Export Restrictions on Critical Raw Materials for the EU

Master Thesis

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Abstract

Many high-tech products depend on specific raw material inputs that are very hard to substitute. Access to these raw material inputs is of growing concern to many modern economies including the EU. In a 2010 raw material report, the European Commission has established 14 raw materials that are critical to the EU economy. Six of these materials (rare earths, antimony, tungsten, fluorspar, graphite and magnesium) are largely controlled by China which also imposes export taxes on these six materials. An export tax lowers the domestic price of a good and at the same time raises the world price of that good. Export taxes on raw materials can thus provide a competitive advantage to raw material using high-tech industries in the exporting countries compared to competing industries in importing countries. The focus of this study is on the six critical raw material markets dominated by China. This study is the first to analyse the impact of raw material export taxes on downstream (high-tech) industries in both the exporting country (China) and the importing region (EU). A CGE analysis is used to measure the impact of raw material export taxes on raw material markets, downstream industries and general welfare. For the CGE analysis, the GTAP model and a modified (disaggregated) GTAP database 8 is used. The main finding it that EU downstream industries benefit substantially if the current Chinese export taxes are removed. Especially sectors producing electronical equipment, metal products and transport equipment benefit in terms of higher output (an increase of 2.2 billion, 1.1 billion and 1.3 billion respectively) and higher value added (an increase of 0,09%, 0,09% and 0,1% respectively). Because of China's great market power, the terms-of-trade effect dominates the trade distortion effect. This causes a decrease in overall welfare for China: GDP decreases by 0,15% and the equivalent variation is -1.3 billion. After removing the export taxes, welfare in EU increases with a small GDP increase (0,02%) and a positive equivalent variation value of 2.2 billion. Raising Chinese export taxes on the six raw materials has reverse effects with welfare increasing in China and decreasing in the EU.

Key words: raw materials, export taxation, computable general equilibrium, rare earths, antimony, tungsten, magnesium, fluorspar, graphite, GTAP

Preface

Throughout the writing of this master thesis I have received support from a number of people. Here, I would like to express my gratitude to some of those people. First of all I would like to thank Dr. Koen Berden for his supervision, guidance and patience throughout the project. Second, I would like to thank Prof. Dr. Joseph Francois for his help with the CGE modelling part of this thesis. My visit to Dr. Francois in Vienna (in august 2012) and his input in the modelling part of this thesis has been of great help. I would also like to thank Ecorys for giving me the opportunity to work on this project and for the help I have received in the past year. Finally, I would like to thank my family, my parents in particular, for their tremendous support.

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List of abbreviations

BAU	Business As Usual
CDE	Constant Difference of Elasticity
CES	Constant Elasticity of Substitution
CGE	Computable General Equilibirum
CIF	Cost, Insurance and Freight
EC	European Commission
EU	European Union
EV	Equivalent Variation
FOB	Free On Board
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
GTAP	Global Trade Analysis Project
HHI	Herfindahl-Hirschman Index
LDC	Least Developed Country
ROW	Rest Of the World
SAM	Social Accounting Matrix
TPR	Trade Policy Review
UN	United Nations
US(A)	United States (of America)
USGS	United States Geological Survey
WTO	World Trade Organization

1 Introduction

In the last couple of years there have been two major trade disputes concerning export taxes on raw materials.[1] In both cases the EU and the US filed a complaint against the export taxes on raw materials imposed by China. The latest case against China concerns (among other complaints) export taxes on rare earths of which China controls 97,45% of world production[2]. A defining factor of these rare earths is that they are used in high value-added industries producing high-tech final goods. A country that controls a large part of the world production of such valuable inputs can use an export tax to benefit its own producers of the high value-added final good. In short, an export tax on the input lowers the price for domestic consumers while raising the world price. The presence of export restrictions on valuable raw materials such as *rare earths*, *tungsten* and *magnesium* creates trade distortions that are potentially damaging to European industries.

Realising the importance of access to valuable raw materials, the European Commission (EC) *Enterprise and Industry* launched the *Raw Materials Initiative*.[3] The goal of this initiative was to determine which materials are critical to the EU economies and how big the supply risk for these materials is. Based on the economic importance for the EU and the supply risk, the Commission has identified 14 *critical raw materials*. This list contains 14 metals and minerals that are crucial in many high-tech products and they are thus of great economic importance. For example, rare earths are required materials for the production of smartphones, computer chips and televisions. The high concentration of production of the critical raw materials in a given non-EU country means a heightened supply risk for European industries. Out of the 14 materials, there are six for which China dominates world production. The focus of this study will be on these six raw materials; *rare earths*, *antimony*, *magnesium*, *fluorspar*, *tungsten* and *graphite*. The importance of access to these critical raw materials is underlined by the two WTO dispute cases against China initiated by net raw materials importers the EU and the US.

This thesis will largely focus on export restrictions in the form of export taxes. No distinction will be made between complementary or similar terms such as export tariffs, export fees, export duties and export levies. An export tax can be a specific percentage of the value of a product (an *ad valorem* tax) or a fixed amount per unit of a product (a *specific tax*). The effect of all export duties is a rise in the cost of exports and therefore an expected decrease in the volume of exports. The best information on the presence of export restrictions worldwide comes from Trade Policy Review (TPR) country reports. Each WTO country TPR report includes a section on measures affecting exports. Kim (2010) provides an overview of current use of export restrictions in the world based on these TPR reports. The main finding from Kim is that in the period 2003-2009, 65 out of 128 WTO members had export taxes in place.[4] In 2010, China had export taxes in place (ranging from 10% to 20%) on each of the six raw materials that will be examined in this study.

[1] WTO dispute settlement cases DS395 and DS432.
[2] World Mining Data 2011.
[3] Raw Materials Initiative website available at: http://ec.europa.eu/enterprise/policies/raw-materials/index_en.htm
[4] Kim (2010), *Recent trends in export restrictions on raw materials*, WTO

Governments can use export taxes to achieve a number of different policy goals. Developing countries often use export taxation as an important source of government revenue. Another use of export taxation is in the stabilisation of domestic food prices. Stabilising food prices is again mostly a policy goal that is relevant for developing countries. The main goal of the export taxes on the materials under examination in this study is the promotion of domestic downstream industries. The limited reserves and production capacities in the world and the high economic importance of the selected critical raw materials make them very valuable inputs in many European industries. The major focus of this study will be on the downstream industries in both the exporting and importing country. The effect on domestic and world prices of both inputs and intermediate goods will be analysed. The main question here is whether export restrictions on strategic raw materials can effectively be used to benefit the domestic industries and whether this hurts (and how much) foreign industries.
The above has led to the following main research question:

What is the impact of critical raw material export taxes on (EU) downstream processing industries and what would be the impact of lifting them?

The focus of this study is on the impact of export taxes on European Union industries. The raw materials that will be analysed are selected based on their importance for the EU. To answer the research question, this study will measure the effect of an export tax on prices, output, value added, GDP, the terms-of-trade and welfare. Besides the impact on the EU, this study will also look at the impact on the export tax imposing country: China.

This study will begin by explaining the effects of an export tax through the use of a partial equilibrium framework (as an illustration) in section 2.1. The policy objectives of export taxation range from the generation of government revenue to the topic of this study; promoting downstream industries. Section 2.2 will discuss the policy objectives of export restrictions and their effectiveness. Section 2.3 will discuss the rules and regulations of the WTO with regards to export taxation. The effect of an export tax will be analysed for six critical raw materials: rare earths, antimony, magnesium, fluorspar, tungsten and graphite. Section 2.4 will explain why these six materials are selected and what their main economic use is.

To analyse the effects of export taxes, a Computable General Equilibrium (CGE) model will be used. The CGE model used in this study is developed by the Global Trade Analysis Project (GTAP). How this model works and how it is used will be explained in sections 3.1 and 3.2. Section 3.3 will show what database aggregation is used and section 3.4 will discuss how the six raw materials are added to the GTAP database. To answer the research question, two main scenarios will be run with the model. The first scenario is the removal of all Chinese export taxes on the selected raw materials. The second scenario is an increase in the export tax on the selected raw materials by 40%. These scenarios are discussed in section 3.5. The results of these scenarios will be presented in section 4.1 and 4.2. The effects of the scenarios on prices, output, value added, GDP and the terms of trade will be shown. For reliability, a sensitivity analysis will be presented in section 4.3. Finally, section 5 will present shortcomings and recommendations and the conclusion of this study will be presented in section 6.

2 Literature and Theory

This chapter contains an introduction into the economics of export taxation. In section 2.1 the economic effects of export taxes will be explained by means of a partial equilibrium model. Contributions in this section will be based on theoretical literature. In part 2.2 the policy objectives of export taxation will be discussed. This section will also contain an overview of the empirical literature regarding policy effects of export taxation. Section 2.3 will shortly discuss the rules and regulations regarding export taxation. Finally section 2.4 explains how the critical raw materials are selected and gives an overview of the market for the selected raw material.

2.1 Partial equilibrium foundations of export taxation

This section explains the basic economic theory of export taxation by means of a partial equilibrium analysis. The model described here is adopted from Cordon (1971). A distinction will be made between a small exporting country and a large one. A small country means that the elasticities of foreign demand and supply are infinite so the small country does not have market power. In other words, an increase or decrease in exports from a small country does not affect the world price. In all cases, production is assumed to be perfectly competitive. First, the effects of an export tax on exportable goods will be demonstrated for a small country. Second, the case for a large country will be examined. In these first two scenarios production is assumed to be vertically integrated. In reality production is often not vertically integrated, wood for example may be sold to IKEA which in turn makes it into furniture. An export tax on wood therefore also affects downstream producers such as IKEA. The effects of an export tax on downstream producers will be discussed in section 2.1.3.

2.1.1 The small country case

Figure 1 depicts the effects of an export tax on an exportable good for a small exporting country. The horizontal axis shows the quantity of the exportable good. In this analysis the exportable good is a homogeneous good produced and consumed at home as well as exported to the rest of the world. Note the distinction between exportable goods (which includes domestically consumed goods) and actual exports. The domestic demand and supply curves are given by DD and SS respectively. World supply is given by WW. In the initial situation domestic supply (OA) exceeds domestic demand (OB) with the difference between the two being exported to the rest of the world. With free trade, the total quantity of export is thus given by BA at a price of OW.

Now consider an *ad valorem* (meaning a tax based on the value of the exportable good) export tax of the fraction TW/OW on the exportable good. The tax lowers the price that domestic exporters receive for their exported goods. The decrease in revenues from exported goods shifts part of the domestic supply from the rest of the world to domestic consumers. The new equilibrium will be reached once the domestic price obtained by producers equals the after tax income from exports. The price paid by domestic consumers and received by domestic producers is now given by OT. The world price remains at OW since the small country has no market power. Exports have been reduced to B’A’, domestic consumption has increased by BB’ and production has decreased by A’A. The tax thus has a number of different effects. First of all, domestic consumers are better off since more is consumed at a lower price, the effect of this is an increase in consumer surplus given by the area WLNT. Domestic producers now receive a lower price for both their exports and domestically sold goods as well as experience a decrease in production. This leads to a loss in producer surplus of the area WVGT. The tax thus has an income redistribution effect: domestic consumers benefit at the cost of domestic producers. Total tax revenue is given by the number of export B'A' times the absolute value of the tax WT. This is given by the shaded area MJGN in Figure 1.

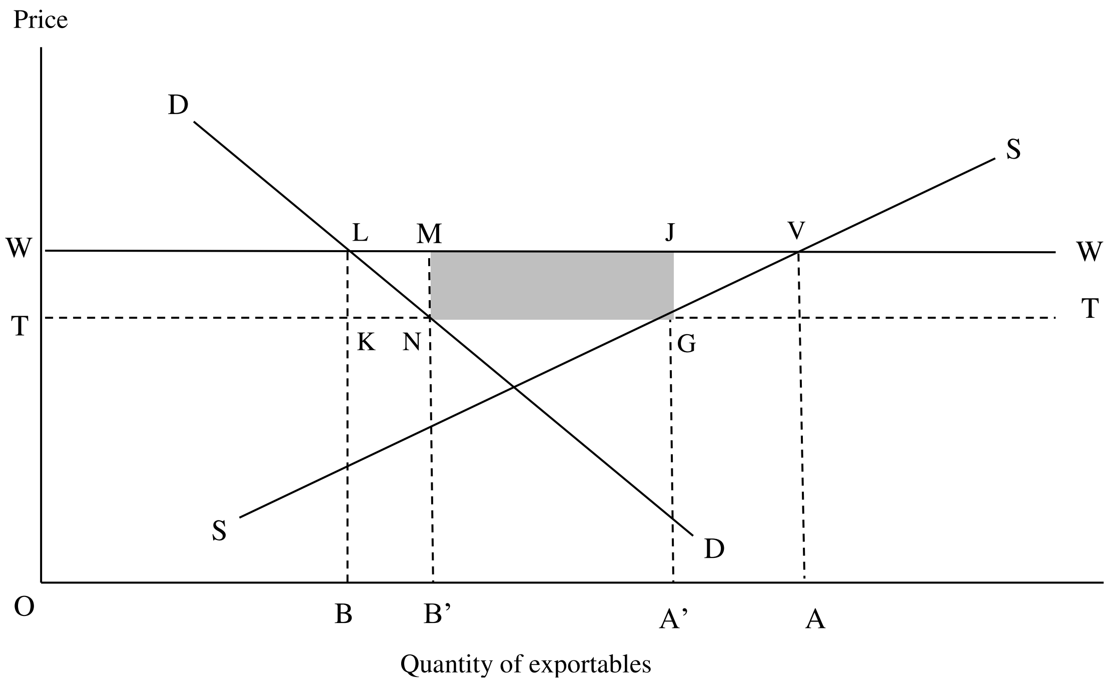

Figure 1 Export taxation in a small country

The distortion created by the tax results in a deadweight loss given by the areas LMN + JGV. This deadweight loss means that the net result of the tax on overall economic welfare is negative. Because of the infinite foreign supply and demand assumptions, nothing changes for the importing countries in the rest of the world.

2.1.2 The large country case

Until now the exporting country was assumed to have no market power and thus no effect on world prices. If the elasticity of foreign demand is negative, a decrease in exports (supply) from the large country will increase the world price. The case of a negative foreign elasticity of demand is shown in Figure 2. The price is again shown on the vertical axis but this time the horizontal axis shows the quantity of exports, not exportables. The supply curve of exports is given by HH and is derived by subtracting domestic demand for exportables (given by DD in Figure 1) from domestic production (given by SS in Figure 1). The initial export demand curve is given by TT. In the free trade situation exports are given by OQ at the world price P.

Now consider the effects of an export tax at the rate of PL/OP. The tax-including foreign demand curve is given by T'T' which lies below the free trade demand curve TT. Initially the tax lowers the price received by domestic producers to OL. The following decrease in supply raises the tax-inclusive world price to P_w with a corresponding price P_d faced by domestic consumers and producers. In the new equilibrium exports have fallen by QR and the tax has created a gap of OL between the domestic price and the world price. Tax revenues are again given by the shaded area. Since the price of exports faced by the rest of the world is now higher, the tax has a positive effect on the terms-of-trade in the exporting country. The value of the exports may have increased or decreased since the price has risen while the quantity has dropped. If the foreign elasticity of demand is greater than unity (minus one since a negative elasticity of demand was assumed) the tax will increase the total value of exports. If the elasticity is less than unity the value will have decreased, if it is exactly minus one the value will have stayed the same.

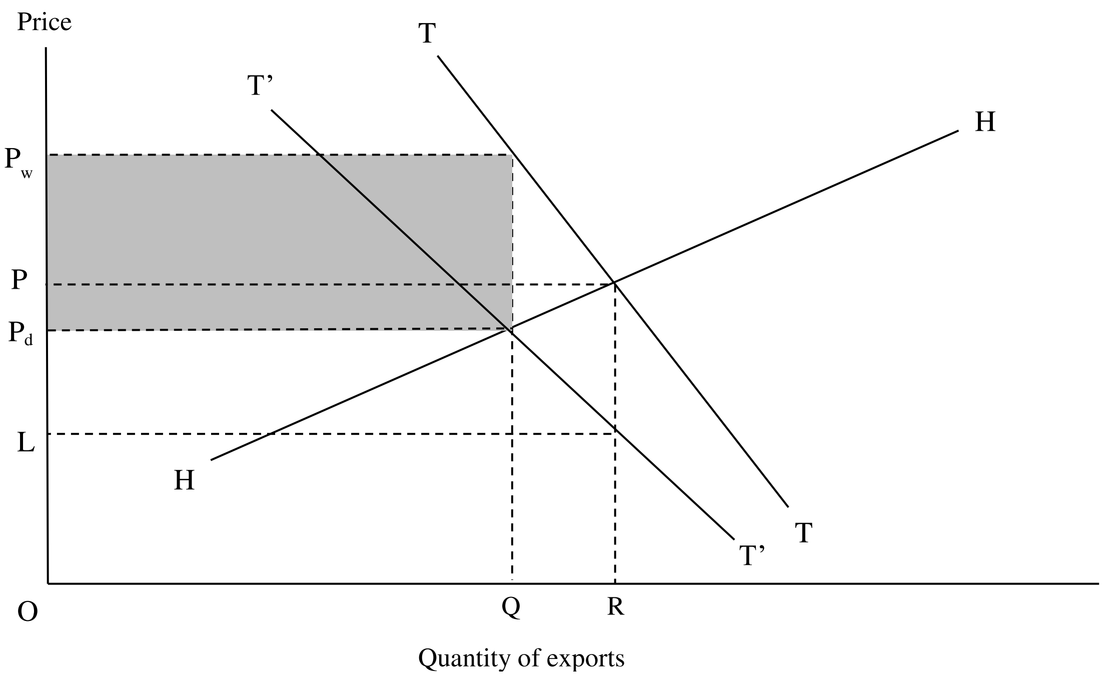

Figure 2 Export taxation in a large country

The improvement in the terms-of-trade for the exporting country now means that the export tax does not necessarily lead to a net loss in economic welfare. If the terms-of-trade effect dominates the trade distortion effect, welfare in the exporting country will have increased as a result of the export tax. For importing countries in the rest of the world, the higher price of the exported good means a worsening of the terms-of-trade and thus a loss in welfare.

2.1.3 Export taxation on inputs

Until now it has been assumed that production of the exportable is vertically integrated. Removing this assumption allows for the possibility of produced inputs used in the domestically produced final good. Consider for example an exportable final good such as cloth that is produced by two factors of production: a produced physical product (wool) and a *value-added product.* The value-added product is the input from labour and capital that produces the cloth and generates the value added in the final good. The question now is how an export tax on the produced input affects the final good. Or, how does the export tax on the input protect the value-added product in the final good? To answer this question, the *effective protective rate* will be used. The *effective protective rate* is defined as the rate of protection provided to the economic activity that generates the value-added in the final good

(Cordon, 1971). In the following analysis three assumptions have to be made: (1) there is a fixed input coefficient of the input (in this case wool) in the production of the final good, (2) the exporting country is small and (3) export taxes are not so high that they eliminate trade altogether.

Assume that the exportable good *j* with nominal price *Pj* uses only one produced exportable input *i*. The share of the input *i* into the cost of *j* is given by a_{ij}. Finally the value-added per unit of *j* is given by P_v before taxes and P'_v after taxes.

$$P_v = P_j(1 - a_{ij}) \qquad \textbf{(1)}$$

$$P'_v = P_j[(1 + t_j) - a_{ij}(1 + t_i)] \qquad \textbf{(2)}$$

In (1) and (2) a tax on *j* and *i* is depicted as t_j and t_i respectively. A tax of say 20% on the exported good *j* will show up as -0.2 in the equation as the tax decreases the domestic price of the exported good. The effective-protective rate (g_j), or the proportional increase in the value-added product of *j*, is given by equation (3).

$$g_j = \frac{P'_v - P_v}{P_v} \qquad \textbf{(3)}$$

Inserting (1) and (2) into (3) gives equation (4) which shows how the effective protection rate depends on taxes on *i* and *j*.

$$g_j = \frac{t_j - a_{ij}\, t_i}{1 - a_{ij}} \qquad \textbf{(4)}$$

So the effective-protective rate depends on the taxes on the input product and final product as well as the share of the input in the final good. For example, an export tax of say 33% of wool with an input share of 40% into cloth means an effective protection rate of 22%. In other words the value-added per cloth has increased by 22% as a result of cheaper inputs.

2.2 Export tax policy objectives

The previous section has discussed the theoretical implications of imposing an export tax. It was shown that an export tax can be used to improve the terms-of-trade of a large country while also affecting the income distribution in the exporting country. In this way governments can use export taxes to achieve a certain policy objective, in this case an *improvement in the terms-of-trade* or an *income redistribution policy*. These two effects of export taxation are usually not the main policy objective of an export tax. This section will discuss the four main policy objectives of export taxation: (1) controlling domestic prices, (2) raising government revenues, (3) environmental protection and natural resources preservation and (4) promoting downstream industries.

