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Towards a Green Energy Economy? A macroeconomic-climate evaluation of Sweden's CO_2 emissions

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HIGHLIGHTS

- The assessment is based on E-3 indicators, econometrics and MRIO analysis.
- Energy intensity decreasing mostly attributed to increases in economic activity.
- Sweden's CO_2 emissions embodied in imports are higher than in exports.
- Mitigation policies needed in sectors with high embodied emissions in imports.
- Bioenergy policies will become crucial for reducing Sweden's CO_2 intensity.

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ABSTRACT

This paper provides a production and consumption-based empirical macroeconomic-climate assessment of Sweden's CO_2 emissions. The core methodology is based on three complementary quantitative methods, namely energy-economy-environment indicators, econometric analyses, and a multi-regional input-output (MRIO) sectoral model. Based on the latest available data (1971–2011), indicators show a sharp decarbonisation of Sweden's energy supply mix pre-1990, and reductions or reversals in energy intensity, CO_2 intensity and energy use post-1990. Reductions in energy intensity are mostly attributed to substantial increases in economic activity rather than reductions in energy use. Econometric results show that variability of CO_2 emissions is best explained by CO_2 intensity than any other tested variable. The MRIO model shows that the Swedish emissions trading balance is negative with both the European Union and the rest of the world (i.e. embodied CO_2 emissions in imports are higher than embodied emissions in exports). Sweden's low-carbon intensity is a critical and horizontal explanatory factor in our results.

1. Introduction

There is growing consensus that traditional economic models have had significant negative effects. It has been argued that they have led to loss of natural capital, unsustainable energy production and consumption, climate instability, social inequalities, and even proven to be economically unsound [1–5]. Consequently, since the 2008–2009 global financial crisis, 'Green Growth', 'New Green Economy' and 'Green Energy Economy' have received increasing attention, and several OECD countries have implemented so-called 'green' economic recovery packages (e.g. [6,7]. With a strong focus on green energy technologies, these recovery packages have been implemented to stimulate green growth and support low-carbon economies, among several policy objectives. Here, a 'Green Energy Economy' refers to an energy-economic system that pursues growth through the expansion of low-carbon energy production, distribution and consumption. As it aims to reduce CO_2 emissions [8], it has important impacts on climate change mitigation.

In this context, several claims have been made about Sweden's success. For example, it has been argued that Sweden has combined welfare development with climate protection to build a green economy [9]. Sweden has been ranked among the world's top green economies [10], created through increased wealth and

Abbreviations: E-3 indicators, Energy-Economy-Environment indicators; ETB, Emissions Trading Balance; EE, Embodied Emissions; IOA, Input–Output analysis; GTAP database, Global Trade Analysis Project database; MRIO model, multiregional input–output model; TPES, Total Primary Energy Supply; VIF, Variance Inflation Factors; WIOD, World Input Output Database.

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jobs, and reduced carbon emissions [11]. While such assertions may hold true for certain sectors (e.g. bioenergy as the literature has pointed [12–14]) there is a lack of sound, peer-reviewed analyses and empirical macroeconomic data. Not only is there a lack of consensus on the definition of a 'green economy', but most of the current scientific literature focuses on empirical evaluations of specific policy instruments, such as a Carbon Tax [15], Tradable Green Certificates [16] and the Programme for Energy Efficiency Improvements [17].

The lack of ex-post studies of macroeconomic-climate aspects of green economies may be explained by the fact that theoretical frameworks and assessment methods are still being developed. Current approaches address specific concerns about job creation or technology patents [18] or the broader issues of sustainable development [7]. At the same time efforts are being made by the Swedish Environmental Protection Agency to support prospective research on production and consumption in a low-carbon economy [19].

Against this background, this paper provides a quantitative macroeconomic-climate assessment of Swedish progress towards a green energy economy. It provides a detailed empirical analysis of production and consumption patterns underlying CO_2 emissions -a rather critical focal point in the green economy policy discourse [7,20,21] and is based on three quantitative approaches, namely: (a) energy-economy-environment (E-3) indicators, (b) an econometric assessment, and (c) a multi-region input–output (MRIO) model. In recent decades concern has grown that reductions in CO_2 emissions in industrialized countries are being cancelled out by imports [22–27]. Therefore our MRIO model examines the role of trade in reducing Swedish CO_2 emissions.

To the best of our knowledge, this is the first empirical analysis of Sweden's CO_2 emissions from an integrated macroeconomic-climate perspective. Using the best available and longest time series data, the three methods are complementary, as they address both the production and consumption side of the Swedish energy-economic system. The two first ones, the indicator and econometric analyses, decompose the production side in different macro-economic indicators, which are heavily used to measure progress towards a green economy [7]. The novelty of the MRIO analysis is the provision of not only CO_2 emissions caused by the Sweden's production side (complementing the modelling and figures obtained by the first set of methods) but also generates estimates resulting from Sweden's consumption side. This approach stresses the systemic view of our analysis and also the role of trading and (potential) carbon leakage of 'national' economic systems, which may favour the outsourcing of production to countries with less costs related to labour and climate policies. For this reason, the aim of this paper is to understand if the path of Sweden to a green economy is coherent not only from a production perspective (that seems to be the case), but also from a consumption point of view. The paper is structured as follows. Section 2 describes the methodology. Section 3 presents the main outcomes. Results are divided into findings coming from E-3 indicators, econometric analyses, and the MRIO analysis. Finally, Section 4 draws some conclusions.

2. Methodology and data sources

Our methodology is based on a quantitative empirical approach. It deploys three complementary analytical tools, namely (a) energy-economy-environment (E-3) indicators; (b) an econometric assessment and (c) a multi-region input–output (MRIO) sectoral model. Details are given below.

Table 1
Data for Sweden for years 1971, 1990 and 2011.

Indicator	1971	1990	2011
CO_2 emissions (Mt)	82.4	52.8	44.9
Population (millions)	8.1	8.6	9.5
TPES (Mtoe)	36.0	47.2	49.0
GDP_{ppp} per capita (2005 USD)	17 374	24 567	35 121
Energy intensity (toe per thousand 2005 USD GDP_{ppp})	0.26	0.22	0.15
Carbon intensity (tCO_2/Tj)	54.6	26.7	21.9

Data source: IEA [30].

2.1. E-3 Indicators

We start with the 'I = PAT' equation[1] [28] and the 'Kaya Identity' [29] to define and estimate indicators. The analysis is based on International Energy Agency (IEA) time series data for the period 1971–2011 [30]. The 'Kaya Identity' builds upon the I = PAT equation; it is a macro decomposition of the energy, economic and demographic indicators used to quantitatively estimate CO_2 emission levels. In this study, the following indicators were estimated or used: Population, per capita Gross Domestic Product (GDP), Total Primary Energy Supply (TPES), Energy Intensity and Carbon Intensity (see Table 1 for definitions and Table 2 for Swedish data). The year 1990 was taken as a baseline and all absolute values were indexed to 100 in that year. We also benchmarked estimated values for Sweden against estimates for the OECD region, OECD Europe, the non-OECD region and the rest of the world.

