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Modelling Foreign Trade in IntERACT

Abstract:

This paper studies how to model the effect of changes in the price of domestically produced goods relative to the price of competing foreign goods on the volume of exports and imports, to outline pros and cons of alternative solutions, with a focus on appropriate treatment for energy intensive industries vulnerable to relocation.

The suggestions presented in this working paper has not been adopted to the CGE model of IntERACT.

The work has been carried out by Copenhagen Economics.

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Modelling of foreign trade in IntERACT

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Copenhagen
Economics

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Executive summary

This paper studies how to model the effect of changes in the price of domestically produced goods relative to the price of competing foreign goods on the volume of exports and imports, to outline pros and cons of alternative solutions, with a focus on appropriate treatment for energy intensive industries vulnerable to relocation.

By far the most used approach in general equilibrium modelling is the so-called Armington approach. A relative percentage increase in the domestic to foreign price leads to a given percentage reduction in volumes demanded on exports or import markets, ie. a fixed price elasticiin demand is assumed . The economic justification is that different firms produce products which are alike but not identical. A lower price of Swedish Volvos will lead to more export sales to Germany, but some Germans will continue to buy BMW and Mercedes. This is a neat structure, it is easy to implement and it requires no specific assumptions about the functioning of the particular trade market, hence its popularity.

The weakness of the approach is that it fails to capture some basic easily observable characteristics of trade patterns. In some industries, there is domestic production but no exports, while in other industries there is foreign production yet no imports. In other industries global competition is so strong that domestic and foreign prices cannot deviate at all, or at least only very little. This is particular common for highly traded commodities. For such goods, trade patterns cannot be characterised by smooth continuous adjustment to relative prices in forms of marginal changes in market shares as prescribed by the Armington assumption.

In applied general equilibrium models it is becoming increasingly common to model specific industries with commodity like assumptions, while other industries are modelled in the usual Armington fashion. This study proposes a generalisation of this approach by which all industries in principle are modelled one part as commodities by so-called Heckscher-Ohlin assumption and one part by Armington assumptions. By this approach the model will accommodate non-continuous shifts in trade patterns, i.e. relocation of production. Once implemented, the demand response can be adjusted by simple choice of parameter values by the users of the model for each industry as they see fit. However, reaching the ultimate goal of a full scale implementation and a full parameterization for all industries is not around the corner. The recommended hybrid model is a novel approach. Small scale testing and further research analysis for parameterization is therefore recommended.

However, the Heckscher-Ohlin assumptions should only be used for industries which are de facto exposed to such risks of discontinued exports in the defined policy scenarios. We define the criteria that determine this risk in terms of *drivers* and *brakes*. Drivers are primarily high energy intensity in production while brakes are first of all high transportation costs and sunk capital costs, the latter implying that firms continue to produce for a certain period to utilise existing capital equipment. Based on these criteria, the Danish industries is ranked where the Heckscher-Ohlin element is most relevant in experiments revolving around prices of and prices of energy, which is the key policy area in focus for the IntERACT project.

Chapter 1
Preface

The Danish Energy Agency is currently developing the Integrated Economic Energy Applied Computational Tool (IntERACT), which is a general equilibrium model. The purpose of IntERACT is to improve the basis for socio-economic analyses of climate and energy policy, and the project was set into action after the Energy Agreement of March 2012.

It is the object of the study to recommend how best to model foreign trade in IntERACT and to identify industries which needs special attention, so that IntERACT will give the best possible prediction of current issues like terms of trade for energy intensive industries, relocation of production and carbon leakage.

The study has two objectives. The first and primary objective is to recommend how best to model foreign trade in IntERACT. The basis for the recommendation is a literature survey and a survey of methods applied in present energy economic CGE models. The result of the surveys is presented in chapter 2 and the proposed method is presented in chapter 3. At the end of chapter 3 a discussion is provided on how to expand the model to address other issues not mentioned above, like market segmentation etc.

The second objective of the study is to identify which industries should be modelled explicitly and with care to detail, and which industries can be handled at a greater level of aggregation with standard assumptions. This task is pursued in chapter 4. The approach is the same as applied by Copenhagen Economics in a recent study for the Nordic Council of ministers.

Chapter 2

Foreign trade in general equilibrium models

This chapter presents the results of the literature survey and of the survey of methods applied in present energy economic CGE models. Section 2.1 deals with the first and section 2.2 deals with the later. In both cases the results are comprised in a tabular format with only a limited amount of surrounding text. The conclusions of the chapter is contained in section 2.3 “Pros and cons of different modelling concepts”.

2.1 Introduction

The general understanding is that a deterioration of the terms of trade, that is a rise in the ratio between the price of exportable and the price of importable goods will lead to decreased production as a result of lower market shares both on the market for exports and on the domestic markets. For the Danish economy as whole this understanding of foreign trade might be sufficient for understanding and even for modelling the response of imports and exports to changes in productions costs. However, since IntERACT aims at providing accurate and realistic economic analysis also at the industry level, it is of great importance to build on an understanding of the determinants of the terms of trade and of exports and imports at the industry level. Below, 3 archetypal industries are defined, partly to describe why specific attention to industries matter, and partly to be used as a point of reference for discussions below.

A) In some industries global competition is possibly so fierce as to effectively eliminate the possibility of any variation in the terms of trade. If faced with higher costs of production firms will not be able to raise the gross price of their product, and they will thus only stay in business if profits are already high enough as to not turn negative.

B) In other industries global competition might be limited, such that higher costs of production can be turned into higher gross prices without losing all demand, thus resulting in a deterioration of the terms of trade and limited effect on production.

C) Last but not least, in some industries transport costs or trade restrictions might make it so costly to trade as to effectively create a barrier against imports and exports. In the case of such barriers local producers can serve the domestic market at higher gross prices than those of potential foreign competitors. The combination of type A industries and trade costs thus gives rise to tipping-points. Ie. the pattern of trade is robust to changes in production costs, but only until a point, by which there will be an abrupt shift in the pattern of trade as a result of relocation of production.

2.2 Trade in theoretical general equilibrium models

This section provides an overview of the theoretical literature on foreign trade in general equilibrium models. Six different models of foreign trade are presented in Table 1. In the text we provide a short discussion of each model against the understanding described above. The presented models include the Heckscher-Ohlin (HO) model, the Armington (ARM) model, New Trade theory (NTT), and the De Melo and Robinson model (DMR). Furthermore two models which combine assumption from the previous models are presented. This includes a model combining the Heckscher-Ohlin model and new trade theory, and a model combining the Armington and the Hecksher-Ohlin assumptions.

