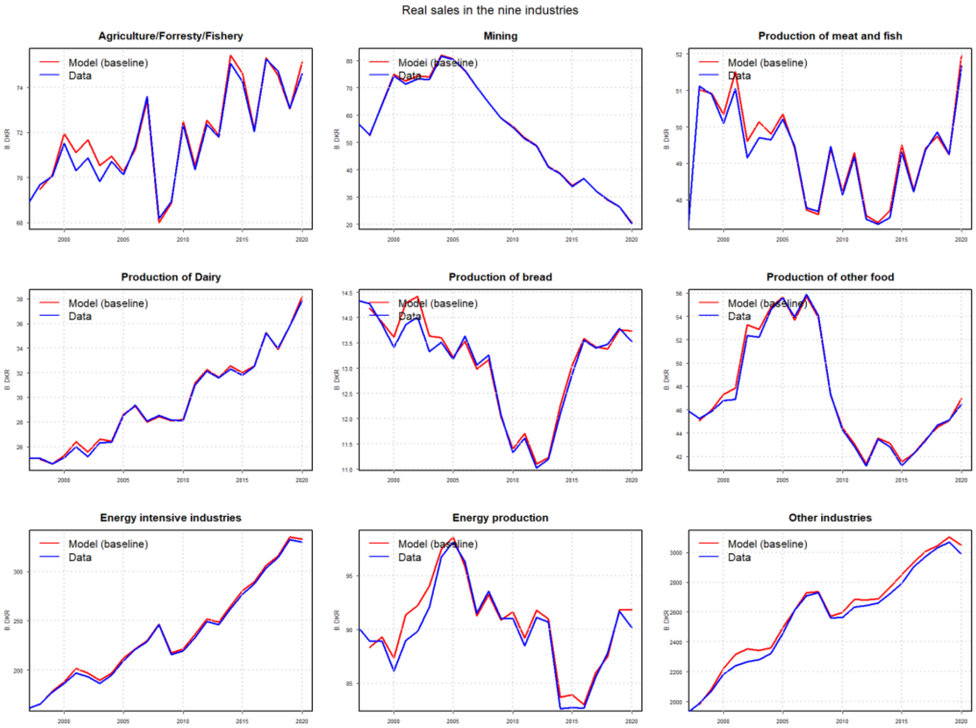
[8] The almost perfect fit for exports is due to the inclusion of adjustment terms in equation 24 see the discussion in section 3.2.

Figure 2 shows the model's predictions for real sales of domestic industries. The model adequately captures both the overall trends and fluctuations within each of the nine industries.

Figure 2: Model evaluation Industry output



For environmental variables, Appendix Figure A1 illustrates the simulated CO2E emissions for each of the six emissions types. In general, the simulated variables appear to capture the fluctuations observed in the data, leading us to conclude that the model provides a realistic representation of the Danish economy.

4. Evaluating Different taxation approaches

In this section, we compare the effects of a carbon tax on consumption of high CO2E-intensive food products, with a producer tax in the Danish agricultural industry. To do so, we perform the two following scenarios:

- In scenario 1, we implement a consumption tax on the consumption of meat products (c_t^{120}) and dairy products (c_t^{140}) of 750 DKK per ton CO2E-emitted. This leads to a total tax-revenue of 2.4 billion DKK, for the year 2010 in which the tax is implemented. The tax-rate is determined using the CO2E-intensity of meat and dairy products, which can be challenging to measure due to lack of information of transportation and foreign production methods. To obtain the best possible estimates of CO2E-intensities, we use calculations from the Svarer Commission (Svarer et al., 2024). According to these estimates, the CO2E-intensity is set at 0.1 kg CO2E per 1 DKK of consumption for meat and 0.15 kg CO2E per 1 DKK of consumption for dairy products.

- In Scenario 2, we implement a production tax in the agricultural industry. In the baseline model, the agricultural industry already pays 1.6 billion DKK in environmental taxes, which is associated with the current taxation of energy usage. The environmental tax implemented in scenario 2 will face out the current environmental taxes and instead implement a tax on CO2E-emissions unrelated to energy usage (as presented in Svarer et al. 2024). Still, we set the tax rate to match the size of the tax revenue in Scenario 1 of 2.4 billion DKK, which results in a tax-rate of 387 DKK per ton CO2E. As a result, the total environmental tax paid by the agricultural industry after implementing the new tax-rate is calculated to be 4 billion DKK as it is implemented in year 2010.

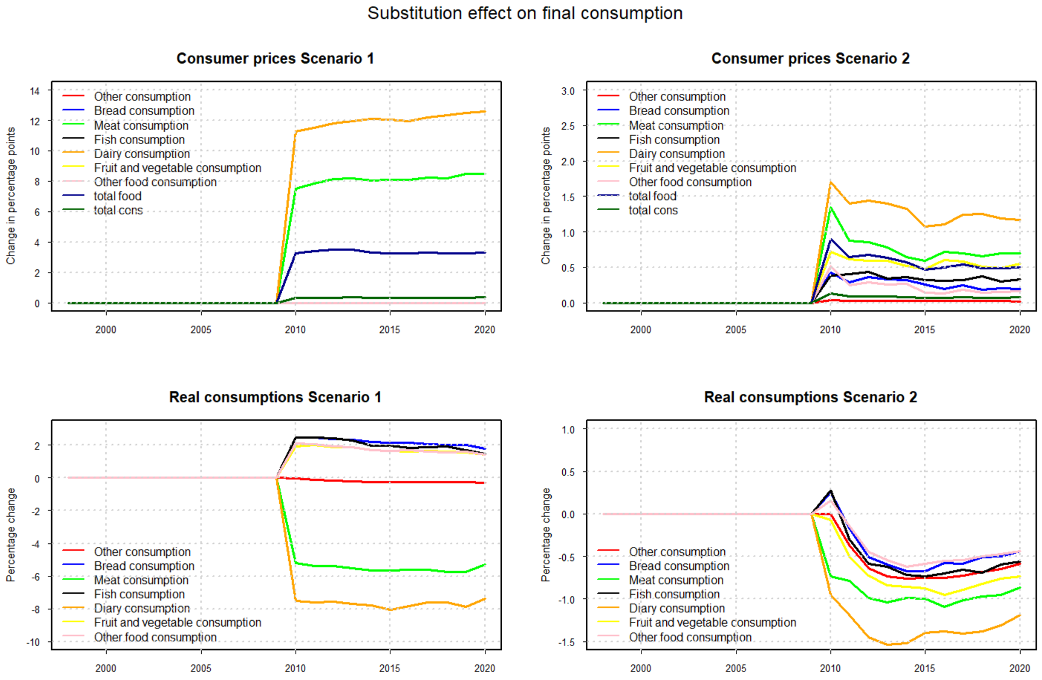
In the next section, we compare the main economic and environmental results of the two tax set-ups.