2.2. Econometric assessment

We used various econometric tests to assess the contribution of different variables to Swedish CO_2 emissions. As the Swedish energy supply has a low carbon content, our initial hypothesis was that CO_2 intensity was most closely correlated with CO_2 emissions. Therefore we carried out bivariate correlation tests of causality among variables. These tests evaluated the relative degree of 'closeness' (or association) between each pair of the following indicators: CO_2 emissions (CO_2), Population (*Pop*), GDP_{ppp} per capita (*g*), energy intensity of GDP_{ppp} (*e_int*), and CO_2 emission intensity of TPES (*c_int*). Secondly, partial correlations were calculated. This step was necessary as more than one variable conveyed the same information -the problem of multicollinearity- which made it difficult to draw any inference about the relative contribution of a particular driver. Tests were applied to measure the correlation between CO_2 emissions and each independent variable to be included in our econometric model (next step), controlling for the effect of the remaining variables.

Thirdly, a stepwise regression analysis quantified the contribution of the various drivers of CO_2 emissions and made it possible to test the hypothesis that the CO_2 emission intensity of TPES (c_int) had the greatest impact. The analysis sequentially assessed the unique value of independent variables on CO_2 emissions. If the addition of a variable contributed to the model, it was retained, while all other variables were re-tested to identify whether they were still significant contributors. When a variable no longer contributed significantly to the model, it was removed. Our aim was to identify the regression equation that explained the greatest part of the variance of CO_2 emissions (i.e. the highest adjusted R^2), where p-values < 0.05 (for independent variables), the variation coefficient was lowest and there was no evidence

[1] The I=PAT equation evaluates the contribution of population P, affluence A (GDP per capita or level of consumption per person), and technology level *T* (environmental impact per unit of GDP) on the overall environmental impact I.

of multicollinearity. For the latter, Variance Inflation Factors (VIF) were computed, with a maximum threshold value of five. Consistent with current work [31], the following initial econometric model was applied:

$$CO_2 = Pop \cdot \left(\frac{GDP_{ppp}}{Pop}\right) \cdot \left(\frac{TPES}{GDP_{ppp}}\right) \cdot \left(\frac{CO_2}{TPES}\right) = Pop \cdot g \cdot e\_int \cdot c\_int \tag{1}$$

where the dependent variable CO_2 represents the emissions from fuel combustion and industrial processes. CO_2 emissions are the product of four driving factors: Pop is the population, $\frac{GDP_{ppp}}{Pop} = g$ is the per-capita GDP_{ppp}, $\frac{TPES}{GDP_{ppp}}=$ e_int is the energy supply intensity of GDP_{ppp}, and $\frac{CO_2}{TPES} = c\_int$ is the CO_2 intensity of the total primary energy supply TPES. All estimates used a 95% confidence level unless otherwise stated.

Based on the above, a multiple regression model for Sweden was formulated as follows:

$$Y_t = \beta_0 + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} + \beta_4 X_{4t} + \mu_t \tag{2}$$

where Y_{it} = CO_2 emissions (in million tonnes) from fuel combustion (dependent variable), $t = 1 \ldots T$ years (=41); β_0 is a constant intercept; β_1, β_2, β_3 and β_4 are the regression coefficients to be estimated for X_1 *(Pop)*, X_2 *(g)*, X_3 *(e_int) and* X_4 *(c_int)* respectively; and μ_{it} is an unobserved error in the model.

2.3. Multi-region input–output analysis

We use a multi-region input–output (MRIO) model to investigate consumption-based emission patterns in Sweden. Input–Output Analysis (IOA), which is the basis for our MRIO model, is a method that is used to understand and account for the links between consumption and production [32]. It is increasingly used in climate research to analyse the displacement of emissions due to imports [23,33].

Our MRIO model was based on data from the World Input Output Database (WIOD) for 2000 and 2009, which includes World Input–Output tables and Environmental Accounts [34].[2] These years were selected as they are the most recent dataset and include details of emission levels equivalent to those of 1990 (i.e. 2000).[3] The data is aggregated into three regions: u (region of origin, i.e. Sweden), r (region 2, in our case the rest of the European Union) and w (region 3, in our case the rest of the world).

The MRIO model begins with the Leontief quantities model and assumes that economic activity can be disaggregated into n productive sectors. Total economic output can be decomposed into final and intermediate demand, as indicated in the following equation:

$$X = A \cdot X + Y \tag{3}$$

where X is a matrix that represents the total production of goods and services; the matrix AX expresses intermediate demand; A is a technical coefficient $n \times n$ matrix which indicates the production inputs to each sector for all the sectors and regions included in the analysis; and the matrix Y represents final demand of all goods and services.

[2] Although WIOT (world input–output tables) have been published for 2010 and 2011, Environmental Accounts are only available up to 2009, which is why our MRIO model was only implemented up to 2009. For further information about the WIOD, see Dietzenbacher et al. [35] and/or visit www.wiod.org

[3] The WIOD database provides detailed information on domestic production and international trade in 40 individual countries and the rest of the world, disaggregated into 35 production sectors.

If expression (3) is re-ordered, the following expression is obtained:

$$X = (I - A)^{-1} \cdot Y \tag{4}$$

where I is the identity matrix and the expression $(I - A)^{-1}$ is the Leontief inverse matrix, which shows the production requirements of the economy.

The MRIO model allows us to analyse links between CO_2 emissions, production sector and final demand. To obtain this, the emission coefficient matrix $\widehat{C}$, represents total emissions (in tonnes) per thousand US dollars of production in each of the n sectors. Total emissions c can be calculated as:

$$c = \widehat{C} \cdot (I - A)^{-1} \cdot Y = \widehat{C} \cdot L \cdot Y \tag{5}$$

where A is the matrix of technical coefficients; Y is the final demand matrix; C is the emission coefficient matrix and L is the Leontief inverse matrix. Total CO_2 emissions in country u when all three regions are considered are expressed by following equation:

$$\begin{aligned}
&\begin{pmatrix} \widehat{C}_u & 0 & 0 \\ 0 & \widehat{C}_r & 0 \\ 0 & 0 & \widehat{C}_w \end{pmatrix} \begin{pmatrix} L^{uu} & L^{ur} & L^{uw} \\ L^{ru} & L^{rr} & L^{rw} \\ L^{wu} & L^{wr} & L^{ww} \end{pmatrix} \begin{pmatrix} Y_{uu} & 0 & 0 \\ 0 & Y_{ru} & 0 \\ 0 & 0 & Y_{wu} \end{pmatrix} \\
&+ \begin{pmatrix} \widehat{C}_u & 0 & 0 \\ 0 & \widehat{C}_r & 0 \\ 0 & 0 & \widehat{C}_w \end{pmatrix} \begin{pmatrix} L^{uu} & L^{ur} & L^{uw} \\ L^{ru} & L^{rr} & L^{rw} \\ L^{wu} & L^{wr} & L^{ww} \end{pmatrix} \begin{pmatrix} Y_{ur} & 0 & 0 \\ 0 & Y_{rr} & 0 \\ 0 & 0 & Y_{wr} \end{pmatrix} \\
&+ \begin{pmatrix} \widehat{C}_u & 0 & 0 \\ 0 & \widehat{C}_r & 0 \\ 0 & 0 & \widehat{C}_w \end{pmatrix} \begin{pmatrix} L^{uu} & L^{ur} & L^{uw} \\ L^{ru} & L^{rr} & L^{rw} \\ L^{wu} & L^{wr} & L^{ww} \end{pmatrix} \begin{pmatrix} Y_{wu} & 0 & 0 \\ 0 & Y_{wr} & 0 \\ 0 & 0 & Y_{ww} \end{pmatrix} \\
&= \widehat{C}(I - A)^{-1}(Y_u + Y_r + Y_w)
\end{aligned} \tag{6}$$

where

$$\begin{aligned} Y_u &= Y_{uu} + Y_{ru} + Y_{wu} \\ Y_r &= Y_{ur} + Y_{rr} + Y_{wr} \\ Y_w &= Y_{uw} + Y_{rw} + Y_{ww} \end{aligned}$$

Once equation (5) is calculated, the following expression is obtained:

$$\begin{aligned}
&\begin{pmatrix} \widehat{C}_u L^{uu} Y_{uu} & \widehat{C}_u L^{ur} Y_{ru} & \widehat{C}_u L^{uw} Y_{wu} \\ \widehat{C}_r L^{ru} Y_{uu} & \widehat{C}_r L^{rr} Y_{ru} & \widehat{C}_r L^{rw} Y_{wu} \\ \widehat{C}_w L^{wu} Y_{uu} & \widehat{C}_w L^{wr} Y_{ru} & \widehat{C}_w L^{ww} Y_{wu} \end{pmatrix} \\
&+ \begin{pmatrix} \widehat{C}_u L^{uu} Y_{ur} & \widehat{C}_u L^{ur} Y_{rr} & \widehat{C}_u L^{uw} Y_{wr} \\ \widehat{C}_r L^{ru} Y_{ur} & \widehat{C}_r L^{rr} Y_{rr} & \widehat{C}_r L^{rw} Y_{wr} \\ \widehat{C}_w L^{wu} Y_{ur} & \widehat{C}_w L^{wr} Y_{rr} & \widehat{C}_w L^{ww} Y_{wr} \end{pmatrix} \\
&+ \begin{pmatrix} \widehat{C}_u L^{uu} Y_{uw} & \widehat{C}_u L^{ur} Y_{rw} & \widehat{C}_u L^{uw} Y_{ww} \\ \widehat{C}_r L^{ru} Y_{uw} & \widehat{C}_r L^{rr} Y_{rw} & \widehat{C}_r L^{rw} Y_{ww} \\ \widehat{C}_w L^{wu} Y_{uw} & \widehat{C}_w L^{wr} Y_{rw} & \widehat{C}_w L^{ww} Y_{ww} \end{pmatrix} \\
&= \begin{pmatrix} gdom_u^u \\ gimp_r^u \\ gimp_w^u \end{pmatrix} + \begin{pmatrix} gexp_r^u \\ gdom_r^r \\ gexp_r^w \end{pmatrix} + \begin{pmatrix} gexp_w^u \\ gexp_w^r \\ gdom_w^w \end{pmatrix}
\end{aligned} \tag{7}$$

The above matrices (Eq. (6)) provide two sets of information. The first (production-based) shows emissions generated by domestic production, whether consumed internally or abroad (through

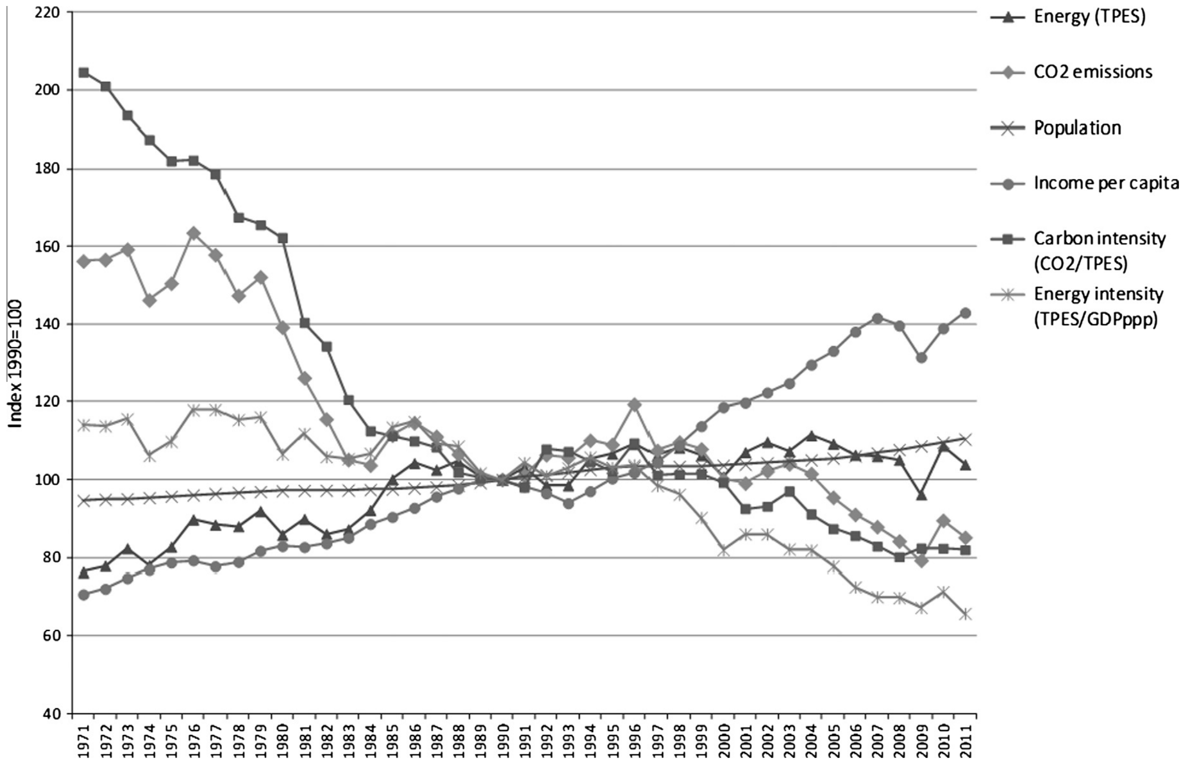

Fig. 1. Estimated indicators for Sweden (1971–2011). All values are indexed to 100 at 1990. See Table 1 for data sources.

exports). The second (consumption-based) provides information about emissions generated by domestic consumption of both national and foreign outputs (through imports).

