Tero Kuusi[1], Martin Björklund[2], Ville Kaitila[1], Kai Kokko[2], Markku Lehmus[1], Michael Mehling[2,4], Tuuli Oikarinen[2], Johanna Pohjola[3], Sampo Soimakallio[3], and Maria Wang[1]

Carbon Border Adjustment Mechanisms and Their Economic Impact on Finland and the EU

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Authors' organisations: [1] = Etla, [2] = Helsingin yliopiston oikeustieteellinen tiedekunta,
[3] = Suomen ympäristökeskus ja [4] = Massachusetts Institute of Technology

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Abstract

In this report, we address an EU carbon border adjustment mechanism (CBAM) and its economic implications. While a CBAM is proposed as a solution to the EU's carbon leakage problem, we acknowledge that there are several ways to implement CBAMs, with varying combinations of technical difficulties, administrative burden, legal risks, and risks of political backlash. We construct scenarios in which the CBAM is designed based on feasibility considerations and compare them with broader, but also more complex, alternatives.

Based on our analysis, the CBAM may face major implementation hurdles in its deployment going forward. Thus, the likeliest approach would be to test its use with a narrow set of imported products that are emission intensive which would limit administrative challenges. After considering a feasible alternative, we find that the economic and environmental impact of such a narrow tariff would most likely be small, and such a CBAM would serve more as a signal of the EU's determination to resolve the carbon leakage problem rather than as a true solution to it.

More ambitious CBAMs will inevitably face difficulties in terms of data collection and administration. Moreover, China in particular will be strongly affected by such CBAMs. Countermeasures could nullify the economic benefits of CBAMs. To avoid the countermeasures, the EU should focus on designing the CBAM in a manner that aims at strengthening multilateral cooperation on climate change.

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Tiivistelmä

Analysoimme tässä tutkimuksessa Euroopan unionin harkitsemaa hiilitullimekanismia (CBAM, carbon border adjustment mechanism) ja sen taloudellisia vaikutuksia EU:ssa ja Suomessa.

Mekanismia on esitetty ratkaisuksi EU:n hiilivuoto-ongelmaan. Käytännössä se voidaan kuitenkin toteuttaa monella tavalla, ja eri toteutustavat luovat erilaisia teknisiä haasteita, hallinnollisia rasitteita sekä oikeudellisia ja poliittisten vastatoimien riskejä. Hankkeessa arvioimmekin hiilitullimekanismia ja sen vaikutuksia erilaisissa skenaarioissa, joissa mekanismin toteuttamistapaa vaihdellaan sen kunnianhimoisuuden ja toteuttamisen helppouden välillä.

Analyysimme perusteella hiilitullimekanismin kunnianhimoinen käyttöönotto voi kohdata merkittäviä esteitä. Sen vuoksi todennäköisimmältä vaikuttava vaihtoehto olisi aloittaa mekanismin käyttö rajatussa joukossa päästöintensiivisiä tuontituotteita, mikä olisi omiaan vähentämään hiilitulleihin liittyviä hallinnollisia haasteita. Tämän rajatun mutta toteuttamiskelpoisen vaihtoehdon taloudellinen ja ympäristöllinen vaikutus olisi kuitenkin todennäköisesti pieni. Näin toteutettuna hiilitullimekanismi toimisi enemmän signaalina EU:n päättäväisyydestä ratkaista hiilivuoto-ongelma kuin todellisena ratkaisuna siihen.

Kunnianhimoisemmat hiilitullimekanismit kohtaisivat väistämättä vaikeuksia, sillä päästötilastojen kerääminen ja hallinnointi on suuri haaste. Lisäksi mekanismit voisivat kohdistua erityisesti Kiinan tuontiin, ja sen mahdolliset vastatoimet voisivat aiheuttaa häiriöitä EU:n vientimarkkinoille. Välttääkseen kauppasodan riskiä EU:n pitäisi pyrkiä suunnittelemaan hiilitullimekanismi reilulla tavalla ja niin, että se olisi omiaan vahvistamaan monenkeskistä ilmastonmuutoksen vastaista kansainvälistä yhteistyötä.

Tämä julkaisu on toteutettu osana valtioneuvoston selvitys- ja tutkimussuunnitelman toimeenpanoa. (tietokayttoon.fi). Julkaisun sisällöstä vastaavat tiedon tuottajat, eikä tekstisisältö välttämättä edusta valtioneuvoston näkemystä.

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I denna forskningsrapport utreder vi den koldioxidtullsmekanism (CBAM, carbon border adjustment mechanism) som övervägs för tillfället i EU och Finland inklusive dess ekonomiska effekter.

Även om mekanismen har anförts som en lösning för det s.k. koldioxidläckaget, vidhåller vi att det finns olika sätt att genomföra koldioxidtullar som skulle innebära varierande grader av tekniska svårigheter, administrativ börda, juridiska risker samt risker för politiska motreaktioner. Vi utreder scenarier i vilka koldioxidtullarna formas utgående från hur genomförbara de är och jämför dem med mera heltäckande men därmed också mera komplicerade alternativ. Utgående från vår analys kommer koldioxidtullar sannolikt att mötas med allvarliga hinder vid genomförandet. Därmed verkar det mest sannolika alternativet vara att rikta dem mot ett rätt snävt urval av utsläppsintensiva importerade varor, vilket skulle begränsa den administrativa bördan. Efter att ha övervägt ett genomförbart alternativ, kommer vi till att det ekonomiska utfallet och miljöeffekterna av en sådan snäv tariff högst sannolikt vore begränsade. I ett sådant utförande skulle en koldioxidtariff innebära mera en signal från EU om ett äkta uppsåt i att ta sig an koldioxidläckaget än en äkta lösning på problemet.

Mera ambitiösa versioner av koldioxidtullar skulle oundvikligen stöta på svårigheter med datainsamling och förvaltning. Utöver detta skulle särskilt Kina påverkas rätt kraftigt av koldioxidtullar. Motåtgärder skulle uppväga koldioxidtullarnas ekonomiska verkan. För att undvika motåtgärder borde EU vinnlägga sig om att utforma sina koldioxidåtgärder på ett sådant sätt att de underbygger och stöder det multilaterala samarbetet för att bekämpa klimatförändringen.

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Content

Raportin tiivistelmä

Arvioimme tässä tutkimuksessa Euroopan unionissa mahdollisesti käyttöönotettavaa hiilitullimekanismia (CBAM, carbon border adjustment mechanism) ja sen taloudellisia vaikutuksia. Vielä täsmentämättömällä tavalla toteutettavaa mekanismia on ehdotettu ratkaisuksi EU:n tiukemman ilmastopolitiikan mahdollisesti kärjistämään hiilivuoto-ongelmaan. Käytännössä se voidaan toteuttaa monella tavalla, ja toteutustavat luovat erilaisia teknisiä haasteita, hallinnollisia rasitteita sekä oikeudellisia ja poliittisten vastatoimien riskejä.

Käyttöönottoon liittyviä asioita

Hiilitullimekanismin on arvioitu toimivan hyvin muun muassa keinona, jolla EU:n ulkopuolisia maita pyritään painostamaan vähentämään saastuttavaa tuotantoaan. Hiilitullia on kuitenkin aikaisemmin tarkasteltu lähinnä teoreettisesti, kun taas meidän lähtökohtamme on arvioida niitä käytännön ongelmia ja epävarmuuksia, joita liittyy hiilitullien käyttöönottoon.

Teknisestä näkökulmasta saattaa olla hyvin vaikeaa mitata mekanismin vaatimaa päästöjen ja hiilen hintaa samalla, kun riittävän luotettavan, asianmukaisen ja ajankohtaisen tiedon käyttäminen on onnistuneen toteuttamisen kannalta tärkeää. Suppea toteuttamistapa voi olla myös juridisesti helpompi toteuttaa. Hiilitullimekanismin esteet ovat todennäköisesti vähäisimpiä, kun se asetetaan koskemaan vain rajallista määrää tuotteita.

Samalla toteutustavan tulisi olla reilu. Toisaalta hiilitullimekanismin tulisi koskea tuontia kaikista kolmansista maista eikä rajautua vain muutamiin, millä voidaan välttää GATT-sopimuksen artiklan I suosituimmuusehdon (engl. Most Favoured Nation, MFN) rikkominen. Toisaalta laaja hiilitullimekanismi, joka kattaisi myös muun muassa monet puolivalmisteet ja lopputuotteet, lisäisi huomattavasti hiilitullimekanismin teknistä ja

hallinnollista monimutkaisuutta. Se voisi johtaa sen sattumanvaraiseen tai suhteettomaan soveltamiseen suhteessa asetettuihin tavoitteisiin ja lopulta sen lainopillisesti kriittiseen tulkintaan GATT-sopimuksen artiklan XX kautta. Hiilitullimekanismissa täytyy mahdollisesti myös ottaa huomioon hiilen hinta tai muut hiilirajoitteet, joita on asetettu tuontituotteille niiden alkuperämaassa.

Laadimme useita skenaarioita, joiden kautta tarkastelemme hiilitullimekanismin käyttöönottoon liittyviä kysymyksiä. Ensimmäisen skenaariomme on toteuttamiskelpoinen (”Feasible”). Siinä pyrkimyksenä on tarkastella helpoiten toteutettavaa vaihtoehtoa. Hiilitullimekanismi otetaan käyttöön vain sementin, kalkin ja kipsin tuonnissa. Niiden tuotanto on hyvin päästöintensiivistä, mutta samalla tullin käyttöönotosta seuraa pienempi riski juridisiin tai poliittisiin vastatoimenpiteisiin. Laajennettu toteuttamiskelpoinen skenaario sisältää lisäksi raudan, teräksen ja alumiinin sekä niistä valmistetut tuotteet. Analyysissa ratkaistaan EU:n ulkopuolisten maiden päästöjen mittausongelma käyttämällä EU:n keskimääräisiä päästöjä laskettaessa hiilitullin tasoa.

Vaihtoehtoisena skenaariona käytämme laajaa 14 päästöintensiivisen toimialan (ks. taulukko 4.1) hiilitullimekanismia ja yksityiskohtaisempaa hiilitullin mittaustapaa, jossa voidaan ottaa huomioon kaikki valmistuksessa syntyvät kasvihuonekaasupäästöt. Kutsumme tätä skenaariota tehokkaaksi (”Efficient”), sillä siinä on kiinnitetty vähemmän huomiota sen käyttöönottoon liittyviin kysymyksiin ja enemmän huomiota sen vaikuttavuuteen.

Taloudellinen analyysi

Tarkastelimme aluksi tullin piiriin mahdollisesti joutuvia markkinoita EU:n tuotannon näkökulmasta. Sementin, kalkin ja kipsin tuotannon osuus EU:n kokonaistuotannosta on hyvin pieni. Sen yhteenlaskettu arvonlisäys oli noin seitsemän miljardia euroa vuonna 2017 ja osuus koko yrityssektorin arvonlisäyksestä oli 0,11 prosenttia. Toisaalta sementti on hyvin tärkeä välituote erityisesti rakentamisen toimialalla. Perusmetallien ja niistä valmistettujen tuotteiden tuotannon arvonlisäys EU27-maissa oli 104 miljardia euroa vuonna 2017 eli 1,67 prosenttia koko yrityssektorin tuottamasta arvonlisäyksestä. Tämä on jo huomattava määrä, kuten on myös näiden tuotteiden merkitys välituotteina erityisesti muussa metalliteollisuudessa.

Sementin, kalkin ja kipsin arvo myös EU:n ulkopuolisesta tavaratuonnissa on hyvin pieni, vain noin 0,3 mrd. euroa. Sen sijaan raudan ja teräksen sekä niistä valmistettujen tuotteiden arvo (52,5 mrd. euroa) on jo paljon suurempi, eli 2,7 prosenttia EU:n ulkopolisesta tuonnista. Alumiinin ja niistä valmistettujen tuotteiden osuus on suunnilleen puolet raudan ja teräksen, ml. tuotteet, tuonnista. Laajassa, tehokkaassa skenaariossa hiilitullimekanismin piiriin kuuluu noin 60 prosenttia kaikesta EU:n ulkopuolisesta tuonnista.

Käytämme ekonometrista gravitaatiomallia laskeaksemme tariffien mahdollisen vaikutuksen tuontiin. Arvio perustuu havaintoihin tullien lähivuosikymmeninä synnyttämistä keskimääräisistä muutoksista tuonnissa. Niiden avulla arvioimme, miten hiilitullit voisivat vaikuttaa EU:n ulkotuontiin. Tulostemme mukaan toteuttamiskelpoisessa skenaariossa (joko vain sementti, kalkki ja kipsi tai näiden lisäksi rauta, teräs ja alumiini ja niistä valmistetut tuotteet) tariffeilla on vain vähäinen vaikutus (alle kolme miljardia euroa) koko bruttotuontiin. Tämä johtuu osittain siitä, että näiden tuotteiden osuus koko ulkotuonnista on varsin pieni.

Tehokkaassa skenaariossa vaikutukset ovat huomattavasti suurempia. Kun tullien määrittelyssä huomioidaan kaikki suorat ja epäsuorat kasvihuonekaasupäästöt, tuonnin arvo vähenee 93 miljardia euroa, mikä on melkein viisi prosenttia koko ulkotuonnista. Suorat päästöt ovat niitä, jotka syntyvät itse tuotantoprosessissa, ja epäsuorat päästöt niitä, jotka syntyvät em. tuotannossa tarvittavien, muilla toimialoilla tuotettujen välituotteiden tuotannossa. Euroissa mitattuna suurin vaikutus on kemikaalien ja kemiallisten tuotteiden tuonnissa (–17 mrd. euroa), radio-, televisio- ja tietoliikennevälineiden tuonnissa (–13 mrd. euroa), muiden sähkökoneiden ja -laitteiden tuonnissa (–11 mrd. euroa) sekä konttori- ja tietokonelaitteiden tuonnissa (–11 mrd. euroa). Kun laskelmassa otetaan huomioon kaikki suorat kasvihuonekaasupäästöt, mutta vain epäsuorat sähkön käyttöön liittyvät päästöt, EU:n ulkotuonti alenee 53 miljardia euroa.

Toteuttamiskelpoisen skenaarion vaikutus on pieni myös Suomen osalta. Sen sijaan tehokkaassa skenaariossa Suomen tuonti EU:n ulkopuolelta vähenee 1,8–3,6 prosenttia riippuen siitä, kumpi skenaario epäsuorien päästöjen osalta on käytössä. Nämä ovat hieman pienempiä lukuja kuin EU:lle arvioidut keskimääräiset vaikutukset, mikä johtuu tuonnin tuote- ja alkuperämaarakenteiden eroista suhteessa EU:n keskimääräiseen tuontiin.

Vastaavasti hiilitullien vaikutus tuontitavaroihin sitoutuneen hiilidioksidin määrään on hyvin pieni toteuttamiskelpoisessa skenaariossa. Tehokkaassa skenaariossa negatiivinen vaikutus on tuonnin alkuperämaiden osalta suurin Kiinalle sekä EU:n ulkopuoliselle Euroopalle (pl. Britannia, Sveitsi ja Venäjä). Suomen ulkotuontiin sitoutuneen hiilidioksidin määrä alenee 10,0 ja 13,1 prosenttia riippuen siitä, ovatko kaikki epäsuorat päästöt laskelmassa mukana vai eivät.

Koko EU:n tasolla tariffien kokonaistuotto on toteuttamiskelpoisessa skenaariossa 0,8 miljardia euroa. Huomattavasti laajemmassa tehokkaassa skenaariossa se on 15,2 tai 25,2 miljardia euroa riippuen siitä, ovatko kaikki epäsuorat päästöt laskelmassa mukana vai eivät. Tullien viimekätinen kohtaanto osuu sekä EU:hun että EU:n ulkopuolelle.

Mittaamme myös kaupan kehitykseen liittyviä maailmanlaajuisia arvoketjuja sekä niihin liittyvää suoraa ja epäsuoraa arvonlisäystä. Yleisesti ottaen muutokset heijastavat hyvin bruttokaupan kehitystä eri skenaarioissa. Kun tulli asetetaan suppeimmassa toteuttamiskelpoisessa skenaariossa (mukana on vain sementti, kalkki ja kipsi), merkittävin yksittäistä maata koskeva arvonlisäyksen menetys nähdään Britanniassa (56,6 % koko skenaarion synnyttämästä arvonlisäyksen laskusta tuonnissa) ja Turkissa (9,0 % vastaavasti). Kun hiilitulli asetetaan myös raudalle, teräkselle ja alumiinille sekä niistä valmistetuille tuotteille, Kiinan menetykset arvonlisäyksessä kasvavat huomattavasti. Tehokkaissa skenaarioissa Kiinan osuus nousee vielä merkittävämmäksi. Sen osuus on noin puolet kaikesta EU:n ulkopuolelta tuodusta arvonlisäyksestä, joka hiilitullien seurauksena häviäisi tuonnista.

Tulostemme mukaan huomattava osa menetetystä arvonlisäyksestä osuu arvoketjuihin, joissa lopputuotteiden valmistus on EU:ssa. Tällaisissa tapauksissa EU:n yritysten on löydettävä vaihtoehto aiemmin tuodulle välituotteelle.

Suomeen päätyvän tuonnin arvonlisäsisältö on hyvin pieni toteuttamiskelpoisen skenaarion tapauksessa. Myös tehokkaassa skenaariossa suomalaisten yritysten arvonlisäyksen tuonti välituotekäyttöön tai niiden oma suora arvonlisäys tuonnissa on suhteellisen vähäinen, noin 100 miljoonaa euroa skenaariosta riippuen. Suhteellisesti ottaen kaupasta riippuvaisimmat alat välituotekäyttäjinä ovat tehdasteollisuudessa. Samanlainen tulos koskee myös EU:ta, vaikkakin Suomessa riippuvuus on keskimäärin pienempää.

Käytämme talouden rakenteita kattavasti kuvaavaa yleisen tasapainon GTAP-mallia analysoidaksemme hiilitullimekanismin mahdollisia vaikutuksia tuotantoon EU:ssa. Kun hiilitullien alaisten tuotteiden tuonti EU:n ulkopuolisista maista vähenee, syntyy substituutiovaikutus. Välituotteiden ja lopputuotteiden tuontia korvataan EU:ssa valmistetuilla tuotteilla, joiden hintaan tullit eivät suoraan vaikuta. Tämä vaikutus lisää EU:ssa valmistettujen tuotteiden kysyntää.

Laajassa toteuttamiskelpoisessa skenaariossa ei-metallisten mineraalituotteiden, raudan ja teräksen sekä muiden metallien valmistus kasvaa Suomessa ja muissa EU-maissa. Tuotanto kasvaa myös niillä toimialoilla (erityisesti kaivannaisteollisuus ja sähköntuotanto), jotka toimittavat näille kasvaville toimialoille merkittäviä määriä välituotteita. Tehokkaassa skenaariossa suuri määrä toimialoja kuuluu hiilitullimekanismin piiriin. Näin tuotanto kasvaa useimmilla toimialoilla.

Kaikki toimialat eivät kuitenkaan ole voittajia EU:ssa. Huomattava osa kaikesta tuonnista on välituotteita, joita käytetään EU:n omassa tuotannossa. Välituotteiden hintojen nousu lisää lopputuotteiden valmistajien kustannuksia. Heikentynyt kilpailukyky näkyy toteuttamiskelpoisessa skenaariossa tuotannon vähenemisenä kulkuneuvojen valmistuksessa, kone- ja laiteteollisuudessa sekä elektroniikkateollisuudessa, jotka käyttävät välituotteina EU:n ulkopuolisista maista tuotuja metalleja ja metallituotteita. Tehokkaassa skenaariossa kustannusvaikutus on selvästi suurempi, koska hiilitullimekanismi koskee paljon useampia toimialoja ja koska asetettu hiilitulli on korkeampi. Tulosten mukaan myös hiilitullimekanismilla suojellut toimialat EU:ssa voivat kärsiä, jos nousseiden valmistuskustannusten negatiivinen vaikutus on suurempi kuin positiiviset vaikutukset suhteellisesta edusta suhteessa EU:n ulkopuolisiin valmistajiin. Näin tapahtuu koneiden ja laitteiden sekä elektronisten tuotteiden valmistuksessa, joiden hyödyt hiilitullimekanismista ovat rajalliset, koska niitä viedään lähinnä EU:n ulkopuolelle. Muilla toimialoilla vaikutukset ovat vähäisiä toteuttamiskelpoisessa skenaariossa. Tehokkaassa skenaariossa resurssien uudelleenkohdentuminen hiilitullimekanismin alaisille toimialoille johtaa tuotannon vähenemiseen useimmilla muilla toimialoilla, ml. palvelualoilla.

Riippuen hiilitullimekanismin laajuudesta sen vaikutus bruttokansantuotteeseen on hyvin vähäinen tai negatiivinen Suomessa ja muissa EU-maissa. EU:n ulkopuolella päästöintensiiviset maat kuten Kiina sekä ryhmä Itä-Euroopan ja Keski-Aasian maita kärsivät hieman hiilitullimekanismista tehokkaassa skenaariossa, kun maakohtaiset tariffit perustuvat EU:n ulkopuolisten maiden tuotannon hiili-intensiivisyyteen. Muissa EU:n ulkopuolisissa maissa vaikutukset ovat hyvin pieniä molemmissa skenaarioissa.

Yllä esitetyissä tuonti-, arvoketju- ja kokonaistaloustarkasteluissa hiilitulli perustuu päästöoikeuden hintaan 25EUR/tCO2. Vaikutukset pääosin kaksinkertaistuvat, jos päästöoikeuden hinta nousee 50 euroon hiilidioksiditonnilta.

Hiilitullimekanismin mahdolliseen käyttöönottoon liittyy riski EU:n ulkopuolisten maiden vastatoimenpiteistä. Kauppasodan mahdollisia vaikutuksia analysoitiin globaalilla makrotalouden NiGEM-mallilla. Tulosten mukaan on hyvin todennäköistä, että kauppasota pyyhkisi pois kaikki hiilitullimekanismin mahdolliset positiiviset talousvaikutukset. Jos muu maailman reagoi hiilitullimekanismiin nostamalla muiden kuin raaka-aineiden osalta tullitasoaan kahdella prosenttiyksiköllä tuonnissaan EU:sta, Suomen bkt alenee pitkällä aikavälillä 0,3 prosenttia ja EU:n bkt keskimäärin 0,25 prosenttia.

Joka tapauksessa analyysimme mukaan hiilivuoto-ongelma täytyy ratkaista, sillä löysimme empiirisessä EU:n viennin ja tuonnin päästödataa hyödyntävässä analyysissamme siitä merkkejä. Vaikuttaa siltä, että EU:n päästökauppajärjestelmän (ETS) eri vaiheet ovat lisänneet tuontituotteiden sisältämän hiilen määrää, erityisesti ETS:n 2. vaiheessa. Lisäksi on jonkin verran todisteita siitä, että tuonnin hiilisisältö on noussut niissä tuotteissa, jotka ovat päästökauppajärjestelmän alaisia. Estimointitulosten mukaan hiilivuotoaste on melkein 20 prosenttia. Tämä estimaatti on aiempien yleisen tasapainon mallien avulla tehtyjen tulosten antaman haarukan ylälaidassa.

Tasapuolisuus, tehokkuus ja hallinta

Arvioimme kolmea hiilitullimekanismin muotoilun näkökulmaa: tasapuolisuutta, tehokkuutta ja sen hallinnointia. Vaikuttaa siltä, että eri vaihtoehdot hiilitullimekanismin muotoilussa johtavat vääjäämättä kompromisseihin eri näkökulmien välillä. Jotta hiilitullimekanismin hallinnointiin liittyvät ongelmat (erityisesti yksityiskohtaisen päästödatan keräämiseen liittyen) voitaisiin ratkaista, tarvitaan yksinkertaistettuja, toiseksi parhaita (second-best) ratkaisuja.

Hiilitullia voidaan yksinkertaistaa käyttämällä karkeita sääntöjä sopeutumislaskemissa tai rajoituksia sopeutumistarpeessa. Yksinkertainen muotoilu tässä suhteessa voi kuitenkin aiheuttaa ongelmia muista näkökulmista. Ne voivat heikentää hiilitullin tasapuolisuutta, erityisesti EU-maiden ja kolmansien maiden yhdenvertaisuutta, mikä voisi helposti johtaa taloudelliseen tehottomuuteen ja juridisiin kiistoihin. Osaratkaisu tähän ongelmaan olisi sallia tuojille yksilöllisesti tuotteiden todellisen hiili-intensiivisyyden todentaminen valvotusti.

EU:n ulkopuolisten maiden olisi helpompi hyväksyä tasapuolinen ja oikeudenmukainen hiilitullimekanismi WTO:n sääntöjen puitteissa. Reiluus eli oikeammin EU:n kansainväliset kauppavelvoitteet edellyttävät, että valittu hiilitullimekanismi on puhdas ratkaisu hiilivuoto-ongelmaan ja ettei EU:n sisällä käytetä mitään muuta mekanismia samaan tarkoitukseen. Hiilitullimekanismin oloissa olisi paljon vaikeampi perustella ilmaisjaollisten päästöoikeuksien jatkuminen turvaamaan teollisuuden kansainvälistä hintakilpailukykyä hiilivuodon oloissa. Kompromissi tässä suhteessa voisi olla luopuminen asteittain ilmaisjaollisista päästöoikeuksista samalla, kun hiilitullimekanismi otetaan käyttöön.

Tehokkuusnäkökulmasta toteuttamiskelpoisin muotoilu, joka kattaisi vain sementin ja siihen liittyvät tuotteet, vaikuttaisi tulostemme mukaan kaikella todennäköisyydellä vain hyvin vähän ulkomaankauppaan ja päästöihin. Laajemmissa skenaarioissa hiilitullimekanismin vaikutus olisi tietenkin suurempi, jolloin sillä olisi huomattava vaikutus myös hiilivuotoon ja päästöihin.

Hiilitullimekanismin laajentaminen laittaisi enemmän painetta yksityiskohtaisen datan keräämiselle. Mekanismissa pitäisi olla tieto päästöistä kaikissa tuotannon eri vaiheissa ja kaikilla toimialoilla, jotka käyttävät päästöintensiivisiä välituotteita omassa tuotannossaan. Arvoketjuanalyysi osoittaa, että suuret määrät päästöintensiivisiä välituotteita käytetään erilaisten lopputuotteiden valmistuksessa muun muassa tehdasteollisuudessa. Jos hiilitullimekanismia ei uloteta näihin tuotteisiin, se voi jättää kilpailuedun EU:hun tuoduille päästöintensiivisille välituotteille, mikä lisäisi hiilivuodon riskiä.

Huolellisesti suunniteltu hiilitullimekanismi tuontituotteille voisi kompensoida erilaisen ilmastopolitiikan aiheuttamia vaikutuksia kustannustasoon ja siten kilpailutilanteeseen. Erot säilyvät edelleen EU:n ulkopuolella, jos vastaavasti kunnianhimoista ilmastopolitiikkaa ei harjoiteta siellä. Globaalin ilmastopolitiikan näkökulmasta on tehotonta, jos EU:n ulkopuoliset maat alkavat käyttää aiempaa enemmän päästöintensiivisempiä omia tuotteitaan, joille ei synny sellaisia hiilikustannuksia, joita EU:n omat tuottajat kohtaavat ilmastopolitiikan vuoksi.

Komplementaarisia veroinstrumentteja tai suoria tukiaisia on ehdotettu vaihtoehtoisena ratkaisuna ilmaisjaollisille päästöoikeuksille. Yksi tapa olisi lisätä nykyjärjestelmään päästölisäinen vero (Stiglitz, 2013). Kuten arvonlisävero, päästönlisävero olisi kulutusvero, joka asetetaan tuotteelle aina, kun sen tuotantoketjussa syntyy päästöjä siihen saakka, kunnes tuote myydään loppukäyttöön. Kuluttaja maksaa veroa sen mukaan, kuinka paljon päästöjä on syntynyt tuotteet valmistuksessa pois lukien ne välituotteiden päästöt, joita on jo verotettu. Jos tuote viedään jollekin toiselle alueelle, sitä ei verotettaisi. Toisaalta tuontituote kohtaisi samanlaisen verokohtelun kuin EU:n oma tuotanto, kun se myydään EU:n alueella. Vaikka tämä järjestely on ajatuksellisesti houkutteleva, siihen liittyy myös monimutkaisia hallinnollisia ja metodologisia haasteita, eikä se ratkaisisi EU:n päästökauppajärjestelmästä syntyvää hiilivuoto-ongelmaa, jos ETS pidettäisiin yhä voimassa.

Johtopäätökset

Analyysimme perusteella hiilitullimekanismin (CBAM) voidaan odottaa kohtaavan merkittäviä esteitä tulevina vuosina. EU:n kansainvälisten velvoitteiden, tehokkuuden, tasapuolisuuden ja teknisten haasteiden näkökulmasta siirtymä hiilitullimekanismin täydelliseen käyttöönottoon on oleva asteittainen ja hankala.

Aiempien ehdotusten perusteella todennäköisin lähestymistapa olisi testata sen käyttöä rajoitetulla määrällä päästöintensiivisiä tuotteita, jotka ovat helppoja hallinnoida ja yksinkertaisia tuottaa. Tulostemme mukaan tällaisen toteuttamiskelpoisen hiilitullimekanismin taloudellinen ja ympäristöllinen vaikutus olisi todennäköisesti pieni. Suppean hiilitullimekanismin toteuttaminen olisi siten enemmän vain signaali EU:n päättäväisyydestä vastata ilmasto- ja hiilivuoto-ongelmaan kuin varsinainen ratkaisu niiden korjaamiseksi.

Toisaalta, jos EU ottaa käyttöön kunnianhimoisemman hiilitullimekanismin, joko heti aluksi tai pidemmällä aikavälillä, se tulee vääjäämättä kohtaamaan suurempia vaikeuksia. Tulostemme mukaan globaalit tuotantoketjut ovat monimutkaisia, ja järjestelmällinen ja kunnianhimoinen hiilitullimekanismi kohtaa huomattavan työn datan keräämisessä ja hallinnoinnissa. Lisäksi tulostemme mukaan hiilitullit koskettaisivat erityisesti Kiinaa, jos tullit asetettaisiin koskemaan toimialoja laajasti. Vastatoimet ja välttämistoimenpiteet kuten vientitukiaiset alkuperämaissa neutraloisivat nopeasti hiilitullien mahdolliset taloudelliset hyödyt. Siten on syytä olla varovainen erityisesti sen suhteen, että hiilitullimekanismi voisi toimia EU:n budjettivarojen lähteenä.

Jos EU ottaa käyttöön hiilitullimekanismin rahoittaakseen elpymispakettia tai jostain muusta ilmastoon liittymättömästä syystä, joka on WTO:n sääntöjen vastainen, se heikentää EU:n uskottavuutta kansainvälisessä ilmastoyhteistyössä, ml. tulevassa UNFCCC COP26:ssa. EU:n pitäisikin suunnitella hiilitullimekanismia niin, että se vahvistaa monenkeskistä yhteistyötä ilmastomuutosta vastaan vahingoittamatta kehitystä YK:n ilmastokonferenssissa ja ottamatta käyttöön menetelmiä, jotka vaikuttavat olevan kansainvälisten velvoitteiden ja sääntöpohjaisen kansainvälisen järjestelmän vastaisia.

Report summary

In this report, we address the idea of an EU carbon border adjustment mechanism (CBAM) and its economic implications. Such a mechanism, while not yet detailed, has been proposed as a solution to emission leakage that may result from the EU's commitment to a stronger climate policy. In a second-best world, there are several ways to implement CBAMs with a varying amount of technical difficulties, administrative burden, legal problems, and risk of political backlash.

Implementation issues

While CBAMs have been argued to work well—for example, as instruments to put pressure on third countries to have less polluting production—our starting point was to address the practical problems and uncertainties that overshadow a CBAM's practical implementation and effectiveness.

In technical terms, we found that it may be very difficult to determine both emissions and an explicit carbon price for CBAMs in practice. In particular, the availability of reliable, appropriate, and timely data is a pressing issue. In legal terms, a CBAM is likely to face less problems in implementation when its scope is limited. By covering imports from all countries, rather than singling out particular countries, a CBAM can avoid violating the most-favored nation principle contained in Article I of the General Agreement on Tariffs and Trade (GATT). Other than that, however, a broader scope, including many semi-manufactured and manufactured goods, dramatically increases the technical and administrative complexity of the CBAM, which could render its application arbitrary or disproportionate vis-à-vis the intended goals and affect its legal assessment under Article XX of the GATT. Finally, the CBAM may need to take into account a carbon price or other carbon constraint imposed on imported products in their country of origin.

We illustrated the implementation issues by using several scenarios. Building on our analysis, we titled our first scenario as "the Feasible Scenario": in this the CBAM is applied down to very few industries (cement, lime, and plaster industries) where production is most emission intensive and there is less threat of legal or political complications in the CBAM's implementation; the CBAM may have an extension to cover iron, steel, and aluminum production. Moreover, we work around the difficulties of the measurement of emissions beyond the EU borders by considering EU emission averages as the benchmark for the calculation of the carbon tariff.

As an alternative, we discuss the option of using a wider scenario with a larger number of emission-intensive products (covering 14 industries; see Table 4.1) and more detailed measurement of the carbon tariff, potentially building on all emissions. As this scenario puts less weight on the practical implementation issues and more weight on the potential impact of the CBAM, we titled it "the Efficient Scenario."

Economic analysis

We started by describing the EU markets that are potentially subjected to the tariffs. We saw that the manufacturing of cement, lime, and plaster plays a very small part in the total EU economy. Its total value added was seven billion euros in 2017 and its share in total business economy value added was just 0.11 %. On the other hand, cement is of course very important as an intermediate good for the construction sector. In terms of EU´s own production, the manufacturing value added of basic metals and products thereof in the EU27 countries was 104 billion euros in 2017, or 1.67 % of the total business sector's value added. This is already significant, as is of course the importance of these products as intermediate goods, especially in other metal industries.

In terms of trade, the value of extra-EU imports of cement, lime, and plaster is very small, only about 0.3 bn. euros. The value of iron and steel imports, including products made thereof, is much larger (52.5 bn. euros) and equal to 2.7 % of all extra-EU imports. The value of aluminum and aluminum product imports is about half the value of iron and steel. Our broadest Efficient Scenario extends the CBAM to cover products that constitute roughly 60 % of the extra-EU imports.

We use econometric gravity analysis to isolate the historical trade effect of tariffs and apply the findings in making projections concerning the effects of the proposed tariff increases on EU imports. We find that the variants of the Feasible Scenario (either with cement, lime, and plaster or with cement, lime, and plaster, and aluminum and steel) have a limited impact (less than 3 bn. euros) on overall gross imports, partly because the products in this scenario constitute such a small share of extra-EU imports.

The Efficient Scenario exhibits much larger effects of course. The total impact when including both direct and indirect CO_2 emissions is 93 billion euros or almost 5 % of all extra-EU imports. The direct emissions are those that are emitted in the production process itself and the indirect emissions are those emitted and embodied in the value chain of this production when intermediate products are produced in other sectors. In euro terms, the biggest impact comes from the EU import effect on manufacturing of chemicals and chemical products (-17 billion euros), the manufacturing of radio, tv, and communication equipment (-13 billion euros), the manufacturing of electrical machinery and apparatus (-11 billion euros), and the manufacturing of office, accounting, and computing machinery (-11 billion euros). When we only include indirect electricity CO_2 emissions along with the direct emissions, the aggregate impact is a decline in extra-EU imports worth 53 billion euros.

While the effect of the Feasible Scenario is also small for Finland, in the Efficient Scenarios, the value of Finnish extra-EU imports declines by between 1.8 % and 3.6 %, depending on the scope of the emissions. These are somewhat smaller figures than for the EU on average and are due to differences in the product and country-of-origin structure of Finnish imports vis-à-vis the EU average.

In terms of the overall tariff revenues, in the Feasible Scenario it amounts to 0.8 billion euros. The much wider Efficient Scenarios yield a tariff revenue of 15.2 billion euros and 25.2 billion euros, depending on whether or not all the indirect CO_2 emissions are included. It is notable that this revenue will be paid to great extent by the European importers, companies and consumers.

The impact on the total CO_2 content of imports in the Feasible Scenarios is negligible. In the Efficient Scenarios, we can see that the impact on the value of imports is the greatest for China and across non-EU Europe (excluding the UK, Switzerland, and Russia). Meanwhile, the CO_2 content of Finnish extra-EU imports declines by between 10.0 and 13.1 %, depending on whether all or part of the emissions are considered.

We measure the associated global value chains and the total direct and indirect value added in them. Overall, they reflect well the magnitude of gross trade in the scenarios. When the tariff is placed, the most important individual-country value-added contribution losses through the decline in imports would be experienced by the UK (56.6% of all value added lost due to the decline of imports) and Turkey (9.0%) in the case of the narrowest Feasible scenario (with cement, lime and plaster). When the basic metal products are included to the Feasible scenario, the Chinese value added embodied in the imports falls substantially. In the Efficient Scenarios, China's role becomes even more dominant. It contributes roughly one half of the total value added in products that would cease to be imported to the EU according to the changes in the gross trade.

We find that a substantial share of the lost value added contributes to value chains for which the final assembly is made in the EU. In these cases, EU production needs to find a substitute for the imported intermediate product.

CBAM-induced changes in the value-added content of intermediate product imports to Finland would be negligible in case of the Feasible scenario.. Also, in the Efficient Scenario, the amount of value added that Finnish firms import from abroad to be used in their final products, or their own value added embodied in the imports, is relatively small, varying around 100 million euros depending on the scenarios. In relative terms, the most reliant industries are the manufacturing industries. This result is comparable to the EU findings, albeit the reliance is smaller than for the European industries on average.[1]

We use a computable general equilibrium model (GTAP[2]) that incorporates more economic structure to the analysis in order to study the impacts on production in the EU. When imports of CBAM products from non-EU countries fall, there tends to be a substitution effect: Imports are replaced in intermediate production or final use with substitute products that are acquired from the EU area (products whose price is not directly affected by the tariff). This effect will boost the demand for EU products.

In the extended Feasible Scenario, the productions of iron and steel, non-metallic minerals, and non-ferrous metals increase in Finland and other EU countries. Production also increased in industries that provide a substantial number of inputs to these sectors, namely mining and electricity. In the Efficient Scenario, a wide variety of industries belong to the CBAM. We found that production increases in most of these industries.

However, not all industries are winners in EU countries. A substantial share of imports are used as intermediate products in EU production. The increase in the price of the intermediate products will add to the cost of final products. The weakened competitiveness is shown in the Feasible Scenario as production losses in the transport equipment, machinery and equipment, and electronics industries that use metals from non-EU countries as intermediate inputs. In the Efficient Scenario, the cost impact is notably larger due to the wider sectoral coverage and higher tariffs based on the country-specific carbon contents. The results show that CBAM-protected industries in the EU

1 Our reliance metric is the imported products' relative share of the overall production value added in the EU, and we acknowledge that in some cases it may not correctly reflect true reliance on them. GTAP model is presented in

2 GTAP model is presented in https://www.gtap.agecon.purdue.edu/models/current.asp

may also suffer if the negative effect due to the increased production costs exceeds the benefits from having a comparative advantage against non-EU producers that face the tariff. That is what happens in the production of machinery and equipment, as well as electronics, whose benefits from improved competitiveness in the EU remain limited as they mainly export to non-EU countries. For other sectors, the impacts are negligible in the Feasible Scenario while in the Efficient Scenario the reallocation of resources to CBAM sectors implies lower production levels in most of other sectors, including, for example, services.