Stabilizing domestic prices: Export restrictions improve the terms-of-trade of a country by affecting world supply and thus world prices. The effect on domestic prices is the opposite; export restrictions divert exports from the world market to the domestic market. The increased supply in the domestic market decreases the domestic price. Export restrictions can thus be used a policy instrument to stabilize domestic prices. For example Argentina has used export taxes to stabilise domestic prices after the peso's devaluation in 2002.[5] To counteract the exchange rate fluctuations, Argentina imposed export taxes ranging from 5 to 45 percent. Stabilising domestic prices is especially relevant in the context of food security. A food exporting country can use export restrictions to decrease or stabilize domestic food prices. In many developing countries (especially in least developed countries (LDCs)), the bulk of disposable income is spend on food products. Changes in food prices thus directly impact the amount of food people can consume. Bouet and Debucquet (2010) use a CGE model to analyse how export taxation can be used to stabilise domestic prices of food products. They find that to keep domestic prices stable (after a positive wheat demand shock), export taxes need to be implemented ranging from 3,3% (Australia) to 5,6% (Russia). The world price of wheat increases by 17%, net food importing countries are thus hurt by a policy like this. An important thing to note here is that Bouet and Debucquet argue that net-exporters of a particular good may react to each other's trade policies. If one country imposes export taxes, other net-exporters might follow in order to keep their domestic prices stable. In the end the importing countries pay the price.

Raising government revenues: If a country lacks the possibility of raising enough revenues through domestic taxation, export taxes may be a viable second-best policy[6]. Traditional methods of generating government revenue (for example income taxation) require strong administrative power of a government. Many LDC's lack the manpower and resources to properly collect income taxation. Export taxes are easy to implement and to collect and thus provide a reliable source of income for many LDC's. In the last decade, the importance of export taxes in this context has declined somewhat (Kim, 2010). In Ghana for example, the share of export taxes in total government revenue decreased from 11,4% in 1998 to 2,3% in 2005.[7]

Protecting the environment and preservation of natural resources: The argument here is that export restrictions decrease demand and thus decrease production. Lower production means less pollution and/or conservation of limited natural resources. This argument is especially true for raw materials. Mining and processing industries are energy and pollution intensive. With export taxes in place it is also easier for a government to monitor the volume and origin of exports. This can be beneficial in cases where scarce materials are obtained and export illegally (for example illegal logging of rainforests). After the Indonesian export tax on wood was removed, illegal logging increased significantly (Kim, 2010). With an export tax in place, illegal wood is much harder to export and thus illegal logging is less attractive. In 2010, China had export taxes in place on a total of 336 product categories. Many of these taxes are placed on raw material products. China argues that these taxes are necessary since the production of these raw materials is highly polluting and energy-intensive.[8] Whether this justification is legitimate depends on whether the export taxes truly decrease pollution and help in preserving natural resources. In the case of China, Korinek & Kim (2010) show that for the materials they investigated (Molybdenum and Chromite), domestic production did not decrease as a result of export taxes.

[5] See Argentina's TPR report (WT/TPR/S/176)
[6] To raise a given amount of revenue, a lump-sum tax is the best (most economically efficient) policy possible (Diamond, 1975).
[7] WTO Ghana TPR report (WT/TPR/S/194)
[8] In a WTO meeting on China's TPR report, China defended its export taxation by claiming that the goal was to decrease pollution and energy use. Some WTO members expressed the concern that the export taxes in fact were not decreasing production and thus did not affect pollution in a positive manner. See WTO TPR minutes of the meeting (WT/TPR/M/199) for the discussion on China's TPR report.

Promote downstream industries: Export restrictions can be used to lower the domestic price of inputs in downstream industries compared to the world price of these inputs. In this context, export taxes effectively serve as indirect subsidies to downstream processing industries. Export restrictions can thus be used to stimulate the development of (higher-value added) downstream industries. For example, Amiruddin (2003) shows that export taxes on palm oil are used by Indonesia and Malaysia to support the development of biodiesel and cooking oil industries. Cameroon has used export taxes on logs (up until 2004 when export was prohibited altogether) to promote its domestic processing industries. The goal was to make sure that 70% of log production was processed domestically and only 30% exported as a raw material.[9] According to its 2008 TPR report, Argentina had export taxes in place on soybean (27,5%), soybean oil (24,5%) and biodiesel (5%). By placing higher export taxes at the beginning of the value chain for biodiesel, Argentina is trying to create a competitive advantage for its biodiesel industry. There are some potential drawbacks associated with using export taxation to promote downstream industries. Ideally, the lower input price will stimulate the growth of downstream processing industries and make them more competitive relative to foreign downstream processing industries. The subsidising effect on downstream industries may however encourage the growth of inefficient industries. If the indirect subsidy leads to inefficient processing industries, these industries will depend on the export tax to be competitive. A second factor affecting the success of export taxes as indirect subsidies is the degree of technological spillovers. Especially in countries with low-value added industries, the goal of the export tax is to develop high-value added industries with competitive technologies. To be successful in the long run then requires that these technologies do no spill over to other sectors or countries (Piermartini, 2004). An example where export taxes on raw materials have led to inefficient processing industries is the case of Indonesian export taxes on logs. The low prices of logs (as a result of an export tax of logs of 30%) in the 90's have led to inefficient logging practices and wood processing (WTO, 1998). The WTO estimated the wastage ratio in the wood processing industry to be up to twice the international average.

2.3 Rules and regulations on export taxes

WTO rules and regulations on the import side of trade are clear, extensive and well known. The rules on export restrictions are more ambiguous. There is no single GATT/WTO article dealing exclusively with export restrictions, most notably there is a clear distinction between quantitative restrictions and export duties. Furthermore in the WTO accession process, country specific obligation may be negotiated. This section will start by discussing the rules and regulations on export taxation. Next, WTO accession protocols will be discussed. The final part of this section will discuss the WTO enforcement possibilities and discuss two major raw material trade disputes with China.

2.3.1 WTO regulations and accession negotiations

The main article dealing with export restrictions is article XI: 1 of the 1994 General Agreement on Tariffs and Trade (GATT):

'No prohibitions or restrictions other than duties, taxes or other charges, whether made effective through quotas, import or export licences or other measures, shall be instituted or maintained by any

[9] WTO Cameroon TPR report (WT/TPR/S/187)

contracting party on the importation of any product of the territory of any other contracting party or on the exportation or sale for export of any product destined for the territory of any other contracting party'[10]

This article specifically prohibits all export restrictions except taxes, duties and other charges on exports. This means that all quantitative restrictions such as quotas, bans and minimum prices are prohibited in principle. Article XI:1 permits export taxes, even if these export taxes are prohibitively high.[11]

There are a number of exceptions to the general rule of article XI. Most important (especially in the context of raw materials) is the exception provided by article XX(g) of GATT 1994. This article permits export restrictions including quantitative restrictions if the conservation of exhaustible natural resources is the main goal. In practice this means that restrictions need to be 'primarily aimed at' the conservation of natural resources and in no case protection of domestic industries may be the goal of the restrictions.[12] Other exceptions include Article XI:2 (critical food shortage), and Article XXI (security exceptions). There is currently no obligation for WTO members to notify the instalment or presence of export restrictions to trading partners.[13] Article X of GATT 1994 does require WTO members to publish trade related laws and regulations in a prompt and accessible manner. This article applies to all trade related laws including export restrictions. The main goal here is transparency and there is no obligation of notification.

As discussed earlier, export taxes are currently allowed under WTO law. Exceptions can be made in country specific cases during the WTO accession process. For example when China entered the WTO, it was negotiated that it would eliminate export taxes on all items with the exception of a specific set of 84 items. The urgency to eliminate export taxes differs from country to country. Specifically for many developing countries export taxes are an easy way to generate public revenue if income taxation is difficult or too expensive.

Raw material	Maximum export tax allowed
Vanadium	30%
Antimony	20%
Tungsten	20%
Silicon	25%
Manganese	20%

Table 1 Raw materials with export tax exemption. Source: WTO, China accession protocol, annex 6

Table 1 shows some raw materials that have been included in the Chinese accession protocol. China is free to impose export taxes on these materials as well as on the other 79 items on the list given in Annex 6 of the accession protocol. From the selected raw materials in this study, only antimony and tungsten are on the exception list. This means that China may not impose export taxes on the other four (rare earths, magnesium, fluorspar and graphite).

[10] GATT 1994, article XI:1
[11] Van Hende and Peterson (2009), *Export restrictions on raw materials – WTO rules and remedies*.
[12] *US-Shrimp,* WTO Appellate body report (1998) and GATT panel report, *Canada- Herring and Salmon* (1988)
[13] Van Hende and Peterson (2009), *Export restrictions on raw materials – WTO rules and remedies*.

2.3.2 WTO enforcement and current disputes

A quantitative export restriction contrary to WTO regulations or WTO accession agreements may be challenged directly before the WTO. The main remedy is the dispute settlement procedure. Furthermore in limited circumstances, export restrictions might be indirectly subject to other WTO regulations. Export restrictions could in some cases be seen as subsidies as defined in the WTO agreement on Subsidies and Countervailing Measures (SCM Agreement). As Van den Hende and Paterson (2009) argue, an export tax that is aimed primarily at providing cheaper raw materials inputs to domestic producers could be seen as a subsidy. In practice, countries almost always use the dispute settlement procedure to resolve conflicts.

Dispute settlement by the WTO is governed by the Dispute Settlement Body which is made up of all WTO members.[14] This body can establish a panel that will investigate the allegations of the complaining country. The Dispute Settlement Body can also accept or reject the panel's findings or the results of an appeal. The first stage in a dispute settlement case is the consultation stage. In this stage the countries in the dispute consult with each other and try to resolve their conflicts by themselves. If this fails, the complaining country may request the installation of a panel. Both the complaining country and the challenged country (since they are WTO members) are part of the Dispute Settlement Body. The challenged country can block the panel once but not the second time the Settlement Body meets. The panel will hear both parties, consult experts and finally present a report with recommendations to the Settlement Body. The panel recommendations automatically become WTO rulings or recommendations if the report is not rejected with consensus by the Dispute Settlement Body. Both sides in the dispute can appeal a panel's ruling. The appeal is heard by three members from the permanent seven-member Appellate Body. This body can confirm, reject or modify a panel report. As was the case for the panel report, the Appellate Body report has to be accepted by the Dispute Settlement Body and can only be rejected by consensus.

In 2009, the EU, US and Mexico jointly filed a complaint against the export restrictions on raw materials imposed by China. China maintains a number of quotas and export taxes on raw materials such as magnesium, coke, zinc and bauxite. Upon entering the WTO, China agreed to refrain from using export taxes on most natural resources including magnesium, coke, zinc and bauxite. Combined with article XI on quantitative restrictions this means that in principle these export restrictions are in violation of WTO regulations. In defence of its export policy, China argued that the export restrictions are justified on environmental grounds. A WTO panel ruled that there was no link between the duties and quota imposed and any conservation objective.[15] In this case the WTO argued that export restrictions are not an efficient policy to address environmental externalities when these externalities arise from domestic production. In other words, the export restrictions imposed by China do not decrease domestic production and thus do not decrease environmental externalities. This is a clear indication on how WTO law should be applied in similar cases. The ruling by the WTO panel was confirmed by the WTO appellate body on January 30 2012.[16]

[14] For a discussion of dispute settlement procedures and links to the relevant legal articles see: http://www.wto.org/english/thewto_e/whatis_e/tif_e/disp1_e.htm

[15] WTO dispute settlement case DS395. Available at http://www.wto.org/english/tratop_e/dispu_e/cases_e/ds395_e.htm

[16] *Measures related to the exportation of raw materials*, WTO, 2012

The second major conflict between the EU and China is about export restrictions imposed on rare earths, tungsten and molybdenum.[17] The EU (together with Japan and the US) requested dispute settlement consultations with China at the WTO in March 2012. EU Trade Commissioner Karel de Gucht stated the reason for the complaint as follows: *"Despite the clear ruling of the WTO in our first dispute on raw materials, China has made no attempt to remove its export restrictions. This leaves us no choice but to challenge China's export regime again to ensure fair access for our businesses to these materials."*[18]. Rare earths and molybdenum are not on the exception list in China's accession protocol. This means that China is in violation of its accession protocol and thus of WTO regulations. China has announced that its defence will be based on the argument of the conservation of natural resources as specified in article XX(g) of GATT 1994. The WTO is, at the time of this writing, establishing a panel that will investigate whether China is indeed in violation of WTO regulations and whether that violation is justified or not.

A major problem with a supranational organisation like the WTO is that its ability to enforce regulations is limited. As said, in the 2009 case, the WTO panel and appellate body both concluded that China is in violation of WTO regulations and that it should remove its export restriction. But what can the WTO do to make sure that China lives up to this ruling? The main goal of the WTO enforcement procedure is to get the losing challenged country to bring its policies in line with WTO regulations. The losing country is therefore not directly penalised but gets the chance to follow the panel recommendations. A plan to implement the panel's recommendations needs to be submitted to the Settlement Body within 30 days. If a country does not comply with the panel ruling, the complaining country and challenged country must enter negotiations to establish mutually acceptable compensation for the complaining country. This compensation can for example be the lowering of import tariffs that are relevant for the complaining country. If the countries in the dispute cannot agree on compensation, the complaining country may impose trade sanctions as a matter of last resort. The WTO enforcement depends largely on negotiations between the countries in the dispute. A losing country may only be sanctioned after all consultation and negotiation has failed. And even then, the power of small countries to penalise large trading partners is much smaller than vice versa. This is a potential problem for raw material importing countries. Even if WTO rules prohibit export taxes, it may be very hard to actually enforce these rules.

2.4 Critical raw materials

The analytical part of this thesis focuses on a limited number of raw materials critical to the economies of EU member states. The focus is on six different raw materials which are crucial to the EU economies and for which production is highly concentrated in China. This section will start by explaining why these six materials are critical to the EU economy and why they are selected for further research. Each of the six raw materials will be shortly discussed individually in the latter part of this section. The starting point for the selection made is the EC report *Critical raw materials for the EU* (2010). This report assesses the criticality of 41 non-energy minerals and metals (see Box 1 for a definition of metals and minerals) for the EU economies. To determine the criticality of each raw

[17] WTO dispute settlement case DS432. Available at http://www.wto.org/english/tratop_e/dispu_e/cases_e/ds432_e.htm

[18] EC press release, available at: http://trade.ec.europa.eu/doclib/press/index.cfm?id=785

material two main criteria are used: (1) economic importance and (2) the supply risk. The Commission uses a relative concept of criticality; a material is critical for the EU when it has a higher supply risk and higher economic importance than most of the other materials examined.

Mineral: a mineral is a solid substance that may or not may contain metallic elements. Besides metallic elements a mineral may contain non-metallic elements. For example the mineral fluorspar contains the non-metallic element fluorine.

Metal: a metal is an element with specific properties: highly malleable, conductive and heat resistant. Examples of metals are iron, gold, lead, silver. Certain elements have both metallic and non-metallic properties, for example the *semimetal* antimony. Metals are found within *minerals.* For convenience, the term metal in this thesis is used to indicate both metals in its raw mineral form (for example iron ore, tungsten ore) as well as the metallic element itself.

Raw material: the term 'raw materials' will be used throughout this thesis to indicate both metals and minerals in both the raw and (semi)processed form.

Box 1 Definitions for mineral, metal and raw material.

The *economic importance* of a raw material is measured by looking at the value added of the sectors that use the material as input. The idea behind this is that an upstream bottleneck in the supply chain of a given raw material can threaten the entire value chain. The materials that are classified as critical therefore do not necessarily have to be used in large quantities or represent huge values themselves. Instead, the Commission looks at the value of the downstream sectors that require the input of the respective raw material. Each material is placed on a scale from zero to ten with zero meaning no economic importance and ten meaning extremely important.

The main instrument used to evaluate the *supply risk* of a raw material is the Herfindahl-Hirschman Index (HHI). This index measures the level of concentration of worldwide production of a given raw material. [19] The higher the concentration of production in a single country, the higher the supply risk is. A high concentration of production in a single country is even more risky if the respective country is politically or economically unstable. The concentration index is therefore linked with the 'Worldwide Governance Indicator' from the World Bank[20]. These two indicators together are used to classify the raw materials on a scale from zero (no supply risk) to five (highest supply risk) for the supply risk. The indicators discussed so far are used to select the critical raw materials for the EU.

For the selected critical materials, the Commission also looks at the *substitutability* and *recycling rate.* The substitutability index is an average of the degree of substitutability of all uses for a given raw material. To determine the degree of substitutability for a single raw material use, the Commission uses substitutability scores from Faunhofer ISI. Each use gets a substitutability score of 0, 0.3, 0.7 or 1.0. A score of 0 means substitution is possible at zero cost, 0.3 means substitution is

[19] The Herfindahl-Hirschman Index is usually used to measure the level of concentration of companies in a certain sector or market. To obtain the HHI for production, the shares in world production of all countries for each raw material are squared and summed up to obtain a single score according to the following formula: $HHI = \sum P_i^2$. P_i here is the share in world production of the evaluated material of country *i*. So when all production is located in one country the HHI will be 1. If HHI approaches zero, production will be evenly spread out over a lot of different countries.

[20] The Worldwide Governance Indicator is an average of six different sub scores; government accountability, political stability, government effectiveness, regulatory quality, rule of law and corruption. The indicator can be found at http://info.worldbank.org/governance/wgi/index.asp

possible at relatively low cost, 0.7 means substitution is possible at high cost and a score of 1.0 means substitution is not possible. These substitutability scores are established by Fraunhofer ISI based on 'expert opinion'. The recycling rate that the commission uses is measured as the percentage of metals and minerals that is not derived from primary production.

The 14 materials that score both high on the supply risk (a score of at least one) and on economic importance (a score of at least five) are presented in Table 2. Examining export restrictions on all of these materials is outside the scope of this thesis. Therefore, detailed analysis in the rest of this thesis will focus on the materials for which China is the major producer in the world. As was discussed in section 2.3.2 export restrictions imposed by China have already sparked two major trade disputes between China and the EU/USA. The significant share in world production that China has in the selected raw materials makes Chinese export restrictions a danger to downstream sectors in the EU.

Selected critical raw materials			
Antimony	Beryllium	Cobalt	**Fluorspar**
Gallium	Germanium	**Graphite**	Indium
Magnesium	Niobium	Platinum Group Metals	**Rare Earths**
Tantalum	**Tungsten**		

Table 2 Critical raw materials as selected by the EU Commission Enterprise and Industry, source: Critical raw materials for the EU (2010). Materials selected for further research in bold

The scores for the two main indicators of criticality as well as the substitutability index and recycling rate are shown in Table 3. As discussed before, the economic importance is expressed as a score from zero to ten with ten being the most important. Out of the six selected raw materials, tungsten and graphite score the highest on economic importance. From the total selection of 14 raw materials made by the commission, only niobium scores higher on economic importance (a score of 8.9). Niobium production is mostly (92%) concentrated in Brazil and will thus not be included in the analysis of this study. Rare earths have the highest supply risk out of all materials examined by the commission. This is largely due to the very high concentration of production in a single country (China). Rare earths also have the highest substitutability score with 0.87. This means that, for most uses, substitution is either not possible or only possible at very high cost. Finally, the recycling rate for the raw materials (except for graphite for which no recycling data is available) is presented in the last row of Table 3. Recycling rates for fluorspar and rare earths are nearly non-existent. Tungsten on the other hand has a fairly high recycling rate. The tungsten processing industry is capable of recovering tungsten form almost any kind of tungsten containing scrap or waste. The fact that the recycling rate for tungsten is this high makes the dependence on imports slightly less than for materials like rare earths.

Indicator	Antimony	Fluorspar	Graphite	Magnesium	Rare Earths	Tungsten
Economic Importance	5.8	7.5	8.7	6.4	5.8	8.7
Supply risk	2.6	1.6	1.3	2.6	4.9	1.8
Substitutability index	0.64	0.9	0.5	0.82	0.87	0.77
Recycling rate	11%	0%	-	14%	1%	37%

Table 3 Indicators of criticality for the six selected draw materials. Source: Critical raw materials for the EU (2010)

In the remainder of this section each of the selected raw materials will be introduced by discussing the main uses of the material, world production capacities and EU imports.

2.4.1 Antimony

Antimony is an element (Sb, atomic number 51) with semi-metallic properties that can be found in volcanic rock and sandstone. Antimony is classified as only partly metal since (unlike typical metals) it is not malleable and is a poor conductor of electricity. Mining of antimony ores is usually a by-product of the mining of other ore such as gold, silver, lead and tungsten. For commercial use, antimony ores are processed into antimony oxides and antimony alloys. An oxide is a chemical compound that is composed of an element (in this case antimony) and at least one oxygen atom. An alloy is a solid, metallic mixture composed of at least two elements. Antimony alloys are usually created by mixing antimony with lead.[21]

Production (region)	Production in 1000t, 2009	Share in world production	EU imports by source	Imports (Millions)
China	166	92.87%	World (total)	252
Russia	3	1.68%	China	224
South Africa	2	1.17%	Turkey	11
ROW	8	4.29%	Bolivia	7
EU27	-	-		

Table 4 Production of Antimony in 1000t, source: World Mining Data 2011. EU imports of processed Antimony, source: UN Comtrade HS 282580.

Table 4 shows the top three antimony producing countries in the world. China dominates world production with a yearly production of 166000 tonnes and a share of 92% in world production. Other important producers are Russia and South Africa with 3000 and 2000 tonnes respectively. There is currently no antimony production within the EU. This means that for antimony the EU is completely dependent on imports. Since China does not export Antimony in its raw form, Table 4 lists the imports of (semi) processed antimony. The high concentration of production in China and the non-existent production of antimony in the EU make the supply risk substantial for antimony.