In the Heckscher-Ohlin model, introduced by Heckscher (1919) and Ohlin (1933) it is assumed that all countries have access to the same technological possibilities and that products of all countries are perfect substitutes for each other. Perfect competition and no trade restrictions ensure that prices are equalised across countries. This results in specialization, where the country with the comparative advantage will be the sole producer of any given product. Within all industries trade runs in only one direction. The Heckscher-Ohlin model is therefore a model of inter-industry trade.

The general assumption of perfect competition implies that all firms are operating at zero profits with gross prices equal to marginal costs. The Heckscher-Ohlin model describes a world of category A industries where firms have no control of the gross price. Production can only be sustained as long as the costs of production, and hence the export price, is lower than price of importable goods. Otherwise production is relocated.

The pattern of trade predicted by the Heckscher-Ohlin model with no mutual trade in similar goods is not compatible with real world observable data where countries appear to be both importing and exporting similar goods. This phenomenon is known as cross-hauling or intra-industry trade.

Armington (1969) therefore proposed a model of trade which describes the phenomenon of intra-industry trade within the framework of an otherwise standard general equilibrium model. By the Armington assumption, consumers differentiate between products by their origin. Within any industry consumers in one country will demand a bundle of goods from different origins, no matter the variation in prices. Thus, every country has market power in every market in which it buys and sells,, and thus specialisation through comparative advantages does not apply under the Armington assumption as in the traditional trade theory[1]. The Armington assumption is often used in models defined at a high level of aggregation as its predictions fit well with the simple understanding of trade outlined in the introduction of the chapter. However, it can also be feasibly applied to type B industries when the exact reasoning for the limitation on competition is not a prime interest.

In the New Trade theory the focus is shifted from a country perspective to a true industry perspective. Market imperfections and product supply side differentiation is modelled explicitly and it thus provides new insights into the reasons for intra-industry trade. The defining articles are Spence (1976), Dixit and Stiglitz (1977), Landcaster (1979), Krugman (1979), and Brander and Krugman (1983). It is difficult to describe the New Trade Theory in brief terms, but basically it revolves around relaxations of the assumption of perfect competition of Heckscher-Ohlin model, very often including assumptions that firms have monopoly power to set prices above marginal costs. The New Trade theory models thus describe category B or C industries where firms, for a variety of reasons and as opposed to the Heckscher-Ohlin, do have

[1] Cf. Zhang (2006) which exams the complex relationship between choice of Armington elasticities and terms of trade effects.

control of the gross price[2]. A further evolution of the literature called the New New Trade Theory focuses on individual firms instead of on industries, and it adds clustering or agglomeration effects to the list of explanations for intra-industry trade.

De Melo and Robinson (1989) introduced supply side product differentiation by similar reasoning and method as in the original Armington model. Producers are assumed to differentiate production in goods supplied for domestic demand and goods supplied for foreign trade, while the perfect competition assumption is maintained, cf. Table 1.

Table 1 Trade in theoretical general equilibrium models

Class	Features	Contribution	Articles
Heckscher and Ohlin (HO)	Perfect competition Product homogeneity	Comparative advantages through differences in relative factor endowments results in specialisation inter industry trade and factor price equalisation.	Heckscher (1919) Ohlin (1933)
Armington (ARM)	Perfect competition. Demand side differentiation between goods by origin.	Allows for intra-industry cross hauling as evidenced in aggregated trade data. No issues with problems of indeterminacy and extreme specialization.	Armington (1969)
New Trade Theory (NTT)	Increasing returns to scale. Monopolistic competition. Firm specific product differentiation. LoV preferences.	Introduces market imperfections explicitly, and thus provides a rigid explanation for intra industry trade. Introduces gains from trade from increased product variety..	Spence (1976) Dixit and Stiglitz (1977) Lancaster (1979) Krugman (1979) Brander and Krugman (1983)
New Trade Theory - Heckscher and Ohlin (NTT-HO)	Two country two industry setting. One industry modelled by HO assumption and the other by NTT assumptions.	Generalization of the HO-theory in the presence of NTT type market imperfections: Revision of the HO theorems, HO explains inter-industry trade and NTT explains intra-industry trade.	Helpman (1981)
De Melo and Robinson (DMR)	Perfect competition. Adds supply side differentiation between goods by destination to ARM model.	In a one-country open economy setting it is demonstrated how supply side differentiation can reduce the terms of trade effects of ARM	De Melo and Robinson (1989)
Armington - Heckscher and Ohlin (ARM-HO)	Two country two industry setting. Each industries good is split into homogenous (HO) and differentiated good (ARM)	Bridges the gap between HO and ARM characteristics in aggregated CGE models. Emphasises the importance of homogeneous versus differentiated goods.	Zhang (2008)

Source: Copenhagen Economics based on the named articles

In all of the basic theoretical models described above and in all of the papers referred to in Table 1, trade is assumed to be as frictionless between countries as it is inside countries. There is in other words one single world market a single market for every unique product. When introduced, transport costs, import quotas etc. creates a wedge between the price of imported goods and the price of exported goods. In the framework of the Heckscher-Ohlin model[3] there will be a range of prices (inside the wedge) at which domestic producers cannot compete on the export markets, while at the same time imported goods can't compete on the domestic market when the cost of transportation is added the prices. Within this range of prices there will be no trade as described for type C industries above.

[3] Wegge (1993) introduces costs of transportation in the Hecscher-Ohlin models and discuss the implications thereof.

Table 2 Trade in applied energy economic CGE models

Trade assumption	Name of model	Articles	Some details about the model
ARM	GEM-E3 (EC)	Capros (1995)	Computable general equilibrium model 11 countries, products and sectors 4 economic agents 8 government revenue categories 13 consumption expenditure categories 2 primarily production factors 3 pollutants Annual time path
	DART	Klepper and Peterson (2004) and (2003)	Recursive dynamic CGE model 11 sectors aggregation 12 regions 2 production factors (labour and capital) Build on data from GTAP
	ADAGE	Ross (2008)	Dynamic general equilibrium model Consists of three modules: International, US regional, Single country SAM, data from 2001 extended to 2010 (base year)
	ENV-Linkages (OECD)	Burniaux and Chateau (2010)	Recursive neo-classical equilibrium model 12 countries/regions 25 economic sectors Five different technologies to produce electricity
NTT	BDS model	Brown, Deardorff and Stern (1993)	Extended version of the Michigan model 8 countries (groups), selected from the 34 Imperfect competition Increasing return to scale Product differentiation
	Version of MSG6	Bjertnæs and Fæhn (2008)	Computable general equilibrium model 40 private production activities 8 government production activities Input/output structure
ARM HO	EPPA (MIT)	Paltsev et al (2005)	Computable general equilibrium model Social Accounting Matrices (SAMs), base year 1997 Build on GTAP 5 data Includes transportation costs
ARM NTT		Böhringer (2008)	Increasing return to scale Imperfect competition 13 sectors 3 primary factors
No trade	DICE	Nordhaus (1992)	Integrated assessment model Modified Ramsey-style optimal growth model with climate investments included. One country model (although the regional model RICE has 12 regions) Two sectors: An Economic sector and a geophysical sector.
Non standard[4]	PAGE	Hope, Anderson and Wenman (1993)	Integrated assessment model Stochastic model 8 regions 3 modules: Economic costs of damages, Non-economic cost of damages, Impact of adaption The PAGE damage function relies on estimates prepared by IPCC Working Group II for the Third Assessment Report (TAR).
Similar to PAGE[5]	E3-ME	Pollitt, Chwepreecha and Summerton (2007)	A dynamic simulation model of Europe estimated by economet-ric methods 33 countries 69 economic sectors 43 categories of household expenditure Can assess both short and long-term impacts