Therefore, production-based total emissions in region u are given by:

$$gdom_u^u + gexp_r^u + gexp_w^u \tag{8}$$

and consumption-based total emissions in region *u* are given by:

$$gdom_u^u + gimp_r^u + gimp_w^u \tag{9}$$

The difference between the two is the Emissions Trading Balance (ETB):

$$\begin{aligned} ETB &= gdom_u^u + gexp_r^u + gexp_w^u - (gdom_u^u + gimp_r^u + gimp_w^u) \\ &= gexp_r^u + gexp_w^u - gimp_r^u - gimp_w^u \end{aligned} \tag{10}$$

3. Main findings

3.1. Estimated indicators

Fig. 1 Shows estimated indicators for Sweden indexed to 1990. Pre-1990, there were substantial decreases in both CO_2 intensity and CO_2 emissions. In particular, there was a sharp decrease (approximately 60%) in CO_2 emissions between the mid-1970s and the mid-1980s. The trend is consistent with the decarbonisation of Sweden's energy supply, which fell by nearly 80% due to the expansion of nuclear power that displaced oil in electricity generation[4]; followed by a greater share of biofuels and use of waste-to-energy after the mid-1980s [36]. For this specific period, absolute values of CO_2 emissions fell from 86.3 Mt in 1976 to 54.7 Mt in 1984 (Fig. 2), while electricity production was dominated by hydro and nuclear power (44% and 39% of the fuel mix in 2010 respectively).

Sweden's CO_2 intensity reflects its lack of dependency on fossil fuels. Its low-carbon fuel mix and the rapid expansion of commercial bio-energy for electricity and heating is reflected in significant reductions in CO_2 intensity pre-1990 and a relatively sustained decarbonisation of the energy supply (Fig. 1). Post-1990 there was an overall improvement of around 20%, which lasted until 2008–2009. While pre-1990 reductions in CO_2 emissions were mostly due to reduced CO_2 intensity, post-1990 reductions were a combination of reductions or reversals in energy intensity, CO_2 intensity and energy use. Post-2000, bioenergy played an increasingly important role. At the risk of oversimplifying, and from an 'environmental-effectiveness' perspective, this can be attributed to the removal of several barriers (e.g. financing), the incentives provided by the energy and CO_2 taxation[5] and the implementation of mandatory quotas from renewable energy (cf. [16,37].[6]

With certain exceptions (e.g. the national banking crisis in 1991–1993, the effects of global financial crisis in 2008–2009), there was clear growth in energy use pre-1990, which then slowed (Fig. 2). Overall, there were no marked reductions in energy use and estimates show long-term fluctuations. There was an average increase of 5% in TPES in the period 1990–2011. At the same time, there was a relatively sustained reduction in energy intensity. Pre-1990, energy intensity decreased very slowly, with absolute values at around 1971 levels. It was only after the mid-1990s that there

[4] Note that after France, Sweden is the second-largest generator of nuclear power in IEA member countries, equivalent to approximately 16 Mtoe of electricity production in 2011.

[5] Biofuels (and peat) are exempt from the CO_2 tax.

[6] In terms of cost-effectiveness (i.e. whether a given target is met with the lowest possible cost), the Swedish green certificate scheme has been severely criticised [16,38, 39].

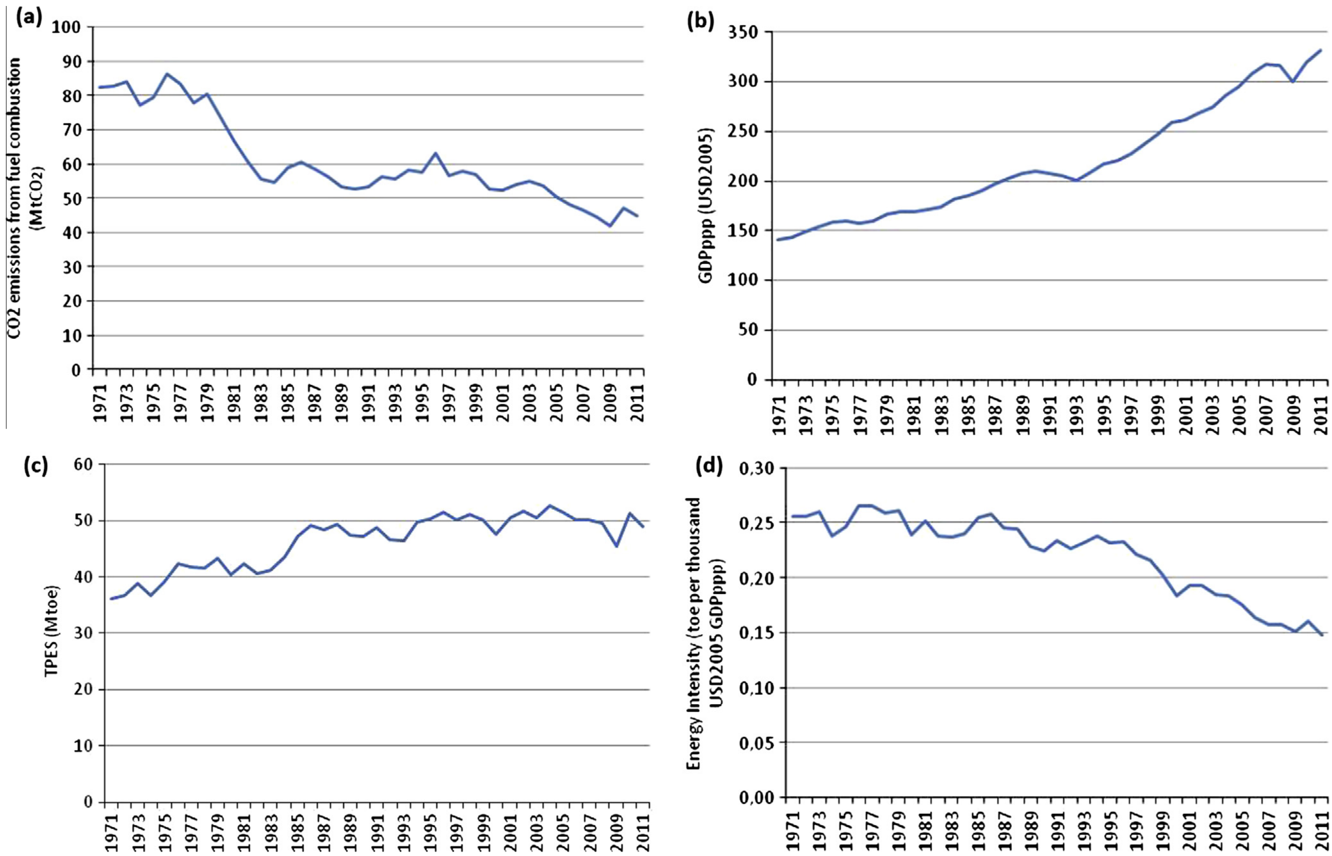

Fig. 2. Estimated absolute values for Sweden (1971–2011): (a) CO_2 emissions from fuel combustion, (b) gross domestic product, adjusted for purchasing power parities (GDP_{ppp}), (c) total primary energy supply (TPES), and (d) energy intensity (TPES/GDP_{ppp}).

was a more marked decline, and by 2011 there was an approximate reduction of 35% energy intensity compared to 1990 levels. This post-1990 progress can be mostly attributed to increases in economic activity (as measured by GDP_{ppp}) rather than reductions in energy use (Figs. 1 and 2) as there are clear increases in GDP_{ppp} growth and GDP_{ppp} per capita for the entire period. In absolute terms, energy intensity estimated at 0.26 in 1971 and reached 0.15 toe/thousand USD 2005 GDP_{ppp} in 2011.

