Anthropogenic N_2O emissions reconstruction

This report is based on CEDS inventory, realised in 2019 by Hoesly and McDuffie. It will explain the different ways we used to reconstruct netCDF fles of N_2O emissions.

1 Working files

1.1 CSV file

It is a single file with emissions from 1970 to 2019, sorted by year, country and subsector.

There are 220 different countries and 60 subcategories. We can gather countries into 20 regions and subcategories into 8 categories.

1.2 NetCDF file

The .nc file provides the spatial distribution of N_2O emissions for years from 2000 to 2019. There are monthly data and sorted by categories (8 in number).

2 Reconstruction: 1970 - 2019

By using a .nc file with regional masks, we can reconstruct emissions year after year. To do so, a simple idea is to use the 2000's pattern (with .nc file) and multiply emissions of a region by a ratio, computed as the emissions of the year we want to calculated, the region and the sector divided by the emissions of 2000 of the region and the sector.

A mathematical formula is:

$$em_{s,r}^{Y} = em_{s,r}^{2000} * \frac{\mathbf{em}_{s,r}^{Y}}{\mathbf{em}_{s,r}^{2000}},$$

where:

- $em_{s,r}^{2000}$ comes from nc file and represents pattern of 2000's emissions;
- $em_{s,r}^{Y}$ will be in a nc file and represents pattern of emissions for year Y;
- $\mathbf{em}_{s,r}^{Y}$ and $\mathbf{em}_{s,r}^{2000}$ are regional and sectoral emissions from csv file.

The regional emissions are the sum of sectors, meaning that:

$$em_{r}^{Y} = \sum_{s} em_{r,s}^{Y} = \sum_{s} em_{s,r}^{2000} * \frac{\mathbf{em}_{s,r}^{Y}}{\mathbf{em}_{s,r}^{2000}}. \quad (1)$$

The total emissions are represented on figure 1 and emissions per sector are in figure 2.

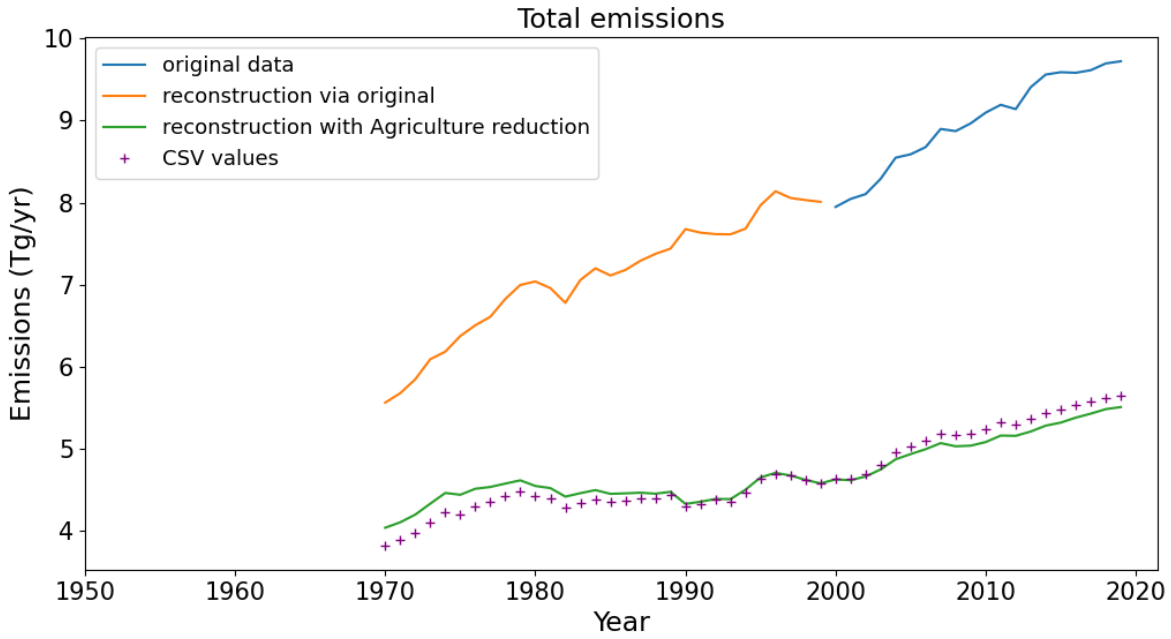

Figure 1: Total emissions from .nc files, reconstructions and csv file. Reconstructions are made from 2000's emissions.

Remark: It is to be noticed that, in fact $em_{s,r}^{2000}$ are not those which are in the initial .nc file, due to the soil emissions part which are taken into account in the orchidee model. This means that we have already multiplied the agricultural sector by the factor representing the soil emissions subsector in the agricultural sector:

$$em_{s=0,r}^{2000} = em_{s=0,r}^{2000} * 0.401034.$$

This number is global and independant on a specific region, it might explain the difference we see for the agricultural sector (figure 2).

Moreover, the difference we constat for the sector "International Shipping/Aviation" is due to the fact that, in .nc file, the aviation is not included in this sector (neither elsewhere).