The impact of the CBAM on gross domestic product (GDP) is negligible or slightly negative in Finland and other EU countries, depending on its scope. In the case of the non-EU area, emission-intensive countries, such as China and the group of Eastern European and former Soviet Union countries, suffer slightly from the CBAM in the Efficient Scenario with country-specific tariffs based on carbon content in the non-EU countries. For other non-EU countries, the impacts are negligible in both scenarios.

The results from trade impact analysis, value chain analysis and economywide GTAP analysis are all based on the carbon tariffs calculated with carbon price of 25 EUR/tCO_2. The effects are mainly doubled if the carbon price increases to a 50 EUR/tCO_2.

There is the possibility of a retaliation by countries outside the EU, which may follow if/when the EU impose the CBAM scheme. The impact was demonstrated with a global macroeconomic model (NiGEM[3]) that was used to measure the potential impacts of trade wars. Based on our analysis, it is highly likely that a resulting trade war could wipe out any economic benefits of the CBAMs. For example, if the rest of the world retaliates to the EU tariff policies with an across-the-board 2 % increase in tariffs in the rest of the world's (non-commodity) goods imports from the EU countries, in the long run Finland and the eurozone suffer from a 0.3 % and 0.25 % GDP fall respectively.

In any case, our empirical analysis with data on emissions embodied in EU's imports and exports points towards a necessity to deal with the carbon leakage problem as we found signs in the data of its existence. It appears that the phases of the EU Emissions Trading Scheme (ETS) have increased the carbon content in the imported goods, especially in Phase 2. Furthermore, there is some evidence that the carbon content of imports has increased more in the product groups that are subject to the EU ETS. The carbon leakage rate with our estimations would be close to 20 %. This estimate is on the higher range compared with previous studies that have used computable general equilibrium methods to estimate carbon leakage.

3 https://nimodel.niesr.ac.uk/

Equity, efficiency, and administration

In our discussion of the CBAM, we consider three basic aspects of its design: equity, efficiency, and administration. At face value, it seems that the design options of the CBAM necessarily create trade-offs between them. To overcome the major problems that arise from the administration of the CBAM (the major burden of collecting detailed information on emissions), there is a need for simplified, second-best, versions of the CBAM. The ways to simplify the design may include crude rules for quantifying the adjustment or limitations of the scope of the adjustments.

However, a simple design may create problems in terms of the other aspects of good design. It may erode the fairness of the system (Would the carbon border adjustments [CBAs] treat EU and non-EU countries similarly?), which would easily lead to economic inefficiency and legal disputes. A partial solution for that problem would be to offer importers the option to individually prove their actual carbon intensity with verified emissions data.

Fair and just CBAMs are easier to accept by countries outside the EU and enforce in the light of World Trade Organization (WTO) rules. Fairness, and rather EU´s international trade obligations, demand that the chosen mechanism be a pure response to carbon leakage, and that no other mechanisms inside the EU are used for the same purpose. In implementing the CBAM, it is much harder to justify the continuation of the free allocation of the EU ETS allowances as a safeguard for the international competitiveness of industrial sectors at risk of carbon leakage. A compromise solution might be the gradual phase-out of the free allocation, alongside the introduction of the CBAM.

From the efficiency perspective, the most feasible design would only involve cement and related products; this would, in all likelihood, only have a small effect on both trade and emissions based on our results. In the case of broader scenarios, the effect of CBAMs would, unsurprisingly, become greater, and thus it is expected that they will have a substantial impact on carbon leakage and emissions.

Extension of the system puts increasing pressure on the level of detail in the design of CBAMs. For one, the CBAM should account for emissions in all stages of production and cover industries that use emission-intensive materials in their downstream production. The value chain data suggests that large quantities of emission-intensive materials are used in the final production of other products, such as manufactures. If the border adjustment is not extended to these products, it may give a competitive advantage to the imports to the EU that use emission-intensive materials (which are left outside the CBAM) as intermediate goods and thus leaves the system vulnerable to carbon leakage.

While a carefully designed CBAM for imported products could compensate for the competition effect that differences in climate policy ambition has on production costs in the EU market, the disparity remains beyond the EU borders if a similarly ambitious climate policy is not conducted there. From the global climate-policy perspective this is inefficient if countries outside the EU turn to using more emission-intensive products of their own that are not burdened by similar carbon costs as those faced by EU products, stemming from climate policy.

As an alternative solution to free allocation, complementary tax instruments or direct subsidies have been proposed. For example, one way would be to complement the current system with an emission-added tax (Stiglitz, 2013). In essence, the emission-added tax (in an analogy with a value-added tax) is a consumption tax that is placed on a product whenever emissions are added at each stage of the supply chain, until the product is sold for final use. The amount of tax that the user pays is based on production emissions, less any of the emissions of intermediate products that have already been taxed. If products are exported to other regions, they would be taxed at a zero rate. On the other hand, imports would be subjected to the same tax treatment as EU products when they are sold in the EU area. However, although conceptually appealing, such an alternative policy approach also raises complex administrative and methodological challenges and would not address the leakage risk stemming from the EU ETS if the ETS remains in place.

Conclusions

Based on our analysis, it is fair to expect that the CBAM will face major implementation hurdles in the coming years. From the perspectives of the EU's international legal obligations, efficiency, fairness, and technical challenges, it is reasonable to assume that the process of moving towards its full implementation will be gradual and burdensome.

As envisaged by past proposals, the most likely approach would be to test its use with a narrow set of imported products that are emission intensive, yet easy to administer and simple to produce. After considering a feasible alternative, we find that the economic and environmental impact of such a narrow tariff would be likely to be small. Thus, the implementation of such a CBAM serves more as a signal of the determination of the EU to address the climate problem and attendant carbon leakage than as a true solution to it.

On the other hand, if the EU introduces a more ambitious CBAM, whether initially or over time, it will inevitably face greater difficulties. Our results show that the global production linkages are complex, and an orderly and ambitious implementation of a CBAM faces the significant task of data collection and administration. Moreover, in our results, China in particular appears as a country that will be strongly affected by the tariffs if they are implemented in a more ambitious way. Retaliatory countermeasures or avoidance strategies such as export subsidies in the country of origin could easily remove any economic benefits of the tariffs. Thus, one should exercise caution, especially when considering a CBAM as a possible source of EU budget resources.

If the EU, implements a CBAM in a way that appears contrary to WTO rules in order to finance the relief package or for other non-climate related reasons, it will undermine the credibility of any EU efforts towards international climate cooperation, including the upcoming United Nations Framework Convention on Climate Change (UNFCCC) conference COP26. Rather, to avoid harming the progress within the UN climate conference and taking measures that appear contrary to international commitments and the rules-based international order, the EU should design the CBAM in a manner that aims at strengthening multilateral cooperation on climate change.

1 Introduction

In line with the UNFCCC and the Paris Climate Agreement, the European Union (EU) and Finland have committed themselves to significantly reducing their human-induced carbon dioxide (CO2) emissions and other greenhouse gas (GHG) emissions influenced in order to mitigate global climate change. This is expected to lead to an increase in the price of CO2 through, inter alia, the EU Emissions Trading Scheme (ETS) and the tightening of carbon/energy taxation. The increase in the price of CO2 emissions should lead to the development and use of technologies that displace, or at least reduce, the CO2 intensity of production and consumption.

One of the key risks of the climate policy, both for the climate and for the economy, is that rising prices can lead to carbon leakage (i.e., the transfer of polluting production to countries that are not committed to strong mitigation measures). One proposed solution to the problem is the use of carbon tariffs on imports from non-EU countries. Accordingly, on 16 July 2019, Ursula von der Leyen—then candidate for President of the European Commission—stated in her political guidelines that she would present a carbon border tax to avoid carbon leakage. According to the preliminary plan, the approach would be sectoral, step-by-step, and fully in line with international trade rules.

On 23 July 2020, the European Commission launched public consultations on two initiatives that aim to maximize the impact of taxation in meeting the EU's climate goals. The revision of the Energy Tax Directive (ETD) and the creation of a carbon border adjustment mechanism (CBAM) were identified in the European Green Deal as means to help with the transition towards a greener and more sustainable economy, together with the European Green Deal investment plan, the just transition mechanism, and other measures. In addition, the European Commission indicated that green own budget resources—including revenue from the CBAM—could contribute to financing the future

EU budget, for recovery and growth in the wake of the COVID-19 pandemic.[4] This report studies the feasibility and economic impact of carbon tariffs. Carbon duties have been argued to work well in principle, for example, they can be used as an instrument to put pressure on third countries to have less polluting production (Hoel, 1996; Kruse-Andersen and Sørensen, 2019). However, due to the practical problems and uncertainties associated with tariffs, further research is needed on both the feasibility and effectiveness of the different models and their possible alternatives, such as a VAT-based carbon tax or a carbon-sensitive mechanism for cement (as proposed by France: non-paper, Feb 2016).

From a practical point of view, the implementation of accurate duties requires appropriate information on the embedded carbon emissions of products and the CBAM regulation of products. The identification of embedded carbon emissions raises challenges in terms of the methods used and the availability and reliability of the data to be applied. If the CBAM means higher customs duties or other trade restrictions on products from non-EU countries in practice, it may violate international trade rules and agreements, and thus its use may lead to the use of counter-tariffs that are harmful among others to the EU economy. Such measures can also target different EU countries and economic sectors through production value chains in different ways, which in turn can also create political conflicts within the EU.

4 https://ec.europa.eu/taxation_customs/news/commission-launches-public-consultations-energy-taxation-and-carbon-border-adjustment-mechanism_en

2 Background

2.1 Previous literature

A successful fight against climate change requires a considerable decrease in the use of carbon-based materials, especially in the various ways they are used to produce energy in production and transportation. By raising the relative price of carbon-intensive production, consumption patterns and thereby production itself will adjust and the use of carbon (oil, coal, natural gas, etc.) and thereby CO_2 emissions will decline.

The EU ETS was constructed in order to make it more costly to emit CO_2 in production.[5] If the producer does not decrease the CO_2 intensity of its product, the product's relative price increases and it loses market shares. It is market-based policy instrument as it allows trade with EU ETS allowances, but it is also an administrative instrument, used in order to distribute the allowances and to control their use (Kokko, 2019). The ETS mainly affects production within the EU. Although, the EU can make bilateral agreements with third countries to build a link between the EU ETS and other trading systems, generally, the EU ETS erodes the competitiveness of EU production vis-à-vis production in third countries, ceteris paribus. This may lead to carbon leakage (see Section 5). The ETS aims to lead to more energy efficient and carbon-neutral production, new technological innovations, and new smaller-carbon-print products that will increase competitiveness and market shares in the future.[6]

Carbon border adjustments (CBAs) are a way to balance at the EU's external border the difference between EU and other countries in regard to the production costs that arise from the EU ETS as a way to "level the playing field." However, there are many economic,

5 Aldy et al. (2010) provided a non-technical discussion of different issues concerning the design of climate mitigation policies. Monjon and Quirion (2010) discussed CBAs from the point of view of the EU. Different market-based carbon-pricing mechanisms are discussed by, among others, Aldy and Stavins (2011).

6 There are of course other factors that can be thought to have a similar impact of raising production costs, such as stricter labor and environmental protection laws.

legal, technical, and political considerations that need to be addressed. The first consideration is an administrative form of the CBAM. In principal, it may have a link to the EU ETS and its allowances or it may be based on, for example, separate import tariffs.

When CBAs are thought of as import tariffs, possibly with an addition of export rebates, a rise in tariffs raises the price of imports, which affects consumer behavior as well as firms' choices for intermediate inputs and investment goods. Among other things, this may raise production costs, decrease competitiveness, and affect productivity growth and thus be an economic consideration, even in the EU. As a result, however, foreign firms outside the EU should have an incentive to lower their CO_2 emissions, which would lead to, not only decreased carbon leakage from the EU, but lower global GHG emissions. Foreign countries may also be induced to implement their own ETSs or join the EU system. However, Böhringer, Carbone, and Rutherford (2018) argued that the main effect of CBAs is to shift the economic burden of developed-world climate policies to the developing world through terms-of-trade effects.

Third countries may interpret such higher tariffs as protection for domestic EU production. If so they may argue that the CBAM is against World Trade Organization (WTO) regulations and thus a legal consideration (this is discussed more thoroughly in Section 3). But even if EU measures do abide by WTO regulations, they may still be met with countermeasures, most probably with similar or even higher tariffs being set by the affected third countries. In the past few years we have seen a rise in tariffs, notably between the United States and China. This may also be coupled to a more general lack of respect for the multilateral trade rules of the WTO as the Appellate mechanism of the dispute settlement is paralyzed. Consequently, a pattern of tit-for-tat tariff hikes has been established. This is a political consideration.

There are also technical considerations, at least in the form of difficulties in establishing how CO_2 intensive the production of a given good is in the EU relative to any given third country (see, e.g., the discussion in the study of Houser et al., 2008). A CBA cannot be imposed if the imported product is equally or less CO_2 intensive than EU production. The CBA measures need to be established in a credible, legally just, and fair way. Furthermore, given global value-added chains and the use of imported intermediate products, the level of CO_2 emissions in any given product may rapidly become blurred.

As CBAs have not yet been implemented (with the exception of a limited subnational application to electricity imports in the state of California), there is little direct empirical evidence of the impact they may have in the short term or the long term. An Organisation for Economic Co-operation and Development (OECD) report by Condon and Ignaciuk (2013) provided a discussion of earlier literature. CBAs are a second-best solution. The first-best solution is to implement a world-wide carbon tax that would set a price on GHG emissions.

According to the results of Babiker (2005), derived using a computable general equilibrium (CGE) model,[7] significant carbon leakage may occur from tightening climate policy, possibly resulting in an increase in global emissions. The topic was further discussed by Babiker and Rutherford (2005). According to Monjon and Quirion (2011), output-based allocation (i.e., free allowances in proportion to current production) is less effective than border adjustment in diminishing leakage, but more effective in decreasing production losses in energy-intensive sectors. The most efficient way to halt leakage is auctioning with CBAs. Another way could be to have auctioning in the electricity sector and output-based allocation in energy-intensive industries. Winchester, Paltsev and Reilly (2011) argued that CBAs are a costly method of reducing leakage, but that they may be an effective strategy for coercion. On the other hand, McKibbin and Wilcoxen (2009) argued that the benefits from CBAs would be too small to justify their administrative complexity or their negative effects on international trade. This is because the tariffs would mostly be small, they would only make a very little reduction in emission leakage, and they would do little to protect import-competing industries.

Manders and Veenendaal (2008) used a global general equilibrium model to assess the effects of CBAs that are placed to protect the competitiveness of energy-intensive industries in the EU. They only found modest effects on competitiveness because, among other things, intra-EU trade is much more important than extra-EU trade. On the other hand, if only the EU adopts a strict CO_2 ceiling, the impact on global emissions is very small. Their results indicate that, if the EU acts unilaterally and without CBAs, the EU gross domestic product (GDP) will decrease by 0.7 % and world GDP by 0.3 %. The decline in the EU comes from energy-intensive ETS sectors. Output in non-ETS sectors would increase slightly. CBAs would mitigate the effects. According to Monjon and Quirion (2011), EU climate policy would lead to a decrease in energy-intensive production but this would mainly be due to a reduction in European demand rather than a decrease in EU competitiveness in the global market.

A number of other research studies indicate that CBAs would not neutralize all the negative output effects of the ETS. According to Burniaux, Château, and Duval (2010), the effect of CBAs on global welfare is slightly negative. Total energy-intensive production declines at the global level, and the effect comes from countries with the ETS. There is some output leakage. They argue that CBAs can reduce carbon leakage if the number of ETS countries is small because then leakage mainly takes place through a loss in

7 Balistreri, Böhringer and Rutherford (2018) discussed how different modelling choices affect the results.

international trade competitiveness rather than through a decline in world fossil fuel prices. On the other hand, Gros (2009) found that CBAs increase welfare.

CBAs do not necessarily cover the output losses incurred by the domestic energy-intensive industries they are intended to protect. On the one hand, these industries may use carbon-intensive intermediate inputs produced by energy-intensive industries elsewhere. Furthermore, energy-intensive industries are more negatively affected by carbon pricing itself and are more prone to the effects of a contraction in market size and competitiveness losses (Burniaux et al., 2010). Also, Aldy and Pizer (2015) argued that a unilateral domestic climate change mitigation policy would lead to a decrease in energy-intensive industries' output and an increase in net imports.

Finally, the legal implications of CBAs, and notably their compatibility with international trade law, have been extensively studied in the related literature, with generally favorable but ultimately inconclusive results. Following earlier studies on the legality of border tax adjustments (BTAs) for environmental and energy taxes, Ismer and Neuhoff (2004) offered one of the earliest analyses of border adjustments and their legality as a tool of climate policy, concluding that a CBA for imports and exports would be admissible under WTO rules provided it is calculated on the basis of a best available technology standard. De Cendra (2006) analyzed the legality of border adjustments and concluded that the relevant WTO rules lack clear guidance on the question. A joint report by the WTO and the United Nations Environment Programme (UNEP) of 2009 affirms that WTO rules permit the use of CBAs, provided the design avoids an arbitrary and unjustified discrimination or disguised restriction on international trade. Likewise, Hillman (2013)—a former member of the WTO Appellate Body—echoed the view that CBAs can be legal with the correct design. Pauwelyn (2013) and Holzer (2014) shared this assessment and discussed the legality of alternative design options. Mehling, van Asselt, Droege, Das, and Verkuijl (2019) reviewed the literature and offered recommendations for CBA design that would minimize the risk of a legal challenge.

2.2 Previous proposals

2.2.1 Overview

To date, three policy proposals have been tabled at the European level, reaching various stages of the legislative process. The first was floated by the European Commission in 2007 as part of an unpublished draft amending the EU ETS directive and would have inserted a provision outlining a "Future Allowance Import Requirement" (FAIR). The second was a political initiative launched by the French government in 2009 to include importers into the EU ETS through a "carbon inclusion mechanism" (CIM). The third and most recent proposal was initiated by the French government in 2016 (and circulated again in a shortened version in 2019) and targeted leakage from the cement sector. All three proposals are summarized briefly in a table at the end of this subsection, and the French government proposal of 2016 is described in greater detail in the following subsection.

All three proposals are structured along similar lines. Firstly—and importantly—instead of introducing a new tax or other type of policy constraint, they all seek to include importers in the EU ETS. This makes sense because the relevant energy-intensive and trade-exposed industries are already subject to the EU ETS as their main sectoral climate policy. It also avoids the requirement of a unanimous vote in the council, something that any measure of a primarily fiscal nature would face, and thus faces fewer hurdles in the European legislative process.

Secondly, past proposals strike a balance between environmental benefit and ease of implementation by only covering products from those energy-intensive sectors considered to be at risk of carbon leakage under the EU ETS and, in one case, even suggest starting with a subset of products with limited trade intensity. Along the same lines, they avoid the need to determine the exact carbon content of foreign products by relying instead on the average sectoral emissions of European producers. The 2009 and 2016 proposals, moreover, envisage giving importers an opportunity to prove that their actual emissions performance exceeds the average performance. Not only does this shift the administrative burden of emissions measurement to importers, but it is also better aligned with the international trade rules discussed in Section 3.

Thirdly, the proposals all begin by extending the duty to surrender allowances under the EU ETS to all products from these sectors, regardless of the country of origin. That is preferable from the perspective of international trade law as differentiation between countries can be construed as being discriminatory. Still, the proposals variously suggest exempting imports from countries that have either acceded to an international climate treaty or enacted comparable mitigation policies to those in place in Europe, without setting out in detail how that determination would be made. Elaborating a robust, objective methodology with which to compare climate policy ambition across countries is intrinsically difficult as any differentiation between countries may be interpreted as arbitrary discrimination. Moreover, it would be likely to be the most vulnerable component under international trade law. According favorable treatment to less economically less advanced countries—as the 2009 proposal envisioned—can be more easily justified.

Fourthly, all three proposals would result in the introduction of a CBA alongside free allocation, only adjusting only for the allowances that an average EU manufacturer would still need to acquire on the market after obtaining its share of freely allocated allowances.

However, the amendment tabled by the Committee on Environment, Public Health and Food Safety (ENVI) Committee in December 2016 marked a departure from this approach in that it would have immediately ended all free allocation to sectors covered by the carbon inclusion mechanism, but then would also adjust for the entire compliance obligation rather than only for the difference between freely allocated allowances and actual emissions. Importantly, none of the proposals would adjust for the share of allowances freely allocated to domestic producers—doing so would constitute a double benefit for domestic producers and thus risk being considered discriminatory.

The proposals differ in terms of how they would have treated exports, with the 2007 FAIR proposal expressly setting out a procedure to issue allowances to exporters and the 2009 non-paper declaring that the treatment of exports should be decided after further study. Favoring exports under a CBA incurs a heightened legal risk under international trade law, including a risk under rules prohibiting export subsidies. Possibly in recognition of this risk, the 2016 non-paper abandoned the favorable treatment of exports.

Fifthly and finally, the amendment proposed by the ENVI Committee in 2016 recognized the importance of a robust process, calling for a prior impact assessment that includes stakeholder consultations and a feasibility study. While it does not set out in greater detail who would be invited to participate in such stakeholder consultations, the established case law of the WTO dispute settlement mechanism has repeatedly highlighted the need to ensure fair, transparent, and inclusive negotiations with affected countries prior to the implementation of environmentally motivated trade restrictions.

Table 2.2.1.1 Previous proposals

Year & Proposal	Sectoral Coverage	Country Coverage	Exports Included?	Calculation
2007 FAIR Proposal	Sectors at risk of carbon leakage (methodology not specified)	All except those taking comparable action or operating an ETS linked to the EU ETS	Yes, based on actual exports	The average carbon intensity of relevant EU goods, corrected for average free allocation
2009 French non-paper	Sectors at risk of carbon leakage (methodology as used in the EU ETS)	All except "less advanced countries" and those either imposing an equivalent carbon cost or participating in a (qualified) future international climate treaty	Possibly, pending further study	The average carbon intensity of relevant EU goods, corrected for benchmark-based free allocation
2016 French non-paper	Initially, the cement and clinker sector, to be gradually expanded to other sectors at risk of carbon leakage	All except countries with adequate mitigation efforts and/or comparable carbon price	No	The average carbon intensity of relevant EU goods (or less, if lower emissions are demonstrated) corrected for benchmark-based free allocation

2.2.2 The CIM (2016)

In February 2016, the French government circulated a non-paper setting out a "carbon inclusion mechanism" for the EU ETS that proposed covering imported products based on three criteria: (1) a high carbon intensity and a significant share of total GHG emissions in Europe; (2) the easy determination of the carbon content; and (3) a limited impact on the downstream sector (France, 2016). It also highlighted the need for a gradual introduction, starting with sectors that have a low trade impact. Specifically, the French proposal therefore envisaged testing the approach with the cement sector, which meets the three criteria above and has low and unevenly distributed trade intensity across Europe. Under this proposal, importers would be included in the EU ETS so that they have to surrender a volume of allowances equivalent to that which an average European manufacturer would have acquired in the market for the same quantity of the product. In the absence of emissions data for imported products, the volume of allowances to be surrendered for imports would thus be based on the difference between the average carbon content of European products and the European benchmark-based free allocation value. Importers who are able to demonstrate better emissions performance than the European average with a "carbon emissions certificate" could lower the required amount of allowances accordingly.

For the cement sector, the benchmarks for clinker would have served for calculating the adjustment. The non-paper also acknowledged that mitigation efforts in other countries would have to be taken into account and indicated that cement importers from countries where its carbon content is priced and requires equivalent efforts from manufacturers should be excluded. Rather than replace free allocation from the outset, the non-paper suggested that this mechanism would allow the progressive reduction of free allocation as the volume of auctions increases. Moreover, for its operational implementation, it outlined a simplified process building on the existing Single Administrative Document (SAD) employed by customs services and linking the EU ETS allowance registry with the EU customs database for automatic calculation of the volume of allowances to surrender. The non-paper anticipated that this proposal could be adopted by way of a new article in the EU ETS directive, describing the basic principles, the criteria for the inclusion of products, and the method for calculating the amount of allowances to be surrendered. Technical details, such as the designation of included products, could then occur through more flexible regulatory acts.

While the European Parliament was deliberating amendments to the EU ETS in December 2016, ENVI took up the proposal and included it in its recommended amendments to the reform package (European Parliament, 2016). Specifically, one amendment called for the establishment of an "import inclusion scheme" that "shall require importers in sectors not having a trade intensity above 10 % in the years 2009 to 2013 covered by the EU ETS to acquire and surrender allowances for imported products." Unlike the mechanism outlined in the non-paper, this scheme would completely replace free allocation to sectors and subsectors deemed at risk of carbon leakage. The amendment further mandated the European Commission with adopting a "delegated act," specifying the exact design of such a mechanism based on a prior impact assessment that included a stakeholder consultation and feasibility study. Moreover, the scheme was to be "fully compatible with WTO rules." Still, despite the committee endorsement, this amendment was rejected in February 2017 when the European Parliament voted against it in the plenary.

Table 2.2.2.1 Details of the French Non-Paper (Feb. 2016) and EP ENVI Committee Amendment Proposal (Dec. 2016)

Design Feature		French Non-Paper (Feb. 2016)	EP ENVI Committee Amendment Proposal (Dec. 2016)
Scope and coverage	For imports/exports	Imports	Imports
	Sectoral/product scope	Initially, the cement sector (starting with products with low trade intensity, but a large contribution to emissions & an easily determined carbon content)	Sectors covered by the EU ETS with a trade intensity no greater than 10%
	Country coverage	"Developments on carbon pricing worldwide" are to be considered, products from regions with "equivalent efforts" are to be excluded	Not specified
The determination of embedded carbon	Emissions scope	Not specified (most likely, only direct emissions)	Not specified (most likely, only direct emissions)
	Benchmark	The assumption that imported products have the same carbon intensity as the average EU producer, but with possibility for importers to prove the lower carbon intensity through a "carbon emissions certificate"	Not specified
The determination of adjustment level	The carbon price in the EU	Not specified (based on the EUA price)	Not specified
	The carbon price in foreign countries	The explicit carbon price taken into account	Not specified
	Revenue use	Not specified, although it mentions using part of revenue towards free allocation in sectors not covered by the CIM	Not specified
	The process	The basic principles in the EU ETS directive, and details in regulatory acts, possibly avoiding co-decisions (model: Art. 24(1)) The SAD declaration used by customs services to interface with the EU ETS registry, allowing the automatic determination of compliance needs	The commission adopts the delegated act with design details; impact assessment, stakeholder consultation and feasibility study precede roll-out, which is timed to coincide with UNFCCC facilitative dialogue

2.3 The key characteristics of CBAs

The previous proposals show that there is no single way to implement CBAs. Rather, their implementation necessitates the definition of key characteristics (Mehling et al., 2019).

2.3.1 Scope and coverage

Any CBA has to determine its scope and coverage, that is, it has to specify the products and trade flows affected by it, the sectors or geographies it applies to, and for which types of carbon constraints it adjusts. A number of design considerations emerge from the literature and case law.

Trade flow: Imports and/or exports

In terms of trade flow, a CBA can be applied to imports only, exports only, or both. Although economic research has suggested that applying a CBA to both imports and exports can increase its effectiveness in preventing leakage, the proposals to date typically limit the scope to imports. Doing so hedges against classification as a prohibited export subsidy under the WTO Agreement on Subsidies and Countervailing Measures (de Cendra, 2006) and avoids providing an incentive for domestic producers to increase the carbon intensity of exports, which could potentially result in an emission increase. Even with this limitation, a CBA on imports will still secure the majority of its potential benefits.

Sectoral coverage

When designing a CBA, the implementing jurisdiction has to determine which sectors and products should be affected by it. Only including products from sectors with a high carbon cost and trade exposure, as well as limited ability to pass through the cost through to consumers, greatly reduces the administrative and technical burden of any CBA while still delivering significant environmental benefits. Such sectors include cement, steel, and aluminum where the value of embodied carbon products, as a percentage of value added, tends to be relatively high compared with manufactured products. By ensuring that the CBA only covers sectors where inclusion affords clear environmental benefits, this narrow scope helps meet the conditions set out in international trade law. It should also be politically useful, as the affected sectors tend to be influential domestic constituencies, yet their inclusion does not cause a strong shift in the terms of trade to the detriment of developing countries.

A caveat of the limited scope is that it may create a competitive advantage for extra-EU goods that carry the emission-intensive products as their components to the EU, thus avoiding the tariff.

The geographic scope

Another design choice related to coverage is the geographic scope of the CBA, that is, which countries are affected by the CBA. To ensure observance of Article I of the General Agreement on Tariffs and Trade (GATT) and prevent the avoidance ("trans-shipment") strategies of importers, a CBA can opt for a sectoral focus instead of targeting or exempting countries based on country-specific attributes, such as domestic climate policies or participation in a common climate agreement. However, uniform application to all countries can compromise the leveraging effect of a CBA, however. Moreover, the exemption of least-developed countries (LDCs)—who only contribute minimally to global emissions—would be compatible with the environmental objective of the CBA and has been a consistent feature in past policy proposals.

Policy coverage

A CBA aims to adjust for asymmetrical climate policy efforts, but to be viable, it has to specify the domestic policies it seeks to adjust for. Determining a differential in ambition is easiest with policies that create an explicit carbon price, rendering the latter a natural starting point for a CBA. However, less than 20 % of global emissions are currently covered by an explicit price on carbon, and price levels tend to be significantly lower than the cost of compliance with other non-price carbon constraints (World Bank et al., 2020). Over time, as data and methodologies improve, a CBA could seek to adjust for the differential between the effective carbon prices faced by domestic and foreign producers in a sector, including both explicit and implicit carbon prices. The inclusion of policies addressing CO2 emissions would already capture a significant share of the emissions associated with imported products, although extension to policies for the emissions of other relevant gases and black carbon, converted using accepted global warming potential metrics, could be pursued to successively increase the efficiency of the CBA.

2.3.2 The determination of embedded carbon

Because CBAs adjust for differences in embedded carbon and applicable carbon constraints, they also have to contain a decision on the scope of the included emissions and a methodology to calculate those emissions.

Applying a CBA requires first determining (or estimating) the amount of embodied carbon in a given product. The carbon content of a product can be determined by calculating the emissions from the production process, which involves emissions from energy inputs such as electricity and heat, as well as emissions from the production process itself. Ideally, this determination would occur at each production facility based on actual emissions, but direct emissions measurement is not always practicable and may face legal challenges. Therefore, a CBA can alternatively be based on standardized benchmarks that serve as a proxy for the carbon intensity of products, with the benchmark values reflecting average performance and the best or worst available technology in a sector, either at a national, regional, or global level.

In the absence of suitable or accurate data, a jurisdiction imposing a CBA could also base the determination of embedded carbon on the average direct and indirect emissions intensity of its domestic goods. Past policy proposals, such as the 2007 FAIR proposal and the 2009 CIM proposal (see above, Section 2.2), avoided technical complexity and legal risk by basing the calculation of embedded carbon on the average carbon intensity of domestic goods. As aggregate values, however, standardized benchmarks will invariably fail to represent the emissions performance of individual emitters accurately. In line with judicial precedent (see below, Section 3.1.1), foreign producers can be afforded a transparent, accessible process to document actual emissions with third-party–verified data and thereby demonstrate that their carbon intensity is lower than a sectoral average benchmark. Importantly, that option introduces a permissible element of differentiation that contributes to the leveraging purpose of the CBA and incentivizes mitigation in exporting countries (Cosbey et al., 2019).

2.3.3 The adjustment level

Once embedded emissions have been calculated, the level of adjustment needs to be determined, factoring in any exemptions and rebates afforded to domestic producers. As a default, the adjustment can be based on a sectoral benchmark multiplied by the amount of product and the explicit carbon price applied in the imposing country, which, in the case of a variable carbon price (e.g., in an ETS), can be averaged across a specified period. Where no explicit carbon price exists, or when the importing jurisdiction has introduced multiple complementary instruments in the covered sector, the determination of the net policy differential is considerably more difficult.

Importantly, the CBA is only meant to adjust for the differential between the foreign and domestic climate policy cost in the covered sectors. For that reason, the level of the CBA should reflect any exemptions, rebates, or free allocation in the importing country, as well as any carbon constraints applied to imports in their country of origin, all of which are then deducted from the determined level. Moreover, as with the calculation of embedded emissions, each exporting emitter should be given an opportunity to submit third-party–verified data on marginal abatement cost under all applicable carbon constraints. A transparent and impartial process involving independent third parties or an international body could help avoid political or judicial challenges.

2.3.4 Revenue use

Revenue collected under a CBA can accrue to the general budget, be recycled to the public or specific sectors, be used to further environmental goals, or be used as climate finance for the developing countries affected. For political reasons, it may be expedient to at least partly allocate revenue to developing countries in order to support domestic mitigation and adaptation efforts, as well as to build capacity for measurement, reporting, and verification, ultimately favouring the emergence of a more homogenous climate landscape.

This kind of revenue use can greatly improve the political prospects of the CBA and has parallels in international law, for instance, the Multilateral Fund for the Implementation of the Montreal Protocol. Moreover, Article 9 of the Paris Agreement encourages developed country parties to provide financial resources to assist developing country parties with respect to both mitigation and adaptation.

3 Implementation issues

3.1 Legal considerations

This subsection provides a discussion of the different characteristics from the legal perspective and provides the basics of the underlying legal framework.

3.1.1 EU law

The legal implications and risks of the prospective CBAM will greatly depend on the policy mechanism used for its implementation, which, at the most general level, could take the form of a price-based instrument, a quantity-based economic instrument, or a regulatory mandate. In its consultation for the CBAM legislative proposal, the European Commission has listed four main options: introducing a new carbon tax on imported and domestic products, introducing a new carbon customs duty or tax on imports, extending the EU ETS to cover imports, or creating a separate pool of allowances outside the EU ETS from which importers would be required to buy allowances at a price mirroring that of EU allowances (European Commission, 2020a).

Each option has, for instance, far-reaching implications under EU law, particularly with regard to the applicable legislative procedure and revenue use: Under Article 192, paragraph 2 of the Treaty on the Functioning of the European Union, a tax would require unanimity in the council unless the council first unanimously exercises a passerelle clause contained in that provision, a steep political challenge. The option of a customs duty, by contrast, may be adopted with a qualified majority vote, but would potentially affect the tariff schedules adopted by the EU under international, regional, and bilateral trade agreements. If the CBAM is introduced as a measure related to the EU ETS rather than as a fiscal measure, the passage of the relevant legislation would very likely only require a qualified majority vote in the council.

Similarly, revenue from a tax would accrue to Member States, whereas customs duty revenue is shared between the EU budget and the Member States, and EU ETS revenue currently falls within the purview of Member States. However, the role of CBA revenue has already featured in the negotiations on the Multiannual Financial Framework for the EU budget, potentially contributing to the future financing of the EU budget and of the Recovery Plan for Europe (European Commission, 2020b).

3.1.2 International trade law

While the introduction of a CBA raises legal questions in more areas than one, international trade law is particularly relevant because of how the measure will be applied to goods traded across national borders. From the earliest announcement of the European CBA in Ursula von der Leyen's political guidelines to various subsequent statements and documents, the European Commission and its president have consistently emphasized the need to ensure that it be "fully compliant with World Trade Organization rules" (von der Leyen, 2019; similarly European Commission, 2019b; European Commission, 2020a).

At the heart of the WTO regime lies the GATT, which dates back to 1947 and is a legally binding international treaty with broad membership. According to its preamble, the GATT aims at a "substantial reduction of tariffs and other barriers to trade" and at "the elimination of discriminatory treatment in international commerce." A central tenet of the GATT—and a cornerstone of the multilateral trading system—is the principle of non-discrimination in international trade. For trade in goods, it consists of two elements: the most-favored-nation (MFN) treatment obligation, set out in Article I of the GATT, and the national treatment obligation, set out in Article III of the GATT.

Article I:1 of the GATT prohibits parties from discriminating between "like" products originating in, or destined for, any other party, whereas Article III of the GATT prohibits discrimination between domestic products and "like" imported products. What constitutes the "likeness" of domestic and imported products is not defined in the GATT, but has been determined to be based on the following in relevant case law: whether they share common physical characteristics and properties, end uses, and tariff classifications; whether they compete in the marketplace; and on relevant consumer preferences.[8]

8 *Japan – Taxes on Alcoholic Beverages*, Appellate Body Report, WT/DS8/AB/R, WT/DS10/AB/R, WT/DS11/AB/R, adopted 1 November 1996, 20-21; Appellate Body Report, *EC – Measures Affecting Asbestos and Asbestos-containing Products*, WT/DS135/AB/R, adopted 5 April 2001, para. 99.

Importantly, differences in the processes and production methods (PPMs) that do not leave a physical trace in the final product—such as the source of energy used during production—are not generally considered to affect the likeness of products.[9] Although the jurisprudence on like products remains inconclusive and has seen some evolution in recent case law,[10] there is a high probability that goods produced with low-carbon PPMs and carbon-intensive goods would be considered like products despite their different embedded carbon emissions. Any differentiation between such products that leads to a competitive disadvantage could thus be considered discriminatory (Pauwelyn, 2013).

Under international trade law, treating domestic and imported goods differently based on the carbon intensity of their production therefore incurs a risk of judicial challenge (Mehling et al., 2019). A CBA that imposes a greater compliance burden on carbon-intensive imports than that faced by less carbon-intensive domestic products, for instance, could be considered discriminatory because such differentiation on the basis of (actual or assumed) carbon intensity is intrinsic to the notion of a CBA. However, and because differentiation is critical to its environmental effectiveness, it is difficult to envision how an effective CBA can altogether avoid risking a violation of the principle of non-discrimination set out in the GATT.

For the same reason, the literature on CBAs has routinely highlighted the importance of Article XX of the GATT, which can provisionally justify measures that would otherwise be considered discriminatory (Condon & Ignaciuk, 2013). Two such general exceptions relate to measures "necessary to protect human, animal or plant life or health" (Article XX(b)) or "relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption" (Article XX(g)). Both the wording of these provisions and their broad interpretation in past case law suggest that measures aimed at reducing GHG emissions can fall under either exception (UNEP & WTO, 2009).

However, several conditions need to be met in order for Article XX's sections (b) and (g) to be successfully invoked, including two that have a bearing on the legal implications: the need for a sufficient connection between the CBA and its environmental objective, which is inferred from the wording "necessary to" and "relating to"; and a requirement that the measure not be applied in a manner that would constitute "a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail," which is derived from the introductory paragraph—or "chapeau"—of Article XX.

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9 Going back to, notably, *United States – Restrictions on Imports of Tuna*, Panel Report, DS21/R, DS21/R, 3 September 1991, unadopted.