Source: Copenhagen Economics based on relevant studies

[4] Trade in PAGE: An important part of the modelling concerns international trade. The basic assumption is that, for most commodities, there is a European 'pool' into which each region supplies part of its production and from which each region satisfies part of its demand. This might be compared to national electricity supplies and demands: each power plant supplies to the national grid and each user draws power from the grid and it is not possible or necessary to link a particular supply to a particular demand.

[5] Pollitt, Chwepreecha and Summerton (2007), page 22

2.1 Trade in presently applied energy economic models?

The Armington assumption is the standard way of modelling foreign trade in applied general equilibrium models, cf Table 2. However, some of the models build with a specific focus on energy related issues does mix assumptions by applying Heckscher-Ohlin type assumptions to particular industries, though not within a generalised framework like Zhang (2008). The EPPA model presented by Paltsev et al (2005) is one such example. While crude oil is assumed to be a homogenous product, other energy products such as coal, gas and refined oil is modelled as Armington goods. The reasons for taking this approach is that crude oil is a very well defined and highly traded good in which prices are best thought of as being dictated exogenously by a world market price.

Likewise, when looking at the applied macroeconomic models used in Denmark, as presented in Table 3, the Armington assumption is the preferred method, though the large model DREAM use a combination of the Heckscher-Ohlin and the Armington assumption much like the models referred to above.

Table 3 Trade in applied macroeconomic models in Denmark

Trade assumption	Name of model	Author	Some details about the model
ARM-HO	DREAM		Dynamic CGE model Study medium to long term issues like demographics Overlapping generations, rational forward looking agents. 9 types of goods, 5 of which are energy. CES production with KELM nest structure. Oil and gas: Homogeneous and traded at fixed world market price, Production is fixed to a forecast and zero profit condition is relaxed.
ARM	Mini DREAM	Stephensen, Christensen and Thomsen (2010)	Static small open economy CGE model Evaluate long term effects to the economy 2 types of goods (energy and all other goods) 1 representative consumer, who demands 3 energy types 1 representative firm, who demands 4 energy types Constant return to scale Perfect competition
ARM*	SMEC (DØRS)	Grinderslev and Smidt (2007)	Macro econometric model Used for forecast and policy analyses Based on national account data 8 production sectors 5 types of import 6 types of demand 3 types of investment 5 types of export
ARM	MUSE (DØRS)	Barslund, Beck, Hauch and Nellemann (2010)	Static general equilibrium model Focus on the long time horizon 11 representative households 130 production sectors
ARM*	ADAM (DST)	DST (2012)	Macro econometric model Used for calculated the effects from policy suggestions Sometimes also used for projections 12 production sectors (used to be 19) 10 types of import 8 types of demand 4 types of investment 7 types of export
No foreign trade modelled (because the model links to ADAM)	EMMA (DST)		Energy and climate module for ADAM Normally used for projection of energy and electricity consumption.

2.2 Pros and cons of different modelling concepts

Most numerical trade models use the Armington assumption (ARM) by which it is assumed that consumers differentiate between otherwise similar products by their origin. This makes it possible to describe the trade pattern which can be observed at aggregate levels, where countries are engaged in mutual trade within many industries (intra-industry). The model does not embody any explicit explanation for why goods are to be thought of as differentiated. Instead, the Armington assumption is often accepted as an ad hoc representation of underlying market imperfections. In terms of the three categories outlined in the introduction of the chapter, the Armington assumption can also be feasibly applied more precisely defines industries of type B.

The Armington models are criticised for yielding *"larger than expected changes in inter-country relative prices, which result in excessive terms of trade effects, especially for small countries."* , ie. it allows the domestic gross price to much variation relative to the price of imported goods. For highly traded and easily transported commodities for which a well-functioning world market exists (type A) the Armington assumption is dubious. To some degree the problems can be solved by careful choice of elasticity of substitution in demand functions[6]. However, the core problem remains that with the Armington assumption, that per definition there is no specialisation through comparative advantages as predicted in the traditional trade theory associated with Heckscher-Ohlin. Under the Armington assumption an industry will never close down shop and relocate production. Therefore this type of industry may be more appropriately modelled by use of Heckscher-Ohlin type assumptions. On the other hand the Heckscher-Ohlin approach does not allow for intra-industry trade. To use it therefore requires that the particular industry is so well defined that intra-industry trade can be ignored.

The New Trade Theory assumptions of increasing returns to scale and love of variety (LoV) preferences offer explicit reasoning for intra-industry trade. In applied models the assumptions used are often somewhat simplified compared to the theoretical literature. Often models build on the framework of Heckscher-Ohlin with a relaxation of the assumptions of perfect competition by some sort of distinction between types of goods belonging to the same industry. As commented by Zhang (2008) *"consumer preferences for country-specific varieties give monopoly power to each country, which leads to large terms of trade effects, similar to what is observed in the Armington model."*[7]. The models may therefore not offer a more realistic prediction than by just using the common standard of Armington.

Both the New Trade Theory and the letter New New Trade Theory is all about understanding and thus modelling the consequence of non-standard production technologies and of various forms of imperfect competition. There is no hindrance for coupling the modelling of trade which we are suggesting in chapter 3 with non-standard models of production and price setting behaviour. It is however beyond the scope of this study. The following quote by Norman (1990) provides the arguments for doing so in the case of non-perfect product markets: *"If the true model is one of oligopoly with product differentiation – with or without free entry – the Armington approximation is quite bad both as regards welfare effects and inter-industry trade effects; only with respects to intra-industry trade can it provide a reasonable approximation."*[8]

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[6] See Zhang(2006) for a discussion of Armington elasticities and terms of trade effects.
[7] Zhang (2008), page XIV
[8] Norman (1990), page 740

While The New Trade theory does provide new insight, we agree with the argument of Zhang that a detailed description of market imperfections will probably not improve the predictions of the model, unless the underlying imperfections are very well understood and described. The conclusion we draw from our study is that all industries are ultimately best described by some mixture of the Armington and Heckscher-Ohlin approach. At some price differential, marked shares and exports will go to zero. However, the cost difference that will trigger this non-continuous jump differs between industries. This also implies that the classification of the industry within the model depends on the policy scenarios. With low price differentials in general most industries can be described by Armington specification. With higher price differentials more industries either starts going from zero to large exports or the reverse. The challenge is to put this concept into practice. This is what we do in chapter 3.