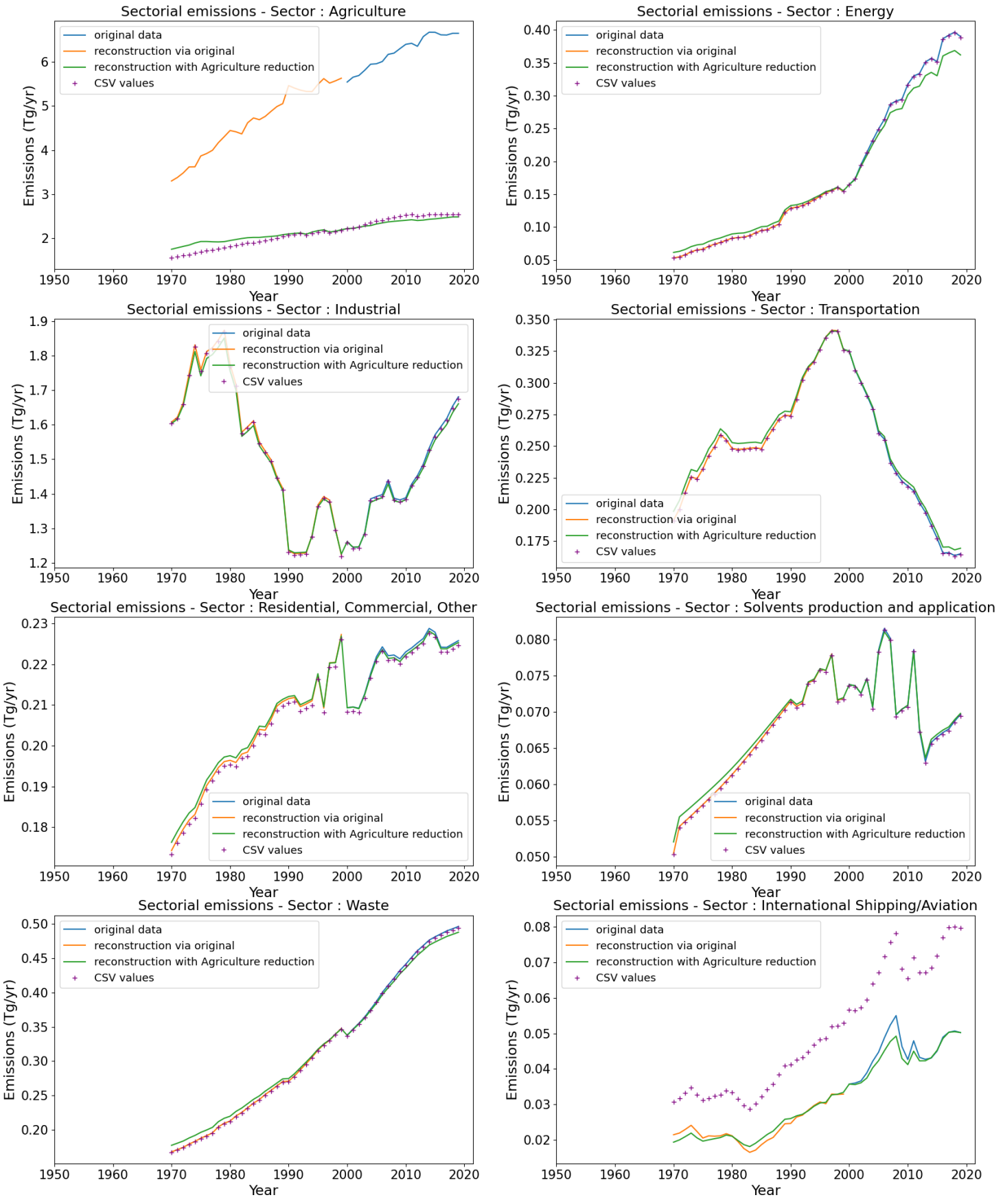

Figure 2: Emissions per sector from .nc files, reconstructions and csv file. Reconstructions are made from 2000's emissions.

3 Reconstruction: 1850 - 1970

Here, we only can reconstruct at a regional scale, ie, each sector will evolve in the same way. As for the previous reconstruction, we use pattern of 2000's emissions and we apply a factor corresponding to the evolution of the region between the year we want to calculate and the 2000. The corresponding mathematical formula is:

$$em_r^Y = em_r^{2000} * \frac{\mathbf{em}_r^Y}{\mathbf{em}_r^{2000}}. \tag{2}$$

Compared to previously, the factor used here is independant of the sector (because we don't know the evolution by sector for this period).

Emissions will only be equivalent if the evolution of emissions per sector is almost equivalent to the evolution of total emissions (not the case, see calculs and figures later).

Results for this reconstruction are in figures 3 and 4. The preindustrial reconstruction is in red on each graph. Total emissions evolution is almost identical but a huge difference exits if we look on sectorial emissions evolution.

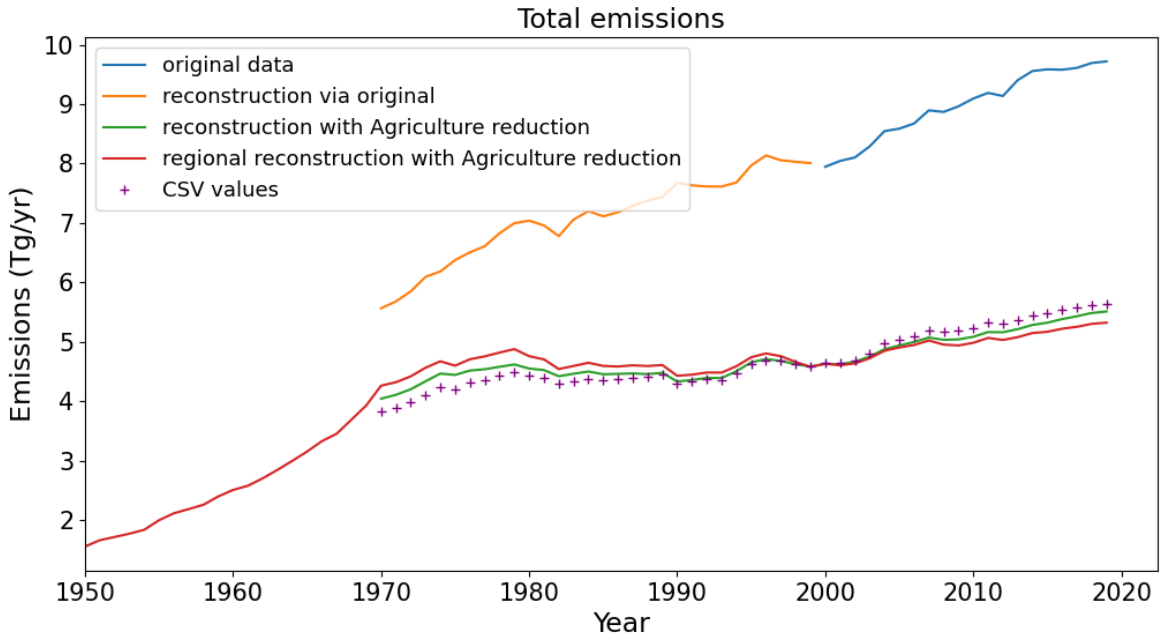

Figure 3: Total emissions from .nc files, reconstructions and csv file. The added line is the red one, which provides emissions from the regional reconstruction.