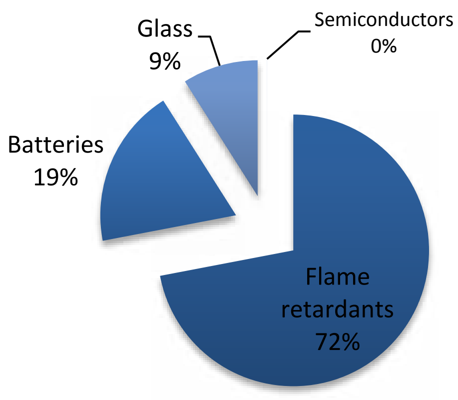

Figure 3 Main uses of Antimony, source: *Critical raw materials for the EU* (2010), Annex V

[21] The information in this block is coming from the United States Geological Survey (USGS). Detailed information on the properties and mining of antimony can be found on the antimony commodity profile webpage from USGS: http://pubs.usgs.gov/of/2003/of03-019/.

Figure 3 shows the main uses of antimony (both oxides and alloys). Antimony is mainly (72% of production) used in the form of oxides to produce flame retardants. Flame retardants are used in a wide range of products to withstand fire. Antimony oxides are mostly used as flame retardants in plastics and plastic products. The value of antimony in this context is amplified because there is currently no substitute available for antimony.

A second major use of antimony is in lead-acid (LA) batteries. LA batteries are the most used rechargeable batteries in the world. Antimony-lead alloys are used to fabricate the plate grid (a plate grid in a battery is used as a conductive path for the electric current) of LA batteries. The final major application of antimony is in glass. Antimony oxides are a necessary component in the production of modern television and computer screens. A very small percentage (0.01%) is used in the production of semiconductors.[22]

2.4.2 Fluorspar

Fluorspar is a mineral containing the chemical element fluorine (F, atomic number 9). Fluorspar reserves are spread out over all continents and are estimated to be around 500 million tons.[23] Despite these large worldwide reserves, China dominates world production with a share in world production of 55%. The two other producers in the top three are Mexico and Russia. As Table 5 shows, production in the EU amounts to 191000 tonnes which is 3.25% of world production. The production of fluorspar within the EU originates from Spain, Germany, UK and Romania and amounts to 25% of EU consumption.[24] Table 5 shows the main import partners of the EU with Turkey being the most important partner in 2010 and China only coming second.

Production (region)	Production in 1000t, 2009	Share in world production	EU imports by source	Imports (Millions)
China	3200	54.55%	World (total)	457
Mexico	1046	17.83%	Turkey	134
Russia	240	4.09%	China	79
ROW	1190	20.28%	Mexico	63
EU27	191	3.25%		

Table 5 Production of Fluorspar in 1000t, source: World Mining Data 2011. EU imports of Fluorspar, source: UN Comtrade HS 252921 and 252922.

The main use of fluorspar is the production of hydrofluoric acid. Hydrofluoric acid is a chemical that is used in the production of computer chips, electronics, air conditioning, thermal insulation and refrigerants. Figure 4 shows that 60% of fluorspar is used to produce hydrofluoric acid. Another important application of fluorspar is the lowering of the melting point of steel and aluminium. A lower melting point means less heat has to be generated (and thus less energy) is required to melt steel and aluminium. Finally, a very small percentage of fluorspar production is used in the cement and glass industries.

[22] The information on the uses and application of antimony comes from the USGS antimony profile report.
[23] USGS (2010), *Fluorspar Mineral Yearbook*
[24] Critical raw materials for the EU, 2010, Annex V, Fluorspar

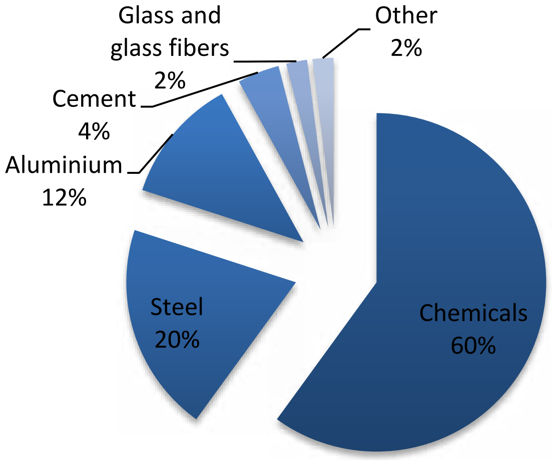

Figure 4 Main uses of Fluorspar, source: *Critical raw materials for the EU* (2010), Annex V

2.4.3 Graphite

Graphite is a mineral with properties of both metals (mainly electrical conductivity) and non-metals (thermal resistance and lubricity). There are three main types of graphite: vein graphite, flake graphite and microcrystalline graphite. The most used form of graphite in high-tech products is flake graphite. Even though there are large reserves of graphite[25] in the EU (mostly in Germany, Czech Republic and Austria) total EU production was only 1000 tonnes in 2009. China is the most important producer of graphite worldwide and is also the biggest exporter to the EU.

Production (region)	Production in 1000t, 2009	Share in world production	EU imports by source	Imports (Millions)
China	780	74.08%	World (total)	141
India	109	10.31%	China	94
Brazil	76	7.22%	Brazil	21
ROW	88	8.32%	Canada	7
EU27	1	0.07%		

Table 6 Production of Graphite in 1000t, source: World Mining Data 2011. EU imports of Graphite, source: UN Comtrade HS 2504.

As Figure 5 shows, graphite has a large number of applications in different sectors. The wide range of graphite uses is mainly caused by the mix of metallic and non-metallic properties that graphite has. The heat resistant nature of graphite makes it very useful in foundry, crucible and steel production. The heat resistant nature of graphite also makes it useful in heat storage applications in solar energy systems. The electrical conductivity of graphite makes it useful in batteries and many electrical applications. Some electrical applications include the use of high-purity graphite in fuel cells for hybrid and electrical cars. With solar systems and electrical cars, graphite has important uses in 'green' technologies. A much more everyday use of graphite is in pencil production.

[25] There are proven reserves of five million tonnes within the EU, source: Critical raw materials for the EU, 2010, Annex V, Graphite.

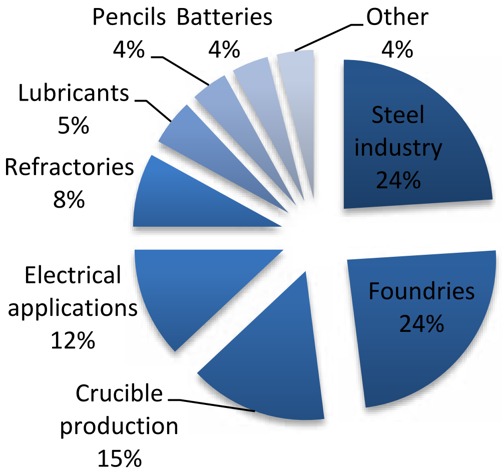

Figure 5 Main uses of Graphite, source: *Critical raw materials for the EU* (2010), Annex V

2.4.4 Magnesium

Magnesium is a metal (Mg, atomic number 12) that is found in over 60 different minerals. The most important mineral for the commercial extraction of magnesium is magnesite. Since there is public production data of magnesium available per country, Table 7 shows production data for magnesite. Even though production of magnesite is largely concentrated in China, the EU also has a substantial share in world production. Production of magnesium is estimated to be 570000 tonnes at world level of which 470000 tonnes (82% of world production) was produced in China.[26] Import data for magnesium is publically available and is shown in Table 7. Despite its own substantial magnesite production, EU imports of magnesium from China amounted to 464 million dollar.

Production (region)	Production in 1000t, 2009	Share in world production	EU imports by source	Imports (Millions)
China	15000	62.47%	World	529
Russia	2600	10.83%	China	464
EU27	2149	8.95%	USA	24
ROW	4262	17.75%	Israel	13

Table 7 Production of Magnesite in 1000t, source: World Mining Data 2011. EU imports of Magnesium, source: UN Comtrade HS 810411.

The major commercial use of magnesium is in the production of aluminium-magnesium alloys. These alloys are used mostly in the aerospace and automobile industry due to their low weight and hardness. Magnesium is also used in the production of (food) packaging products most notably beverage cans. Other applications include the use of magnesium in a wide range of consumer products such as tennis rackets, fishing materials, computer printers and bakery racks.

[26] Detailed per country data is not publically available for magnesium. This estimate comes from *Critical raw materials for the EU*, 2010, annex V

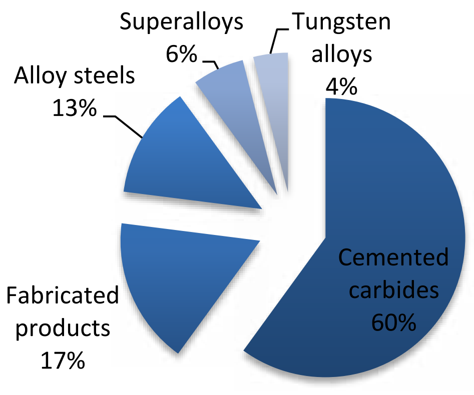

Figure 6 Main uses of Magnesium, source: *Critical raw materials for the EU* (2010), Annex V

2.4.5 Rare Earth Elements

Rare earth elements refers to a group of 17 elements which are shown in Table 8. The 17 elements occur mostly together in the minerals bastnaesite and monazite and are therefore always mined together. Total world reserves of rare earths are estimated to be 99 million tonnes of which one third are found in China.[27]

Rare earth elements					
Lanthanum	Neodymium	Europium	Dysprosium	Thulium	Yttrium
Cerium	Promethium	Gadolinium	Holmium	Ytterbium	Scandium
Praseodymium	Samarium	Terbium	Erbium	Lutetium	

Table 8 All 17 rare earth elements, source: USGS

Even though China 'only' has one third of world reserves, world production is almost completely based in China as can be seen in Table 9. EU imports come unsurprisingly mostly from China with the USA and Russia coming second and third respectively. China is expected to need all of its production for domestic uses in the not too distant future. Additional mining projects have therefore been started in the US, Canada and Australia in the hope of becoming less dependent on Chinese production.[28]

Production (region)	Production in 1000t, 2009	Share in world production	EU imports by source	Imports (Millions)
China	129	97.45%	World	219
Russia	3	1.89%	China	139
Brazil	1	0.64%	USA	46
ROW	0	0.02%	Russia	17
EU27	-	-		

Table 9 Production of Rare Earths in 1000t, source: World Mining Data 2011. EU imports of Rare Earths, source: UN Comtrade HS 280530, 284610 and 284690.

The rare earths group consists of 17 different elements that are used in a lot of high-tech products with high unit value.[29] Many rare earths are used in catalysts which in turn are used in oil refineries.

[27] World Mining Data 2011
[28] USGS (2011), *Chinese rare earth industry*
[29] USGS (2011), *Rare earth elements: uses and recyclability*

Some rare earths have magnetic properties and are used in the development of *permanent magnet technologies*. These magnetic rare earths are necessary for the production of numerous electronic components used in computers, portable disk drives, electrical cars, video equipment and a lot of other high-tech electronical equipment. Other applications include the polishing of glass and the use in metallurgy and steel industries to add specific properties to other metals.

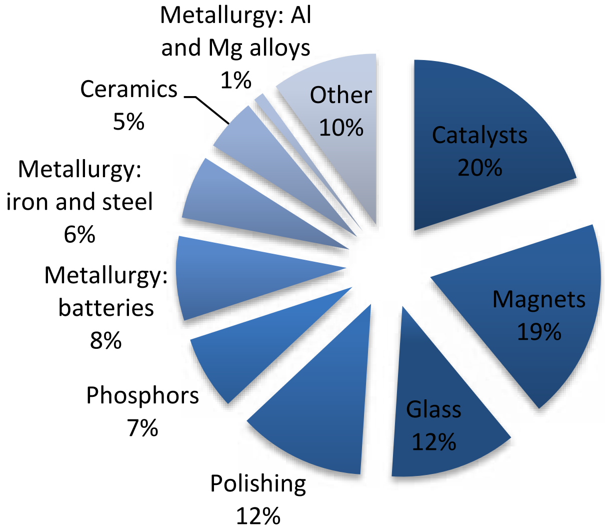

Figure 7 Main uses of Rare Earths, source: *Critical raw materials for the EU* (2010), Annex V

2.4.6 Tungsten

Tungsten is a metal (W, atomic number 74) that is found in the minerals wolframite and scheelite.[30] It is a very hard metal and has the highest melting point of all (non-alloyed) metals. World production is mostly (83%) concentrated in China. Tungsten in its raw form (tungsten ore) is not exported by China so EU imports come mostly from Russia, Bolivia and Canada. Chinese tungsten ores are first processed into powders and bars before being exported to the rest of the world. EU imports of processed tungsten amounted to 245 million in 2010 with 53 million coming from China.[31]

Production (region)	Production in 1000t, 2009	Share in world production	EU imports by source	Imports (Millions)
China	50	82.68%	World	86
Canada	3	4.14%	Russia	44
Russia	2	3.97%	Bolivia	12
ROW	4	5.92%	Canada	10
EU27	2	3.30%		

Table 10 Production of Tungsten in 1000t, source: World Mining Data 2011. EU imports of Tungsten, source: UN Comtrade HS 2611

As Figure 8 shows, the largest use for tungsten is in cemented carbides (also called hard metals). Cemented carbides are hard, wear-resistant materials that are used in the metalworking, mining (drilling tools) and construction industries. The hardness of tungsten makes it very useful in fabricating heavy metal alloys which are used as heat sinks, weight and counterweights and tool

[30] USGS (1998), *International strategic mineral issues – Tungsten*
[31] UN comtrade, HS8101

steels. The category fabricated products includes metal wires, electrodes and other electrical/electronic applications.[32]

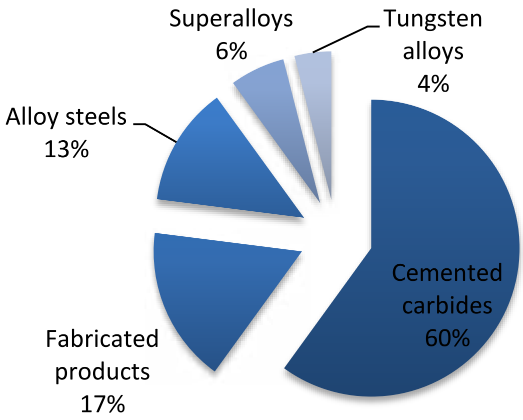

Figure 8 Main uses of Tungsten, source: *Critical raw materials for the EU* (2010), Annex V

[32] For a detailed description of the uses of tungsten, see: USGS (1998), *International strategic mineral issues – Tungsten*

3 Methodology and data

The main question in this study is how an export restriction (in the form of an export tax) on the selected raw materials affects downstream producers and welfare in both the exporting and importing country. To quantify the effect of an export tax this study will use a Computable General Equilibrium Model (CGE). Section 3.1 will start by explaining what a CGE model is and what its advantages and disadvantages are. In section 3.2 the specific model that is used in this study (GTAP) will be introduced. Section 3.3 explains which regions and sectors are included in the analysis and why. Section 3.4 introduces Splitcom and explains how the six raw materials are added to the GTAP database. Finally, section 3.5 discusses the scenarios that will be run by the model.

3.1 Computable General Equilibrium Modelling

Computable General Equilibrium (CGE), or Applied General Equilibrium (AGE), models are simulation models used to measure the impact of policy changes. A CGE model explains the effects of a certain policy change on macro-economic variables by simulating the re-allocation of resources in the economy. CGE models are computed using two main assets; a set of model equations and a database. The CGE model computes the general equilibrium state of the economy by solving a set of equations in a pre-defined manner. The database consists of all flows of goods, services and payments as well as elasticity variables. The data is presented in the form of a Social Accounting Matrix (SAM) or Leontief input-output tables. A detailed discussion of CGE modelling can be found (among others) in Francois and Reinert (1998) and Burfisher (2011). In this next part the two main characteristics (the set of equations and the database) of a CGE model will be discussed.

The set of equations needed to compute a CGE model includes equations specifying the structure of the economy, the agents in the economy, the behaviour of all agents and the equilibrium conditions in the economy. The main agents in standard CGE models are private households and producers. Private households maximise their utility subject to a budget constraint and producers maximise their profit subject to income restraints (Francois and Reinert, 1998). The equilibrium conditions in a classical CGE model specify that all markets clear and that supply and demand in factor and product markets is equal. In equilibrium, the economy operates at full capacity and there is thus no unemployment. In other words, the economy is on the production possibilities frontier (Burfisher, 2011). To include foreign trade in a CGE model, imported goods have to be separable from domestically produced goods. This is achieved by introducing Armington elasticities. These elasticities depict the elasticity of substitution between goods of different origin regions. Armington elasticties are based on the Armington assumption that there is imperfect substitution between a domestically produced good and an imported good (Francois and Reiner, 1998; Armington, 1969). Together, the set of equations form a model that can be used to evaluate all kinds of policy changes. The structure of the economy, which agents exists and the equilibrium conditions are in principle all up to the modelling author. For example, a model may be specifically built to evaluate the environmental effects of policy changes (for example GTAP-E). CGE models might for example also differ in their assumptions about perfect or imperfect competition, full employment or not and the way international transactions are modelled. This adaptability of CGE modelling also means the results of a CGE analysis should be interpreted with caution. The outcome of a study may be very dependent on specific assumptions made or on how the market structure is modelled.

In order to run a CGE model, the user must provide data presented in a database. The data used by CGE models is presented in a Social Accounting Matrix (SAM) or Leontief input-output table. A SAM database is a (square) matrix representation of all economic transactions in an economy (at regional, national or international level). The database is square in the sense that all agents (firms, consumers, government, foreign regions) in the economy are both buyers and sellers. A typical SAM database is presented in Table 11 as an example. All agents are presented in both the columns and the rows. The columns represent buyers and the rows sellers. For example, firms (row) sell products to household buyers (column). The payment for this consumption by the household is shown in table X and depicts a value flow from households to consumers.

	Firm	Household	Government	Rest of World	Net Investment	Total (Received)
Firm		Consumption (C)	Government transfers to firms (G_F)	Net exports Firms ($(X-M)_K$)	Investment (I)	$C+G_F+(X-M)_K+I$
Household	Wages (W)		Government transfers to Households (G_H)	Net exports Households ($(X-M)_C$)		$W+G_H+(X-M)_C$
Government	Taxes Firms (T_F)	Taxes Households (T_H)				T_F+T_H
Rest of World	Net imports Firms ($(X-M)_K$)	Net imports Households ($(X-M)_C$)				$(X-M)_K+(X-M)_C$
Net Investment		Savings Households (S_H)	Savings Government (S_G)			S_H+S_G
Total (Expended)	$W+T_F+(X-M)_K$	$C+T_H+(X-M)_C+S_H$	$G_F+G_H+S_G$	$(X-M)_C+(X-M)_K$	I	

Table 11 Monetary flows represented in a typical SAM matrix. Source: Mitra-Kahn (2008)

With the database and the model equations, the model can be calibrated to a base scenario or business-as-usual (BAU) scenario. To do this, the parameters of the model will be estimated and the base equilibrium of the economy will be computed. With the BAU model in place, a researcher can adjust one or more of the model parameters to see how the variables and the equilibrium changes. The CGE approach captures all the effects of a given change on all variables in the economy. This means the effect of a given policy change can be shown for not only the directly affected sector, but for all variables in the economy including labor and capital markets, foreign markets and welfare levels.

3.2 GTAP

The CGE model used to answer the research question of this thesis is the GTAP model. The Global Trade Analysis Project (GTAP) was founded in 1992 and consists of a network of researchers conducting quantitative analysis of international policy issues.[33] Initially, the GTAP project was inspired by the Australian IMPACT project and its main goal was to lower the entry barriers to global CGE analysis.[34] Over the years, the GTAP network has grown and in 2012 the GTAP network consists of nearly 10.000 members (Hertel, 2012). GTAP has two major assets; the model itself and the GTAP database. This section will discuss and explain both the model and the database.

3.2.1 The GTAP model and database

The GTAP model is build up similar to other CGE models. The equations of the model specify which agents exist in the economy (households, firms and governments), what their incomes and expenditures are and how they optimise their behaviour. The income and expenditure of agents is subject to accounting principles that make sure that the economy is in balance and no agent can run a structural deficit. Each agent's behaviour is modelled by a behavioural equation that optimises an agent's utility. The way the model is build up will be demonstrated below by shortly discussing the income, expenditure, accounting principles and optimising behaviour of each major agent.[35]

Figure 9 shows the major agents in the GTAP model (from the perspective of a single region) and how they relate to each other. First of all there is the *regional household* which collects all income in a given region. The other agents in the regional economy are the *private households*, the *government* and the *producers*. The *rest of the world* is shown at the bottom of the figure and consists of all other regions in the model. The arrows in Figure 9 denote value flows and not goods flows. For each value flow depicted, there is a corresponding (not drawn in this figure) flow of goods, services or ownership going the other way. For example, the value of export sales is shown to go from the rest of the world to the regional producers. This value flow is a payment for the actual physical exports going from the producers to the rest of the world. The only value flows for which there are no corresponding flows of goods, services or ownership are the tax flows collected by the regional household.

The *regional household* in the GTAP model is an entity that collects all income in the regional economy and distributes it between three forms of final demand: private household expenditure, savings and government expenditure. Regional income is divided according to a Cobb Douglas utility function. This function is constant which means that the share of the three forms of final demand also remains constant. In other words, an increase in regional income leads to proportional changes in private expenditure, government expenditure and savings. Equation (5) shows the change in aggregate regional utility of the regional household.

