Methodology for the calculation of the Dutch Emission Trade Balance

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1. Introduction

There are different ways in which countries can be held accountable for their contribution to the greenhouse gas effect. The *production approach* considers greenhouse gas (GHG) emissions caused during the economic activities of a country's residents. However, the production approach does not take into account GHG emissions that occur abroad, during the production of products that are consumed in the home country, the so called embodied or indirect emissions. The approach in which GHG emissions are related to the consumption requirements of countries is referred to as the *consumption approach* or carbon footprint. Indirect emissions can be calculated with a technique called environmentally extended input-output analysis.

There already exists a vast and quickly expanding literature on the subject (see Wiedmann 2009 for an overview; Wilting 2009).

In this background paper we present the input output (IO) model used by Statistics Netherlands in its calculation of carbon footprints and emissions trade balances. We will discuss in detail several aspects: the theoretical model used; the various datasources and assumptions made; conceptual issues such as treatment of non-competitive imports; trade and transport margins and re-exports. We conclude by giving a brief assessment of strengths and weaknesses of our approach compared to other approaches.

2. Model

2.1 Two-country pollution model

Our model is essentially what Andrew *et al* 2009 call a unidirectional trade model[1] that generalizes the 2-country model into a larger number of regions (de Haan 2004; Druckman and Jackson 2009). Following de Haan, the pollution model for the situation of two countries can be presented as follows:

$$\begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \begin{pmatrix} A_1 & M_2 \\ M_1 & A_2 \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} + \begin{pmatrix} y_1 \\ y_2 \end{pmatrix}$$

where x_1 describes output of country 1; A_1 the technical coefficients matrix of country 1; M_1 the import use matrix of country 1; y_1 final demand of country 1. Rewriting and premultiplying with the vector of emission intensities yields:

$$\begin{pmatrix} v^x{}_1 \\ v^x{}_2 \end{pmatrix} = \begin{pmatrix} e_1 & e_2 \end{pmatrix} \begin{pmatrix} L_{11} & L_{12} \\ L_{21} & L_{22} \end{pmatrix} \begin{pmatrix} y_1 \\ y_2 \end{pmatrix}$$

where

$$L_{11} = (I - (I - A_1)^{-1} M_2 (I - A_2)^{-1} M_1)^{-1} (I - A_1)^{-1}$$

$$L_{12} = (I - (I - A_1)^{-1} M_2 (I - A_2)^{-1} M_1)^{-1} (I - A_1)^{-1} M_2 (I - A_2)^{-1}$$

$$L_{21} = (I - (I - A_2)^{-1} M_1 (I - A_1)^{-1} M_2)^{-1} (I - A_2)^{-1} M_1 (I - A_1)^{-1}$$

$$L_{22} = (I - (I - A_2)^{-1} M_1 (I - A_1)^{-1} M_2)^{-1} (I - A_2)^{-1}$$

with I the identity matrix and $v^x{}_1$ the production emissions of country 1. In order to arrive at the consumption emissions $v^c{}_1$ we disaggregate final demand of country 1 into consumption and exports as $y_1 = d_1 + f_1$. If we substitute these expressions and we collect terms we arrive at:

[1] This is called a quasi MRIO by Druckman and Jackson and a partial multi-region input-output model by Wilting.

$$v^c{}_1 = (e_1{}' L_{11} + e_2{}' L_{21}) d_1 + (e_1{}' L_{12} + e_2{}' L_{22}) f_2$$

If we now make the assumption that $M_2 = 0$ (the "small country assumption") that is that Dutch exports are small compared to total output of the rest of the world, our expressions simplify significantly and we obtain:

$$v^c{}_1 = \underbrace{e_1 (I - A_1)^{-1} d_1}_{FD\_D} + \underbrace{e_2 (I - A_2)^{-1} M_1 (I - A_1)^{-1} d_1}_{FD\_Iic} + \underbrace{e_2 (I - A_2)^{-1} f_2}_{FD\_If} \qquad [1]$$

The first term FD_D presents the indirect domestic emissions behind final consumption, the second term FD_Iic presents indirect foreign emissions in order to satisfy intermediate demand for goods destined for final consumption and the third term FD_If gives indirect foreign emissions in order to produce goods and services that go directly to final consumption.

