

The Due diligence system in the EU's
Timber Regulation: non-tariff trade barrier
or leverage effect?

Abstract

This paper presents a novel spatial equilibrium model to analyse the leverage impact of the EU's Timber Regulation on sustainable timber production. This leverage effect is an argument in favour of FLEGT but it has never been investigated thoroughly, or simultaneously for demand and supply. The leverage effect is measured in terms of the market share of sustainable timber in the total timber consumption and production of a region. Our research finds that FLEGT does not provide an incentive for sustainable timber production and consumption at global level. FLEGT creates a non-tariff trade barrier at the conventional timber markets of important producing regions (Europe and North America). This protectionist situation favours conventional timber which decreases the importance of sustainable timber. In addition, the protectionist situation decreases global welfare.

1. Introduction and literature review

This paper investigates the leverage for legal timber production and consumption of the EU's Forest Law Enforcement, Governance and Trade programme (FLEGT). FLEGT aims 'at stimulating both legal timber production and good forest governance' around the world (Wiersum and Elands 2013). Hence, FLEGT also aims to sustain forest management and production. A straightforward indicator of the leverage effect is the market share for the sustainable timber.

To our knowledge, the leverage of FLEGT for sustainable timber production has never been investigated. Assessments of FLEGT exist, but those assessments focus on the trustworthiness of the legality claims throughout the supply chain. These studies safeguard the interest of the importing party – the EU. Albeit useful, those assessments do not demonstrate whether sustainable timber production is gaining importance (or not) over conventional timber production. Also the official monitoring of the policy's impact is very EU-centred. The official monitoring tracks the changes on the EU's internal market, and to what extent certified timber is recognised and rewarded. But the official monitoring does not track the evolutions at the non-EU timber markets. This is essential however since FLEGT aims to sustain timber production and forest management around the world. This paper aims to address this flaw in literature.

The EU's assumption that its policies can impact other region's timber markets is correct. Previous research already demonstrated the international dimension of timber markets. Timber industries in different regions are 'increasingly linked through international trade and global environmental policies' (Buongiorno 2003). Consequently, demand and supply shocks in one region can impact on other regions' timber markets. In addition, forest conservation policies – such as certification – in one region can lead to deforestation in other regions (Gan and McCarl 2007, Sedjo and Sohngen 2013). This indicates the relevance of this research question. A Spatial Equilibrium Model is used to analyse the impact of the European policy at global level. These kind of models allow interaction between different regions' markets.

In 2013, the EU implemented the EU's Timber Regulation (EUTR) in order to achieve the objectives of FLEGT. This regulation must ensure that no illegal timber or timber products are sold in the EU. In practise, EUTR obliges 'traders who place timber products on the EU market for the first time to exercise due diligence' (Commission 2015). Due diligence is a risk management exercise which must minimize the risk of placing illegally harvested timber at the EU's market¹.

¹ The three key elements of the "due diligence system" are: 1) Information: The operator must have access to information describing the timber and timber products, country of harvest, species, quantity, details of the supplier and information on compliance with national legislation. 2) Risk assessment: The operator should assess the risk of illegal timber in his supply chain, based on the information identified above and taking into account criteria set out in the regulation. 3) Risk mitigation: When the assessment shows that there is a risk of illegal timber in the supply chain that risk can be mitigated by requiring additional information and verification from the supplier.

Setting up a due diligence system or following an existing monitoring scheme at company level is often costly. Two techniques can lower the due diligence cost however, both techniques involve a type of certification. First of all, countries can negotiate and implement a Voluntary Partnership Agreement (VPA) with the EU. If a country has a VPA, it must develop a timber legality assurance system. If this legality assurance system is declared functional, the country can award FLEGT certificates to its timber producers, processors and traders. The FLEGT certified timber can then be exported to the EU without passing the due diligence exercise.

Second, also (eco-)certified timber facilitates the fulfilment of the due diligence (Breukink 2015): eco-certified timber can pass a ‘due diligence light’. In some cases, the import of eco-certified timber even does not entail additional due diligence costs (D’Haeseleer 2015). This is confirmed by UNECE (2015) who noticed that FSC² eco-certified timber is accepted as sufficient proof of legal harvest within the EU’s due diligence system. In these cases, the eco-certificate has the same value as the FLEGT-certificate for countries with a VPA.

For this reason, this paper will assume that the eco-certificates and the FLEGT certificate are homogeneous concepts. The assumption of homogeneity is required in order to analyse the impact of FLEGT at global level. Both certification types’ characteristics and properties differ to some extent, but their similarities are more apparent. The FLEGT-certificate for example focusses more on the legality aspect, but the VPA’s also have sustainability and societal aspects. VPA’s are intended for less developed countries however. Negotiating a VPA is not an option for countries in, for example, North America. For this region’s producers, obtaining an eco-certificate will be a priority in order to facilitate timber exports to the EU.

Despite their potential usefulness in timber trade to the EU, the FLEGT- and eco-certificates are currently not important in the Southern hemisphere. The importance of the certificates is measured in terms of market share in total timber production and consumption. In May 2015, 10.9% of the total global forest area was certified. The regional distribution of the certified area is, however, apparent: The Northern hemisphere accounts for 89% of the globally certified area while the Southern hemisphere only accounts for 11% (UNECE 2015). At the same time, only 7 countries signed and implemented a VPA³. Hereafter, the paper refers to both types of certification by the term ‘certificate’, unless explicitly mentioned differently.

The second part of this paper presents the basic framework and methodology of this paper, including the explanation of the Spatial Equilibrium Model. The third part will discuss the outcomes of the model, while the fourth part will discuss and explain some particularities of the outcome. The final part of the paper provides a brief summary and conclusion.

2. Methodology

This paper constructs demand and supply functions in accordance with the standard single-product SEM by Takayama and Judge (1971). Two specificities of the case study justify the choice of the single-product SEM. First, the SEM can distinguish a policy measure’s welfare

² FSC and PEFC are the two main – and only – eco-certificates for the timber industry at global level.

³ Cameroon, Central African Republic, Ghana, Indonesia, Liberia, Republic of the Congo.

impact on the demand side from the welfare impact on the supply side of a market. Since it is the goal of FLEGT to increase both demand and production of certified timber it is essential to analyse both sides of the market simultaneously.

Second, the SEM allows different regions' markets to interact. Our SEM takes five regions into account: Latin America, North America, Europe (including Russia), Africa, and Asia (including Oceania). The model cannot be run at country level due to the lack of accurate data at this level.

Other specificities of the case study require a modification to the SEM's maximization framework. The main modification distinguishes conventional products from certified products for a region's production and consumption. Both timber types are physically homogenous but the certificate indicates that their production processes differ. Consequently, certified timber becomes a credence good which is vertically differentiated by process attributes (Dulleck et al. 2011). Hence, certified and conventional timber are substitute goods. The introduction of the Willingness to Pay (WTP) and Willingness to Accept (WTA) will enable the distinction between certified and conventional timber.