[33] The GTAP website contains extensive information on the project's history, model, database and researchers involved and can be found at https://www.gtap.agecon.purdue.edu.
[34] See Powell and Snape (1993) for a discussion of the IMPACT project and its impact on CGE analysis.
[35] This section demonstrates how the GTAP model works by describing the main agents in the model, how they behave and how they relate to each other. For a (technical) discussion on the market structure modelled in GTAP, see Annex A.

$$INCOME\ (r) * u\ (r) = PRIVEXP\ (r) * \ up\ (r) + \ GOVEXP\ (r) * \left[ug(r) - \ pop(r)\right] + SAVE\ (r) * [qsave\ (r) - pop\ (r)] \qquad \textbf{(5)}$$

Per capita utility from the regional household (aggregate), private expenditure and government expenditure is given by u, up and ug respectively. The (r) denotes region and is used to show that the variables contain values for a given region (r). Population change is denoted by pop and $qsave$ denotes the change in regional demand for net savings. From equation (5) it can be seen that all regional income is exhausted on private expenditure, government expenditure and savings. Equations (6) and (7) denote the change in real expenditure on savings and government activities.

$$qsave\ (r) = y\ (r) - psave + saveslack\ (r) \qquad \textbf{(6)}$$

$$ug\ (r) = y\ (r) - pgov\ (r) + govslack\ (r) \qquad \textbf{(7)}$$

Expenditure on savings and government activities depend on regional income *y (r)* and prices (psave and pgov). The slack variables can be used to determine the savings and government expenditure exogenously by swapping them for the quantities of savings and government composites.

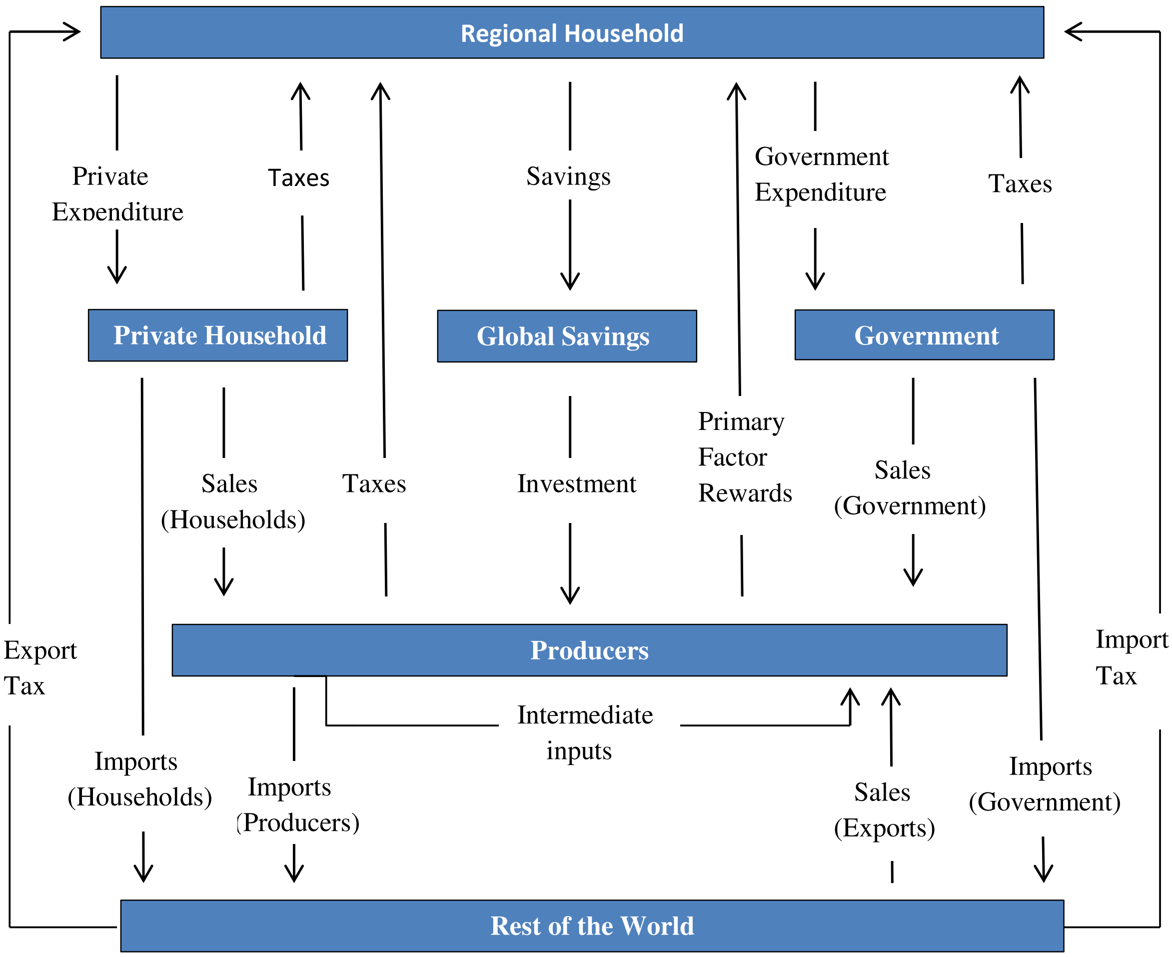

Figure 9 Value flows between all major agents in the GTAP model. Figure adapted from *A graphical exposition of the GTAP model*.

The important accounting relationship for the regional household is that all income is both collected from and distributed among the three forms of final demand. Modelling the final demand like this means that no agent in the economy can spend more income than they receive. The income of the regional household consists of taxes and the primary factor rewards. Taxes in the GTAP model are calculated by comparing value flows at agent's prices with value flows at market prices. Any difference in these two values is a tax or a subsidy. The tax flows shown in Figure 9 consist of tax income minus subsidies and thus are net flows.

The *government* spends its income on commodities according to a Cobb Douglas utility function. The government utility function divides the income between all commodities according to a constant share in expenditure for each commodity. Equations (8) establishes an aggregate price index for all government purchases (pgov).

$$pgov(r) = \sum[\frac{VGA\,(i,r}{GOVEXP\,(r)}] * pg\,(i,r) \qquad \textbf{(8)}$$

VGA (i, r) depicts government expenditure on good i in region while pg (i, r) depicts the percentage change in government consumption price of good i in region r. Equation (9) then uses this index to derive the government demand for composite tradeable goods $qg\,(i, r)$.

$$qg\,(i,r) = ug\,(r) - [pg\,(i,r) - pgov\,(r)] \qquad \textbf{(9)}$$

The government thus spends its income on composite goods with each good having a constant share in total expenditure. Government income (taxes) is shown in Figure 9 and goes from the regional government to the regional household. This income is generated by government taxes and consists of consumption taxes on regionally produced commodities.

The behaviour of *private households* is modelled with a CDE (constant difference of elasticity) expenditure function. The CDE expenditure function is calculated using data on income and price elasticities of demand. The main difference between a CDE function and a more standard CES (constant elasticity of substitution) function is that elasticities are not constant in a CDE function. The elasticities in a CDE function vary with expenditure shares and relative prices; a CDE function is thus more flexible than a CES function. The CDE implicit expenditure function is given in equation (10).

$$\sum B(i,r) * UP(r)^{\beta(i,r)\gamma(i,r)} * \left[\frac{PP(i,r)}{E(PP(r))}\right]^{\beta(i,r)} \equiv 1 \qquad \textbf{(10)}$$

E(.) in equation (10) depicts the expenditure required to obtain the given (prespecified) level of private household utility *UP*(*r*). *PP*(*i,r*) represents the vector of private households. The parameters β and γ represent the own-price elasticities of demand and the income elasticities of demand respectively. The difficulty lies in the estimation of the two elasticities of demand. In GTAP, these parameters are initially calibrated to replicate a prespecified vector of price and income elasticities. As said before however, the elasticities in a CDE function are not constant but vary (in this case) with relative price levels and expenditure shares (Hertel & Tsigas, 2012; Hertel et al., 2010). Equation (10) is used to obtain the per capita private household demand for tradeable commodities shown in equation (11).

$$qp\,(i,r) = \sum EP(i,k,r) * pp(k,r) + EY(i,r) * [yp(r) - pop(r)] + pop(r) \qquad \textbf{(11)}$$

As can be seen from (11), private household demand for commodity i (qp) depends on the price elasticity of private demand for good i with respect to the price of good k in region r (EP), the private consumption price of good k (pp), the private income elasticity of demand for good i (EY), regional private consumption expenditure (yp) and the population change (pop). Next to expenditure on commodities, private households pay both income taxes and consumption taxes to the regional household.

Savings in the regional economy are, as Figure 9 shows, entirely exhausted on investment. The economy in the GTAP model is savings driven. The total amount of savings is given by (as discussed earlier) a fixed share in total regional income, the level of investments adjusts accordingly. There is no real money in the GTAP model, instead, each sector produces a certain amount of homogeneous capital goods.[36] All capital goods are purchased by the global bank and then sold to regional households based on their need for investment goods. The GTAP model provides two alternatives for modelling the distribution of investment across regions (see Hertel (2012) for a detailed discussion of these two methods). In the first alternative, the rate-of-return on capital is assumed to be equal across different regions. To obtain the same global rate-of-return across regions, the shares of regional investment in global investments vary. The second scenario fixes region capital composition and lets the rate-of-return vary. By default, GTAP uses the first alternative and this alternative is also used in this study.

The *producers* in the economy sell their products/services to private households, the government, the rest of the world (exports) and to other producers (intermediate inputs). The GTAP model operates under the assumption of zero profits for the producers. This means that all income generated by the producers is spent on taxes, primary factor rewards, intermediate inputs and imported inputs. Production in the GTAP model exhibits constant returns to scale and every sector produces a single product.

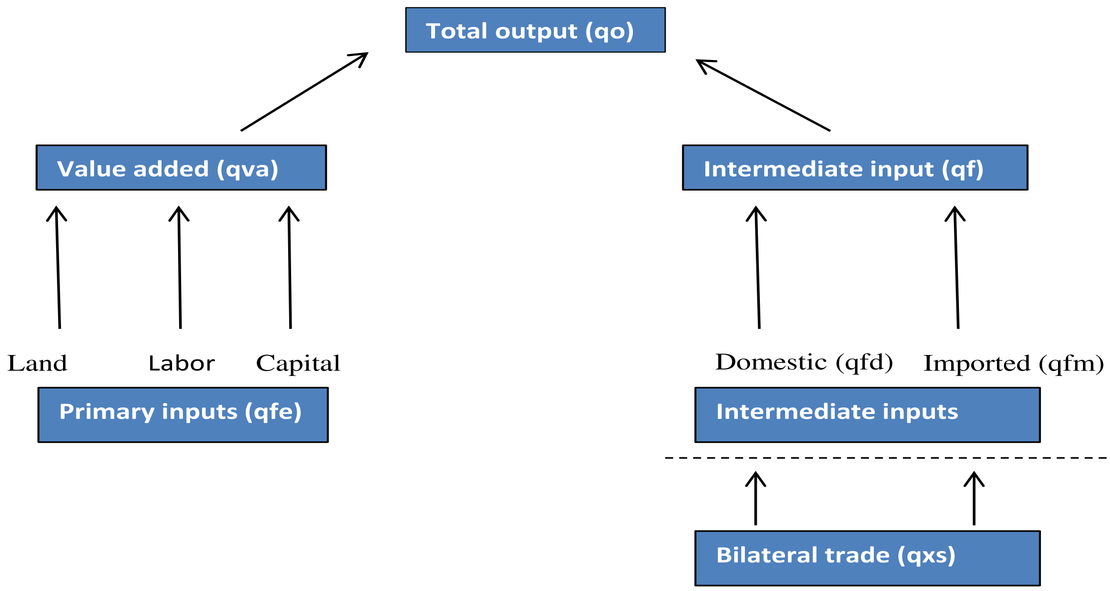

Figure 10 GTAP production structure. Adapted from Hertel & Tsigas (2012).

[36] The variable name for this good in GTAP is cgds and the respective price variable is psave.

Figure 10 shows the production structure modelled in GTAP. Firms purchase primary inputs (qfe) and intermediate inputs (qf). Intermediate inputs are either domestically produced (qfd) of imported (qfm). Firms chose their optimal mix of primary inputs independent of the prices of intermediate inputs. As discussed before, production exhibits constant return to scale and the level of output is thus also irrelevant for the demand for primary inputs. The demand for primary inputs is thus solely determined by the relative prices of land, labor and capital. Intermediate inputs demand is similarly independent from primary input prices. As will be discussed in more detail in the paragraph below, goods are separable by their region of origin. Producers thus first select the source of their imports and then decide on the optimal mix between imported and domestically produced goods. Equation (12) is used to determine the source of imports.

$$qxs\ (i,r,s) = qim\ (i,r) - \sigma_M * [pms\ (i,r,s) - pim(i,r)] \qquad \textbf{(12)}$$

The aggregate imports of good i in region r are depicted by *qim(i, r).* The market price of good i in region r imported from region s is given by pms. The price of composite imports of good i in region r is given by pim. The lowest import price (pms) determines the sourcing of imports. Demand for domestically produced inputs and imported inputs is given by equations (13) and (14).

$$qfm\ (i,j,r) = qf(i,j,r) - \sigma_D(i) * [pfm(i,j,r) - pf(i,j,r)] \quad \textbf{(13)}$$

Equation (13) shows that demand for imported input i in sector j in region r depends on total demand for i (*qf*), the import price of i (pfm) and the firms price of i (*pf*). The demand for domestically produced goods can be seen in equation (14) and depends on the price index for domestic purchase of *i* (*pfd*).

$$qfd\ (i,j,r) = qf(i,j,r) - \sigma_D(i) * [pfd(i,j,r) - pf(i,j,r)] \quad \textbf{(14)}$$

The total value of output (qo) is obtained by summing the value added product (qva) with the total intermediate input value (qf).

The *rest of the world* consists of all regions included in the model. These regions behave in the same way as the region described in this section. The rest of the world interacts with the regional economy through export, imports, savings and trade taxes. International trade in the GTAP model is subject to the Armington assumption. This assumption means that traded goods are differentiated by their country of origin and thus imports are separable from domestically produced goods. Producers in the regional economy first chose the country of origin for their imports and then determine the optimal mix of imported good and domestically produced goods. Like the producers, the government and private households also chose an optimal mix of imported and domestic goods. Not shown in Figure 9 are the two global sectors: global banking and global transportation. The savings depicted in Figure 9 are summed with all savings of all other regions in the world to get the global savings. In the GTAP model, savings and investment are computed on a global level. This means that all regions pay/receive the same price for savings money. The transportation sector is a global sector that provides transportation and is responsible for the difference between fob prices (prices excluding transport costs) and cif prices (prices including transport costs). Each region export transport services to the global transportation sector. The services provided by the global transportation sector are uniform and thus do not differ between commodities or forms of transport.

As discussed before, taxes in the GTAP model are calculated based on the difference between the value at agent's prices and the value at market prices. The power of the tax is given by the ratio of market prices to agent prices. In the case of an export tax, the power of the tax is given by the ratio of the market price to the global price. An export tax means the market price is lower than the global price so the power of an ad valorem export tax is less than one. Equation (15) shows how the power of an export tax is calculated. TXS depicts the power of a tax on a good *i* from origin region *r* to destination *s*. TXS is calculated by dividing the value of exports at the domestic price (VXMD) by the value of exports at the world price (VXWD).

$$TXS\ (i,r,s) = \frac{VXMD\ (i,r,s)}{VXWD\ (i,r,s)} \qquad \textbf{(15)}$$

The effect of an export tax in the GTAP model is shown graphically in Figure 11. PM is the domestic price (region *r*) of the exported good *i.* PFOB is the price of the exported good in destination region *s*. The curves D and S represent import demand (D) and export supply (S). As a result of the export tax, the supply of exports shifts to the left (a decrease in export supply). In the new equilibrium there is a gap between the domestic price and the world price which is equal to the export tax (XTAX). The value of exports at world prices is given by summing VXMD with the value of the tax (XTAX).

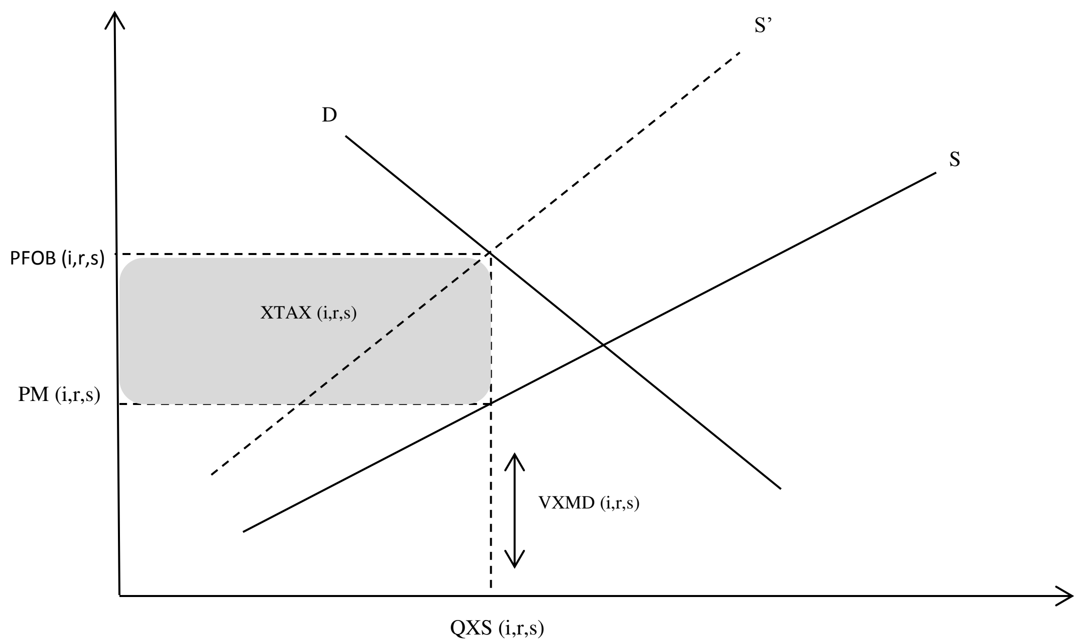

Figure 11 Effects of export taxation in the GTAP model, source: A graphical exposition of the GTAP model.

To actually run the GTAP, the model needs data. This study uses the newest version of the GTAP database (GTAP 8) which contains data from 2007. The database covers 57 sectors and 129 regions. Three main files together form the core of the GTAP database: a *sets* file, a *parameter* file and the *main data* file. The sets file specifies the regions and sectors that need to be included in the database. The sets file also contains the information on how the sectors and regions are aggregated and/or split. The parameter file contains behavioural parameters such as elasticities of substitution. For example, the elasticity of substitution between domestic produced goods and imported goods is included in this file. Finally, the main data file contains data on flows of goods and services within the global economy.

3.3 Database aggregation

The number of regions and sectors included in the standard GTAP database is much larger then needed. In practice, solving the full model takes a long time and provides a lot of information that is not needed for this study. Fortunately, the program GTAPagg can aggregate several regions into one new region. For example, all European Union countries can be aggregated into one new region called EU27. Sectors can be aggregated into broad categories as well which means a much smaller and more practical database can be created by using GTAPagg. The regions that are of interest for this study are either large exporters of certain raw materials or large importers of raw materials. The sectors that are included in the final aggregation either produce one of the six selected raw materials or use at least one of the materials as input. The rest of the sectors are aggregated in broad categories such as services.

The most important regions included in the aggregation are China (as the major exporter for the selected materials) and the major importing regions EU, US and Japan. Other raw material exporting countries that are included as regions are Bolivia (Antimony and Tungsten), Russia (all six materials), Brazil (Graphite, Rare Earths and Magnesium), Australia (Antimony and Magnesium), South Africa (Antimony and Fluorspar), India (Graphite), Canada (Magnesium and Tungsten) and Mexico (Fluorspar). The rest of the countries in the base dataset are aggregated into the region rest of the world (ROW). The final aggregation is listed in Table 12 below.

Region	Countries
CHI	China
IND	India
BZL	Brazil
BLV	Bolivia
SA	South-Africa
RUS	Russia
CAN	Canada
USA	United States of America
JPN	Japan
EU27	EU 27 countries
MXC	Mexico
AUS	Australia
ROW	All other countries

Table 12 Regional aggregation

Sectors that are included in the final aggregation are selected because they either include one of the selected materials or use one or more of the selected materials as input. The GTAP base sector *Minerals* (omn) includes production of raw tungsten, antimony and fluorspar. *Non-Metallic Minerals* (nmm) contains graphite production. Rare earths and the processed form of antimony are part of the *Chemicals, Rubbers and Plastics* (crp) sector. Finally, the sector *Non-Ferrous Metals* (nfm) contains magnesium and processed tungsten.

Sectors that use the raw materials as inputs are selected based on section 2.4. This leads to three categories of sectors that use the raw materials as inputs. First of all, the new (aggregated) sector *Metal Products* contains the old sectors *Iron and Steel* (i_s) and *Fabricated Metal Products* (fmp). The second new aggregated sector is *transport equipment* which contains *motor vehicles and parts* (mvh) as well as *other transport equipment* (otn). Finally, the new sector *Electrical Machinery* includes *Electronic Equipment* (ele) and *Other Machinery and Equipment* (ome). The rest of the sectors are divided between three new aggregations: *Energy* (coal, oil, gas), *Other Goods* (includes all other manufacturing and agricultural products) and *Services*. The full aggregation with description and included sectors is shown in Table 13.

