MRIO linkages and Switzerland's CO_2 profile

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We examine the importance of linkages between the Swiss economy and other regions (especially Western Europe) for Switzerland's CO2 profile. Overall, both final production and consumption carbon footprints and intensities are much larger than (about double) the footprint from territorial production, which is the traditional measure used within the framework of the Kyoto Protocol. The carbon footprint of territorial production decreased during 1997–2011, whereas the carbon footprint of consumption remained quite steady and the footprint from final production increased over the same period. All carbon intensities have decreased, however, though the differential between territorial production and final production and consumption has remained the same. These findings highlight the role of emissions embodied in trade flows, particularly with the group of developed members of the European Union, for a small open economy like Switzerland. They also call for the use of consumption-based criteria, together with criteria based on territorial production and final production, to establish and monitor the Swiss carbon footprint.

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1 Introduction

During the 20th century, the temperature increased in Switzerland by between 1°C and 1.6°C depending on the geographic area, a large proportion of the volume of glaciers was lost, and river water temperatures increased significantly (OECD, 2013; ProClim, 2007).[2] Global warming is expected to increase temperatures in Switzerland further and to continue these processes of change in the ecosystem. There will also be resulting impacts on economic sectors such as agriculture and winter tourism.

The effectiveness of environmental regulations based on territorial production measures of pollution such as the Kyoto Protocol has been challenged by different factors. Carbon dioxide (CO_2) is a global pollutant – its negative impacts are externalized globally. The expansion of international supply chains and cross-border trade and production linkages has undermined the connections between national environmental targets and the incentives for emissions control and abatement.[3] With outsourcing and cross-border production networks,

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2 As indicated by FOEN (2016), temperatures in Switzerland have increased by 0.35°C per decade on average over the last 30 years (CH2011, 2011), while glaciers are estimated to have retreated by 12% in volume since 1999 (FOEN, 2014).
3 On international supply-chains, see Baldwin and López-González (2015) and Koopman et al. (2014).

national targets for industries in Switzerland, for example, will not be binding for industries located in another country such as China, despite production there being an important part of the imports consumed in Switzerland. In this context, the concept of a carbon footprint becomes relevant (Fernández-Amador et al., 2016a; Steinberger et al., 2012). In addition, growing production and incomes in emerging economies challenge the viability of international regulatory frameworks that do not encompass both developed and developing economies. These two factors underlie the failure of the Kyoto Protocol.

The need for urgent action regarding climate change has been underlined by the UN's sustainable development goals (SDGs) (UNGA, 2015). The Paris climate conference (COP21) (United Nations, 2015), adopted by 195 developed and developing countries, has opened for the first time doors of opportunity for international action to combat global warming. Switzerland ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1993, and since 2004, has submitted yearly national inventory reports under the convention. Several authors have addressed the computation of carbon footprints as a relevant indicator of the cost associated with economic development. For example, Peters et al. (2012), Aichele and Felbermayr (2012), and Fernández-Amador et al. (2016b) have calculated comparable inventories of carbon emissions based not only on national (territorial-based) production, but also on final consumption. These datasets reveal that developed countries show much larger emissions associated with consumption than with production, and that the decrease in carbon emissions embodied in territorial production has been offset by an increase in consumption-based emissions. These carbon footprints in developed countries include emissions embodied in imports with relatively high ratios of emissions to output.

In this paper, we examine international linkages of the Swiss economy to Europe and more broadly to the world, and how these affect Swizerland's profile in terms of CO_2 emissions. In controlling for cross-border linkages between production-based emissions in one country and final consumption in another, we are able to focus on the entire carbon chain. For this purpose, we work with a recent dataset of inventories of CO_2 emissions from fossil fuel combustion developed in Fernández-Amador et al. (2016b). These data comprise a panel of 78 geographic entities (66 countries and 12 composite regions, covering a total of 178 economies) over the years 1997, 2001, 2004, 2007, and 2011. The data provide comparable inventories of emissions based on territorial production, final production, and final consumption for 14 years following the adoption of the Kyoto Protocol and the first six years since it came into effect in 2005. These data, by construction, trace emissions through stages of production. Trade in CO_2

embodied in trade in intermediate input is traced to final production, whereas emissions embodied in total trade are traced to final consumption.