4.1. Main results

Since the objective is to compare the outcomes of both scenarios, we present the results of scenario 1 and 2 concurrently. One crucial aspect of introducing both the consumer and producer tax, is their effect on the consumer price indices. In the upper part of the figure below, we depict the development of consumer price indices presented in equation 12, across the seven categories of consumption, as well as the two aggregate indices for food products and total consumption.

In Scenario 1, where a tax is applied directly to meat and dairy products, it is expected that the most substantial price increases occur in these two categories. Additionally, there is a minor increase in the aggregate food price index. In Scenario 2, price increases are largest for food products for which production relies on the agricultural industry. This outcome is consistent with the design of the tax, where producers, as presented in equation 12, transfer the increased production costs to consumers. The most significant effects are observed in dairy and meat products, with price increases of 1.7 and 1.35 percentage points, respectively, reflecting the large share of agricultural inputs in the production of these products.

Figure 3 The effect on consumer prices and consumption as a production or consumer tax is implemented.



The changes in relative prices between different products will result in substitutions across product categories, as illustrated in the bottom part of the figure above, where we focus on the changes in consumption for each product type. The shift in consumption patterns is primarily driven by three effects:

I) **Income/Wealth effect**; as the aggregate consumer price ($ppcon_t^{tax}$) increase, households face a drop in both real disposable income (yd_t^H) and real net financial wealth (fnw_t^H) according to equation 2 and 3. From equation 1, we can derive that the elasticity of real disposable income to real consumption is 0.93 and the elasticity of real financial net wealth to real consumption is 0.07. Thereby, the elasticity of the average consumer price to real consumption is approximately 1. As the aggregate consumer price index increase in both scenario 1 and 2, total real consumption (c_t^{tot}) falls below the baseline level.

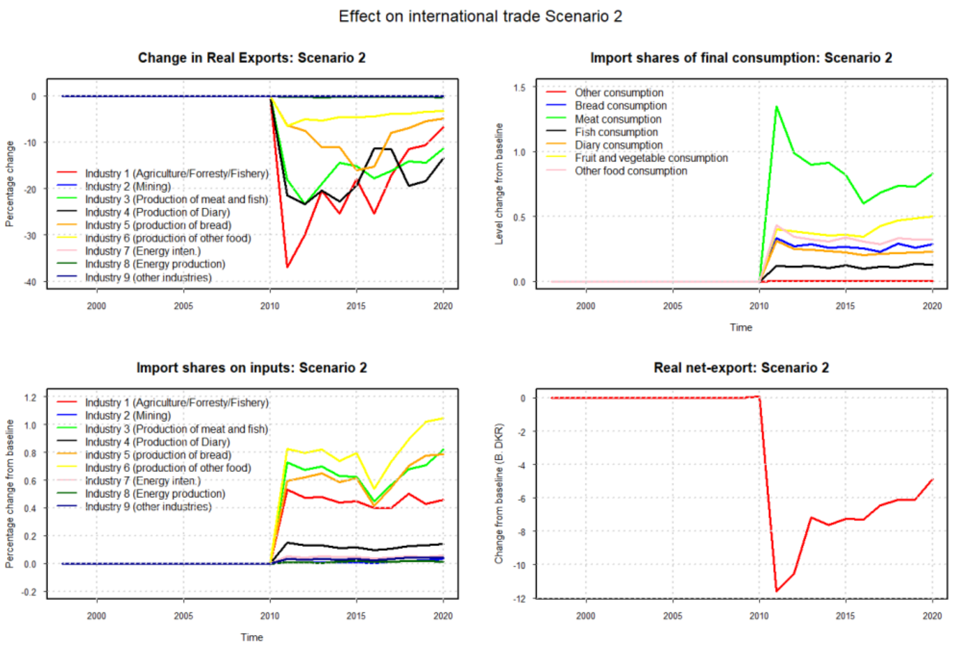
II) Substitution between product types occurs as consumers adjust their consumption based on relative price levels, as presented in equations 5-11, where substitution is structured into two nests. In the first nest, consumers decide between food products and other industry-specific consumption products using a substitution elasticity of 0.3, driven by relative price levels. In the second nest, consumers choose between the six different food products with a higher elasticity of 1.1, again based on relative prices. In Scenario 1, as the prices of meat and dairy products rise, consumers substitute these with other types of food products. In Scenario 2, prices increase across all food products, but the rise is less pronounced for categories like other food products and bread.

Consequently, the substitution effect in Scenario 2 primarily drives consumers toward these relatively cheaper food options.

III) Substitution between domestic and foreign products: as domestic prices rise while foreign prices remain constant, consumers shift towards foreign-produced goods. This mechanism is captured in equation 27, where the import share of household consumption for each product type p is endogenized. In Scenario 1, both domestically produced and imported goods are equally taxed under the consumption tax, following WTO regulations. This ensures that there is no relative price change between domestic and foreign goods, resulting in no substitution between the two (as seen in Figure A2 in the appendix).[9] In Scenario 2, however, the substitution effect becomes significant for food products reliant on inputs from the domestic agricultural industry. Here, the tax is applied only to domestically produced goods, causing a relative price increase. This price disparity leads to a shift in consumption from domestically produced goods to imported alternatives.[10]

A main concern when implementing environmental taxes, especially in a small open economy, are in relation to the contagious effects, that might deteriorate the international trade balance. In the figure below, we focus on the effects on exports and imports for scenario 2. The effects of scenario 1 is not included, as it aligns with expectations and shows negligible effects.[11]

Figure 4 Effects on international trade as a carbon tax is implemented in the agricultural industry



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[9] The small changes observed in the appendix Figure A2 are caused by indirect effects through domestic producer prices (py_t^n).