2.2 Generalization to multi-regions

If we now generalize the model defined above towards the multi region situation, the indirect emissions behind the i-th final demand category (households, government, inventories, investments, exports) can be expressed as follows:

$$v_1^{i,g} = e^{1,g}{}_k (I - A_D)^{-1} y^i{}_k + \sum_{z=2}^{18} e^{1,g}{}_k (I - A_Z)^{-1} M^z (I - A_D)^{-1} y^i{}_k + \sum_{z=2}^{18} e^g{}_{kz} (I - A^d)^{-1} i^{i,z}{}_k \qquad [2]$$

where[2]

$e^{1,q}{}_k$ the vector of emission coefficients by country *z* by industry *k* for greenhouse gas *g* (we distinguish CO_2, N_2O, CH_4 and total GHGs);

A_Z the technical coefficients matrix for region z; $(I - A_Z)^{-1}$ is the Leontief inverse;

M_z the import use matrix for imports from region z to region 1;

$y^i{}_k$ final demand by i-th category by industry; NB: in the 2-country model above d_1 excludes exports.

$i^{i,z}{}_k$ final demand by i-th category by industry for all regions;

We impose that $A_Z = A_D + M_T$ where M_T is the total import use matrix. This implies that there is trade between regions, but that this trade is estimated by the domestic technology assumption. By contrast, Druckman and Jackson (2009) appear to assume that $A_Z = A_D$, which would underestimate the indirect emissions that occur abroad as it "cuts" the production chain after the second step.[3] Arguably, for a country like the Netherlands which is a large importer (although we exclue re-exports), this assumption may lead to an overestimate of indirect emissions compared to MRIO estimates that explictly take interregional trade into account.

The main reason, however to estimate trade by the domestic technology assumption is, that in the limit our model reduces to a single region IO model. This is a property that we exploit when doing cross-sectional analysis to isloate drivers of emissions trade balance.

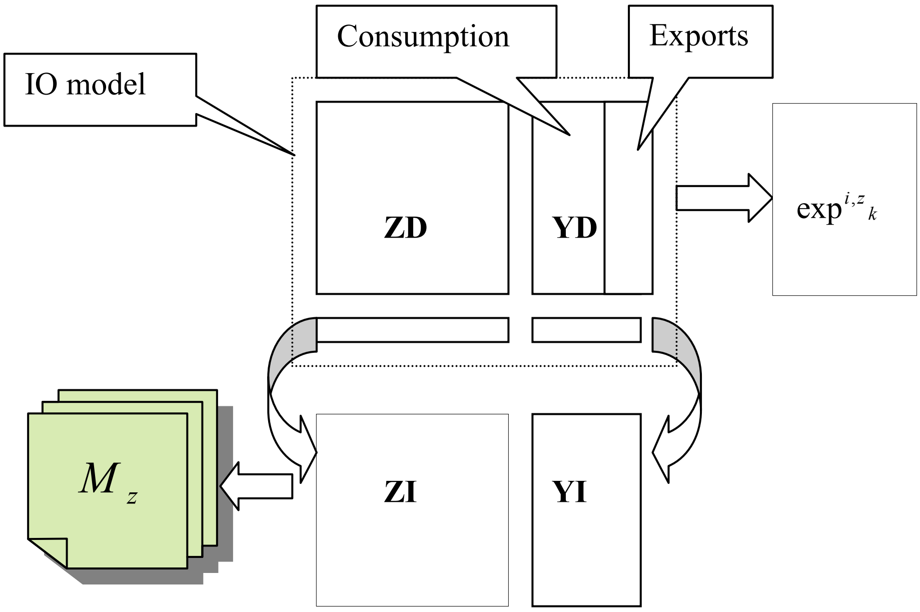
3 Methodology and data sources

We will now discuss the the data sources as well as methods used in applying our IO model. Figure 1 shows a schematic of an IO table in which we distinguish between the intermediate demand block ZD; the final demand block YD and a row of imports.

[2] The convention is that capital letters indicate matrixes, and lower case letters indicate vectors. Vector subscripts are made explicit to indicate that we use an industry breakdown. Matrix subscripts are suppressed. Superscripts note regions as well as additional degrees of freedom such as choice of green house gas.

[3] According to Druckman and Jackson, their estimates are slighly lower than estimates from MRIO studies.