The inventories of the Swiss economy show that Switzerland moderately decreased its CO_2 emissions based on traditional territorial production between 1997 and 2011. However, taking into account the fact that Switzerland is a small open economy closely integrated into the global trade network shows a different picture. The emissions embodied in foreign intermediates used as inputs of Swiss final production and the imports of final goods for final consumption in Switzerland have more than offset territorial emission reductions. Indeed, CO_2 emissions embodied in Swiss final production and final consumption increased during the sample period. Therefore, the carbon footprint of Switzerland, as for other developed economies, may be better measured by means of emissions embodied in final production or consumption. This underlines the need for a broader set of criteria, based on embodied emissions in final production and consumption, to inform the Swiss strategy for reducing greenhouse gas emissions.

The next section of this paper revisits the methodology applied in Fernández-Amador et al. (2016b) in order to compute CO_2 emissions inventories based on territorial production, final production and final consumption. Section 3 reviews some stylized facts of the Swiss economy during 1997-2011. Section 4 concludes.

2 Methodology and data

We work with a dataset of national inventories of CO2 emissions embodied in national standard (geographical) production, final (or embodied) production, and consumption. The dataset was constructed in Fernández-Amador et al. (2016b) using multiregional input–output (MRIO) methodology.[4] It encompasses 187 economies (grouped into 78 countries and regions) and 55 sectors, and covers the years 1997, 2001, 2004, 2007 and 2011. The MRIO tables in Fernández-Amador et al. (2016b) allow us to follow primary emissions created by production processes through global supply chains to the region where the final good leaves the factory (final production) or where it is finally consumed (final consumption). These flows of CO_2 emissions allow us to calculate the final production and consumption inventories that we compare with traditionally territorial-based inventories throughout this study. We now briefly give some insights into the process of constructing the MRIO tables.

4 Environmentally extended MRIO methodologies are the preferred method to compute emission inventories and related measurements in the complex framework of international trade (Lenzen et al., 2012).

Calculating MRIO tables for this many regions and sectors requires a considerable amount of input-output and trade data. Furthermore, data on CO_2 emissions for these regions and sectors is required as well. Fernández-Amador et al. (2016b) relied on the database of the Global Trade Analysis Project (GTAP), which combines all this data. Additionally, that paper sourced population data from the World Development Indicators (WDI) database. The paper also used different releases of the database benchmarked to the years 1997 (GTAP 5), 2001 (GTAP 6) and 2004, 2007, 2011 (GTAP 9). Because the number of regions in the dataset varies (from 78 in GTAP 5 to 140 in GTAP 9), the authors decided to aggregate all releases to the 78 regions present in GTAP 5 (1997). All the countries that only appear in the later releases were assigned to the 12 composite regions of GTAP 5 (1997).[5]

Also, the authors collapsed the 57 sectors present in all of the relevant GTAP releases into 55 sectors. The reason for this was the treatment of the three transport sectors in the database (land, air and marine transport). In a world characterized by fragmented supply chains, it is important to look at emissions embodied in international transportation. Furthermore, transportation services are one of the most pollution-intensive ones (Fernández-Amador et al. 2016b). However, GTAP does not link demand for international transportation in a sector to its supplier, which makes it difficult to assign these emissions to a final producer or consumer. Thus, Fernández-Amador et al. (2016b) followed the assumptions of Peters et al. (2011a) and endogenized demand for international transportation. In this process, they collapsed the three transportation sectors, which resulted in 55 different sectors in the final MRIO tables.

Given this raw data, Fernández-Amador et al. (2016b) proceeded in the following steps to calculate final production-based and final consumption-based CO_2 inventories. First, the energy data of the GTAP database had to be corrected for accountancy problems. Here the authors followed the approach of Ludena (2007) and Lee (2002, 2008) and created standard production-based CO_2 inventories for the regions in the dataset. Dividing the standard production of CO_2 per sector by gross output per sector allowed them to define sectoral emission intensities in each region as $e_i = (e_{i,1}, e_{i,2}, \ldots, e_{i,s})$ (of dimension s which denotes the number of sectors in their dataset).[6] The next step is to calculate the MRIO tables for each year based on the raw data from the GTAP database. In this

5 Table A1 in the appendix gives an overview on the countries that have been aggregated to these composite regions.
6 We will use the notation of Fernández-Amador et al. (2016b) throughout this section.