Despite economic setbacks, major reductions in energy intensity were achieved in 2000 (18%) and late 2007 (28%). These results are consistent with the findings of [40], who identified energy intensity as the main driving factor behind reductions in Swedish CO_2 emissions for the period 2001–2008. Our review of the literature highlighted that in the absence of foreign trade, there would have been even greater reductions in energy intensity and Sweden would have been a net energy exporter until at least the year 2000 [41].

After 2008–2009, the Swedish indicators are consistent with the so-called 'Carbon Emission Rebound effect' that most regions in the world experienced in 2010 [3]. This took the form of increased energy use, economic activity and CO_2 emissions, which led to increases in energy intensity and halted progress in the reduction of CO_2 intensity. In Sweden, the fall in CO_2 intensity ceased to decrease after 2008–2009 (Fig. 1)

Taking into consideration relevant cross-sectional heterogeneity in economic growth, energy use, technology level and resulting CO_2 emissions [42,31], we briefly benchmarked estimated indicators and related trends for Sweden with different regions (see Fig. 3). Although there is a risk of oversimplification, there are obvious differences – in particular for CO_2 emissions and CO_2 intensity. Pre-1990, Sweden made clear progress compared to OECD and OECD Europe regions. This is in dramatic contrast to the sharp acceleration in global CO_2 emissions [31]. Post-1990 (in particular between 2003 and 2008) the combined effect of reduced energy and CO_2 intensities led to further Swedish CO_2 emission reductions compared to other regions [40]. The indicators also reveal that Sweden's increasing GDP_{ppp} per capita correlated well with other regions, particularly from 1971 until 2001–2002 (with the exception of 1991–1993) when growth in emerging economies (e.g. China, Brazil and India) became much higher. The analysis of energy intensities suggests a clear downward trend, in particular post-1990 (again with the exception of 1991–1993). Although estimated indicators show energy intensity convergence across selected regions (including Sweden), more detailed analyses reveal that regions are converging at significantly dissimilar rates [43,3].

3.2. Econometric results

The results of bivariate correlation tests are shown in Table 2. All the tested independent variables showed the potential to individually explain the variability of Sweden's CO_2 emissions. Relationships between CO_2 and all independent variables were statistically significant, with p-values below 0.05. The CO_2 intensity of energy supply (c_int) had the highest correlation (96.9%) followed by GDP per capita (g) (83.2%), population (Pop) (81.3%) and energy intensity (e_int) (78.2%). The close correlation between CO_2 and c_int is consistent with the decarbonisation of Sweden's energy supply in the early 1970s. Despite the significant correlations between variables, the fact that independent variables were themselves highly correlated (e.g. 96.1% between e_int and g) indicated signs of multicollinearity.

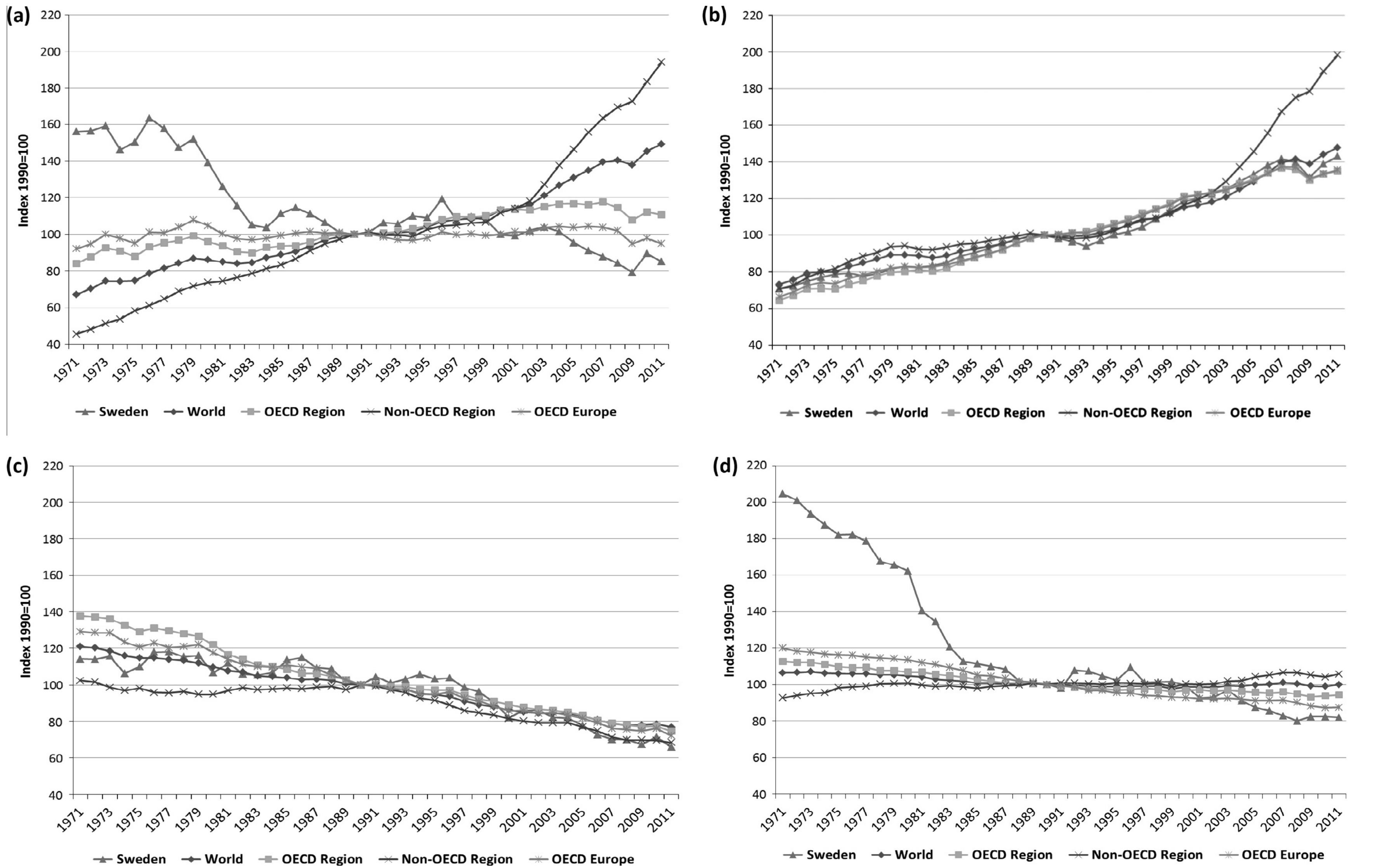

Fig. 3. Estimated indicators for Sweden and other regions of the world (1971–2011): (a) CO_2 emissions from fuel combustion, (b) GDP_{ppp} per capita, (c) energy intensity, and (d) CO_2 intensity. All values are indexed to 100 at 1990. Data source IEA [30].