Figure 1: Disaggregation of IO table into import and export regions



3.1 Disaggregating imports of the IO table into regions

The main objectives of the chosen methodology are to ensure consistency with National accounts data and principles as well as with data from the environmental accounts. As is well-known there are several differences conceptual between international trade statistics which in principle follow the cross-border principle and the National accounts that are based on the residence principle. These differences are for instance due to merchanting, and goods sent abroad for processing. As a result different values for imports and exports and reported in trade statistics and in the Natinonal Accounts.

The following steps can are taken:

- First an IO tabel is compiled of the industry by industry type (60*60) in current prices. To be precise, we distinguish in our IO table 58 industries as well as households in their productive capacity and a pseudo industry "margins" (see next section). Although a higher level of disaggregation of the IO table exists (maximum 118*118 industries), we have chosen to bring the IO table to the level of detail available in our air emission accounts.
- The matrices *M* with import coefficients per region are constructed in such a way as to assure consistency with national accounts data. We use international trade statistics not for its levels, but only for calculating fractions of imports and exports for each imported product.
    - First, using international trade statistics on goods we calculate proportions for the 17 regions[4] that we distinguish in our model for each imported good.
    - A similar procedure is followed for trade in services statistics (IMTS).
    - Integration of both data sets is done in order to avoid double counting. For instance both computer services as well as computers are imported.
    - The number of different products that we use is dictated by the level of disaggregation that is available in the database from which the IO table is derived. We distinguish around 228 separate product groups.

[4] These regions are: Germany; Belgium; USA; UK; China; France; Russian Federation; Italy; Spain; Japan; Sweden; Eastern Europe; other Western; Africa; South and Middle America; other Asian; Middle East. See Annex II for an allocation of countries / areas to our chosen regional disaggregation.

- In a subsequent step, these fractions are multiplied with the national accounts import data per product. As a result we have import by industry (use) of each product disaggregated by region.
- In a final step, these import data on goods and services are allocated to supplying industries for each region individually. This is done by assuming that all trade partners have an identical production structure as the Netherlands. For instance, if a certain product X is produced by two different industries in proportion A/B than also the imported product X is assumed to be produced by the same ratio of industries.[5] However when also imports are used in the production of product X, these are not taken into account to avoid arriving in a regression. As a result the row of imports in our IO table is transformed in a square matrix ZI which is decomposed into the 17 different regions that we distinguish.
- The YI matrix which is subsequently decomposed in the $i^{i,z}$ matrices is obtained in a similar way.

3.2 Disaggregating exports of the IO table into regions

Likewise, also the exports are disaggregated into the 17 regions by industry using similar procedures as for imports i.e. based upon international trade in goods and services data. However, in case of exports we know exactly which industries produce what export products. The result is a matrix of 17 countries by 60 industries that decomposes the final demand vector of exports from the original IO table.

3.3 Emission coefficients

Emission coefficients have been estimated for the year 2006 as well as 1996 for 17 regions, for the 60 industries that we distinguish in our air emission accounts, separately for CO_2, N_2O, CH_4 and total GHGs. The emisison coefficients are defined as the total emissions divided by gross output in basic prices. As our IO table is in current prices, also the intensities are expressed in current prices.

- Regarding the emissions data, for most EU countries data from the air emisisons accounts from Eurostat have been used. For the non-European countries the most important data sources are: IEA database; UNFCCC database; and data obtained from Wilting[6]. For some countries additional sources have been used such as data available on National Statistical Institutes' (NSI) websites. Sources used for the estimation of gross output are: UN data; and other sources (NSIs). Finally, when emissions and output data were available for different years, output data has been extrapolated based on inflation estimates.
- The emission intensities have been estimated for 1996 and for 2006. They have been extrapolated to more recent years (e.g. 2009) by assuming that the development in intensities for foreign industries can be estimated by the changes that occurred for domestic industries.

4 Conceptual issues

In this section we will briefly discuss several conceptual issues that are important when compiling footpirnts. These are the treatment of non-competing imports; treatment of transport margins and re-exports and the choice to present gross or net emission trade balances.

4.1 Treatment of non-competing imports

In the Dutch IO table, one of the largest non-competing imports consists of imports of goods and services purchased by households abroad. This is due to the fact that the residenc principle is strictly adhered to. However there are no direct data sources that would allow a breakdown of these expenditures of Dutch tourists abroad across industries as in general inboudn tourism is better measured than outbound tourism. We assume: the following

[5] In an earlier version, each product was assigned to one single industry.
[6] Personal correspondence.