Table 4 Pros and cons of different modelling concepts

Class	Pros	Cons
Heckscher and Ohlin (HO)	Explains inter-industry trade and specialisation through comparative advantages.	Does not explain intra-industry trade between countries with similar endowments as evidenced in aggregate trade. Problems of indeterminacy and extreme specialisation.
Armington (ARM)	Easily applicable model of intra-industry trade with a smooth response to changes in terms of trade. No problems with indeterminacy.	Ad hoc representation of market imperfections. No comparative advantages. Arguably too strong terms of trade[9] effects
De Melo and Robinson (DMR)	In a one-country open economy setting it is demonstrated how supply side differentiation can reduce the terms of trade effects of ARM	The essential properties of ARM are maintained. Thus, the criticism remains.
New Trade Theory (NTT)	Explicit explanation for intra-industry trade. Lower terms of trade effects than in traditional Armington models.	Like HO, NTT suffers from problems of indeterminacy and complete specialisation. This is solved through ad hoc pricing rules, which though makes it questionable if NTT results in greater realism in applied models.
New Trade Theory - Heckscher and Ohlin (NTT-HO)	Revision of the HO theorems, HO explains inter-industry trade and NTT explains intra-industry trade.	Much of the criticism of HO and NTT also applies to the mixed model.
Armington - Heckscher and Ohlin (ARM-HO)	Bridges the gap between HO and ARM characteristics in aggregated CGE models. Emphasises the importance of homogeneous versus differentiated goods.	Like ARM the assumption of split goods is an ad hoc representation of market imperfections.

Note: *) Both export and import reacts with a lagged respons of several years to a change in the terms of trade.

Source: Copenhagen Economics based on relevant articles

[9] *"if one country reduces its tariff rates, the model tend to display large negative terms of trade effects…This factor will reduce the gains from trade liberalisation… As a consequence, any benefits from reducing tariffs tend to be small, and occasionally negative."* Zhang (2006), page IX

Chapter 3

Proposed approach for modelling foreign trade in IntERACT.

We have conducted a survey of the literature and a survey of methods applied in present energy economic CGE models, the results of which are presented in the previous chapter. The conclusion which we draw from our studies is that there is not any single best way of modelling foreign trade. For every method there are obvious pros and cons. The best strategy would be one in which assumptions are industry specific. One industry might be best described by HO assumptions while for another ARM or NTT is a better choice. A few recent CGE models goes some length in this direction, by pointing out a single or few goods to be modelled by HO assumptions, while the rest are modelled by ARM.

Our recommendation is to take this approach one step further. The proposed model is one in which a mix of HO and ARM assumptions is applied to every industry within a generalized framework. The inspiration is found in the hybrid model of Zhang (2008). However, the model which we present is further extended by applying the “small open economy” assumption and by adding transport costs . The “small open economy” assumption is that the domestic economy has no influence on prices on the world markets, while transport costs are added in order to support tipping-points in the prediction of trade patterns as discussed previously. The predictions for the patterns of trade, relocation, and of terms of trade effects will for each industry depend crucially on parameter values. For every industry, parameter values can be chosen, so as to reflect a market response of a change in prices in accordance with any of the three archetypal industries listed in the preface, ie. type A, B and C. The main challenge for future work is to estimate exact parameter values for type A and C industries. However, since the model of Zhang is indeed a novel approach, small scale implementation and tests are also needed prior to implementing a full scale version of the recommended hybrid model in IntERACT.

This chapter presents our proposal for modelling foreign trade in IntERACT, while the following chapter identifies industries, which in the light of the issues discussed in the preface should be modelled with the greatest care to detail. A general discussion on how to choose appropriate parameter values is also provided.

3.1 Building blocks of the proposed model

At the time of writing the IntERACT project is in its very early stages, why only very little is known about the model. The chosen approach is therefore to describe how to extent a standard static perfect competition closed economy CGE model with the recommended trade module[10]. At the end of the chapter we will provide discussions on the limitations and possible expansions of the model. Readers are expected to be familiar with general equilibrium models[11].

The trade hybrid model consists of 4 components:
a) The HO trade assumption
b) The Small open economy assumption
c) Transport costs
d) The Armington trade assumption.

In a step by step manner we demonstrate how to implement each component independently and we point to the implications thereof with references to the discussions of the previous chapter[12]. Finally, we gather the pieces so as to demonstrate how to implement the hybrid trade model.

Adding trade to a closed economy model is essentially a task of changing the way goods markets are equilibrated. The modelling of trade is for that same reason often referred to as "the external closure" of the model. What follows is a very brief description of how the goods markets are equilibrated in the standard closed economy general equilibrium model:

All agents, producers and consumers, acts as price takers who successfully maximizes profits or utility by choosing appropriate levels of demand and supply. For every goods market first order conditions translates into a supply function, $S_i(P_i)$, and a function of aggregate demand, $D_i(P_i)$, the later which is defined as the sum of demand of all consumers as well as demand for input to production of all producers. This leaves prices ungoverned. The model is closed by adding a market clearing condition for every goods markets[13] $S_i(P_i) = D_i(P_i)$.

a) The Heckscher-Ohlin assumption

Imagine two autonomous economies, the domestic economy (D) and the foreign economy (F). By the homogenous goods assumption of Heckscher-Ohlin goods originating from either country are perfect substitutes for each other. Introducing trade between the two economies is basically therefore just a question of merging the markets for traded goods by adding up supply and demand of both countries into one single market clearing condition, such that for all industries i,

$$S_i^D(P_i^D) + S_i^F(P_i^F) = D_i^D(P_i^D) + D_i^F(P_i^F)$$

Furthermore a perfect competition restriction condition is added on prices, $P_i^D = \varepsilon P_i^F$

[10] Implementation in a dynamic model with a standard product market closure is functionally no different, except for the addition of a time subscript on all variables.

[11] Readers who are not familiar with general equilibrium models are referred to Hosoe, Gasawa, and Hashimoto (2010), which gives a thorough introduction to the subject.

[12] Apart from making it easier to understand, this approach also shows how to implement either the Armington or the Heckscher-Ohlin model on its own for particular industry as done in models like Paltsev (2005).