The simultaneous solution of all regions' equilibria under the assumption of bilateral trade costs results in an equilibrium state at global level. However, due to the modifications, the model's outcome will not solely consist of an equilibrium price and equilibrium quantity. The equilibrium price is still calculated and constitutes the price of conventional timber. The equilibrium quantity is a region's total timber production and consumption (certified plus conventional). In addition, an equilibrium price premium is calculated on top of the equilibrium price. This equilibrium premium is used to determine the equilibrium share of certified timber within the total timber consumption and production. These outcomes finally allow us to determine each region's quasi-welfare.

I. Retaining part of the standard SEM

Respecting the standard approach, this paper's SEM maximizes the sum of all regions' quasi-welfare under the assumption of transport costs. In this set-up, the demand function endogenously determines the equilibrium demand quantity of (certified plus conventional) timber $Q_{d,i}^*$ and the equilibrium demand price $P_{d,i}^*$ in region i . The demand function does not distinguish between certified and conventional timber. $Q_{d,i}^*$ and $P_{d,i}^*$ are calculated from the baseline demand quantity $Q_{d,i}^0$ and the baseline demand price $P_{d,i}^0$ as a function of the response to a price change ($\Delta P_{d,i} = P_{d,i}^* - P_{d,i}^0$). The extent to which the demand quantity responds to price changes is determined by each region's price elasticity for demand $e_{d,i}$:

$$Q_{d,i}^* = Q_{d,i}^0 \left(1 + e_{d,i} \frac{\Delta P_{d,i}}{P_{d,i}^0} \right) \quad (1)$$

The supply function is constructed accordingly and endogenously determines the equilibrium supply quantity and supply price:

$$Q_{s,i}^* = Q_{s,i}^0 \left(1 + e_{s,i} \frac{\Delta P_{s,i}}{P_{s,i}^0} \right) \quad (2)$$

The value of each region's $Q_{d,i}^0$, $Q_{s,i}^0$, $P_{d,i}^0$, and $P_{s,i}^0$ is based on Buongiorno and Shushuai (2014). The remaining parameters in equations (1) and (2) are the price elasticities for demand $e_{d,i}$ and supply $e_{s,i}$. Buongiorno and Shushuai (2014) conducted a meta-analysis on both price elasticities for timber. They found a price elasticity in demand for (industrial round-) timber which varies between -0.05 and -0.37 depending on the income level (higher in developing countries). The price elasticity for supply varies between 0.11 and 2.84. To tighten the range, Buongiorno and Shushuai (2014) set the price elasticities at 0.8.

II. Modification 1: distinguish certified from conventional timber

A first modification to the single-product SEM distinguishes certified from conventional timber. At first sight, it appears to be more straightforward to use the multi-product SEM by Takayama and Judge (1971). Unfortunately, the price mechanism in the multi-product SEM is not appropriate for markets characterized by the presence of certified products alongside conventional ones. The multi-product SEM for substitute products applies the standard price mechanism for substitute products (Takayama and Judge 1970, O'Sullivan et al. 2011). This implies the assumption of a positive (negative) cross-price elasticity for demand (supply) for substitute goods. This would imply that a changing conventional timber price indirectly affects the certified timber price (through the demand and supply quantities).

However, the certified and conventional timber prices are directly related to each other. The price of certified timber ($P_{d,i}^{cer}$ and $P_{s,i}^{cer}$ for demand and supply respectively) consists of the conventional timber price ($P_{d,i}$ and $P_{s,i}$) with the addition of a price premium. The premiums ($Pprem_{d,i}$ and $Pprem_{s,i}$) are expressed as a percentage of the conventional price:

$$P_{d,i}^{cer} = P_{d,i}^*(1 + Pprem_{d,i}) \quad (3)$$

$$P_{s,i}^{cer} = P_{s,i}^*(1 + Pprem_{s,i}) \quad (4)$$

Because the price of certified timber partially comprises the conventional timber price, the generally assumed positive (negative) cross-price elasticity in demand (supply) for substitutes does not hold for certified and conventional substitute goods. The price premium is expressed as a percentage increase to the conventional price. Hence, a price increase for conventional timber involves increasing the certified timber price by the same percentage. As a consequence, certified and conventional timber remain equally expensive in relative terms. The multi-product SEMs do not allow for this kind of price relationship.

Instead, a new price mechanism is built into the standard (single-product) SEM. Key to the new price mechanism is the introduction of the price premiums $Pprem_{d,i}$ and $Pprem_{s,i}$ as endogenous regional variables, using equations (3) and (4). Based upon the regional price premiums, the SEM endogenously determines the proportion of total consumption and production which is certified: respectively $Share_{d,i}^{cer}$ and $Share_{s,i}^{cer}$. The Willingness to Pay (WTP) and Willingness to Accept (WTA) functions for each region describe the relationship between the price premium and the certified share. The model uses a logistical distribution function for WTA and WTP because the function can be analytically integrated, which is not possible for the normal distribution.

On the demand side, the WTP expresses the price premium a certified timber consumer is prepared to pay on top of the conventional timber price (Michaud et al. 2012). This price premium constitutes remuneration for the credence qualities attributed to the certified products. Those credence qualities relate to the environmental and societal-friendly production practices applied in the certified production process. Hence, the credence good is vertically differentiated by process attributes (Dulleck et al. 2011). The WTP in region i is symmetrically distributed around a known mean ($\mu_{WTP,i}$) following a logistic distribution with variance $\pi^2 \sigma_{WTP,i}^2 / 3$. The cumulative distribution function for this logistical distribution links the certified share of total consumption to the price premium level:

$$Share_{d,i}^{cer} = 1 - \frac{1}{1 + e^{-\frac{(P_{pprem,d,i} - \mu_{WTP,i})}{\sigma_{WTP,i}}}} \quad (5)$$

For each price premium level, the cumulative distribution function determines the certified share of the total timber consumption in region i . Figure 1 demonstrates how a low price premium P_{pprem}^{low} on top of the conventional equilibrium timber price $P_{d,i}^*$ results in a high proportion of certified consumption ($Share_{d,i}^{cer}$ hi) in the total equilibrium timber consumption $Q_{d,i}^*$. A high price premium P_{pprem}^{high} results in a small share: $Share_{d,i}^{cer}$ low. This reasoning is also justified by Fajgelbaum et al. (2011) who demonstrated that higher incomes lead to larger fractions of consumers buying high-quality goods.