10 See, for instance, *United States – Measures Concerning the Importation, Marketing and Sale of Tuna and Tuna Products*, Panel Report, WT/DS381/R, adopted 13 June 2012, para. 7.78; more generally, also see Potts, 2008.

For the CBAM currently being elaborated by the EU, this means that if in some cases relatively less carbon-intensive EU products face a lower compliance burden than relatively more carbon-intensive foreign products, it risks being considered discriminatory and the admissibility of the CBAM under international trade law will depend on whether it can be provisionally justified by one or more of the general exceptions found under Article XX of the GATT. As mentioned above, Article XX sections (b) and (g) are the exceptions of greatest relevance in this context, and both require a sufficient connection between the measure and the legitimate objective specified in Article XX. Additionally, past case law has interpreted the "chapeau" of Article XX to require that application of the measure in question be preceded by a transparent, fair, and inclusive process of "across-the-board" negotiations.[11]

In the only formal trade dispute involving an environment-related border adjustment to date, the United States v. Superfund case, a GATT panel affirmed a BTA imposed by the United States under the Superfund Amendments and Reauthorization Act of 1986 on certain imported substances produced from feedstock chemicals subject to a domestic excise tax.[12] Importers were required to furnish the information necessary to determine the amount of feedstock chemicals and thus of tax to be imposed, but if they failed to do so, the United States would impose a fixed penalty based on the value of the product. While the latter was considered discriminatory, a provision foreseen in the legislation enabling the US to apply a baseline rate equal to the predominant method of production in the US was seen as sufficient to demonstrate equivalence under Article III of the GATT between the domestic excise tax and the border measure applied to imports.[13]

In a more recent case, United States v. Reformulated Gasoline, the Appellate Body conversely held that a rule under the Clean Air Act regulating the composition and emission effects of gasoline in order to prevent air pollution was discriminatory by setting out different calculation methods for domestic and foreign gasoline.[14] In particular, the Appellate Body objected to the fact that importers were subject to a default "statutory baseline" that had no connection to the particular gasoline imported, while refiners of domestic gasoline were assessed against an individual baseline representing the quality of gasoline produced by each refiner. The Appellate Body thought that this constituted

11 *United States – Import Prohibition of Certain Shrimp and Shrimp Products*, Appellate Body Report, WT/DS58/AB/R, adopted 6 November 1998.

12 *United States – Taxes on Petroleum and Certain Imported Substances*, Panel Report, L/6175 – 34S/136, adopted 17 June 1987. In assessing whether this border adjustment complied with the national treatment obligation, the panel cited Article III of the GATT, stating that it "permits the imposition of an internal tax on imported products provided the like domestic products are taxed, directly or indirectly, at the same or a higher rate" (see ibid., para. 5.2.7).

13 Ibid., para. 5.2.9.

14 *United States – Standards for Reformulated and Conventional Gasoline*, Appellate Body Report, WT/DS2/AB/R, adopted 20 May 1996.

an "unjustifiable discrimination" and a "disguised restriction on international trade" in the context of Article XX(g) of the GATT.[15] It also rejected the practical argument that verification on foreign soil, and subsequent enforcement actions, would be so difficult as to rule out individual baselines. Here, the Appellate Body pointed to the possibility of relying on documentary evidence provided by the foreign refiners themselves—citing, inter alia, the option of third-party verification—and also highlighted the importance of cooperation on such administrative arrangements.[16]

International trade law also plays an important role in determining the permissibility of a CBAM that applies to exports in addition to, or instead of, imports only. Including both imports and exports in its coverage would maximize the ability of the CBAM to address competitiveness, impacts, and leakage, because limiting coverage to imports does not level the playing field for European products being sold in international markets. At the same time, the coverage of exports also incurs considerable legal risk. Exempting or rebating the carbon constraint imposed on European producers under the EU ETS when their products leave the EU risks that the CBA will be classified as a prohibited export subsidy under the Agreement on Subsidies and Countervailing Measures (the SCM Agreement). Under that treaty, a subsidy is defined as a financial contribution by a government that confers a benefit. This broad definition includes foregone government revenue that would otherwise be due, as is the case when a government allocates allowances for free where auctioning has otherwise become the default, when it compensates for relevant costs, or when it altogether exempts exporters from compliance.

Such relief will further be considered a prohibited subsidy if its award is made contingent on export performance, that is, if there is a relationship of conditionality or dependence between the award and exportation. Because an export CBA would be conditional on exportation, it could be, prima facie, classified as a prohibited subsidy. Importantly, the SCM Agreement contains no environmental justification comparable to Article XX of the GATT. Hence a violation of the SCM Agreement cannot be "healed" through recourse to a legitimate exception, as it can under the GATT if certain conditions are met. Moreover, because a CBAM that extends to exports would narrow the scope of the EU ETS by exempting exports, such a CBAM might be less successful in invoking the environmental exceptions of Article XX and also increases its chances of violating the GATT in addition to the SCM Agreement.

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15 Ibid., 29.

16 An exception could only apply for cases where "the source of imported gasoline could not be determined or a baseline could not be established because of an absence of data" (see ibid., 27).

3.1.3 International environmental law

Legal requirements for CBA can also arise from international rules related to the environment. Under the Paris Agreement, an international climate treaty adopted in 2015 with nearly universal participation, parties agreed that the pace and ambition of domestic climate efforts is to be decided at the national level. According to Article 4(2) of the Paris Agreement, it is up to each party to "prepare, communicate and maintain successive nationally determined contributions that it intends to achieve"; Article 4(3) goes on to state that successive contributions should reflect each party's "common but differentiated responsibilities and respective capabilities, in the light of different national circumstances."

A CBA could be held to contravene this fundamental principle about common but differentiated responsibilities if it is considered a unilateral measure that coerces other countries to increase their domestic climate efforts in order to avoid or limit compliance obligations for products entering the EU without any exceptions. However, it is debatable whether the Paris Agreement, whose overarching objective is to "strengthen the global response to the threat of climate change" (Article 2[1]), can be interpreted to limit unilateral action if such action is primarily aimed at increasing climate ambition (like that of a CBAM) since all parties to the Paris Agreement have also committed to the goal of achieving carbon neutrality in the second half of the century (a measure taken to enable stronger domestic climate action without incurring carbon leakage.

3.1.4 General international law

Finally, by seeking to influence policy choices in foreign jurisdictions and basing its calculation on physical processes taking place on foreign territory, a CBA could be considered an extraterritorial measure that infringes on the territorial sovereignty of affected trade partners. Territorial sovereignty comprises the right of states to exercise state authority within their territory and manifests itself in the principle of non-intervention in the internal affairs of other states.[17] Unilateral measures that take into account circumstances within foreign territory risk being considered a violation of that principle and of the domaine reservé of affected states.

In a case involving the inclusion of international aviation in the EU ETS, the European Court of Justice (ECJ) held that a climate policy measure covering foreign entities and based on activities occurring, at least in part, over foreign territory "did not infringe the principle of territoriality" because the entities were physically located within the EU

17 Deriving it from the principle of the sovereign equality of states enshrined in Article 2(1) of the Charter of the United Nations: International Court of Justice, *Military and Paramilitary Activities in and against Nicaragua (Nicaragua v. U.S.)*, Merits, Judgment of 27 June 1986, [1986] ICJ Rep. 14, para. 202.

when the measure was applied.[18] Although a similar reasoning could be applied to a CBA because it will only be applied once imports enter the territory of the implementing states, the ECJ decision was by no means free from controversy (Hartmann, 2013). Generally, coercive action taken by one state to secure a change in the policies of another is likely to constitute an intervention in the internal affairs of the latter (Jamnejad & Wood, 2009). This suggests that the design of a CBA should be imposition of mandatory requirements on the importers of covered products and on the public authorities of other countries—such as, for example, reporting and disclosure duties—and should instead rely on default values combined with voluntary reporting (cf. the US v. Superfund and US v. Reformulated gasoline cases above, cited in Subsection 3.1.1, as well as the French non-paper of 2016 proposing a similar mechanism based on a presumption about the average EU product carbon intensities coupled with an individual carbon emissions certificate for the EU, described in Subsection 2.2).

3.1.5 Legal risk and the possibility of a judicial challenge and countermeasures

In announcing the CBA, the European Commission specifically mentioned that whatever its form, it should be WTO compatible (von der Leyen, 2019). At the same time, however, the Appellate Body (AB) of the dispute settlement mechanism of the WTO was about to become paralyzed by the refusal of the US to appoint new members to the AB as the terms of previous members drew to a close. By the end of 2019, the AB has had too few members to function in accordance with the covered agreements of the WTO. This has had the effect of significantly weakening the dispute settlement mechanism, although several states have agreed on a mechanism whereby disputes between them may be appealed to an ad hoc set of arbitrators. The US, among several other prominent WTO members, is not, however, a party to this mechanism. The significance of this is twofold—on the one hand, it makes it impossible to get a definitive answer in terms of WTO procedures to the question of whether any particular measure contested by one of the parties to the covered agreements is indeed in breach of the agreements. On the other hand, those member states that have the economic capability to act on their own are more likely to start instituting various countermeasures whenever they perceive a need to do so. Both of these factors increase the likelihood that any CBA would result in various forms of countermeasures regardless of whether it is expressly designed to be WTO compatible.

18 ECJ, Case C-366/10, *Air Transport Association of America and Others v. Secretary of State for Energy and Climate Change*, Judgment of the Court of 11 December 2011, 2011 I-13755, para. 125.

In contrast to the original announcement by then President-designate of the Commission von der Leyen in 2019, the conclusions of the European Council from July 2020 do not mention WTO rules. In the conclusions, however, the CBA is mentioned as a source of EU "own resources," which adds a fiscal dimension to the CBA. There is no mention of where the resources collected by the CBA should be directed, although it has been discussed that they could be a source of revenue for the European post-pandemic recovery package, "Next Generation EU." It may be worth mentioning that although possibly providing the EU with resources a CBA on imported goods would be transferred on the price of the goods and therefore ultimately be paid by EU consumers. From a WTO legal perspective, the fiscal incentive and the uncertainty of where the resources might be used are features that do not follow the original environmental aim and as such risk weakening the WTO compatibility of the measures. Someone might argue that WTO compatibility has become a lesser priority as the paralysis of the Appellate Body drags on and the COVID-19 health crisis wreaks havoc on the economies of EU Member States and the EU as a whole struggles to come up with the resources to rescue their economies. There is, however, a significant risk for more than just trade relations in such an approach.

Even a medium-term perspective should take into account that the climate for international economic co-operation might change significantly (i.a., after a change in US administration).[19] The outcome of the US elections will hopefully be known before the commission is due to present its design for the European CBA in the first half of 2021. A change in administration might again strengthen the case for stricter adherence to WTO rules in order to facilitate reinstating a functioning Appellate Body and renewed cooperation at the WTO—possibly even a return to the Paris Agreement and a greater dynamic for international agreements on de-carbonization. The continuance of the current administration would seem to make the opposite scenario likely, placing greater emphasis on unilateral measures such as CBAs rather than on further co-operation for multilateral solutions to trade and decarbonization.

In order to follow the original announcement on a European CBA by the President of the Commission, we have laid out above (in Section 3.1.1) the key elements of a CBA that are likely to lay at the center of a contestation from the WTO. We are thereby assuming that there is an inherent value in the EU constructing its CBA so as to avoid any intentional

19 The importance of the current US administration's attitude towards climate change, the Paris Agreement, and the relevance of this for the EU CBAM is discussed in Bellora & Fontagné's *Possible Carbon Adjustment: An Overview* (p. 11). The particular political differences between the current administration and other political actors related to these same subjects are discussed in Sapir & Horn's *Political Assessment of Possible Reactions of EU Main Trading Partners to EU Border Carbon Measures* (pp 6–7, 9 & 12). A briefing paper for the EUP's committee on trade policy at
https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/603493/EXPO_BRI(2020)603493_EN.pdf (last accessed 18 September 2020).

or plausible conflict with WTO law. It is worth noting, however, that no matter how well a CBA measure is constructed and communicated to EU trading partners, it is likely to face challenges from those affected. Whether the challenge is merely at the level of vocal protests or goes further, to become a formal complaint and request for a WTO panel or if it results in unilaterally determined countermeasures in disregard of agreed WTO rules will depend on both the complainant in question and the political climate at the time of the event—both international and domestic—of any potential complainant.

Assuming a complaint was lodged against an EU CBA at the WTO—either at a time when the Appellate Body has again been rendered functional or lodged into the temporary replacement system—it is important to note that it is likely to take anywhere between two-and-a-half to three years from the time the case is notified as a formal complaint with the WTO secretariat (whereupon a panel is formed that hears the case; a panel report is circulated, published, and most likely appealed against, handled by the Appellate Body or a surrogate appeals body; and ultimately, a final report of the Appellate Body or a surrogate possibly declares such a measure to be in breach of the covered agreements). Add to this that the EU is likely to request a reasonable time of implementation, wait until that time runs out, wait until a finding of non-implementation is given in a separate procedure before, finally, authority to retaliate will be given. We argue that this is not the greatest worry any EU institution or Member State currently has. The reason for our assessment is that what really matters far more and what is a much more immediate concern from a climate change point of view is going to happen outside a WTO dispute settlement in the multilateral climate negotiations starting with the next COP meeting in Glasgow, UK, in November 2021 - advancing the Paris treaty towards more coherent climate solutions.

The primary concern of the EU and each Member State should be not to harm the possibility of progress within the UN climate conference through measures that appear contrary to international commitments. If the EU, in order to finance the relief package or for other non-climate–related reasons, implements a CBA in a way that appears contrary to WTO rules, it will undermine the credibility of any EU efforts at the COP. If there is no significant progress in these negotiations between the major emitters of GHGs within the next three years, possible WTO retaliation measures will pale in comparison to the dire consequences of such a failure.

WTO compatibility therefore will matter not primarily due to the fear of losing a case and any subsequent retaliation but because of the harmful effect that a blatant disregard for WTO rules is likely to have on the EU and its Member States as credible negotiating partners in any other multilateral processes. This is why great care has to be taken—even in the absence of a formally functioning Appellate Body—in both the design of any CBA, as well as in the notifications and dialogue with EU trading partners, who are also going to be at the negotiating table of the climate conference.

EU regional trade agreements and carbon adjustment

If it is, as we argue, important for the EU to negotiate in general with its trading partners whilst constructing a CBAM, both for legal and diplomatic reasons, it becomes even the more important with the trading partners with which the EU has various free trade agreements. To the extent that these partners have their own carbon pricing mechanisms, it is essential that these be taken into account in the implementation of a future CBAM.

This is not only for the sake of preserving good relations with these trading partners, but also because whatever special arrangement is reached, it is likely to be questioned by third parties for adherence with the MFN rule enshrined in the first article of the GATT, which forbids discrimination among trading partners that are within the WTO. The EU trading partners with carbon pricing mechanisms are Canada, Chile, Iceland, Japan, Norway, South Korea, and Switzerland. On-going negotiations with New Zealand should also be taken into account.

Environmental cooperation is routinely mentioned in the texts of EU FTA's. Carbon pricing as such, however, is less frequently mentioned specifically in these agreements. Specific mentions are to be I.a. found in the agreements with Vietnam (EU-Vietnam, Art. 13.6.2(a-b) as and the EU-Singapore FTA Article 7.1. Nonetheless various environmental clauses in EU free trade agreements could be used to argue for the introduction of carbon-related measures. In several, however, the wording of the environmental clauses mirrors the language of GATT article XX. This does require, among other things, that the measure not be a disguised restriction of trade and the clause has in WTO disputes been considered to require adherence to the proportionality-principle. Regarding possible favourable treatment of at least developed countries the covered agreements of the WTO do allow for more lenient approaches – whether as a matter of climate policy this is considered effective is another issue.

It is most likely that any arrangement concluded with trading partners of n EU FTA concerning the implementation of a CBAM would be thoroughly scrutinized by third countries outside such arrangements. This is notably so with larger repeat players at the WTO dispute settlement system who are keen to find fault and discrimination that could constitute grounds for a WTO complaint. The US and China are of course the main protagonists, but India and Brazil have also frequently made use of the WTO dispute settlement mechanism.

China has been testing a carbon pricing mechanism in several of its regions and might therefore be amenable to negotiate how the EU could accommodate a CBAM to take into account its future nationwide carbon pricing mechanism. Should the US elections result in a change of administration in early 2021, it is not unlikely that a federal carbon-pricing scheme would be introduced.[20]

Nonetheless, even if this were the case, it does not mean that just any EU CBAM would be met favorably outright—the devil will very much be in the detail. Extensive and probing negotiations with the US Trade Representative are to be expected regardless of which administration is in charge. However, should there be a change of administration in the US, it is not entirely out of the question that such negotiations in time would be incorporated in the framework of renewed negotiations of a larger free trade agreement, such as the currently dormant Transatlantic Trade and Investment Partnership (TTIP) initiative.

Could environmental concerns in the EU related to dumping also include carbon adjustment?

The new EU anti-dumping regulation that entered into force in 2018 includes the possibility of taking into account the cost of implementing environmental legislation in the EU. Hitherto, this environmental aspect has only been mentioned as part of the calculation of anti-dumping duties in one case: Case AD649—Urea and Ammonium Nitrate (UAN). This case establishes anti-dumping duties for Russia, the US, and Trinidad and Tobago on the importation of certain fertilizers. The price of natural gas is an important factor in the establishment of dumping and calculation of the duties. As the price of fossil fuel–based energy sources is likely to rise due to stricter measures within the EU, we may yet see more cases of this kind. One might speculate about the use of anti-dumping measures in parallel with a possible future CBAM or their occasional use as an alternative measure to combat indirect carbon leakage. Russia challenged Ukrainian anti-dumping duties on the same product in the WTO dispute settlement system (DS493: Ukraine—Anti-Dumping Measures on Ammonium Nitrate) and prevailed on a point concerning the pricing of energy. It remains to be seen whether these EU duties will be challenged at the WTO and how they would be viewed by a dispute settlement panel. Notably, in the scenario of continued fossil fuel subsidies outside the EU and the possible reduction of the same within the EU, such measures may well be necessary to complement a CBAM. It is also perhaps worth considering whether the detailed insight given by the procedures of anti-dumping investigations into both the production methods and prices of various components of the imported products investigated could

20 See Sapir & Horn, supra note 16.

provide some of the detailed information necessary for the design of CBAMs. Depending on how the EU chooses to compensate exporting industries for the increasing cost of carbon emissions of production within the EU, importing countries might also start to consider those exports as dumping as they would be selling below cost outside the EU.

3.2 Technical issues

CBAs adjust for differences in embedded carbon and applicable carbon prices (Mehling et al., 2019). A CBAM may be determined by the following equation:

$$\textbf{CBAM} = \textbf{weight}_{\text{imported product}} \times \textbf{carbon intensity}_{\text{imported product or benchmark}} \times (\textbf{carbon price}_{\text{EU}} - \textbf{carbon price}_{\text{foreign country}}).$$

Here, carbon intensity refers to carbon emissions embodied in a product or its benchmark per unit of weight of imported product (e.g., mass or monetary value). In the determination of CBAMs, two major practical challenges are encountered. First, the determination of carbon intensity is not straightforward and is subject to methodological choices and issues related to data quality. Second, the determination of carbon price is also not straightforward as there may be various types of instruments affecting the carbon price and the price is not necessarily easy to detect.

When determining carbon intensity for products, methodological issues typical in life cycle assessment (Finnveden et al., 2009) are encountered. These include the selection of emission components (CO_2, other GHGs, other climate forcers such as aerosols) and characterization factors (i.e., how non-CO_2 forcers are converted into CO_2 equivalents), the setting of system boundaries (i.e., which processes from upstream/downstream are included), choosing allocation rules (i.e., how the emissions are allocated in the case of co-products), and applying representative data. These choices may significantly influence the carbon intensity of products, as shown, for example, by Soimakallio et al. (2011) for electricity and by Soimakallio and Koponen (2011) for biofuels. In addition, the representativeness of data remains a question for each of the processes in which emissions take place. For example, which data sources are acceptable, which emission factors should be applied, and how accurate actual data should be are questions that need to be responded to through given criteria. Similar types of question have been considered earlier, for example, in the context of implementing the sustainability criteria introduced by the EU for the transportation of biofuels and bioliquids (Soimakallio et al., 2010).

The more flexibility that exists in determining the carbon intensity of products, the more heterogenous data is likely to be applied. On the other hand, as the methodological choices required are always (at least to some extent) subjective, it may be difficult to find unique choices that satisfy all the stakeholders involved. One option is to set some kind of default values that can be used if desired and replaced by actual values in case producers want to use their own data. Yet, the questions related to data quality and methodological choices that needs to be made remain valid.

In the ideal case, the carbon price is determined based on the explicit carbon price of relevant emission components. This means that all the instruments—such as the price of emission allowances, taxes, and revenues—explicitly influencing the carbon price should be considered. However, different emission components may face various carbon prices; for example, some of the emission components may be regulated under emission trading scheme, some of them may be less penalized through free emission allowances, some of them may be taxed in other sectors, and some of them may be subsidised (or less penalized) by tax relief or revenues. Due to these reasons, it may be very difficult to determine an explicit carbon price for CBAMs in practice.

4 Scenarios

Due to the various implementation uncertainties, we argue that the best way to analyse the potential impacts of CBAs is to consider several alternative scenarios. First, we constructed the Feasible Scenario that aims to represent implementation that is relatively practical, based on techno-economic and legal aspects. As it is constructed to avoid various hurdles in the implementation process, we consider that this scenario is the easiest to implement. Second, in our Efficient Scenario, more products are considered compared to the Feasible Scenario, with the aim of imitating global carbon pricing. While this set-up allows us to make comparisons between the economic impacts in different scenarios, we acknowledge that the techno-economic and legal problems become more pressing in this more ambitious scenario.

In addition, a few variants for the two scenarios were considered in order to see how sensitive the results are to changes in certain key factors. The key features of the main scenarios and their variants are shown in Table 4.1.

In all the scenarios, CBAs are assumed to be implemented for imports from all countries outside the EU (including Norway but excluding the UK). That is preferable from the perspective of international trade law as differentiation between countries can be construed as discriminatory.

Two different sets of explicit carbon prices were considered for all the carbon intensities: 25 and 50 EUR/tCO_2. The lower value corresponds to the price level in early 2020, after recent reforms and the introduction of the Market Stability Reserve in the EU ETS, resulting in greater scarcity in European carbon markets (Bayer & Aklin, 2020). The higher value corresponds the carbon price in the EU in 2040 according to the reference scenario published by the European Commission (2016). Here, these price levels illustrate the difference in carbon price between the EU and non-EU countries/regions. Implicitly, this means that the carbon price in non-EU countries is assumed to be zero. Thus, the influence of a varying carbon price is considered, but the difference in carbon price among countries outside the EU is not considered. The use of revenues from CBAs is not specified and considered. Furthermore, results from economic analysis arise solely from the introduction of the CBAM, and not consider the effects of possible complementary policy reforms, such as changes in the allocation of free allowances.

The data for the carbon content of products is derived from EXIOBASE3 data, which is a global, detailed, multi-regional environmentally extended supply-use table (MR-SUT) and a multi-regional input–output table (EXIOBASE, 2020). In EXIOBASE version 3.4, input–output tables are provided for the years 1995–2011. It covers 200 product groups (see Appendix 1), 44 countries, and five "rest of the world" (ROW) regions. Besides EU countries, the UK, the US, Japan, China, Canada, South Korea, Brazil, India, Mexico, Russia, Australia, Switzerland, Turkey, Taiwan, Norway, Indonesia, and South Africa are presented separately. The ROW is separated into the rest of Asia and the Pacific (EXIOBASE code: WA), America (code: WL), Europe (code: WE), Africa (code: WF), and the Middle East (code: WM).

Table 4.1. The key features of main Feasible and Efficient Scenarios and their considered variants.

		The Feasible Scenario	The Efficient Scenario
Scope and coverage	For imports/exports	Import CBA	Import CBA
	Sectoral/product coverage	Feasible 1: cement (incl. lime and plaster) Feasible 2: cement (incl. lime and plaster), aluminium, iron, &steel	14 manufacturing sectors: non-metallic minerals; iron and steel; aluminum and aluminum products; textiles; pulp and paper; chemicals, plastic, rubber; rubber and plastic products; fabricated metal products, except machinery and equipment; electrical machinery and apparatus n.e.c.; machinery and equipment n.e.c.; medical, precision, and optical instruments; watches and clocks; office machinery and computers; radio, television, and communication equipment and apparatus; furniture; other manufactured goods n.e.c.
	Country coverage	All	All
The determination of carbon intensities (contents)	Emissions scope	Direct + indirect domestic electricity/heat (CO_2 only)	Efficient 1: Direct + indirect (except imports from the EU) (CO_2 only) Efficient 2: Direct + indirect domestic electricity/heat (CO_2 only)
	Benchmark	EU-specific averages (weighted by production value in case of the aggregation of product groups)	Non-EU country/region-specific averages (weighted by imports to the EU in the case of the aggregation of product groups)
The determination of the adjustment level	Carbon price in the EU	25 or 50 EUR/tCO_2	25 or 50 EUR/tCO_2
	Carbon price in foreign countries	0 EUR	0 EUR
	Revenue use	Not specified	Not specified

4.1 The Feasible Scenario

The Feasible Scenario aims to represent implementation that is relatively practical, based on techno-economic and legal aspects. A very limited number of products are included (see Table 4.1.) and the description below). Only products from the energy-intensive sectors that are considered to be at risk of carbon leakage under the EU ETS are included, even starting with a subset of products with limited trade intensity in accordance with the previous proposals discussed in Section 2.

In its first variant—namely, the Feasible 1 scenario—only cement (including lime and plaster) was considered. This choice was based on the following aspects: Internationally, cement is only traded in limited amounts and typically only between nearly neighboring countries, which is likely to increase the general acceptability of a CBA addressing it, thus reducing the risk for countermeasures from non-EU countries. Also, the macro-economic impacts of this implementation are likely to be marginal. On the other hand, cement has high CO_2 emission intensity, which make it an interesting product from a CBA point of view. CBA for cement has been proposed by France in its non-paper on a carbon inclusion mechanism for the cement sector (see Section 2).

In its second variant—namely, the Feasible 2 scenario—altogether three products were considered: (1) cement (including lime and plaster), (2) aluminium, and (3) iron and steel. This choice was reasoned for by the fact that all these products have high CO_2 emission intensity yet the number of products considered remains very limited. However, compared with the Feasible 1 scenario, the risk of countermeasures being taken by non-EU countries is higher as aluminium and steel are internationally traded in significant amounts. Consequently, the feasibility of the implementation of the Feasible 2 scenario is likely to be lower compared with the Feasible 1 scenario. As another balance between environmental benefit and the ease of implementation, the Feasible Scenario avoids the need to determine the exact carbon content of foreign products by relying instead on the average sectoral emissions of European producers. Carbon intensities (i.e. carbon contents) for products were determined based on direct process emissions and indirect domestic electricity/heat emissions embodied in products or intermediate products. Only CO_2 emissions were considered (non-CO_2 emissions were excluded). The reason for considering these emissions is that the application of CBAs particularly aims to adjust the impacts that the ETS has on the competition of emission-intensive sectors. The majority of these emissions are included in the EU ETS (only small-scale energy boilers are not included in the EU ETS), and they formulate the majority of the emissions covered by the EU ETS (only some industrial nitrous oxide emissions not considered here).

EU-specific averages were used as a benchmark for CBAs in case the carbon intensity of a product in an exporting country was higher than the intensity in the EU. If the opposite held true, the carbon intensity of a particular country/region was used as the benchmark. Thus, the exporting countries face CBAs that correspond at most with the carbon price paid in the EU, even if the carbon intensity is higher than in the EU. This makes the system likely to be more acceptable by such countries. The categories "Basic iron and steel and of ferro-alloys and first products thereof" and "Secondary steel for treatment, Re-processing of secondary steel into new steel," taken from EXIOBASE3, were combined into the category "Iron and steel," and the CO_2 emissions were weighted by production volumes in order to calculate the carbon intensity for iron and steel.

The carbon intensities were calculated using EXIOBASE3 data representing the year 2011. We acknowledge that the representativeness of such old data is an issue, but at the same time, it illustrates the general problem that the implementation of CBAs easily encounters. The time lag in statistics is typically a few years, and databases applying data from various statistics can thus be few years out of date. In addition, the lack of transparency, sectoral cut-offs, and other methodological choices (discussed in Section 3.2) can limit the general acceptability and thus the applicability of the databases behind CBAs.

It is notable that in our scenarios we do not allow importers an opportunity to prove that their actual emissions performance exceeds the average performance, as suggested in previous proposals. We acknowledge that this could decrease the economic impacts for high-emission countries if there is large variation in the individual importer firms´ emission intensities. We illustrate the impact in our sensitivity analysis.

From a legal perspective, the Feasible 1 and Feasible 2 scenarios only raise limited concerns. By only covering imports, there is no risk of this design being considered a prohibited subsidy under the WTO Agreement on Subsidies and Countervailing Measures. Also, by covering imports from all countries rather than singling out particular countries, it avoids violating the MFN principle contained in Article I of the GATT. A relatively limited scope of products helps avoid the arbitrary discrimination that might occur with the broader coverage of more complex goods as the data will be more readily available and the production processes more familiar. Reliance on the average carbon intensity of EU producers should be compatible with trade law, based on the 1987 US v. Superfund case (see above, Section 3), and this is also the approach proposed in the French non-paper of 2016. Not allowing individual adjustment—that is, not having a process for importers to prove the actual carbon intensity of their products—need not disqualify the measure given the reliance on such a relatively favorable benchmark, again based on the US v. Superfund case. The emissions scope is broader than that of the EU ETS, which only covers direct emissions, but because the EU ETS also covers the electricity sector and electricity used by other covered sectors, it should include the carbon price and including Scope 2 emissions in this scenario should be justifiable. Finally, this scenario does not take into account a carbon price or other carbon constraint imposed on imported products in their country of origin. There is no directly relevant case law to assess whether or not this increases the legal risk of such a CBAM design, but it is conceivable that not accounting for foreign policies—at least the explicit carbon prices paid in the country of origin—could be considered "arbitrary and unjustifiable discrimination between countries where the same conditions prevail," as indicated in the introductory paragraph of Article XX of the GATT.

4.2 The Efficient Scenario

To further illustrate how the balance between the environmental benefit and ease of implementation would affect the economic impact of the CBAs, we also considered the Efficient Scenario. This scenario puts less weight on the implementation issues and more weight on the aim of imitating global carbon pricing.

Clearly more products were considered compared with the Feasible Scenario, but the amount still remained limited (see Table 4.1 and the description below). While being broader, the scenario still focused on energy-intensive sectors considered to be at risk of carbon leakage under the EU ETS. The selection of the products was based on the following process. First, the average carbon intensity of all 200 products produced in non-EU countries/regions (excluding Norway and including the UK) were calculated. All the direct and indirect CO_2 emissions were considered except those embodied in the imports of intermediate products from the EU (as these emissions are likely to already be priced in the EU ETS). The monetary values of the imports to the EU were used as a weighting factor in the aggregation process. Second, products with a carbon intensity above the average carbon intensity were selected. However, a few exceptions were made; mining was not included as most of the emissions occur in extraction, which does not fall under the EU ETS; refined oil products were not included due to the very low (or even positive) reaction of imports to tariffs; and electricity was not included due to several problems (EXIOBASE3 shows the monetary value of zero for imports to the EU in 2011—the reliability of the estimated elasticities is unclear and transmission data is lacking). Consequently, 14 products were considered (see Table 4.1.).

In the first variant, the Efficient 1 scenario, carbon intensities (i.e. carbon contents) for products were determined based on all direct and indirect CO_2 emissions, applying country/region-specific averages for non-EU countries (excluding Norway and including the UK). However, those emissions embodied in the imports of intermediate products from the EU were excluded as described above. The inclusion of all the direct and indirect non-EU CO_2 emissions embodied in products aims to imitate the situation where the carbon price affects all the CO_2 emissions within the EU. In the second variant, the Efficient 2 scenario, the carbon intensities were determined dissimilarly to in the Efficient 1 scenario but only considering direct process emissions and indirect domestic electricity/heat emissions embodied in products or intermediate products. This is reasoned for in a similar way to the reasoning in the case of the Feasible Scenario.

Non-metallic minerals, iron and steel, textiles, pulp and paper, chemicals, plaster, and rubber all included two or more products aggregated from EXIOBASE3. The CO_2 emissions were weighted by production volumes in order to calculate carbon intensities for these products.

From the technical perspective, similar issues related to the data applied are raised to those raised in the Feasible Scenarios. However, as more indirect emissions are considered in the Efficient 1 scenario than in the Feasible Scenario or the Efficient 2 scenario, data issues become even more relevant in the Efficient 1 scenario.

From a legal perspective, all the same considerations listed with regard to the Feasible Scenario also apply to the Efficient Scenario with two exceptions: the broader scope, including many semi-manufactured and manufactured goods, dramatically increases the technical and administrative complexity of the CBAM, which could affect its legal assessment under Article XX of the GATT. Parts of the tests involved in the application of this provision require balancing the means and end, for instance, balancing whether the measure is "necessary" in order to achieve the end state or whether less burdensome alternatives might have been used. Likewise, the embedded carbon emissions relative to the value of goods diminishes rapidly as a CBAM progresses down the value chain, and thus the proportionality of its imposition as an environmentally motivated measure could be challenged. The other legally problematic aspect of this scenario is the inclusion of Scope 3 emissions: since a border adjustment can only adjust for the burden imposed on domestic products and producers, imposing a CBAM on imports that also encompasses Scope 3 (and other indirect) emissions is likely to be challenged as producers covered under the EU only have to report and surrender allowances for Scope 1 emissions (and electricity as a sector is included, meaning that Scope 2 emissions are to some extent included indirectly). Ultimately, if a CBAM design were proposed that resembles the Efficient Scenario, it would be likely to face greater scrutiny under international trade law and incur a greater risk than the Feasible 1 and 2 scenarios.

5 The gravity estimations of the impact of CBAMs on trade

In this section, we study the potential trade effects of the proposed CBAMs. We use gravity analysis to isolate the historical trade effect of tariffs and apply the findings in making projections concerning the effects of the different CBAM scenarios constructed in Section 4. The gravity model is the main tool for evaluating the effects of changes in variables that in some ways affect barriers to trade between countries. (see, e.g., Anderson and Yotov, 2010; Anderson and Van Wincoop, 2003; Helpman, Melitz, and Rubinstein, 2008; Egger and Larch, 2011; Head and Mayer, 2014; Brakman, Kohl, and Van Marrewijk, 2015; Bekkers and Rojas-Romagosa, 2016). As such, they also provide a useful tool for the analysis of the CBAMs.

In economics, in an analogy with the gravity theory of physics, the gravity model is used to analyze sources of economic gravitational pull in order to explain trade patterns. The economic gravitational pull depends on country-specific and pair-specific variables, such as economic size (GDP) and the distance between two trading partners. A large GDP, a short distance, and close ties tend to increase trade, while a long distance and trade barriers increase transportation costs and other trade costs and thereby reduce trade. In addition to distance, a selection of other variables—such as a common border, language, or religion, or an earlier colonial relationship—have been included in the traditional gravity model to capture other trade costs.[21]

In this report, we use an extensive dataset that contains historical patterns of trade in order to empirically assess how much a change in trade costs could change the value of imported products. Our focus on EU imports is based on our assessment that the CBAM

21 More recently, indicator (dummy) variables have been substituted for these gravity variables. When, for example, distance is unchanged from year to year, it can be substituted for by an interactive dummy variable between the two countries. If a time dimension is included, even changes in trade agreements or exchange rates can be covered using dummy variables.

is likely to focus on imported goods, not on exports. We estimate the tariff elasticity of the EU's imports, that is, we estimate how much import demand falls when there is an increase in tariffs and other economic factors are kept constant. We apply the analysis in order to understand the impacts of the different CBAM scenarios and their underlying assumptions.

The trade analysis is useful in several respects. First, the estimated elasticities provide us with a first-order assessment on how much it affects EU imports whether or not CBAMs are used as a complementary tool in the EU's climate policy. The detailed, product-specific information on tariffs and trade allows us to make inferences on the expected decline in imports that would be most consistent with the patterns experienced in the previous two decades.

Second, the analysis allows us to study the potential value chain impacts of the CBAMs. This perspective is important as the imported products are not merely used in the EU for final demand, but rather, they are often used as intermediate components in EU firms' production. Due to global value chains, the complicated interactions and interdependencies across country borders in production need to be taken into account when considering the economic impact of the CBAMs. Assessment of the economic impact with the current production structure allows us to quantify areas where the production structure needs to be changed the most if the CBAMs are introduced.

Third, the estimated trade elasticities are used to calibrate a CGE model. The CGE model allows us to incorporate the tariff elasticities as a part of an overall assessment of the EU's climate policy. Namely, the model allows us to analyze the tariff effects jointly with the impact of climate policy that may, for example, partly neutralize the effect of the ETS. The modelling issues are discussed more thoroughly in the next section.

At the end of this section, we will also address empirical evidence on carbon leakage. While the evidence of the ETS impact is still preliminary and most of the impact analysis is still based on theoretical models, we argue that the empirical view can provide a useful complementary view. In particular, it allows us to ask how much the increase in the level of ambition in the ETS could affect carbon leakage.

5.1 The direct impacts of the CBAM on gross imports

To quantify the direct impact of the CBAM on imports, we analyzed two factors. First, we studied how sensitive the import demand of different products is on changes in trade costs. The effect depends on various substitution and income mechanisms that steer the amount of demand and product choices in the EU. We estimate the trade elasticities of import tariffs by isolating the historical variation in global imports that is due to changes in tariffs. The second factor is the dependence of the different countries on these goods a priori. For example, due to geographical and other differences, some EU countries may be less dependent on the supply of imports, and therefore the impact of tariffs is smaller. The joint analysis of these two factors allows us to make inferences on the changes in imports due to the introduction of the CBAM.

5.1.1 Methodology and data

As a first step in the trade impact analysis, we estimated trade elasticities using global bilateral trade and tariff data. We used UN Comtrade data for countries' imports in the Harmonized System (2007) six-digit product level for the years 2000–2018. These data are for goods trade only and therefore do not include trade in services.[22]

Our dataset includes 132 reporter countries[23] (including all the EU countries) and all their partner countries. There are 236 partner countries and geographic regions. The number of reporter countries is limited because we needed to combine the trade data with information from the WTO on their MFN import tariffs at the Harmonised System (HS) 6-digit product level each year. However, the dataset covers almost all global trade.

We also include information on free trade agreements between the countries when applicable. Countries that do not have bilateral free trade agreements are assumed to trade at MFN tariffs. If they do have a free trade agreement, all tariffs between them are

22 Our interest is CO_2 emissions that only accrue from the production of physical goods. Of course, they do need to be transported, which is a service and so is not included in the emissions.