[13] By the law of Walras one market clearing condition is removed and the price of this so called numeraire good is set to 1. This implies that all prices are measured in terms of that particular good, hence why it is called the numeraire good. This applies to all of the models but is ignored for the sake of convenience.

The model is finally closed by adding a balance of payment condition as follows:

$$\sum_i P_i^D\left(S_i^D - D_i^D\right) - \sum_i P_i^F\left(S_i^F - D_i^F\right) = 0$$

This is balanced by endogenous determination of the exchange rate ε. If one wants to operate with a fixed exchange rate, endogenous foreign savings will need to be added to the balance of payments.[14]
For every good the net exports can be calculated residually as

$$X_i = S_i^D - D_i^D - S_i^F + D_i^F.$$

Unlike the standard closed economy model, in the Heckscher-Ohlin model there is not a positive supply by all producers. On the contrary, the general prediction is that all of production will be relocated to the country where marginal costs are lower. In the special case of equal marginal costs, equilibrium is not even unique. In CGE models these features poses a real challenge. Aside from the problem of uniqueness, or indeterminacy, which can be avoided by careful choice of input data, the first order conditions are not sufficient for describing supply. One needs to also control for the case of zero output. Howerver, since the proposed model does not suffer from these issues we will not go into further details on how to solve them.

b) The small open economy assumption
By the small open economy assumption the domestic (D) economy has no influence on the rest of the world (F). Demand for exports and supply of imports is assumed to be completely elastic, i.e. unsatisfiable, at the foreign price P_i^F. Therefore only net exports X_i enter the model, and thus the market clearing condition becomes $X_i = S_i^D - D_i^D$, and the balance of payments condition becomes $\sum_i P_i^D X_i = 0$

Maintaining the HO assumption, the restriction on domestic and foreign prices is still $P_i^D = \varepsilon P_i^F$.
The price of traded goods cannot deviate from the world market price. Industries that cannot maintain non-negative profits at the world market price will shut down, production will relocate to abroad and domestic demand will thus be met solely by imports.

c) Transport costs as a barrier against trade
Transport costs act as a barrier against specialisation and relocation of production. They make it possible for an industry to serve the domestic market at a price higher than the world market price. The net import price, that is the world market price inclusive of transport costs, acts as a tipping-point. If the costs of production rises above this point the domestic industry will be faced with competition from imports, it will not be able to maintain profits, and hence it must shut down and production is relocated.

Transport costs create a wedge between the supply and demand price of both exports and imports. Staying in the setting of the small open economy and the HO assumption the world market price is still exogenous P_i^F. The price perceived by exporting firms is however $\varepsilon\left(P_i^F - t_i\right)$. At any supply price P_i^S at or below this level, export demand is unsatisfiable. At any price higher than this level, exports are zero.
This is implemented in the model by a series two equations, wich basically dictates that if exports are positive, the domestic price must equal the export price, and otherwise exports must be zero:
$\left(P_i^S - \varepsilon\left(P_i^F - t_i\right)\right) X_i = 0$ and $X_i \geq 0$, where X_i is now gross exports.

[14] Hosoe, Gasawa and Hashmoto (2010)

As in the Hecksher-Ohlin model with no transport costs domestic production is only feasible if the supply price is lower or equal to the net price of imports. Three equations are added, which dictates that if domestic supply is positive, the supply price (P_i^S) must be lower or equal to the price of imports ($\varepsilon(P_i^F + t_i)$) and imports must be zero, and, otherwise domestic supply is zero and imports indefinite[15]:

$\left(P_i^S - \varepsilon(P_i^F + t_i)\right) S^D{}_i \leq 0$ and $S_i{}^D \geq 0$ and $S_i{}^D M_i = 0.$

The price faced by consumers (P_i^D) is either equal to the price of imports or the domestic price, depending on which is lower. This is assured by adding two further equations dictating that if imports are zero, the consumer price equals the domestic supply price (P_i^S) and vice versa if domestic supply is zero:
$\left(P_i^D - \varepsilon(P_i^F + t_i)\right) S^D{}_i = 0$ and $(P_i^D - P_i{}^s)M_i = 0$

At the range of prices $P_i^S \epsilon \left]\varepsilon(P_i^F - t_i)\right.$; $\left.\varepsilon(P_i^F + t_i)\right[$ both imports and exports are zero. If the price is higher than this, domestic supply will be zero, and demand will instead be med by imports. At the other end of the price range, the export price sets a lower bound, since at this price demand for exports is indefinite. The clearing of product markets is thus rather complex.
The market clearing condition:
$X_i - M_i = S_i^D - D_i^D$

The balance of payments restriction:
$\sum_i \varepsilon(P_i^F - t_i)X_i + \sum_i \varepsilon(P_i^F + t_i)M_i = 0$

d) The Armington assumption
By the Armington assumption domestic and foreign goods are differentiated in the perception of both domestic and foreign consumers. This allows for two way trade in accordance with the kind of aggregated data which numerical trade models are usually calibrated against. At the same time the Armington assumption dictates that the trade patterns observed in the same data will be maintained in simulations. Hence, relocation of production is gradual at all level of prices and never complete.

By the ARM assumption goods are geographically differentiated. There is no restriction on relative prices as under the HO assumption. Domestic demand of industry i goods, D_i^D, is defined as composite good made up of domestically produced goods, d_i^D, and imported goods, d_i^F.
It is common practice to model D_i^D by a CES production function, i.e.:
$D_i^D(d_i^F, d_i^D) = (\beta_i^D d_i^D + \beta_i^F d_i^F)^{\left(\frac{1}{1-\gamma}\right)}$

Agents still take the price, P_i^D, for given and $D_i^D(P_i^D)$ still define aggregate demand of all agents in the economy as a function of the price. Cost minimizing behaviour in the production of the composite good results in the following functional relationship between the price of the composite good, P_i^D , and the prices of the two input goods, p_i^D and $(p_i^F + t_i)$ that is:

$$P_i^D = \left({p_i^D}^{1-\gamma} {\beta_i^D}^{\gamma} + \left(\varepsilon(p_i^F + t_i)\right)^{1-\gamma} {\beta_i^F}^{\gamma}\right)^{\frac{1}{1-\gamma}}$$

[15] As in the previous section and for the same reason we won't go into detail on how to solve for equilibrium when domestic supply is zero.