The regional parameters $\mu_{WTP,i}$ and $\sigma_{WTP,i}$ are retrieved from the global meta-analysis on consumers' WTP for certified timber by Cai and Aguilar (2013). At global level, they found a mean WTP of 12.2% with a standard deviation of 8%. The logistic regression model by Jacobsen and Hanley (2009) is used to determine each region's mean WTP based on the regional GDP per capita (Appendix A). Regional differences in the GDP per capita then explain regional differences in WTP. Hence, some regions' consumers will be more interested in certified timber compared to other regions' consumers. The modified SEM determines the certified share of total consumption and the price premium on the demand side of the market endogenously.

On the supply side, environmental and societal-friendly production practices restrict forest management options. Consequently, the production costs for certified timber are higher than for conventional timber (Van Deusen et al. 2010). According to the assumption of competitive behaviour, producers will only produce certified timber if those additional costs are compensated by a price premium $P_{pprem,s,i}$. The WTA measures the minimum price premium requested by a producer.

In practice, certification entails direct and indirect costs. The direct costs are the costs of the certification process: Direct costs are not supposed to differ regionally. The indirect costs comprise all costs required to change management practices to meet certification standards (Bass 2001). The magnitude of the indirect cost is inversely related to the quality of the current management practices. Some regions manage their forests better than other regions. This entails regional differences in the WTA.

In accordance with the WTP approach, a cumulative distribution function of certified production is constructed out of a region i 's logistically distributed WTA (equation 6). This allows the SEM to determine the certified share of a region's production and the price premium on the supply side of the market endogenously:

$$Share_{s,i}^{cer} = \frac{1}{1+e^{-\frac{(P_{prem,s,i}-\mu_{WTA,i})}{\sigma_{WTA,i}}}} \quad (6)$$

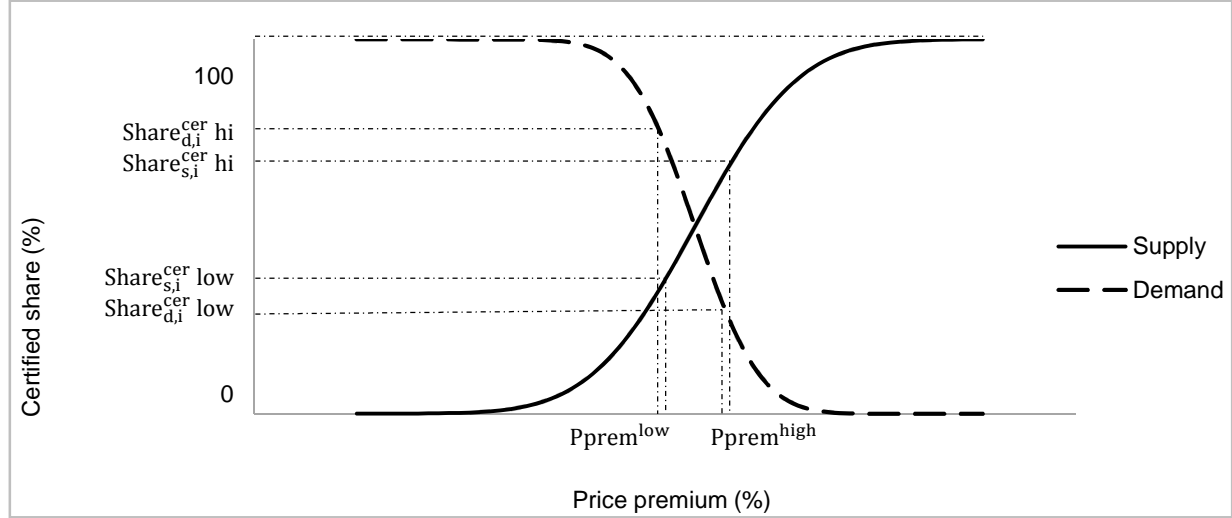


Figure 1: Cumulative distribution function of certified timber in total demand and supply for a region i .
NOTE.-The low and high price premium are determined arbitrarily.

Figure 1 visualizes how a high price premium stimulates certified timber production ($Share_{s,i}^{cer hi}$) and a low price premium discourages certified production ($Share_{s,i}^{cer low}$). The regional parameters μ_{WTA_i} and σ_{WTA_i} are determined from the combination of the price premiums reported by the certification bodies and the actual certified percentage of forest area per region (Appendix B). This WTA is highest for Africa and Asia which have the lowest percentage of certified area. In Europe and North America the WTA is lower, in contrast to their percentage of certified area (Table B1).

The outcome of these modifications is an equilibrium state for the market which is no longer two-dimensional (price and quantity). Instead, the equilibrium consists of four dimensions: price, quantity, price premium, and certified share of total consumption/production.

III. Modification 2: Impact on objective function

The introduction of certified alongside conventional timber impacts on the objective function of the SEM. In accordance with Takayama and Judge (1971), each region's consumer surplus equals the integral of the demand function (equation 1) over the equilibrium quantity and price (Appendix C). Hence, this consumer surplus is calculated for the consumption of both certified and conventional timber. Simultaneously, each region's producer surplus is derived from the integrated supply function (equation 2) over the equilibrium quantity and price (Appendix C). This producer surplus also relates to the production of both certified and conventional timber.

The introduction of the price premium for certified timber creates some additional consumer and producer value. This must be taken into account by the objective function. Figure 1 demonstrates how a low price premium $Pprem^{low}$ encourages a high percentage of a region i 's consumers ($Share_{d,i}^{cer}$) to acquire certified timber. But this $Pprem^{low}$ is lower than most of the certified timber consumers are willing to pay for certified timber. For those certified timber consumers willing to pay a higher price premium, an equilibrium price premium equal to $Pprem^{low}$ creates additional consumer value. This additional consumer value is quantified by integrating the cumulative logistic distribution function (equation 5) over the right hand side of the equilibrium price premium. A maximum price premium of 100% is assumed:

$$CS_i^{cer} = \int_0^1 Share_{d,i}^{cer} dPprem_{d,i} - \int_0^{Pprem_{d,i}} Share_{d,i}^{cer} dPprem_{d,i} \quad (7)$$

This additional consumer surplus is added to the traditional consumer surplus (Appendix C).

On the supply side of the market, the introduction of the price premium creates additional value for producers. This additional producer surplus is quantified by integrating the cumulative logistic distribution function of the certified share of timber production (equation 6) over the left hand side of the equilibrium price premium. This additional producer surplus is added to the standard producer surplus in order to construct a new objective function (Appendix C).

$$PS_i^{cer} = \int_0^{Pprem_{s,i}} Share_{d,i}^{cer} dShare_{d,i}^{cer} \quad (8)$$

IV. Modification 3: Modify the trade balances

The non-negativity constraints on prices and physical quantities placed on standard SEMs remain valid in the modified SEM: $P_{d,i}^*$, $P_{s,i}^*$, $Q_{d,i}^*$, $Q_{s,i}^*$, and $TQ_{i,j}^*$ cannot be negative. In addition it is also assumed that the price premiums ($Pprem_{d,i}$ and $Pprem_{s,i}$) are non-negative. Hence, the conventional timber price is below or equal to the certified timber price.