Sector	Description	Old sector(s)[37]
Minerals	Minerals	OMN
Non-Ferrous Metals	Non-Ferrous Metals	NFM
Non-Metallic Minerals	Non-Metallic Minerals	NMM
Chemicals, rubbers and Plastics	Chemicals, rubbers and Plastics	CRP
Transport Equipment	Includes fabrication of all kinds of transport vehicles and equipment. Includes cars and other motorised vehicles as well as airplane construction	MVH, OTN
Metal Products	Fabricated iron, steel and other fabricated metal products	I_S, FMP
Electrical Machinery	Electrical equipment, machinery, computing, televisions, smartphones	ELE, OME
Other Goods	Includes all other manufacturing and agricultural goods	PDR, WHT, V_F, OSD, C_B, PFB, OCR, CTL, OAP, RMK, WOL, FRS, FSH, CMT, OMT, VOL, MIL, PCR, SGR, OFD, B_T, TEX, WAP, LEA, LUM, PPP, P_C, OMF
Energy	Coal, Oil, Gas	COA, OIL, GAS, ELY, GDT
Services	All services	WTR, CNS, TRD, OTP, WTP, ATP, CMN, OFI, ISR, OBS, ROS, OSG, DWE

Table 13 Sectoral aggregation

3.4 Splitcom

With the basic aggregation in place, the six selected raw materials can be split from the main sector they belong to. The program that is used to do this is *Splitcom*. Splitcom allows a user to split a base sector into two or more new sectors. To split a sector, Splitcom uses splitting weights to determine the size of each new sector. To split a sector in two or more new sectors Splitcom uses four main weight arrays: TradeWeight, RowWeight, ColumnWeight and CrossWeight. Tradeweight is used to determine the import and export flows of the new sectors. RowWeight is used to determine output level for the new sectors. ColumnWeight specifies the cost structure of a new sector and CrossWeight determines trade between the new sectors. The program doesn't need all data to split a sector. If for example only output data is provided, Splitcom uses the output shares of each sector to

[37] The abbreviations in this column refer to the original sector classifications of the full GTAP 8 database. See Annex B for a table with descriptions for all individual sectors

determine the weights for all other weight arrays. To split the six raw materials from the existing sectors, data on export, imports and output for each region will be used. This means that, since no data on the cost structure of the sectors is provided, any new sectors will retain the same cost structure as the original sector they were split from. Table 14 shows how the sectors will be split into new sectors.

Old sector	New (sub)sectors
Minerals (omn)	Other Minerals
	Fluorspar
Non-Ferrous Metals (nfm)	Other Non-Ferrous Metals
	Processed Tungsten
	Magnesium
Non-Metallic Minerals (nmm)	Non-Metallic Minerals
	Graphite
Chemicals, Rubbers and Plastics (crp)	Other Chemicals, Rubbers and Plastics
	Rare Earth Elements
	Processed Antimony

Table 14 Breakdown of new sectors created with Splitcom. Sectors relevant for this thesis in bold.

Both tungsten and antimony in their raw form are part of the minerals section. As was discussed in section 2.4, China (which is the major producer of these raw materials) does not export these materials in its raw form. Instead, the materials are first processed into bars, alloys, powders or oxides and then exported to the world. Since the processed form of antimony and tungsten does get exported and taxed by China it makes more sense to include them in the model instead of their raw form.

The data used to create the new GTAP database comes from UN Comtrade and World Mining Data 2011. Export and import data for each new commodity in each region is used in the TradeWeight array in Splitcom. This export and import data is from 2010 and is available for each raw material in the UN Comtrade database. The trade data is not bilateral. This means that only total rare earths exports are provided (instead of specific bilateral flows to each region in the database). For the RowWeight array in Splitcom, (regional) output data for each new material is used. The World Mining Data 2011 report provides production data (in tonnes) for five of the raw materials selected in this study. Since no production data is available for magnesium, magnesite production will be used as a proxy for magnesium production. Magnesite is the mineral that is processed into raw magnesium so regional magnesite production gives a reasonable approximation of regional magnesium production. Since the value per tonne differs substantially between the six raw materials, the value of production needs to be calculated. The price per tonne of each material is obtained from UN Comtrade and is a trade-weighted average of the import and export prices of the respective material. This traded price is multiplied with the production data to obtain the total raw material production values for each region. The trade and output data are used to split the trade and output arrays of the GTAP database. The other arrays are split using the 'simple' splitting weights. If, for example, a sector is split into three new sectors, the default simple splitting weights will be 0,33 for each new sub-sector. In this study, the simple splitting weights have been adjusted based on the output levels of each new sector. In other words, if a given new sector is responsible for 90% of the output of the old sector, the splitting weight for this new sector will be 0,9.

3.5 Model scenarios

The focus of this study is on raw materials that are critical for the EU and for which China is the major producer in the world. The goal is to analyse what the effect of export taxation on these materials is on producers in importing regions (most notably the EU) and the exporting region China. Before running any scenarios, a base scenario needs to be created. This base scenario is the reference point to which the outcomes of the other scenarios will be compared. For the base scenario the reference year will be 2010. The GTAP 8 database uses 2007 data and will be calibrated to 2010 by using GDP growth rates per region. Also included in the base scenario are the export taxes on the selected raw materials as they were in 2010. These Chinese tax rates are presented in Table 15.

China	Export tax
Fluorspar	15%
Rare Earths	15%
Graphite	20%
Processed Tungsten	15%
Processed Antimony	20%
Magnesium	10%

Table 15 Export taxes on selected materials in 2010. Source: ETCN 2010, Circular of the customs tariff commission of the state council on the tariff execution plan

The goal of this thesis is to find out what the impact of the current Chinese export taxes is on EU downstream industries. The results of the scenarios that will be run in this study will thus naturally include the changes in the EU downstream industries. To see how the impact on EU industries differs from other net-importing regions, the impact on Japanese and US downstream industries will be examined as well. Attention will also be given to the impact on downstream industries in the major exporting country in this study: China. Besides the downstream industries, the effect on the six raw material markets in the EU and China is also interesting to analyse. Finally, the welfare effects in the EU and China will be analysed to see what the overall (net) effects of the scenarios are. With this in mind, the scenarios will be run to obtain the following results:

- Price changes of the selected raw materials in the EU and China
- Changes in value added of downstream sectors in importing countries and China
- Output changes of selected raw materials in the EU and China
- Output changes in downstream sectors
- Welfare changes (change in GDP, regional utility (equivalent variation) and terms-of-trade)

Before discussing the scenarios that will be run, one additional model assumption has to be made. The way the GTAP model works is that when the import price of a good rises, domestic output level in the importing country might rise thus substituting imports for domestically produced goods. In the case of for example rare earths this leads to unsatisfactory results since there are no known reserves of rare earth elements within the EU. So in case a region has no known reserves of a given material and/or no current production capacity, output in that region will be fixed. So for example, in the model it will be specified that the output of rare earths in the EU is fixed at a value close to zero. This automatically means that the time horizon of this analysis is limited. In the future, rare earth reserves may be discovered within the EU thus creating the possibility of European rare earth production.

Since the process from the discovery of a raw material reserve base to actual production takes at least 15 years,[38] the results should be valid for the next 15-20 years.

3.5.1 Scenario 1

As Table 15 shows, in 2010 all materials under examination were taxed by China. The first scenario that will be run is the removal of all export taxes on all of the selected raw materials. The expectation is that the removal of export taxes on the materials will level the price difference between China and other parts of the world and thus be beneficial for downstream producers in importing countries.

Raw Material	Base Taxes	Taxes after scenario 1
Fluorspar	15%	0%
Rare Earths	15%	0%
Graphite	20%	0%
Processed Tungsten	15%	0%
Processed Antimony	20%	0%
Magnesium	10%	0%

Table 16 Chinese raw material taxes in base scenario and in scenario 1

As was discussed in previous sections, most taxes on these materials are actually prohibited by WTO law. It is thus interesting to examine what the benefits to EU downstream industries are if these taxes are removed. In this first scenario, none of the other raw material exporters react to trade policy changes initiated by China. This means that there will be six shocks implemented in the model: for each material, the tax is shocked to 0%.

3.5.2 Scenarios 2A and 2B

The second scenario that will be run is an increase of export taxation on all materials by 40% points. China needs more and more of its raw material production for its own industries. Politicians in the EU, Japan and the US fear that China might use stronger export restrictions on its raw materials to decrease exports and satisfy Chinese domestic consumption. It is therefore interesting to analyse what the effects of such measures on the economies of importing countries and on the Chinese economy are. In scenario 2A, the Chinese export taxes on the six selected raw materials will increase by 40 percentage points. To see how the results of this scenario depend on the size of the shock, this scenario will also be run with a 30 and 50 percentage point increase.

Raw Material	Base Taxes	After scenario 2A
Fluorspar	15%	55%
Rare Earths	15%	55%
Graphite	20%	60%
Processed Tungsten	15%	55%
Processed Antimony	20%	60%
Magnesium	10%	50%

Table 17 Chinese raw materials taxes in scenario 2A

The second scenario will also look at trade policy interdependence. Bouet and Debucquet (2010) have shown that net exporters of food use export taxation to stabilise domestic food prices. If one

[38] USGS (2011), *Minerals yearbook 2011*

country starts with using export taxes, other net exporters might follow to keep their terms-of-trade constant and to keep domestic prices stable. In the case of raw materials this interdependence between trade policies is also relevant. For example, if China imposes an export tax on rare earths, Russia might follow with export taxes on its own exports in order to keep Russian downstream producers competitive. Scenario 2B will be run with additional taxes from other net exporters on the relevant raw materials. So for example in the case of rare earths, the other two net exporters of rare earths (Russia and Brazil) follow China by imposing an equal export tax.

	Russia	Brazil	Mexico	Canada	South Africa	India	Bolivia	Australia
Fluorspar	40%	0%	40%	0%	40%	0%	0%	0%
Rare Earths	40%	40%	0%	0%	0%	0%	0%	0%
Graphite	40%	40%	0%	0%	0%	40%	0%	0%
Processed Tungsten	40%	0%	0%	40%	0%	0%	40%	0%
Processed Antimony	40%	0%	0%	0%	40%	0%	40%	40%
Magnesium	40%	40%	0%	40%	0%	0%	0%	40%

Table 18 Additional export taxes imposed by net-exporters of the respective raw material

Table 18 lists the net exporters for which the export taxes are increased to 40%. Finally, an overview of the base scenario and scenarios 1, 2A and 2B is presented in Table 19.

Scenario	Description
Base	Calibration of GTAP to 2010 with estimation of current Chinese taxes on raw materials
Scenario 1	Removal of all current export taxes on critical raw materials
Scenario 2A	China to raise export taxes on all critical raw materials by 40% points
Scenario 2B	China to raise export taxes on all critical raw materials by 40% points, other net exporters react by also imposing an export tax of 40% on the respective raw material

Table 19 Scenarios

4 Results

The results of the CGE analysis will be separately presented for scenario 1 and 2 in section 4.1 and 4.2. The tables and graphs included in this section focus on the effects of the scenario on China and the major importing countries; Japan, the US and the EU. Section 4.3 contains a sensitivity analysis with respect to the shocks employed in this study.

4.1 Scenario 1

The first scenario was to remove all current Chinese export taxes on critical raw materials. The export taxes ranged from 10% on magnesium to 20% on graphite and antimony. The removal of the export taxes leads to an increase in Chinese exports of the raw materials and thus leads to a greater world supply. As a result of the greater world supply, the price of the raw materials paid for by the EU drops. Figure 12 shows these main price results for the EU. The largest drop in prices occurs for rare earths with a price drop of 14%. This result is not surprising since the concentration of production within on country (China) is the highest of all materials for rare earths with 96% of production controlled by China. The least change occurs for magnesium with a price drop of only 0.5%. The explanation for this is that first of all the EU is a significant producer of magnesium itself and thus less dependent on imports. Second, the tax on magnesium was the lowest of the taxes (10%) on raw materials to begin with. Finally, production of magnesium is not as concentrated in one country (China) as in this case of rare earths or antimony, which implies that substitution is easier for magnesium.

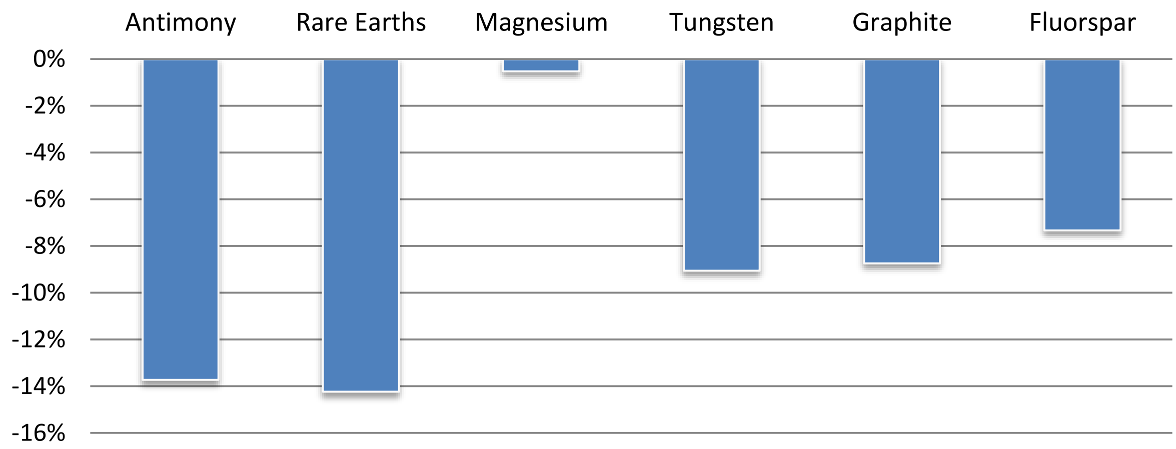

Figure 12 Price changes of the six raw materials for the EU as a result of scenario 1.

Table 20 shows the price changes for the six raw materials and the downstream processing industries. The prices of the raw materials drop significantly for Japan and the US as well. Chinese raw material prices are only slightly higher than with taxes. Also presented here are the price changes for the downstream industries. Since these sectors are very large in terms of value and output and the raw materials relatively small, the percentage changes are minor. The biggest change for the EU can be found in the sectors electrical machinery (-0,19%), metal products (-0,17%) and transport equipment (-0,12%). The decrease in prices of these sectors is a direct result of the lower input prices of the raw materials that these sectors use. Important to note here is that these sectors are basically an aggregation of a lot of different sectors that may or may not be affected by the lower input price of these materials. For example the production of television screens is only a small part of the sector electrical machinery. Even though the percentage change on the entire sector is relatively small, the effect on individual industries within the sectors are likely much larger. Also included in Table 20 are trade weighted averages for each of the three groups of sectors. The average is weighted using trade (export plus import) data for each region.

	China	Japan	USA	EU27
Antimony	0,04%	-14,61%	-13,98%	-13,73%
Rare Earths	0,09%	-15,99%	-14,39%	-14,24%
Magnesium	0,02%	-6,08%	-5,02%	-0,52%
Tungsten	0,03%	-9,62%	-8,71%	-9,06%
Graphite	0,05%	-9,65%	-8,09%	-8,74%
Fluorspar	0,06%	-7,68%	-7,54%	-7,33%
Average (weighted)	0,06%	-10,01%	-9,46%	-8,42%
Minerals	-0,06%	-0,31%	-0,23%	-0,26%
Non-Ferrous Metals	-0,08%	-0,03%	-0,10%	-0,09%
Chemicals, rubbers and plastic	-0,08%	-0,03%	-0,09%	-0,10%
Non-Metallic Minerals	-0,08%	-0,37%	-0,45%	-0,42%
Average (weighted)	-0,08%	-0,05%	-0,11%	-0,12%
Metal Products	-0,08%	-0,07%	-0,15%	-0,17%
Transport Equipment	-0,09%	-0,11%	-0,13%	-0,12%
Electrical Machinery	-0,11%	-0,20%	-0,17%	-0,19%
Other Goods	-0,07%	0,03%	-0,06%	-0,03%
Energy	-0,08%	0,06%	-0,06%	-0,05%
Services	-0,08%	0,09%	-0,03%	0,01%
Average (weighted)	-0,09%	-0,12%	-0,10%	-0,09%

Table 20 Price change (%) as a result of scenario 1. Weighted averages are calculated using regional trade data (imports + exports) from GTAP

The change in value added of sectors is presented in Table 21. Again, since most of these sectors are really large, the percentage changes are pretty small. The most affected sectors are off course the six raw materials. The lower world price of the materials leads to decrease in value added for these materials in the importing regions that range from -3% (magnesium, EU) to -16% (rare earths, Japan). The Chinese mining and processing industries for the raw materials benefit from the removal of the export tax with increases in value added between 2,9% (rare earths) and 8,59% (magnesium). The downstream producers of electrical machinery in China are hurt by the higher input prices which leads to a decrease of 0,38% in value added. This is a substantial loss to this sector given the size of the sector relative to the size of the raw materials. The removal of the export taxes thus has a negative on Chinese downstream producers. Within the EU, most downstream sectors benefit from the lower input prices although the percentage changes are again minor. The most affected EU sector is the metal products sector with an increase in value added of 0,1%. Overall, the weighted average for the downstream sector shows that the value added increases by 0,05% on average for these sectors.

	China	Japan	USA	EU27
Antimony	2,92%	-14,29%	-13,59%	-13,27%
Rare Earths	4,04%	-15,67%	-14,00%	-13,79%
Magnesium	8,59%	-5,73%	-4,59%	-2,93%
Tungsten	5,02%	-9,28%	-8,29%	-8,58%
Graphite	6,27%	-9,31%	-7,68%	-8,26%
Fluorspar	5,92%	-7,34%	-7,12%	-6,84%
Average (weighted)	5,48%	-9,68%	-9,05%	-8,70%
Minerals	0,08%	-0,97%	-0,42%	-0,29%
Non-Ferrous Metals	-0,23%	-0,19%	0,02%	0,01%
Chemicals, rubbers and plastic	-0,01%	-0,12%	-0,01%	0,05%
Non-Metallic Minerals	0,00%	-0,12%	-0,12%	-0,01%
Average (weighted)	-0,03%	-0,13%	-0,02%	0,03%
Metal Products	-0,12%	-0,05%	0,04%	0,10%
Transport Equipment	-0,07%	0,03%	0,06%	0,09%
Electrical Machinery	-0,38%	0,17%	0,00%	0,09%
Other Goods	0,03%	-0,05%	0,02%	-0,01%
Energy	0,04%	-0,18%	-0,04%	-0,09%
Services	-0,03%	0,03%	0,01%	0,02%
Average (weighted)	-0,16%	0,09%	0,02%	0,05%

Table 21 Change in value added (%) of sectors as a result of scenario 1. Weighted averages are calculated using regional trade data (imports + exports) from GTAP

The benefit or cost of the removal of export taxes to downstream producers can be better demonstrated by the change in output volumes. Table 22 presents the change in output value (in billion US dollars) for six downstream industries. The changes in absolute terms are substantial; the sector electrical machinery in China loses 2 billion dollars of output as a result of the removal of export taxes. EU downstream industries benefit mostly (except for the energy and other goods sectors) with increases in output ranging from 1.1 billion (metal products) to 2.2 billion (electrical machinery). Of note is the large increase in the EU services sector output with an increase of 2.2 billion. The service sector contains all services sub-sector that provide services (financial, transport, construction, electricity etc.) to the manufacturing sectors in the economy. So when the manufacturing sectors grow, the services sectors profit since more services can be sold to the manufacturing sector. This strong linkage between the services sector and the manufacturing sectors means that changes in the manufacturing sector are strongly reflected in changes in the services sector. The other way around, a malfunctioning services sector might negatively affect manufacturing sectors.

	Brazil	China	Russia	EU	Japan	USA
Antimony	-	200	-22	-	-	-
Rare Earths	-226	1140	-299	-	-	-

	Brazil	China	Russia	EU	Japan	USA
Magnesium	-51	1524	-32	-815	-	-
Tungsten	-21	375	-11	-	-	-
Graphite	-31	734	-22	-	-	-
Fluorspar	-38	694	-22	-	-	-
Sub-total	-367	4667	-408	-815	-	-
Minerals	-44	87	-31	-261	-113	-180
Non-Ferrous Metals	26	-521	45	25	-121	24
Chemicals, rubbers and plastic	155	-54	-1	743	-476	-71
Non-Metallic Minerals	-47	-5	-41	-22	-54	-93
Sub-total	90	-493	-28	485	-764	-320
Metal Products	5	-847	-95	1112	-157	222
Transport Equipment	65	-252	-105	1298	124	514
Electrical Machinery	-108	-4996	-164	2214	1409	-67
Other Goods	419	633	347	-313	-506	542
Energy	70	172	144	-707	-282	-267
Services	-25	-890	116	2157	1424	2645
Sub-total	426	-6180	243	5761	2012	3589
Total	151	-2007	-193	5432	1248	3270

Table 22 Output volume change (billion US dollar) as a result of scenario 1.