step, the authors followed PETERS ET AL. (2011a).[7] Recognizing that gross output in each region and each sector – denoted by vectors $(x_1, x_2, x_3, \ldots, x_n)'$[8] where n denotes the number of regions in the database – can be used as intermediate or final demand, global production of gross output can be represented as follows,

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_n \end{pmatrix} = \begin{pmatrix} A_{11} & A_{12} & A_{13} & \cdots & A_{1n} \\ A_{21} & A_{22} & A_{23} & \cdots & A_{2n} \\ A_{31} & A_{32} & A_{33} & \cdots & A_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_{n1} & A_{n2} & A_{n3} & \cdots & A_{nn} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_n \end{pmatrix} + \begin{pmatrix} y_{11} & y_{21} & \cdots & y_{n1} \\ y_{12} & y_{22} & \cdots & y_{n2} \\ y_{13} & y_{23} & \cdots & y_{n3} \\ \vdots & & & \\ y_{1n} & y_{2n} & \cdots & y_{nn} \end{pmatrix} l \,, \qquad (1)$$

where r denotes an exporter region and p an importer region. Then A denotes the MRIO matrix, and its submatrices, A_{rp}, of dimension, $s \times s$, capture trade in intermediates normalized to gross output ($r = p$ denotes domestic flows). The last term in equation (1) denotes transactions of final demand between the regions within the database. Multiplied by the unity vector, l, it collapses to a column vector of final demand, denoted by y.

Noting that matrix A denotes the direct requirements to produce final goods only, this takes us to the fourth, and final step undertaken by FERNÁNDEZ-AMADOR ET AL. (2016b). They condensed equation (1) to $x = Ax + y$ and solved for vector x in order to obtain the famous Leontief inverse matrix $(I - A)^{-1}$ (where I is the identity matrix). Compared to the MRIO matrix, the Leontief inverse also accounts for the indirect intermediate input requirements that are necessary to produce final output in each sector in each region. The authors then combined the Leontief inverse matrix with the regional emission intensities to construct emission inventories based on final production and consumption for each of the 78 regions in the database.

7 The reader may refer to KANEMOTO ET AL. (2012) for a comparison of methods to account for embodied CO_2 emissions. A discussion on MRIO methodologies in general can be found, among others, in DAVIS and CALDEIRA (2010), DAVIS ET AL. (2011), and PETERS (2008). Hereafter, we again follow the notation of FERNÁNDEZ-AMADOR ET AL. (2016) and denote vectors and matrices with lower and upper case letters, respectively. We also refer to FERNÁNDEZ-AMADOR ET AL. (2016) for a more detailed description of the methodology.

8 The reader may note that the dimension of x_n is equal to s, the number of sectors in the database.

This was done by combining regional emissions per sector with the Leontief inverse in the following way:

$$f_r^o = E(I - A)^{-1} o_r, \quad (2)$$

$$f_r^c = E(I - A)^{-1} c_r, \quad (3)$$

where E (dimension $(n \cdot s) \times (n \cdot s)$) is a diagonal matrix with the elements being equal to e as defined above. Multiplied with the Leontief inverse as shown above, matrix E allows the authors scale the global flows of direct and indirect input requirements to flows of CO_2 emissions. The last remaining step was to capture the flows of emissions embodied in a final good to the region where its final producer and consumer are located. This was done by multiplying the scaled Leontief inverses by vectors o_r and c_r (both of dimension $n \cdot s$), which denote final production and final consumption per region and sector, respectively.

3 Stylized facts for Switzerland

Tables 1 and 2 summarize the standard (territorial) production-based, final production-based and final consumption-based emissions inventories for Switzerland and for 14 other countries and regions. Paying attention to the first column of both tables, we can follow the dynamics of Kyoto-type CO_2 inventories based on location of activity. According to this inventory, Switzerland's emissions decreased from 47 million metric tons (MMT) in 1997 to 44 in 2011. However, Switzerland is an open economy, embedded in Europe. Over this same period, there has been a dramatic reorganization of industrial production into cross-border production networks (known as "value chains"). Switzerland has been no exception.