The distinction between conventional and certified timber in the modified SEM requires the modification of the constraints in the other standard SEM. First, the consumption of certified (conventional) timber in region i cannot exceed the sum of each region j 's transported quantities of certified (conventional) timber to region i : $TQ_{j,i}^{cer}$ ($TQ_{j,i}^{con}$). This includes region i 's production which is destined for the domestic market.

$$Share_{d,i}^{cer} * Q_{d,i}^* \leq \sum_j TQ_{r,j}^{cer} \quad (9)$$

$$(1 - Share_{d,i}^{cer}) * Q_{d,i}^* \leq \sum_j TQ_{j,i}^{con} \quad (10)$$

Accordingly, region i cannot transport more certified (conventional) timber to other regions $TQ_{i,r}^{cer}$ ($TQ_{i,r}^{con}$) than it produces itself. This also includes production for the domestic market:

$$Share_{s,i}^{cer} * Q_{s,i}^* \leq \sum_j TQ_{i,j}^{cer} \quad (11)$$

$$(1 - Share_{s,i}^{cer}) * Q_{s,i}^* \leq \sum_j TQ_{i,j}^{con} \quad (12)$$

In the standard SEM, a price condition determines whether trade occurs between two regions i and j . This standard price condition still holds as a condition for the conventional timber trade:

$$P_{s,i}^* + TC_{i,j} \leq P_{d,j}^* \rightarrow TQ_{i,j}^{con} > 0 \quad (13)$$

This price condition implies that the demand price in the importing region must compensate the supply price in the exporting region plus the per unit transport costs between both regions ($TC_{i,j}$). The non-negativity constraint for the transported quantities implies that $TQ_{i,j}^{con} = 0$ if the price condition is not met. The standard price condition cannot, however, determine whether trade in certified timber will occur. A modified price premium takes the price premium into account:

$$P_{s,i}^* + TC_{i,j} + P_{prem_{s,i}} \leq P_{d,j}^* + P_{prem_{d,j}} \rightarrow TQ_{i,j}^{con} > 0 \quad (14)$$

The demand price for conventional timber, together with the price premium of demand for certified timber in importing region j must compensate region i 's supply price and price premium as well as the unit transport costs between regions i and j . If this price condition is not met, no certified timber trade will occur ($TQ_{i,j}^{con} = 0$).

In this setting, the transport costs separate, but do not isolate, markets in different regions. The parameters' value for the bilateral transport costs are based on Buongiorno and Shushuai (2014). The unit costs of shipping timber between two regions comprise two parts. The first component is a fixed cost of shipping one unit from one region to another (USD 20.2). The second component is a region-dependent ad valorem percentage. This ad valorem percentage varies from 7.197% for Africa to 0% for Europe and North America. The transport costs are not just taken into account to determine whether bilateral trade flows will occur. In accordance with the standard SEM, they must also be taken into account as an additional cost in the objective function (Appendix C). Hence the objective function maximizes quasi-welfare, which consists of the regional aggregation of the traditional consumer and producer surplus plus the additional consumer and producer surplus associated with certification minus all transport costs (equation A1).

V. Modelled shock

This paper will analyse and compare two scenarios. The first 'baseline scenario' assumes FLEGT does not exist. In this scenario both conventional and certified timber can be imported in the EU. In addition, importing timber does not entail any additional costs, besides the standard transport costs. The second 'FLEGT scenario' assumes the perfect implementation of FLEGT. Hence, only certified timber can be imported in the EU. However, a non-negative price premium needs to be paid for the imported and certified products. This price premium represents a compensation for the additional costs of applying for the certificate. Alternatively, if producers do not apply for a certificate, the price premium compensates the additional costs related to setting up a due diligence system.

These costs of applying for a certificate or setting up a due diligence system are not necessarily perfectly equal. Nevertheless we assume that both approaches for timber import in

the EU entail comparable costs. This is justified by the observation that certification in many cases is the alternative to setting up a due diligence system. Hence, in these cases the costs of certification are likely to be less or equal to the costs of the due diligence exercise.

The FLEGT scenario implies that the non-negativity constraint for the transported conventional timber quantity towards the EU ($TQ_{j,EU}^{con}$) must be further tightened. This variable is set at zero for each region, except the EU:

$$\forall j \neq EU: TQ_{j,EU}^{con} = 0 \quad (15)$$

This restriction on trade is a non-trade barrier for conventional timber. But the outcome of the policy is not straightforward. At the one hand, it may indeed stimulate certification in the non-EU regions since certification becomes a prerequisite to trade towards the EU. At the other hand, this policy favours the EU's conventional timber producers who acquire a monopoly position within the EU. This might stimulate conventional timber production in the EU.

3. Main outcomes

The FLEGT impacts different aspects of the regional timber markets. The different aspects are discussed separately. First of all, the impact on the certified share of timber production and consumption is discussed. This enables an assessment of the FLEGT's main objective: to provide a leverage effect for sustainable timber consumption and production. Certified timber in this narrative is legal and sustainable timber. Hereafter, the welfare impact of the policy is discussed per region.

1. Certified production

The production potential of each region is quite distinct. At present, Europe, North America, and Asia are producing the most timber (respectively 29.66%, 29.46%, and 25.89% of the world's production). Latin America and Africa produce less timber (12.57% and 2.42% of global production, respectively).

This paper assumes that a region's certified timber production is positively linked to the region's certified forest area. Consequently, it is assumed that increases in certified timber production positively impact on forest conservation and sustainable forest management practices. In the baseline scenario, Europe and North America are the most important certified timber producers. Respectively 46.53% and 84.84% of their timber production is certified (

Table 1). The certified share in the three remaining regions' production is less than 5%.

FLEGT manages to increase the certified timber production in Africa, Latin America, and Asia. The certified timber production in these regions increased by 18.16%, 18.16%, and 17.64% respectively. Nevertheless, the overall volume of certified timber production in these regions is still marginal. Africa, Latin America, and Asia together only account for 5.17% of the global certified timber production in the FLEGT scenario.

In fact, the global certified timber production decreased by 26.69% in the FLEGT scenario. This is due to the decreased certified timber production in Europe and North America. The decreased certified timber production in Europe is explained by the trade distorting impact of

FLEGT. The policy prevents the import of conventional timber in the EU. This situation compares to protectionist measures which strengthen the position of the EU's conventional timber producers. This newly acquired monopoly situation makes the production of conventional timber more interesting. Consequently, a part of the previously certified producers switched to conventional timber production in the FLEGT scenario. The existence of transport costs forces part of the European consumers to follow this trend. The transport costs, together with the price premium, are added to the domestic conventional timber price. This makes it more expensive to switch from conventional to certified timber consumption.