The demand of the two goods is given by these two equations:

$$d_i^D = \beta_i^{D\gamma} \left(\frac{p_i^D}{P_i^D}\right)^{-\gamma} D_i$$

$$d_i^F = \beta_i^{F\gamma} \left(\frac{\varepsilon\left(p_i^F + t_i\right)}{P_i^D}\right)^{-\gamma} D_i$$

The demand for exports are modelled in the same way, but since by the small open economy assumption the foreign price is exogenous, demand is given by the following

$$x_i = A \left(\frac{\frac{1}{\varepsilon}\left(p_i^D + t_i\right)}{p_i^F}\right)^{-\varepsilon}$$

The market clearing condition is:

$$S_i^D = d_i^D + x_i$$

The balance of payments is:

$$\sum_i p_i^D x_i - \sum_i \varepsilon\left(p_i^F + t\right) d_i^F = 0$$

Domestic industries will be faced with a continuous downwards sloping demand curve, both in demand for exports and in domestic demand. At any level of costs of production the industry will be able to maintain non-negative profits by raising the price and thus suffering a lower but always positive demand. Similarly, while transport costs does have a negative impact on the level of trade it does not act as an absolute barrier against trade.

3.2 The recommended hybrid model

Our recommendation for modelling foreign trade in the IntERACT is to build on a combination of elements of all of the assumptions described above. Firstly, we will build on the small open economy assumption and the assumption of transport costs. World market prices will be taken as exogenous and transport costs are established, either exogenous or endogenous, for all traded goods. Secondly, and borrowing from the ideas of the DMR model, we assume that firms in all industries are able to transform their product into two distinct variations. For the first variation of goods we employ the Armington assumptions of geographically differentiated goods and for the second we employ the HO assumption of geographically homogeneous goods.

Assuming a nonzero demand for both variants of goods of a particular industry, the predictions of the model will be a mixture of those of the HO and Armington models as described above.

An industry will face a positive demand of the Armington product variant at any level of prices, just as there will always be a positive demand for imports. Hence, a complete relocation of production will never take place. By this feature the model is robust to the problems of indeterminacy of the pure HO and NTT models; cf. Table 4 and Zhang 2008.

On the other hand, an industry will face a positive demand for the HO product variant only as long as its price is lower than the net price of imports. The net price of imports acts as a tipping point at which the industry will lose or gain all of the total demand for the HO variant of the domestic market. The degree to which this tipping point affects the level of production is determined by the preferences of consumers.

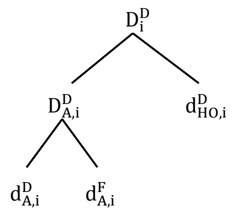
Basically, the higher the total purchases of the HO variant is relative to the size of the domestic production, the greater the impact will be of losing or gaining the market. At the other end of the price range the gross price of exports, that is the world market price minus transport costs, act as a lower bound on the price of any traded good. The reason is, that should the price of the HO variant drop below this level it would be exposed to an unsatisfiable export demand, which in turn would act to force the price upwards.

Applied modelling of the recommended hybrid model

For every industry i domestic demand, D_i^D, is assumed to be a composite good made up of subsidiary demand for the following three differentiated products:

1. $d_{A,i}^D$: demand for a domestically produced Armington variant and its price, $p_{A,i}^D$.
2. $d_{A,i}^F$: corresponding demand for foreign produced Armington variant and the foreign price including transport costs $\varepsilon(p_{A,i}^F + t_i)$
3. $d_{HO,i}^D$ demand for a HO variant and the price $p_{HO,i}^D$

$D_i^D(d_{A,i}^D, d_{A,i}^F, d_{HO,i})$ is a composite of all three types of goods modelled as a nested CES production with a nesting structure as sketched below:



Given demand for the composite good, $D_i^D(P_i^D)$, and prices, $p_{A,i}^D$, $\varepsilon(p_{A,i}^F + t_i)$ and $p_{HO,i}^D$ the demand for three underlying goods is determined by the following system of equations, as the solution of cost minimizing the production of the composite good:

$$P_i^D = \left(P_{A,i}^{D\;1-\gamma}\,\beta_i^{A\,\gamma} + P_{HO,i}^{D\;1-\gamma}\,\beta_i^{HO\,\gamma}\right)^{\frac{1}{1-\gamma}}$$

$$D_{A,i}^D = \beta_i^{A\,\gamma}\left(\frac{P_{A,i}^D}{P_i^D}\right)^{-\gamma} D_i^D$$

$$d_{HO,i}^D = \beta_i^{HO\,\gamma}\left(\frac{p_{HO,i}^D}{P_i^D}\right)^{-\gamma} D_i^D$$

$$P_{A,i}^D = \left(p_{A,i}^{D\;1-\delta}\,\beta_i^{D\,\delta} + \left(\varepsilon\left(p_i^F + t_i\right)\right)^{1-\delta}\,\beta_i^{F\,\delta}\right)^{\frac{1}{1-\delta}}$$

$$d_{A,i}^D = \beta_i^{D\,\delta}\left(\frac{p_{A,i}^D}{P_{A,i}^D}\right)^{-\delta} D_{A,i}^D$$

$$d_{A,i}^F = \beta_i^{F\,\delta}\left(\frac{\varepsilon\left(p_{,i}^F + t_i\right)}{P_{A,i}^D}\right)^{-\delta} D_{A,i}^D$$

Demand for exports of the Armington variant is:

$$x_{A,i} = A\left(\frac{\frac{1}{\varepsilon}p_{A,i}^{D} + t_i}{p_i^F}\right)^{-\varepsilon}$$

The market equilibrium condition:
$s_{A,i}^{D} = x_{Ai} + d_{A,i}^{D}$ governs the price $p_{A,i}^{D}$, and $p_{A,i}^{F}$ and t_i are exogenous.

The goods market closure of the HO good is parallel with the description in section 3.1:
$\left(p_{A,i}^{D} - \varepsilon\left(P_i^F - t_i\right)\right)X_i^{HO} = 0$ and $X_i^{HO} \geq 0$, where X_i^{HO} is gross exports.
$\left(p_{A,i}^{D} - \varepsilon\left(P_i^F + t_i\right)\right)S_{HO,i} = 0$ and $S_{HO,i} \geq 0$ and $M_{HO,i}S_{HO,i} = 0$, where $S_{HO,i}$ is domestic supply and $M_{HO,i}$ is imports.