The removal of the export taxes leads to lower prices in the EU, US and Japan and thus stimulates downstream sectors at the cost of Chinese downstream industries. Exporters of the raw materials in China benefit from the removal of the tax. Increases in output of raw materials in China range from 200 million (antimony) to 1.5 billion (magnesium). Competing exporters in Russia and Brazil are hurt by the lower world price and thus produce less than with the taxes in place. The six raw materials only show changes in Table 22 if they're not fixed for the respective country. Overall, output in China decreases while output in the major importing economies increases. The total benefit to the EU economy here is a 5.4 billion increase in output.

The effect of an export tax is an increase in world price as a result of lower world supply. This increase in world price improves the terms-of-trade for exporting countries. Removing the export taxes on raw materials thus should worsen the terms-of-trade of exporting countries while improving the terms-of-trade of importing countries. The change in the overall terms-of-trade of each region as a result of scenario 1 is presented in Table 23. The drop in world price of the raw materials leads to a worsening of the terms-of-trade for the exporting country China by -0,13%. The importing regions Japan, USA and EU all have slightly better terms-of-trade. Finally the overall effect on GDP is presented in Table 23. Overall the effect of removing the taxes is negative for the Chinese GDP and positive for the EU. Again, the small effect on the total EU economy is expected because of the small size of the raw materials studied in this thesis.

	Brazil	China	Japan	Russia	USA	EU27
Change in GDP	-0,15%	-0,15%	0,11%	-0,10%	-0,02%	0,02%

	Brazil	China	Japan	Russia	USA	EU27
value (%)						
Terms-of-trade change (%)	-0,06%	-0,13%	0,02%	0,01%	0,01%	0,02%

Table 23 Change in terms-of-trade and GDP

One of the best ways to measure the welfare change resulting from a policy shock is the (regional household) equivalent variation (EV) value. The EV value is equal to the difference between the expenditure required to obtain the new level of utility at initial prices and the initial expenditure (McDougall, 2001; Berrittella, 2004). In other words, EV measures how much more or less expenditure in the old situation (before the shock) should be in order to obtain the same level of utility as in the new situation (after the shock). So a negative EV value means a regional household can obtain the same level of utility as in the new situation with less expenditure; welfare has decreases as a result of the policy shock. A positive value on the contrary means welfare has increased.[39]

	Allocative Efficiency	Endowment Effect	Technical Change	Population effect	Terms-of-trade	I-S factors	EV (total)
China	329	0	0	0	-1499	-80	-1250
EU27	821	0	313	0	959	63	2156

Table 24 Equivalent Variation (EV) effect of scenario 1. In millions (value)

Table 24 shows the EV result for China and EU in scenario 1. The six columns show what contributes to the welfare change. The first column, allocative efficiency, captures welfare effects arising from the redistribution of resources. The endowment and population effects capture changes in the availability of primary factors such as the size of the labor force, the population or the available (agricultural) land. None of these have been changed so there is no welfare effect in these columns. The technical change captures mostly labor productivity. The last columns show the terms-of-trade effects and I-S effects (effects arising from changes in the price of savings). The total EV score is a sum of the six columns and shows the net welfare effect of the policy change. As seen in Table 24, welfare in Chine decreases (as seen by the negative EV value) while welfare in the EU decreases. The main cause of the decrease in Chinese welfare is due to the large negative terms-of-trade effect. The removal of the export taxes lowers the export price of raw material exporters and thus worsens the terms-of-trade. The removal of the export taxes does remove the negative trade distortion effect as seen by the positive allocative efficiency value. For the EU, the gains in welfare arise mainly from the removal of the trade distortion (allocative efficiency) and the better terms-of-trade.

The main result of scenario 1 is that the removal of export taxes on the raw materials leads to a substantial decrease in the price of raw material inputs for the EU industries. This lower price translates into higher value added and higher output levels for the affected downstream industries in the EU. At the same time downstream industries in China are hurt while the raw material exporting industries benefit. Welfare in the EU increases overall while welfare in China decreases.

[39] See Annex C for a technical explanation on how the EV value is calculated in GTAP.

4.2 Scenario 2

Scenario 2 includes two variants; A and B. In scenario 2A, export taxes on the six materials are increased by 40%. In scenario 2B, other exporters of the six materials want to keep the domestic price of raw materials inputs on par with the Chinese price and thus also impose an export tax of 40% on the raw material that they export. The main price results are presented in Figure 13. The increase in raw material prices for the EU is large, especially for rare earths. The rare earths price in the EU increases by 29% in scenario 2A and by 49% in scenario 2B. Similar to scenario 1, magnesium is least affected with a price increase of 1% and 2% for scenario 2A and 2B respectively. The fact that (in scenario 2B) other exporters react to changes in Chinese trade policy leads to higher price increases for all six raw materials.

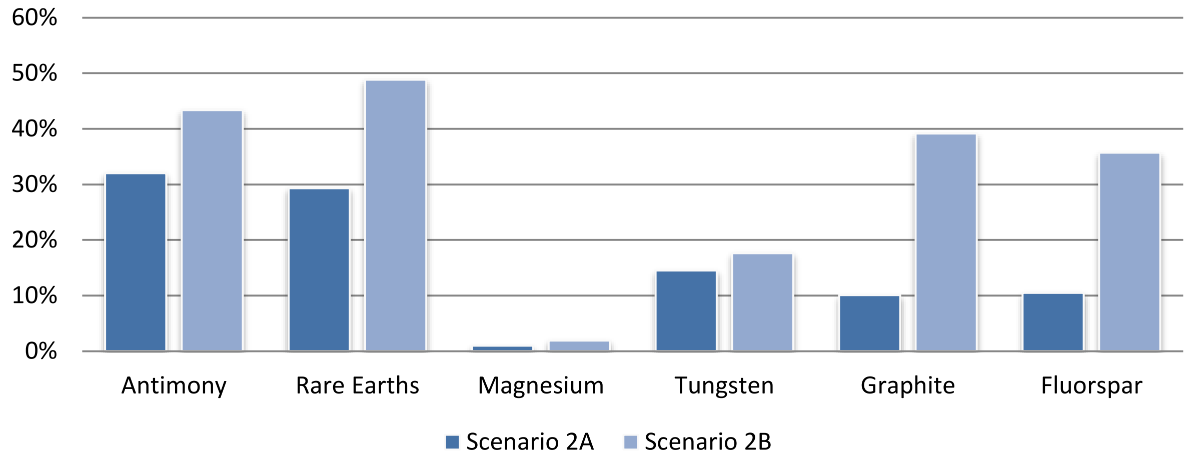

Figure 13 Price changes of the six raw materials for the EU as a result of scenarios 2A and 2B

Table 25 contains the price changes for the six materials and the downstream industries for the EU, the US and Japan. In general, for both scenario 2A and 2B, the increase in export taxes leads to large increases in raw material prices for the EU, US and Japan while Chinese prices remain more or less equal. The change in prices is more substantial in scenario 2B than in 2A as expected. The most affected downstream industries in the EU are metal products, transport equipment and electrical machinery. In scenario 2A their price increases by 0,27%, 0,22% and 0,37% respectively. The increase in price is more substantial under scenario 2B with 0,56%, 0,40% and 0,67% respectively.

	China		Japan		USA		EU27	
	A	B	A	B	A	B	A	B
Antimony	0,06%	0,19%	36,37%	49,16%	33,31%	44,32%	31,97%	43,31%
Rare Earths	0,03%	0,22%	37,50%	53,66%	28,09%	51,50%	29,29%	48,78%
Magnesium	0,11%	0,37%	11,88%	34,38%	8,32%	19,24%	0,96%	1,88%
Tungsten	0,08%	0,33%	17,94%	21,69%	13,45%	20,38%	14,49%	17,60%
Graphite	0,09%	0,29%	12,80%	44,22%	8,96%	28,14%	10,04%	39,15%
Fluorspar	0,08%	0,35%	12,41%	40,34%	10,29%	30,18%	10,45%	35,68%
Average (weighted)	0,06%	0,28%	20,24%	41,63%	17,19%	33,35%	15,35%	31,05%
Minerals	0,14%	0,45%	0,63%	1,27%	0,43%	0,82%	0,49%	0,94%

	China		Japan		USA		EU27	
Non-Ferrous Metals	0,16%	0,41%	0,03%	0,10%	0,18%	0,34%	0,16%	0,31%
Chemicals, rubbers and plastic	0,15%	0,38%	0,03%	0,14%	0,17%	0,30%	0,20%	0,38%
Non-Metallic Minerals	0,16%	0,42%	0,71%	1,49%	0,80%	1,60%	0,32%	1,52%
Average (weighted)	0,15%	0,39%	0,07%	0,21%	0,20%	0,37%	0,21%	0,45%
Metal Products	0,16%	0,42%	0,05%	0,23%	0,26%	0,51%	0,27%	0,56%
Transport Equipment	0,17%	0,43%	0,16%	0,40%	0,23%	0,44%	0,22%	0,40%
Electrical Machinery	0,20%	0,47%	0,40%	0,68%	0,32%	0,59%	0,37%	0,67%
Other Goods	0,14%	0,36%	-0,12%	-0,15%	0,12%	0,21%	0,05%	0,10%
Energy	0,15%	0,39%	-0,17%	-0,26%	0,13%	0,23%	0,10%	0,16%
Services	0,15%	0,42%	-0,25%	-0,38%	0,06%	0,11%	-0,01%	-0,02%
Average (weighted)	0,17%	0,42%	0,21%	0,41%	0,19%	0,35%	0,16%	0,30%

Table 25 Price changes (%) as a result of scenarios 2A and 2B. Weighted averages are calculated using regional trade data (imports + exports) from GTAP

The change in the value added of raw material and downstream sectors is presented in Table 26. The overall result is again that EU downstream producers are hurt both in scenario 2A and 2B although slightly more in 2B. The benefit to Chinese downstream producers is especially large in scenario 2B with substantial increases in value added for metal products (0,24%) and electrical machinery (0,9%). Important to note is that the increase in value added in especially rare earths is very large for the importing regions. Since ‘only’ about 30% of worldwide rare earth reserves[40] can be found within China, US or EU investors might be tempted to invest in rare earth production somewhere outside of China (especially the continent of Africa is known to hold rare earths reserves). With increases in prices and value added this large, mining operations that were previously deemed unprofitable might become economically viable to pursue. A complicating factor (next to the political factors included because the reserves are usually found outside of the EU, US) is that once China removes its export taxes again, world prices will sharply drop again and a mine that was previously profitable might go bankrupt. This uncertainty may withhold investors from investing in mining of these raw materials. On average, downstream EU sectors see a decrease in value added by 0,09% and 0,15% in scenarios 2A and 2B respectively.

	China		Japan		USA		EU27	
	A	B	A	B	A	B	A	B
Antimony	-5,21%	-3,13%	35,40%	46,98%	32,25%	42,06%	30,72%	40,68%
Rare Earths	-9,01%	-2,61%	36,53%	51,41%	27,07%	49,12%	28,06%	46,04%
Magnesium	-10,79%	-8,96%	11,09%	32,41%	7,46%	17,37%	4,23%	10,96%
Tungsten	-7,24%	-6,79%	17,10%	19,91%	12,55%	18,48%	13,40%	15,43%
Graphite	-5,43%	-2,99%	12,01%	42,05%	8,10%	26,13%	9,00%	36,59%

[40] World Mining Data 2011

	China		Japan		USA		EU27	
Fluorspar	-6,64%	-4,20%	11,62%	38,22%	9,41%	28,13%	9,40%	33,18%
Average (weighted)	-8,54%	-4,64%	19,39%	39,53%	16,26%	31,25%	15,35%	31,47%
Minerals	-0,05%	0,08%	2,00%	3,56%	0,75%	1,44%	0,54%	0,99%
Non-Ferrous Metals	0,42%	0,33%	0,48%	0,72%	-0,01%	-0,06%	0,02%	-0,06%
Chemicals, rubbers and plastic	0,03%	-0,13%	0,34%	0,43%	0,01%	0,04%	-0,10%	-0,22%
Non-Metallic Minerals	0,15%	0,74%	0,24%	0,33%	0,25%	0,43%	0,02%	0,04%
Average (weighted)	0,10%	0,06%	0,36%	0,48%	0,04%	0,09%	-0,06%	-0,15%
Metal Products	0,21%	0,24%	0,18%	0,19%	-0,06%	-0,11%	-0,15%	-0,31%
Transport Equipment	0,09%	0,06%	0,06%	-0,26%	-0,12%	-0,20%	-0,16%	-0,25%
Electrical Machinery	0,72%	0,90%	-0,44%	-0,50%	0,02%	0,03%	-0,19%	-0,29%
Other Goods	-0,07%	-0,26%	0,13%	0,20%	-0,04%	-0,06%	0,02%	0,02%
Energy	-0,05%	-0,18%	0,40%	0,66%	0,07%	0,11%	0,18%	0,29%
Services	0,02%	0,04%	-0,06%	-0,11%	-0,03%	-0,05%	-0,03%	-0,06%
Average (weighted)	0,30%	0,31%	-0,18%	-0,30%	-0,03%	-0,06%	-0,09%	-0,15%

Table 26 Change in value added (%) as a result of scenarios 2A and 2B. Weighted averages are calculated using regional trade data (imports + exports) from GTAP

The change in output for the main raw material producers (China, Russia and Brazil) and the EU is presented in Table 27. Industries in the EU are hurt substantially by the increase in taxes with again the results being worse in scenario 2B. Total damage to the EU industries is 11.7 billion and 21.7 billion in scenarios 2A and 2B respectively. Chinese downstream industries benefit from their relatively beneficial input prices and output for these six sectors increases by 10 billion in 2A and 8 billion in 2B. Combined with the losses to the raw material sectors in China, total output in China increases by 4.6 billion in scenario 2A and 5.2 billion in 2B. Of note is here that the decrease in Chinese raw material output is less in scenario B than in scenario A. Because exporters in competing countries now also have to pay an export tax, the damage to Chinese exporters is less than in scenario A. The strong linkage between the service sector and the manufacturing sectors can (as in scenario 1) be seen by the decrease in service output by 5.6 billion in 2A and 11.5 billion in 2B. Since (overall) EU manufacturing sectors are damaged substantially, the services sector is also damaged substantially.

	Brazil		China		Russia		EU27	
	A	B	A	B	A	B	A	B
Antimony	-	-	-357	-214	112	2	-	-
Rare Earths	1068	-44	-2541	-736	1356	-11	-	-
Magnesium	99	277	-1914	-1589	60	-16	1176	3048

	Brazil		China		Russia		EU27	
Tungsten	46	64	-541	-507	22	-10	-	-
Graphite	44	-29	-636	-350	29	6	-	-
Fluorspar	69	322	-778	-492	36	8	-	-
Sub-total	1326	590	-6767	-3888	1615	-21	1176	3048
Minerals	96	167	-58	94	83	62	481	877
Non-Ferrous Metals	-83	-68	979	753	-193	8	46	-133
Chemicals, rubbers and plastic	-420	-442	235	-905	-48	111	-1495	-3251
Non-Metallic Minerals	102	143	222	1122	111	87	35	75
Sub-total	-305	-200	1378	1064	-47	268	-933	-2432
Metal Products	-128	39	1432	1651	82	352	-1623	-3421
Transport Equipment	-242	-159	345	230	-51	47	-2357	-3636
Electrical Machinery	72	509	9624	11973	216	741	-4620	-6980
Other Goods	-997	-1300	-1650	-6386	-900	-751	875	1052
Energy	-182	-234	-219	-758	-491	-221	1388	2188
Services	28	238	494	1331	-308	-159	-5642	-11537
Sub-total	-1449	-907	10026	8041	-1452	9	-11979	-22334
Total	-425	-515	4636	5216	118	256	-11736	-21716

Table 27 Output volume change (billion us dollar)

The change in terms-of-trade and GDP are presented in Table 28. The changes in the terms-of-trade are expected with an improvement in the terms-of-trade for China and a worsening for the importing regions. Overall GDP in the EU is decreased, especially in scenario 2B where all exporters impose export taxes on the selected raw materials. Chinese GDP increase by 0,18% and 0,50% respectively. The fact that other exporters also increase their export taxes in scenario 2B drives the world price even further up. The difference in input cost between Chinese downstream producers and downstream producers in the EU, US and Japan thus increases substantially. At the same time, the exporters of raw materials in China are hurt less since their competitors in other exporting countries also have to pay an export tax. The result is a stronger positive overall effect on GDP for China.

	GDP value change (%)		Terms-of-trade change (%)	
	A	B	A	B
Brazil	0,35%	0,50%	0,17%	0,30%
China	0,18%	0,50%	0,17%	0,31%
Japan	-0,28%	-0,43%	-0,07%	-0,08%
Russia	0,21%	0,32%	0,03%	0,03%
USA	0,04%	0,06%	-0,02%	-0,04%
EU27	-0,04%	-0,07%	-0,03%	-0,05%

Table 28 Terms-of-trade and GDP change

Table 29 presents the EV values for scenarios 2A and 2B. Welfare in the EU decreases in both scenarios. This decrease in welfare is largely caused by the worsening of the terms-of-trade and the change in resource allocation. The increase in welfare for China is especially substantial in scenario 2B. The main cause for this is a large beneficial terms-of-trade effect and a less negative effect for the allocation of resources. In 2B, the damage to raw materials producers is less, the benefit for Chinese downstream producers is greater and the distortion caused by the export tax is less damaging. This leads to a lower negative welfare effect from the allocative efficiency column.

	Allocative Efficiency	Endowment Effect	Technical Change	Population effect	Terms-of-trade	I-S factors	EV (total)
China (2A)	-1945	0	0	0	2225	127	407
EU27 (2A)	-1722	0	-616	0	-1779	-124	-4242
China (2B)	-981	0	0	0	4010	-32	2998
EU27 (2B)	-2774	0	-1203	0	-2812	-211	-7001

Table 29 Equivalent variation scenarios 2A and 2B

Scenarios 1 and 2 have shown that export taxation has a large effect on the selected raw materials. The percentage changes to downstream sectors are somewhat minor thanks to the size of these sectors relative to the size of the raw material sectors. The greatest supply risk for the EU is the fact that exporting countries can work together to limit world supply of a given raw material. These exporters profit from the higher market price and low input price to their domestic industries. The damage to individual industries within the EU is large in scenario 2A and 2B with price increases of inputs of up to 49%. This higher price of inputs puts high-tech EU industries at a disadvantage compared to their competitors in China.

4.3 Sensitivity analysis

One way to measure the reliability of CGE results is to do a sensitivity analysis with respect to the parameter values or the shock values in the model. For this study, it is interesting to see how the results vary with the magnitude of the shock applied. All taxes in scenario 1 are removed, so not much can be varied in this scenario. For scenarios 2A and 2B, export taxes were shocked with 30% and 50% (in addition to the standard 40% used so far) to see how the price changes, value-added changes and welfare changes vary.

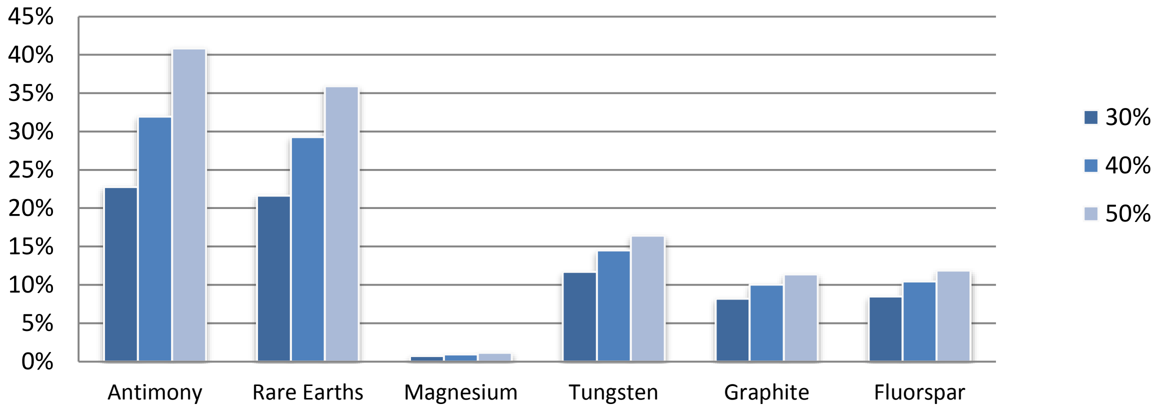

Figure 14 EU price changes of raw materials with export tax increases of 30%, 40% and 50% in scenario 2A

Figure 14 shows the effect on EU raw material prices with export tax increases of 30%, 40% and 50%. In general, variation between price increases can be substantial. For example, the difference in the rare earths price increase between the 30% case and the 50% case is 14,26%. In other words, by raising the export tax 20% (from 30% to 50%), the price increase grows by 65%. Figure 15 shows the same experiment for scenario 2B. In this case the variation is even greater. For rare earths, the price increase grows by 134% between the 30% and 50% cases.