The production in North America decreased by 41.70% due to FLEGT. This is explained by the evolution of the certified timber price in relation to the conventional timber price. In the baseline scenario, the supply price premium in North America was above the price premiums in the other regions. The market shock initiated by FLEGT drives the different regional price premiums closer to each other. In addition, the decreased interest for certified timber in Europe lowers the price premium in North America. This made certified timber production less interesting for the producers in North America, and forced a number of them to switch to conventional timber. The home-effect of the transport costs again force consumers to follow this trend.

II. Certified consumption

The global consumption of certified timber must be in balance with the global certified timber production and consequently decreased by 26.69%. Table 2 displays the SEM's solution for each supply-related variable for both scenarios.

In most cases, the consumption of certified timber follows the trend of a region's certified timber production. The transport costs explain this phenomenon. The transport costs create an additional margin between a region's domestic price, and other region's prices. The higher this margin, the lower the degrees of freedom of consumers to switch from domestically produced timber to imported timber, and the more they are bound to the position of their regional producers. If for example less certified wood is produced by domestic producers, consumers can not compensate easily by imports due to the existence of transport costs. Consequently, domestic producers can increase their prices to some extent without losing a competitive advantage over their foreign competitors. The transport costs in this logic separate, but do not isolate, the different regions' markets.

The consumption of certified timber only decreases in Europe and North America. The explanation of the declining European certified production has received ample attention in the previous part. The protectionist nature of FLEGT attracts more European timber producers to the conventional market segment. The decreased certified supply of timber cannot be compensated by imports due to the transport costs on top of the conventional timber price and price premium. Hence, the home effect of the monopolistic situation outweighs the potential benefits of certified timber imports into Europe.

Also the consumption of certified timber in the other regions follows the evolution of the certified share in a region's timber production. In North America this implies a 41.7% decrease of the certified timber consumption. In the baseline scenario, certified timber

consumption was the standard in North America. Even to that extent that no price premium was required at the demand side of the market. The lost volume of certified timber consumption in North America surpasses the global loss of certified timber consumption.

The losses of certified consumption are partially compensated by increases in Africa, Latin America, and Asia. The situation in Latin America is remarkable. This region is importing certified timber in the FLEGT scenario as well. This is a result of the disappearance of conventional timber export towards Europe. Due to this disappearance, the relative conventional timber price decreased compared to the certified timber price in this region. Latin America imports certified wood to fulfil the growing demand.

III. Welfare implication

FLEGT has the same effect as a protectionist anti-trade measure. Restrictive policies do not maximise welfare at global level. In the FLEGT scenario: the global welfare decreased by 0.26%. The global decrease can be decomposed in 2 distinct manners. First, we decompose the evolution of the global welfare into the different regions' welfare evolutions. Second, we decompose each regional welfare evolution into the evolution of the consumers' and producers' welfare. Table 3 displays the percentage change of each region's total, consumer, and producer welfare.

Some trends in Table 3 are apparent. At first, the consumer welfare decreases in each region. This is a result of the restrictions to trade which increase the conventional timber price (and consequently the certified timber price). Higher prices decrease the consumed quantities and decrease consumer welfare. Only the consumers in North America are consuming more timber, but those consumers' welfare is damaged by the steep increase of the timber prices (and the reappearance of the price premium).

A second trend concerns the increased producer welfare in all regions, except North America. The protectionist measures drive up prices, which encourages production. This leads to an increased producer welfare. Only the producers in North America do not benefit from this situation. The explanation for this phenomenon is twofold. First, the North American producers experience a considerable drop in certified timber production. As a consequence, they miss out a considerable amount of price premium. Due to the importance of certified timber production in North America, this negatively impact the producer welfare. This drop is less big in Europe for example. Second, FLEGT exempts the North American conventional timber producers from Europe's timber market. In the baseline scenario, North America exported conventional timber towards Europe. This decreased export possibilities negatively impact the producer welfare in North America.

In General, a region's welfare decreases if the decreasing consumer welfare outweighs the increasing producer welfare. This is the case in all regions, except Europe and Africa. The increase in Africa is rather small and is explained by the increased certified timber production for export towards Latin America. The considerable welfare increase of the European producers (+1.42%) is a direct consequence of the protectionist situation created by FLEGT. The acquired monopolistic power at their domestic European allow them to maximise their welfare.

Table 1: Production of timber, production of certified timber, supply prices, and supply price premiums (baseline scenario and FLEGT scenario)

	Africa		Latin America		Asia		Europe		North America		World	
	Baseline	FLEGT	Baseline	FLEGT	Baseline	FLEGT	Baseline	FLEGT	Baseline	FLEGT	Baseline	FLEGT
Quantities:												
$Q_{s,i}$	.38	.38	1.95	1.96	3.34	3.35	4.61	4.65	4.58	4.59	14.87	14.92
$Q_{s,i}$ change (%)		+14		+14		+14		+83		+14		+35
$Q_{s,i}^{cer}$	.01	.01	.04	.05	.15	.18	2.15	2.07	3.89	2.27	6.23	4.57
$Q_{s,i}^{cer}$ change (%)		+18.16		+18.16		+17.64		-3.65		-41.70		-26.69
$Share_{s,i}^{cer}$ (%)	2.12	2.51	2.12	2.51	4.52	5.31	46.53	44.46	84.84	49.39	41.93631	30.63391
$Share_{s,i}^{cer}$ change (%)		+18.00		+18.00		+17.48		-4.45		-41.78		-26.95
Prices:												
$P_{s,i}$	1.05	1.06	1.05	1.06	1.05	1.06	1.05	1.06	1.05	1.06	1.05	1.06
$P_{s,i}$ change (%)		+17		+17		+17		+1.05		+17		+45
$P_{prem,s,EU}$ (%)	27.83	28.57	27.83	28.57	27.83	28.57	27.83	27.46	36.27	28.57	33.10	28.07
$P_{prem,s,EU}$ change (%)		+2.69		+2.69		+2.69		-1.32		-21.23		-37.83
$P_{s,i}^{cer}$	1.35	1.36	1.35	1.36	1.35	1.36	1.35	1.36	1.44	1.36	1.40	1.36
$P_{s,i}^{cer}$ change (%)		+76		+76		+76		+76		-5.49		-3.23

NOTE.-Prices are in 100 USD per m³. Quantities are standardised. Asia encompasses Oceania and Europe encompasses Russia. The world prices are calculated as the volume weighted average of each region's prices. The percentage changes represent the change of the variable's value in the FLEGT scenario compared to the baseline scenario. The displayed price premiums are the percentage increase on top of the conventional timber price.