For every industry i firms are assumed to be able to costlessly transform their supply S_i^D into the two variants, such that $S_i^D = s_{A,i} + s_{HO,i}$. Since transformation is costless profit maximisation implies that the price of the two variants is the same. The price faced by consumers ($p_{HO,i}^{D}$) is either equal to the price of imports or the domestic supply price ($p_{A,i}^{D}$), depending on which is lower. The two following equations make sure of that:
$\left(p_{HO,i}^{D} - \varepsilon\left(P_i^F + t_i\right)\right)S_{HO,i} = 0$ and $\left(p_{HO,i}^{D} - p_{A,i}^{D}\right)M_{HO,i} = 0$

The market clearing condition is given by:
$X_i - M_i = s_{HO,i}^{D} - d_{HO,i}^{D}$

The model is closed by adding the balance of payments condition:
$\sum_i p_i^D\left(x_{A,i} + x_{HO,i}.\right) - \sum_i \varepsilon\left(p_i^F + t\right)\left(d_{A,i}^F + d_{HO,i}^F\right) = 0$

3.3 The challenge of calibration and possible extensions

The choice of parameters is what will ultimately determine the actual predictions of the model. The real challenge is therefore in the calibration of the model. The model is very flexible in its reign of predictions. If, across all industries transport costs are high, the predictions of the model will tend toward those of a closed economy model. If transport costs are low and consumer preference for the HO product variant is strong, the predictions of the model will be similar to those of the pure HO model. If preferences for the HO product variant are weak and transport costs are low, the predictions of the model will be similar to those of the pure Armington model.

To setup the model, and for the first attempts of using it, it is probably better to let the model collapse into a pure Armington model. This can be done in the following way: 1) Remove transport costs on the Armington variants, that is in the equations governing $P_{A,i}^{D}$, $d_{A,i}^{F}$ and $x_{A,i}$.[16] 2) Set transport costs on HO variants to be very high, so as to effectively force both imports and exports of the HO variant to zero. 3) Set the HO share parameter, β_i^{HO}, to zero, such as to also force domestic demand of the HO variant to zero.

[16] Alternatively transport costs can be assumed to differ between the HO and Armington goods, ie. by defining $t_{A,i}$ and $t_{HO,i}$ seperately.

When this is done, the model is no different from the standard Armington model, and hence the process of calibration is no different either.

The hybrid features of the model can then be tried and tested, one industry at a time. In practice it will not be feasible or necessary to implement the hybrid features of the model for every single industry. In chapter 4 we identify which industries are the most relevant. For other industries than these, a first approach of using pure Armington assumptions and zero transport costs is to be preferred.

From a calibration perspective, these are the questions that much be addressed in the application of the hybrid features of the model:

- Does the industry consists of sub aggregate goods which is to be thought of as homogenous, that is either type A or type C industries, cf. section 1.2? If so, the level of domestic demand to be considered homogenous, $d^D_{HO,i}$, is to be estimated and subtracted from the original total demand $d^D_{A,i} + d^F_{A,i}$. In the calibration process this requires appropriate adjustment of the share parameters, the beta's, while the original dataset does not necessarily need to be altered.
- Is the domestic industry exporting homogenous goods ? If so, X^{HO}_i is to be estimated and subtracted from $x_{A,i}$ in the calibration process. At the same time it is necessary to impose the restriction that $p^D_{HO,i} = \varepsilon(P^F_i - t_i)$ on the relation between prices and transport costs. The manipulation of prices may be a less trivial matter, depending on the original setup of the model.
- Is the domestic industry protected by transportation costs or other trade barriers? If so, imports must also be zero, ie. $M^{HO}_i = 0$. At the same time it is necessary to set the transportation costs and prices to plausible values, such that $\varepsilon(P^F_i - t_i) < p^D_{A,i} < \varepsilon(P^F_i + t_i)$. This part is very important, as it is this wedge between import and export prices which governs the distance between current prices and the tipping-points.
- If exports of homogenous goods is set to a positive value, $X^{HO}_i > 0$, the domestic supply price must be equal to the foreign price adjusted for exchange rate and transport costs ie. $p^D_{A,i} = \varepsilon(P^F_i - t_i)$.
- When imports are zero, domestic supply of homogenous goods must be set equal to the sum of domestic demand and exports, ie. $s^D_{HO,i}$=. $d^D_{HO,i}$+, X^{HO}_i, and subtracted from the total domestic supply, ie. $s^D_{A,i}$.
- If imports are positive, they must be equal to domestic demand, ie. $M_{HO,i} = d^D_{HO,i}$, and domestic supply is zero, and thus the domestic supply price must be set higher than the price of imports, ie. $p^D_{A,i} > \varepsilon(P^F_i + t_i)$

There is no exact statistics that one can rely on for answering the questions above[17]. As also discussed in chapter 4, it is necessary to perform a thorough analysis of relevant industries in order to evaluate the size of trade costs, differences in domestic and foreign prices, and the size of production at risk of relocation. Such analysis is essential whether or not the results thereof are integrated into the core of IntERACT as recommended above. Therefore, such industry analysis must be considered the most important next step in the process towards modelling the effects of tipping-points on both trade patterns and relocation of production.

[17] This also applies for the elasticity of substitution of demand between HO and ARM type goods, which though must be considered of minor importance compared to issues discussed below .

The recommended hybrid model is a novel approach. It builds on Zhang 2008, who proposed a very similar model, though within a theoretical framework, as the solution to how to bridge the gap between the pros and cons of existing methods, but to our knowledge it has not been tested in applied work. Compared to a pure Hecksher-Ohlin model there will always be a positive demand for all domestically produced goods, which makes much easier to solve for equilibrium. However, the discontinuities in prices and demand may still be problematic in practice. It is therefore our recommendation that the model should be tested in a small scale experiment, by adaption of an otherwise standard CGE-model, and by following the stepwise procedure explained above, so as to test the feasibility of the approach.

Discussion of possible expansions

All of the CGE models, theoretical as well as applied models, that we have come across during this study treat the response from changes in terms of trade unto patterns of trade from a static comparative perspective, that is there is no concern for the timing of the demand response. The two macro econometric models SMEC and ADAM as (See Table 3) both incorporates lagged response functions in both the equations for exports and imports. In fact this lagged response is responsible for much of the difference between short term and long term dynamics in the models. It is our belief that it is a path worth looking further into in IntERACT project if realistic short term dynamics is a key concern.

Another issue worth mentioning is the question of market differentiation. In the setup of the trade model all of the rest of the world has been treated as on big entity. Especially concerning the question of relocation this is a very simplified assumption. Too see why, imagine one industry in which Denmark has a cost advantage against Sweden but not against China, and imagine that transport costs are so high as to create a barrier against trade with Sweden. If transport costs would somehow fall, production would relocate from Sweden to Denmark, but if they were to fall even further all of production would relocate to China. It is possible to incorporate such effects by defining transport costs and foreign prices, imports and exports for the HO goods variant, but that is beyond the scope of this study.

Chapter 4

Identification of exposed sectors

We have proposed a very general and flexible approach of modelling foreign trade in IntERACT which takes the methodology applied in the most recent energy economic CGE models one step further into a generalized framework with the addition of transport costs in order to support the existence of tipping-points. In simple terms the object of this chapter is, as also formulated in preface, to identify industries which needs special attention, so that IntERACT will give the best possible prediction of current issues like terms of trade for energy intensive industries, relocation of production and carbon leakage.