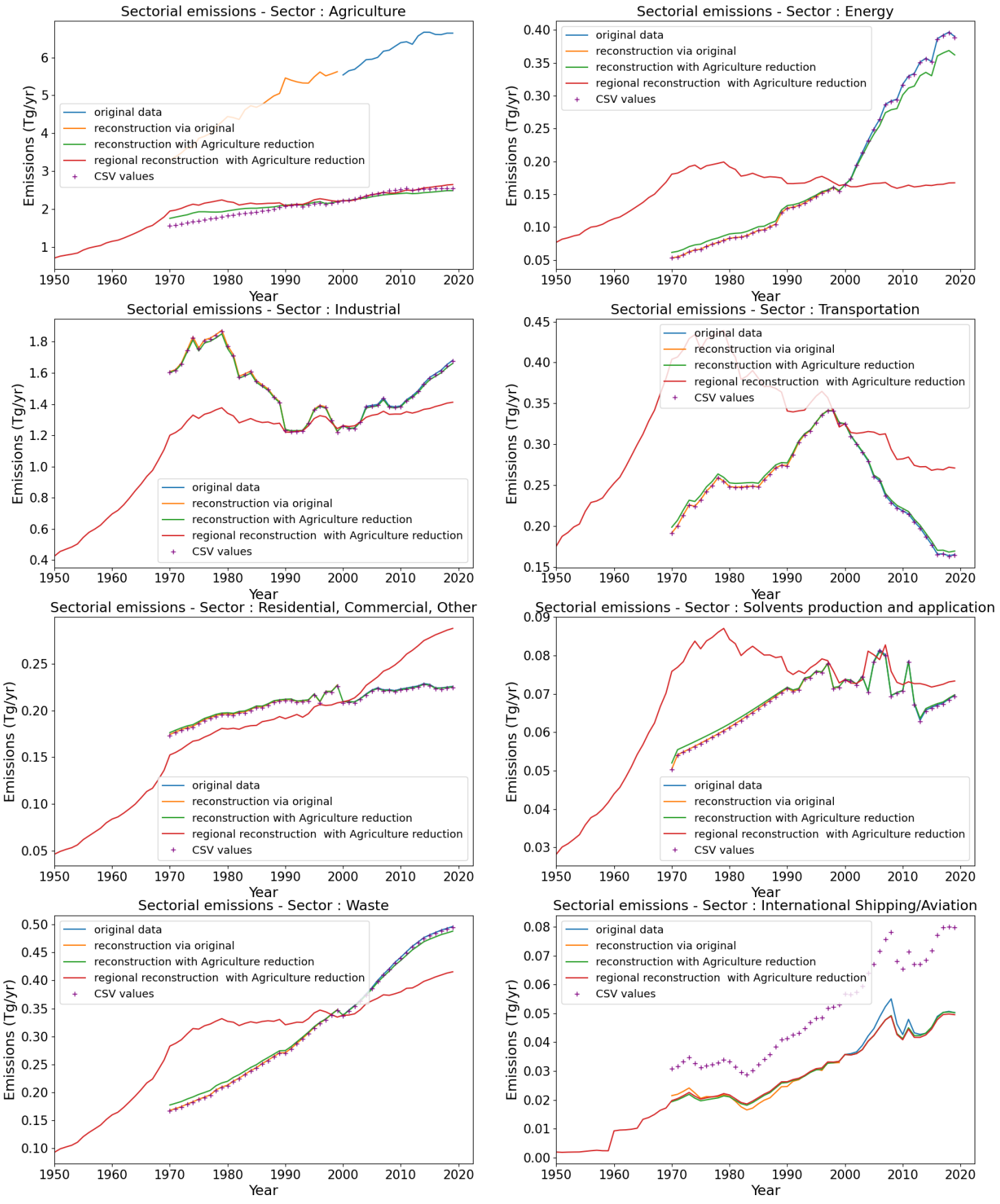

Figure 4: Emissions per sector from .nc files, reconstructions and csv file. The added line is the red one.

4 Why results are different ?

If we use (1), total emissions are equal to:

$$\sum_r em_r^Y = \sum_r \sum_s em_{r,s}^{2000} * \frac{\mathbf{em}_{r,s}^Y}{\mathbf{em}_{r,s}^{2000}}$$

Whereas, by using (2), we obtain:

$$\sum_r em_r^Y = \sum_r em_r^{2000} * \frac{\mathbf{em}_r^Y}{\mathbf{em}_r^{2000}} = \sum_r \left(\sum_s em_{r,s}^{2000} \right) * \frac{\sum_s \mathbf{em}_{r,s}^Y}{\sum_s \mathbf{em}_{r,s}^{2000}}.$$

We see that, in fact, for the first reconstruction, we have $\frac{\mathbf{em}_{r,s}^Y}{\mathbf{em}_{r,s}^{2000}}$ whereas for the preindustrial reconstruction, we have $\frac{\sum_s \mathbf{em}_{r,s}^Y}{\sum_s \mathbf{em}_{r,s}^{2000}}$.