Table 2: Consumption of timber, consumption of certified timber, demand prices, and demand price premiums (baseline scenario and FLEGT scenario)

	Africa		Latin America		Asia		Europe		North America		World	
	Baseline	FLEGT	Baseline	FLEGT	Baseline	FLEGT	Baseline	FLEGT	Baseline	FLEGT	Baseline	FLEGT
Quantities:												
$Q_{d,i}$	.28	.28	1.81	1.81	4.00	4.00	4.64	4.64	4.13	4.19	14.87	14.92
$Q_{d,i}$ change (%)		-.07		-.06		-.03		-.01		+1.34		+0.35
$Q_{d,i}^{cer}$	.00	.00	.06	.19	.14	.05	2.15	2.05	3.89	2.27	6.23	4.57
$Q_{d,i}^{cer}$ change (%)		-18.54		+215.14		-59.99		-4.24		-41.70		-26.69
Share $_{d,i}^{cer}$ (%)	.80	.65	3.36	10.58	3.43	1.37	46.26	44.30	94.09	54.13	41.94	30.63
Share $_{d,i}^{cer}$ change (%)		-18.48		+215.34		-59.98		-4.24		-42.47		-26.95
Prices:												
$P_{d,i}$	1.33	1.33	1.27	1.27	1.26	1.26	1.26	1.26	1.55	1.26	1.34	1.26
$P_{d,i}$ change (%)		+15		+14		+14		+14		-18.81		-5.94
Pprem $_{d,EU}$ (%)	23.60	24.24	30.50	24.40	20.81	24.00	23.35	23.98	0.00	23.98	8.80	24.00
Pprem $_{d,EU}$ change (%)		+2.71		-20.02		+15.35		+2.71		+∞		+172.76
$P_{d,i}^{cer}$	1.65	1.66	1.66	1.58	1.52	1.57	1.55	1.56	1.55	1.56	1.55	1.56
$P_{d,i}^{cer}$ change (%)		+.66		-4.54		+2.79		+.66		+.66		+.70

NOTE.-Prices are in 100 USD per m³. Quantities are standardised. Asia encompasses Oceania and Europe encompasses Russia. The world prices are calculated as the volume weighted average of each region's prices. The percentage changes represent the change of the variable's value in the FLEGT scenario compared to the baseline scenario. The displayed price premiums are the percentage increase on top of the conventional timber price.

Table 3: Percentage change of the total, consumer, and producer welfare per region

	Regional Welfare	Producer welfare	Consumer welfare
Africa	0.0062	0.3052	-0.1902
Latin America	-0.4228	0.3040	-0.7896
Asia	-0.1717	0.3305	-0.2604
Europe	0.0331	1.4171	-0.0531
North America	-0.5979	-7.2989	-0.1091
World	-0.2601	-1.8366	-0.1161

NOTE.- Asia encompasses Oceania and Europe encompasses Russia. The percentage changes represent the change of the variable's value in the FLEGT scenario compared to the baseline scenario and are displayed in 100%.

4. Discussion

I. Trade barrier

FLEGT creates a trade barrier for conventional timber to Europe. Two regions are directly impacted by this ban: North America and Latin America. Latin America managed to redirect its flow of certified timber from Europe to Asia. In fact, Latin America is exporting more conventional timber in the FLEGT scenario. Since the Latin American conventional timber producers receive a slightly higher price, this positively impacts their situation and welfare. All other regions' conventional international timber export collapsed. As a result, also the international trade of conventional timber decreased by 1.21%.

FLEGT does not stimulate trade of certified timber towards Europe. The transport costs and ad valorem tariff in addition to the price premium and conventional price complicate trade since the European producers are efficient certified timber producers. They fulfil the remaining demand for certified timber themselves. This finding is in line with the home-effect by Fajgelbaum et al. (2011) who explain why richer countries specialise in high-quality goods. The global trade of certified timber increased by 636.28% however. This is due to increased exports of certified timber from Africa and Asia towards Latin America. The actual volumes of produced and traded certified timber in these regions remain small however.

The approach in our research – which is based on the assumption of perfect competition – is valid: experts of the *International Tropical Timber Council* described that without ‘tangible benefits deriving from certification in terms of profitability or competitiveness, enterprises will have little incentive to improve forest management with higher costs. The problem is particularly serious in the case of tropical timber producing countries’ (Simula et al. 2004). As we observed, those tropical regions are still not able to compete at the certified timber market of Europe and North America. This kind of trade barrier endangers the future of certification. If ‘producers are forced to drop out from traditional markets, as has already happened in some cases, product prices are driven down’. In some regions, this can lead to a reduction in the value of the resource, encouraging its conversion into other uses.

II. Interpretation of the leverage effect of FLEGT

The SEM describes how both the consumption and production of certified timber decreased at global level. Hence, in this setting, FLEGT does not provide a leverage for certified and legal timber production or consumption. In addition, the certified share of timber consumption and production in the Southern hemisphere remains equal to or below 10%. The positive relationship between the WTP, the GDP, and the certified share in a region's consumption indicates that ‘Willingness to Pay’ is probably the wrong choice of words. It rather reflects the ‘Capacity to Pay’ for certified products.

The SEM's outcomes are also observed in reality (Table B1). This suggests that the cost of certification is higher than the price premium received by the producers in the Southern hemisphere. Government policies could aim to reduce the costs of certification to make certification more inclusive at global level. Potential points of attention are: the legislative framework in support of certification (Putz et al. 2000), the distance and convenience of timber transport (Gullison 2003), and the available financial means (ITTC 2004). Other

government policies could focus on group dynamics and cooperative initiatives in the forest industry. A higher level of vertical integration along the production chain, for example, reduces certification costs (Atyi and Simula 2002).

Cooperative initiatives among producers can also decrease the direct certification costs since the direct costs are not dependent on the size of a forest/company (Ebeling and Yasué 2009). Consequently, the costs are relatively low for large-scale producers and relatively high for small-scale producers (Gullison 2003). In addition, large-scale timber producers are also favoured over small-scale timber producers by the buyers of certified timber. Demand for certified timber is mainly driven by retail, which demands large volumes, consistent quality, and low prices. Large-scale timber producers are better able to meet these requirements (Molnar and Trends 2003, Rametsteiner and Simula 2003, Klooster 2005, Taylor 2005). But large-scale producers and operators tend to be located in the Northern hemisphere. Cooperative initiatives in the Southern hemisphere can tackle the issue of scale. But a phased approach is needed for this kind of policy (Simula et al. 2004). In a more comprehensive strategy, certification can play a complementary role in sustainable forest management.

5. Conclusion

At global level, FLEGT does not stimulate the consumption and production of certified timber. However, a leverage effect is observed in the production in the Southern hemisphere. The market shares of certified timber in these regions remain small however. These findings are in line with what is currently observed in reality, suggesting that more attention must be devoted to the costs of certification. This leverage effect is not realised in Europe and North America (the main producers of timber) In Europe, FLEGT allows producers to switch to conventional production and exploit a monopoly position on this market segment.