Table 2
Results of bivariate correlation tests.

		CO_2	Pop	G	e_int	c_int
CO_2	Correlation	1	−0.813	−0.832	0.782	0.969
	p		0.000	0.000	0.000	0.000
	N	41	41	41	41	41
Pop	Correlation	−0.813	1	0.955	−0.925	−0.823
	p	0.000		0.000	0.000	0.000
	N	41	41	41	41	41
g	Correlation	−0.832	0.955	1	−0.961	−0.832
	p	0.000	0.000		0.000	0.000
	N	41	41	41	41	41
e_int	Correlation	0.782	−0.925	−0.961	1	0.725
	p	0.000	0.000	0.000		0.000
	N	41	41	41	41	41
c_int	Correlation	0.969	−0.823	−0.832	0.725	1
	p	0.000	0.000	0.000	0.000	
	N	41	41	41	41	41

Estimated parameters from the partial correlation tests confirmed our initial hypothesis that *c_int* was most significantly correlated with CO_2 emissions (Table 3). When others variables were controlled, the correlation between CO_2 and c_int increased to 97.9% (compared to 96.9% in bivariate correlation tests). This result suggests that the correlation between CO_2 and c_int was slightly mediated by the other variables. Partialling out Pop, g and e_int individually suggested that Pop was the principle mediator, as it showed the lowest correlation with CO_2 (52.4%) when the effects of c_int, g and e_int were controlled. Partial correlation tests also indicated that both g and in particular e_int were highly correlated with CO_2 (77.7% and 88.9% respectively).

The results of the stepwise multiple regression are shown in Table 4. Consistent with bivariate and partial correlation tests, all variables were kept in the model (referred to as 'Model 1'). Estimated parameters showed that Model 1 was significant ($F_{4,\ 36} = 720.33$; *p*-value = .000 [i.e. $p < 0.05$]); including all its independent variables. The adjusted R^2 was 0.986, indicating that 98.6% of the variability of CO_2 emissions was explained collectively by c_int, Pop, g and e_int although, e_int and Pop contributed marginally to the model's coefficient of determination (1.3% and 0.5% respectively). Estimated coefficients showed that c_int ($\beta = 1.14$) had the greatest impact on CO_2 emission levels when all other variables were held constant. The coefficient of variation of the estimated regression model ($Coef\_Var_{reg}$ = Std. error estimate (±1.47)/mean value of CO_2 emissions (60.73 $MtCO_2$)) yielded a value of 2.42%, which suggested that the estimated Model 1 was useful in predicting CO_2 emission interval values, as the estimated ratio was lower than the 10% maximum allowed threshold. However, Variance Inflation Factors (VIF) revealed strong evidence of multicollinearity, as estimated values were much higher than the defined maximum threshold level (VIFg = 30.5).

Based on the above, and taking into consideration correlation tests and estimated coefficients, new models with different independent variables were computed. In this case, each highly-correlated independent variable was removed individually. Finally, the regression equation that explained the most variance of CO_2 (i.e. highest adjusted R^2), where $p < 0.05$ (for independent variables), the coefficient of variation was lowest and there was no evidence of multicollinearity was adopted. This second, stepwise, approach resulted in 'Model 2', which was significant ($F_{2,\ 40} = 376.40$; $p = .000$) with only c_int and e_int as statistically significant predictors. The adjusted R^2 was still very high, indicating that 94.9% of the variability of CO_2 emissions was explained collectively by c_int and e_int (slightly lower than in Model 1). The standard error was slightly higher (±2.82 $MtCO_2$) than in Model 1; however the coefficient of variation of Model 2 was still 4.65% – this was lower than the 10% threshold and suggested that Model 2 would also be useful in predicting CO_2 emission interval values. Another relevant point is that estimated coefficients confirmed that c_int ($\beta = 0.847$) had the highest impact on CO_2 emission

Table 3
Results of partial correlation tests.

Control variables: *g, e_int, c_int*			CO_2	Pop
	CO_2	Correlation	1	0.524
		p	–	0.001
		df	0	36
	Pop	Correlation	0.524	1
		p-value	0.001	–
		df	36	0
Control variables: *e_int, c_int, Pop*			CO_2	g
	CO_2	Correlation	1	0.777
		p	–	0.000
		df	0	36
	g	Correlation	0.777	1
		p-value	0.000	–
		df	36	0
Control variables: *c_int, Pop, g*			CO_2	e_int
	CO_2	Correlation	1	0.889
		p	–	0.000
		df	0	36
	e_int	Correlation	0.889	1
		p-value	0.000	–
		df	36	0
Control variables: *g, Pop, e_int*			CO_2	c_int
	CO_2	Correlation	1	0.979
		p	–	0.000
		Df	0	36
	c_int	Correlation	0.979	1
		p-value	0.000	–
		Df	36	0

Table 4
Summary of results from the stepwise regression method.

		R	R^2		Adjusted R^2		Std. Error
Regression statistics							
Model 1		0.994	0.988		0.986		1.47
Model 2		0.976	0.952		0.949		2.82
ANOVA		Sum of squares	df	Mean square		F	p
Model 1	Regression	6233.54	4	1558.38		720.33	0.000
	Residual	77.88	36	2.16			
	Total	6311.43	40				
Model 2	Regression	6008.15	2	3004.07		376.40	0.000
	Residual	303.27	38	7.98			
	Total	6311.43	40				
Coefficients		β (Standardised)	Std. Error	t		p	VIF
Model 1	(Constant)	−165.77	21.41	−7.74		0.000	–
	P	0.240	2.11	3.69		0.001	12.32
	g	0.758	0.00	7.40		0.000	30.54
	e_int	0.905	27.08	11.63		0.000	17.66
	c_int	1.142	0.04	28.93		0.000	4.54
Model 2	(Constant)	14.15	2.88	4.90		0.000	–
	e_int	0.168	17.96	3.26		0.002	2.10
	c_int	0.847	0.06	16.40		0.000	2.10

Table 5
Estimated emissions trading balance (ETB) for Sweden (u) with the European Union (r) and the rest of the world (w).