23 The countries are Albania, Angola, Argentina, Armenia, Australia, Austria, Bahrain, Bangladesh, Belgium, Belize, Benin, Bolivia, Botswana, Brazil, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, the Central African Republic, Chile, China, Colombia, Congo, Costa Rica, Croatia, Cuba, Cyprus, the Czech Republic, Côte d'Ivoire, Denmark, the Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Eswatini, Fiji, Finland, France, Gabon, Georgia, Germany, Ghana, Greece, Guatemala, Guinea, Guyana, Honduras, Hong Kong, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, South Korea, Kuwait, Kyrgyz, Latvia, Lesotho, Lithuania, Luxembourg, Macao, Madagascar, Malawi, Malaysia, Mali, Malta, Mauritania, Mexico, Moldova, Mongolia, Montenegro, Morocco, Mozambique, Myanmar, Namibia, Nepal, the Netherlands, New Zealand, Nicaragua, Niger, Nigeria, North Macedonia, Norway, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, the Philippines, Poland, Portugal, Qatar, Romania, the Russian Federation, Rwanda, Saudi Arabia, Senegal, Sierra Leone, Singapore, the Slovak Republic, Slovenia, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Ukraine, the United Arab Emirates, the United Kingdom, the United States of America, Uruguay, Venezuela, Vietnam, Zambia, and Zimbabwe.

assumed to be zero. In practice this is not necessarily strictly so because there may be exceptions and/or transition periods if the agreement is very recent. However, we do not have HS6-level product information on this. Any error in this respect is likely to be extremely small at the level of global trade.

Next, we introduced information on industry sectors at the two-digit level of the International Standard Industrial Classification of All Economic Activities (ISIC) Rev. 3 classification for each HS6 product. This industry classification is used in the EXIOBASE database (see Section 4 on the scenarios for more details) that provides us with information on the CBAM. Average import tariffs for each two-digit industry between any two countries are calculated for each year, weighted by the value of imports in each HS6 product.

We then use Poisson pseudo-maximum likelihood (PPML) estimation to estimate global tariff elasticities by industry. PPML estimation is a standard estimation method that is used in gravity analysis. A more technical presentation of this method is given in Appendix 2. As expected, the global tariff elasticities are negative, meaning that higher tariffs decrease imports and vice versa.

Next we introduce information on border carbon adjustment tariffs (see Section 4 on how these have been calculated) by product or industry, as required in the different scenarios presented in Section 4. These are also calculated as weighted averages in EU imports from non-EU countries. The UK is treated as a non-EU country to reflect the post-Brexit reality while Norway and Iceland are included in the EU as members of the European Economic Area. We note that the tariffs reflect differences in the emission intensity between the EU and extra-EU countries, while here we do not consider the possibility of mitigating climate policy in the extra-EU countries. We address their role in Section 6.

The global tariff elasticities and the CBAM tariffs are then combined when calculating the effect of CBAM tariffs on EU imports.

Because the World Input-Output Database (WIOD) data used in our global value chain analysis (see Section 5.2) uses the more recent ISIC Rev. 4 classification, we finally ran the results again from the HS6 product level by combining these data with this other industry classification.

5.1.2 Scenarios

We analyze two main scenarios, the Feasible Scenario and the Efficient Scenario, and their variations (introduced in Section 4). The Feasible Scenario is much more limited in its scope of sectors. Its variants only include the manufacturing of cement, lime, and plaster; the manufacturing of iron and steel, and products thereof; and the manufacturing of aluminum and products thereof. Our motivation for only including products from these sectors arises from the fact that they have high carbon cost and trade exposure, as well as a limited ability to pass through the cost to consumers, and narrowing the scope to these goods greatly reduces the administrative and technical burden of any CBA but still delivers significant environmental benefits.[24]

The scenarios Efficient 1 and 2 encompass most manufacturing sectors and put more weight on the economic and environmental aspects instead of on practical implementability. Table 4.1 collects detailed descriptions of the scenarios. We note that two different explicit carbon prices were considered in the calculations of the tariffs for all the carbon intensities: 25 and 50 EUR/tCO_2. In what follows, we will show the results for the baseline price of 25 EUR/tCO_2. With 50 EUR/tCO_2, the tariffs and correspondingly the import impacts, are twice as large.[25] Table 5.1.1 collects information on the importance of key sectors in the EU economy. That is, it shows the value added in all EU countries in 2017 for the Feasible Scenarios' sectors in order to show how important these are for the different countries.[26]

We can see that the manufacturing of cement, lime, and plaster plays a very small part in the total EU economy. Its total value added was seven billion euros in 2017 and its share in total business economy value added was just 0.11 %. On the other hand, cement is of course very important as an intermediate good for the construction sector.

The importance of cement, lime, and plaster is at least twice as important as the EU average for Romania, Croatia, Slovakia, Poland, Greece, Bulgaria, and Belgium. New member countries and the Balkans are over-represented in this group.

The manufacturing value added of basic metals and products thereof in the EU27 countries was 104 billion euros in 2017, or 1.67 % of total business sector value added. This is already significant, as is of course the importance of these products as intermediate goods, especially in other metal industries. The importance of iron, steel, and aluminum (including other metals) exceeds the EU average, especially in Slovenia, Slovakia, Austria, Bulgaria, Finland, Poland, Belgium, and Italy. Total manufacturing industry value added in the EU27 countries is 17 % of total value added. Consequently, relative to manufacturing value added, these sectors are more important.

24 We should acknowledge that while our scenarios aim at grasping the key features of the CBAMs, their economic analysis is bound to be stylized. For example, our economic models are calibrated based on historical global emissions and trade linkage data that typically lag behind by several years.

25 This follows from the fact that our impact model is linear.

26 Note that because of limitations in data availability for many EU countries, we have had to combine iron and steel together with aluminum. Furthermore, the data also includes other metals. Even after this, we do not have all data for all the countries.

Table 5.1.1.Value added (factor prices) by sector in the Feasible Scenarios in different EU countries in 2017, NACE Rev. 2

Country	Billions of euros			% of total business economy	
	B-N_S95_X_K; total business economy	C235; the manufacture of cement, lime, and plaster	C24, C251; the manufacture of basic metals and of structural metal products	C235; the manufacture of cement, lime, and plaster	C24, C251; the manufacture of basic metals and of structural metal products
EU27 (from 2020)	6 203	6.9	103.9	0.11	1.67
EU28 (incl. the UK)	7 454	7.0	113.2	0.09	1.52
Belgium	222	0.5	4.8	0.22	2.14
Bulgaria	27	0.1	0.7	0.23	2.51
Czech Republic	103	0.2	2.0	0.18	1.90
Denmark	149	.	1.2	.	0.79
Germany	1 738	1.8	31.0	0.10	1.79
Estonia	13	.	0.2	.	1.59
Ireland	207	0.2	0.9	0.08	0.42
Greece	49	0.1	0.9	0.23	1.87
Spain	500	0.6	8.2	0.12	1.64
France	987	1.0	10.2	0.10	1.03
Croatia	23	0.1	0.4	0.33	1.68
Italy	728	0.6	15.5	0.08	2.13
Cyprus	9	.	0.1	.	0.96
Latvia	12	.	0.1	.	0.90
Lithuania	19	.	0.1	.	0.71
Luxembourg	25	.	.	.	.
Hungary	64	0.1	1.2	0.10	1.89
Malta	7	0.0	.	0.00	.
Netherlands	364	.	4.5	.	1.25
Austria	194	0.1	5.6	0.08	2.88
Poland	216	0.5	4.7	0.25	2.17
Portugal	84	0.1	1.2	0.12	1.47
Romania	67	0.2	1.2	0.37	1.84
Slovenia	23	0.0	0.8	0.12	3.54
Slovakia	38	0.1	1.3	0.29	3.45
Finland	102	0.1	2.5	0.10	2.49
Sweden	234	0.1	4.2	0.05	1.79
United Kingdom	1 251	0.1	9.3	0.01	0.75
Iceland	.	0.0	0.5	.	.
Norway	.	.	2.4	.	.
Switzerland	.	0.3	2.9	.	.

Source: Eurostat.

5.1.3 Estimation results: The potential direct impacts of higher tariffs on gross trade

Table 5.1.2 shows descriptive data on the EU imports of the products and industries that are analyzed in the scenarios. These are gross value figures, and they are thus not directly comparable to the above value-added data.

The scenario Feasible 1 only includes cement, lime, and plaster while some other products are added in the scenario Feasible 2. The scenario Feasible 2 includes cement, lime, and plaster (HS 4-digit codes 2521–2523); iron and steel, including products thereof (HS4 codes 7201–7320); and aluminum, including products thereof (HS4 codes 7601–7616). As we can see, the value of extra-EU imports of cement, lime, and plaster is very small. Iron and steel, including products thereof, is much larger and equal to 2.7 % of all extra-EU imports. The value of aluminum and aluminum product imports is about half the value of iron and steel.

In the Efficient Scenarios we have a much larger set of industries and products. These cover almost 60 % of all extra-EU goods imports. The gross value is 8.5 % relative to the EU GDP. The largest sectors at the level of disaggregation we use is the manufacturing of chemicals and chemical products, followed by the manufacturing of textiles and wearing apparel, and different metal industries. The smallest industries are paper and paper products, and other non-metallic mineral products. Taken together, the metal industries cover a little over half of all extra-EU imports in the broad Efficient Scenarios.

Table 5.1.2. Descriptive trade statistics for 2018

Sector	Total extra-EU imports, bn EUR	Share in total extra-EU imports, %	Total extra-EU imports, % of EU GDP
Feasible Scenarios			
Cement, lime, and plaster	0.3	0.0	0.00
Iron and steel, incl. products thereof	52.5	2.7	0.39
Aluminum, incl. products thereof	24.1	1.2	0.18
Efficient Scenarios			
17. Manufacture of textiles, wearing apparel, etc.	166.5	8.6	1.24
21. Manufacture of paper and paper products	14.4	0.7	0.11
24. Manufacture of chemicals and chemical products	229.8	11.8	1.70
25. Manufacture of rubber and plastics products	44.1	2.3	0.33
26. Manufacture of other non-metallic mineral products	16.3	0.8	0.12
271. Iron and steel, incl. products thereof	52.5	2.7	0.39
272. Aluminum, incl. products thereof	24.1	1.2	0.18
28. Manufacture of fabricated metal products	24.2	1.2	0.18
29. Manufacture of machinery and equipment n.e.c.	135.1	7.0	1.00
30. Manufacture of office, accounting, and computing machinery	108.8	5.6	0.81
31. Manufacture of electrical machinery and apparatus n.e.c.	95.2	4.9	0.71
32. Manufacture of radio, television, and communication equipment and apparatus	102.9	5.3	0.76
33. Manufacture of medical, precision, and optical instruments, and watches and clocks	82.2	4.2	0.61
36. Manufacture of furniture; manufacturing n.e.c.	54.0	2.8	0.40
Total extra-EU CBAM imports	1150.0	59.3	8.5
Other goods imports	789.3	40.7	5.9
Total	**1939.3**	**100.0**	**14.4**

Note. The UK is treated as a non-EU country in 2018 to simulate the post-Brexit situation.
Source: Our calculations, based on UN Comtrade data.

Table 5.1.3 shows the estimated global import tariff elasticities. They measure how sensitive the import demand of different products is to changes in import tariffs while controlling for other factors and trade costs due to various substitution and income mechanisms that steer the amount of demand and product choices globally. According to calculations by the World Bank, the applied weighted mean tariff rate for all products in world trade declined from 4.96 % in the year 2000 to 2.59 % in 2017. Most of the decline took place during 2000–2006.

From the first numerical column we can see the elasticity of imports with respect to import tariffs. For example, the imports of machinery and equipment have an elasticity of –0.031. Consequently, the imports of these products decline by 3.1 % if tariffs are raised by one percentage point.[27]

27 The table approximates percentual changes that can be derived from the table by using the formula exp(*x*)-1, where *x* is the number in question. However, they are very close to actual percentages, and thus we report the approximative results.

Table 5.1.3. Global import elasticities with respect to tariffs during 2000–2018

	Tariff elasticity	Statistical significance	95 % confidence interval, lower bound	95 % confidence interval, upper bound
Feasible scenarios				
Cement, lime, and plaster	-0.0529	***	-0.0690	-0.0367
Iron and steel, incl. products thereof	-0.0289	***	-0.0447	-0.0130
Aluminum, incl. products thereof	-0.0647	***	-0.0989	-0.0305
Efficient scenarios				
Manufacture of textiles, wearing apparel, etc.	-0.0071		-0.0175	0.0032
Manufacture of paper and paper products	-0.0186	***	-0.0293	-0.0078
Manufacture of chemicals and chemical products	-0.0386	***	-0.0533	-0.0238
Manufacture of rubber and plastics products	-0.0143	***	-0.0250	-0.0036
Manufacture of other non-metallic mineral products	-0.0263	***	-0.0383	-0.0143
Iron and steel, incl. products thereof	-0.0289	***	-0.0447	-0.0130
Aluminum, incl. products thereof	-0.0647	***	-0.0989	-0.0305
Manufacture of fabricated metal products	-0.0239	***	-0.0366	-0.0111
Manufacture of machinery and equipment n.e.c.	-0.0310	***	-0.0400	-0.0221
Manufacture of office, accounting, and computing machinery	-0.0472	***	-0.0753	-0.0192
Manufacture of electrical machinery and apparatus n.e.c.	-0.0557	***	-0.0676	-0.0438
Manufacture of radio, television, and communication equipment and apparatus	-0.0610	***	-0.0874	-0.0346
Manufacture of medical, precision, and optical instruments, and watches and clocks	-0.0235	**	-0.0437	-0.0033
Manufacture of furniture; manufacturing n.e.c.	-0.0358	***	-0.0497	-0.0219

Note: The first numerical column shows how sensitive the import demand of different products is to changes in import tariffs while controlling for other factors and trade costs due to various substitution and income mechanisms that steer the amount of demand and product choices globally. Statistical significance: *** < 0.01, ** < 0.05, * < 0.1.

The results suggest that there are major differences across products and industries in terms of their sensitivity to changes in tariffs. We find that many of the products that are in the Feasible Scenario (cement, lime, and plaster; and aluminum) belong to the group where the elasticities are the largest, implying that a rise in tariffs has a large negative effect on imports. For these products, as well as for electrical machinery and equipment (including radio, television, and communication equipment), a one percentage point increase in tariffs may lead to a more than 5 % decline in imports. This finding suggests that these products are easily substituted for similar products from other countries or their overall demand changes significantly when a tariff is introduced.

On the other hand, we find that the imports of textiles and wearing apparel, paper and paper products, and rubber and plastic products are much less sensitive to changes in tariffs. Also, other non-metallic mineral products, iron and steel, and fabricated metal products are relatively insensitive in this regard. In the case of textiles and wearing apparel, the low elasticity could be partly due to the Agreement on Textiles and Clothing (ATC) negotiated during the WTO Uruguay Round. Its elasticity is not statistically different from zero while other estimated values are statistically very significantly different from zero. On the other hand, the ATC was only in force up until 2004. Furthermore, we also ran an estimation with an ATC dummy. This did not change the results for the textile and wearing apparel sector.

Imbs and Mejean (2017) have estimated trade elasticities. Our results show somewhat smaller elasticities to theirs. The differences may arise both from dissimilarities in the methodology and data. For example, we used a significantly larger number of trading countries. Note that our model is best equipped to analyze relatively small tariff changes, whereas if the changes are large, their size only provides an approximation that is bounded by the non-negativity constraint on trade.

Tables 5.1.4 and 5.1.5 show the effects of CBAM tariffs on extra-EU imports. The CBAM tariffs are calculated in the EXIOBASE database using the formulation shown in Section 3.2 and a carbon price of 25 euros per ton. If the carbon price is higher than this, the CBAM tariff will also be higher.

The first table is based on our broadest Efficient 1 scenario (see Table 4.1), which includes both direct and indirect CO_2 emissions. The negative effect on gross imports is 93 billion euros or almost 5 % of all extra-EU goods imports. This is 0.7 % relative to the EU GDP. The biggest impact comes from chemicals and chemical products, followed by different metal industries.

Table 5.1.4. Efficient 1: The impact of CBAM tariffs on extra-EU imports with both direct and indirect CO2 emissions

	CBAM tariff, weighted averages	The effect of the CBAM on gross imports, bn EUR	The effect of the CBAM on gross extra-EU imports, % of extra-EU trade	The effect of the CBAM on gross extra-EU imports, % of EU GDP
Feasible Scenarios				
Cement, lime, and plaster	0.0450	-0.1	-23.2	0.00
Iron and steel, incl. products thereof	0.0137	-2.0	-3.9	-0.02
Aluminum, incl. products thereof	0.0047	-0.7	-3.0	-0.01
The Efficient 1 scenario				
Manufacture of textiles, wearing apparel, etc.	0.0181	-2.1	-1.3	-0.02
Manufacture of paper and paper products	0.0182	-0.5	-3.3	0.00
Manufacture of chemicals and chemical products	0.0192	-16.7	-7.3	-0.12
Manufacture of rubber and plastics products	0.0390	-2.4	-5.5	-0.02
Manufacture of other non-metallic mineral products	0.0521	-2.2	-13.5	-0.02
Iron and steel, incl. products thereof	0.0579	-8.6	-16.5	-0.06
Aluminum, incl. products thereof	0.0258	-3.9	-16.2	-0.03
Manufacture of fabricated metal products	0.0366	-2.1	-8.6	-0.02
Manufacture of machinery and equipment n.e.c.	0.0196	-8.1	-6.0	-0.06
Manufacture of office, accounting, and computing machinery	0.0211	-10.6	-9.7	-0.08
Manufacture of electrical machinery and apparatus n.e.c.	0.0216	-11.1	-11.7	-0.08
Manufacture of radio, television and communication equipment and apparatus	0.0214	-13.0	-12.7	-0.10
Manufacture of medical, precision, and optical instruments, and watches and clocks	0.0189	-3.6	-4.4	-0.03
Manufacture of furniture; manufacturing n.e.c.	0.0410	-7.8	-14.4	-0.06
Total		**-92.8**	**-4.8**	**-0.69**

Note: The CBAM tariffs are calculated using the global import tariff elasticities, information on CO_2 emissions is from the EXIOBASE database, and a carbon price of 25 euros per ton is used.

Of course, the Feasible Scenarios again show much smaller effects of less than three billion euros in total, mostly arising from iron and steel. The impact on cement, lime, and plaster is small in euro terms but very large in relative terms as the decline is almost a quarter of total extra-EU imports of these products. However, the Efficient 1 scenario also shows industries with double-digit effects that can be deemed considerable. The largest relative effects are found in the same sectors that are represented in the Feasible 2 scenario. However, the implemented CBAM tariffs are larger in the Efficient Scenarios than in the Feasible Scenario, which explains why imports decrease more in the Efficient Scenarios.

The second table shows the results for our Efficient 2 scenario, which incorporates all direct CO_2 emissions but only indirect electricity CO_2 emissions. Consequently, the indirect CO_2 emissions that arise other than those resulting from the use of electricity are not included in the Efficient 2 scenario. The CBAM tariff is therefore smaller than above, and thus, the impact on extra-EU imports is smaller by almost one half. In this scenario the CBAM tariffs would decrease extra-EU imports by 53 billion euros. The difference between the two scenarios is the smallest in the manufacturing of other non-metallic mineral products, furniture etc., rubber and plastics products, and iron and steel. This implies that in these sectors there are less indirect emissions other than those arising from electricity.

Table 5.1.5. Efficient 2: Impact of CBAM tariffs on extra-EU imports with all direct and indirect electricity CO2 emissions

	CBAM tariff, weighted averages	The effect of the CBAM on gross imports, bn EUR	The effect of the CBAM on gross extra-EU imports, % of extra-EU trade	The effect of the CBAM on gross extra-EU imports, % of EU GDP
Feasible scenarios				
Cement, lime, and plaster	0.0350	-0.1	-18.0	0.00
Iron and steel, incl. products thereof	0.0137	-2.0	-3.9	-0.02
Aluminum, incl. products thereof	0.0047	-0.7	-3.0	-0.01
The Efficient 2 scenario				
Manufacture of textiles, wearing apparel, etc.	0.0081	-1.0	-0.6	-0.01
Manufacture of paper and paper products	0.0114	-0.3	-2.1	0.00
Manufacture of chemicals and chemical products	0.0119	-10.4	-4.5	-0.08
Manufacture of rubber and plastics products	0.0288	-1.8	-4.1	-0.01
Manufacture of other non-metallic mineral products	0.0404	-1.7	-10.5	-0.01
Iron and steel, incl. products thereof	0.0415	-6.2	-11.8	-0.05
Aluminum, incl. products thereof	0.0171	-2.6	-10.7	-0.02
Manufacture of fabricated metal products	0.0199	-1.1	-4.7	-0.01
Manufacture of machinery and equipment n.e.c.	0.0088	-3.6	-2.7	-0.03
Manufacture of office, accounting, and computing machinery	0.0098	-4.9	-4.5	-0.04
Manufacture of electrical machinery and apparatus n.e.c.	0.0089	-4.6	-4.8	-0.03
Manufacture of radio, television, and communication equipment and apparatus	0.0104	-6.3	-6.2	-0.05
Manufacture of medical, precision, and optical instruments, and watches and clocks	0.0128	-2.4	-3.0	-0.02
Manufacture of furniture; manufacturing n.e.c.	0.0308	-5.9	-10.8	-0.04
Total		**-52.8**	**-2.7**	**-0.39**

Note: The CBAM tariffs are calculated using the global import tariff elasticities, information on CO2 emissions is from the EXIOBASE database, and a carbon price of 25 euros per ton is used.

The difference is the largest in the manufacturing of electrical machinery and apparatus; machinery and equipment; office, accounting, and computing machinery; textiles and wearing apparel; and radio, television, and communication equipment and apparatus. This implies that in these sectors there are more indirect emissions other than those arising from electricity.

Pyrka et al. (2020) analyzed the effects of a CBAM using a CGE model. Their model specification is thus different from ours. They also include a smaller selection of industries than we do in our Efficient Scenario. Pyrka et al. included oil, ferrous metals, non-ferrous metals, chemical products, paper products, and non-metallic minerals. In terms of the effects on extra-EU imports, their results are mostly smaller to ours in the Efficient 2 scenario, as shown in Table 5.1.5., but similar in regard to ferrous metals (our "iron and steel" category), and paper and paper products. According to their results, global CO_2 equivalent emissions decline by just 24 Mt, which is much less than in our scenarios, as we will next see. One factor behind these results is the fact that our scenarios include a much larger share of manufacturing sectors and trade.

Table 5.1.6 The effects of the scenarios Efficient 1 and 2 on the value and CO2 content of imports from different partner countries

	The Efficient 1 scenario, % change in …		The Efficient 2 scenario, % change in …		Change in CO2, kilotons	
	the value of EU imports	the CO2 content of EU imports	the value of EU imports	the CO2 content of EU imports	Efficient 1	Efficient 2
Australia	-0.7	-3.4	-0.2	-2.2	-33	-7
Brazil	-0.9	-5.3	-0.4	-4.4	-315	-138
Canada	-2.1	-6.2	-0.9	-3.2	-455	-109
China	-11.6	-15.5	-6.8	-10.0	-100320	-39446
India	-6.8	-15.9	-3.6	-11.3	-8458	-3376
Indonesia	-3.4	-11.1	-0.9	-7.7	-1222	-333
Japan	-3.8	-5.7	-2.0	-3.3	-2729	-836
Mexico	-2.6	-5.9	-0.8	-3.0	-538	-78
Russia	-1.0	-9.7	-0.5	-7.8	-2710	-1592
South Africa	-6.9	-38.1	-6.4	-37.0	-7221	-5930
South Korea	-4.8	-8.2	-1.8	-3.8	-3004	-530
Switzerland	-1.0	-1.6	-0.2	-0.7	-358	-22
Turkey	-2.7	-7.9	-1.4	-7.5	-2612	-1117
United Kingdom	-2.0	-4.0	-0.6	-2.3	-2460	-714
United States	-3.0	-5.9	-2.2	-4.5	-7350	-3593
The rest of Africa	-0.7	-5.9	-0.1	-3.8	-891	-238
The rest of Asia and Pacific	-5.2	-17.3	-2.4	-21.4	-29167	-18899
The rest of Europe	-10.0	-32.4	-7.7	-27.9	-25566	-17018
The rest of Latin America	-0.6	-6.3	-0.3	-5.9	-404	-213
The rest of the Middle East	-3.4	-20.3	-2.7	-19.3	-9997	-7714
Total	**-4.4**	**-14.4**	**-2.5**	**-12.1**	**-205811**	**-101904**

What impact would CBAM tariffs have on the CO_2 content of extra-EU imports? The next two tables show the effects of CBAMs in terms of imports from different non-EU countries and regions, as well as in terms of in which sectors the largest effects arise. The effects are calculated using trade data from 2014. Table 5.1.6 shows the effects by partner country and region. The first two columns show the results for the Efficient 1 scenario. We can see that the impact on the value of imports is the greatest for China and across non-EU Europe (including the UK, Switzerland, and Russia). The impact on the CO_2 content of goods imports is the largest on trade with South Africa, non-EU European countries, the Middle East, and many Asian countries, followed by India and China. The fifth column shows that, in terms of the total tonnage of imported CO_2 emissions, by far the largest impact is on China which accounts for almost half of the total decrease. Output effects in different countries and sectors are discussed in Section 6.

The results in the Efficient 2 scenario are similar to those in the Efficient 1 scenario, but only somewhat smaller because indirect non-electricity emissions are excluded there. The impact on the total CO_2 content of imports in the Feasible Scenarios is negligible.

Table 5.1.7 shows the effects by sector. The Efficient 1 scenario has the biggest impact on the value of imports of iron and steel, and aluminum producing sectors. Both decrease by about 16 % in value. The impact is also greater than 10 % in the manufacturing of furniture, etc.; other non-metallic mineral products; radio, television, and communication equipment and apparatus; and electrical machinery and apparatus. The CO2 content of imports decreases the most in the iron and steel, and aluminum producing sectors. The overall impact on the CO2 content of all the manufacturing sectors that would face the CBAM is some 14 %. If we look at the decline in the quantity of CO2 emissions in imports, we find the largest cuts in iron and steel, chemicals and chemical products, and furniture etc. These three sectors account for almost half of the total decrease.

We can also calculate the CBAM tariff revenue on the basis of the information presented in the above tables. We take the value of trade by sector in 2018, subtract the value of imports that the higher tariffs will erase, and multiply the now lower value of imports by the average weighted CBAM tariff by sector, as shown in the tables. The CBAM tariff revenue in the Feasible 2 scenario is 0.8 billion euros. The much wider Efficient Scenarios yield a tariff revenue of 15.2 billion euros and 25.2 billion euros, depending on whether or not all indirect CO_2 emissions are included. Note that these effects reflect a 25 EUR/tCO_2 baseline price, while the income would double if the baseline price were set at 50 EUR/tCO_2.

Table 5.1.7 The effects of the scenarios Efficient 1 and 2 on the value and CO2 content of imports by different manufacturing sectors

ISIC Rev3 sectors	Efficient 1 scenario, % change in …		Efficient 2 scenario, % change in …		Change in CO2, kilotons	
	the value of EU imports	the CO2 content of EU imports	the value of EU imports	the CO2 content of EU imports	Efficient 1	Efficient 2
Manufacture of textiles, wearing apparel, etc.	-1.3	-1.5	-0.5	-1.0	-885	-265
Manufacture of paper and paper products	-3.0	-6.0	-2.4	-4.8	-883	-447
Manufacture of chemicals and chemical products	-7.4	-12.3	-4.6	-10.5	-31737	-16856
Manufacture of rubber and plastics products	-5.5	-9.1	-4.0	-7.7	-8931	-5604
Manufacture of other non-metallic mineral products	-13.8	-17.8	-10.8	-14.6	-8175	-5191
Iron and steel, incl. products thereof	-16.5	-24.5	-11.8	-20.3	-38164	-22745
Aluminum, incl. products thereof	-16.0	-35.7	-10.5	-30.5	-9689	-5497
Manufacture of fabricated metal products	-8.6	-12.5	-4.7	-7.8	-6200	-2114
Manufacture of machinery and equipment n.e.c.	-5.8	-9.0	-2.9	-4.8	-13044	-3145
Manufacture of office, accounting, and computing machinery	-9.6	-11.2	-4.7	-7.1	-15218	-4513
Manufacture of electrical machinery and apparatus n.e.c.	-11.7	-16.0	-4.8	-7.9	-16903	-3432
Manufacture of radio, television, and communication equipment and apparatus	-12.6	-15.2	-6.1	-8.7	-17812	-4958
Manufacture of medical, precision, and optical instruments, and watches and clocks	-4.3	-10.6	-3.0	-10.7	-9701	-6614
Manufacture of furniture; manufacturing n.e.c.	-14.4	-23.2	-10.8	-22.3	-28470	-20522
Total	**-4.4**	**-14.4**	**-2.5**	**-12.1**	**-205811**	**-101904**

THE DIRECT IMPACTS OF CBAM ON GROSS IMPORTS FOR FINLAND

The value of Finnish extra-EU imports declines by 3.6 per cent in our Efficient scenario 1 and by 1.8 per cent in Efficient scenario 2. These are somewhat smaller figures than for the EU on average and are due to differences in the product and country-of-origin structure of Finnish imports vis-à-vis the EU average. Meanwhile, the CO2-content of Finnish extra-EU imports declines by 13.1 and 10.0 per cent respectively. The share of Finland in the total decline in CO2 imports is 1.0 per cent. We study the structure of the Finnish imports more closely in Section 5.2 that concerns the global value chains.

5.2 The impacts of CBAs seen through global value chains

In this subsection, we apply a measurement framework for the analysis of the value-chain impacts of CBAs. The analysis is necessary due to the complexity and globalization of production. In the era of global value chains, the trade effects of CBAs do not merely concern extra-EU final products that are substitutes for EU products. Rather, the imported products are often used in the EU production as intermediate goods or services. These production linkages need to be considered when assessing the EU's overall economic reliance on the emission-intensive imports. Moreover, the analysis of the value chains also helps to better understand the importance of EU trade for the extra-EU countries. Their exports to the EU often include third-country intermediate products that needs to be considered in order to account for the true value of trade for individual exporting countries.

Our analysis builds on the CBA-induced changes in the bilateral gross trade flows that are analyzed in Section 5.1. In the second stage, we insert them to the world input–output data that represents the underlying value chain structure. Ultimately, we can study which countries produce value added to the emission-intensive imported products and which final producers are the most reliant on them.

Methodologically, our approach builds on the so-called hypothetical extraction method that is based on an input–output representation of the global economy (Los, Timmer, and de Vries, 2016). This approach has a clear economic intuition and can be easily applied to the data. It compares the actual GDP of a country with a hypothetical GDP in cases where all the bilateral effects of the CBAs are introduced. The bilateral gross-trade effects are estimated with our sectoral gravity model, after which the global input–output tables are used to extract the total amount of value added in all production stages involving intermediate goods and services that are embodied in the bilateral trade flows. To yield the total value-added content of the CBA's impact, the difference between the actual value added and the value added with CBAs are introduced.

It is worth noting that our analysis is an accounting exercise that measures the value chain impacts of the changes in trade due to the CBAs ceteris paribus. That is, it allows us to measure the value chain impacts under the existing value chains and economic behavior. However, it is possible that the underlying economic conditions may adjust to the changing conditions. We consider these dynamics more closely with our macroeconomic model.

5.2.1 Methodology

We next briefly introduce the key element of the analysis in a non-technical manner—a technical description is available in Appendix 3.

In terms of the bilateral trade impacts of the CBAs, we use tariff-elasticity estimates based on the gravity model at the level of the EXIOBASE product groups. The gravity model provides an estimate of the average effect of tariffs on trade based on the historical variation of tariffs and trade within the product groups. The methodology and the results concerning gross-trade elasticities are reported in Appendix 3.

In our analysis, we use the 2016 release of the WIOD database (Timmer et al., 2015; 2016). The data contains sector-level world input–output tables (WIOTs) with underlying data for 43 countries (and a category that summarizes the rest-of-the world) and 56 sectors, including services. The countries were chosen by considering whether there was a sufficient level of data availability and by attempting to cover a major part of the world economy. The selected countries include 27 EU countries and 15 other major countries. Data for the 56 sectors are classified according to the International Standard Industrial Classification Revision 4 (ISIC Rev. 4). The tables adhere to the 2008 version of the System of National Accounts. The dataset provides WIOTs using current prices, denoted in millions of US dollars (Timmer et al., 2016). These countries account for more than 85 % of the world's GDP at current exchange rates. WIOTs are built based on National Accounts data, which are extended by means of disaggregating imports by country of origin and using categories to generate international supply and use tables (Timmer et al., 2016).

Let us next shortly describe how data is transferred between the gravity model and the WIOD data. The gravity model, when applied in a global context, provides an estimate of the percentual change in the value of trade of all bilateral trade flows involving CBAs in our scenarios. We analyze their implications on gross trade in the year 2014, which is the latest observation year in the WIOD database, and construct a set of counterfactual bilateral trade flows that represents world with the CBAs. The counterfactual is constructed by altering the trade flows in the WIOD data according to the percentual changes of trade that were forecasted by the gravity model. We alter the trade flows of final and intermediate goods in the same proportion in order to build the counterfactual. A similar approach has previously been used by Nilsson-Hakkala et al. (2019) to analyze the impacts of the EU's free trade agreements.

It is notable that the transfer of information between the gravity model predictions and the WIOD data requires some aggregation. The WIOD data only includes 43 countries, while all other countries are aggregated to a ROW category. Therefore, all changes in the bilateral trade flows in the gravity model that occur within the ROW category of the WIOD dataset have to be aggregated together. In these cases, we use the magnitude of the corresponding bilateral trade flows to weight the relative changes of trade within the ROW category.

5.2.2. Results

We next discuss the value-chain implications of our four main CBA scenarios. We begin our analysis by studying how much value-added different countries contribute to the bilateral trade flows. We analyze the contributions by measuring how much less value added different countries would have if gross trade patterns were to decline according to the prediction of the gravity model if the world input–output structure otherwise remained the same as in our WIOD data for the year 2014.

Table 5.2.2.1 reports the contributions of different countries to the value added embodied in the trade that would be affected by the CBAs in euros (a) and as a percentage of total contributions (b).

In terms of the total contributions, we find that in the Feasible 1 scenario, with CBAs only imposed on cement, lime, and plaster, the total value added is only 0.1 billion euros. The total contribution increases to 4.9 billion euros when the CBA is extended to also include basic steel and aluminum products. The Efficient Scenario with the emission-intensive industries and all emissions as the basis for the CBA measurements increases the total contribution to 142.5 billion euros. The Efficient Scenario with the emission-intensive industries and direct and electricity emissions as the basis for the CBA measurements sets the total contribution to 79.9 billion euros.

Overall, we thus find that the Feasible Scenarios have negligible impacts at the aggregate level, while in the Efficient Scenarios, the effects are more substantial.

The underlying country-level contributions in Table 5.2.2.1 provide further information concerning the potential economic impacts of the CBA-induced changes on trade. First, we find that the overall value-added contribution of EU countries to the affected imports are small (not exceeding 8 % of all value added). The result suggests that the role of back-and-forth trade with the EU and the trade partners does not play a major role in the production. For Finland, the corresponding value-added contributions to the products are 0.1, 5.6, 127.5, and 68.0 million euros.

Second, we study the role of the extra-EU countries. In the case of the narrowest Feasible Scenario (Feasible 1), the most important individual-country value-added contributors are made by the UK (56.6 %) and Turkey (9.0 %). The ROW category of small developing countries contributes 15.7 %.

Table 5.2.2.1. CBA-induced loss in value added by the producer country of value added.

	Value added loss of imports in the different scenarios, EUR millions				Value added loss of imports in the different scenarios, share of total loss in the scenario			
	Feasible 1: Cement, lime, and plaster	Feasible 2: Cement, lime, and plaster + metals	Efficient 1: all emissions	Efficient 2: direct + electricity emissions	Feasible 1: Cement, lime, and plaster	Feasible 2: Cement, lime, and plaster + metals	Efficient 1: all emissions	Efficient 2: direct + electricity emissions
AUS	0.3	86	1347.6	746.6	0.30 %	1.80 %	1.00 %	0.90 %
BRA	0.3	75	1074.6	515.4	0.20 %	1.60 %	0.80 %	0.70 %
CAN	0.6	163.9	1227	633.4	0.60 %	3.40 %	0.90 %	0.80 %
CHE	2.1	67.2	971.5	259.5	2.10 %	1.40 %	0.70 %	0.30 %
CHN	2.1	905.9	70335	41334.8	2.10 %	18.90 %	50.00 %	52.30 %
GBR	57.1	329.6	2664.4	1310.4	56.60 %	6.90 %	1.90 %	1.70 %
IDN	0.2	37.6	2000.9	853.5	0.20 %	0.80 %	1.40 %	1.10 %
IND	0.4	211.3	4614.7	2646.8	0.30 %	4.40 %	3.30 %	3.40 %
JPN	0.7	463.9	6636.5	3399.4	0.70 %	9.70 %	4.70 %	4.30 %
KOR	0.2	230	6153.9	2577	0.20 %	4.80 %	4.40 %	3.30 %
MEX	0.1	72.6	852.9	393.8	0.10 %	1.50 %	0.60 %	0.50 %
RUS	1.3	435.3	2799	1674.2	1.30 %	9.10 %	2.00 %	2.10 %
TUR	9.1	318.8	2908.3	1458.3	9.00 %	6.60 %	2.10 %	1.80 %
TWN	0.1	15	1546.7	826.8	0.10 %	0.30 %	1.10 %	1.00 %
USA	2.4	267.1	8517.7	5020.1	2.40 %	5.60 %	6.10 %	6.40 %
ROW	15.8	861.7	21959	12651.1	15.70 %	17.90 %	15.60 %	16.00 %
Extra-EU total	**92.9**	**4540.9**	**135609.6**	**76301.3**	**92.00 %**	**94.60 %**	**96.30 %**	**96.60 %**
EU	**8.1**	**260.4**	**5160.8**	**2689.4**	**8.00 %**	**5.40 %**	**3.70 %**	**3.40 %**
Total	**101**	**4801.3**	**140770.4**	**78990.7**	**100.00 %**	**100.00 %**	**100.00 %**	**100.00 %**

Note: The authors' calculations are based on WIOD data. We analyze the losses by measuring how much less value added different countries would have if gross trade patterns were to decline according to the prediction of the gravity model while the world input–output structure otherwise remains the same as in our WIOD data for the year 2014.

When the basic metal products are included, the contribution of China increases substantially. In the Feasible 2 scenario, its contribution is 0.9 billion euros (18.5 %) while other important individual contributor countries are Japan and Russia.

In the Efficient Scenarios, China's role becomes even more dominant. It contributes roughly one half of the total value added in products that would not be imported to the EU according to the changes in the gross trade.

Another way to elaborate the potential trade linkages that would be affected by the CBAs is to assign the total value added to the corresponding final producer countries. That is, we sum up the value-added contributions of different countries that are embodied in a final good produced by a particular country. This information helps us to further understand the intermediate-product linkages between the EU and the extra-EU countries.