The second column in Tables 1 and 2 reports total carbon embodied in final production in Switzerland. In other words, this second definition of CO_2 from production includes not only the inputs of final goods produced in Switzerland, but also intermediates used to produce final goods in Switzerland that have been produced in other countries and regions, such as the EU and China, and thus the carbon emitted from those activities. On this basis, carbon emissions of Swiss final production have risen steadily, from 92 MMT in 1997 to 130 MMT by 2011. In other words, even before turning to the sources of carbon embodied in Swiss production, it is clear that the decline in the carbon intensity of local activity in Switzerland from 1997-2011 has been more than offset by a shift to inputs from outside Switzerland that are relatively more carbon intensive, such that Switzerland's net carbon intensity per unit of GDP (including embodied emissions) went up over the 1997-2011 period. The third column in Tables 1 and 2 presents the emissions based on final consumption. From these figures, it can be seen that Swiss consumption-based emissions increased in the beginning of the sample, with a peak in 2001, to decline again and only increased again in 2011.

Table 1: Geographic production, embodied production, and consumption inventories, 1997, 2001 and 2004

		CO_2 in geographic production	**CO_2 in final production**	**CO_2 in consumption**
Australia	1997	313	280	288
EU15	1997	3,290	3,992	3,846
EEU	1997	802	694	682
Switzerland	**1997**	**47**	**92**	**91**
China	1997	3,045	2,648	2,587
Japan	1997	1,163	1,447	1,435
USA	1997	5,595	5,597	5,748
India	1997	874	826	816
Canada	1997	499	480	481
South Korea	1997	419	447	421
Russia	1997	1,485	1,208	1,240
Brazil	1997	271	314	320
Middle East	1997	1,138	330	1,122
Mexico	1997	326	333	321
R.O.W.	1997	3,435	4,013	3,306
Australia	2001	379	306	318
EU15	2001	3,210	3,947	3,794
EEU	2001	687	660	638
Switzerland	**2001**	**49**	**101**	**105**
China	2001	2,849	2,462	2,373
Japan	2001	1,032	1,316	1,312
USA	2001	5,955	6,193	6,454
India	2001	964	901	898
Canada	2001	527	503	487
South Korea	2001	372	377	339
Russia	2001	1,480	1,126	1,144
Brazil	2001	283	290	290
Middle East	2001	1,421	1,249	1,302
Mexico	2001	364	408	394
R.O.W.	2001	3,482	3,216	3,207

		CO_2 in geographic production	CO_2 in final production	CO_2 in consumption
Australia	2004	379	342	364
EU15	2004	3,593	4,567	4,488
EEU	2004	715	714	689
Switzerland	**2004**	**48**	**106**	**91**
China	2004	4,511	3,690	3,551
Japan	2004	1,104	1,429	1,395
USA	2004	6,076	6,494	6,755
India	2004	1,115	1,060	1,055
Canada	2004	584	543	539
South Korea	2004	414	462	406
Russia	2004	1,606	1,221	1,238
Brazil	2004	303	305	296
Middle East	2004	1,658	1,436	1,514
Mexico	2004	382	421	417
R.O.W.	2004	3,916	3,613	3,606

Table 2: Geographic production, embodied production, and consumption inventories, 2007 and 2011

		CO_2 in geographic production	CO_2 in final production	CO_2 in consumption
Australia	2007	396	353	380
EU15	2007	3,577	4,588	4,460
EEU	2007	739	780	753
Switzerland	**2007**	**46**	**107**	**91**
China	2007	5,688	4,669	4,440
Japan	2007	1,112	1,368	1,311
USA	2007	6,095	6,518	6,787
India	2007	1,350	1,314	1,320
Canada	2007	599	573	583
South Korea	2007	428	517	460
Russia	2007	1,624	1,361	1,412
Brazil	2007	330	358	360
Middle East	2007	1,939	1,755	1,870
Mexico	2007	423	462	456
R.O.W.	2007	4,775	4,398	4,438

		CO_2 in geographic production	CO_2 in final production	CO_2 in consumption
Australia	2011	404	374	407
EU15	2011	3,177	4,024	3,878
EEU	2011	718	744	708
Switzerland	**2011**	**44**	**130**	**97**
China	2011	7,431	6,620	6,338
Japan	2011	1,086	1,360	1,316
USA	2011	5,630	5,881	6,103
India	2011	1,791	1,738	1,745
Canada	2011	578	547	557
South Korea	2011	505	544	477
Russia	2011	1,709	1,454	1,515
Brazil	2011	409	462	482
Middle East	2011	2,320	2,054	2,189
Mexico	2011	435	470	466
R.O.W.	2011	4,733	4,569	4,693