Due to the existence of transport costs, the European consumers are obliged to follow this trend to some extent. The transport costs in this logic further separate the European timber market. The same evolution is observed in all other regions, except Latin America. This is explained by the relative price evolution of certified timber. The intended leverage effect is not present at the demand side of the market.

The innovative features added to traditional Spatial Equilibrium Modelling also allow us to analyse the impact of the policy for each regions' quasi-welfare. At global level, the quasi-welfare decreased because FLEGT creates a protectionist situation in Europe. Protectionism by default lead to non-optimal welfare outcomes. The considerable weight of the consumer welfare in the quasi-welfare of Latin America, Asia, and North America decreases their regional quasi-welfare. These decreases occur at the expense of a welfare increase in Europe (the initiator of FLEGT) and Africa.

This model is a simplified representation of reality however. Therefore it cannot be used for exact forecasting of the leverage effect of FLEGT on each region's certified share of timber consumption and production. But the model's mechanisms reveal what the impact of FLEGT will be for a country with a country profile which is comparable to one of the 5 regions' profiles.

Appendix A: Determination of mean regional WTP and scale factor

The design of the modified SEM requires the specification of each region's WTP logistic distribution in terms of mean and scale factor. This paper opts for the logistic distribution instead of the normal distribution, because the logistic distribution can be integrated.

To our knowledge, no comparative research on the WTP for certified timber exists at global level. Therefore, Cai and Aguilar (2013) conducted a meta-analysis of the regional WTP assessments to gain a global picture of WTP. They conclude that the global mean WTP for certified timber products is 12.2 % and has a standard deviation of 8 %.

Each region's WTP distribution is determined based on the findings of Cai and Aguilar (2013). This is done by linking the WTP to the regional GDP per capita. This approach follows the argument that GDP per capita is as good a predictor of WTP for environmental services as income (Jacobsen and Hanley 2009). Linking the WTP to GDP occurs via the double logistic regression model developed by Jacobsen and Hanley (2009). One of their models describes the impact of GDP per capita as the sole explanatory variable on the WTP for ecosystem services. Moreover, they found a coefficient of 0.38 for the GDP per capita. This coefficient describes the percentage change in the WTP following a one percentage change in the GDP per capita.

Hence, the percentage deviation for each region's WTP from the global mean WTP of 12.2 % is determined from the regional percentage deviation of the GDP per capita to the global mean GDP per capita:

$$WTP_i = 0.122(1 + 0.38 * \Delta\%GDP_i) \quad (16)$$

Table displays the global mean GDP per capita (6913.83 USD/year) and each region's percentage deviation. The mean WTP of 12.2 % is linked to the mean global GDP per capita of 6913.83 USD/year. Equation (17) determines each region's percentage deviation for the WTP.

Subsequently, it is necessary to determine the scale factor for the WTP logistic distribution. Cai and Aguilar (2013) found a standard deviation of 8 %. Transforming a normal distribution into a logistic distribution requires the modification of the standard deviation into the logistic distribution's scale factor. In practice, this implies multiplication of the standard deviation with factor $\sqrt{3}/\pi$. Hence the scale factor for the global WTP's logistic distribution becomes 4.41 %. In order to determine the regional scale factors, this paper continues to apply the 8%/12.2% fraction for the regional WTP estimate. The results are presented in Table A1. This is an arbitrary approach, to some extent, but necessary due to the lack of better data.

Table A1: Calculation of the regional WTP and scale parameter estimates based on the regional GDP per capita.

Region	Annual GDP per capita (1000 USD)	Percentage deviation to global GDP per capita	WTP estimate (%)	Scale parameter (%)
Africa	1.56	-77.44	8.61	3.11
Latin America	9.25	33.85	13.77	4.98
Asia	2.78	-59.78	9.43	3.41

Europe	21.75	214.54	22.15	8.01
North America	26.76	287.07	25.51	9.22
World	6.91	-	12.20	-

SOURCE.-Cai and Aguilar (2013): Meta-analysis of consumer's willingness-to-pay premiums for certified timber products, and own calculation.

NOTE.-Asia encompasses Oceania and Europe encompasses Russia. If the percentage deviation to global GDP per capita is named u , the WTP estimate per region is found by $0.122*(1+0.38*u)$. If the percentage deviation to global GDP per capita is named μWTP_i , the scale parameter is found by $0.08/0.122* \mu WTP_i * \sqrt{3}/\pi$.

Appendix B: Determination of regional mean WTA and standard deviation

Producers of certified timber receive a price premium. This premium varies depending on the type of forest product and country of production. Previous research estimates price premiums ranging from 1 % to 30 % on top of the conventional timber price (Yamamoto et al. 2014). FSC (2012) reported price premiums ranging between 15 and 25 %. This research, at the first stage, assumes that certified producers around the world receive a price premium of 25 %.

The data by UNECE/FAO (2014) demonstrates that the leverage effect for certification of the 25 % price premium is not consistent across the 5 regions analysed (Table). Only a marginal fraction of the forest in the Southern hemisphere is certified. In contrast, certification is much more present in the Northern hemisphere. The regional differences are explained by the regional differences in WTA. The WTA expresses the price premiums producers require in order to produce certified timber. The higher the costs associated with certification, the higher the WTA.

It is assumed that for each region, the WTA is symmetrically distributed around an unknown mean. With a known $Pprem_{s,i}$ of 25 %, and known share of certified forests $Share_{s,i}$ it is then possible to determine the mean WTA per region ($\mu WTA_{s,i}$):

$$Share_{s,i} * \sigma WTA_{s,i} + 0.25 = \mu WTA_{s,i}$$

The standard deviation from the demand side of the market is also applied to the supply side of the market. However, the WTA distribution is transformed into a logistic distribution by computing new scale variables. This is again done by multiplying with $\sqrt{3}/\pi$ and simultaneously safeguarding the proportion 8%/12.2%.

Table B1: Calculation of the regional WTA and scale parameter estimates based upon the certified forest area

	Africa	Latin America	Asia	Europe	North America	World
Certified forest area (%)	1.0	1.8	2.2	65.2	35.4	10.9
WTA estimate (%)	44.64	41.80	41.08	21.88	27.96	25.0
Scale variable	9.86	9.44	9.28	4.94	6.32	8.00

SOURCE.-UNECE/FAO (2015): Forest Products Annual Market Review 2014 – 2015, and own calculation

NOTE.-Asia encompasses Oceania and Europe encompasses Russia. If the regional WTA estimate is named μWTA_s , the scale variable is found by $(0.08/0.122)* \mu WTA_s * \sqrt{3}/\pi$.