	Results (kt CO_2) 2000				Results (kt CO_2) 2009			
	u	r	w	Total	u	r	w	Total
Production (A)	23282	9938	14629	47849	22294	10756	20196	53246
Consumption (B)	23282	20554	17351	61187	22294	20762	22042	65097
ETB (A-B)	0	−10616	−2723	−13338	0	−10005	−1846	−11851

levels. Finally, VIF measures revealed no evidence of multicollinearity; estimated tolerance values for independent variables were equal to 2.10, which was lower than the maximum threshold. This indicated that the results regarding estimated individual predictors were reliable.

3.3. Sweden's CO_2 emissions trading balance

Table 6 shows the MRIO model of the 'Emissions Trading Balance' (ETB). Region u is Sweden, r is the European Union (EU) and w includes the rest of the world. As described above, the ETB is the difference between 'Embodied Emissions' (EE) in exports and imports. It covers the years 2000 and 2009, i.e. prior to, and just after, the economic crisis of 2008. These dates were chosen as 2009 is the latest year for which Environmental Accounts data is available in the WIOD [34].

Table 5 shows that in both 2000 and 2009, EE in Swedish imports were higher than in exports and the ETB was negative in both years. The difference was 27% and 22% in 2000 and 2009 respectively. However, some points need to be stressed. Firstly, in EU trade, EE in imports were around double EE in exports in both years. This finding is interesting, as it shows that although Swedish production helped to reduce territorial CO_2 emissions, the country's consumption of EU goods and services increased total emissions. Secondly, in 2000 EE in imports from the rest of the world were about 19% higher than EE in exports, while in 2009, although the difference remained negative, it fell to 9%. This is explained by the fact that EE in Swedish exports to the rest of the world increased rapidly (in 2009, EE in Swedish exports to the rest of the world were double those to the EU). Fourthly, and regardless of the actual volume of trade, Sweden's low-carbon intensity electricity production is a critical explanatory factor.

Our findings are consistent with those of Carlsson-Kanyama et al. [44],[7] who found that Sweden was a net importer of CO_2 emissions. Their study used the Global Trade Analysis Project (GTAP) database[8] [45] and was based on previous work [46,47]. While some authors [48,49] have argued that foreign trade has improved the Swedish environmental situation in recent decades (the displacement hypothesis), less sophisticated input–output models [41] have failed to find support.

3.3.1. Sweden's CO_2 emissions trading balance with the EU

Table 6 shows that the estimated ETB between Sweden and the EU was negative in both 2000 (−10616 kt) and 2009 (−10005 kt) and Sweden's CO_2 emissions were driven by consumption rather than production. Table 6 shows that there were significant differences in EE in exports and imports between Sweden and individual EU countries. In both 2000 and 2009, Sweden's ETB with most EU countries was negative.

Table 6 shows that in 2000 most EE in Swedish imports from the EU came from: Germany (DE) (3752 kt), the United Kingdom (UK) (2996 kt), Denmark (DK) (2453 kt), Poland (PL) (1970 kt), Finland (FI) (1659 kt) and the Netherlands (NL) (1484 kt). These countries remained the highest contributors to EE in imports in 2009, although with different weights: Germany (DE) (3873 kt), Finland (FI) (2249 kt), Denmark (DK) (2222 kt), the United Kingdom (UK) (2139 kt), Poland (PL) (2019 kt) and the Netherlands (NL) (1852 kt). Table 6 also shows that in 2009 Sweden exported most of its EE to: Germany (DE) (1945 kt), the

[7] The model used by Carlsson-Kanyama covered 87 regions and 57 sectors (18 primary industries, 28 secondary and 11 tertiary).

[8] GTAP data is contributed voluntarily by users and Swedish input–output data come from 1985. However emissions data was updated for the year 2001 and the model represents the world economy in 2001. Given that the GTAP database is based on data from different sources and years, results should be viewed with caution.

Table 6
Embodied Emissions (EE, in kt) in Swedish imports and exports and the Emissions Trading Balance (ETB) with the EU and the rest of the world for 2000 and 2009.

	2000			2009		
	EE in exports	EE in imports	ETB	EE in exports	EE in imports	ETB
EU-27						
AUSTRIA (AT)	360	251	109	230	292	−62
BELGIUM (BE)	386	1104	−718	457	1158	−700
BULGARIA (BG)	11	131	−120	29	139	−110
CYPRUS (CY)	13	8	5	15	8	7
CZECH REPUBLIC (CZ)	82	373	−291	122	522	−400
GERMANY (DE)	1997	3752	−1755	1945	3873	−1928
DENMARK (DK)	1023	2453	−1431	1088	2222	−1134
ESTONIA (E)	25	405	−380	47	310	−262
GREECE (EL)	108	104	4	140	153	−14
SPAIN (ES)	546	684	−138	698	775	−76
FINLAND (FI)	739	1660	−920	821	2249	−1429
FRANCE (FR)	954	1044	−90	1194	976	218
HUNGARY (HU)	60	152	−92	79	209	−131
IRELAND (IE)	81	181	−99	111	142	−32
ITALY (IT)	762	842	−80	784	790	−5
LITHUANIA (LT)	39	265	−226	64	174	−110
LUXEMBOURG (LU)	21	22	0	30	16	14
LATVIA (LT)	36	64	−28	52	77	−25
MALTA (MT)	4	3	1	5	7	−1
NETHERLANDS (NL)	567	1484	−918	530	1852	−1321
POLAND (PL)	284	1970	−1686	381	2019	−1638
PORTUGAL (PT)	100	178	−78	118	241	−123
ROMANIA (RO)	31	227	−196	72	173	−101
SLOVENIA (SL)	23	34	−11	29	44	−15
SLOVAKIA (SK)	20	167	−147	50	204	−153
UNITED KINGDOM (UK)	1664	2996	−1333	1664	2139	−475
SUB-TOTAL	9938	20554	−10616	10756	20762	−10005
REST OF THE WORLD						
AUSTRALIA (AUS)	202	311	−109	336	326	10
BRAZIL (BRA)	2049	317	1732	293	529	−236
CANADA (CAN)	299	709	−410	345	543	−197
CHINA (CHN)	410	2755	−2345	1770	8177	−6407
INDONESIA (IDN)	82	242	−159	173	217	−44
INDIA (IND)	129	947	−818	348	1204	−856
JAPAN (JPN)	867	715	151	633	707	−74
KOREA (KOR)	280	555	−276	239	818	−579
MEXICO (MEX)	183	142	41	173	168	5
RUSSIA (RUS)	159	6609	−6450	396	5005	−4609
TURQUIA (TUR)	214	274	−60	245	329	−84
TAIWAN (TWN)	164	444	−280	113	857	−744
UNITED STATES (USA)	3079	3087	−8	2633	3024	−391
SUB-TOTAL	12498	138	12360	12498	138	12360

United Kingdom (1664 kt), France (FR) (1194 kt), Denmark (DK) (1088 kt) and Finland (FI) (821kt) (Fig. 4a and b).