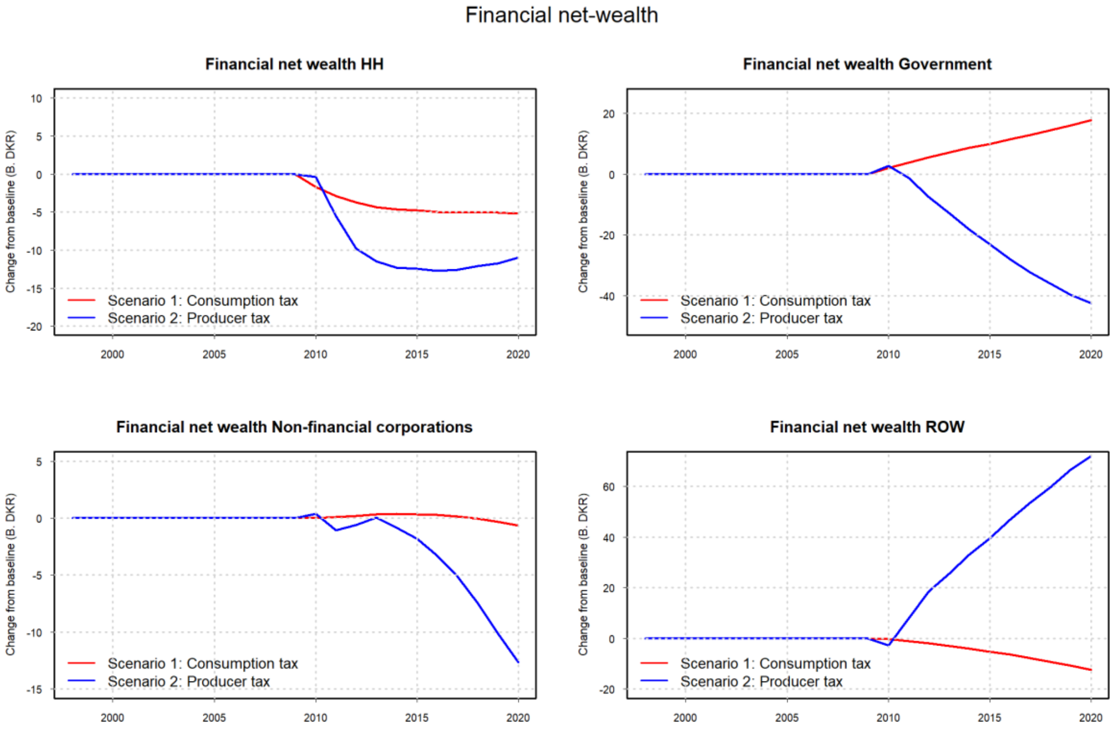
[10] This effect is largest for meat products (see figure 4, top right plot) where the elasticity is estimated to be 3.37.

[11] The effect on international trade in scenario 1 are shown in the appendix Figure A2.

In the top left corner of Figure 4, we display the change in exports across the nine domestic industries. Both the agricultural and food production industries experience a decline in exports as domestic prices rise relative to foreign prices. As previously discussed, import shares of final consumption also increase as a result of higher domestic prices. As shown in the top right corner, the import share of meat products rises the most, reflecting its relatively high import elasticity (see Table A2 in appendix). In section 3.2, we also endogenized the import share of inputs used in production for the nine domestic industries (see equation 26). The increase in domestic production prices py_t^n results in substitution towards imported inputs especially for industries relying on the agriculture and food production industries as seen in the bottom left corner. Lastly, the overall effect on the trade balance can be seen in the bottom right corner, where the real net exports fall by approximately 5 billion DKK in the end of the simulation period.

Next, we utilize the stock-flow-consistent aspect of our model to examine how the two different tax setups are ultimately financed. To do this, we analyze the effect on real financial net-wealth of the different sectors in the economy. Specifically, we look at changes in the real financial net-wealth of households, the government sector, non-financial corporations, and the rest of the world in the figure below.

Figure 5: The effect on financial net wealth in different sectors, comparing the two scenarios.

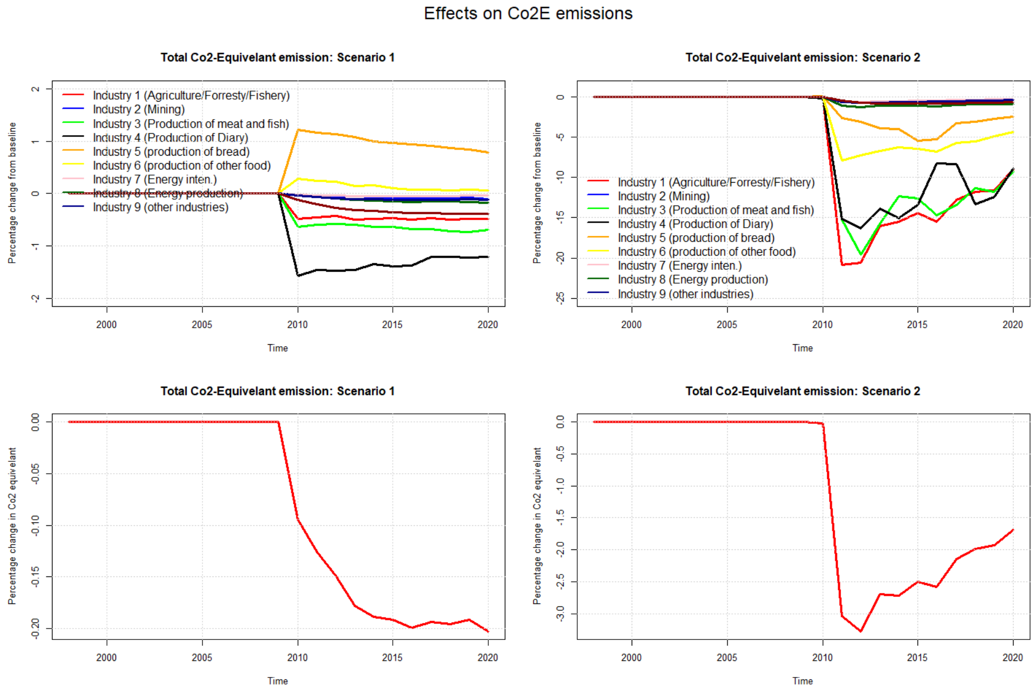


In scenario 1, the implementation of a consumer tax leaves the households as the main domestic contributor in financing the environmental policy as they directly face the increased costs when consuming final demand products. It might come as a surprise that financial net wealth does not fall by more than 5 billion DKK. The reason is found in the income/wealth effect where consumers reduce consumption as the average consumer price increases. Looking at the government sector, it directly receives the tax revenue and without any tax recycling its net-wealth increase by approximately 19 billion DKK. For the non-financial corporations financial net wealth remains nearly unchanged, where lower household consumption reduces financial net wealth for while a corresponding drop in employment leads to lower wage payments, ultimately balancing out the impact. Lastly, the financial net wealth of the rest of the world decreases by 12 billion DKK as the decline in household consumption reduces demand for imported products.