Comparing the three inventories of Switzerland, we see on the one side that emissions from final production have been consistently larger than emissions from territorial production, which highlights the net balance of trade in intermediates. The Swiss economy incorporates into final products imports that are more carbon intensive than domestic production. On the other side, final consumption is associated with fewer emissions than final production. Thus, imports of final goods consumed in Switzerland are less polluting than exports of final goods produced in Switzerland and consumed in other regions of the world. Consumption patterns in Switzerland seem to be more "green" than final production, but much more carbon intensive than territorial production.

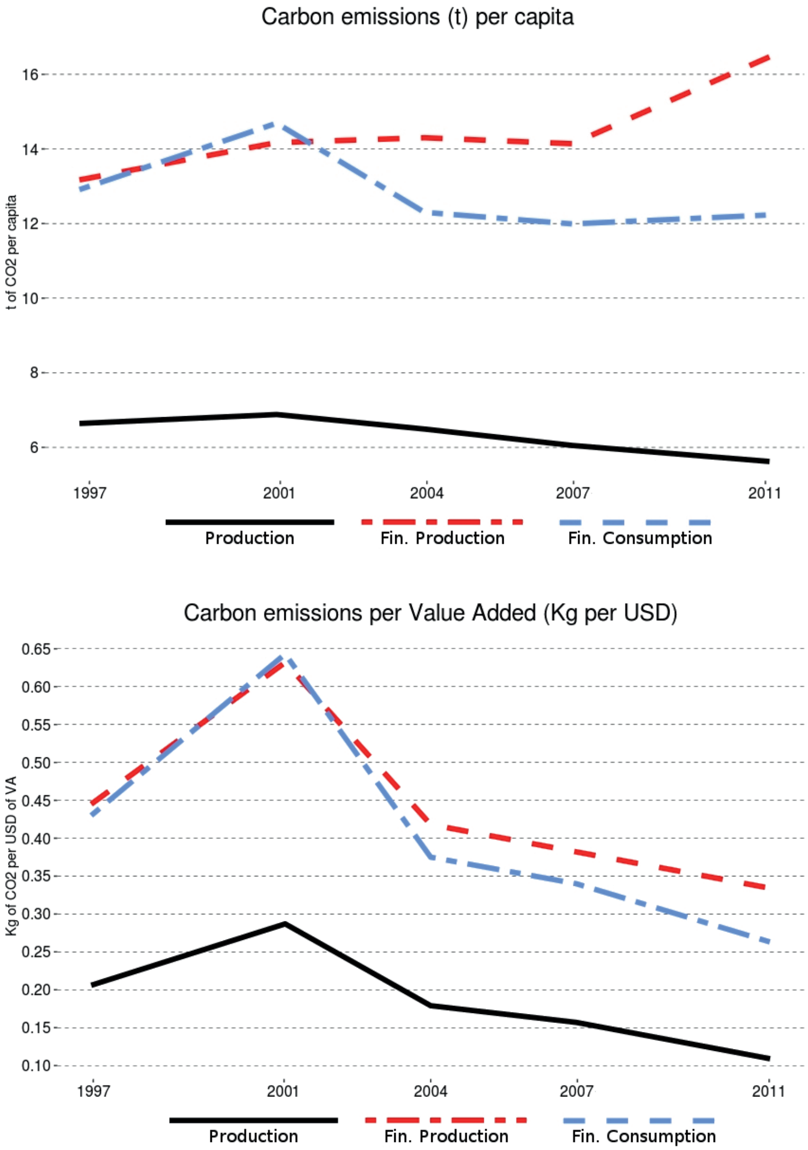
Figure 1 provides the time profile of emissions per capita (footprint) and emissions per value added (intensity) for the three sets of inventories for Switzerland. Again, these reflect the patterns identified in Tables 1 and 2. Overall, both final production and consumption carbon footprints and intensities are much larger than (about double) the footprint of territorial production, which is the traditional measure used within the framework of the Kyoto Protocol.