- Expenditures by Dutch residents abroad follow the same breakdown as the expenditures of foreign tourists in the Netherlands.
- Secondly, total expenditures are distributed over regions based on tourism statistics, sepcfically, based upon the number of days spent on average in a particular country.

Other non-competing imports are assigned to one single producing industry. For instance tobacco is assigned to agriculture.

4.2 Treatment of transport margins

Before the revision of 1987 transport and trade margins (in non self produced goods) were recorded in the IO table in a functional way. All trade activities regardless of the activity that produced them were allocated to the industry "trade". This would not cause any difficulties in performing environmentally extended IO analysis and emissions would be correctly attributed to final demand categories as long as all emissions inherent in trade and transport activities would be attributed to the trade industry.

Since the 1987 revision, the trade and transport margins are separately recorded in an additional row and column in the IO table. The reason is that starting with this this revision, all industries are functionally recorded, i.e. including their secondary activities. As a result, trade and transport margins that are produced as a secondary activity by a non trade industry are registered as a transaction from this non-trade industry to a final demand category "margins". The total of the final demand column is distributed via an extra row outside the intermediate demand block "margins"across intermediate and final demand categories. This is done on the basis of the intermediate use (final consumption) by these industries (final demand catgeories) of products on which these margins lie.

During the revision it was attempted to incorporate these margins by including them in the regular rows and columns. However due to data limitations this proved to be infeasible. The reason being, that we do not have accurate information regarding the destination of industry specific margins i.e. in which industries they should be booked as intermediate consumption.

Performing IO analysis therefore becomes more difficult as the standard intermediate block excludes transport activities. The solution that we found is the following:

- When constructig our IO table this final demand column margins as well as our fictional industry "margins"are pulled inside the intermediate demand block which therefore increase in size.
- The emission intensity of this fictional industry is set equal to 0. As final demand categories such as final consumption by household also consume margins (based on their consumption of goods and services), part of the indirect emissions attributed to households are from this fictional industry margins. This is due to the fact that the pseudo industry margins, although having a zero emission intensity itself, "receives" emissions due to its intermediate consumption of products from other industries that do have a non-zero emisison intensity.

4.3 Treatment of re-exports: gross and net approaches

A third important issue when doing consumption based accounting is how one should define consumption. As we saw in our discussion of the 2-country pollution model, consumption is normally defined as the sum of all final demand categories excluding of exports (NB: including investments and changes in inventories). This appears to be the standard approach taken in the literature. There are however two cases that we need to distinguish:

- Imports that go directly to export. There is agreement that imports that are allocated directly to exports (the so-called re-exports) should be excluded. Especially for a small open economy as the Netherlands this makes a huge impact as around 50 percent of our trade consists of re-exports.[7]

[7] It is important to realize that re-exports (in Dutch wederuitvoer) is booked differently in international trade statistics than in National Accounts. In trade statistics one single value is reported, in national accounts re-exports in imports are lower than the value of re-exports in exports due to trade and transport margins.

- Import products first consumed by industries and subsequently going to final demand category export. As formula 2 shows, these emissions are represented by one of the columns of FD_Iic.[8] We will call these emissions “indirect intermediate to export” emissions or IIE.

Should IIE be included in an emission trade balance? And if they are included, should they be included both at the import side as well as at the export side? Depending on the answers to the above questions, we differentiate between various approaches to attributing responsibility for emissions:

- Net approach: IIE emissions are excluded both on import and on export side;
- Gross approach: IIE emissions included in imports and exports; possibly also emissions included in re-exports;
- Mixed approach: IIE emissions included in imports, but not in exports.

The emission trade balance is usually defined as the difference between export emissions minus import emissions

$$ETB = E - I \qquad [3]$$

A positive balance implies that we emit more in order to produce our exports than other countries emit in order to satisfy Dutch consumption. Now it can be easily seen that the net approach and the gross approach result in the same ETB as in the gross approach the same additional amount is added to both import as well as the export side. The mixed approach however results in higher import emissions and a more negative trade balance.

Each of these approaches has its own appeal. The mixed approach counts all import emissions regardless of whether they are destined eventually for consumption or exports. In line with the literature, and also in line with the results of MRIO models, we favor the net approach. The net approach is easier to interpret than the gross approach as the export emissions exclusively take place on Dutch territory and not as in the gross approach also partly abroad.[9]

5. Discussion

It is feasible to compile an annual emission trade balance statistics that satisfies criteria of consistency with National Accounts data and principles, environmental accounts data and whose results are timely and reliable. However, as we have described in this paper, inherent in performing environmentally extended IO analysis are several assumptions regadring choice of model and methodology. In addition there are significant data limitations that may have a strong impact on the results especially concerning the measurement of emission intensities for foreign economies.