In Scenario 2, the implementation of a production tax reduces the financial net wealth of non-financial corporations by 12.5 billion DKK. This decline is primarily driven by a reduction in gross operating surplus and mixed income, as both domestic and foreign demand for agricultural and food production products decrease due to price increases. Household financial net wealth also drops by 11 billion DKK, largely due to a reduction in the wage bill, as layoffs occur in the agriculture and food production industries as sales decline. Additionally, households "own" a significant portion of the agricultural industry, so the drop in gross operating surplus in this industry directly impacts household financial net wealth. The government sector experiences the largest decline in financial net wealth, falling by over 40 billion DKK. This is because the reductions in household and corporate incomes lead to lower tax revenues, which outweigh the gains from the environmental tax. As financial net wealth fall in all domestic sectors, it increases for the rest of the world by identity. In this sector, financial net-wealth increase by 68 billion DKK in the final simulation period. The large increase in financial net-wealth for ROW is of no surprise as Danish net-exports falls by a large amount as observed in figure 4.

Finally, in figure 6 we examine the changes in CO2E emissions across industries, as well as at an aggregate level.

Figure 6: Effects on Co2E emissions comparing the two scenarios.



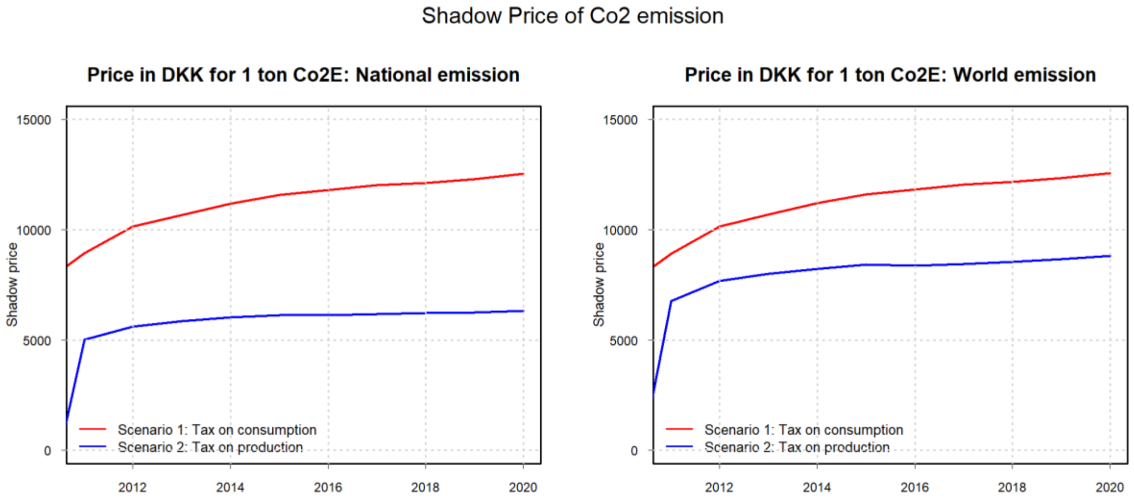
In Scenario 1, the primary contributors to the reduction in emissions are the food and dairy production industries, where emissions decrease as a result of lower production. Household emissions also decline, primarily due to the wealth/income effect, which reduces real consumption. In Scenario 2, the most significant drop in emissions occurs in the agricultural, meat production, and dairy production industries. This reduction is directly linked to lower production levels as these industries lose competitiveness. At an aggregate level, the drop in emission is almost 10x higher in Scenario 2 compared to Scenario 1. In the next section, we discuss the results obtained from the two scenarios both from an environmental, economic, and financial perspective.

5. Discussion

To assess the two tax setups, we evaluate them across three dimensions: I) Environmental impact, focusing on CO2E emissions; II) Economic impact, including effects on GDP and employment; and III) Financial impact, examining changes in financial net-wealth.

Looking at the environmental aspect alone, the results presented in Figure 6 clearly favors the production tax in the agriculture industry, where the cumulative drop over the entire simulation period reach 26 million tons CO2E emissions compared to only 2 million tons CO2E in scenario 1. Instead of evaluating the two tax setups based on environmental aspect alone, we include the economic dimension by calculating shadow prices. The shadow price can be seen as the price of lowering emissions by 1 ton Co2E emissions in the form of lowering GDP. The cumulative change in emissions and GDP in both scenarios, provides the following results:

Figure 7: Comparing the development of the shadow price in the two scenarios using national emission and global emission reductions.



In the left-hand plot, only domestic CO2E reductions are considered, while the right-hand plot accounts for carbon leakage effects by examining global emissions. The inclusion of carbon leakage rates is crucial, as one of the primary advantages of a consumption tax is the potential to mitigate carbon leakage. We calculate industry specific carbon leakage rates using coefficients from (Beck et al. 2021), which link changes in exports and imports for Danish industries to shifts in emissions outside Denmark. Using these coefficients, we find the aggregate carbon leakage rate to be 0% in Scenario 1 and 27% in Scenario 2. As shown in Figure 7, Scenario 2 has the lowest shadow price based on domestic emissions. This remains the case even after accounting for carbon leakage, even though the shadow price for Scenario 2 does rise once carbon leakage is included.