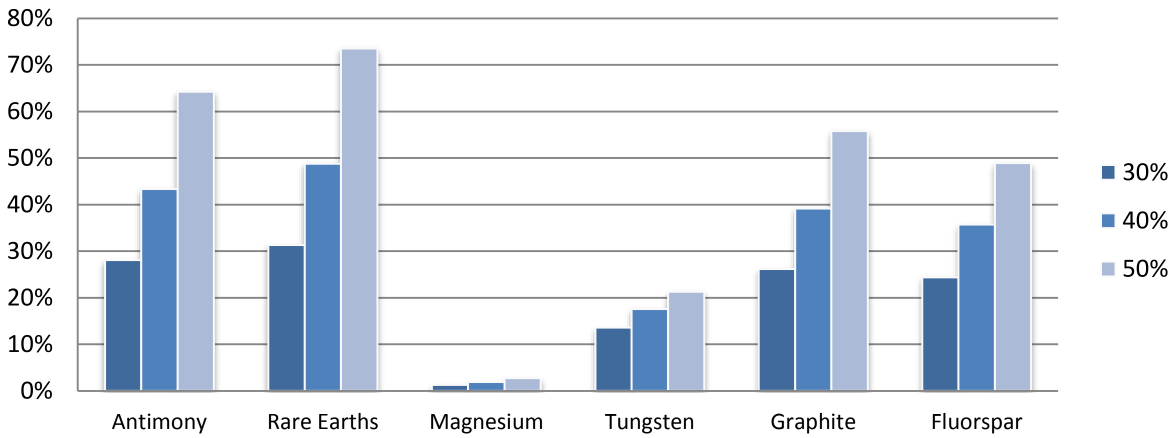

Figure 15 EU price changes of raw materials with export tax increases of 30%, 40% and 50% in scenario 2B

Figure 16 shows the variation between the three export tax increases for the value added in three downstream processing industries. Again, the variation is much larger in scenario 2B than in 2A. The variation is especially large for the sector electrical machinery (ELM) in scenario 2B.

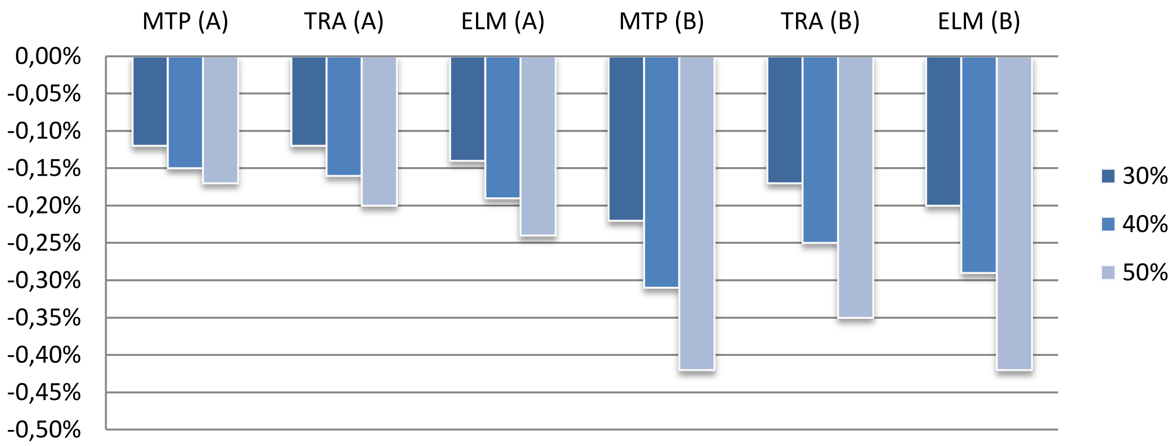

Figure 16 Value-added changes in EU downstream sectors after different export tax increases (30%, 40% and 50%) in scenario 2A (A) and 2B (B). MTP = metal products, TRA = transport equipment, ELM = electrical machinery

Finally, the variation in the welfare effect is shown in Figure 17. Welfare changes vary by 62% in scenario 2A and by 114% in scenario 2B (between the 30% and 50% cases).

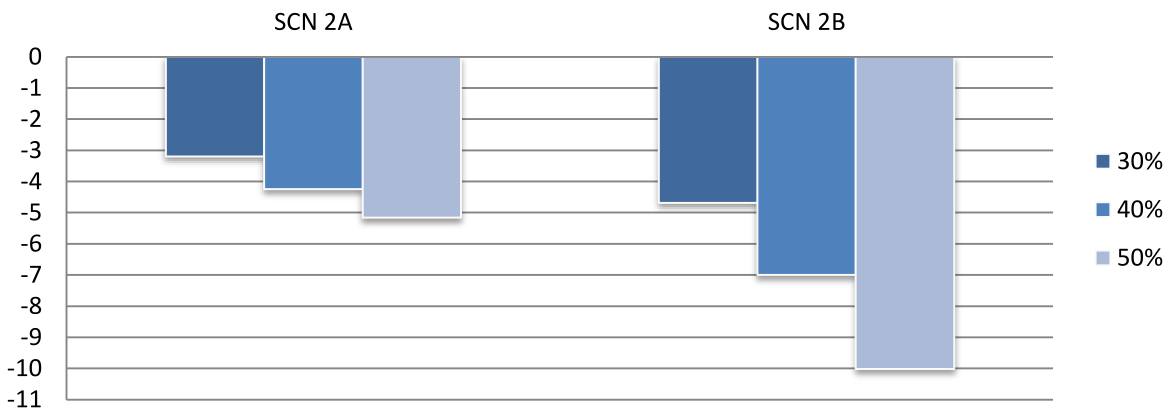

Figure 17 Welfare changes as a result of different tax increases (30%, 40% and 50%). Value in billions

This section shows that the results of the CGE analysis in this study depend relatively strongly on the value of the (tax) shock. The overall results are consistent between the different shock values. The magnitude of the results however can differ quite a bit between different shock values.

5 Recommendations and shortcomings

This study uses a CGE model to estimate what the effects of export restrictions on downstream industries are. There are some shortcomings to his approach. Some of the shortcomings have to do with the specific way in which the CGE model is used. Other shortcomings are inherent to the specific characteristics of the raw materials market.

One major problem with any CGE model is the reliance on assumptions made by the researcher. In the case of this study it was assumed that countries that are currently no major player in a given raw material market have their output for that raw material fixed. Since starting up a mine from scratch takes a long time (at least 15 years according to USGS mineral yearbook reports and that is if a reserve base is already discovered and prospected) it makes no sense to allow regions such as the EU to increase their (non-existent) rare earth production in the model. This automatically limits the timeframe of this study. In twenty years, the EU might be a significant player in the rare earths market itself. Something that increases this uncertainty about the reliance on a specific raw material is the unpredictable variable of technological change. Currently all materials analysed in this thesis are rare and practically not substitutable. Technological change however might lead to new substitutes being found or to new technologies that render current high-tech technologies useless and outdated. In twenty years, China might still control the market for these materials and the materials might still be relevant. But the factors influencing whether this is true or not are not included in this analysis so no conclusion can be drawn for the long run.

Specific to the CGE modelling in this study are some shortcomings relating to Splitcom, the aggregated downstream sectors and the elasticities used by the model. Splitcom allows a researcher to split one aggregated sector into two or more new sectors. To do this the program needs data on for example export, imports and output. With this data, Splitcom creates the new sectors with the limitation that all accounting principles are followed. This means that the program does no precisely use your data to create the sectors of exactly the size you specified. The relative shares of each country in production and trade are respected by Splictom. The exact size of a new sector however may be slightly larger or smaller than intended. This is a general shortcoming of CGE modelling and GTAP specifically. Since the sectors included in GTAP are huge and include a range of varied subsectors, it is very hard to isolate the effects for one very specific sector. For the six raw materials this problem was solved by using Splitcom (with the limitation discussed above), the downstream processing industries however are not split from the main aggregated sectors. So, in this study, it is for example possible to see the effects on the aggregated sector electrical machinery but it is not possible to distinguish between the television sector and the computer chips sector. One last shortcoming relating to the CGE modelling in this study is the use of the default GTAP elasticities. The new graphite sector has different production and trade data than the original non-metallic minerals sector. The elasticities for the new sector however are identical to the old sector. Since the materials discussed in this study are very difficult to substitute (which is not captured by the actual elasticities), the model might underestimate the effects of an export tax on these materials.

With the major shortcomings out of the way, the main recommendations for future studies can now be discussed. To be more specific on which sectors are most affected, the downstream industries need to be split. Although this is a huge amount of work, this will provide more precision. In the electrical machinery sector, it might be that computer chips are very reliant on rare earths but toasters are not. Splitting the downstream sectors will make the research more specific and precise. The downside is the huge amount of work on the database this will take. All new sectors will need to be newly created with a new database containing at least output, trade and intermediate input data. A second approach that might be interesting in future research is to include dynamic factors into the model such as rising raw material demand (due to the growth of new economies), environmental consequences and the depletion of natural resources.

This study clearly shows the effect that raw material export taxes have on the raw material markets involved. The effect on downstream industries in both exporting and importing industries is, although small relative to the size of the sector, also clear. The overall welfare effects are very small and somewhat less relevant since the focus of this study is on competing downstream industries. For policy makers there are three main things this study proves. First of all, export taxes directly damage industries in importing regions. In that sense export taxes are just as damaging to importing industries as (foreign) import taxes can be to exporting industries. From an economic institutional point of view this is not reflected in the rules and regulations of the WTO. Import taxes are mostly prohibited while export taxes are, in principle, not prohibited. Second, the (percentage) effects of an export tax on aggregated sectors are relatively small. However, the effect on some sub-sectors within those aggregated sectors is much larger. All of these affected sectors are also strategically (from an economic viewpoint) important. Finally, importing regions are very vulnerable if exporting countries react to each other's trade policies. As argued in this study and by Bouet and Debucquet (2010), net exporting countries have an incentive to impose export taxes if one exporting country imposes an export tax. The CGE results show that the damage to EU downstream industries is much higher in this scenario.

The main policy recommendations of this study are (1) to focus on finding substitutes for the selected raw materials and (2) to work on a political framework in which export taxes are prohibited and (most importantly) this prohibition can be effectively enforced. Clear from this study is that the EU (and other net importing regions) is highly dependent on China for the selected raw materials. To decrease this dependency on China the EU can either start producing the materials themselves or focus on finding substitute materials and or technologies. Starting a mining operation is costly and depends on the availability of raw material reserves in a place the EU has access to. In the foreseeable future, EU mining is not an option for all of the materials except magnesium (for which the EU already has significant production capabilities). The focus should therefore be on finding alternatives to the selected materials in order to be less dependent on them. The second recommendation is to exert political pressure on the WTO, China and other exporting countries to abandon export taxation. As argued in this study, currently export taxation is not in all cases prohibited and enforcement can be a problem.

6 Conclusion

Innovation and technology are important components of modern European economies. To produce high-tech products, a wide range of raw materials are needed. The two WTO dispute settlement cases against China underline the growing concern that EU member states have about their access to raw materials. The EC's *raw materials initiative group* has selected 14 materials with a heightened supply risk that are of high economic importance to EU economies. Out of those 14, six materials have been selected in this study for further research: antimony, tungsten, rare earths, graphite, magnesium and fluorspar. These materials have in common that China is responsible for the majority of world production for each of the materials. In 2010, China had export taxes in place on each of the six selected raw materials. An export tax creates a difference between the price Chinese downstream producers pay for the raw materials and the price producers in importing regions pay. An export tax can thus be used to create a competitive advantage for Chinese producers at the cost of producers in for example the EU.

The main goal of this study has been to examine what the effects of export taxation on these raw materials is for downstream industries in the EU. The six raw materials have a number of characteristics that make them especially relevant to investigate in the context of export taxation and in the context of promoting downstream industries. These characteristics are a high supply risk, great economic importance and a low substitutability. An export tax on these materials is potentially very damaging to certain EU downstream industries. The materials in this study are used in a variety of products including glass (rare earths, antinomy, fluorspar), batteries (antimony), magnets (rare earths), steel products (graphite), various chemicals (fluorspar) and a variety of metal alloys (tungsten, magnesium, antimony). In turn, for example, the magnets created with rare earths are used in high-tech products we use on a daily basis such as smartphones and computer chips.

Export taxation is in principle not prohibited by WTO law. When a country joins the WTO however, country specific prohibitions may be agreed upon. China has agreed to abstain from export taxes on products that are not included on the exemption list that is part of the accession protocol. From the six materials analyzed in this study, only tungsten and antimony are on the exemption list. This means that China may not impose export taxes on rare earths, magnesium, fluorspar or graphite. Nevertheless, China has export taxes in place on all of the six raw materials, including the four materials that are not on the exemption list. The export taxes in 2010 ranged from 10% on magnesium to 20% on graphite and Antimony. These export taxes have led to complaints from the EU (together with the US and Japan) against China. The dispute settlement case dealing with this complaint is at the time of this writing still ongoing.

To answer the central question of this study, a CGE analysis has been used. The goal was to examine what the effects of removing the existent (in 2010) Chinese export taxes on EU industries are. A second scenario that has been analyzed is an increase of Chinese export taxes by 40%. Since China is a huge and growing economy, it needs substantial raw material resources for itself. It is therefore not unlikely that China would try to keep a large part of their raw material production for its own industries. To run these two main scenarios, a modified GTAP model and database has been used.

Some of the standard sectors in GTAP have been split using Splitcom to include the six raw materials as separate sectors in the model. The model uses the latest GTAP database with 2007 data which is calibrated to 2010 with GDP data.

Removing the export taxes in the model has very clear effects on the raw material markets. Since production of these materials is very concentrated in a single region (China), the effects on raw materials are rather high. The price drop for the EU is the strongest for rare earths and antinomy (14%) and tungsten (9%). To determine what the effect on individual sectors in China and the EU is, the value-added per sector is used. The value-added in the raw material sectors increase substantially in China (ranging from 2,9% for rare earths to 8,59% for magnesium). Value-added in the downstream sectors decreases in China and increases in the EU. The percentage changes are small because of the relatively big size of the aggregated sectors compared to the raw material sectors. The metal products sector in the EU benefits the most with an increase of 0,1%. In absolute terms, these changes can be quite substantial. For example, the downstream sector electrical machinery in China loses 2 billion dollars of output. EU downstream industries benefit mostly with increases in output ranging from 1.1 billion (metal products) to 2.2 billion (electrical machinery).
The overall welfare effects of removing the export taxes are very small. The EU experiences an increase in welfare as demonstrated by the higher GDP value and the positive EV value. Chinese GDP and welfare decreases by a small margin.

In the second scenario, two variants are presented. In the first variant, China raises its export taxes by 40%. In the second variant, other net-exporters also impose an export tax on the respective materials. EU Raw material prices are again strongly affected by the export taxes. The price of rare earths increases the most with 29% in scenario 2A and with 49% in scenario 2B. In general, the price increase is stronger in scenario 2B as expected. The value-added in downstream industries in China increases in general and decreases in the EU. Chinese downstream producers benefit the most in scenario 2B with substantial increases in value added for metal products (0,24%) and electrical machinery (0,9%). The sectors in the EU that are hurt the most are metal products (a decrease of 15% in 2A and 31% in 2B), transport equipment (a decrease of 16% in 2A and 25% in 2B) and electrical machinery (a decrease of 19% in 2A and 29% in 2B). In absolute terms, total output in China increases by 4.6 billion in 2A and 5.2 billion in 2B. EU total output decreases substantially with 11.7 billion and 21.7 billion in 2A and 2B respectively. The overall welfare effects are negative for the EU and positive for China. The positive welfare effect for China arises mainly from the great market power it has in the raw material markets analysed in this study. This market power translates in substantial improvements in the term of trade. For the EU, welfare has to decline since there is both a negative terms-of-trade effect and a negative trade distortion effect.

The main conclusion of this study is that the effects of export taxation on the selected raw materials are substantial for both the raw material sectors themselves and the downstream industries. A major cause of this is that the price changes as a result of the export taxes are very large. The high concentration of production in China and the impossibility of starting up new mines in the short term lead to large price decreases and increases in scenarios 1 and 2 respectively. Downstream industries are hurt by the export taxation but the overall effect on the aggregated sectors is small in relative terms. Given the size of the aggregated sectors, the consequences for the affected individual sub-sectors is much more substantial. Welfare in the EU reacts positively to the removal of export taxes as expected. Increases in export taxation negatively affect welfare. In China, welfare decreases in scenario 1 and increases in scenario 2. This means that for China, the terms-of-trade effects and the positive effect on downstream producers of (higher) export taxes dominate the trade distortion effect and the negative effect on raw material markets.

7 References

Amiruddin, M.N. (2003). *Palm Oil Products Exports, Prices and Export Duties: Malaysia and Indonesia Compared*. Oil Palm Industry Economic Journal 3 (2): 15–20.

Armington, P. S. (1969). *A theory of Demand for Products Distinguished by Place of Production*. IMF staff papers 16(1).

Berritella (2004). *Methods for decomposing welfare changes in the GTAP model*. GTAP technical note, Global Trade Analysis Project, Purdue University, West Lafayette, Indiana, U.S.A.

Bhagwati, J.N., Srinavasan, T.N., 1983. *Lectures in International Trade*. MIT Press, Cambridge, MA.

Bouët, A. and D. L. Debucquet (2010). *Economics of Export Taxation in a Context of Food Crisis: A Theoretical and CGE Approach Contribution*. IFPRI Discussion Paper 00994, June 2010, IFPRI, Washington, D. C.

Bouet, A., and Laborde, D. (2010). *Economics of Export Taxation: A Theoretical and CGE Approach Contribution.* International Food Policy Research Institute, Washington

Brockmeier, M. (2001). *A Graphical Exposition of the GTAP Model*. GTAP Technical Paper, Center for Global Trade Analysis, Purdue University, West Lafayette, IN.

Burfisher, M. E. (2011). *Introduction to Computable General Equilibrium Models*. Cambridge University Press.

Corden, W. M. (1971). *The theory of protection*. Oxford, U.K.: Clarendon Press.

Corden (1997). *Trade policy and economic welfare*. Oxford, U.K.: Clarendon Press.

Diamond, P.A. (1975). *A many person Ramsey rule*. Journal of Public Economics 4: 335 – 342

E-to-China.com (ETCN) (2010). *Circular of the customs tariff commission of the state council on the tariff execution plan*. Available at: http://www.e-to-china.com/tariff_changes/data_tariff_changes/2010/0108/73155.html. Retrieved on April 2nd 2012.

European Comission (2008). *The raw materials initiative – meeting our critical needs for growth and jobs in Europe*. Available at: http://ec.europa.eu/enterprise/policies/raw-materials/documents/index_en.htm. Retrieved on April 23rd 2012.

European Commission (2010). *Critical raw materials for the EU*. Report of the Ad-hoc Working Group on defining critical raw materials. Avaliable at: http://ec.europa.eu/enterprise/policies/rawmaterials/files/docs/report-b_en.pdf. Retrieved on April 23rd 2012.

European Comission (2012). *EU challenges China's rare earth export restrictions*. EC press release, available at: http://trade.ec.europa.eu/doclib/press/index.cfm?id=785. Retrieved on June 2nd 2012.

Francois, J.F. & Reinert, K.A. (1998). *Applied Methods for Trade Policy Analysis: A Handbook*. Cambridge: Cambridge University Press, First edition

GATT panel report (1988). *Canada- Herring and Salmon*. Available at: http://www.worldtradelaw.net/reports/gattpanels/canadaherring.pdf. Retrieved on April 13th 2012.

GATT (1994). *Article X, XI and XX*. Available at: http://www.wto.org/english/docs_e/legal_e/legal_e.htm. Retrieved on May 15th 2012.

Hertel, T.W. (2010). Chapter 2: *The structure of GTAP.* Originally in: Hertel, T.W. (ed.) (1997). Global Trade Analysis: Modelling and Applications, Cambridge University Press.

Hertel, T.W. (2012). *Global Applied Equilibrium Analysis using the GTAP Framework*. GTAP working paper no. 66. Originally in: Hertel, T. W. (ed.) (1997). Global Trade Analysis: Modelling and Applications, Cambridge University Press.

Horridge, M. (2008). *SplitCom – Programs to disaggregate a GTAP sector*. Melbourne: Monash University

Huff, K. and T. Hertel. (2001). *Decomposing Welfare Changes in GTAP*. GTAP Technical Paper No. 5, Center for Global Trade Analysis, Purdue University, West Lafayette, IN.

Karapinar, B. (2011). *China's export restriction policies: complying with 'WTO plus' or undermining multilateralism*. World Trade Review, 10:3, 389 – 408.

Kim, J. (2010). *Recent trends in export restrictions on raw materials*. In: The economic impact of export restrictions on raw materials. (Trade Policy Studies, 13–57). Paris: OECD.

Kim, J. and Korinek, J. (2010). *Export Restrictions on Strategic Raw Materials and Their Impact on Trade*. OECD Trade Policy Working Papers, No. 95, OECD Publishing.

Marrewijk, C. van (2007). International Economics: Theory, Application, and Policy. New York: Oxford University Press.

McDougall, R.A. (1993). *Uses and Abuses of AGE Models*. Presentation to the Short Course in Global Trade Analysis, Purdue University, 25-31 July 1993.

McDougall, R. A. (2003). *A New Regional Household Demand System for GTAP*. GTAP Technical Paper No. 20, Global Trade Analysis Project, Purdue University, West Lafayette, Indiana, U.S.A.

Mitra-Kahn, B. H. (2008). *Debunking the myths of computable general equilibrium models*. SCEPA Working Paper 1: 1–93. 56.

Narayanan G., B., Dimaranam, B.V., & McDougall, R.A. (2010). *Chapter 2: Guide to the GTAP database*. Part of: Narayanan, G. & Walmsley, L. (2010). *Global Trade, Assistance, and Production: The GTAP 7 Data Base*. West Lafayette: Center for Global Trade Analysis, Purdue University.

OECD (2010). *Summary Report of the Raw Materials Workshop*. Available at: http://www.wto.org/english/res_e/publications_e/wtr10_forum_e/wtr10_oecd_summary_report_e pdf. Retrieved on March 28th 2012.