So, in order to have similitude between reconstructions, the evolution of sectorial ratios have to be equivalent to the evolution of regional ratios:

$$\frac{\mathbf{em}_{r,s}^Y}{\mathbf{em}_{r,s}^{2000}} \approx \frac{\mathbf{em}_r^Y}{\mathbf{em}_r^{2000}}. \tag{3}$$

This formula shows that there is no link with mean of sectorial factors (potential hypothesis to explain difference between results).

This difference of evolution between ratios is shown in figure 5 when we gather regions and in figure 6 if we plot ratios per region. On this last figure, we clearly see that some sectorial ratio doesn't have same evolution as regional ratio.

5 Which factor to use in order to have same results?

If we use the same concept as for the sectorial emissions, we want to write regional emissions as:

$$em_r^Y = \mathbf{f}_r * em_r^{2000} = \mathbf{f}_r * \sum_s em_{s,r}^{2000},$$

where $\mathbf{f}_r$ has to be computed with the csv file.

But, from (3), emissions will be identical if:

$$\mathbf{f}_r = \frac{\mathbf{em}_{s,r}^Y}{\mathbf{em}_{s,r}^{2000}}. \tag{4}$$

The main ambiguity, here, is that the factor $\mathbf{f}_r$ is not independant of sectors.

6 Why sectorial emissions are above regional emissions?

Because most of the time, $\frac{em_{s,r}^Y}{em_{s,r}^{2000}} >> \frac{em_r^Y}{em_r^{2000}}$ (see figure 5).

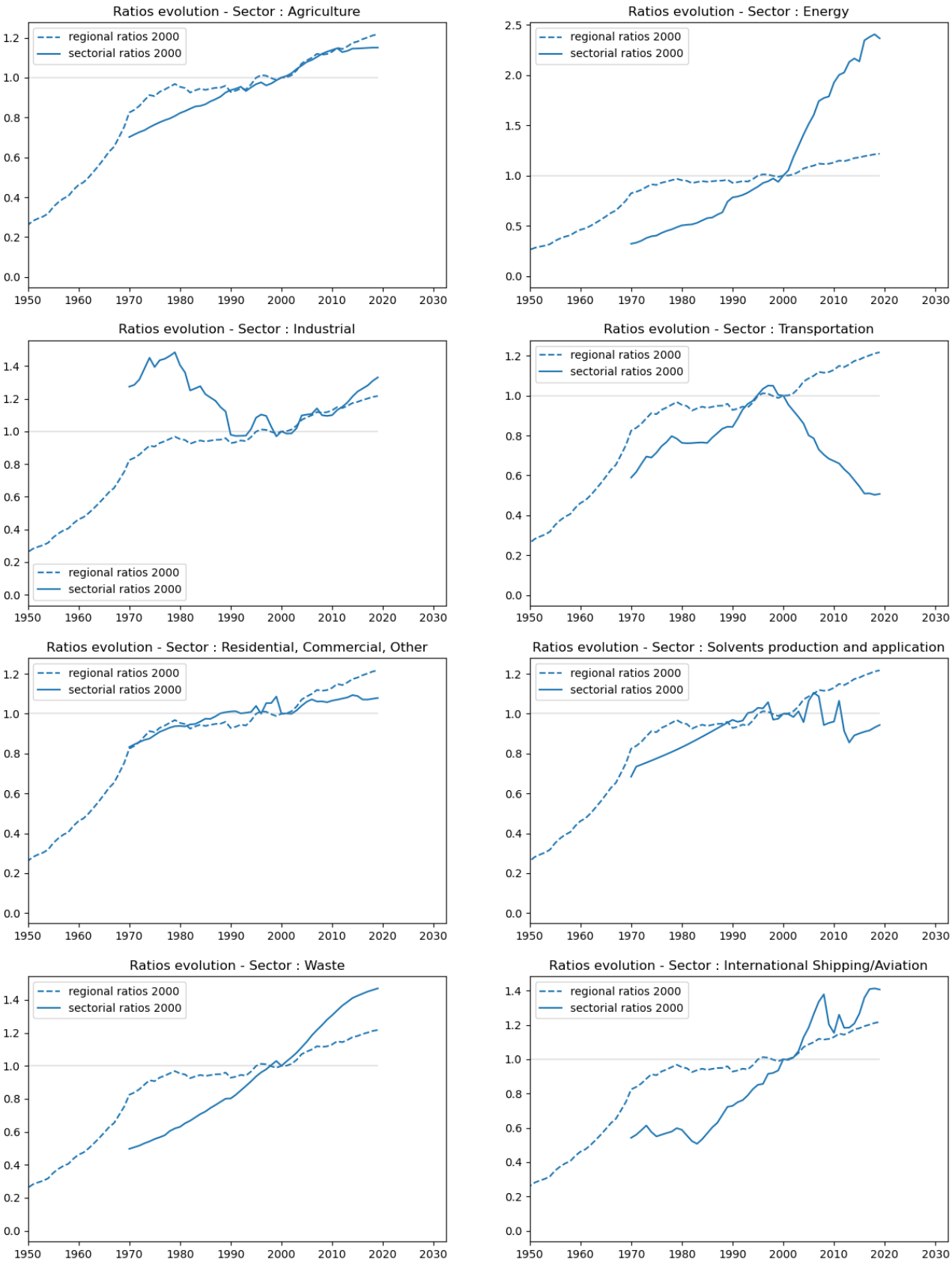

Figure 5: Evolution of emissions ratios per sector. The dotted line represents regional ratios (same for each sector) and the continuous line is ratios per sector.