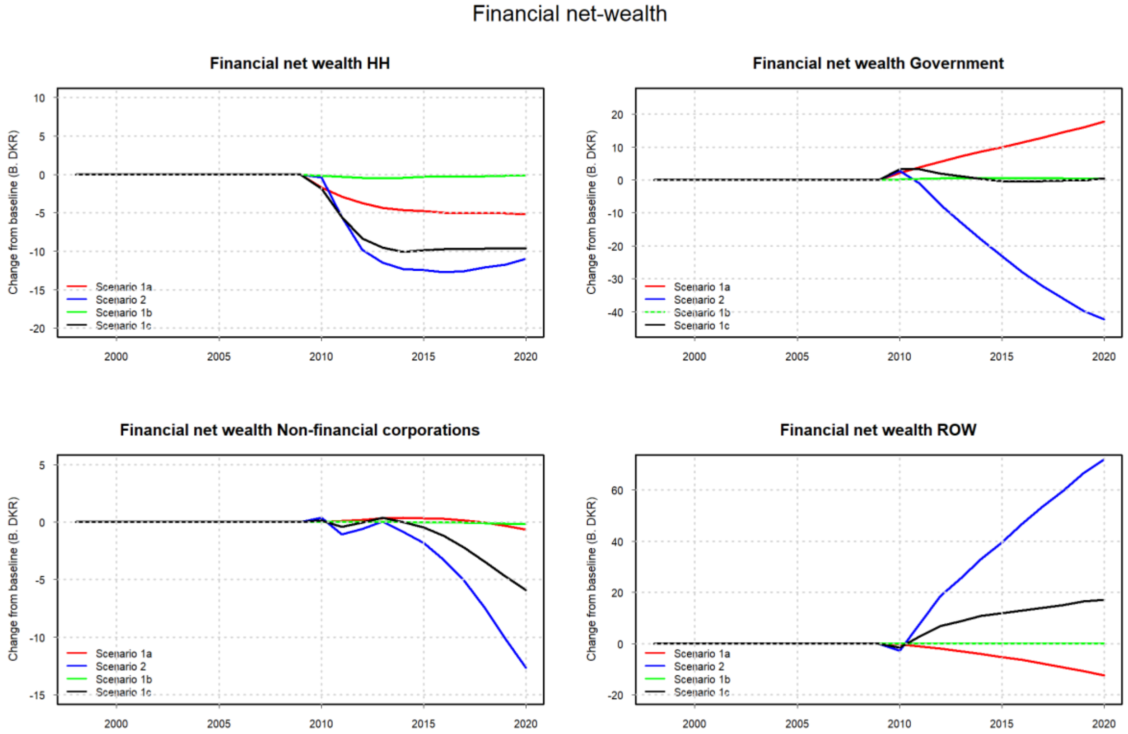
We now broaden the analysis by incorporating the financial side of the economy, considering the effects on financial net wealth as presented in Figure 5. The increase in financial net wealth observed in the government sector under Scenario 1 provides an opportunity to explore further scenarios where this surplus is reinvested in additional climate-friendly policies. Therefore, we extend Scenario 1 as follows:

- **Scenario 1b:** In this extended scenario, the government surplus is utilized to implement subsidies on food products with low CO2E intensity. Specifically, subsidies are applied to bread, fish, fruits, vegetables, and other food products. The subsidy rate is set at a level that ensures the government's fiscal balance remains nearly neutral by the end of the simulation period.
- **Scenario 1c:** In this scenario, we implement a combination of the consumption and production tax. The same consumption tax introduced in Scenario 1 is applied, but now an additional tax is levied on

agricultural production. The tax rate is calibrated so that the change in government net wealth is approximately zero by the final period of the simulation.[12]

In the figure below, we present the development of financial net wealth across the two new scenarios, alongside the results from the previous scenarios. This comparison allows us to analyze how the combined consumption and production tax, as well as the implementation of subsidies, impact the financial net wealth of different sectors relative to the initial scenarios.

Figure 8: Financial net wealth for different sectors allowing for recycling of the government surplus.



In both Scenario 1b and Scenario 1c, the government's financial net wealth returns to zero by the end of the simulation period. In Scenario 1b, where subsidies are applied to low CO2E-intensity consumption products, wealth is redistributed back to consumers, leading to minimal changes in the overall distribution of wealth across sectors. However, in Scenario 1c, the combination of production and consumption taxes results in wealth being transferred from domestic sectors (households and firms) to the rest of the world due to a decline in Danish net exports. As shown in Scenario 2, this reduction in net exports lowers the government's financial net wealth by reducing income tax revenue as economic activity declines. Nevertheless, the revenue generated from both the consumption and production taxes offsets these losses, allowing the government's financial net wealth to remain unchanged by the final simulation period.

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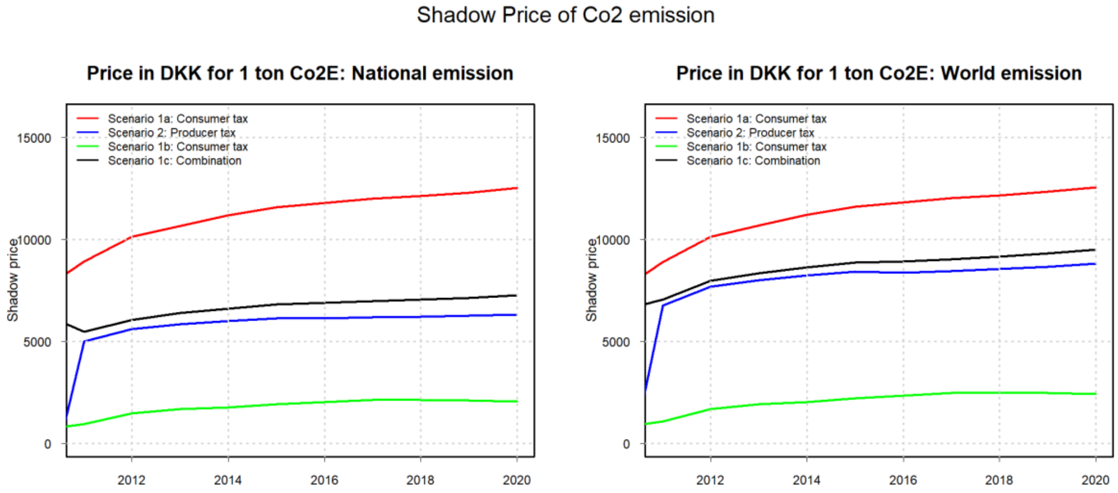
[12] The tax on Co2E emissions in the agricultural industry is set to 262 DKK per ton Co2E.

Finally, we can again use the shadow price to calculate the cost of 1 tons CO2E reduction in the figure below, now also including the two new scenarios:

Figure 9: Development of the shadow price when allowing for recycling of government surplus.



In scenario 1b, the reduction in GDP associated with 1 ton lower CO2E emissions (the shadow price) is much lower compared to the other three cases. The main reason for this finding is that the wealth/income effect, lowering household consumption, is not present, as the change in the average price on food is almost 0 (see figure 12 in appendix). Still, there is an effect on Co2E emissions, as households substitute away from food products with high Co2E intensity (dairy and meat) to other food products with lower Co2E intensity.

The introduction of a consumer tax on high CO2E-intensity products accompanied by subsidies on food products with relatively lower CO2E-intensity, as done in scenario 1b, seem to provide the best results looking at both economic, environmental and financial aspects.