We report the findings in Table 5.2.2.2. It again shows the value-added embodied in the trade that would be affected by the CBAs in euros (a) and as a percentage of total contributions (b).

Table 5.2.2.2. CBA-induced loss in contributed value added, decomposed by the final producer country

	(a) EUR millions value-added import loss embodied in final products of the row country				(b) The percentage of total value-added import loss embodied in row country final products, as compared to the scenario total.			
	Feasible 1: Cement, lime, and plaster	Feasible 2: Cement, lime, and plaster + metals	Efficient 1: all emissions	Efficient 2: direct + electricity emissions	Feasible 1: Cement, lime, and plaster	Feasible 2: Cement, lime, and plaster + metals	Efficient 1: all emissions	Efficient 2: direct + electricity emissions
AUS	0.6	24.4	439.9	237.5	0.60 %	0.50 %	0.30 %	0.30 %
BRA	0.8	30.4	740.4	345.4	0.80 %	0.60 %	0.50 %	0.40 %
CAN	0.4	25.8	686.9	348.7	0.40 %	0.50 %	0.50 %	0.40 %
CHE	0.6	22.5	757.3	236.3	0.60 %	0.50 %	0.50 %	0.30 %
CHN	6	359.9	44839.7	25263	5.90 %	7.50 %	31.90 %	32.00 %
GBR	3.1	63.9	2070.3	1068.4	3.10 %	1.30 %	1.50 %	1.40 %
IDN	1	22.9	1100.2	433.8	1.00 %	0.50 %	0.80 %	0.50 %
IND	1.7	59.7	2274.7	1274.8	1.70 %	1.20 %	1.60 %	1.60 %
JPN	2.5	113.1	2765.6	1466.9	2.50 %	2.40 %	2.00 %	1.90 %
KOR	1.4	68.9	2404.3	962.5	1.40 %	1.40 %	1.70 %	1.20 %
MEX	0.3	20.6	860.3	299.9	0.30 %	0.40 %	0.60 %	0.40 %
RUS	0.4	28.9	806.9	494.9	0.40 %	0.60 %	0.60 %	0.60 %
TUR	2.2	47.9	1864.1	828.9	2.20 %	1.00 %	1.30 %	1.00 %
TWN	0.4	15.2	321.4	178.5	0.40 %	0.30 %	0.20 %	0.20 %
USA	3.6	187.4	5247.3	3026.5	3.60 %	3.90 %	3.70 %	3.80 %
ROW	44.8	2463.9	44069.6	25609.1	44.40 %	51.30 %	31.30 %	32.40 %
Extra-EU total	**69.8**	**3555.5**	**111248.9**	**62075.2**	**69.10 %**	**74.10 %**	**79.00 %**	**78.60 %**
EU	**31.2**	**1245.8**	**29521.6**	**16915.5**	**30.90 %**	**25.90 %**	**21.00 %**	**21.40 %**
Total	**101**	**4801.3**	**140770.4**	**78990.7**	**100.00 %**	**100.00 %**	**100.00 %**	**100.00 %**

Note: The authors' calculations are based on WIOD data. We assign the total value added to the corresponding final producer countries. That is, we sum up the value-added contributions of different countries that are embodied in a final good produced by a particular country, as shown by the row. We use ISO 3166-1 alpha-3 codes for abbreviation of country names.

We find that a substantial share of the value added contributes to final products that are assembled in the EU. This share is the highest in case of the Feasible 1 and 2 scenarios, 30.9 % and 25.9 % correspondingly, while the share lowers to roughly 21 % in the Efficient Scenarios. Thus, EU production has major dependencies on the imported intermediate goods that would be affected by the CBAs in our scenarios. Overall, the shares in the Efficient scenarios reflect quite well the average intermediate product shares in the EU imports.

In terms of the individual countries, China's role continues to be large. It is most often the final assembly country of the corresponding final products when measured by all value-added share embodied in its final products. The role of small developing countries in the ROW is also substantial. It is notable that the final-producer country, distribution is rather similar between the two Efficient Scenarios.

We further decompose the total value added embodied in the EU final products into the contributions of the individual EU final producer country in Table 5.2.2.3.

Table 5.2.2.3. CBA-induced loss in contributed value added, as decomposed by the EU final producer country

	EUR millions value-added import loss embodied in final products of the row country				The percentage of total value-added import loss embodied in row country final products, as compared to the scenario total.			
	Feasible 1: Cement, lime, and plaster	Feasible 2: Cement, lime, and plaster + metals	Efficient 1: all emissions	Efficient 2: direct + electricity emissions	Feasible 1: Cement, lime, and plaster	Feasible 2: Cement, lime, and plaster + metals	Efficient 1: all emissions	Efficient 2: direct + electricity emissions
AUT	1.0	28.1	600.2	348.8	3.1 %	2.3 %	2.0 %	2.1 %
BEL	0.6	60.9	1388.8	876.5	1.8 %	4.9 %	4.7 %	5.2 %
BGR	2.5	18.1	230.5	154.0	8.0 %	1.5 %	0.8 %	0.9 %
CYP	0.1	4.4	58.3	40.4	0.3 %	0.4 %	0.2 %	0.2 %
CZE	0.2	25.1	858.0	465.5	0.5 %	2.0 %	2.9 %	2.8 %
DEU	2.4	274.4	7045.5	3941.1	7.8 %	22.0 %	23.9 %	23.3 %
DNK	0.4	20.3	535.8	312.8	1.4 %	1.6 %	1.8 %	1.8 %
ESP	1.8	94.5	2142.6	1245.5	5.8 %	7.6 %	7.3 %	7.4 %
EST	0.1	4.6	102.9	63.0	0.2 %	0.4 %	0.3 %	0.4 %
FIN	0.0	5.9	150.3	82.6	0.1 %	0.5 %	0.5 %	0.5 %
FRA	11.0	150.1	4344.7	2448.7	35.2 %	12.1 %	14.7 %	14.5 %
GRC	0.9	19.0	305.3	193.9	2.9 %	1.5 %	1.0 %	1.1 %
HRV	1.4	9.1	146.4	102.3	4.4 %	0.7 %	0.5 %	0.6 %
HUN	0.3	21.2	785.0	429.4	0.8 %	1.7 %	2.7 %	2.5 %
IRL	0.4	18.6	490.4	258.2	1.3 %	1.5 %	1.7 %	1.5 %
ITA	2.7	189.9	3303.4	2028.8	8.7 %	15.2 %	11.2 %	12.0 %
LTU	0.5	4.7	104.7	69.9	1.6 %	0.4 %	0.4 %	0.4 %
LUX	0.0	4.5	71.0	40.1	0.1 %	0.4 %	0.2 %	0.2 %
LVA	0.1	5.6	80.8	54.8	0.2 %	0.4 %	0.3 %	0.3 %
MLT	0.0	1.2	47.7	24.8	0.1 %	0.1 %	0.2 %	0.1 %
NLD	0.8	81.7	2465.4	1286.1	2.4 %	6.6 %	8.4 %	7.6 %
NOR	0.2	26.7	458.9	255.0	0.7 %	2.1 %	1.6 %	1.5 %
POL	0.8	59.5	1458.0	853.7	2.4 %	4.8 %	4.9 %	5.0 %
PRT	0.4	20.1	314.5	191.2	1.4 %	1.6 %	1.1 %	1.1 %
ROU	2.0	42.5	562.5	354.1	6.4 %	3.4 %	1.9 %	2.1 %
SVK	0.1	14.8	642.6	324.1	0.5 %	1.2 %	2.2 %	1.9 %
SVN	0.1	9.2	139.7	85.4	0.4 %	0.7 %	0.5 %	0.5 %
SWE	0.5	31.1	687.5	384.6	1.5 %	2.5 %	2.3 %	2.3 %

Note: The authors' calculations are based on WIOD data. We assign the total value added to the corresponding final producer countries. That is, we sum up the value-added contributions of different countries that are embodied in a final good produced by a particular country, as shown by the row. We use ISO 3166-1 alpha-3 codes for abbreviation of country names.

We find that in the case of the broad cement product CBA, France has a substantial role as a final producer (accounting for 35.2 % of the total final goods assembled in the EU), whereas in other scenarios, Germany is the largest user of the imported products in its final production, followed by France, Italy, and the Netherlands.

In Table 5.2.2.4, we provide a perspective on the reliance of the EU countries on the trade of the CBA-related intermediate products. In the table, we compare the trade in value added to the total value added of the final good's producer country. If the domestic value added is small compared with the value added embodied in the imports, it is more likely that the country is reliant on the particular imports in its final production.

Table 5.2.2.4. The CBA-related value-added imports of intermediate goods by EU final producer country

	% of total value-added import loss embodied in the country's final products compared to the country's total value added			
	Feasible 1: Cement, lime, and plaster	Feasible 2: Cement, lime, and plaster + metals	Efficient 1: all emissions	Efficient 2: direct + electricity emissions
AUT	0.000 %	0.01 %	0.20 %	0.12 %
BEL	0.000 %	0.02 %	0.39 %	0.24 %
BGR	0.007 %	0.05 %	0.62 %	0.41 %
CYP	0.001 %	0.03 %	0.37 %	0.26 %
CZE	0.000 %	0.02 %	0.61 %	0.33 %
DEU	0.000 %	0.01 %	0.27 %	0.15 %
DNK	0.000 %	0.01 %	0.24 %	0.14 %
ESP	0.000 %	0.01 %	0.23 %	0.13 %
EST	0.000 %	0.03 %	0.58 %	0.36 %
FIN	0.000 %	0.00 %	0.09 %	0.05 %
FRA	0.001 %	0.01 %	0.23 %	0.13 %
GRC	0.001 %	0.01 %	0.19 %	0.12 %
HRV	0.004 %	0.02 %	0.40 %	0.28 %
HUN	0.000 %	0.02 %	0.89 %	0.49 %
IRL	0.000 %	0.01 %	0.29 %	0.15 %
ITA	0.000 %	0.01 %	0.23 %	0.14 %
LTU	0.002 %	0.01 %	0.32 %	0.21 %
LUX	0.000 %	0.01 %	0.16 %	0.09 %
LVA	0.000 %	0.03 %	0.39 %	0.26 %
MLT	0.000 %	0.02 %	0.67 %	0.35 %
NLD	0.000 %	0.01 %	0.41 %	0.22 %
NOR	0.000 %	0.01 %	0.14 %	0.08 %
POL	0.000 %	0.016 %	0.399 %	0.234 %
PRT	0.000 %	0.013 %	0.207 %	0.126 %
ROU	0.002 %	0.032 %	0.424 %	0.267 %
SVK	0.000 %	0.022 %	0.937 %	0.472 %
SVN	0.000 %	0.029 %	0.433 %	0.265 %
SWE	0.000 %	0.008 %	0.180 %	0.101 %

Note: The authors' calculations are based on WIOD data. We analyze the losses by measuring how much less value added would different countries have if gross trade patterns were to decline according to the prediction of the gravity model while the world input–output structure otherwise remains the same as in our WIOD data for the year 2014. We use ISO 3166-1 alpha-3 codes for abbreviation of country names.

Overall, we find that the value-added ratio is small in the case of the Feasible Scenarios, a finding that suggests that the reliance on imports is small (i.e., the value of the imports is not high compared with the value of the overall economic activity). The largest ratios are seen in Eastern Europe (Bulgaria, Croatia, Estonia, and Latvia).

In case of the Efficient Scenarios, the ratios are moderately higher. In several cases, the ratio exceeds 0.5 % of the aggregate value added (for Hungary, Malta, Bulgaria, and the Czech Republic). Again, these countries are mostly Eastern European countries or countries that have close economic ties with the UK. For Finland, the reliance on the imports is small with this metric when compared to other countries.

We then decompose the value added according to the producer industry of the final product in the EU. In terms of the share of the total embodied value added in Table A3.1, we find that the largest final user industry is construction. In particular, in the Feasible Scenario with only cement, lime and plaster, the value added that is embodied in its final products is 43.8 %. Other important user industries of the affected value-added imports are those related to (1) the manufacture of food products, beverages, and tobacco products; (2) the manufacture of coke and refined petroleum products; and (3) the manufacture of motor vehicles, trailers, and semi-trailers.

When the CBAs are extended to also include basic metal products, the role of various manufacturing industries increases. They entail the manufacture of items such as computers, electrical equipment, machinery, and vehicles.

In Table A3.1b (which can be found in Appendix 3), we repeat the reliance measurement on the industry level. This time, we compare the trade in value added to the total value added of the final producer industry. We find that the reliance is the highest in the manufacture of coke and refined petroleum products, as well as in the production of computers, electrical equipment, machinery, and vehicles.

We also repeat the industry-level analysis for Finland. The results can be found in Table A3.2. We note that in the case of the narrow Feasible Scenario, the value-added content is very small. One explanation is that the Finnish construction industry is not particularly reliant on the extra-EU intermediates, as the industry decomposition shows. Instead, it appears that manufacturing industries in particular are reliant on intermediate goods. This result is comparable to the EU findings, albeit the reliance is smaller than for the European industries on average.

VALUE-CHAIN RESULTS FOR FINLAND

We also characterized the related Finnish value chains. First, we measured total value added that would be lost as a result of the decline in imports in the different scenarios (the Feasible 1: Cement, lime, and plaster; Feasible 2: Cement, lime, and plaster + metals; Efficient 1: all emissions; and Efficient 2: direct + electricity emissions). We found that the overall loss in value added would be 0.1, 5.6, 127.5, and 68.0 EUR millions, correspondingly. Thus, especially in the case of the narrow Feasible scenario, the role of Finnish final production is negligible for the value-added losses.

We also repeat the industry-level analysis for Finland. The results can be found in Table A3.2. We note that in the case of the narrow Feasible scenario, one explanation for the small value-added content is the Finnish construction industry, which is not particularly reliant on extra-EU intermediates, as the industry decomposition shows. Instead, it appears that especially manufacturing industries are reliable on intermediate goods. This result is comparable to the EU findings, albeit the reliance is smaller than for the European industries, on average.

5.3 Carbon leakage: Empirical evidence

As a part of the goal of reducing CO_2 emissions and having a carbon neutral economy by 2050, the EU has implemented the ETS since 2005. The EU ETS is a cap-and-trade system that allocates a limited number of allowances for emissions in specific industries. However, as the system only covers production in the EU, there have been worries of carbon leakage. In this section, we conduct an ex post empirical study of whether carbon leakage has occurred due to the EU ETS. We first briefly describe the EU ETS and review previous studies of its impacts, and then describe our data and methodology and discuss the results.

5.3.1 The EU ETS

The EU ETS Handbook (European Commission, 2015) explains the history of the system, as described next. The first phase of the system was a pilot period during 2005–2007, used for testing price formation in the carbon market and establishing the necessary infrastructure for the functioning of the system. The second phase, 2008–2012, included more actual commitments, although the system still gave most of the allowances for free. The third phase, 2013–2020, is close to ending now, and during this time, the system has been harmonized across the EU (as previously the allowances had varied nationally).

Besides CBAs, the free allocation of emission allowances is another way to prevent carbon leakage. In the current EU ETS, about 43 % of emission allowances have been distributed free of charge, although auctioning is the general rule in the regime (Directive [EU] 2018/410). The amount of free allowances allocated in ETS can be calculated in three ways. Free allocation can be based on historical emissions only (grandparenting), that is to say, on emissions from a certain baseline period. This system was used during EU ETS Phases 1–2. Another way to determine the amount of free allowances is to employ actual or recent production and an efficiency benchmark for the sector (output-based allocation). The third option is a certain hybrid model used in the current EU ETS where both historical production levels and an efficiency benchmark for each sector play a role (fixed-sector benchmarking) (Acworth, Kardish, & Kellner, 2020). Apart from that, the amount of free allowances is affected by the carbon leakage rate of the sector along with a linear reduction factor or cross-sectoral correction factor to ensure that free allowances are not overallocated and the cap is reduced, that is to say, the total amount of emission allowances is lower every year (during Phase 4 the total amount of emission allowances is reduced by 2.2 % every year) (Consolidated text: Directive 2003/87/EC).

The amount of free allowances has been decreasing gradually (European Commission, 2015). Table 5.3.1.1 shows how the amount of free allowances has developed in the third phase.

Table 5.3.1.1. The development of free allowances in EU ETS Phase 3

The share of free allocation, calculated based on benchmarks per sector	2013	2014	2015	2016	2017	2018	2019	2020
Electricity production	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
Industry sectors	80 %	72,9 %	65,7 %	58,6 %	51,4 %	44,2 %	37,1 %	30 %
Industry sectors deemed to be exposed to carbon leakage	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %

Source: EU ETS Handbook

As can be seen from Table 5.3.1, the share of free allowances based on benchmarks per sector has been quite high. The benchmark is calculated as the average emission level of the 10 % most efficient installations within each sector (European Commission, 2015). In Phase 3, the total amount of free allocation each installation received has been determined by the product-related emission benchmark so that efficient plants can have received all (or almost all) of their allocations for free. As already stated, in the previous phases, the allowances were calculated based on historical emissions (European Commission, 2015).

In practice most free allowances are allocated for industrial installations because most of them are deemed to be exposed to carbon leakage. In principle, no free allowances are allocated for electricity production, and district heating is allocated some allowances. For industry sectors not deemed to be exposed to carbon leakage, the amount of free allocation has been cut substantially during 2013–2020. Sectors and subsectors deemed to be exposed to carbon leakage are allocated free allowances 100 % of the benchmark (Consolidated text: Directive 2003/87/EC). Consequently, the most efficient installations of carbon leakage sectors get all their emissions allowances free of charge, whereas the least efficient ones need to buy allowances the most.

In practice, carbon leakage regulation provided for long industrial installations with so much free allowances that 2017 was the first year that industrial installations as a whole faced direct costs. Until then, there was a surplus of allowances (Marcu et al., 2019). The definition of sectors deemed at risk of carbon leakage will be tightened at the beginning of Phase 4 (2021) (Directive [EU] 2018/410), but the carbon leakage list covers still 94 % of industrial emissions (European Commission, 2019a).

The free allowances could decrease the amount of carbon leakage, but in our empirical analysis, we will study whether it still occurs. The prices of the allowances have also varied significantly over the years. Recently, the spot price has increased from 22 euros in June 2020 to almost 30 euros in September 2020, but at its lowest, in 2013, the price was only approximately 3 euros. For comparison, according to the OECD, a low-end estimate of carbon costs in 2018 was 30 euros, and a midpoint estimate in 2020 it was 60 euros (OECD, 2018). As such, the system has been criticized for the overallocation of free permits and the volatility of carbon prices. However, according to the European Commission,[28] the amount of total emissions in the EU has decreased according to the target for 2020 (emissions that are 21 % lower than in 2005).

5.3.2 Previous literature

As the EU ETS has now been functioning for 15 years, researchers have been able to study its effects with the past data. Especially as the system becomes stricter, the effects should be expected to become clearer. It has been shown that emission levels have decreased in the EU due to the EU ETS, but at the same time, firm competitiveness has not suffered negative impacts (see, e.g., Arlinghaus, 2015, for a survey). For example, Abrell, Ndoye Faye, and Zachmann (2011) used firm-level panel data to show that the shift from the first to the second phase of the EU ETS reduced emissions by firms while the impact on company performance was modest. Dechezleprêtre and Sato (2017) discussed whether

28 https://ec.europa.eu/clima/policies/ets_en

the so-called Porter hypothesis could apply. That is, more regulation and consequent innovation in green technologies could in fact increase firms' competitiveness and thus more than fully offset the costs of compliance. However, according to Dechezleprêtre and Sato (2017), although the EU ETS has indeed been shown to have fostered innovation, firm competitiveness has not been impacted.

According to the EU, free allocation has prevented carbon leakage (Directive [EU] 2018/410), although the low price of carbon has also played a role. Regarding this, it is important to note that this data is from the first two phases of ETS, covering 2005–2012. Back then almost all emission allowances were distributed free of charge. When all the emission allowances were distributed for free, carbon leakage due to the ETS would seem unlikely.

Although the effect of environmental regulation on firm performance has been the topic of many studies, research on carbon leakage is still lacking. A rare example of an ex post study on this topic is the study of Aichele and Felbermayr (2015), who studied the impact of the ratification of the Kyoto Protocol in 2001-2003 on carbon leakage with data from 1995 to 2007. Their findings suggest that there has been some amount of carbon leakage from countries party to the protocol to countries that are not party to it. To be specific, they estimated that the amount of imports from the non-participants to participating countries were 8 % higher than if the Kyoto Protocol did not exist and that the carbon intensity of these imports was also 3 % higher than without the protocol. They also found variation between different industries. However, we have not been able to find many ex post studies specifically on the EU ETS and carbon leakage, most likely due to the fact that the system is still relatively new and has not been strictly enforced. One exception to this is the study by Naegele and Zaklan (2017), who used a similar but somewhat adjusted methodology to that of Aichele and Felbermayr (2015) in order to study the impacts of the EU ETS with data from the computable general equilibrium model GTAP (Global Trade Analysis) database for the years 2004, 2007, and 2011. Their results did not show any significant carbon leakage. In addition, Dechezleprêtre, Gennaioli, Martin, Muûls, and Stoerk (2019) studied within-firm carbon emissions data to find the distribution of the carbon emissions of multinational firms across countries between 2007 and 2014. Their findings showed no significant evidence of carbon leakage with regards to company decisions on relocating to different countries.

Studies that try to estimate the possibility of carbon leakage because of environmental regulation most often use a CGE type of model for the ex ante evaluation of future changes in policy. The estimates for possible carbon leakage rates (as a percentage of the domestic emission reductions that are offset by foreign increases) are generally moderate, in the range between 2 and 20 % (Larch & Wanner, 2014). In a review of the CGE literature and environmental policy, Carbone and Rivers (2017) found that previous studies have mostly been in agreement that there will be some amount of carbon leakage in response to unilateral climate policies. Studies also show variation in carbon leakage between different industries. For example, Santamaría, Linares, and Pintos (2014) found that the cement sector would be the most vulnerable to carbon leakage, whereas the risk of leakage is smaller for steel and oil refining. However, their study only uses Spanish data. On the other hand, Fischer and Fox (2012) simulated a US-based carbon tax on a multi-region CGE model and found an overall leakage rate of 7 %, while iron and steel experience respective leakage rates of 58 and 57 %. The CGE estimates in general can have large variations because of different model assumptions.

5.3.3 Data

We obtain data on the CO2 emission intensities embodied in gross imports (tons of CO2 per million USD) from the OECD "Carbon dioxide emissions embodied in international trade" database. The database covers 60 countries[29] and the years 2005–2015. This emissions data is then combined with bilateral manufacturing trade data extracted from the UN Comtrade database for the same countries and years. Comtrade has data on the HS6 level, which we convert to the ISIC Rev. 3 industry classification to match the OECD data. Some ISIC categories are further combined if the OECD classification so requires. Table 5.3.3.1 shows the final categories we have in the data. Table 5.3.3.2 then shows the industries that are included in the ETS.

29 The countries are Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, the People's Republic of China, Colombia, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Kazakhstan, Latvia, Lithuania, Luxembourg, Malaysia, Malta, Mexico, Morocco, the Netherlands, New Zealand, Norway, Peru, the Philippines, Poland, Portugal, Romania, Russia, Saudi Arabia, Singapore, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Switzerland, Thailand, Tunisia, Turkey, the United Kingdom, the United States of America, and Vietnam.

Table 5.3.3.1. The industry categories in the OECD data

ISIC Rev. 3	Industry
01–05	Agriculture, forestry, and fishing
10–14	Mining and quarrying
15–16	Food products, beverages, and tobacco
17–19	Textiles, wearing apparel, leather, and related products
20	Wood and products of wood and cork
21–22	Paper products and printing
23	Coke and refined petroleum products (and nuclear fuel)
24	Chemicals and chemical/pharmaceutical products
25	Rubber and plastic products
26	Other non-metallic mineral products
27	Basic metals
28	Fabricated metal products, except machinery and equipment
29	Machines and equipment n.e.c.
30–33	Computers, and electronic and electrical equipment
34	Motor vehicles, trailers, and semi-trailers
35	Other transport equipment

In our analysis, we only study the effects of Phases 2 and 3 as Phase 1 was a trial period with no actual commitment. The ISIC Rev. 3 categories that match the ETS application are 21–22, 23, 26, and 27 in the second phase and category 24 in addition to the previous ones in Phase 3. It should be noted that categories 21–22 include both paper products and printing, although the ETS only applies to paper and pulp, not to printing (due to the OECD classification).

Table 5.3.3.2 The industries and countries included in the ETS.

Key features	Phase 1 (2005–2007)	Phase 2 (2008–2012)	Phase 3 (2013–2020)
Geography	EU27	EU27 + Norway, Iceland, Liechtenstein	EU27 + Norway, Iceland, Liechtenstein, Croatia from 1.1.2013 (aviation from 1.1.2014)
Sectors	- Power stations and other combustion plants ≥ 20MW - Oil refineries - Coke ovens - Iron and steel plants - Cement clinker - Glass - Lime - Bricks - Ceramics - Pulp - Paper and board	The same sectors as Phase 1 plus aviation (from 2012)	- The same sectors as Phase 1 plus: - Aluminum - Petrochemical - Ammonia - Nitric, adipic, and glyoxylic acid production - CO_2 capture, transport in pipelines, and geological storage of CO_2 - Aviation

Source: EU ETS Handbook.

5.3.4 Methodology

Our econometric estimation model in this analysis is again based on the theoretical gravity model. The estimation here uses regressions with fixed effects on country and year (and industry) levels in order to take into account both the time-invariant and time-varying effects of different factors affecting trade between countries. In this estimation, we largely follow the methodology of Aichele and Felbermayr (2015) who studied the effect of the Kyoto agreement on carbon leakage.

We estimate the following regression equation (where m refers to the importer, x to the exporter, and t to time):

$$\ln y^{i}_{mxt} = \kappa * ETS_{mxt} + \gamma * POL_{mxt} + \nu_{mt} + \nu_{xt} + \nu^{i}_{mx} + \varepsilon^{i}_{mxt} \quad (1)$$

which includes a full set of country–year fixed effects (,) and a country-pair–industry effect (). We estimate the equation for natural logarithms (ln) of four independent variables, y:

the value of imports (in USD)

the CO_2 intensity of imports (tons per USD million)

the CO_2 content of imports (CO_2 intensity x import value)

the CO_2 intensity of exports / the CO_2 intensity of imports

The last variable shows the relative impact on the CO_2 intensity of imports compared to the CO_2 intensity of exports.

Our dependent variable of interest is , which equals 1 if the importer country is in the ETS and -1 if the exporter is in the scheme. It equals 0 if neither party is or if both are ETS members. The estimated coefficient therefore shows the effect of a differential ETS commitment.

The vector has controls for trade policy (i.e., free trade agreements and joint EU memberships, both including policies that have only been applied after 2005). The error term is a mean zero transitory error, and it is clustered at the country-pair–industry level.

5.3.5 Results: Is there evidence on leakage and, if so, how large it is expected to be?

We first estimate equation (1) on an aggregate level with pooled sectoral data. The estimated coefficients in Table 5.3.5.1, in columns 1–4, show by how many percent (after multiplying by 100) the different variables have changed due to the EU ETS from 2008 to 2015 in the industries that are part of the system. The results imply that both the value of imports and the CO2 intensity of imports have increased due to the EU ETS. Consequently, the CO2 content of imports has also increased. This is logical considering that the CO2 content of imports is defined as the CO2 intensity of imports multiplied by the amount of imports.

We also divide the general ETS effect into Phases 2 and 3 in columns 5–8. The estimated coefficient for the CO_2 intensity shows an increase from Phase 2 to 3. This indicates that the products that have been imported to the EU ETS countries have become more carbon intensive as the enforcement of the ETS has become stricter, although free allocation has still been in place for many sectors deemed vulnerable to carbon leakage. At the same time, we can see that the amount of imports only shows a statistically significant increase in Phase 2 in column 5, although this was not apparent in column 1, for the years 2008–2015. The increase in imports in Phase 2, together with the increase in the CO_2 intensity of imports, makes the estimated coefficient for the CO_2 content of imports greater in Phase 2 than in Phase 3.

The CO_2 intensity ratio coefficient has been negative both in general during the ETS, and more significantly, when divided into the two phases. This implies that the CO_2 intensity has increased more for imports than for exports due to the EU ETS, which aligns with the EU having decreased its carbon-intensive production due to the ETS, as opposed to the non-ETS countries.

Table 5.3.5.1. Regressions on pooled sectoral data

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Ln imports	Ln CO_2 intensity of imports	Ln CO_2 content of imports	Ln CO_2 intensity ratio (exports/ imports)	Ln imports	Ln CO_2 intensity of imports	Ln CO_2 content of imports	Ln CO_2 intensity ratio (exports/ imports)
Joint EU membership	0.469***	-0.113***	0.355***	0.115***	0.467***	-0.113***	0.354***	0.112***
	(0.032)	(0.005)	(0.032)	(0.006)	(0.032)	(0.005)	(0.032)	(0.006)
RTA	0.060***	-0.002	0.058***	0.000	0.061***	-0.002	0.059***	0.001
	(0.018)	(0.003)	(0.018)	(0.004)	(0.018)	(0.003)	(0.018)	(0.004)
EU ETS (2008–2015)	0.052***	0.019***	0.070***	-0.019***				
	(0.014)	(0.002)	(0.014)	(0.003)				
EU ETS Phase 2 (2008–2012)					0.080***	0.015***	0.094***	-0.015***
					(0.014)	(0.002)	(0.015)	(0.003)
EU ETS Phase 3 (2013–2015)					0.024	0.023***	0.047***	-0.022***
					(0.017)	(0.003)	(0.017)	(0.004)
Observations	532,820	532,820	532,820	504,537	532,820	532,820	532,820	504,537
R-squared	0.920	0.956	0.919	0.949	0.920	0.956	0.919	0.949

Note. The fixed effects include country–time and country-pair–industry effects. Standard errors are clustered on country-pair and industry levels. The regressions include the full set of countries and industries in our data. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Next, for the robustness of our results, we separate the data into industries that are in the EU ETS and the ones that are not. The purpose of this step is to see if the industries that belong in the ETS have had more imports with higher CO_2 content compared with the unaffected industries. Table 5.3.5.2 again first shows the aggregate effect of the EU ETS in columns 1–4 and the separate effects of Phase 2 and 3 in columns 5–8. Column 2 shows that the estimated coefficient the CO_2 intensity of imports is positive for both ETS and non-ETS group, with almost the same values. This indicates that there is no significant difference in the CO_2 intensities of imports between these groups. The CO_2 intensity ratios are also similar for both groups as a result.

When looking at the value of imports in column 1, we can see that the ETS industry group has a positive estimated coefficient (i.e., the value of imports has increased due to the EU ETS) while the other group shows no significant changes. When we separate this effect into the different phases in column 5, we can see that there was in fact an increase for both groups in Phase 2, while in Phase 3 the ETS group shows no statistically significant changes, and the non-ETS group has a negative coefficient. It follows that the CO_2 content of imports also increased more for the ETS group than for the non-ETS group in Phase 2.

It should be noted that the financial crisis of 2007–2008 occurred at the same time as the start of ETS Phase 2, which in fact reduced imports globally (see Figure 5.3.5.1), but these types of crises that affect most countries in our data are absorbed by the country–time fixed effects. As such, our results still show an increase in imports due to the dummies we have defined.

Table 5.3.5.2. Effects on ETS and non-ETS sectors

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Ln imports	Ln CO_2 intensity of imports	Ln CO_2 content of imports	Ln CO_2 intensity ratio (exports/ imports)	Ln imports	Ln CO_2 intensity of imports	Ln CO_2 content of imports	Ln CO_2 intensity ratio (exports/ imports)
Joint EU membership	0.463***	-0.098***	0.365***	0.099***	0.443***	-0.095***	0.348***	0.096***
	(0.032)	(0.005)	(0.033)	(0.006)	(0.032)	(0.005)	(0.032)	(0.006)
RTA	0.061***	-0.004	0.057***	0.003	0.069***	-0.005*	0.063***	0.004
	(0.018)	(0.003)	(0.018)	(0.004)	(0.018)	(0.003)	(0.018)	(0.004)
Sectors in the EU ETS (2008–2015)	0.046***	0.034***	0.081***	-0.032***				
	(0.015)	(0.002)	(0.015)	(0.003)				
Sectors not in the EU ETS (2008–2015)	-0.010	0.029***	0.019**	-0.027***				
	(0.009)	(0.002)	(0.010)	(0.002)				
Sectors in the EU ETS, Phase 2 (2008–2012)					0.099***	0.026***	0.125***	-0.025***
					(0.015)	(0.002)	(0.015)	(0.003)
Sectors in the EU ETS, Phase 3 (2013–2015)					-0.016	0.044***	0.028	-0.041***
					(0.018)	(0.003)	(0.018)	(0.004)
Sectors not in the EU ETS, Phase 2 (2008–2012)					0.043***	0.021***	0.064***	-0.019***
					(0.009)	(0.002)	(0.009)	(0.002)
Sectors not in the EU ETS, Phase 3 (2013–2015)					-0.108***	0.044***	-0.064***	-0.040***
					(0.013)	(0.002)	(0.013)	(0.003)
Observations	532,820	532,820	532,820	504,537	532,820	532,820	532,820	504,537
R-squared	0.920	0.957	0.919	0.949	0.920	0.957	0.920	0.949

Note. The fixed effects include country–time and country pair–industry effects. Standard errors are clustered on country–pair and industry level. The regressions include the full set of countries and industries in our data. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

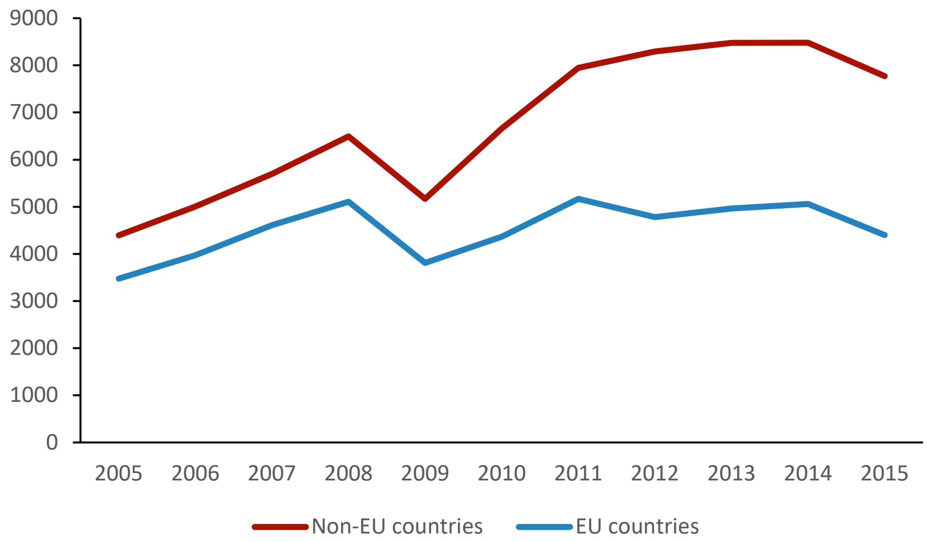

Figure 5.3.5.1. The value of total imports to EU and non-EU countries (billion USD)

The results above indicate that the possible carbon leakage is mostly apparent in the value of imports. The CO_2 intensity of imports has also increased, but this holds for both industries that have and have not been included in the EU ETS, and as such, it is not clear that this would in fact be due to the ETS. The total amount of carbon content that has been imported has increased as a consequence, which works against the EU's climate goals.

To put the results into perspective, Figure 5.3.5.2 shows how much carbon was produced in the EU versus how much carbon was imported to the EU during 2005–2015 (in all industries). This figure uses OECD data on total carbon emissions based on production. The imports are from extra-EU countries to EU countries. As can be seen, a much larger amount of CO_2 is produced in the EU to be used in final consumption and exports than the amount that is imported to the EU. This means that even if there is carbon leakage, the decrease in CO_2 content in EU production due to the EU ETS is not easily offset by carbon leakage.

In Table 5.3.5.2 we estimated an 8.1 % increase in the carbon content of imports in the covered industries due to the EU ETS. In our data, the total amount of CO_2 content imported to the EU from extra-EU countries in the industries that are covered in the EU ETS was 3.1 billion tons in total between 2008 and 2015. If the EU ETS had indeed increased the carbon content by 8.1 %, this would amount to 234 million tons of carbon more than if the system had not been in place. On the other hand, a recent study by Bayer and Aklin (2020) estimated that the EU ETS has decreased the carbon content in EU's total production by 1.2 billion tons between 2008 and 2016 compared with the counterfactual with no such system. This estimate includes the year 2016, which our data on imports does not, but the scale of the two numbers can still be compared. The carbon leakage rate with our estimations would thus be close to 20 %. This estimate is on the higher range of previous studies that have used CGE methods to estimate carbon leakage. The carbon leakage in our estimation thus does offset some of the carbon content reductions in the EU achieved by the EU ETS.

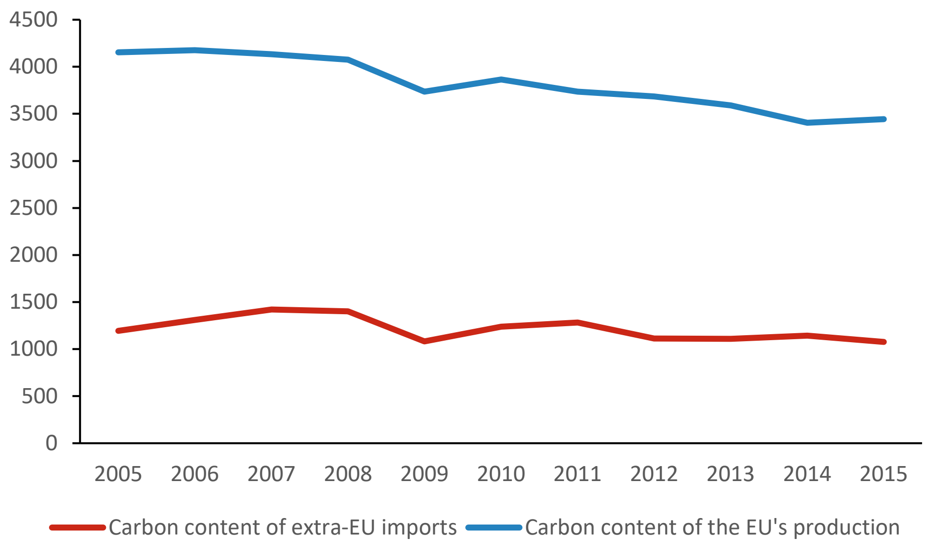

Figure 5.3.5.2. The CO2 content of imports and domestic production in the EU for all industries (tons of CO2)

Finally, we separate the analysis into different industries to see industry-level effects of the EU ETS. Table 5.3.5.3 shows the estimated coefficients for the EU ETS industries. The effects are separated into Phases 2 and 3. The results suggest that the ISIC Rev. 3 category 27 (i.e., basic metals) has been the most affected by the ETS, both in Phase 2 and Phase 3. Category 24 (chemicals) was only added to the ETS in the third phase, and the results also only show a statistically significant positive coefficient for the CO_2 intensity of imports in Phase 3. Categories 21–22 are quite wide as they include both paper products and printing, but they also shows the increased CO_2 intensity of imports in Phase 3 while the value of imports first shows an increase in Phase 2 and then a decrease in Phase 3. Category 26 also shows a decrease both in the value of imports and in the CO_2 intensity of imports in Phase 3. Interestingly for our analysis, category 26 includes cement (as well as, e.g., lime, glass, and ceramics).