It is therefore important to provide an assessment of strengths and weaknesses of our method compared to other approaches:

- The model used is clearly inferior compared to comprehensive Multi Regional Input Output models that are better able to capture interregional trade. We have to introduce assumptions that may bias the results such as the domestic technology assumption. As a result indirect import emissions are less robust and dependent on these model assumptions.
- The strength of our methodology is that is fully consistent with national accounts concepts such as residence and national accounts data; this requires additional data sources such as tourism statistics that are normally not used in other approaches. Also the integration of trade in goods and services statistics provides value added.
- Estimation of indirect export emissions is highly accurate due to exact match between level of detail of the IO table and air emission accounts. Other approaches sometimes resort to the use of emission

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[8] These can be expressed formally as $\sum_{z=2}^{18} e^{g}{}_{kz}(I - A_Z)^{-1} M_z (I - A_D)^{-1} Y_{5k}$

[9] CBS 2009 was based on the gross approach. CBS 2008 showed results for both gross and net approach. In ealrier publications the gross approach included not only IIEs but also emissions embodied in re-exports.

inventory data that are however not based upon the residence concept and therefore deviate (Especially for a small open economy as the Netherlands) from emisisons data in the environmental accounts.

- The level of disaggregation of products when trade linking is relatively low due to our choice to use IO tables rather than supply use tables. This reduces the possibilities to identify non-competitive imports.
- Timeliness is a key strength: our methodology uses data sources that are all available in year t+1 which allows us to compile estimates on a yearly basis for the previous year.
- Time series available. Due to the enormous data requirements, existing MRIO studies often estimate data with a large time lag of several years. Also they sometimes resort to using unintegrated data sources such as emisison inventories and economic statistics, or combine data sources from different years, which make them less suitable for use as an indicator for changes over time for instance in the context of measuring sustainable development. In addition to getting accurate absolute levels about consumption based emissions, it is equally important to account for changes over time in a consistent way.

6. Dissemination and future work

Future improvements are expected to come from use of MRIO models that are currently under development in various consortiums such EXIOPOl and WIOD and that are expected to become open source. Constructing a complete in house MRIO model is arguably outside the scope of a NSI due to the fact that MRIO models are highly data intensive and require use of data sources that are normally considered to lie outside of the scope of a national statistical office. Examples are country specific IO tables that often need to be adjusted in order to obtain consistent classifications.

Results of emisison trade balanced will be included in our annual publication. They will also be included in the sustainability monitor. Results fro year t-1 are always spreliminary and will be updated regulary when more information is available (e.g. the IO table for 2009 will be updated during the regular national accounts work process; emission intensities may be updated as well).

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Annex 1 Single region IO model in the limit

We can quickly see that the used model reduces to a single region model (what Andrew *et al* call a domestic technology assumption) by assuming that $e_2 = e_1$. Applying this to formula 1 we obtain:

$$v^c{}_1 = e_1\left[(I - A_1)^{-1} d_1 + (I - A_2)^{-1} M_1 (I - A_1)^{-1} d_1 + (I - A_2)^{-1} f_2\right]$$

If we now substitute the following identity:

$I = (I - A_2)(I - A_2)^{-1}$ we derive:

$$v^c{}_1 = e_1 (I - A_2)^{-1}\left[(I - A_2)(I - A_1)^{-1} d_1 + M_1 (I - A_1)^{-1}\right] d_1 + (I - A_2)^{-1} f_2$$

If we now make the additional assumption that $A_2 = A_1 + M_1$ the term between brackets reduces to the identity matrix and we therefore obtain (see also de Haan 2004):

$$v^c{}_1 = e_1 (I - A_1 - M_1)^{-1} (d_1 + f_2)$$

which we will denote as e1*LDI*Yih (or FD_DI) where LDI is the Leontief inverse including imports.

The indirect emissions behind consumption that occur abroad can therefore be obtained by taking the difference between FD_DI and FD_D (the difference between the large system including imports and the domestic system). The difference can also be understood in terms of production chain length. Whereas FD_D estimated domestic indirect emissions and essentially cuts the chain at the border, FD_DI includes emissions that accrue over the whole chain including the part that lies abroad.