5.1. Implementation issues of consumer taxes

Even though the consumer tax, as implemented in scenario 1b, seem superior, the implementation of such a tax might prove difficult. One such issue is related to the calculation of CO2E-intensities, which in practice, is associated with high levels of uncertainty and require a large administrative burden. For meat products, this would require knowledge of production equipment used, transport, living standard of the animal, feeding, race and others (Svarer et al. (2024)). The more detailed the tax needs to be, the greater the administrative burden will be, as it requires extensive information. Consequently, it is typically advised to design a consumption tax to target fewer but broader product categories (Rocco et al., 2020).

The consumption tax and subsidies proposed in Scenario 1b are applied to broader product categories, which generally results in a lower administrative burden since less detailed information on specific production methods is required. However, using more narrowly defined product categories can create stronger incentives for producers to reduce their CO2E intensity. This is because if producers can lower their CO2E intensity, they might influence the overall tax rate for these specific categories, assuming that individual producers can affect the average CO2E intensity for more narrowly defined product types.

Besides the administrative burden, the consumer tax might face limitations in the level of CO2E reduction that can be achieved. In Scenario 1b, the reduction in CO2E emissions amounts to only 0.83 million tons over the simulation period. This is based on substantial price increases, with dairy and meat products rising by 11.25% and 7.5%, respectively (see Figure A3 in the appendix). To achieve more radical reductions in CO2E emissions, higher taxes on specific products would be necessary, which might be challenging to implement.

6. Conclusion

In June 2024 the Danish Parliament reached an agreement with several interest organizations to implement a CO2E tax on the agriculture industry with the aim of reaching both national and international climate goals. To reach these goals in the most efficient way a commission was formed to provide recommendations for the policy makers. In their report (Svarer-report), two different tax-setups are discussed, namely a consumer tax and a production tax, where their final recommendations are all pointing towards different versions of production taxes as most efficient. The main argument for this is, that a production tax unlike a consumption tax covers emissions from the production of exported goods, just like it also encourages individual farmers to adopt more climate-friendly technologies. On the other hand, two main advantages of a consumption tax must be taken into account: i) a consumption tax will under the regulations of WTO most likely be enforced on both domestically and imported goods, ii) a consumption tax will affect prices on domestically produced and imported products evenly, so no carbon leakage effects will occur.

To evaluate the effects of the two different types of taxes we use an empirical ecological SFC-IO model for the Danish Economy, which allows us to evaluate both the economic, financial, and environmental impact of implementing environmental taxes under different conditions. In the first scenario we introduce a consumer tax directly on specific products (meat and dairy), while we implement a production tax on agricultural products in the second scenario. Measured by the reduction of domestic emission, our result fully supports the Svarer-report, since the reduction in scenario 2 by far exceeds the reduction achieved with a consumer tax. In both scenarios the domestic households are facing higher consumer prices as a result of the taxation, with the big difference that the increase in scenario 1 is focused on meat and dairy product alone, while all products using agricultural input in the production, are affected in scenario 2. These relative increases in domestic prices affects the competitiveness in scenario 2, which leads to a deterioration of the trade balance. Another key difference is in how the tax burden is distributed. In Scenario 1, the primary burden falls on households and the rest of the world, while the government sector benefits from a surplus of 19 billion DKK. Conversely, in

Scenario 2, the costs are spread across all domestic sectors, and the rest of the world sees an increase in financial net wealth of 68 billion DKK. The government surplus in Scenario 1 provides an opportunity to explore various policy measures involving the recycling of this surplus. Such policies might include a mix of consumer taxes and subsidies based on CO2E intensity, which could effectively reduce emissions without adversely affecting the economy or financial wealth.

To reach the climate goals important decisions needs to be taken very soon. According to both the Svarer Commission and our evaluation implementing a tax on the agricultural sector will lead to reduction in emission, but as our results also reveals, the priority between reduction in emission, increases in consumer prices and redistribution of wealth must be clear in order to decide which policy is the most effective.

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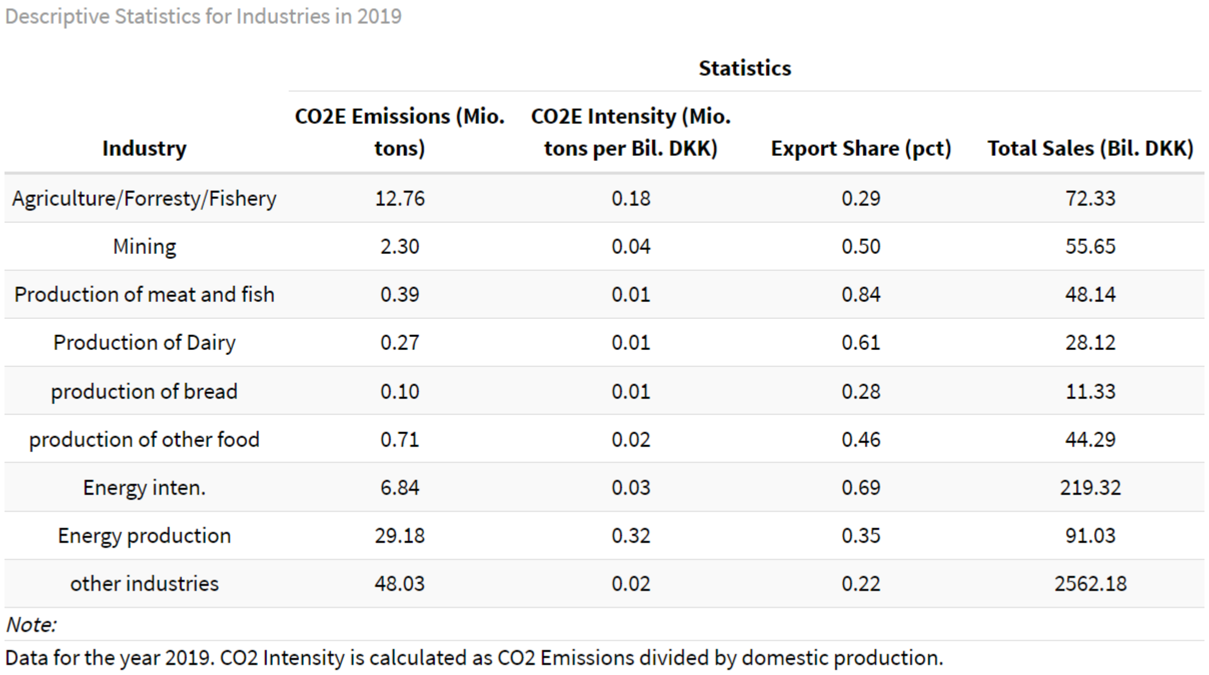
Appendix:

Table A1: Industry specific statistics



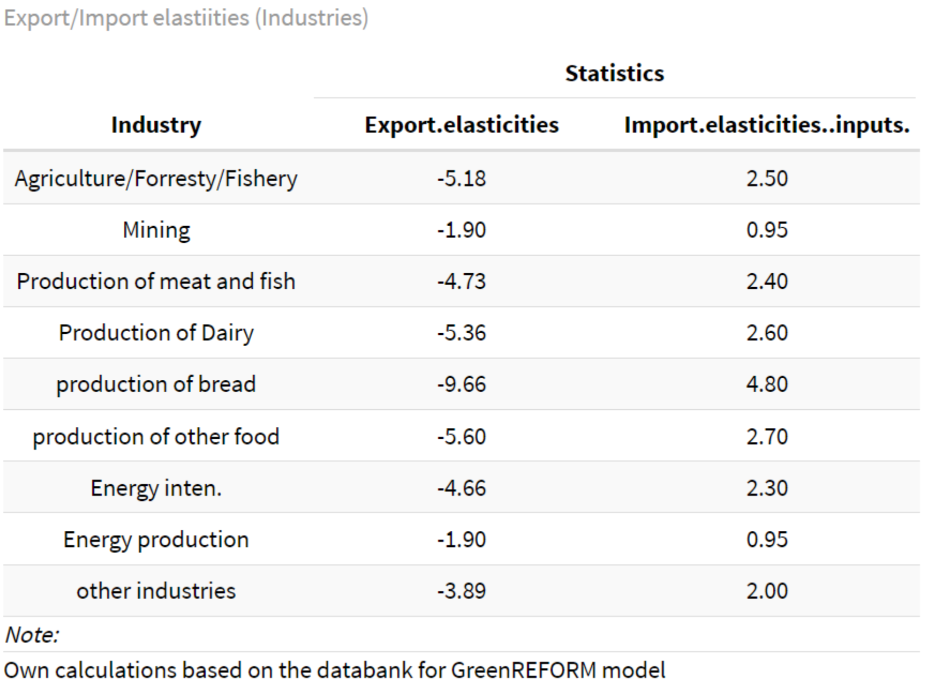
Descriptive Statistics for Industries in 2019

	Statistics			
Industry	**CO2E Emissions (Mio. tons)**	**CO2E Intensity (Mio. tons per Bil. DKK)**	**Export Share (pct)**	**Total Sales (Bil. DKK)**
Agriculture/Forresty/Fishery	12.76	0.18	0.29	72.33
Mining	2.30	0.04	0.50	55.65
Production of meat and fish	0.39	0.01	0.84	48.14
Production of Dairy	0.27	0.01	0.61	28.12
production of bread	0.10	0.01	0.28	11.33
production of other food	0.71	0.02	0.46	44.29
Energy inten.	6.84	0.03	0.69	219.32
Energy production	29.18	0.32	0.35	91.03
other industries	48.03	0.02	0.22	2562.18

Note:

Data for the year 2019. CO2 Intensity is calculated as CO2 Emissions divided by domestic production.

Tabel A2: Export and import elasticities for the nine industries



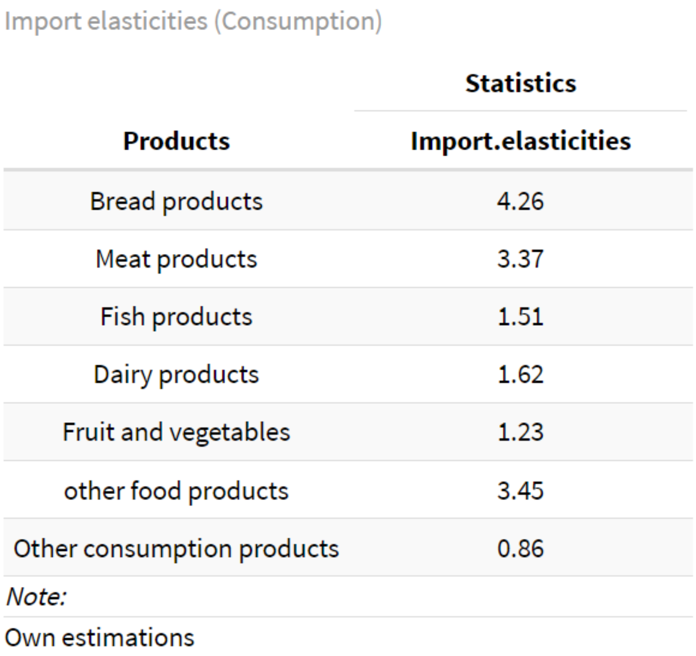
Export/Import elastiities (Industries)

	Statistics	
Industry	**Export.elasticities**	**Import.elasticities..inputs.**
Agriculture/Forresty/Fishery	-5.18	2.50
Mining	-1.90	0.95
Production of meat and fish	-4.73	2.40
Production of Dairy	-5.36	2.60
production of bread	-9.66	4.80
production of other food	-5.60	2.70
Energy inten.	-4.66	2.30
Energy production	-1.90	0.95
other industries	-3.89	2.00

Note:

Own calculations based on the databank for GreenREFORM model

Tabel A3: Import elasticities for the seven product types



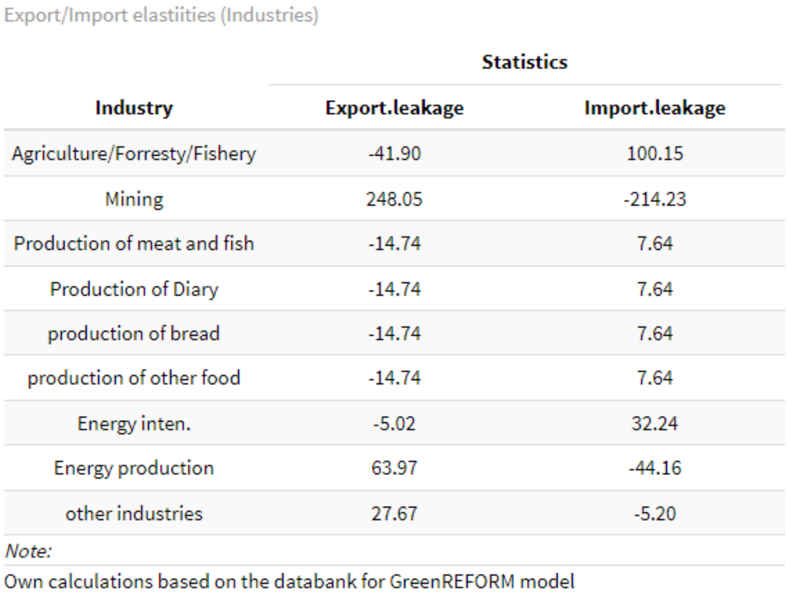
Import elasticities (Consumption)