Table 5.3.5.3. Regressions with separate industries

VARIABLES	(1)	(2)	(3)	(4)
	Ln imports	Ln CO_2 intensity of imports	Ln CO_2 content of imports	Ln CO_2 intensity ratio (exports/ imports)
Phase 2. 21–22: Paper products and printing	0.060*	0.013**	0.073**	-0.010*
	(0.034)	(0.005)	(0.035)	(0.006)
Phase 3. 21–22: Paper products and printing	-0.165***	0.047***	-0.118**	-0.040***
	(0.047)	(0.009)	(0.048)	(0.009)
Phase 2. 23: Coke and refined petroleum products (and nuclear fuel)	0.094	-0.023***	0.071	0.021**
	(0.076)	(0.009)	(0.077)	(0.009)
Phase 3. 23: Coke and refined petroleum products (and nuclear fuel)	-0.122	-0.027**	-0.149	0.026**
	(0.095)	(0.012)	(0.096)	(0.013)
Phase 2. 24: Chemicals and chemical/ pharmaceutical products	0.034	0.007	0.041*	-0.005
	(0.025)	(0.005)	(0.025)	(0.005)
Phase 3. 24: Chemicals and chemical/ pharmaceutical products	-0.024	0.059***	0.035	-0.058***
	(0.033)	(0.007)	(0.034)	(0.007)
Phase 2. 26: Other non-metallic mineral products	0.012	0.003	0.016	0.000
	(0.029)	(0.006)	(0.030)	(0.006)
Phase 3. 26: Other non-metallic mineral products	-0.121***	-0.024**	-0.145***	0.033***
	(0.041)	(0.009)	(0.043)	(0.009)
Phase 2. 27: Basic metals	0.199***	0.074***	0.273***	-0.070***
	(0.038)	(0.006)	(0.039)	(0.006)
Phase 3. 27: Basic metals	0.191***	0.126***	0.317***	-0.119***
	(0.053)	(0.008)	(0.054)	(0.008)

Note. There are separate regressions for each industry. The regressions include all the countries and years in our dataset, but they are conducted separately for each industry with a varying amount of observations available. The fixed effects include country–time and country-pair effects. Standard errors are clustered on a country-pair level.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

6 Macroeconomic modelling of the CBA's impacts

6.1 GTAP modelling

6.1.1 Model, data, and scenarios

The multiregion, multisector computable general equilibrium model GTAP was used in the following economy-wide analysis of carbon border adjustment mechanism. The GTAP model has been developed in Purdue University[30]. GTAP analysis widens the scope of out earlier trade flow analysis by analysing the impacts for the whole economy. In the analysis, the adjustments in all markets due to the changes in relative prices (substitution effect) and income levels are taken into account. Bilateral trade is handled via an Armington assumption, according to which goods from different regions are imperfect substitutes to each other. The model is static and describes the long-run impact of the CBAM. Thus, it does not take into account the short-term costs during the adjustment process.

We used the GTAP 10 database that is the most recent dataset and mainly for the year 2014. The database consists of 121 countries and 20 aggregate regions as well as 65 sectors that for this analysis have been aggregated into 23 countries or regions and 27 sectors, that are presented in Table 6.1.

Two scenarios were analysed with the GTAP model. In the Feasible scenario, the CBAM covers more products than in the analysis in Chapter 5. In GTAP data, cement and aluminium are not included as separate products. Thus, instead of cement, we included 'non-metallic minerals' industry, that covers the manufacturing of glass and ceramic products in addition to cement. For aluminium, we included 'non-ferrous metals' industry.

30 GTAP model is presented in https://www.gtap.agecon.purdue.edu/models/current.asp

Table 6.1. Countries, sectors and carbon tariffs in the scenarios examined with the GTAP model.

Countries	Sectors	CBAM tariffs in Feasible 2 scenario	CBAM tariffs in Efficient 1 scenario (range of country-specific tariffs)
EU countries	Agriculture and fishery		
Finland	Forestry		
Sweden	Coal		
Germany	Oil		
France	Gas		
Italy	Mining		
Spain	Food products		
Rest of EU	Textiles		0.006–0.025
Non-EU countries	Wood products		
UK	Pulp and paper		0.005–0.049
Switzerland	Refined oil products		
USA	Iron and steel	0.014	0.011–0.143
Northern America, other	Non-ferrous metals (including aluminium)	0.005	0.008–0.084
Latin America	Non-metallic minerals (including cement)	0.024	0.011–0.141
Russia	Fabricated metal products		0.008–0.062
Eastern Europe and Former Soviet Union excl. Russia	Chemicals		0.004–0.060
Middle East	Rubber and plastics		0.003–0.070
North Africa	Electronics		0.006–0.030
Sub-Saharan Africa	Electrical equipment		0.005–0.031
China	Machinery and equipment		0.007–0.040
Japan	Transport equipment		
Korea	Furniture and other manufacturing		0.005–0.040
Rest of Asia	Electricity		
Oceania	Construction		
Rest of the world	Accomodation		
	Transport services		
	Rest of services		

For the Efficient scenario, we analyse the impact of Efficient 1 that has higher carbon tariffs than Efficient 2. This is due to the fact that in the scenario Efficient 1 carbon tariffs are based on all direct and indirect emissions. The carbon tariffs are presented in Table 6.1. In the Feasible scenario, the tariffs are the same in imports from different non-EU countries as they are based on the carbon contents of the product in the EU. In the Efficient scenario, country-specific carbon tariffs are based on the carbon contents in non-EU countries and their range is shown in Table 6.1. The tariffs are based on the carbon price of 25EUR/tCO_2.

We analyse the impact of CBAM *ceteris paribus*, i.e. without any other policy changes. The impact of phase out of free allowances is discussed in Section 6.1.5.

First, we represent the results for Finland in each subchapter. The results for other EU countries are compared to the ones obtained for Finland. Finally, we report the outcomes in the case of non-EU countries.

6.1.2 The impacts of CBAMs on trade flows

CBAMs affect trade flows, both directly and indirectly. For exports, the direct impacts on the competitiveness of CBAM sectors in world markets are twofold. In EU markets, EU producers have a notable competitive advantage against non-EU countries whose products face the tariff. The direct impact of the tariff for the EU is thus improved competitiveness in EU markets while, on the other hand, competitiveness is negatively affected both in EU and non-EU markets by more expensive imported inputs from non-EU countries that raise the production costs. In addition, changes in factor and product prices due to the adjustment in the economy and income affect the export impacts in all markets. In the case of a CBAM, the substitution effects due to the changes in relative prices are likely to dominate, but the income effect also has some importance.

A CBAM implies that Finnish imports from non-EU countries are partly substituted with imports from other EU countries, as well as with domestic products. In the Feasible Scenario with a unified carbon tariff, based on carbon contents in the EU, the reductions of Finnish imports from different non-EU countries are almost equal. The impact is largest, namely -10 % for non-metallic minerals (including cement) that have the highest carbon content. Imports of iron and steel are reduced by 6 % and non-ferrous metals (including aluminum) are reduced by 2 %. Due to the substitution between imports from non-EU and EU countries, the impact of overall imports is notably smaller.

In the Efficient scenario, the impacts of imports are notably larger as country-specific carbon tariffs are based on the carbon contents in the non-EU countries. Imports are reduced most from countries with high embedded carbon in their products. For example, the imports of non-metallic minerals, and iron and steel from Eastern Europe and the former Soviet Union, as well as from China, were halved. On the other hand, imports from non-EU countries with low carbon content are only slightly reduced (e.g., the imports of non-metallic minerals from the UK were reduced by 6 % and imports of iron and steel were reduced by 2 %). For products with lower carbon contents, like electronics, the variation between countries is smaller. In addition, imports are increased from some non-EU countries with low carbon contents, such as USA.

For exports, we first sum up the impacts on Finnish exports. The main findings are that Finnish exports to the EU are increased for all CBAM products in both scenarios examined, due to the improved competitiveness resulting from the tariff. Exports of non-CBAM products to the EU are decreased as the substitution effect exceeds the income effect.

Exports of all products to non-EU countries are decreased as both substitution and income effects are negative. Below, we present the more detailed results.

In the Feasible Scenario, the CBAM increases the Finnish exports to other EU countries of non-metallic minerals by 2.4 %, iron and steel by 1.7 %, and non-ferrous metals by 1.4 %. However, the impacts on the total exports of these products are smaller—namely 1.5, 1.2, and 0.5 % respectively—due to the decrease in exports to non-EU countries. Exports of those products that are not under the CBAM are reduced by 0–0.2 %. The reduction is largest for electronics, machinery and equipment, and transport equipment using imported metals as intermediate inputs and exporting a large share to non-EU countries. The reduction is larger for exports to non-EU countries compared to exports to the EU as overall demand levels are reduced in non-EU countries and increased in EU countries.

We found that a decrease in exports due to the increase in the costs of imports remained small. Carbon tariffs result in the 2.4, 1.4, and 0.5 % increases for the import prices of non-metallic minerals, iron and steel, and non-ferrous metals from non-EU countries. However, the prices of the aggregate imported intermediate inputs of these products are only increased by 0.65, 0.3, and 0.25 % as the original shares of imports from non-EU countries are low and imports of non-EU products are substituted for with imports from the EU. The upward adjustment in wages and the price of capital are negligible.

In the Efficient scenario, the impacts on exports are notably larger. Finnish exports to other EU countries are increased for all CBAM products. However, the increase is not only dependent on the size of the carbon tariff for products imported from non-EU countries. For example, the exports of electronics are increased more than the exports of non-metallic minerals. Total exports are increased for iron and steel, non-metallic minerals, non-ferrous metals, chemicals, rubber and plastics, and textiles, as well as for pulp and paper. On the other hand, a CBAM reduces the total exports of electronics, and machinery and equipment as the negative impact of exports to non-EU countries exceeds the positive impact on exports to the EU. Exports of electronics to non-EU countries are reduced by 5 % and exports of machinery and equipment by 4 %; they export a notable share to non-EU countries.

In the Efficient scenario, the highest increase in the import prices of carbon-intensive products from emission-intensive countries is about 15 %. The prices of intermediate imports for Finnish industries increase considerably less due to the substitution effect. The increase in the prices of imports is highest in the case of non-ferrous metals, rubber and plastics, electronics, non-metallic minerals, which have 1.4–1.6 % higher prices. Although electronics have a low carbon content, electronics are mainly imported from non-EU countries, which explains the fact that the increase in aggregate import price of electronics is one of the highest. The prices of labor and capital are increased by 0.3 %.

The increases in production costs imply that export prices are increased. The increase in production costs increased most the export prices of electronics (by 0.6 %), non-ferrous metals, textiles, transport equipment, fabricated metal products, and furniture, as well as iron and steel.

The export and import impacts for other EU countries are similar than the ones for Finland, especially in the case of Germany. In the Efficient scenario, there is some variation in the impacts on total exports of CBAM products due to the different shares of exports to EU and non-EU countries. For example, in the case of France, the total exports of furniture and textiles decreases, as do the exports of electronics and machinery and equipment. On the other hand, total exports of electronics increase from 'The rest of the Europe'.

For non-EU countries, the impacts on trade flows are mainly the opposite of those for EU countries. In the Efficient scenario with country-specific tariffs, the impact of carbon tariffs differs between countries, with the largest reductions in countries with high carbon intensity. Exports from China to the EU are reduced by 9–42 % for different CBAM products. On the other hand, Chinese exports to non-EU countries are increased by 1–3 %. Thus, the total exports of CBAM products are only reduced by 0.1–3 % as the share of exports to the EU is small. In contrast, other carbon intensive countries are only able to compensate the loss in EU exports with increase in exports to non-EU to a small extent. The developed non-EU countries with low carbon intensities might even increase their exports of CBAM products to the EU. For example, this applies to electronics from the UK, Switzerland, and the USA. The finding is explained by the fact that their competitiveness against EU producers only weakens slightly, and they receive some competitive advantage in EU markets against other non-EU countries with higher carbon content.

Finally, we sum up the main impacts on the trade flows of CBAM products in the case of Feasible Scenarios in Figures 6.1.1.a and 6.1.1.b The impacts are largest in EU markets with a decrease in exports from non-EU countries and an increase in intra-EU exports. The impacts in exports to non-EU countries follows from the indirect effects of the CBAM and are notably smaller. The adjustment in prices lowers the production costs in non-EU countries and increases them in EU countries. Thus, exports of CBM products from the EU to non-EU countries are decreased while exports between non-EU countries are increased.

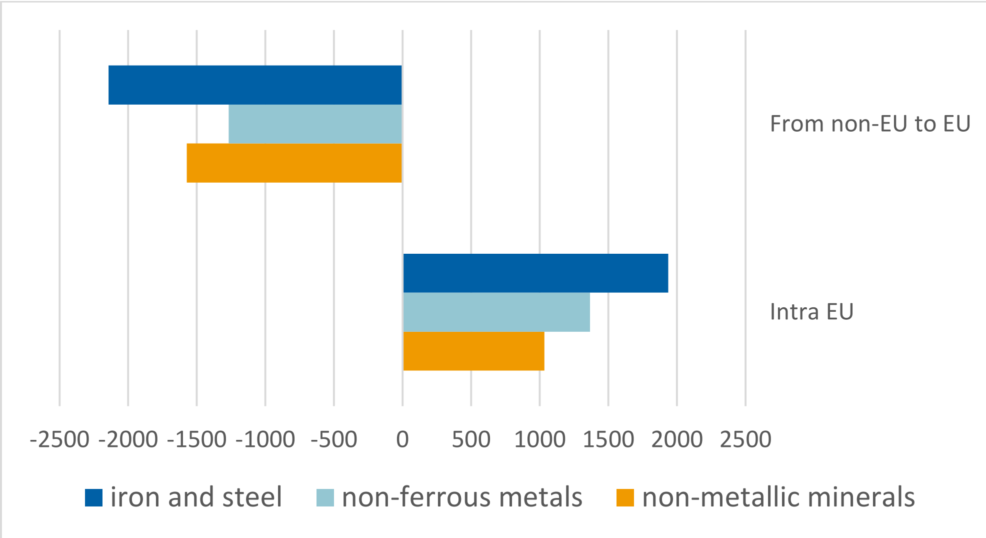

Figure 6.1.1.a The impact of the CBAM on the value of exports from non-EU countries and EU countries to EU countries for CBAM products in the Feasible Scenario (million USD).

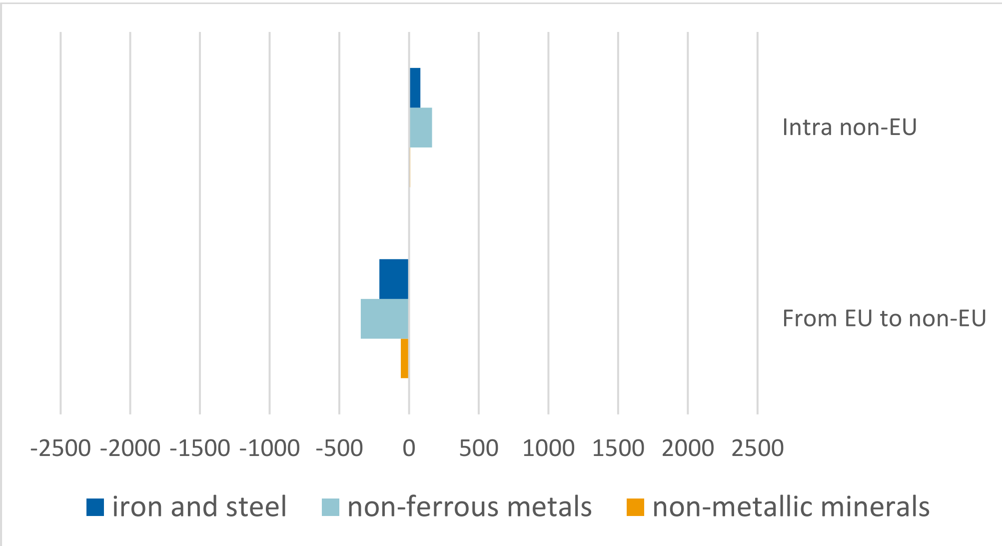

Figure 6.1.1.b The impact of the CBAM on the value of exports from non-EU and EU countries to non-EU countries for CBAM products in the Feasible Scenario (million USD).

6.1.3 The impacts of the CBAM on production levels

The results for production are mainly driven by export impacts. The impacts of the CBAM on production levels in Finland in both scenarios is presented in Figure 6.1.3, with percentage changes. In the Feasible Scenario, production is increased in all CBAM sectors and the increase is 0.5–1 % in Finland. This implies that production is also increased in those sectors that provides significant amounts of inputs to CBAM sectors. These include electricity and mining. For other sectors, production is decreased. In the Efficient scenario, the reallocation of resources between sectors is larger as the carbon tariffs are higher and almost all industry products from non-EU countries face the carbon tariff. Production is increased in most of the CBAM sectors. The highest increase is found in the manufacture of iron and steel, with a nearly 4 % increase. The production of non-ferrous metals, non-metallic minerals, and rubber and plastics is also notably increased. Unlike in the Feasible Scenario, some CBAM sectors suffer. These include electronics, and machinery and equipment. These are sectors that export a large share to non-EU countries and use other CBAM products, like metals, as intermediate inputs. For non-CBAM sectors, production is increased for electricity and mining, and reduced for all other sectors. The production in service sectors is also slightly reduced, although their private and public consumption is slightly increased.

The production impacts are similar to other EU countries for both the Feasible Scenario and Efficient scenario, as in the case of exports. However, in other EU countries, machinery and equipment form the only CBAM sector that suffers and the production of electronics is increased.

In non-EU countries, the production levels are mainly decreased due to the CBAM. In the Feasible Scenario, the productions of CBAM products are slightly decreased with the largest effects in the UK, Eastern Europe, and the former Soviet Union. For the other sectors, the production level is mainly decreased. In the Efficient scenario, the productions of CBAM products are mainly decreased. However, the production is increased for those products whose production was decreased in the EU area, namely electronics, and machinery and equipment. In addition, the production of fabricated metal products is increased. The largest production impact is found for iron and steel in Eastern Europe and the former Soviet Union, with a 7.5 % decrease. However, the downward adjustment in wages and the price of capital implied that production was notably increased in sectors with lower carbon contents. In China, the impacts on production are modest; the largest reduction is for fabricated metal products (0.3 %) while the largest increase is for transport equipment (0.5 %). For the UK, the largest reduction is in the production of iron and steel (0.9 %) while the largest increase was a 1 % increase for electronics.

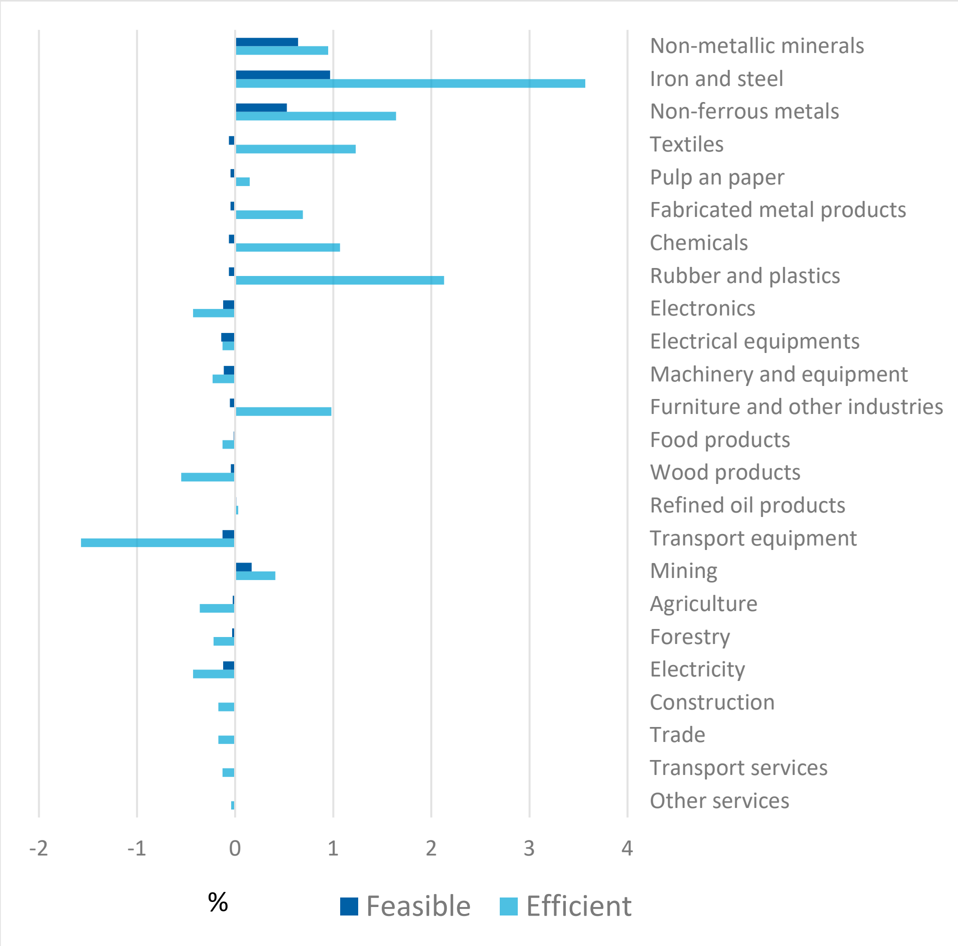

Figure 6.1.2. The impacts of the CBAM on production levels in Finland as a percentage change in the Feasible and Efficient scenarios. In the Feasible Scenario, the non-metallic minerals, non-ferrous metals, and iron and steel are under the CBAM, while in the Efficient scenario, the products ranging from non-metallic minerals to pulp and paper are under the CBAM.

6.1.4 The impacts of the CBAM on GDP and welfare

The economy-wide impacts of the CBAM are small and diversified. Taking into account the price mechanism and substitution possibilities reduces the impacts compared with the value change analysis presented above.

In the Feasible Scenario, GDP impacts are negligible. The GDP impact is very slightly positive for all EU countries while it is mostly negative for non-EU countries (with a couple of exemptions: Korea and Russia). In the Efficient scenario, the GDP impact is slightly negative for all EU countries, as shown in Figure 6.1.3.a. According to the model results, in Finland the GDP would be reduced less than in other EU countries. For non-EU countries, those countries with the highest carbon content, like China and the group of eastern European and former Soviet Union countries as well Russia, would suffer slightly, as presented in Figure 6.1.3.b. For developed non-EU countries, the impact is close to zero while Korea and North Africa would benefit slightly.

GDP is affected by efficiency loss due to the reallocation of the resources. The model assumes that labour and capital are mobile across sectors within a country/region. On the other hand, the regional levels of capital and labour are not affected, which limits the magnitude of GDP impact. This follows from the model assumptions of non-mobile labour and capital between countries. These are typical assumptions applied in economic assessment of CBAM, e.g. in Böhringer et al. (2018) and in Pyrka et al. (2020).

Welfare, as well as consumption, increases in the EU in both the Feasible Scenario and the Efficient scenario. This result is in line with Böhringer et al. (2018). For non-EU countries, the direction of the impact is same in both scenarios for all countries except the USA. Welfare is increased in the USA, Japan, and Korea and decreased in all other countries. In the study by Böhringer et al. (2018), welfare was decreased in all countries that face the carbon tariff, that includes non-OECD countries in his analysis. The difference might be explained by the fact that in the study of Böhringer et al., OECD countries have a climate policy and non-OECD countries face the tariff while in our analysis we look at the EU-level CBA policy.

The welfare impacts are driven by the terms of the trade effect. Terms of trade are improved for EU countries as export prices are higher and import prices are lower. Welfare loss due to the reallocation of resources is also notable. However, in some cases this impact is positive. In the Feasible Scenario, the allocation impact is in line with GDP impacts as it is positive for all EU countries, Korea, and Russia. On the other hand, in the Efficient scenario there is a loss in efficiency due to the reallocation of resources in all other countries or regions except in the USA, Canada, Latin America, and Korea.

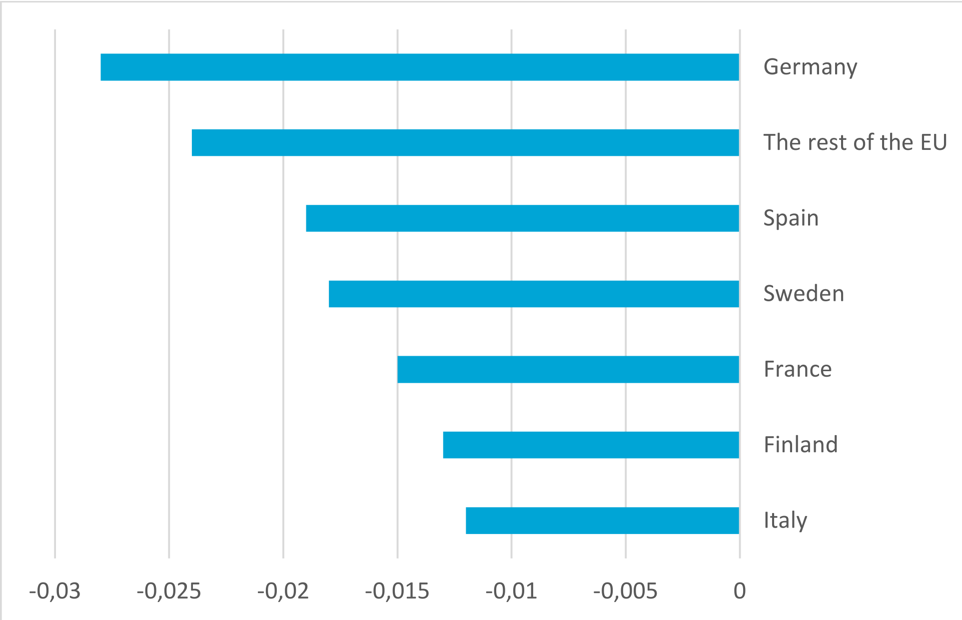

Figure 6.1.3.a The impacts of the CBAM on GDP in EU countries in the Efficient scenario, %

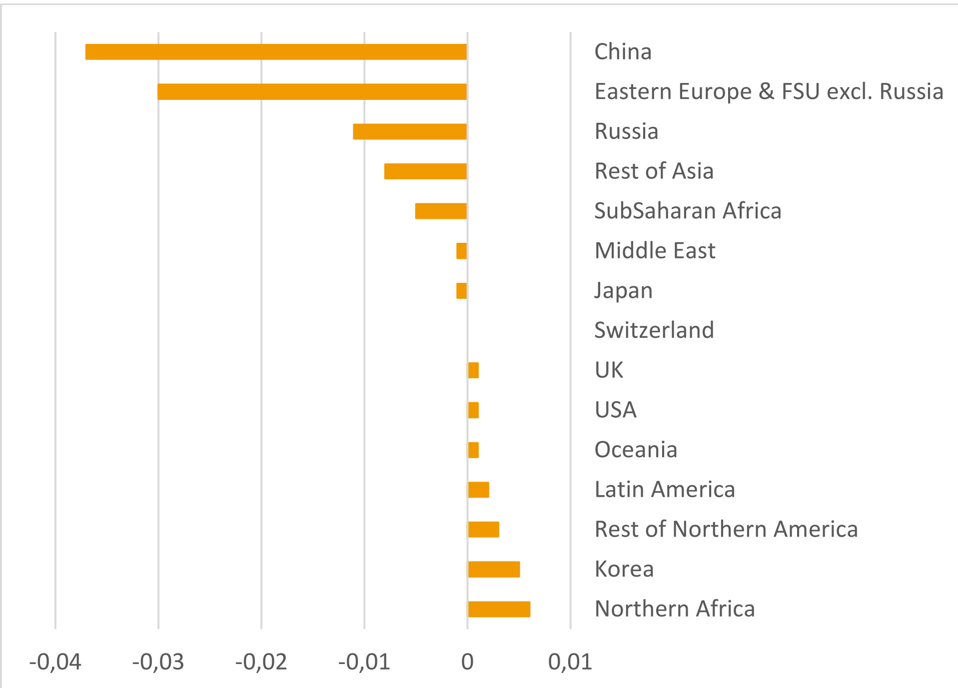

Figure 6.1.3.b The impacts of the CBAM on GDP in non-EU countries in the Efficient scenario, %

6.1.5 Discussion on the results from economy-wide GTAP analysis

The results obtained from the GTAP model are in line with the ones by Pyrka et al. (2020) that assessed the impacts of CBAM by using a same type of computable general equilibrium model. In Pyrka et al., the carbon tariffs were set to six products (ferrous metals, non-metallic minerals, chemical products, non-ferrous metals, paper products and oil). Thus, their coverage of products is between the ones in the Feasible and Efficient scenarios. The sizes of carbon tariffs are lower in their analysis as indirect emissions included only those from electricity. In both analyses, the GDP impacts are found to be close to 0 %. The changes in production levels in Pyrka et al. are mostly smaller than in our analysis as expected due to the lower tariffs. However, for manufacturing of non-metallic minerals they find a slightly higher impact. In addition, they find the negative impact for production of non-ferrous metals in half of the EU countries, including Finland. Manufacturing of iron and steel benefits most also in their analysis, and according to both analyses the increase in the production of iron and steel is one of the highest in Finland. Consumers in EU countries benefit from CBAM in both analyses due to the improved terms of trade.

The results are based on the carbon tariffs calculated with the carbon price of 25 EUR/ tCO_2. In the Feasible scenario, the effects nearly doubled if the carbon price increases to a 50 EUR/tCO_2. In the Efficient scenario, the production levels doubled for most of the industries protected by CBAM. The increase in production due to higher carbon price was however lower for those industries that use imported CBAM products as intermediate inputs.

The results on the impacts of carbon border adjustment mechanism are based on the ceteris-paribus analysis without taking into account the effects of other policy changes. The (gradual) phase-out of free emission allowances would weaken the positive impacts of CBAM to some extent. The mechanisms of these two instruments to protect EU industries differ partly because CBAM affect the competitiveness between EU and non-EU producers in the EU markets, while free allowances improve the competitiveness of EU producers in all markets. The impact of free allowances, and thus their phase-out, is dynamic because the production decisions today affect the amount of free allowances in the future. In addition, profits from free allowances increase the number of firms in the market and thus imply the lower price level.

The magnitudes of the trade flow impacts are highly affected by the values of Armington elasticities describing the degree of substitution possibilities between domestic and imported products as well as between imported products from different countries. The values of elasticities used in CGE models are, however, uncertain and sometimes characterized as 'guesstimates' rather than estimates. To partly overcome this problem, we assessed the sensitivity of the results by using the values of elasticities estimated with gravity model and presented in Table 5.1.3. The elasticities based on the gravity model are somewhat higher for non-ferrous metals, chemicals and electronics and lower for textiles, pulp and paper products, fabricated metal products, rubber and plastics as well as machinery and equipment, compared to the ones in the GTAP model. We found that the impacts on production levels are only slightly or not at all affected, with the exception of textiles and electronics. The GDP impacts remain the same. In this experiment we could not consider the values of elasticities between imports from different countries that affect the results in the Efficient scenario with country-specific carbon tariffs.

In the scenarios presented above, all non-EU countries face the full carbon tariff, although some of them have emission trading or other pricing mechanisms. If the carbon tariffs were set according to the differences between carbon prices, the negative impacts in developing countries without climate policy would be larger and some developed non-EU countries would benefit.

6.2 The possible retaliation of other countries: NIGEM analysis

This section analyzes the possible retaliation of the extra-EU countries, which may follow if/when the EU imposes a CBAM scheme. The following analysis is done using a global macroeconomic model, NiGEM[31], developed and maintained at the National Institute of Social and Economic Research (NIESR). The NiGEM multi-country macro model comprises more than 60 countries. It is based on estimation using historical data. The long-term equilibrium properties of the model are built in a way that the model can also accommodate forward-looking behavior.

We begin by assuming that the CBAM set by the EU first provokes a counteraction in the US trade policy. The US has used tariffs as a policy instrument several times lately and has also proved that it can impose them on EU countries' imports as well. A 25 % tariff on steel and a 10 % tariff on all aluminum imports that was imposed by the US government in 2018 is a useful reference point for our analysis. This was one of the first round of increases in the tariffs between the US and China, which later escalated to the actual trade war between these two countries. The EU also retaliated to the US tariffs and imposed tariffs on US exports to the EU, covering steel and aluminum products and also selected consumer and agriculture products, equivalent of 2.8 billion euros in total.

31 About the structure of the NiGEM, see https://nimodel.niesr.ac.uk/.

To quantify the effects of the US tariffs on the EU's steel industry, for instance, the US Department of Commerce (2018) expected that they will reduce the EU exports of steel by the equivalent a little over 1 % of 2017 EU production. While this was probably significant for the industry in case, the total effects of tariff increases can be assessed as being relatively small on EU economies on average. For China, the initial tariff increases represented a somewhat greater issue. Yet, when calculating the effects of the steel and aluminum tariff increases on aggregate terms, these represented only a 0.6 % increase in total US tariffs on Chinese exports (as analyzed by Bown, 2020).

All in all, the US retaliation scenario is quite natural. When taking the previous steel and aluminum tariff increases as our reference point—that is, comparing these with the CBAM scheme assumed in Section 4—we can also presume that the first retaliation from the US side could be relatively modest in size. After discussion of the US case, we assume a much more severe retaliation scenario where it is the ROW that imposes counter-tariffs on the EU. Although maybe not fully realistic, this latter scenario is to illustrate the possible worst-case implications of the EU's CBAM scheme. Finally, we simulate these scenarios with stronger policy responses, that is, with counter-tariffs that are double the size of the first two scenarios.

In the following simulations, the effects of tariffs are driven by higher import prices. Thus, higher tariffs raise import prices, which reduces demand for imported goods. On the other hand, it leads to an increase in the domestic price level while the goods produced abroad are replaced with their more expensive domestic counterparts. Hence, in addition to foreign producers, domestic consumers are also hurt by higher tariffs. In NiGEM, the coefficients of the behavioral equations representing relationships between these variables are estimated from macro data. These all are documented on the NiGEM website.

In the Efficient 1 scenario (representing a broader scope of the CBAM compared with the Feasible Scenario) analyzed in Section 4 of the report, the CBAM scheme was applied to products that cover circa 3 % of the EU countries' total imports. Using this scenario, together with the steel and aluminum tariff increases analyzed above as a reference point, the first simulation assumes that, as a retaliation, the US imposes a 2 % increase in tariffs for imported (non-commodity) goods from the EU countries. This leads to a clear reduction of exports volumes in the eurozone and even more so in Finland alone. Both these areas see around a 0.25 % decrease in exports in the long run. The US and Chinese exports are more moderately affected amid cuts in global demand due to the increase in tariffs.

The tariffs also reduce the GDP in our selected group of countries. The US suffers the most from the tariffs it has self-imposed, but Finland's GDP also takes a considerable hit. The eurozone comes just behind Finland in terms of the size of the effect, whereas the Chinese economy is much less affected. All in all, the US GDP declines by almost 0.1 % in the long run, that of Finland a little less, while the eurozone's GDP shrinks by around 0.05 % in the long run.

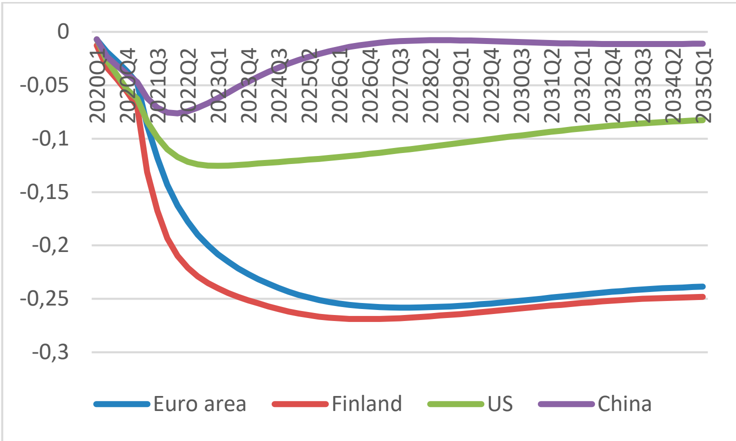

Figure 6.2.1. The effect of a 2 % increase in the US tariffs for imported (non-commodity) goods from the EU countries, expressed as the percentage change in exports

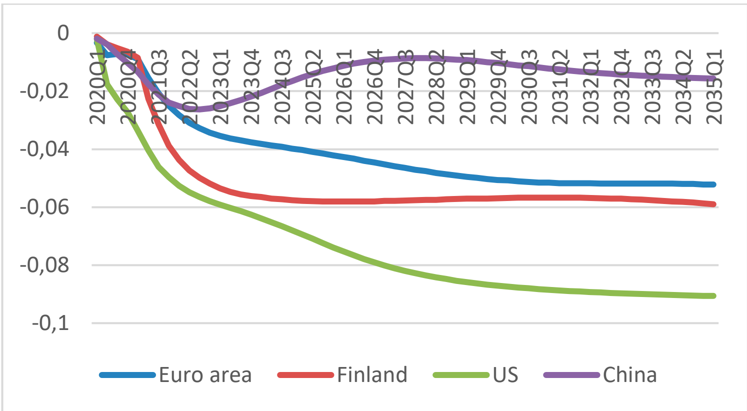

Figure 6.2.2. The effect of a 2 % increase in the US tariffs for imported (non-commodity) goods from the EU countries, expressed as percentage change in GDP

In our second scenario, the EU is faced with a more severe confrontation due to the CBAMs it has imposed earlier. In this scenario, the ROW retaliates to the EU tariff policies. The simulation assumes a 2 % increase in tariffs in the ROW's (non-commodity) goods imports from the EU countries. This kind of retaliation leads to a sharp decrease in Finland's exports, as well as the EU's and the US's exports. Finland's exports decline by 1.2 % while both the eurozone's and the US's exports decline by 1.1 % in the long run. China's exports decline by circa 0.7 % in the long run.

The GDP effects also become larger in this scenario. Finland and the eurozone suffer most severely with their GDP falling by 0.3 % and 0.25 % respectively in the long run. The US and most notably China face smaller declines (even though the long-run decline of the US GDP is almost in line with the eurozone's).