4.1 Drivers and brakes for relocation of production

In our proposed method for modelling foreign trade in IntERACT, we look aside from New Trade theory. However, it is still important to recognise the contributions of modern trade theory. Factors such as firm heterogeneity, increasing returns to scale, agglomeration effects, barriers to entry and so forth is important for explaining patterns of trade and differences in terms of trade, - not least in a specialised and disaggregated model like IntERACT. The basic lesson is that all forces which diminishes direct competition between domestic and foreign firms has the function of a barrier to relocation, and all forces which promotes direct competition has the function of a driver for relocation.

In the context of the proposed model of foreign trade, strong drivers should be translated into either a high percentage of demand for the HO variant or high Armington elasticities. Similarly, strong brakes should be translated into either low armington elasticities or high transport costs. If an industry is described at a disaggregated level or if there is other reasons to believe that tipping-points exists the HO approach should be used. If industries are described at a higher level of aggregation or demand response for other reasons are thought to be gradual, the armington approach should be used.

In a recent study for The Nordic Council of Ministers Copenhagen Economics defined a number of fairly simple and observable drivers and brakes for identifying industries which are especially important in relation to industrial carbon leakage. The drivers are forces which promote reallocation of production, or forces which in other ways enhances the scale of carbon leakage in the face of significant increases in the costs of production. Similarly the brakes are forces, which prevent or which slow down relocation of production. Since industrial carbon leakage revolves around the question of relocation, the drivers and brakes are equally relevant for the issue of relocation in its own right.

For the present study we have revised the list of industries identified in the study for the Nordic Council of Ministers. It is this list of industries that we recommend should be handled with special care to detail in relation to the general treatment of foreign trade in IntERACT in order to give the best possible prediction of current issues like terms of trade for energy intensive industries, relocation of production and carbon leakage. As discussed previously, one most accept that all industries are ultimately at risk of relocation if burdened with sufficiently high costs. Hence, for other types of policy not related to the use of energy, the relevant list of industries might be very different. In general, in the search for industries at risk, the first criteria should be if the policy in question has a significant effect on the total costs of production, hence the first driver being energy intensity.

Drivers

- Energy intensity
- Ability to split and outsource the production processes
- Relative energy efficiency in production and fuel mix (Exclusive to carbon leakage)

Brakes

- Transportation costs and transportability
- Capital intensity
- Trade barriers and exchange rate risks
- Product differentiation

The first criteria in the filtering process is in this case the energy intensity since, for issues concerning both energy prices and policies, these sectors are priori the most vulnerable for relocation[18]. Secondly most of the industries are defined at a fairly detailed level of aggregation and many of them contain only a very limited number of firms. By these features the industries are obvious HO candidates. In relation to calibration this implies that a large share of demand should be defined as HO. The share should be chosen as the share of production which is thought to relocate if the domestic gross price is increased above the level of imported goods, or the share of domestic demand that can be achieved if the gross price falls below the price of imported goods plus transport costs. The discussion on how to score product differentiation in appendix A provides some guidance on how to possibly proceed, but it must be realized that there is no exact statistics that one can rely on. Transport costs are joint factor in the determination of the risk of relocation, as they will allow production to be maintained at a range of prices. Transport costs are however more easily estimated by evaluating the weight/to value as also described in the appendix.

For each of the identified industries a careful analysis should be carried out in order to derive credible parameters for the trade model. So far, the drivers and brakes do point in the right direction. Each industry is given a score from 1-5. A high score is an indicator of a high risk of relocation and vice versa.[19] In table 5 we have shown only two of the drivers/brakes “Product differentiation” and “Transportability”. Very homogenous goods are thus given a score of five for “Product differentiation” and so are easily transported goods for “Transportability”. The scores are presented in Table 5.

[18] For other reasons issues than the ones listed, other industries will likely also need special attention. Even so we choose to keep a strict focus on the energy intensive industries.

[19] More information on the principles for how scores are assigned is found in appendix A.

Table 5 Quantifying the drivers and brakes

Nace	Industry	Energy intensity	Product differentiation	Transportability
152	Processing and preserving of fish and fish products	14 %	5	4
154	Manufacture of vegetable and animal oils and fats	18 %	3	3
1562	Manufacture of starches and starch products	13 %	1	2
1597	Manufacture of malt	15 %	2	2
173	Finishing of textiles	13 %	5	5
2112	Manufacture of paper and paperboard	34 %	3	2
2411	Manufacture of industrial gases	12 %	4	2
2416	Manufacture of plastics in primary forms	10 %	4	4
261	Manufacture of glass and glass products	13 %	2	1
264	Manufacture of bricks, tiles etc.	24 %	1	3
265	Manufacture of cement, lime and plaster*	? %	5	1*
275	Casting of metals	16 %	5	4

Note: *The cement industry in Denmark only consist of one firm, therefore data is kept confidential, however, we know that the sector should also be included in the energy intensive industries. Transportability are product specific measures and is not expected to vary across countries. Therefore the quantification for the other three Nordic countries (Sweden, Norway and Finland) is used for the cement, lime and plaster industry.

Source: Copenhagen Economics based on data from Eurostat and WITS

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Appendix A
Methodology for selecting exposed sectors

The scores on almost all drivers are assigned based on a percentile approach. This means that generally the 20% highest observations are assigned the score "5", while the 20% lowest are assigned the score "1". In order to ensure that observations with similar values get the same score, we manually re-assign some scores. This has been the case for some industries being close to the "cut-off point" between percentiles. Moreover, qualitative assessments have also been necessary in order to capture specific industry characteristics, which are explained below. Finally, scores on the "trade barrier-driver" has been assigned through a slightly different approach, which is further elaborated below.

Product differentiation
In order to quantify product differentiation, we use data on trade intensity. If a product is homogenous across countries it will most likely be traded across borders. Hence a low degree of differentiation, and thus high risk of leakage, will be associated with a high trade intensity. Some qualitative evaluation has been necessary though. Consider e.g. cement industry, which is a fairly homogenous good (within specific types of cement). Since cement is heavy, it is quite expensive to transport and thus has low trade intensity, and hence would not receive an accurate score. Quantifying this driver has thus been coupled with a qualitative evaluation of the other relevant drivers for each industry.

Transportability
In order to quantify transportability, we use data on a product's weight-to-value ratio. The higher the weight-to-value ratio is, the higher the transport costs will be, and consequently the lower the products' transportability and the risk of leakage will be. We have also made specific qualitative assessment of the industries in order to assess if a product is in fact transportable based on product characteristics. While dairy products may be relatively cheap to transport, their durability is relatively low thus making them less transportable. The score on such products has manually been adjusted in order to capture this.