We therefore see that in the limit, our model reduces to a single region model.

Annex II: Countries / areas allocated to regions used in the emission trade balance

1 Germany		
2 Belgium		
3 United States of America		
4 United Kingdom		
5 China		
6 France		
7 Russian Federation		
8 Italy		
9 Spain		
10 Japan		
11 Sweden		
12 Eastern Europe		Albania; Armenia; Azerbaijan; Belarus; Bulgaria; Czech Republic; Estonia; Georgia; Hungary; Kazakhstan; Kirgizie; Latvia; Lithuania; Poland; Republic of Moldova; Romania; Slovakia; Slovenia; Tajikistan; Turkmenistan; Ukraine; Uzbekistan.
13 Other Western	EU	Andorra; Bosnia and Herzegovina; Ceuta; Denmark; Faeroe Islands; Finland; Gibraltar; Greece; Greenland; Ireland; Iceland; Croatia; Liechtenstein; Luxembourg; Malta; Melilla; Austria; Portugal; San Marino; Serbia; The former Yugoslav Republic of Macedonia; Switzerland; Holy See
	Asia	Republic of Korea; Singapore; Taiwan;
	Oceania	Australia; New Zealand; Norfolk Island; Fiji; New Caledonia; Papua New Guinea; Solomon Islands; Vanuatu; Micronesia; Guam; Kiribati; Marshall Islands; Micronesia (Federated States of); Northern Mariana Islands; Palau; Polynesia; American Samoa; Cook Islands; French Polynesia; Niue; Pitcairn; Samoa; Tokelau; Tonga; Tuvalu; Wallis and Futuna Islands
	Americas	Canada; Greenland
14 Africa	Eastern Africa	Burundi; Comoros; Djibouti; Eritrea; Ethiopia; Kenya; Madagascar; Malawi; Mauritius; Mayotte; Mozambique; Réunion; Rwanda; Seychelles; Somalia; Uganda; United Republic of Tanzania; Zambia; Zimbabwe
	Middle Africa	Angola; Cameroon; Central African Republic; Chad; Congo; Democratic Republic of the Congo; Equatorial Guinea; Gabon; Sao Tome and Principe.
	Northern Africa	Algeria; Egypt; Libyan Arab Jamahiriya; Morocco; Sudan; Tunisia; Western Sahara.
	Southern Africa	Botswana; Lesotho; Namibia; South Africa; Swaziland.
	West Africa	Benin; Burkina Faso; Cape Verde; Cote d'Ivoire; Gambia; Ghana; Guinea; Guinea-Bissau; Liberia; Mali; Mauritania; Niger; Nigeria; Saint Helena; Senegal; Sierra Leone; Togo.
15 Middle and South America	Caribbean	Anguilla; Antigua and Barbuda; Aruba; Bahamas; Barbados; British Virgin Islands; Cayman Islands; Cuba; Dominica; Dominican Republic; Grenada; Guadeloupe; Haiti; Jamaica; Martinique; Montserrat; Netherlands Antilles; Puerto Rico; Saint-Barthélemy; Saint Kitts and Nevis; Saint Lucia; Saint Martin (French part); Saint Vincent and the Grenadines; Trinidad and Tobago; Turks and Caicos Islands; United States Virgin Islands.
	Central America	Belize; Costa Rica; El Salvador; Guatemala; Honduras; Mexico; Nicaragua; Panama
	South America	Argentina; Bolivia (Plurinational State of); Brazil; Chile; Colombia; Ecuador; Falkland Islands (Malvinas); French Guiana; Guyana; Paraguay; Peru; Suriname; Uruguay; Venezuela.
	Other	Bermuda
16 Other Asian		Afghanistan; Bangladesh; Bhutan; Brunei Darussalam; Cambodia; Democratic People's Republic of Korea; India; Indonesia; Lao People's Democratic Republic; China, Macao Special Administrative Region; Maldives; Malaysia; Mongolia; Myanmar; Nepal; Pakistan; Philippines; Sri Lanka; Thailand; Vietnam; Timor Leste.
17 Middle East		Bahrain ; Occupied Palestinian Territory ; Cyprus ; Iraq ; Iran ; Israel; Yemen; Jordan; Kuwait ; Lebanon; Oman; Qatar; Saudi Arabia ; Syrian Arab Republic; Turkey; United Arab Emirates.