While the carbon footprint of the Swiss consumer improved between 2001 and 2004, there has been no real change since. Over the whole period, on a consumption basis, the annual carbon footprint of the Swiss consumer fell from 12.9 tons per capita in 1997 to 12.2 tons by 2011. Per-capita emissions from territorial production fell from 6.6 tons in 1997 to 5.6 tons by 2011 (a drop of 15.5%). However, emissions per capita of carbon embodied in final production rose from 13.2 tons in 1997 to 16.5 tons in 2011. When we focus on carbon intensities (i.e. CO_2 per unit of value added) calculated for the three inventories, it should be noted that they have all decreased continuously from 2001. Nevertheless, the differentials across inventories remain similar – rather small for final production and consumption inventories.

For comparison, Figure 2 provides a geographic breakdown of territorial production and consumption for Switzerland, its main partner (the EU15), and another high-tech and innovative developed country (Japan). The figures are based on the average shares over the sample period. Starting with production, we see that while in the EU15 and Japan, roughly 84% of produced emissions are actually consumed domestically; the local consumer share of produced emissions is closer to 74% in Switzerland. It is noteworthy that Switzerland shows a large share of emissions generated by domestic activity but destined for consumption elsewhere in Western Europe (around 11.5%) and for US consumers (4.3%). Focusing on consumption, we can again see how important the integration of Switzerland in Europe is for the carbon footprint of Swiss consumers. While 69% of carbon consumed in Japan comes from Japan itself, in Switzerland the home share on the consumer side is only 37%. Indeed, Western Europe is the source of a large share of Swiss carbon consumption (over 21%), whereas no country or region has such a dominant role in supplying consumption in Japan. The United States stands out even more for consumption than for production, serving as the country of origin for 6.7% of embodied carbon ultimately consumed in Switzerland.

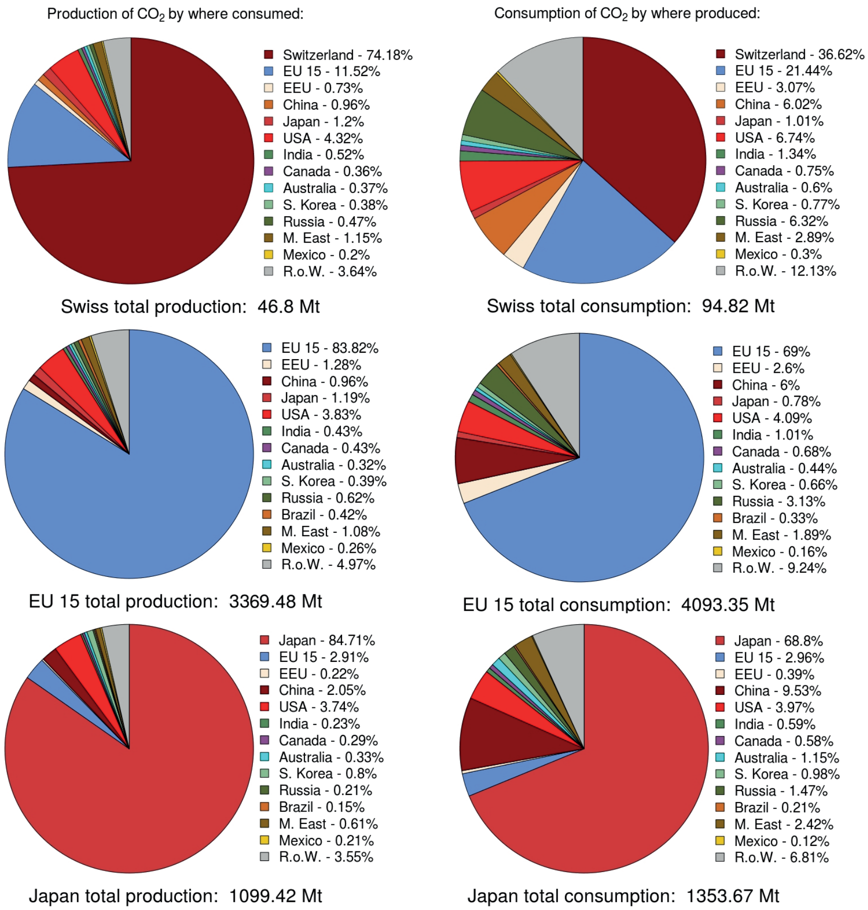
A decomposition of the overall trend of the geographic composition of Swiss imports and exports is provided in Figure 3. In the figure, we present the net trade position of Switzerland in terms of MMT of CO_2. The bars on the left indicate imports of carbon (for example, the emissions contained in steel produced in Germany and shipped to Switzerland for use in construction), while the bars on the right indicate carbon emissions contained in Swiss exports that are from Swiss activity. Given that in Tables 1 and 2 we have a substantial gap between location-based inventories and total inventories (the first two columns), we should not be surprised that a clear negative net balance for Switzerland is displayed in Figure 3.