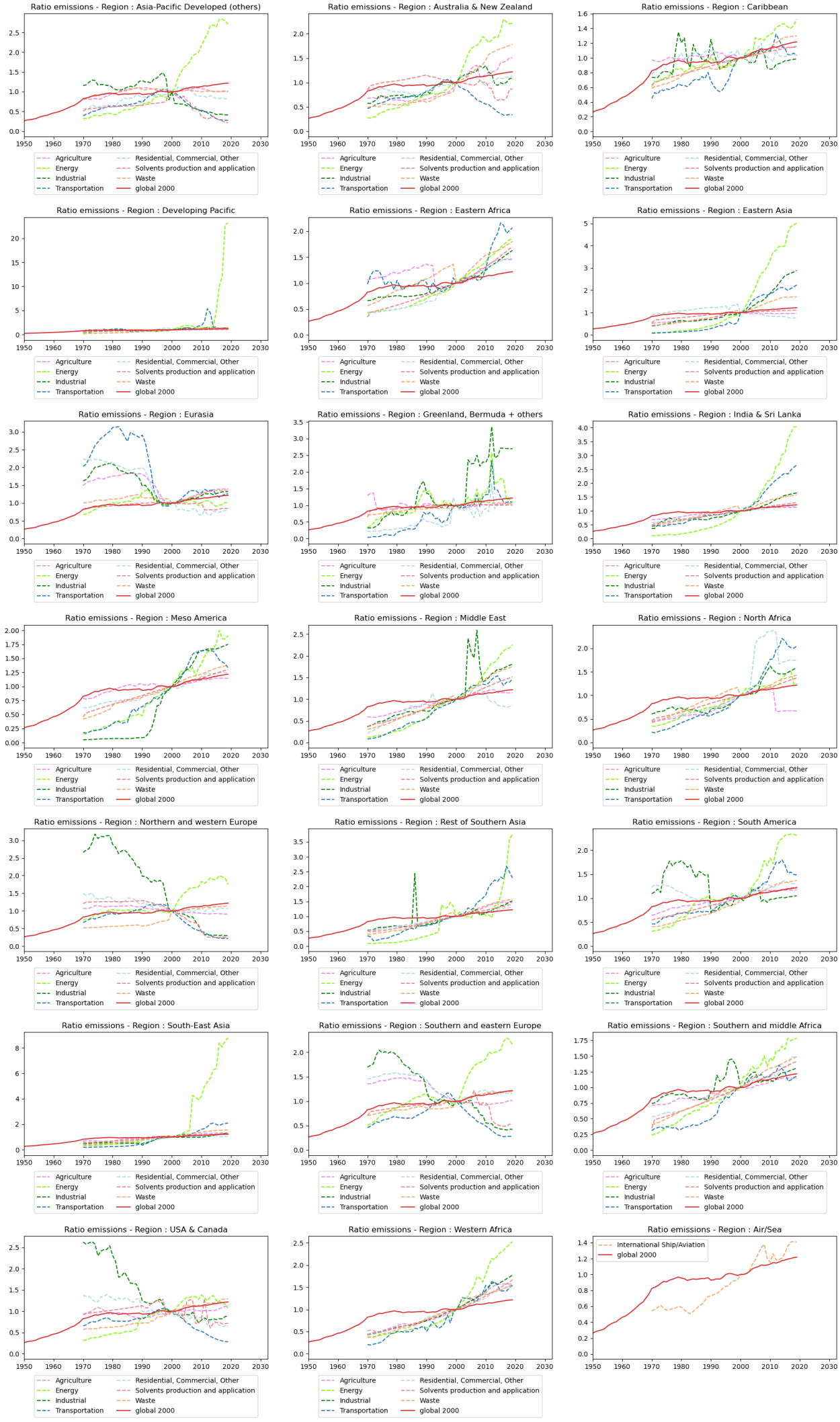

Figure 6: Evolution of regional emissions ratios per sector and for each region. The dotted line represents regional ratios (same for each sector) and the continuous line is ratios per sector.

7 Same method applied on 1970's

Rather than taking 2000 emissions as a reference, we also can use 1970 emissions:

$$em^{Y}_{s,r} = em^{1970}_{s,r} * \frac{\mathbf{em}^{Y}_{s,r}}{\mathbf{em}^{1970}_{s,r}},$$

or

$$em^{Y}_{r} = \sum_{s} em^{1970}_{s,r} * \frac{\mathbf{em}^{Y}_{s,r}}{\mathbf{em}^{1970}_{s,r}}.$$

For Agricultural sector, we take only 47% of the global agriculture part in order to compensate the soil emissions already computed into orchidee model.

Results of this computation are presented on figures 7 and 8.

We see that the reconstruction with sector information doesn't give a good result. An explanation can be found looking on the sectorial and regional ratios (figures 9), that are higher than the one of 2000's reconstruction. Figure 10 also shows a huge difference between regional and sectorial ratios for each region (maybe more than with 2000's emissions).