	Statistics
Products	**Import.elasticities**
Bread products	4.26
Meat products	3.37
Fish products	1.51
Dairy products	1.62
Fruit and vegetables	1.23
other food products	3.45
Other consumption products	0.86

Note:

Own estimations

Tabel A4: Leakage coefficients for international trade



Export/Import elastiities (Industries)

	Statistics	
Industry	**Export.leakage**	**Import.leakage**
Agriculture/Forresty/Fishery	-41.90	100.15
Mining	248.05	-214.23
Production of meat and fish	-14.74	7.64
Production of Diary	-14.74	7.64
production of bread	-14.74	7.64
production of other food	-14.74	7.64
Energy inten.	-5.02	32.24
Energy production	63.97	-44.16
other industries	27.67	-5.20

Note:

Own calculations based on the databank for GreenREFORM model

Figure A1: Model fit for aggregate emission measures

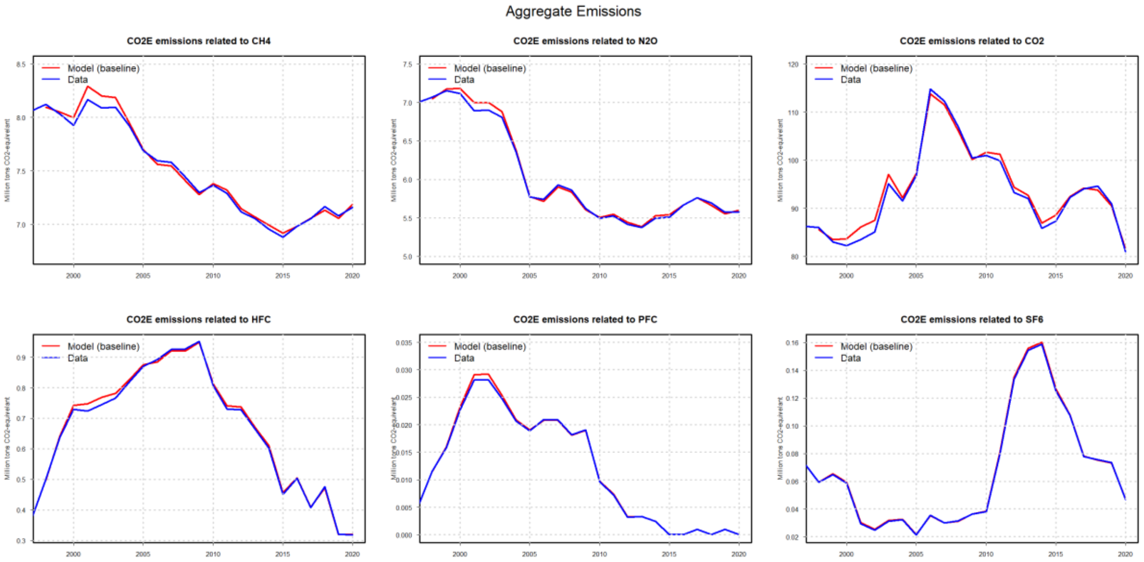


Figure A2: Effect on international trade variables in Scenario 1

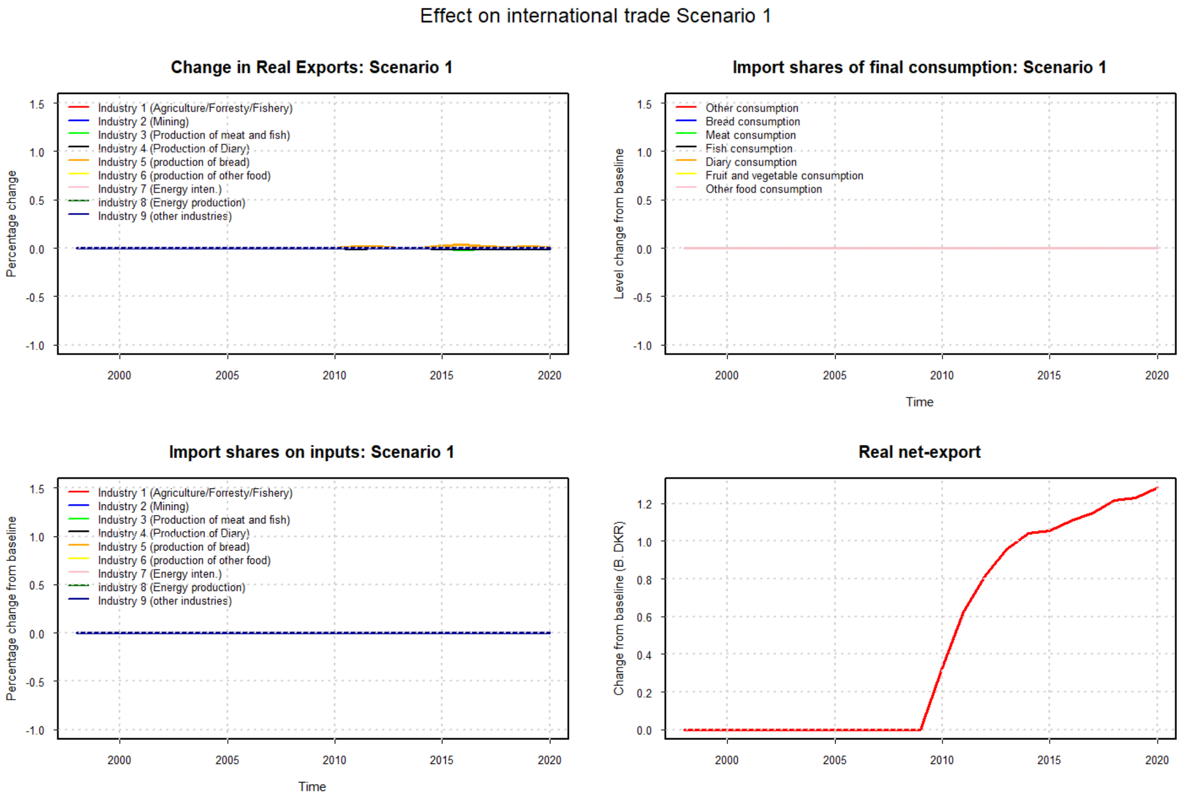


Figure A3: Changes in consumer prices in scenario 1b