Figure 1: Swiss carbon emissions per capita and value added



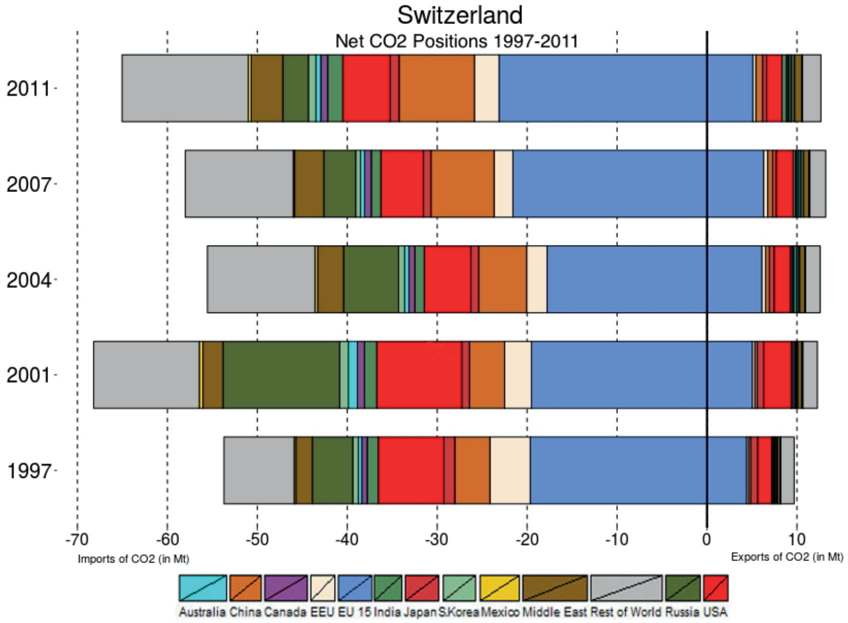
Notes: Measures are in kg of CO_2 per capita and kg of CO_2 per US dolar, respectively. Based on traditional geographic inventories, consumption inventories, and embodied production inventories. For years 1997, 2001, 2004, 2007, and 2011.

Figure 2: Comparison of CO2 emission inventories for Switzerland, EU 15 and Japan: Main partners (1997–2011 average)



Notes: Plots on the left column show the composition of CO_2 emissions embodied in goods and services by where CO_2 was produced. The right column shows the shares of CO_2 emissions produced by final country of consumption.

Figure 3: Swiss carbon emissions embodied in international trade: main partners



Notes: The barplots show CO_2 emissions (Mt.) embodied in exports and imports, and their distribution amongst the main partners considered, in 1997, 2001, 2004, 2007, and 2011.

In terms of regional patterns, in 1997 36% of Swiss imports of embodied emissions came from the higher-income EU economies (the EU15 in Figure 3). This same share holds in 2011, reflecting the deep integration of the Swiss economy in Europe in terms of sourcing inputs from abroad. At the same time, China has gone from supplying roughly 7% of emissions embodied in Swiss imports to around 14%. Interestingly, this has clearly been at the expense of lower-income members of the EU (denoted EEU in the figure). These economies have seen their share drop from 9% to 4.5% of Swiss imports on a carbon basis. Russia has also seen a dramatic decline, with a carbon share that peaked in 2001 and has fallen steadily since. Overall, the carbon structure of Swiss imports reflects both the steady reliance of Switzerland on Western Europe for inputs to production over the full 1997–2011 period, and also a shift away from Eastern Europe (EEU and Russia) towards East Asia over the same period. This strong dependence on the Western European partnership can be also seen on the side of exports.