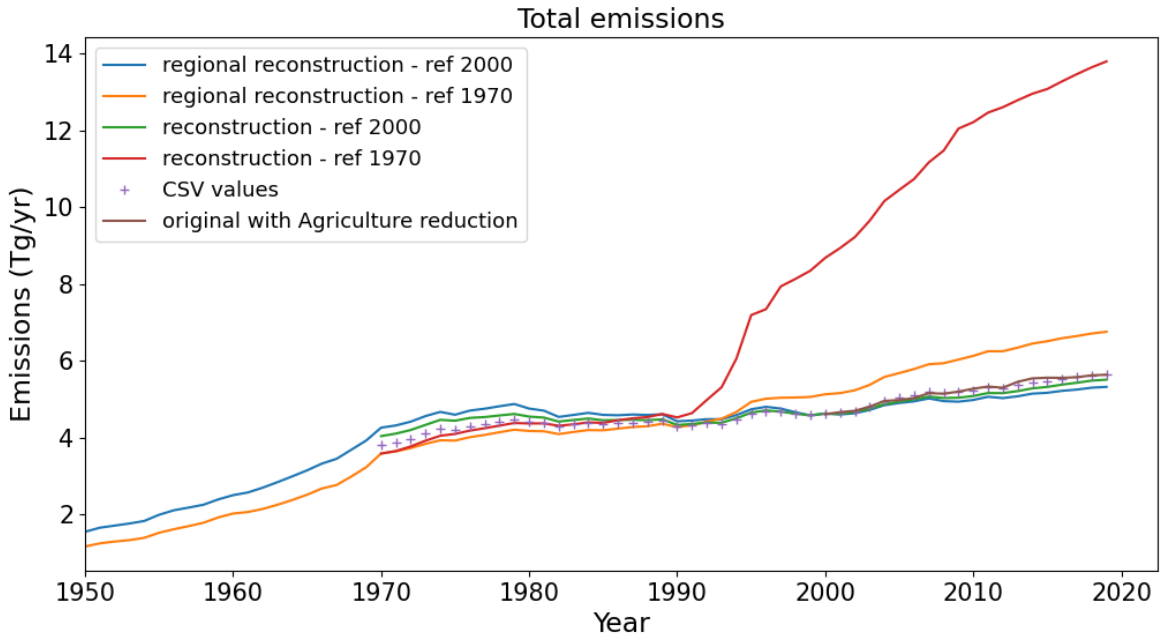

Figure 7: Total emissions from .nc files, reconstructions and csv file. Blue and yellow lines are regional reconstruction (for pre industrial) and green and red lines are sectorial reconstruction.

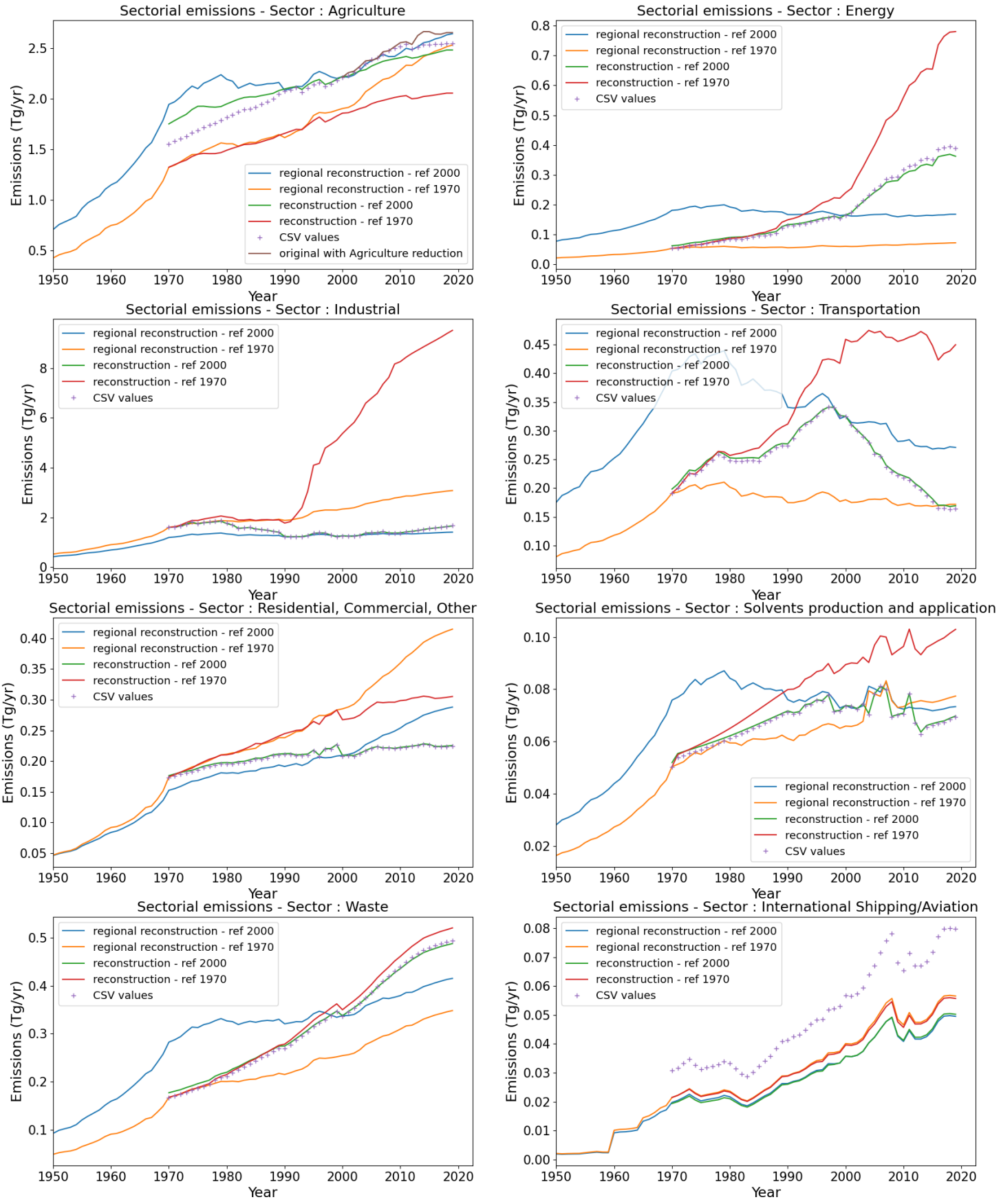

Figure 8: Emissions per sector from .nc files, reconstructions and csv file. Blue and yellow lines are regional reconstruction (for pre industrial) and green and red lines are sectorial reconstruction.