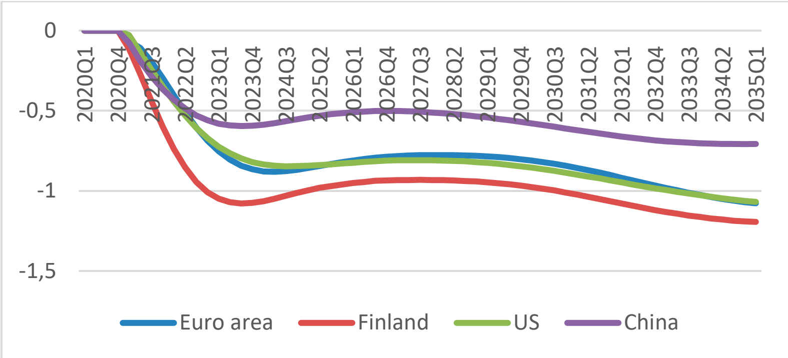

Figure 6.2.3. The effect of a 2 % increase in the extra-EU tariffs for imported (non-commodity) goods from the EU countries, expressed as the percentage change in exports

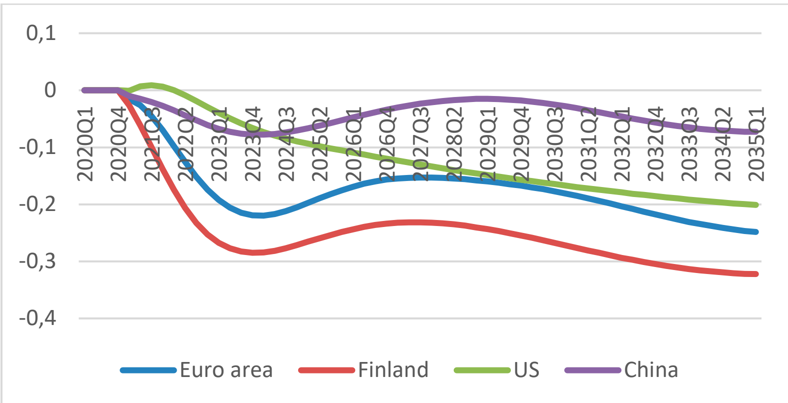

Figure 6.2.4. The effect of a 2 % increase in the extra-EU tariffs for imported (non-commodity) goods from the EU countries, expressed as the percentage change in GDP

While NiGEM is close to being a linear model, the scenario that assumes a 4 % increase in the US tariffs for imported (non-commodity) goods from the EU countries produces export and GDP effects that are around double the size of the effects shown in Figures 1 and 2. Thus, the outcome of the simulation is qualitatively similar to the first simulation: The US GDP shrinks the most from the tariffs it has self-imposed and Finland's and the eurozone's GDP also fall considerably, whereas the Chinese economy is clearly less affected.

Finally, the scenario that assumes a 4 % increase in tariffs in the ROW's (non-commodity) goods imports from the EU countries produces a 0.65 % and 0.5 % decline in GDP in Finland and the euro area, respectively, in the long run. The US is confronted by a clearly smaller decline in GDP in the short run but loses almost as much GDP as the eurozone in the long run. In contrast, China's output takes just a minor hit in the long run.

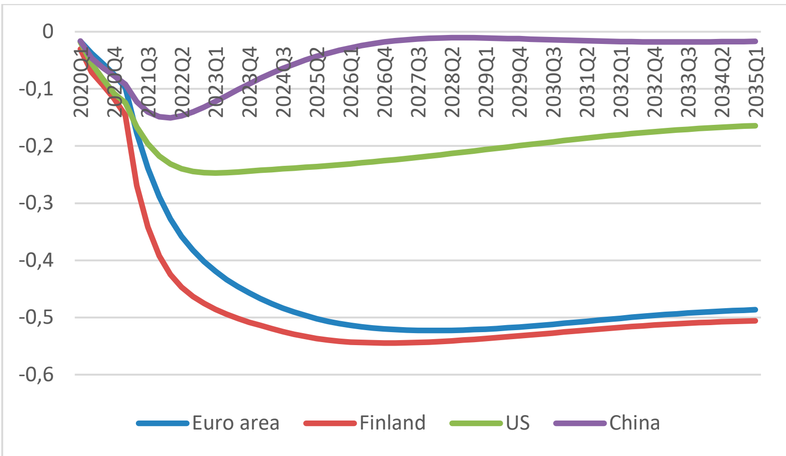

Figure 6.2.5. The effect of a 4 % increase in the US tariffs for imported (non-commodity) goods from the EU countries, expressed as the percentage change in exports

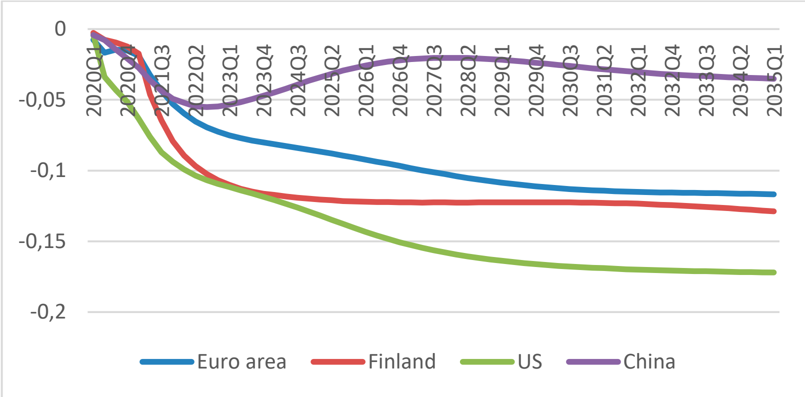

Figure 6.2.6. The effect of a 4 % increase in the US tariffs for imported (non-commodity) goods from the EU countries, expressed as the percentage change in GDP

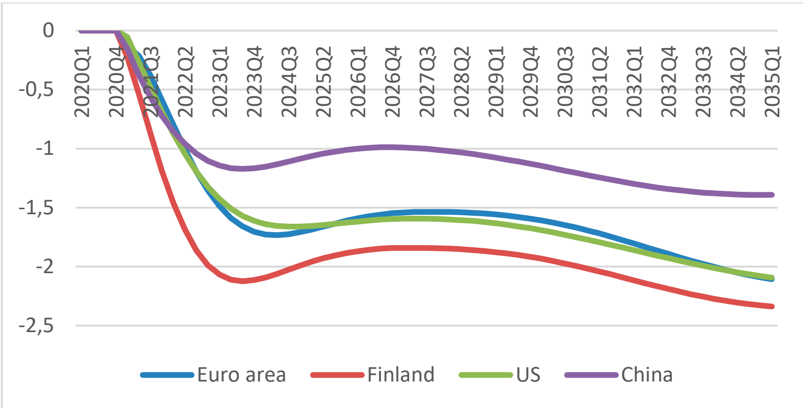

Figure 6.2.7. The effect of a 4 % increase in the extra-EU tariffs for imported (non-commodity) goods from the EU countries, expressed as the percentage change in exports

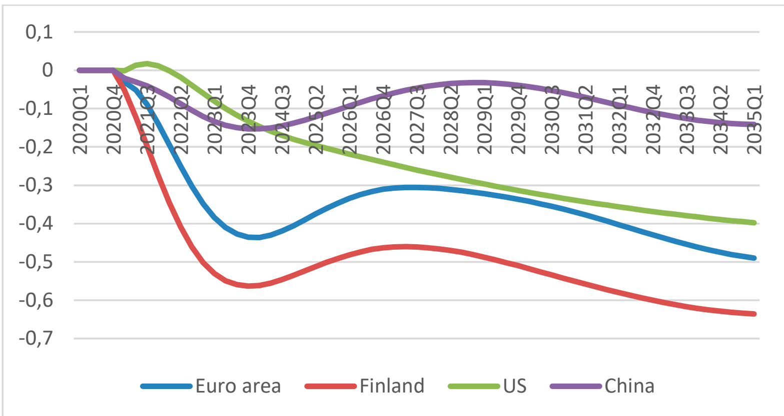

Figure 6.2.8. The effect of a 4 % increase in the extra-EU tariffs for imported (non-commodity) goods from the EU countries, expressed as the percentage change in GDP

7 Synthesis

7.1 The main results

In this report, we addressed an EU CBAM and its economic implications. Recently, the mechanism has been proposed as a solution to the emission leakage that may result from the union's commitment to stronger climate policy. We analyzed various CBAMs from technical, legal, and economic perspectives. While CBAMs have been argued to work well (for example, as an instrument to put pressure on third countries to have less polluting production), our starting point is to address the practical problems and uncertainties that overshadow a CBAMs practical implementation and effectiveness.

In a second-best world, there are several ways to implement the CBAMs with varying amount of technical difficulties, administrative burden, legal problems, and political backlashes. In order to implement a CBAM, one has to determine its scope and coverage, that is, one must specify the products and trade flows affected by it, the sectors or geographies it applies to, and the types of carbon constraints for which it adjusts. A number of design considerations emerge from the literature and case law. When choosing the best policy option, these different aspects need to be weighed together with their economic impacts.

7.1.1 Legal and technical implementation issues

The first part of our legal analysis discusses the various implementation issues in detail. The legal implications and risks of the prospective CBAM will greatly depend on the policy mechanism used for its implementation. Each implementation option has, for instance, far-reaching implications under EU law, particularly with regard to the applicable legislative procedure and revenue use, and legal questions under international trade law. In technical terms, we find that it may be very difficult to determine the emissions and explicit carbon price for CBAMs in practice. When determining the carbon intensity of products, the methodological issues include the selection of emission components (CO2, other GHGs, other climate forcers such as aerosols) and characterization factors (i.e., how non-CO2 forcers are converted into CO2 equivalents), the setting of system boundaries (i.e., which processes from upstream/downstream are included), choosing allocation rules (i.e., how the emissions are allocated in the case of co-products), and applying representative data. In particular, the availability of reliable and timely data is a pressing issue.

In an ideal case, the carbon price is determined based on the explicit carbon price of relevant emission components. This means that all the instruments—such as the price of emission allowances, taxes, and revenues—explicitly influencing carbon price should be considered. However, different emission components may face various carbon prices; for example, some of the emission components may be regulated under an emission trading scheme, some of them being less penalized through free emission allowances, some of them being taxed in other sectors, and some of them subsidised (or less penalized) by tax reliefs or revenues.

In legal terms, a CBAM is likely to face less problems in implementation when its scope is limited. First, when it covers only imports, the design would not be considered a prohibited subsidy under the WTO Agreement on Subsidies and Countervailing Measures. A relatively limited scope of products also helps avoid the arbitrary discrimination that might occur with the broader coverage of more complex goods as the data will be more readily available and the production processes more familiar. Meanwhile, by covering imports from all countries, rather than singling out particular countries, such a CBAM avoids violating the MFN principle contained in Article I of the GATT. Overall, the emissions scope of the CBAM should preferably be matched with the EU ETS (direct emissions from industrial processes and electricity generation). By relying on the average carbon intensity of EU producers, the practical measurement of the tariff should be compatible with trade law, while possibly allowing for individual adjustment (that is, allowing for a process for importers to prove the actual carbon intensity of their products as a complementary feature).

A broader scope, including many semi-manufactured and manufactured goods, dramatically increases the technical and administrative complexity of the CBAM, which could affect its legal assessment under Article XX of the GATT. Part of the tests involved in the application of this provision require balancing the means and ends; for instance, balancing whether the measure is "necessary" in order to achieve the stated end, or whether less burdensome alternatives might have been used. Likewise, accounting for the full the embedded carbon emissions of production along the value chain is problematic. The carbon footprint relative to the value of goods diminishes rapidly as a CBAM progresses down the value chain, and thus the proportionality of its imposition as an environmentally motivated measure could be challenged.

Another legally problematic aspect of the Efficient Scenario is the inclusion of Scope 3 emissions: since a border adjustment can only adjust for the burden imposed on domestic products and producers, imposing a CBAM on imports that also encompasses Scope 3 (other indirect) emissions is likely to be challenged as producers covered under the EU only have to report and surrender allowances for Scope 1 emissions (and electricity as a sector is included, meaning Scope 2 emissions are to some extent included indirectly).

Finally, a CBAM may need to take into account a carbon price or other carbon constraint imposed on imported products in their country of origin. It is conceivable that not accounting for foreign policies—and at least explicit carbon prices paid in the country of origin—could be considered "arbitrary and unjustifiable discrimination between countries where the same conditions prevail," as indicated in the introductory paragraph of Article XX of the GATT.

7.1.2 Economic analysis

We proceeded to illustrate the implementation issues in several economic scenarios. Based on the implementation analysis, we titled our first scenario the Feasible Scenario: the CBAM is narrowed down to few industries (cement, lime, and plaster industries) where production is the most emission intensive and there is less threat of legal or political complications in its implementation, with a possible extension to cover iron, steel, and aluminum production. Moreover, we work around the difficulties of the measurement of emissions beyond the EU borders by considering EU emission averages as the benchmark for the calculation of the carbon tariff.

As an alternative, we discussed the option of using a wider scenario with larger number of emission-intensive products and more detailed measurement of the carbon tariff, potentially building on all emissions. We titled this scenario as the Efficient Scenario. The features of the scenarios are collected in Table 4.1 and discussed in Section 4.

We should acknowledge that while our scenarios aim at grasping the results that arise from economic analysis, they are bound to be stylized and build on simplifying assumptions. For example, our economic models are calibrated based on historical global emissions and trade linkage data that typically lag behind by several years. While this is likely to bias our results to some extent—for example, due to the recent impacts of Covid-19—it also serves as a reminder of the practical informational problems that a CBAM would face.

Our economic analysis proceeded in steps that each added more layers of economic assumptions and, consequently, allowed us to make a deeper analysis while increasing the amount of modelling uncertainty in the results.

We started by describing the markets that are potentially subjected to the tariffs. We saw that the manufacturing of cement, lime, and plaster plays a very small part in the total EU economy. Its total value added was seven billion euros in 2017 and its share in total business economy value added was just 0.11 %. On the other hand, cement is of course very important as an intermediate good for the construction sector. The importance of cement, lime, and plaster is at least twice as large as the EU average for Romania, Croatia, Slovakia, Poland, Greece, Bulgaria, and Belgium. New member countries and the Balkans are over-represented in this group.

In terms of EU´s own production, the manufacturing value added of basic metals and products thereof in the EU27 countries was 104 billion euros in 2017 or 1.67 % of the total business sector value added. This is already significant, as is of course the importance of these products as intermediate goods, especially in other metal industries. The importance of iron, steel, and aluminum (and other metals) exceeds the EU average, especially in Slovenia, Slovakia, Austria, Bulgaria, Finland, Poland, Belgium, and Italy.

In terms of trade, the value of extra-EU imports of cement, lime, and plaster is very small. Iron and steel, including products thereof, imports are much larger, equal to 2.7 % of all extra-EU imports. The value of aluminum and aluminum product imports is about half the value of iron and steel.

In the Efficient Scenario, we included a much larger set of industries and products. These covered almost 60 % of all extra-EU goods imports. The gross value is 8.5 % relative to EU GDP in 2018. Clearly more products were considered compared to Feasible Scenario, but still the amount was limited to 14 industries (see Table 4.1). While being broader, the scenario still focused on energy-intensive sectors that are considered to be at risk of carbon leakage under the EU ETS.

We used econometric gravity analysis to isolate the historical trade effect of tariffs and apply the findings in making projections concerning the effects of the proposed tariff increases on EU imports. We found that the variants of the Feasible Scenario (the Feasible 1 scenario with cement, lime, and plaster and the Feasible 2 scenario with cement, lime, and plaster, and aluminum and steel) have a very limited impact on overall gross imports, partly because the products in this scenario constitute such a small share of extra-EU imports. However, in relative terms, the impact is large for cement, lime, and plaster where we find a 23 % decline in imports when both direct and indirect CO_2 emissions are included. The overall impact on total extra-EU imports is a little less than three billion euros.

It is notable that the estimates arise solely from the introduction of the CBAM as an import tariff, and we abstract from the effects of possible complementary policy reforms, such as changes in the allocation of free allowances.

In the same context, the Efficient Scenario exhibits much larger effects of course. The total impact when including both direct and indirect CO_2 emissions is 93 billion euros or almost 5 % of all extra-EU imports. In euro terms, the biggest impact comes from the manufacturing of chemicals and chemical products (-17 billion euros), the manufacturing of radio, tv and communication equipment (-13 billion euros), the manufacturing of electrical machinery and apparatus (-11 billion euros), and the manufacturing of office, accounting and computing machinery (-11 billion euros). When we only include indirect electricity CO_2 emissions along with the direct emissions, the aggregate impact is a decline in extra-EU imports of 53 billion euros.

While the effect of the Feasible Scenario is also small for Finland, in the Efficient Scenarios value of Finnish extra-EU imports declines by between 1.8 % and 3.6 %, depending on the scope of the emissions. These are somewhat smaller figures than for the EU on average and are due to differences in the product and country-of-origin structure of Finnish imports vis-à-vis the EU average.

In terms of the overall tariff revenues, in the Feasible Scenario it amounts to 0.8 billion euros. The much wider Efficient Scenarios yield a tariff revenue of 15.2 billion euros and 25.2 billion euros, depending on whether all indirect CO_2 emissions are included or not.

The impact on the total CO_2 content of imports in the Feasible Scenarios is negligible. In the Efficient Scenarios, we can see that the impact on the value of imports is the greatest for China and across non-EU Europe (including the UK, Switzerland, and Russia). The impact on the CO_2 content of goods imports is the largest in trade with South Africa, non-EU European countries, the Middle East, and many Asian countries. The fifth column shows that in terms of the total tonnage of imported CO_2 emissions, by far the largest impact is on China, which accounts for almost half of the total decrease. Meanwhile, the CO_2 content of Finnish extra-EU imports declines by between 10.0 and 13.1 %, depending on whether all or part of the emissions are considered.

Due to the global value chains, the imported products are often used in the EU production as intermediate goods or services, that is, the importers contribute their value added to the final products that are assembled in the EU. When tariffs are set, their production is affected, and the linkages need to be considered when assessing the EU's overall economic reliance on the emission-intensive imports. Moreover, the analysis of the value chains also helps to better understand the importance of EU trade for extra-EU countries. Their exports to the EU often include third-country intermediate products that need to be considered in order to account for the true value of trade for individual exporting countries.

In terms of the total contributions of value added to the imports by the extra-EU and EU countries, we find that in the Feasible 1 scenario, with CBAs only imposed on cement, lime, and plaster, the total value-added contribution that is lost is only 0.1 billion euros in total. The total lost contribution increases to 4.9 billion euros when the CBA is extended to also include basic steel and aluminum products. The Efficient Scenario with the emission-intensive industries and all emissions as the basis for the CBA measurements increases the total contribution to 142.5 billion euros. The Efficient Scenario with the emission-intensive industries and direct and electricity emissions as the basis for the CBA measurements sets the total contribution to 79.87 billion euros.

The most important individual-country value-added contributions that are lost are made by the UK (56.6 % of the total value-added contributions in all countries) and Turkey (9.0 %) in the case of the narrowest Feasible Scenario (with cement, lime, and plaster). When basic metal products are included in the Feasible Scenario, the contribution of China increases substantially. In the Efficient Scenarios, China's role becomes even more dominant. It contributes roughly one half of the total value added in products that would not be imported to the EU according to the changes in the gross trade. Meanwhile, the results suggest that the EU does not play a major role in providing value added to the production of imports, thus implying that the role of back-and-forth trade with the EU and the trade partners is small.

We find that a substantial share of the lost value added contributes to value chains for which the final assembly is made in the EU. In these cases, the EU production needs to find a substitute for the imported intermediate product. The share of intermediate value added is the highest in case of the Feasible 1 scenario (with cement, lime, and plaster) and the Feasible 2 scenario (with cement, lime, and plaster, and aluminum and steel), 30.9 % and 25.9 % respectively, while the share lowers to roughly 21 % in the Efficient Scenarios. Thus, EU production has major dependencies on the imported intermediate goods that would be affected by the CBAs.

We find that in case of the broad cement product CBA, France has a substantial role as a final producer. Of the lost value added that is embodied in the imports and are used in EU final products, 35.2 % end up in French final goods. In other scenarios, Germany is the largest user of the imported products in its final production, followed by France, Italy, and the Netherlands.

We also decomposed the lost value added according to the producer industry of the final product in the EU. In terms of the share of the total embodied value added in the CBA-related imports, we find that the largest final user is the construction industry. In particular, in the Feasible Scenario with only cement, lime, and plaster, the value added that is embodied in its final products is 43.8 % of the total value added in imports. Other important user industries are industries that (1) manufacture food products, beverages, and tobacco products; (2) manufacture coke and refined petroleum products; and that (3) manufacture motor vehicles, trailers, and semi-trailers. When the CBAs are extended to other product classes, the role of various manufacturing industries increases.

For Finland, the lost value-added content in the Feasible Scenario goods is negligible. Also, in the Efficient Scenario, the amount of value added that Finnish firms export from abroad to be used in their final products or their own value added, embodied in the imports, is relatively small, varying around 100 million euros depending on the scenarios. In relative terms, the most reliant industries are found in manufacturing industries. This result is comparable to the EU findings, albeit the reliance is smaller than for the European industries on average.

Naturally, the import dynamics only provide hints of the potential overall impacts that the CBAMs may have on the production in the EU and beyond. We used a computable general equilibrium model (GTAP) that incorporates a more economic structure into the analysis in order to study the impacts on production in the EU.

When imports of tariff products from non-EU countries fall, there tends to be a substitution effect: In intermediate production or final use, imports are replaced with substitute products that are acquired from the EU area (products whose price is not directly affected by the tariff). This effect will boost the demand for EU products. On the other hand, the tariff tends to increase the prices of the tariff products in the EU because the CBAM will limit the availability of cheap imports and create a cost–push effect in the EU. The tariff will distort the prevailing equilibrium in international trade that features the comparative advantage of different countries; the resulting decrease in efficiency will ultimately lower the purchasing power of the consumers and decrease their overall demand. On the other hand, a CBAM would generate revenue in EU, which increases demand.

Indeed, the GTAP model shows how the exports of EU countries to other EU countries increases while exports to non-EU countries decreases due to the crowding out effect of the EU demand.

In the extended Feasible Scenario, the production of iron and steel, non-metallic minerals, and non-ferrous metals increases in Finland and other EU countries. Production also increases in industries that provide a substantial amount of inputs to these sectors, namely mining and electricity. In the Efficient Scenario, a wide variety of industries belong to the CBAM. We found that production increases in most of these industries.

However, not all industries are winners. A substantial share of the imports are used as intermediate products in the EU production. In terms of the competitiveness of EU producers, the increase in the price of the intermediate products will generate an additional cost to final products, which will generate similar substitution and income effects for their product demand as the tariff generates for the imported goods. Thus, for an EU industry participating in global value chains, the effects of tariffs may be more negative than for an EU industry that solely competes with imports in the final product market. Moreover, the increased competitiveness results in inflationary pressures that tend to hurt industries that are not directly benefitting from the tariffs in the EU market.

The higher costs of intermediate inputs are reflected in the Feasible Scenario as production losses in the transport equipment, machinery and equipment, and electronics industries that use metals from non-EU countries as inputs. In the Efficient Scenario, the cost impact is notably larger due to the wider coverage of products and higher tariffs based on country-specific carbon contents. The results show that industries protected by CBAM may also suffer if the negative effect due to the increased production costs exceeds the benefits from the comparative advantage against non-EU producers that face the tariff. This is what happens in the production of machinery and equipment, as well as the production of electronics whose benefits from improved competitiveness in EU area are limited as they mainly export to non-EU areas. For other sectors, the impacts are negligible in the Feasible Scenario while in the Efficient Scenario the reallocation of resources to CBAM sectors implies lower production levels in most of other sectors, including services for example.

The overall impact on GDP is negligible or slightly negative in Finland and other EU countries, depending on its scope. The result arises from the loss in efficiency that the CBAM generates through the reallocation of resources. On the other hand, welfare is increased due to the improved terms of trade.

It is notable that in the all the economic analysis presented above, we have based the findings on a 25 EUR/tCO_2 carbon price, while the effects are mainly doubled if the price increases to a 50 EUR/tCO_2 carbon price. Moreover, it should be noted that the carbon tariffs only reflect emission intensity differences between the EU and extra-EU countries, or the simplified benchmarks, while the measurements do not take into account a carbon price or any other carbon constraint imposed on imported products in their country of origin.

In the case of the non-EU area, emission-intensive countries, such as China and the group of Eastern European and former Soviet Union countries, suffer slightly from the CBAM in the Efficient Scenario, with country-specific tariffs based on their carbon content. For other non-EU countries, the GDP impacts are negligible in both scenarios. Some developed non-EU countries with low carbon content can increase their exports of CBAM products. This is reflected in increased production levels, as well as in slightly improved welfare in the US, Japan, and Korea.

The impacts of the CBAM remain limited as EU countries import a large share of products from the EU. This both implies that an increase in production costs in those sectors using imported CBAM products as intermediate inputs is modest and the impacts on non-EU economies remain small. If the carbon pricing mechanisms in non-EU countries had been considered when setting carbon tariffs, the negative impacts on developing countries would have been larger while some developed non-EU countries would have benefitted.

Our gravity and value chain analysis provide a few interesting cases of these effects. For example, tariffs imposed on cement, lime, and plaster (the Feasible 1 scenario) would result in a marked fall in the imports of intermediate products to France, especially from the UK. The main final producer is the construction industry. As a result, we expect to see an increase in the demand for local substitutes as these products are not easily transferable from a distance.

We note that these changes are due to the CBAM, ceteris paribus, while it could be that the allocative changes are partly offset by the EU climate policy and, for example, retaliatory measures from non-EU countries.

A global macroeconomic model (NiGEM) was used to measure the potential impacts of trade war, that is, the possibility of retaliation by the extra-EU countries, which may follow if/when the EU imposes a CBAM scheme. Based on our analysis, it is highly likely that the resulting trade war could wipe out any economic benefits of the CBAMs. For example, when the ROW retaliates to the EU tariff policies with an across-the-board 2 % increase in tariffs in the ROW's (non-commodity) goods imported from the EU countries, Finland and the eurozone suffer from a 0.3 % and 0.25 % GDP fall, respectively, in the long run. The US, and most notably China, faces smaller declines, even though in the long run, the decline of the US GDP is almost in line with the eurozone's.

In any case, there is a need to deal with the carbon leakage problem as we find signs in the data of its existence. It appears that the phases of the EU ETS have increased the carbon content in imported goods, especially in Phase 2. Furthermore, there is some evidence that the carbon content of imports has increased more in the product groups that are subjected to the EU ETS. The carbon leakage rate with our estimations is close to 20 %. This estimate is on the higher range of the estimates of previous studies that have used CGE methods to estimate carbon leakage.

7.2 Discussion

Our approach provides a unique multidisciplinary perspective on the CBAMs. Let us next discuss our different perspectives before making our conclusions in the next subsection.

To organize the discussion, we take stock of the public finance theory, a branch of economics that, broadly speaking, studies the role of government and the impacts of various revenue and expenditure instruments on the functioning of society. When discussing the different options for organizing climate policy, Stiglitz (2013) identified three basic aspects of instruments that need to be considered in design:

1. Efficiency—how to design instruments in order to minimize distortions?
2. Equity—How does the instrument affect different groups (What is its incidence?) and is the burden of the instrument, in some sense, fair?
3. Administration—Is the instrument effectively enforced, at reasonably low transaction costs, and relatively immune from corruption? Usually, also administrative burden for example from monitoring in the EU member state is included the third section.

It is fair to say that the design of the CBAM is still unclear at the EU level. At face value, it seems that the design of CBAMs necessarily creates trade-offs between the different features of good public finance instruments. To overcome the major problems that arise from the administration of the CBA (the major burden of collecting detailed information on emissions), there is a need for simplified, second-best, versions of the CBAs. The ways to simplify the design may include crude rules in regard to quantifying the adjustment or limitations of the scope of the adjustments. A simple design, however, may create problems in terms of the other aspects of good design. It may erode the fairness of the system (Would the CBAs treat extra-EU and EU countries similarly?), which can easily lead to legal disputes.

Moreover, the system may not be economically efficient as the crude rules may distort the incentives for climate actions or even lead to moral hazards. Similarly, the environmental benefits from the CBAM will be weakened if the EU relies on default carbon intensities to simplify implementation; because foreign producers will be treated equally regardless of their actual carbon intensity, they have a much more limited incentive to improve their environmental performance, whereas those who are already more carbon efficient than the default intensity are effectively penalized. A partial solution to that problem would be to offer importers the option to individually prove their actual carbon intensity with verified emissions data; such an "individual adjustment mechanism" would improve the incentive structure of the CBAM without significantly increasing the administrative burden for the implementing authorities.

Let us next discuss these aspects in more detail, based on our analysis.

7.2.1 Equity considerations

Fair and just CBAMs are easier to accept by third countries outside the EU and enforce in the light of WTO rules. Fairness demands that the chosen mechanism is a pure response to carbon leakage and no other mechanisms inside the EU is used for the same purpose.

In this respect, a few details are worth discussing. First, after implementing the CBAM, it is much harder to justify the commission continuing the free allocation of EU ETS allowances as a safeguard for the international competitiveness of industrial sectors at the risk of carbon leakage. Still, affected EU sectors have already indicated in their submissions to the Inception Impact Assessment consultation on the CBAM roadmap (held by the European Commission in spring 2020) that an abrupt ending to free allocation would be met with considerable opposition.

A compromise solution might be a gradual phase-out of free allocation alongside the introduction of the CBAM, with the CBAM only adjusting for the share of emissions for which EU producers in a sector benefitting from free allocation have to, on average, still purchase allowances since the current system of free allocation only ensures that the 10 % most efficient producers obtain 100 % emissions coverage, whereas the remaining 90 % have to buy a varying amount based on the difference between their actual emissions and the product benchmark that applies to them.

When our results suggest that carbon leakage may indeed offset some of the effects of the EU's climate policy and the EU ETS, at least in the current policy context, it is worth noting that the new and possible amended policy instruments are also not neutral in this sense similarly to the CBAMs. When the use of the Market Stability Reserve raises carbon prices in the EU, it may again add the leakage risk if the CBAM tariffs do not properly react to the price increase. The possible roles of the reserve should also be transparent in CBAMs. Energy taxes and their levels inside the EU may also have at least indirect effects on the carbon prices. Thus, although the need for a CBAM is based on wide political reasoning about, for example, suitable energy tax levels or even compensation for the Covid-19 costs, the assessment of CBAM tariffs should be transparent, fair, and just. Moreover, international and third countries' ETSs and international carbon units or credits should somehow be considered in the new CBAM and its tariffs. Thus, operative climate policy instruments should link up the CBAM in a fair and just way. However, even in spite of the possible formal fairness, the CBAM may lead to the above-mentioned countermeasures against the EU. The risk of countermeasures is lower if the CBAM is duly justified to the non-EU countries.

7.2.2 Efficiency considerations

From the efficiency perspective, a well-designed climate policy should aim at correctly pricing the societal cost of the emissions and create sufficient incentives for achieving environmental sustainability. In a second-best world, where common, global climate policy is not in place, the CBAM can be used as one instrument for achieving efficiency.

While previous literature has already broadly discussed CBAMs, in this study we have paid special attention to the details of the design and the structure of trade in products that would be the most likely to be subjected to the CBAMs.

The most feasible design would only involve cement and related products; based on our results, in all likelihood it would only have a small effect on both trade and emissions. Moreover, we do not find particularly strong evidence of carbon leakage in the non-metallic mineral sector. The narrow CBAM's strongest impacts would be narrowed down to some specific areas, possibly in trade between France and the UK.

Thus, while the narrowest scenario with only cement and related products might be easy to administer and lack some of the legal challenges that would accompany a CBAM affecting a broader set of products, it is fair to say that it would be an economically and environmentally weak solution to carbon leakage and thus to the climate challenge. In its documents and statements to date, the European Commission has repeatedly signaled an intention to start with "selected sectors" and gradually expand thereafter. The main merit of such an approach would be the opportunity to pilot the CBAM with a limited measure that risks fewer diplomatic confrontations and legal challenges, and allows demonstrating the "proof of concept" as it were. Still, if effective leakage prevention is the mid- to long-term objective in an EU with significantly more robust decarbonization targets, then such a limited scope will not be sufficient.

In the case of broader scenarios, the effect of the CBAMs would, unsurprisingly, become greater, and thus it is expected that they will have a substantial impact on the carbon leakage. From the efficiency perspective, the extension of the system puts increasing pressure on the level of detail in the design of the CBAMs. In particular, as we observed large flows of final and intermediate goods to the EU area from extra-EU countries, an efficiently designed CBAM should account for the arising diversity of production linkages.

For one, the CBAM should account for emissions in all stages of production and cover industries that use emission-intensive materials in their downstream production. The value chain data suggests that large quantities of emission-intensive materials are used in the final production of other products, such as manufactures. If the border adjustment is not extended to these products, it may give a competitive advantage to the extra-EU imports that use emission-intensive materials (which are left outside the

CBAM) as intermediate goods and thus leave the system vulnerable to carbon leakage. While the inclusion of semi-manufactured and manufactured goods would significantly increase the technical complexity of the CBAM, not taking into account such downstream substitution and leakage risks would pose a serious environmental and political problem that may otherwise necessitate alternative solutions, such as state aid for disadvantaged intermediate producers in the EU.

While a carefully designed CBAM for imported products could compensate for the competition effect that differing climate policies have on production costs in the EU market, the disparity remains beyond the EU borders if a similarly ambitious climate policy is not conducted there. From the global climate-policy perspective, this is inefficient if the extra-EU countries turn to using their own more emission-intensive products that are not burdened by a similar cost to the cost of the climate policy that the EU products face. The problem is the most severe in areas where the extra-EU demand is highly price elastic (i.e., where the demand reacts strongly to changes in product prices). Based on our findings concerning the sensitivity of imports to tariffs (presented in Section 5), for example aluminum and miscellaneous electrical products fall into this category.

In principle, the CBAMs could be extended to involve export rebates to resolve this issue, but such a feature would be hard to implement in accordance with international trade law. One way to adjust for exports would be to continue the free allocation to products leaving the EU, thereby counteracting competitiveness impacts due to EU climate policy. However, because such an export adjustment would be contingent on export performance, it risks violating the WTO the SCM Agreement as a prohibited subsidy; moreover, unlike the GATT, this agreement does not contain an exception clause that would allow justifying environmentally motivated measures.

In absence of export rebates, there is still pressure to compensate for the price differences by using free allowance allocation to mitigate the cost impacts on EU exports of a more ambitious climate policy. Free allowance allocation, on the other hand, weakens the effects of the carbon pricing as the amount of free allowance is linked to the amount of current economic activity. Due to this design, firms that produce and generate emissions more today, tend to receive more free allowances in the future. The resulting expectations of future free allowances may, at least in some cases, mute the response of current production decisions to changes in the current carbon price.

In particular, free allocations may distort incentives for climate actions, both in production value chains and in final demand. For example, they may induce the allocation of resources to carbon-intensive production and thus result in the partial pass-through of the carbon price, at least when product market competition is imperfect and firms have pricing power. As a result, there may be more carbon-intensive production under the existence of free allowances than the EU ETS would otherwise suggest. As we have found that there are strong value chain connections between the EU and extra-EU countries, it is possible that the existence of free allocations generates disruptions to the emission efficiency of the value chains.

As an alternative solution, complementary tax instruments or direct subsidies have been proposed. For example, one way to overcome these problems would be to complement the current system with an emission-added tax (Stiglitz, 2013). In essence, the emission-added tax (in an analogy with value-added tax) is a consumption tax that is placed on a product whenever emissions are added at each stage of the supply chain, until the product is sold for final use. The amount of tax that the user pays is based on the production emissions, less any of the emissions of intermediate products that have already been taxed. If products are exported to other regions, they are taxed at a zero rate. On the other hand, imports would be subjected to the same tax treatment as EU products when they are sold in the EU area.

The general benefits of the emission-added tax would be that (1) as a consumption (rather than a production) tax, it would not generate incentives to divert production from countries that have a stricter climate policy and (2) it allows production to be flexibly organized into value chains (Stiglitz, 2013). Most of the critique of such a tax concerns the challenges of its technical implementation (see, e.g., McLure, 2010). As in the case of CBAMs, the system induces a substantial administrative burden when the amount of emissions in the imported goods are assessed and the system should be made consistent with the EU ETS. The broader the implementation, the bigger the informational problem becomes. However, as we have discussed, the CBAM would face similar challenges.

As in the case of CBAMs, the practical implementation issues could be, to some extent, resolved by limiting the scope of the tax to specific products and emissions. Indeed, the inclusion of consumption (IoC) of carbon-intensive materials in emission trading has emerged as one more practical ways of moving ahead. For example, in the proposal by Neuhoff et al. (2016), a liability would be created upon the production of carbon-intensive materials, and the liability is then passed onto products along the value chain.

According to the proposal, firms can register with national authorities to receive, handle, and dispatch products under duty suspension arrangements or buy products free of liability. When a product is sold to a non-registered firm or to a consumer, the seller has to pay a charge to a national trust fund that is then to be used for climate action. The same liability for the charge is also created upon the import of carbon-intensive products and acquitted upon their export. A de minimis rule limits administrative effort.

Arguably, the proposal would help to compensate for some of the weaknesses of the CBAMs. Namely, when combined with a reduction of the free allocations, the proposal would increase the symmetry in the treatment of EU and extra-EU products, both in the EU market and globally.

In particular, the possibility to acquit the liability upon exporting to extra-EU countries could partially mitigate the cost impact of the EU climate policy, a feature that would allow the reduction of the free allocations of emissions (which could be auctioned instead). Consequently, in the EU market, the reduction of free allocations could level the playing field for the imported and domestic materials and build avenues for the further reduction of emissions in the value chains. Moreover, the inclusion of the liability as a consumption tax rather than a tariff could calm the political tensions that the tariff would generate.

However, limiting the system to only a few industries is not without problems. In industries that would not be part of the IoC system, the direct emissions would still generate cost disparities in the extra-EU market, albeit they may benefit from the cost reductions on their intermediate goods. Thus, the cost mitigation effect would not be complete. Also, in the EU market the treatment of direct emissions in the other industries would still necessitate the use of CBAMs. Without a fully implemented emission-added tax system, there would be still a need for both the CBAM and free allocations as complementary tools.

All in all, the benefits of the IoC remain to be seen. In any case, the relative benefits of the tax system would increase together with its scope. In the case of having both a CBAM and an emission-added tax, the informational and administrational burdens could be broadly similar, whereas the tax system would not necessitate the use of free allocations as a complementary policy tool if its scope is broad.

While the emission-added tax could help to decrease the use of free allocations, a remaining problem is that it does not incentivize the emission reductions of the EU exports. They would be zero-taxed at the EU border, while they may be subjected to less stringent climate-policy measures in the extra-EU countries. One option is to use direct government support for the financing in the energy efficiency improvements in order to foster the reduction of the emissions (Sartor and Bataille, 2019). However, careful attention should be given to the design and control of the support as the use of direct research and development subsidies easily leads to the inefficient selection of technologies.

7.2.3 Administrative considerations

Finally, the administrative burden of the CBAM fundamentally depends on the implementation. It can be directly connected to the EU ETS or it can be a tax or tariff set at a level to reflect the carbon price in the EU ETS. As there are still large uncertainties, detailed conclusions about its administrative burden in Finland and the EU are premature, although it is safe to say that, as a policy applied to imports taking into account carbon intensity and potentially also carbon prices in the country of origin, it will be more complex to administer than most domestic taxes.