4 Conclusions

In this paper, we have examined the importance of linkages between the Swiss economy and other regions (especially Western Europe) for the carbon profile of Switzerland using the dataset recently developed in Fernández-Amador et al. (2016b). Carbon inventories developed using the MRIO methodology allow us to trace emissions across the supply chain and to move beyond direct emissions produced inside Switzerland to look at emissions elsewhere that are supported either by demand from Swiss industry or from Swiss consumers.

A number of patterns stand out. First, given the strong intermediate linkages between Switzerland and its neighboring economies, these trade partners are an important source of the carbon footprint of Swiss consumers. Historically 21% of CO_2 emissions embodied in Swiss consumption have come from the higher-income members of the EU (the EU15). At the same time, we observe that the Swiss emissions profile, based on geographic production inventories, does not reflect the entire carbon footprint from Switzerland. Over the period 1997–2011, there was a substantial drop in the Swiss emissions footprint and intensity, whether measured per capita or per unit of value added. However, this was accompanied by a pattern of emissions outsourcing. The growth of China as a source of Swiss imports of goods has also implied an increasing role of China as a source of carbon embodied in Swiss imports. China has grown as a supplier of embodied carbon at the expense of Eastern Europe (including Russia). The net Swiss carbon deficit has grown, and the overall intensity of Swiss final production – once we allow for embodied emissions from other countries who have supplied inputs to the Swiss economy – has moved in the opposite direction to territorial production inventories.

The application of MRIO-based analysis to carbon accounting illustrates the complexities we face in managing emissions in a world where global and regional value chains mean there is a disconnect between national commitments to emissions and the carbon footprints of consumers. Focusing on Switzerland, we can see clear evidence of carbon outsourcing. Some of this logically reflects a relatively stable integration in the industrial landscape of Western Europe. However, East Asia also looms larger over time as a supplier of carbon to the Swiss consumer. All in all, these findings call for the use of consumption-based criteria, together with territorial production-based and final production-based criteria, to establish and monitor the Swiss carbon footprint.

Appendix

Table A1: Definition of GTAP composite regions

Composite Regions	Countries
Rest of Andean Pact	Bolivia and Ecuador
Central America, Caribbean	Anguilla, Antigua & Barbados, Aruba, Bahamas, Barbados, Belize, Cayman Islands, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Grenada, Guatemala, Haiti, Honduras, Jamaica, Netherlands Antilles, Nicaragua, Panama, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago and Virgin Islands (GB)
Rest of EFTA	Iceland, Liechtenstein and Norway
Rest of Former Soviet Union	Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan
Middle East	Bahrain, Iran (Islamic Republic of), Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Rep., United Arab Emirates and Yemen
Rest of North Africa	Algeria, Egypt, Libyan Arab Jamahiriya and Tunisia
Other Southern Africa	Angola and Mauritius
Rest of South African Customs Union	Lesotho, Namibia, South Africa and Swaziland
Rest of South America	Guyana, Paraguay and Suriname Rest
Rest of South Asia	Bhutan, Maldives, Nepal and Pakistan
Rest of Sub-Saharan Africa	Benin, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Mali, Mauritania, Mayotte, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, Sudan, Togo and Congo (DPR)
Rest of World	Afghanistan, Albania, Andorra, Bermuda, Bosnia and Herzegovina, Brunei, Cambodia, Faroe Islands, Fiji, French Polynesia, Gibraltar, Greenland, Guadeloupe, Kiribati, Lao (PDR), Macau, Macedonia (former Yugoslav Republic of), Marshall Islands, Micronesia, Monaco, Mongolia, Myanmar, Nauru, New Caledonia, Korea (DPR), Papua New Guinea, San Marino, Solomon Islands, Tonga, Tuvalu, Vanuatu, Western Samoa, Rest of former Yugoslavia

Notes: Computations were performed using the disaggregation of each year. Afterwards, the composite regions for all the following GTAP releases were computed according to the regional aggregation of GTAP 5 for the one retained for the analysis in our research. Countries that show up in later GTAP databases but not in GTAP 5 were assigned to the Rest of World composite region. Those countries are too small to change results, however. They are mainly small islands states or territories belonging to the jurisdiction of another country, which show up in one of the later composite regions (Wallis and Fortuna, for example). The only notable exceptions are Timor-Leste and Greenland.

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