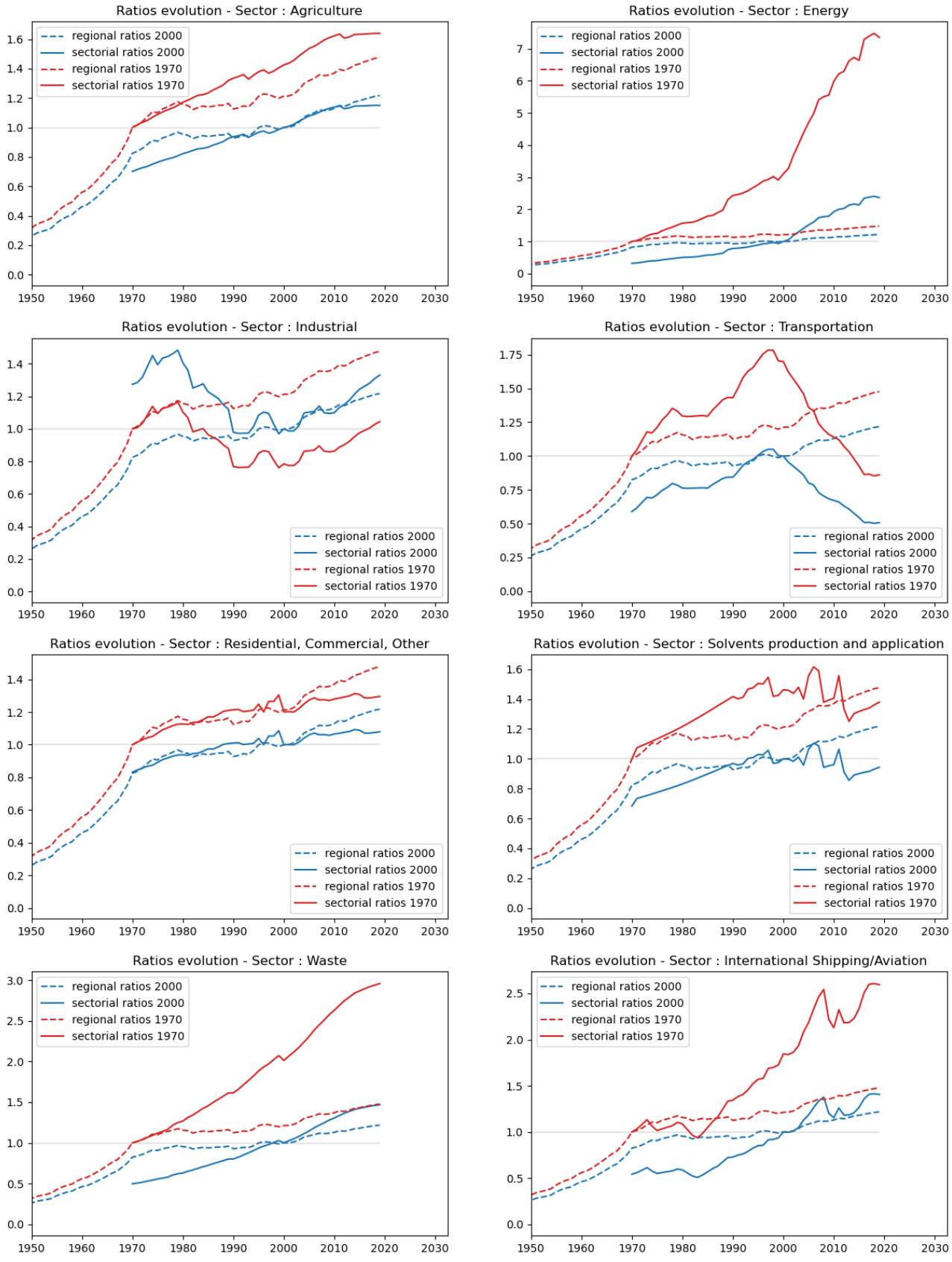

Figure 9: Evolution of emissions ratios per sector. The dotted line represents regional ratios (same for each sector) and the continuous line is ratios per sector. Ratios with 2000's emissions are in blue and with 1970's emissions in red.