7.3 Conclusions

One of the key risks of climate policy, both for the climate and for the economy, is that rising carbon constraints, such as carbon prices, can lead to carbon leakage. In the EU, the use of carbon tariffs on imports from non-EU countries has gained momentum as a proposed solution to the problem. The creation of a CBAM was identified in the European Green Deal as a means to help with the transition towards a greener and more sustainable economy. In addition, the European Commission indicated that green own budget resources—including revenue from the CBAM—could contribute to financing the future EU budget, for recovery and growth in the wake of the COVID-19 pandemic.

Based on our analysis, it is fair to expect that the CBAM will face major implementation hurdles in the coming years. From the perspectives of efficiency, fairness, and technical challenges, it is reasonable to assume that the process towards its full implementation will be gradual and burdensome. As envisaged by past proposals, the likeliest approach would be to test its use with a narrow set of imported products that are emission intensive, yet easy to administer and simple to produce. After considering a feasible alternative, we found that the economic and environmental impact of such a narrow tariff would be likely to be small. Thus, the implementation of such a CBAM serves more as a signal of the determination of the EU to address the climate problem and the attendant carbon leakage rather than a true solution to it.

On the other hand, if the EU introduces a more ambitious CBAM, whether initially or over time, it will inevitably face greater difficulties. A CBAM should be constructed in a fair and efficient manner that could help it to avoid any intentional or plausible conflict with WTO law and unnecessary disruptions of production value chains. However, as our results show, the global production linkages are complex, and an orderly and ambitious implementation of a CBAM faces the significant task of data collection and administration. Further mechanisms to incentivize information gathering (such as self-reporting) and also complementary tools to replace free allowance distribution (an emission-added tax, technology subsidies) may be necessary in the future.

No matter how well a CBAM is constructed and communicated to EU trading partners, it is likely to face challenges from those who are affected. In our results, China in particular appears as a country that would be strongly affected by the tariffs if they are implemented in an ambitious way. Retaliatory countermeasures could easily remove any economic benefits of the tariffs. Thus, one should exercise caution, especially when considering a CBAM as a possible source of EU resources, albeit that the tariff is directly paid by EU companies and consumers. The fiscal incentive and the uncertainty of where the resources might be used are features that may weaken its value as a source of public revenue. The use of a CBAM as a source of revenue generation rather than a mechanism for the prevention of leakage does not strengthen the WTO compatibility and may exacerbate trade tensions.

One might, of course, argue that WTO compatibility has become a lesser priority due to the paralysis of the Appellate Body and the COVID-19 health crisis. However, it may be very harmful for the progress within the UN climate conference if measures that appear contrary to international commitments and the rules-based international order are taken by an actor simultaneously seeking to strengthen multilateral cooperation on climate change. If the EU, in order to finance the relief package or for other non-climate related reasons, implements a CBA in a way that appears contrary to WTO rules, it will undermine the credibility of any EU efforts at the Conference of the UNFCCC Parties. If there is no significant progress in these negotiations between the major emitters of GHGs within the next three years, possible WTO retaliation measures will pale in comparison to the dire consequences of such a failure. Thus, using an EU CBAM for fiscal purposes rather than purely for the prevention of carbon leakage undermines its equity and ultimately its efficiency as a policy instrument in international climate law.

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Appendix 1. Product groups in the EXIOBASE3 database

Table A1. Product groups in the EXIOBASE3 database (EXIOBASE, 2020).

1	Additives/blending components
2	Air transport services
3	Aluminium and aluminium products
4	Aluminium ores and concentrates
5	Animal products n.e.c.
6	Anthracite
7	Ash for treatment, re-processing of ash into clinker
8	Aviation gasoline
9	Basic iron and steel and of ferro-alloys and first products thereof
10	Beverages
11	Biodiesels
12	Biogas
13	Biogasoline
14	Bitumen
15	BKB/peat briquettes
16	Blast furnace gas
17	Bottles for treatment, recycling of bottles by direct reuse
18	Bricks, tiles and construction products, in baked clay
19	Cattle
20	Cement, lime and plaster
21	Ceramic goods
22	Cereal grains n.e.c.
23	Charcoal
24	Chemical and fertilizer minerals, salt and other mining and quarrying products n.e.c.
25	Chemicals n.e.c.
26	Coal tar
27	Coke oven coke
28	Coke oven gas
29	Coking Coal
30	Collected and purified water, distribution services of water
31	Computer and related services
32	Construction work
33	Copper ores and concentrates
34	Copper products
35	Crops n.e.c.
36	Crude petroleum and services related to crude oil extraction, excluding surveying
37	Dairy products
38	Distribution and trade services of electricity
39	Distribution services of gaseous fuels through mains
40	Education services
41	Electrical machinery and apparatus n.e.c.
42	Electricity by biomass and waste
43	Electricity by coal
44	Electricity by gas
45	Electricity by geothermal
46	Electricity by hydro

47	Electricity by nuclear
48	Electricity by petroleum and other oil derivatives
49	Electricity by solar photovoltaic
50	Electricity by solar thermal
51	Electricity by tide, wave, ocean
52	Electricity by wind
53	Electricity n.e.c.
54	Ethane
55	Extra-territorial organizations and bodies
56	Fabricated metal products, except machinery and equipment
57	Financial intermediation services, except insurance and pension funding services
58	Fish and other fishing products; services incidental of fishing
59	Fish products
60	Food products n.e.c.
61	Food waste for treatment: biogasification and land application
62	Food waste for treatment: composting and land application
63	Food waste for treatment: incineration
64	Food waste for treatment: landfill
65	Food waste for treatment: waste water treatment
66	Foundry work services
67	Furniture; other manufactured goods n.e.c.
68	Gas coke
69	Gas works gas
70	Gas/diesel oil
71	Gasoline type jet fuel
72	Glass and glass products
73	Health and social work services
74	Heavy fuel oil
75	Hotel and restaurant services
76	Inert/metal/hazardous waste for treatment: landfill
77	Inland water transportation services
78	Insurance and pension funding services, except compulsory social security services
79	Inert/metal waste for treatment: incineration
80	Iron ores
81	Kerosene
82	Kerosene type jet fuel
83	Lead, zinc and tin, and products thereof
84	Lead, zinc and tin ores and concentrates
85	Leather and leather products
86	Lignite/brown coal
87	Liquefied petroleum gases (LPGs)
88	Lubricants
89	Machinery and equipment n.e.c.
90	Manure (biogas treatment)
91	Manure (conventional treatment)
92	Meat animals n.e.c.
93	Meat products n.e.c.
94	Medical, precision and optical instruments, watches and clocks
95	Membership organisation services n.e.c.
96	Motor gasoline
97	Motor vehicles, trailers and semi-trailers
98	Naphtha

99	Natural gas and services related to natural gas extraction, excluding surveying
100	Natural gas liquids
101	N-fertiliser
102	Nickel ores and concentrates
103	Non-specified petroleum products
104	Nuclear fuel
105	Office machinery and computers
106	Oil seeds
107	Oil/hazardous waste for treatment: incineration
108	Other bituminous coal
109	Other business services
110	Other hydrocarbons
111	Other land transportation services
112	Other liquid biofuels
113	Other non-ferrous metal ores and concentrates
114	Other non-ferrous metal products
115	Other non-metallic mineral products
116	Other services
117	Other transport equipment
118	Other waste for treatment: waste water treatment
119	Oxygen steel furnace gas
120	P-fertiliser and other fertilisers
121	Paddy rice
122	Paper and paper products
123	Paper and wood waste for treatment: composting and land application
124	Paper for treatment: landfill
125	Paper waste for treatment: biogasification and land application
126	Paper waste for treatment: incineration
127	Paraffin waxes
128	Patent fuel
129	Peat
130	Petroleum coke
131	Pigs
132	Plant-based fibers
133	Plastic waste for treatment: incineration
134	Plastic waste for treatment: landfill
135	Plastics, basic
136	Post and telecommunication services
137	Poultry
138	Precious metal ores and concentrates
139	Precious metals
140	Printed matter and recorded media
141	Private households with employed persons
142	Processed rice
143	Products of forestry, logging and related services
144	Products of meat cattle
145	Products of meat pigs
146	Products of meat poultry
147	Products of vegetable oils and fats
148	Public administration and defence services; compulsory social security services
149	Pulp
150	Radio, television and communication equipment and apparatus

151	Railway transportation services
152	Raw milk
153	Real estate services
154	Recreational, cultural and sporting services
155	Refinery feedstocks
156	Refinery gas
157	Renting services of machinery and equipment without operator and of personal and household goods
158	Research and development services
159	Retail trade services, except of motor vehicles and motorcycles; repair services of personal and household goods
160	Retail trade services of motor fuel
161	Rubber and plastic products
162	Sale, maintenance, repair of motor vehicles, motor vehicle parts, motorcycles, motorcycle parts and accessories
163	Sand and clay
164	Sea and coastal water transportation services
165	Secondary aluminium for treatment, re-processing of secondary aluminium into new aluminium
166	Secondary construction material for treatment, re-processing of secondary construction material into aggregates
167	Secondary copper for treatment, re-processing of secondary copper into new copper
168	Secondary glass for treatment, re-processing of secondary glass into new glass
169	Secondary lead for treatment, re-processing of secondary lead into new lead
170	Secondary other non-ferrous metals for treatment, re-processing of secondary other non-ferrous metals into new other non-ferrous metals
171	Secondary paper for treatment, re-processing of secondary paper into new pulp
172	Secondary plastic for treatment, re-processing of secondary plastic into new plastic
173	Secondary precious metals for treatment, Re-processing of secondary precious metals into new precious metals
174	Secondary raw materials
175	Secondary steel for treatment, Re-processing of secondary steel into new steel
176	Services auxiliary to financial intermediation
177	Sewage sludge for treatment: biogasification and land application
178	Steam and hot water supply services
179	Stone
180	Sub-bituminous coal
181	Sugar
182	Sugar cane, sugar beet
183	Supporting and auxiliary transport services; travel agency services
184	Textiles
185	Textiles waste for treatment: incineration
186	Textiles waste for treatment: landfill
187	Tobacco products
188	Transmission services of electricity
189	Transportation services via pipelines
190	Uranium and thorium ores
191	Wearing apparel; furs
192	Vegetables, fruit, nuts
193	Wheat
194	White spirit & SBP
195	Wholesale trade and commission trade services, except of motor vehicles and motorcycles
196	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials
197	Wood material for treatment, re-processing of secondary wood material into new wood material
198	Wood waste for treatment: incineration
199	Wood waste for treatment: landfill
200	Wool, silk-worm cocoons

Appendix 2. Structural gravity model: A technical introduction

A2.1 The structural gravity model

The structural gravity model is a tractable framework for trade policy analysis in a multi-country environment. It has been widely used in empirical international trade literature (e.g., Anderson and Yotov, 2010; Anderson and Van Wincoop, 2003; Helpman, Melitz, and Rubinstein, 2008; Egger and Larch, 2011; Head and Mayer, 2014; Brakman, Kohl, and Van Marrewijk, 2015; Bekkers and Rojas-Romagosa, 2018; and Nilsson Hakkala et al., 2019).

An important element in the structural gravity model is the so-called multilateral resistance (MLR) terms, which are related to price indices. When these price index terms are included, changes in tariffs change the MLR terms, thus affecting the entire trading system because trade between any pair of countries takes place against the background of changed price indices. The fixed effects in the estimation cover country, year, and industry factors. We thus have origin–industry–time effects, destination–industry–time effects, and origin–destination, industry-specific terms (see Larch, Wanner, Yotov, and Zylkin, 2017). They absorb the country and industry-size variables from the structural gravity model as well as all other observable and unobservable country and industry-specific characteristics that vary across these dimensions, including national policies, institutions, and exchange rates. Country-pair fixed effects cover all time-invariant bilateral factors, such as distance, a common language, or a historical colonial tie. The pair's fixed effects can also account for endogeneity in trade policy variables (Baier and Bergstrand, 2007).

A2.2 Model specification

We closely follow the work of Yotov, Piermartini, Monteiro, and Larch (2016) in the exposition of the structural gravity system, and also discussed in Nilsson Hakkala et al. (2019). We construct a world with *N* countries. Each country produces a variety of goods that are differentiated by the country of origin (Armington, 1969). These products are traded internationally. We omit the time dimension t from the equations to simplify them.

The value of domestic production (the GDP) in country *i* is given by $Y_i = p_i Q_i$, where Q_i is the volume of output and pi is its factory-gate price. Aggregate expenditure is denoted by E_i. If output and expenditure are equal, the country's trade account is balanced. If expenditure exceeds output, the country is running a trade deficit.

Consumers maximize a homothetic constant elasticity of scale (CES) utility function that is identical across all countries. In country *j*, it is given by:

$$\left[\sum_i \alpha^{\frac{1-\sigma}{\sigma}} c_{ij}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma-1}{\sigma}}, \tag{1.1}$$

where $\sigma > 1$ is the elasticity of substitution between the different varieties of products originating from different countries, $\alpha > 0$ is an exogenous preference, and c_{ij} denotes the consumption in country *j* of products produced in country *i*. Consumers' budget constraint is given by:

$$\sum_i p_{ij} c_{ij} = E_j. \tag{1.2}$$

Delivered prices, $p_{ij} = p_i t_{ij}$, are given by the factory-gate prices in the country of origin, multiplied by bilateral trade costs $t_{ij} \geq 1$ between countries *i* and *j*. Bilateral trade costs are defined as iceberg costs (Samuelson, 1952), meaning that a part of the shipment "melts" *en route* to its destination.

Solving the consumers' optimization problem, we find that exports X_{ij} from country *i* to country *j* are given by:

$$X_{ij} = \left(\frac{\alpha_i p_i t_{ij}}{P_j} \right)^{1-\sigma} E_j, \tag{1.3}$$

where

$$P_j = \left[\sum_i \left(\alpha_i p_i t_{ij} \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{1.4}$$

is a CES consumer price index.

Some conclusions arise from these equations. When all else is equal, larger and/or richer countries consume more of all varieties from all source countries. Imports from country *i* are affected negatively by higher factory gate prices and higher bilateral trade costs.

The relatively more expensive other countries' varieties are, the more consumers in country *j* will substitute away from them and toward the goods from country *i*. Furthermore, a higher elasticity of substitution will increase the trade diversion effects from more expensive commodities to cheaper ones.

Market clearance for goods from each origin is given by:

$$Y_i = \sum_j \left(\frac{\alpha_i p_i t_{ij}}{P_j} \right)^{1-\sigma} E_j \quad . \tag{1.5}$$

Accordingly, the value of output at delivered prices in country *i*, Y_i, is equal to the total expenditure of this country's variety in all countries, including i itself. We next define $Y \equiv \sum_i Y_i$ and divide the market clearing condition by *Y*. After rearranging we get

$$\left(\alpha_i p_i\right)^{1-\sigma} = \frac{\frac{Y_i}{Y}}{\sum_j \left(\frac{t_{ij}}{P_j} \right)^{1-\sigma} \frac{E_j}{Y}} \quad . \tag{1.6}$$

The term in the denominator can be rewritten as $\Pi_i^{1-\sigma} \equiv \sum_j \left(t_{ij} / P_j \right)^{1-\sigma} E_j / Y$ (Anderson and van Wincoop, 2003). Consequently,

$$\left(\alpha_i p_i\right)^{1-\sigma} = \frac{Y_i / Y}{\Pi_i^{1-\sigma}} \quad . \tag{1.7}$$

The structural gravity system is thus given by three equations:

$$X_{ij} = \frac{Y_i E_j}{Y} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} , \tag{1.8}$$

$$\Pi_i^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{P_j} \right)^{1-\sigma} \frac{E_j}{Y} , \tag{1.9}$$

$$P_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{\Pi_i} \right)^{1-\sigma} \frac{Y_i}{Y} \quad . \tag{1.10}$$

The first equation can be divided into two terms, a size term, $Y_i E_j / Y$, and a trade cost term, $\left[t_{ij} / \left(\Pi_i P_j \right) \right]^{1-\sigma}$. Accordingly, exports *X* from country *i* to country *j* depend positively on output *Y* in country *i*, expenditure *E* in county *j* (i.e., GDP in the two countries) and negatively on world GDP. Based on these equations, large producers will export more to all destinations, big/rich markets will import more from all source countries, and trade flows between countries *i* and *j* will be larger the more similar in size the countries are.

In trade cost terms, inward multilateral resistance (P_j) represents importer *j*'s ease of market access (see Anderson and van Wincoop, 2003). Outward multilateral resistances, Π_i, measures exporter *i*'s ease of market access. These are affected by, among other things, tariffs and non-tariff barriers between the countries. Multilateral resistances translate the initial, partial equilibrium effects of trade policy at the bilateral level into country-specific effects on consumer and producer prices (Yotov, Piermartini, Monteiro, and Larch, 2016).

A2.3. The estimation method

We use Poisson pseudo maximum likelihood (PPML) estimation—more specifically, its ppml_panel_sg version in STATA. The use of PPML is encouraged by Santos Silva and Tenreyro (2006). This method allows us to use pair-fixed effects in a multiplicative space. Importantly, PPML also allows for the existence of trade flows that are equal to zero. In a linear, logarithmic ordinary least squares (OLS) estimation, these would impose a problem because one cannot calculate their logarithms. This is particularly important when we estimate the impact on different sectors because in this case there are a lot of zero trade flows between countries.

PPML also accounts for heteroscedasticity, its additive property ensures that the gravity-fixed effects are identical to their corresponding structural terms, and the estimator can also be used to calculate the theory-consistent general equilibrium effects of trade policies (Yotov, Piermartini, Monteiro, and Larch, 2016).

The estimated model is given by:

$$M_{ijkt} = \exp\left(\pi_{ikt} + \chi_{jkt} + \mu_{ijk} + \beta_1 tariff + \beta_2 CBAM\right) * e_{ijkt}$$

where M_{ijkt} are the imports of product/sector *k* by reporter country *i* from partner country *j* in year *t*. The term π_{ikt} represents the time-varying reporter-country dummies by sector, which controls for the outward multilateral resistances, output shares, and, potentially, other observable and unobservable factors that may affect bilateral trade. χ_{jkt} is the same for partner country *j*. The term μ_{ijk} denotes the set of country-pair fixed effects by sector. In the equation tariff is the tariff elasticity of imports calculated by sectors from global trade during 2000–2018, and CBAM is the CBAM tariffs by sector, calculated in the EXIOBASE database using the formulation shown in Section 3.2.

Appendix 3: Global value chains – A technical introduction and appendix tables

We next formally represent the exclusion method that we use to analyze the global value chains. Similar to Los, Timmer, and de Vries (2016) and Ali-Yrkkö and Kuusi (2020a, 2020b), we partition the global input–output table. In our case, we have a region s that sets up a carbon border adjustment (CBA) for trade with a region r. Each region consists of countries c. After noting that we refer to input–output tables in a certain year t, while abstract from the further use of time indices, we construct a matrix A as follows:

$$\boldsymbol{A} = \begin{bmatrix} \boldsymbol{A}_{ss} & \boldsymbol{A}_{sr} \\ \boldsymbol{A}_{rs} & \boldsymbol{A}_{rr} \end{bmatrix}.$$

In the equation A contains the input coefficients , which give the value units of intermediate goods from industry i required to produce one value unit of gross output in industry j. In the equation represents the domestically purchased requirements of industries in country s, while gives the requirements by industries in r of products bought from industries in s. For the final demand block, we can similarly write the following:

$$\boldsymbol{y} = \begin{bmatrix} \boldsymbol{y}_{ss} & \boldsymbol{y}_{sr} \\ \boldsymbol{y}_{rs} & \boldsymbol{y}_{rr} \end{bmatrix}$$

in which the vectors and represent the values of flows from industries in country s to all domestic final users and to final users in r.

For any country c, ratios of value added to gross output in industries in country c are contained in a row vector . The length of this vector equals the numbers of industries in s and r (with r containing multiple countries), with value-added ratios for industries in c as elements () and zeros elsewhere: =. The actual value added in country c () then equals

$$\boldsymbol{GDP}_c = \boldsymbol{v}_c(\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{Y} * \boldsymbol{i}$$

in which i is a column vector wherein all elements are unity, implying that it sums the two elements in each of the rows of the matrix Y. The element is the well-known Leontief inverse, in which I is the identity matrix of appropriate dimensions. The expression is the key to accounting for the complexity of the trade patterns. In particular, can be interpreted as the limiting value of the infinitely long sum of value-added contributions, with the number of stages varying from 1 to ∞.

Our estimation of the value-added impact builds on the sector-level gravity model. The gravity model allows us to build a counterfactual that measures trade flows in the absence of the trade agreement. Let us denote the counterfactual of trade from country-industry i to country-industry j with the symbol *. Then, the corresponding final trade is denoted by and the intermediate use by .

It is notable that our trade model does not allow us to distinguish the effects of the CBAs on intermediate and final goods separately. Therefore, the percentual effect on both flows is the same and given by the overall impact in the gravity model. For example, if the trade model forecasts an x % decrease in the volume of this particular bilateral trade, we adjust the amount of final demand to be and .

After constructing all the bilateral counterfactual trade flows, we create hypothetical global value chains with the impact of CBAs by collecting the bilateral flows into our expression of the aggregate value added. We define the matrices and as

$$\boldsymbol{A}^{*} = \begin{bmatrix} \boldsymbol{A}_{ss} & \boldsymbol{A}_{sr}^{*} \\ \boldsymbol{A}_{rs}^{*} & \boldsymbol{A}_{rr} \end{bmatrix}$$

and

$$\boldsymbol{Y}^{*} = \begin{bmatrix} \boldsymbol{y}_{ss} & \boldsymbol{y}_{sr}^{*} \\ \boldsymbol{y}_{rs}^{*} & \boldsymbol{y}_{rr} \end{bmatrix}$$

where we have replaced bilateral trade flows from r to s, and vice versa, with the counterfactuals. More generally, s can be a group of countries corresponding with all extra-EU partners that will be subjected to the CBA.

The hypothetical GDP in c can be obtained by post-multiplying the hypothetical Leontief inverse with the hypothetical final demand as

$$\boldsymbol{GDP}_{r}^{*} = \boldsymbol{v}_{r}(\boldsymbol{I} - \boldsymbol{A}^{*})^{-1}\boldsymbol{Y}^{*} * \boldsymbol{i}.$$

Following the logic of hypothetical extraction, the domestic value added in exports of r that result from the free trade agreement with country s can be derived as the difference between the GDP in the actual and hypothetical situations:

$$\boldsymbol{\Delta VA}_{r} = \boldsymbol{GDP}_{r} - \boldsymbol{GDP}_{r}^{*}.$$

 correctly measures the indirect and direct effects on the value chains and trade routes that follow from the exclusion of the direct trade linkage for region r.

Table A3.1. The CBA-related value-added loss in intermediate products, decomposed by the final producer industry in the EU

Sector	(a) Intermediate value-added import loss: Loss of value-added contribution for the row final producer industry, as relative to the total value-added loss in the scenario, %.				(b) Intermediate value-added import loss: Loss of value-added contribution for the row final producer industry, as relative to the total value of the same industry, %.			
	Feasible 1:	Feasible 2:	Efficient 1: all emissions	Efficient 2: direct + electricity emissions	Feasible 1:	Feasible 2:	Efficient 1: all emissions	Efficient 2: direct + electricity emissions
Crop and animal production, hunting and related service activities	1.0 %	0.6 %	1.1 %	1.2 %	0.0 %	0.0 %	0.2 %	0.1 %
Forestry and logging	0.1 %	0.0 %	0.1 %	0.1 %	0.0 %	0.0 %	0.1 %	0.0 %
Fishing and aquaculture	0.1 %	0.1 %	0.1 %	0.1 %	0.0 %	0.0 %	0.2 %	0.1 %
Mining and quarrying	0.2 %	0.2 %	0.1 %	0.2 %	0.0 %	0.0 %	0.0 %	0.0 %
The manufacture of food products, beverages, and tobacco products	5.1 %	3.6 %	4.6 %	4.9 %	0.0 %	0.0 %	0.6 %	0.4 %
The manufacture of textiles, wearing apparel, and leather products	0.7 %	0.6 %	1.2 %	1.2 %	0.0 %	0.0 %	0.6 %	0.3 %
The manufacture of wood and of products of wood and cork, except furniture; the manufacture of articles of straw and plaiting materials	0.2 %	0.1 %	0.2 %	0.2 %	0.0 %	0.0 %	0.2 %	0.1 %
The manufacture of paper and paper products	0.2 %	0.2 %	0.3 %	0.3 %	0.0 %	0.0 %	0.2 %	0.1 %
Printing and reproduction of recorded media	0.0 %	0.0 %	0.1 %	0.1 %	0.0 %	0.0 %	0.1 %	0.1 %
The manufacture of coke and refined petroleum products	5.6 %	2.3 %	2.2 %	2.4 %	0.0 %	0.1 %	3.0 %	1.9 %
The manufacture of chemicals and chemical products	1.2 %	0.8 %	2.2 %	2.3 %	0.0 %	0.0 %	0.5 %	0.3 %
The manufacture of basic pharmaceutical products and pharmaceutical preparations	0.7 %	0.5 %	1.9 %	2.0 %	0.0 %	0.0 %	0.6 %	0.4 %
The manufacture of rubber and plastic products	0.4 %	0.4 %	0.9 %	1.0 %	0.0 %	0.0 %	0.3 %	0.2 %

The manufacture of other non-metallic mineral products	1.6 %	0.3 %	0.3 %	0.4 %	0.0 %	0.0 %	0.2 %	0.1 %
The manufacture of basic metals	0.2 %	1.5 %	0.4 %	0.5 %	0.0 %	0.0 %	0.2 %	0.1 %
The manufacture of fabricated metal products, except machinery and equipment	0.8 %	6.7 %	2.1 %	2.3 %	0.0 %	0.1 %	0.4 %	0.2 %
The manufacture of computer, electronic and optical products	0.8 %	2.1 %	8.0 %	6.6 %	0.0 %	0.0 %	2.6 %	1.2 %
The manufacture of electrical equipment	0.8 %	3.7 %	3.0 %	2.8 %	0.0 %	0.1 %	1.0 %	0.5 %
The manufacture of machinery and equipment n.e.c.	2.1 %	11.8 %	7.6 %	7.4 %	0.0 %	0.1 %	1.1 %	0.6 %
The manufacture of motor vehicles, trailers, and semi-trailers	3.5 %	13.8 %	9.9 %	9.8 %	0.0 %	0.1 %	1.7 %	0.9 %
The manufacture of other transport equipment	1.2 %	3.2 %	2.6 %	2.4 %	0.0 %	0.1 %	1.5 %	0.8 %
The manufacture of furniture; other manufacturing	1.0 %	2.5 %	2.4 %	2.6 %	0.0 %	0.0 %	0.9 %	0.6 %
The repair and installation of machinery and equipment	0.6 %	1.8 %	1.3 %	1.3 %	0.0 %	0.0 %	0.5 %	0.3 %
Electricity, gas, steam, and air conditioning supply	3.0 %	1.6 %	1.6 %	1.6 %	0.0 %	0.0 %	0.2 %	0.1 %
Water collection, treatment, and supply	0.2 %	0.3 %	0.2 %	0.2 %	0.0 %	0.0 %	0.2 %	0.1 %
Sewerage; waste collection, treatment, and disposal activities; materials recovery; remediation activities and other waste management services	0.3 %	0.9 %	0.4 %	0.4 %	0.0 %	0.0 %	0.2 %	0.1 %
Construction	43.8 %	18.0 %	14.0 %	14.7 %	0.0 %	0.0 %	0.7 %	0.4 %
Wholesale and retail trade and the repair of motor vehicles and motorcycles	0.9 %	1.1 %	1.2 %	1.2 %	0.0 %	0.0 %	0.2 %	0.1 %
Wholesale trade, except trade of motor vehicles and motorcycles	1.9 %	2.1 %	2.3 %	2.4 %	0.0 %	0.0 %	0.1 %	0.1 %

Retail trade, except trade of motor vehicles and motorcycles	1.9 %	1.6 %	2.0 %	2.0 %	0.0 %	0.0 %	0.1 %	0.1 %
Land transport and transport via pipelines	1.6 %	1.1 %	1.0 %	1.0 %	0.0 %	0.0 %	0.1 %	0.1 %
Water transport	0.5 %	0.4 %	0.4 %	0.4 %	0.0 %	0.0 %	0.3 %	0.2 %
Air transport	0.6 %	0.4 %	0.4 %	0.4 %	0.0 %	0.0 %	0.4 %	0.2 %
Warehousing and support activities for transportation	0.5 %	0.6 %	0.5 %	0.5 %	0.0 %	0.0 %	0.1 %	0.0 %
Postal and courier activities	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Accommodation and food service activities	2.3 %	1.5 %	1.9 %	1.9 %	0.0 %	0.0 %	0.2 %	0.1 %
Publishing activities	0.2 %	0.2 %	0.4 %	0.4 %	0.0 %	0.0 %	0.2 %	0.1 %
Motion picture, video, and television program production; sound recording and music publishing activities; programming and broadcasting activities	0.2 %	0.2 %	0.3 %	0.3 %	0.0 %	0.0 %	0.1 %	0.1 %
Telecommunications	0.5 %	0.7 %	1.8 %	1.5 %	0.0 %	0.0 %	0.4 %	0.2 %
Computer programming, consultancy, and related activities; information service activities	0.4 %	0.5 %	1.0 %	0.9 %	0.0 %	0.0 %	0.1 %	0.1 %
Financial service activities except insurance and pension funding	0.2 %	0.2 %	0.3 %	0.3 %	0.0 %	0.0 %	0.0 %	0.0 %
Insurance, reinsurance, and pension funding, except compulsory social security	0.3 %	0.3 %	0.4 %	0.4 %	0.0 %	0.0 %	0.1 %	0.1 %
Activities auxiliary to financial services and insurance activities	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Real estate activities	2.8 %	2.3 %	2.0 %	2.1 %	0.0 %	0.0 %	0.1 %	0.0 %
Legal and accounting activities; the activities of head offices; management consultancy activities	0.2 %	0.1 %	0.2 %	0.2 %	0.0 %	0.0 %	0.0 %	0.0 %
Architectural and engineering activities; technical testing and analysis	0.3 %	0.4 %	0.5 %	0.5 %	0.0 %	0.0 %	0.1 %	0.1 %
Scientific research and development	0.8 %	0.5 %	0.8 %	0.8 %	0.0 %	0.0 %	0.3 %	0.2 %

Advertising and market research	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Other professional, scientific, and technical activities; veterinary activities	0.1 %	0.1 %	0.1 %	0.1 %	0.0 %	0.0 %	0.1 %	0.0 %
Administrative and support service activities	0.4 %	0.4 %	0.5 %	0.5 %	0.0 %	0.0 %	0.0 %	0.0 %
Public administration and defense; compulsory social security	2.4 %	2.7 %	2.9 %	2.9 %	0.0 %	0.0 %	0.1 %	0.1 %
Education	1.1 %	0.8 %	1.1 %	1.1 %	0.0 %	0.0 %	0.1 %	0.0 %
Human health and social work activities	2.9 %	2.5 %	7.2 %	7.5 %	0.0 %	0.0 %	0.3 %	0.2 %
Other service activities	1.5 %	1.3 %	2.1 %	2.1 %	0.0 %	0.0 %	0.2 %	0.1 %
The activities of households as employers; undifferentiated goods- and service-producing activities of households for their own use	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %

Note: The authors’ calculations are based on World Input-Output Database (WIOD) data.

Table A3.2. The CBA-related value added of intermediate products, decomposed by the final producer industry in Finland

Sector	(a) Intermediate value-added import loss: The loss of value-added contributions for the row's final producer industry, relative to the total value-added loss in the scenario (%)				(b) Intermediate value-added import loss: The loss of value-added contributions for the row's final producer industry, relative to the total value of the same industry (%)			
	Feasible 1	Feasible 2	Efficient 1: all emissions	Efficient 2: direct + electricity emissions	Feasible 1	Feasible 2	Efficient 1: all emissions	Efficient 2: direct + electricity emissions
Crop and animal production, hunting, and related service activities	0.2 %	0.1 %	0.1 %	0.1 %	0.0000 %	0.0 %	0.0 %	0.0 %
Forestry and logging	0.0 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %
Fishing and aquaculture	0.0 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %
Mining and quarrying	0.0 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %
The manufacture of food products, beverages, and tobacco products	4.7 %	1.6 %	2.5 %	2.8 %	0.0001 %	0.0 %	0.1 %	0.1 %
The manufacture of textiles, wearing apparel, and leather products	1.9 %	0.6 %	1.3 %	1.5 %	0.0001 %	0.0 %	0.5 %	0.3 %
The manufacture of wood and of products of wood and cork, except furniture; the manufacture of articles of straw and plaiting materials	0.0 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %
The manufacture of paper and paper products	0.5 %	0.2 %	0.3 %	0.4 %	0.0000 %	0.0 %	0.0 %	0.0 %
The printing and reproduction of recorded media	0.1 %	0.0 %	0.1 %	0.1 %	0.0000 %	0.0 %	0.0 %	0.0 %
The manufacture of coke and refined petroleum products	19.4 %	2.2 %	2.4 %	2.7 %	0.0015 %	0.0 %	1.0 %	0.6 %
The manufacture of chemicals and chemical products	1.9 %	0.3 %	0.9 %	1.1 %	0.0000 %	0.0 %	0.1 %	0.0 %
The manufacture of basic pharmaceutical products and pharmaceutical preparations	0.8 %	0.2 %	0.8 %	0.9 %	0.0000 %	0.0 %	0.1 %	0.1 %

The manufacture of rubber and plastic products	1.0 %	0.4 %	0.8 %	0.9 %	0.0000 %	0.0 %	0.1 %	0.1 %
The manufacture of other non-metallic mineral products	1.2 %	0.3 %	0.2 %	0.3 %	0.0000 %	0.0 %	0.0 %	0.0 %
The manufacture of basic metals	0.9 %	1.9 %	0.5 %	0.6 %	0.0000 %	0.0 %	0.1 %	0.0 %
The manufacture of fabricated metal products, except machinery and equipment	2.5 %	6.8 %	1.9 %	2.2 %	0.0000 %	0.0 %	0.1 %	0.1 %
The manufacture of computer, electronic, and optical products	6.9 %	4.3 %	22.3 %	20.6 %	0.0000 %	0.0 %	0.8 %	0.4 %
The manufacture of electrical equipment	9.4 %	16.5 %	16.4 %	15.8 %	0.0002 %	0.1 %	1.5 %	0.8 %
The manufacture of machinery and equipment n.e.c.	22.1 %	40.9 %	29.1 %	29.0 %	0.0001 %	0.1 %	1.0 %	0.6 %
The manufacture of motor vehicles, trailers, and semi-trailers	5.4 %	7.7 %	5.2 %	5.3 %	0.0004 %	0.1 %	1.9 %	1.1 %
The manufacture of other transport equipment	4.6 %	7.4 %	4.6 %	4.8 %	0.0003 %	0.1 %	1.5 %	0.8 %
The manufacture of furniture; other manufacturing	2.8 %	4.0 %	2.5 %	3.0 %	0.0001 %	0.0 %	0.6 %	0.4 %
The repair and installation of machinery and equipment	0.8 %	1.4 %	1.2 %	1.2 %	0.0000 %	0.0 %	0.1 %	0.1 %
Electricity, gas, steam, and air conditioning supply	0.2 %	0.1 %	0.1 %	0.1 %	0.0000 %	0.0 %	0.0 %	0.0 %
Water collection, treatment, and supply	0.0 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %
Sewerage; waste collection, treatment, and disposal activities; material recovery; remediation activities and other waste management services	0.0 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %
Construction	0.1 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %
Wholesale and retail trade and the repair of motor vehicles and motorcycles	0.1 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %

Wholesale trade, except trade of motor vehicles and motorcycles	0.7 %	0.3 %	0.4 %	0.4 %	0.0000 %	0.0 %	0.0 %	0.0 %
Retail trade, except trade of motor vehicles and motorcycles	0.0 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %
Land transport and transport via pipelines	1.6 %	0.3 %	0.4 %	0.4 %	0.0000 %	0.0 %	0.0 %	0.0 %
Water transport	2.6 %	0.4 %	0.5 %	0.5 %	0.0001 %	0.0 %	0.1 %	0.1 %
Air transport	2.8 %	0.3 %	0.4 %	0.5 %	0.0001 %	0.0 %	0.1 %	0.1 %
Warehousing and support activities for transportation	0.5 %	0.2 %	0.2 %	0.3 %	0.0000 %	0.0 %	0.0 %	0.0 %
Postal and courier activities	0.1 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %
Accommodation and food service activities	0.1 %	0.0 %	0.1 %	0.1 %	0.0000 %	0.0 %	0.0 %	0.0 %
Publishing activities	0.1 %	0.0 %	0.1 %	0.1 %	0.0000 %	0.0 %	0.0 %	0.0 %
Motion picture, video, and television program production; sound recording and music publishing activities; programming and broadcasting activities	0.1 %	0.0 %	0.1 %	0.1 %	0.0000 %	0.0 %	0.0 %	0.0 %
Telecommunications	0.0 %	0.0 %	0.1 %	0.1 %	0.0000 %	0.0 %	0.0 %	0.0 %
Computer programming, consultancy, and related activities; information service activities	1.1 %	0.6 %	1.8 %	1.7 %	0.0000 %	0.0 %	0.0 %	0.0 %
Financial service activities, except insurance and pension funding	0.3 %	0.1 %	0.4 %	0.4 %	0.0000 %	0.0 %	0.0 %	0.0 %
Insurance, reinsurance, and pension funding, except for compulsory social security	0.1 %	0.0 %	0.1 %	0.1 %	0.0000 %	0.0 %	0.0 %	0.0 %
Activities auxiliary to financial services and insurance activities	0.0 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %
Real estate activities	0.0 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %
Legal and accounting activities; the activities of head offices; management consultancy activities	0.4 %	0.2 %	0.4 %	0.4 %	0.0000 %	0.0 %	0.0 %	0.0 %

Architectural and engineering activities; technical testing and analysis	0.1 %	0.0 %	0.2 %	0.1 %	0.0000 %	0.0 %	0.0 %	0.0 %
Scientific research and development	0.4 %	0.2 %	0.4 %	0.4 %	0.0000 %	0.0 %	0.0 %	0.0 %
Advertising and market research	0.0 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %
Other professional, scientific, and technical activities; veterinary activities	0.0 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %
Administrative and support service activities	0.9 %	0.3 %	0.7 %	0.7 %	0.0000 %	0.0 %	0.0 %	0.0 %
Public administration and defense; compulsory social security	0.1 %	0.0 %	0.0 %	0.1 %	0.0000 %	0.0 %	0.0 %	0.0 %
Education	0.3 %	0.1 %	0.2 %	0.2 %	0.0000 %	0.0 %	0.0 %	0.0 %
Human health and social work activities	0.0 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %
Other service activities	0.0 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %
The activities of households as employers; the undifferentiated goods- and services-producing activities of households for their own use	0.0 %	0.0 %	0.0 %	0.0 %	0.0000 %	0.0 %	0.0 %	0.0 %

Note: The authors' calculations are based on WIOD data.

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