Appendix C: Mathematical construction of the objective function

A. Baseline scenario

The objective function in the modified SEM respects the logic of the standard SEM's objective function, as first developed by Takayama and Judge (1971). The standard SEM's objective function maximizes global quasi-welfare through the simultaneous solution of all regions' equilibria under the assumption of bilateral trade costs. This first requires the calculation of each region's quasi-welfare by integrating the regional demand (equation 1) and supply functions (equation 2) over the region's equilibrium price and quantity. Those integrals respectively represent the regional consumer and producer surplus. Equation (1) can be rewritten and subsequently integrated:

$$CS_i^{con} = \int_0^{Q_{d,i}^*} \left(\frac{Q_{d,i}^* P_{d,i}^0}{Q_{d,i}^0 e_{d,i}} - \frac{P_{d,i}^0}{e_{d,i}} + P_{d,i}^0 - P_{d,i}^* \right) dQ_{d,i}^* = Q_{d,i}^* \left(P_{d,i}^0 \left(1 - \frac{1}{e_{d,i}} \right) - P_{d,i}^* \right) + \frac{Q_{d,i}^{*2} P_{d,i}^0}{2 * e_{d,i} * Q_{d,i}^0}$$

Accordingly, equation (2) is rewritten and integrated:

$$PS_i^{con} = \int_0^{Q_{s,i}^*} \left(\frac{Q_{s,i}^* P_{s,i}^0}{Q_{s,i}^0 e_{s,i}} - \frac{P_{s,i}^0}{e_{s,i}} + P_{s,i}^0 - P_{s,i}^* \right) dQ_{s,i}^* = Q_{s,i}^* \left(P_{s,i}^0 \left(1 - \frac{1}{e_{s,i}} \right) - P_{s,i}^* \right) + \frac{Q_{s,i}^{*2} P_{s,i}^0}{2 * e_{s,i} * Q_{s,i}^0}$$

The standard SEM's objective function takes the difference of those two integrals to determine each region's quasi-welfare. However, these two integrals are calculated for the equilibrium quantity and equilibrium price. The equilibrium quantity incorporates the certified and conventional volumes of timber. Hence, the potential price premium and the accompanying certified share of a region's timber consumption and production is not taken into account. Therefore, the modified SEM introduces 2 additional quasi-welfare components to a region's quasi-welfare calculation. The two components consist of the integral of equation (5) and equation (6) if governments were to behave like all other consumers. Those equations constitute the logistic distribution function for the WTP and WTA per region. The logistic distribution function is preferred over the standard distribution function, because the logistic distribution function can be integrated. In the baseline scenario, however, the governments do not act like the other consumers and solely purchase conventional timber. The maximum certified share of a region's total timber demand in this case equals 100% minus the government's share in final consumption. This is described in equation (15). The integral of this equation is:

$$\begin{aligned} & \int_0^{P_{prem_{d,i}}} Share_{d,i}^{cer} dP_{prem_{d,i}} \\ & = (1 - G_i) * P_{prem_{d,i}} - (1 - G_i) * (\sigma_{WTP,i} \\ & * \ln(e^{\mu_{WTP,i}/\sigma_{WTP,i}} + e^{P_{prem_{d,i}}/\sigma_{WTP,i}}) - \mu_{WTP,i}) \end{aligned}$$

However, this integral does not represent the additional consumer surplus relating to the introduction of a price premium $P_{prem_{d,i}}$ in the modified SEM. This integral equals the surface at the left hand side of the equilibrium price premium, underneath the logistic distribution function. The consumer surplus represents what the current consumers of certified timber are willing to pay on top of the equilibrium price premium. This is the integral of the

cumulative distribution function at the right hand side of the price premium. This integral is found by taking the difference of the integral over a maximum value for the price premium and the integral over the equilibrium price premium (as calculated above). The maximum value is arbitrarily set at 1, a value which is not attained in the SEM. Consequently, a consumer is not willing to pay twice the conventional timber price in order to acquire certified timber. The additional consumer surplus relating to the purchases of certified timber is then:

$$CS_i^{cer} = \int_0^1 Share_{d,i}^{cer} dP_{prem_{d,i}} - \int_0^{P_{prem_{d,i}}} Share_{d,i}^{cer} dP_{prem_{d,i}}$$

Calculation of the integrals leads to:

$$CS_i^{cer} = 1 - G_i - (1 - G_i) * \sigma_{WTP,i} * \ln(e^{\mu_{WTP,i}/\sigma_{WTP,i}} + e^{1/\sigma_{WTP,i}}) - (1 - G_i) * P_{prem_{d,i}} + (1 - G_i) * \sigma_{WTP,i} * \ln(e^{\mu_{WTP,i}/\sigma_{WTP,i}} + e^{P_{prem_{d,i}}/\sigma_{WTP,i}})$$

For the actual quasi-welfare calculation, $CS_{cer,i}$ is multiplied with the equilibrium conventional timber price and equilibrium consumed quantity on the demand side of the market.

Simultaneously, the additional producer surplus relating to the production of certified timber is calculated from the logistic distribution function of the WTA (equation 16). This producer surplus equals the surface at the left hand side of the price premium underneath the logistic distribution function of the WTA in Figure 1. This is simply the integral of this function over the equilibrium price and quantity:

$$PS_i^{cer} = \int_0^{P_{prem_{s,i}}} Share_{d,i}^{cer} dShare_{d,i}^{cer}$$

This equals:

$$PS_{cer,i} = \sigma_{WTA,i} * \ln(e^{\mu_{WTA,i}/\sigma_{WTA,i}} + e^{P_{prem_{s,i}}/\sigma_{WTA,i}}) - \mu_{WTA,i}$$

Also, this producer surplus is multiplied with the equilibrium conventional timber price and equilibrium consumed quantity on the supply side of the market.

Finally, the modified SEM's objective function takes all transport costs into account for each bilateral trade flow between the 5 regions. Bilateral transport costs are the per unit transport costs between the two regions ($TC_{i,j}$) multiplied with the traded quantities of timber ($TQ_{i,j}^{cer}$ and $TQ_{i,j}^{con}$):

$$\sum_i \sum_j (TQ_{i,j}^{cer} + TQ_{i,j}^{con}) * TC_{i,j}$$

The combination of the standard SEM's objective function and the additional elements added due to the modifications then results in the following objective function:

$$\begin{aligned}
Max\ GW = & \sum_i CS_i^{con} + \sum_i (P_{d,i}^* * Q_{d,i}^* * CS_i^{cer}) + \sum_i PS_i^{con} + \sum_i (P_{s,i}^* * Q_{s,i}^* * PS_i^{cer}) - \\
& \sum_i \sum_j ((TQ_{i,j}^{cer} + TQ_{i,j}^{con}) * TC_{i,j})
\end{aligned} \tag{A1}$$

This objective function maximizes the global quasi-welfare GW .

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