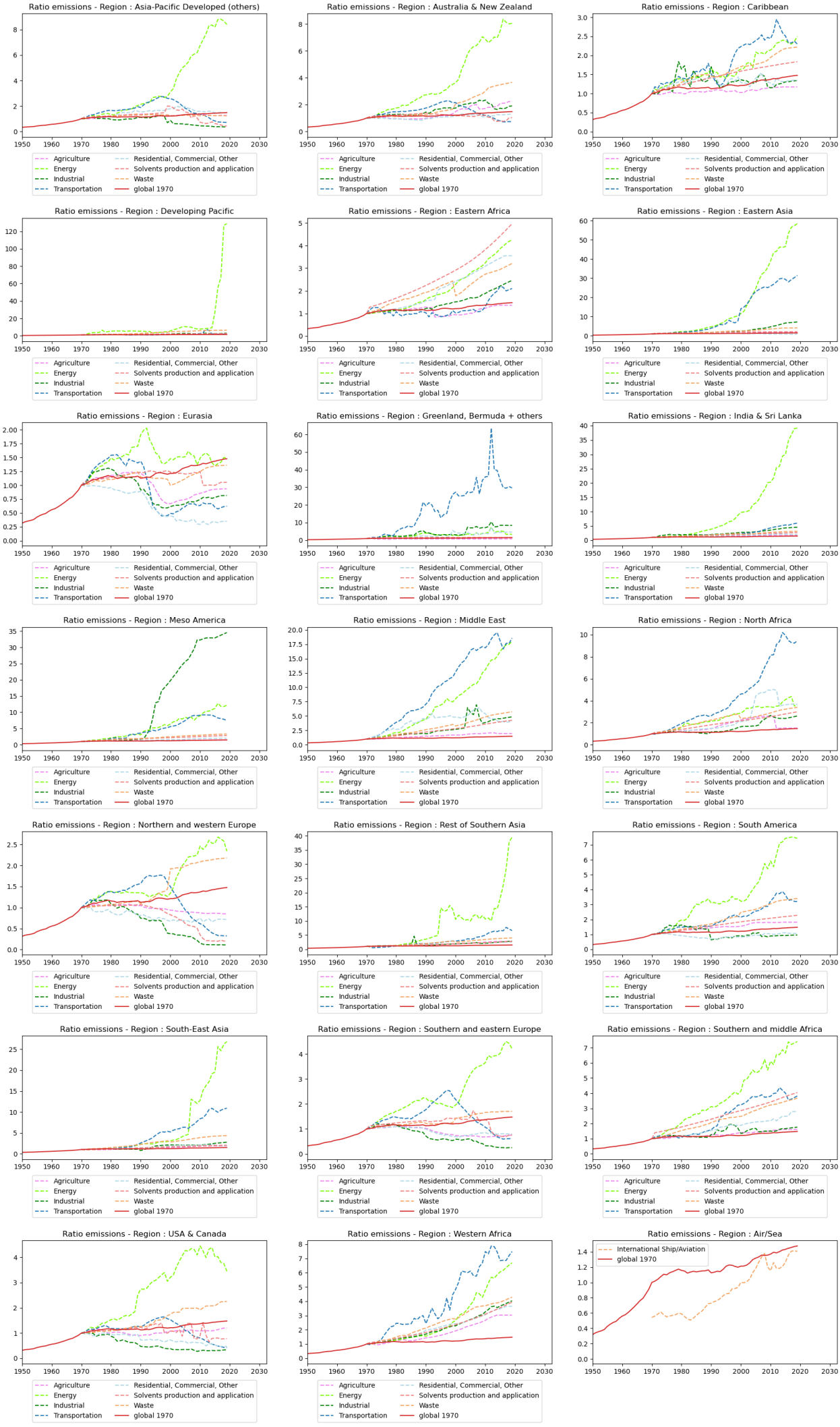

Figure 10: Evolution of regional emissions ratios per sector and for each region. The continuous line represents regional ratios (same for each sector) and the dotted lines is ratios per sector.

8 Conclusion

To have anthropogenic N_2O emissions from 1850 to 2019, we use:

- from 1850 to 1969: a regional reconstruction with 1970's emissions as a reference;
- from 1970 to 2019: a regional and sectorial reconstruction with 2000's emissions as a reference.

Finally, total emissions are in figure 11 and the repartition per sector is presented figure 12. There is good continuity between the two reconstructions used.

Figure 11: Reconstruction of N_2O.

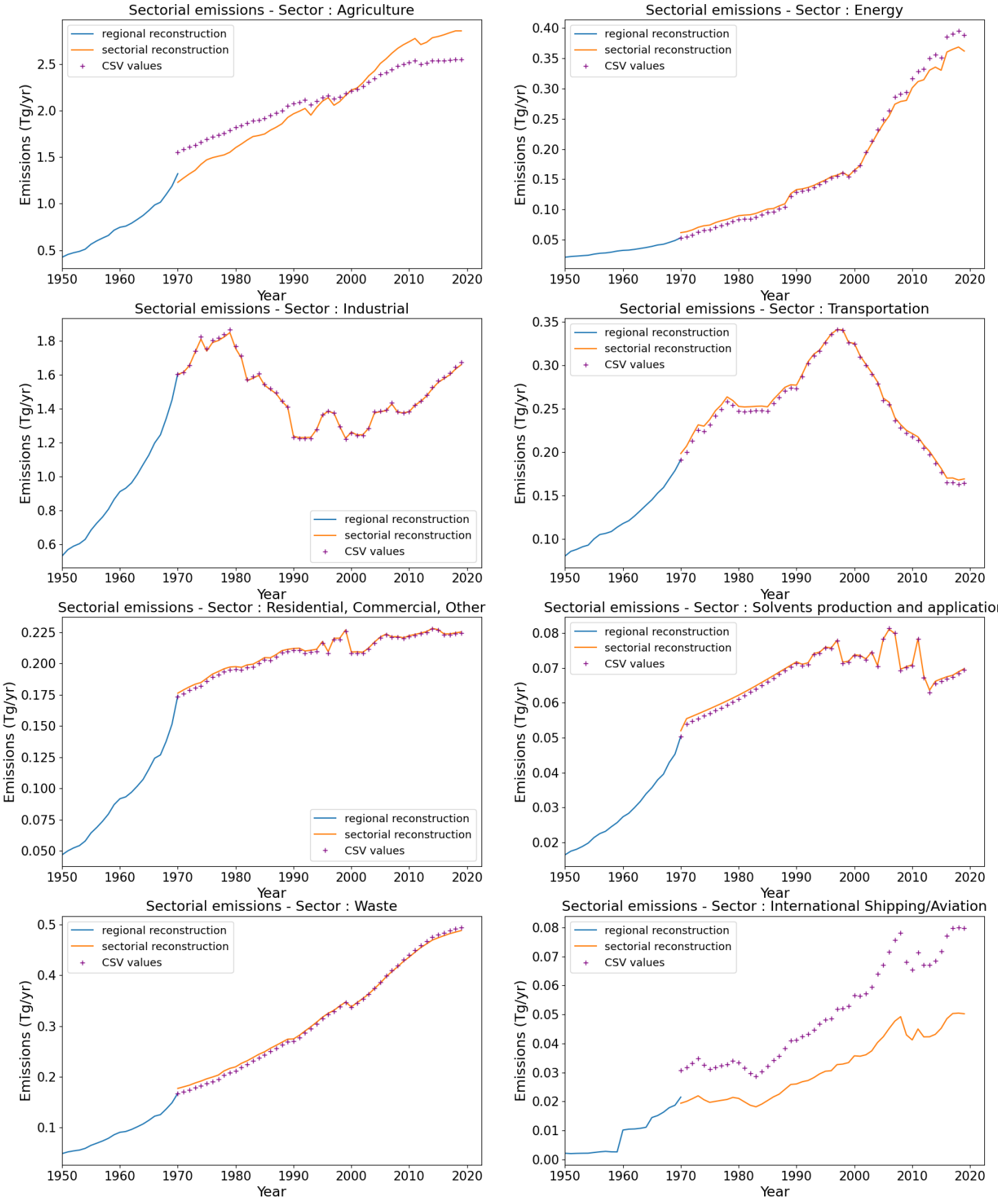

Figure 12: Reconstruction of N_2O per sector.