Piermartini, R. (2004). *The Role of Export Taxes in the Field of Primary Commodities.* WTO Discussion Paper. Geneva: World Trade Organization.

Robinson, S. (2003). *Macro models and Multipliers: Leontief, Stone, Keynes and CGE models*. International Food Policy Research Institute.

Round, J. (2003). *Social accounting matrices and SAM-based multiplier analysis*. In L. A. da Silva Pereira, & F. Bourguinon, *Techniques for evaluating the poverty impact of economic policies*. World Bank and Oxford University Press.

Rutherford, T.F. (1998). *GTAP in GAMS: The dataset and Static Model*. Available at: https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=409. Retrieved on December 15th 2012.

Rutherford, T.H. and Arbor, A. (2005). *GTAP6 in GAMS: The dataset and Static Model*. Available at: http://www.mpsge.org/gtap6/gtap6gams.pdf on 20 August 2011. Retrieved on December 15th 2012.

Seaman, J. (2010). *Rare Earhs and Clean Energy: Analyzing China's upper Hand*. Institut francais des relations internationals (Ifri).

Seaman, J. (2009). *China's rare earth strategy, policy and practice*. Institut francais des relations internationals (Ifri).

USGS (1998). *International strategic mineral issues – Tungsten.* Available at: http://pubs.er.usgs.gov/publication/cir930O. Retrieved on: October 4th 2012.

USGS (2011). *Antimony profile report.* Available at: http://minerals.usgs.gov/minerals/pubs/commodity/antimony/index.html#myb. Retrieved on: October 4th 2012.

USGS (2011). *Chinese rare earth industry*. Available at: http://pubs.usgs.gov/of/2011/1042/. Retrieved on: October 4th 2012.

USGS (2011). *Fluorspar Minerals Yearbook*. Available at: http://minerals.usgs.gov/minerals/pubs/commodity/fluorspar/index.html#myb. Retrieved on: October 4th 2012.

USGS (2011). *Rare earth elements: uses and recyclability*. Available at: http://www.usgs.gov/science/cite-view.php?cite=2774. Retrieved on: October 4th 2012.

USGS (2012). *Minerals Yearbook 2011*. Available from: http://minerals.usgs.gov/minerals/pubs/myb.html. Retrieved: august 14th 2012

Van Den Hende, L. and J. Paterson (2009). *Export Restrictions on Raw Materials: WTO Rules and Remedies*. Herbert Smith LLP, Bloomberg Law Reports.

Weber, L. and Zsak, G. (2011). *World Mining Data 2011.* International Organising Committees for World Mining Congresses. Available at: http://www.wmc.org.pl/?q=node/49. Retrieved on May 24th 2012.

WTO. *Dispute settlement case DS395*. Available at: http://www.wto.org/english/tratop_e/dispu_e/cases_e/ds395_e.htm. Retrieved on May 5th 2012.

WTO. *Dispute settlement case DS432*. Available at: http://www.wto.org/english/tratop_e/dispu_e/cases_e/ds432_e.htm. Retrieved on May 5th 2012.

WTO (1998). *US-Shrimp.* WTO Appellate body report. Available at: http://www.worldtradelaw.net/reports/wtopanels/us-shrimp(panel).pdf. Retrieved on April 12th 2012.

WTO (1998). *Trade Policy Review: Indonesia.* WTO secretariat report (WT/TPR/S/51). Available at: http://www.wto.org/english/tratop_e/tpr_e/tp94_e.htm. Retrieved on December 16th 2012.

WTO (2001). *Protocol on the Accession of the People's Republic of China (Accession Protocol).* WTO Secretariat (WT/L/432). Available at: http://www.worldtradelaw.net/misc/chinaaccessionprotocol.pdf. Retrieved: Jun 1st 2012.

WTO (2001). *Trade Policy Review: Ghana.* WTO secretariat report (WT/TPR/S/194). Available at: http://www.wto.org/english/tratop_e/tpr_e/tp157_e.htm. Retrieved on December 16th 2012.

WTO (2007). *Trade Policy Review: Argentina.* WTO secretariat report (WT/TPR/S/176). Available at: http://www.wto.org/english/tratop_e/tpr_e/tp277_e.htm. Retrieved on December 16th 2012.

WTO (2007). *Trade Policy Review: Cameroon.* WTO secretariat report (WT/TPR/S/187). Available at: http://www.wto.org/english/tratop_e/tpr_e/tp288_e.htm. Retrieved on December 16th 2012.

WTO (2008). *Trade Policy Review: China.* WTO secretariat report (WT/TPR/S/199). Available at: http://www.wto.org/english/tratop_e/tpr_e/tp299_e.htm. Retrieved on September 8th 2012.

WTO (2008). *Trade Policy Review minutes of the meeting, China.* WTO minutes of the meeting (WT/TPR/M/199). Available at: http://www.wto.org/english/tratop_e/tpr_e/tp299_e.htm. Retrieved on September 8th 2012.

WTO (2012). *Trade Policy Review: China.* WTO secretariat report (WT/TPR/S/264). Available at: http://www.wto.org/english/tratop_e/tpr_e/tp364_e.htm. Retrieved on September 8th 2012.

Annex A Market structure of GTAP

This section will shortly discuss the market structure of GTAP formally. The discussion in this section is based on the GTAP market structure discussion in Rutherford (1998 and 2005).

Regional production and demand

Producers in the GTAP economy produce two main types of goods: goods for the domestic markets and goods for the export market. Domestic goods and tradeable goods are imperfect substitutes in the GTAP model as per the Armington (1969) assumption. Total output is given in equation (16). In (16), output is made up from domestic goods (D) and export goods (X).

$$Y_{ir} = \left[\propto_{ir}^{Y} D_{ir}^{1+\frac{1}{n}} + \beta_{ir}^{Y} X_{ir}^{1+\frac{1}{n}} \right]^{\frac{1}{1+1/n}} \quad \textbf{(16)}$$

As can be seen from (17) and (18), domestic supply and export supply depend on economic activity (*Y*), export prices and import prices.

$$D_{ir} = Y_{ir} a_{ir}^{D} (p_{ir}^{D}, p_{ir}^{X}) \quad \textbf{(17)}$$

$$X_{ir} = Y_{ir} a_{ir}^{X} (p_{ir}^{D}, p_{ir}^{X}) \quad \textbf{(18)}$$

Producers in the GTAP model demand inputs based on the level of activity in the respective sector (*Y*). The total demand for intermediate good *i* can be seen in equation (19) and consists of the sum of economic activity of all sectors and the input coeficient (a_{ijr}, the input coefficient for good *i* in sector *j* in region *r*) of the input for each sector. In the standard GTAP model the input coefficient is fixed for all industries and inputs. This means that input coefficients do not change if price suddenly rise or fall substantially.

$$ID_{ir} = \sum_j Y_{jr} a_{ijr} \quad \textbf{(19)}$$

Intermediate inputs are, as equation (20) shows, also divided in domestic inputs and traded (in this case imported) inputs. *DI* depicts domestically produced inputs and *MI* expresses imported inputs.

$$ID_{ir} = \left[\propto_{ir}^{I} DI_{ir}^{\rho} + \beta_{ir}^{I} MI_{ir}^{\rho} \right]^{\frac{1}{\rho}} \quad \textbf{(20)}$$

Producers also demand factor inputs. Equation (21) shows that this factor demand depends on the level of activity in the respective sector, factor prices and factor taxes.

$$FD_{fir} = Y_{ir} \alpha_{fir}^{F} (p_{r}^{F}, t_{ir}^{F}) \quad \textbf{(21)}$$

Next to producers, the public sector in GTAP also produces output. Equation (22) presents government output as a Cobb-Douglas aggregation of market commodities.

$$G_r = \Gamma_r \prod_i GD_{ir}^{\theta ir} \quad \textbf{(22)}$$

Government demand is given by equation (23). As was the case for the producers, government demand is split up in demand for domestically produced goods and imported goods.

$$GD_{ir} = [\propto_{ir}^{G} DG_{ir}^{\rho} + \beta_{ir}^{G} MG_{ir}^{\rho}]^{\frac{1}{\rho}} \quad \textbf{(23)}$$

Final demand in the GTAP model is determined by a single agent (the regional household). This agent both collects and distributes all income. In GTAP private households are endowed with primary factors, tax revenues and (net) transfers from other regions. This income is spend on private consumption, public consumption and investment. As can be seen from (24), total (regional) utility is a function of domestic consumption (CD).

$$U_r = \sum_i \theta_{ir}^{C} \log(CD_{ir}) \quad \textbf{(24)}$$

Domestic consumption again is a combination of domestic demand and import demand as can be seen from equation (25).

$$CD_{ir} = \left[\alpha_{ir}^{C} DC_{ir}^{\rho} + \beta_{ir}^{C} MC_{ir}^{\rho}\right]^{1/\rho} \quad \textbf{(25)}$$

The function for the final demand is shown in equation (26). Demand (CD) is a function of total regional expenditure (*M*), prices (*p*) and consumption taxes t^C.

$$CD_{ir} = \frac{\theta_{ir}^{C} M_r}{p_{ir}^{C}\left(1 + t_{ir}^{C}\right)} \quad \textbf{(26)}$$

Trade

Equation (27) shows the three main forms of imports: imports of intermediates (MI), government imports (MG) and private imports (MC). The right hand side of (27) shows that all forms of imports have the same regional composition of imports.

$$MI_{ir} + MG_{ir} + MC_{ir} = \left[\sum_s \alpha_{isr}^{M} M_{isr}^{\rho}\right]^{1/\rho} \quad \textbf{(27)}$$

In the GTAP model, there are two margins of trade: taxes and transportation costs. Equation (28) shows the function for transportation costs. As (28) shows, transport costs are proportional to the size of trade flows.

$$T_{irs} = \tau_{irs} M_{irs} \quad \textbf{(28)}$$

Demand for bilateral imports is given in equation (29). Each region minimises its costs given the export price from region *r* (p_{ir}^{X}), the export tax rate (t_{irs}^{X}) and the import tax t_{irs}^{M}.

$$M_{irs} = M_{is} a_{irs}^{M}\left(p_{ir'}^{X}, t_{ir's}^{X}, p^{T}, t_{ir's}^{M}\right) \quad \textbf{(29)}$$

Market clearance

To obtain an equilibrium, GTAP triest to satisfy a number of market clearance conditions. Equation (30) shows that domestic output equals demand for intermediate inputs, public sector use of inputs, consumer demand and investment.

$$D_{ir} = DI_{ir} + DG_{ir} + DC_{ir} + I_{ir}$$
$$D_{ir} = ID_{ir} a_{ir}^{D,G} + GD_{ir} a_{ir}^{D,G} + CD_{ir} a_{ir}^{D,G} + I_{ir} \quad \textbf{(30)}$$

The market clearance condition for import markets is given in equation (31). Aggregate supply of imports (an aggregation of imports from all regions) must equal import demand by producers, consumers and the government.

$$M_{ir} = MI_{ir} + MG_{ir} + MC_{ir}$$
$$M_{ir} = ID_{ir} a_{ir}^{M,G} + GD_{ir} a_{ir}^{M,G} + CD_{ir} a_{ir}^{M,G} + I_{ir} \quad \textbf{(31)}$$

The market clearance condition for export markets is given in equation (32). This equation shows that the supply of exports (X) must equal foreign demand for domestic exports (MI) plus transportation demand (TD).

$$X_{ir} = \sum_s MI_{irs} + TD_{ir}$$
$$X_{ir} = \sum_s MI_{ir} a_{irs}^{M} + Ta_{ir}^{T} \quad \textbf{(32)}$$

Finally, factor markets clear if factor endowment (*F*) equals total factor demand. In equation (33), Y_{ir} is again the level of activity of good *i* and a_{fir} is the input coefficient of factor *f* in the production of good *i*.

$$F_{fr} = \sum_i Y_{ir} a_{fir}^{F} \quad \textbf{(33)}$$

All producers operate under the constant return to scale assumption and earn zero profits in equilibirum. The zero-profits condition for producers is shown in equation (34). The left hand side of (34) shows total output excluding consumption taxes. The right hand side shows total costs. Costs consist of factor costs (plus taxes) and intermedite goods costs (plus taxes). In equilibirum, these two terms should be equal.

$$\left(p_{ir}^{D} a_{ir}^{D} + p_{ir}^{X} a_{ir}^{X}\right)\left(1 - t_{ir}^{Y}\right) = \sum_f a_{fir}^{F} p_{fr}^{F}\left(1 + t_{fir}^{F}\right) + \sum_j a_{jir} p_{jr}^{ID}\left(1 + t_{jir}^{ID}\right) \quad \textbf{(34)}$$

The trade sector is also perfectly competetive and thus operates under the zero-profit condition. As (35) shows, the domestic (cif) import price must equal (fob) export price of the trading partner plus export taxes, transport costs and import taxes.

$$p_{ir}^{M} = \sum_s a_{irs}^{M} \left[p_{is}^{X}\left(1 + t_{isr}^{X}\right) + \tau_{irs} p^{T}\right]\left(1 + t_{isr}^{M}\right) \quad \textbf{(35)}$$

Annex B GTAP sector abbreviations

List of GTAP sector abbreviations with their descriptions. ISIC stand for International Standard Industrial Classification. Only the manufacturing sectors in GTAP are listed here. Agricultural and services sectors are less relevant in the context of this study.

Sector no.	Code	ISIC code	Description
14	fsh	015	Hunting, trapping and game propagation including related service
		05	Fishing, operation of fish hatcheries and fish farms; service activities incidental to fishing
15	coa	101	Mining and agglomeration of hard coal
		102	Mining and agglomeration of lignite
		103	Mining and agglomeration of peat
16	oil	111	Extraction of crude petroleum and natural gas (part)
		112	Service activities incidental to oil and gas extraction excluding surveying (part)
17	gas	111	Extraction of crude petroleum and natural gas (part)
		112	Service activities incidental to oil and gas extraction excluding surveying (part)
18	omn	12	Mining of uranium and thorium ores
		13	Mining of metal ores
		14	Other mining and quarrying
27	tex	17	Manufacture of textiles
		243	Manufacture of man-made fibres
28	wap	18	Manufacture of wearing apparel; dressing and dyeing of fur
29	lea	19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
30	lum	20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
31	ppp	21	Manufacture of paper and paper products
		22	Publishing, printing and reproduction of record media
32	p_c	231	Manufacture of coke oven products
		232	Manufacture of refined petroleum products
		233	Processing of nuclear fuel
33	crp	241	Manufacture of basic chemicals
		242	Manufacture of other chemical products
		25	Manufacture of rubber and plastic products
34	nmm	26	Manufacture of other non-metallic mineral products
35	i_s	271	Manufacture of basic iron and steel
		2731	Casting of iron and steel
36	nfm	272	Manufacture of basic precious and non-ferrous metals
		2732	Casting of non-ferrous metals
37	fmp	28	Manufacture of fabricated metal products, except machinery and equipment
38	mvh	34	Manufacture of motor vehicles, trailers and semi-trailers
39	otm	35	Manufacture of other transport equipment

Sector no.	Code	ISIC code	Description
40	ele	30	Manufacture of office, accounting and computing machinery
		32	Manufacture of radio, television and communication equipment and apparatus
41	ome	29	Manufacture of machinery and equipment n.e.c.
		31	Manufacture of electrical machinery and apparatus n.e.c.
		33	Manufacture of medical, precision and optical instruments, watches and clocks
42	omf	36	Manufacturing n.e.c.
		37	Recycling
43	ely	401	Production, collection and distribution of electricity
44	gdt	402	Manufacture of gas; distribution of gaseous fuels through mains
		403	Steam and hot water supply

Table 30 GTAP manufacturing sectors descriptions. Source: Guide to the GTAP database (2012)

Annex C Equivalent variation (technical note)

As discussed in section 4.1, the best way to measure welfare changes in GTAP is the (regional household) equivalent variation (EV). The EV value is equal to the difference between the expenditure required to obtain the new level of utility at initial prices and the initial expenditure. In other words, EV measures how much more or less expenditure in the old situation (before the shock) should be in order to obtain the same level of utility as in the new situation (after the shock). This annex contains a technical explanation on how this EV value is calculated in GTAP) and is based on Berrittella (2003), McDougall (2003) and Hertel & Huff (2001).

The basic EV expression is shown in equation (36). Y_{EV} depicts the expenditure required to obtain the new level of utility at initial prices and $\bar{Y}$ depicts the initial expenditure.

$$EV = Y_{EV} - \bar{Y} \quad \textbf{(36)}$$

After differentiating (36), equation (37) is obtained.

$$dEV = (0.01)Y_{EV}y_{EV} \quad \textbf{(37)}$$

In (37), y_{EV} represents the percentage change in Y_{EV}. This percentage change can be broken up into a change in population (*n*) and the per capita percentage change in expenditure required to achieve the new utility at initial prices (X_{EV}). Equation (38) shows this relation.

$$y_{EV} = n + X_{EV} \quad \textbf{(38)}$$

Equation (39) introduces the elasticity of expenditure with respect to utility. This elasticity is used to capture the impact of non-homotetic preferences for private consumption on utility. The expenditure required to achieve the new utility is then given by (39).

$$X = P + \Phi u \quad \textbf{(39)}$$

To obtain the EV value, prices are fixed at initial levels. The per capita change associated with the EV measure then simplifies to the expression in equation (40).

$$X_{EV} = \Phi_{EV}\, u \quad \textbf{(40)}$$

Inserting (40) and (39) into (37) results in the expression for the change in regional welfare shown in equation (41). The first term on the left hand side in (41) captures the per capita welfare changes caused by population changes. The second term captures changes in real income as a result of policy shocks (with the exception of a shock to population). The goal is to decompose this term in order to see where the change in welfare comes from (for example a terms-of-trade effect or tax distortion effect.

$$dEV = (0.01)Y_{EV}n + (0.01)Y_{EV}\Phi_{EV}u \quad \textbf{(41)}$$

Equation (42) shows the total regional real income. The total real income can be calculated by summing the percentage changes in per capita expenditure and population ($\mathrm{y} = \mathrm{n} + \mathrm{x}$). Using this in combination with equation (39) results in equation (43).

$$D \equiv Y(y - p) \quad \textbf{(42)}$$

$$u = \Phi^{-1}(\mathrm{y} - \mathrm{p} - \mathrm{n}) \quad \textbf{(43)}$$

Finally, inserting (43) into (41) results in the final expression for EV. The change in welfare is composed of two terms. The first term captures changes in population. The second term captures the relation between total real income and the EV.

$$dEV = (0.01)\left[1 - \frac{\Phi_{EV}}{\Phi}\right] Y_{EV} n + (0.01)\frac{\Phi_{EV}}{\Phi}\frac{Y_{EV}}{Y} D \quad \textbf{(44)}$$

The GTAP code includes the factors that contribute to the second term in equation (44). This GTAP code is shown in equation (45). Important in this expression are the terms PTAX (output tax), ETAX (endowment tax), DFTAX (intermediate use tax), DGTAX (tax on government consumption), MTAX (import tax) and XTAXD (export tax). All of these taxes (or subsidies if positive) are linked to the relevant quantity changes. Other important contributers to welfare changes in the GTAP are terms-of-trade effects and effects caused by changes in the price of savings/investments. In GTAP all of these factors are tracked and summed. This way, the total EV value is obtained and this EV value can be broken down into the main causes for the welfare change.

```
EV_ALT(r)  (27)
=  [0.01*EVSCALFACT(r)]
* [sum{i,ENDW_COMM, VOA(i,r)*[qo(i,r) - pop(r)]}
  - VDEP(r)*[kb(r) - pop(r)]
+ sum {i,NSAV_COMM, PTAX(i,r)*[qo(i,r) - pop(r)]}
+ sum {i,ENDW_COMM, sum{j,PROD_COMM, ETAX(i,j,r)*[qfe(i,j,r) - pop(r)] }}
+ sum {j,PROD_COMM, sum{i,TRAD_COMM,IFTAX(i,j,r)*[qfm(i,j,r) - pop(r)] }}
+ sum {j,PROD_COMM, sum{i,TRAD_COMM,DFTAX(i,j,r)*[qfd(i,j,r) - pop(r)]}}
+ sum {i,TRAD_COMM, IPTAX(i,r)*[qpm(i,r) - pop(r)]}
+ sum {i,TRAD_COMM, DPTAX(i,r)*[qpd(i,r) - pop(r)]}
+ sum {i,TRAD_COMM, IGTAX(i,r)*[qgm(i,r) - pop(r)]}
+ sum {i,TRAD_COMM, DGTAX(i,r)*[qgd(i,r) - pop(r)]}
+ sum {i,TRAD_COMM, sum{s,REG,XTAXD(i,r,s)*[qxs(i,r,s) - pop(r)]}}
+ sum {i,TRAD_COMM, sum{s,REG,MTAX(i,s,r)*[qxs(i,s,r) - pop(r)] }}
+ sum {i,TRAD_COMM, sum{s,REG, VXWD(i,r,s)*pfob(i,r,s)}}
+ sum {m,MARG_COMM, VST(m,r)*pm(m,r)}
- sum {i,TRAD_COMM, sum{s,REG, VXWD(i,s,r)*pfob(i,s,r)}}
- sum {m,MARG_COMM, VTMD(m,r)*pt(m)}
+ NETINV(r)*pcgds(r)
- SAVE(r)*psave(r) ]
+ 0.01*INCOMEEV(r)*pop(r);
```

(45)