In 2000, EE in Swedish imports from the EU mainly came from the following sectors: 'Electricity, Gas and Water Supply'[9] and 'Basic Metals and Fabricated Metal' (Table A, Appendix A). The 'Electricity, Gas and Water Supply' sector is important because it is both energy-intensive and key to the economy; Swedish demand for natural gas and electricity (from Germany)[10] explains part of the CO_2 emissions attributed to this sector. In addition, 'Air Transport' was responsible for a significant increase in EE in imports between 2000 and 2009 (Tables A and B, Appendix A). Finally, the 'Chemicals and Chemicals Products' and 'Coke, Refined Petroleum and Nuclear Fuel' sectors were notable for high levels of EE in imports, due to the traditional strength of the chemical industry in countries such as Germany, the United Kingdom and France. The most important sectors did not change between 2000 and 2009 (Table B, Appendix A), although the 'Inland Transport' sector increased its contribution.

EE in Swedish exports were linked to two sectors: 'Basic Metals and Fabricated Metal' and 'Coke, Refined Petroleum and Nuclear fuel' (Tables A and B, Appendix A). Demand from the EU for Swedish goods triggered an increase in Swedish production. 'Basic Metals and Fabricated Metal' EE were exported to Germany, the United Kingdom, Denmark, France and Italy, while 'Coke, Refined Petroleum and Nuclear fuel' EE exports were sent to Germany, Denmark and the United Kingdom.

3.3.2. Sweden's CO_2 emissions trading balance with the rest of the world

Like the EU, the Swedish ETB with the rest of the world was negative in both 2000 (−2723 kt) and 2009 (−1846 kt) (Table 6).

[9] According to the statistical classification of economic activities in the EU (NACE Rev 1.1), this sector covers NACE Division 40, and its activities are subdivided into three groups: The production and distribution of electricity (corresponding to NACE Group 40.1); The production and distribution of gas fuels through mains (NACE Group 40.2); and The production and distribution of steam and hot water supply (NACE Group 40.3).

[10] Electricity imports from Russia and Germany increased to 25 TWh in 2000, while in the period 1990–2000, electricity imports were stable (5 TWh approx.). Previous research has highlighted that imported electricity made up 3% of total Swedish electricity consumption in 2000 [41]. Annual results for the CO_2 embodied in imported electricity are influenced by two factors; the market and the weather. After the liberalization of the Swedish electricity market through the Nord Pool, price formation in the wholesale electric market played a very important role in determining who is an exporter or an importer. As hydropower is an important Swedish energy provider, weather is another key variable. 2010 was very dry in Norway and Sweden, which meant that both countries were net importers in that year. More information can be found in [50].

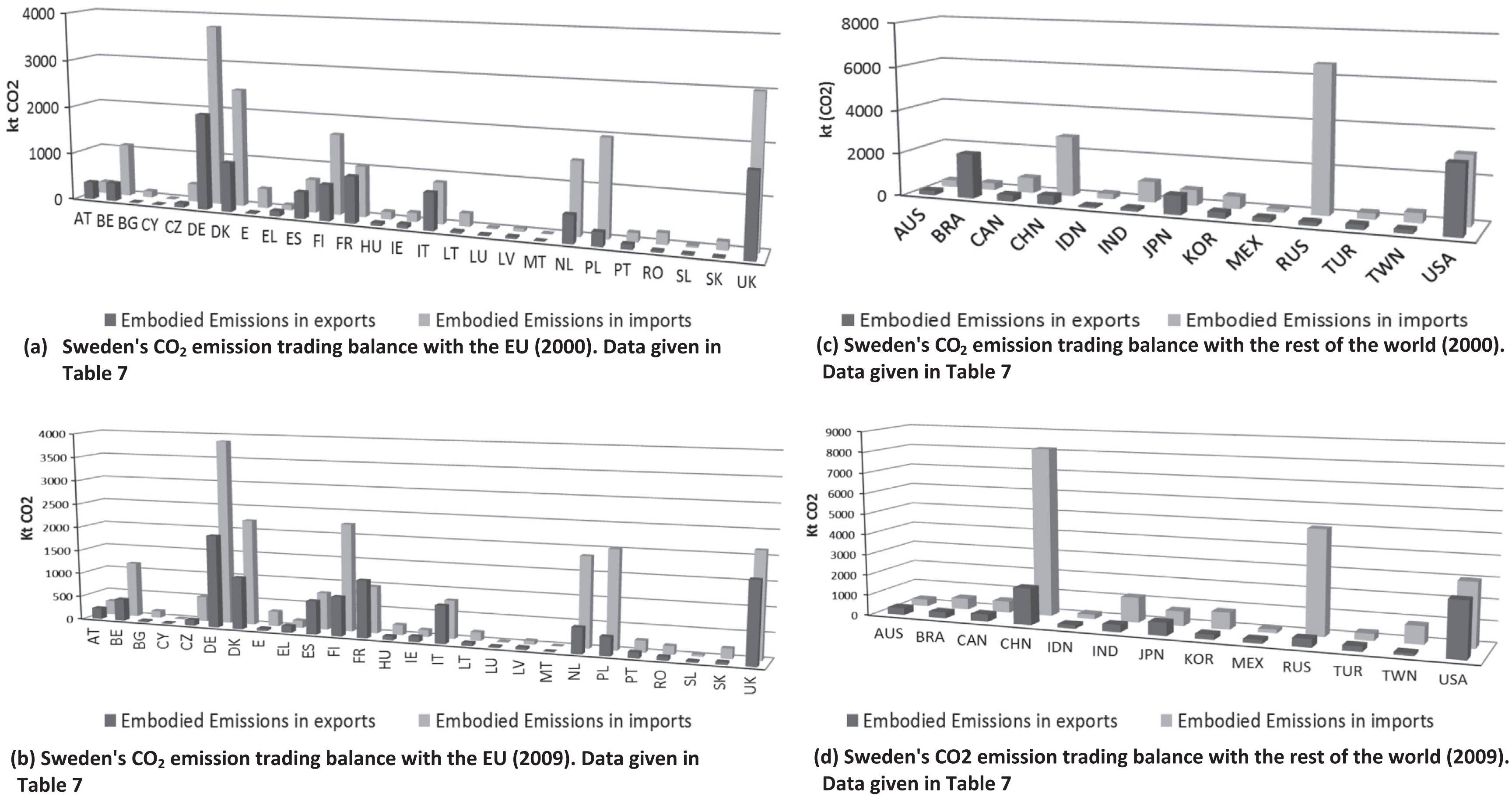

Fig. 4. Sweden's CO_2 emission trading balance with the EU and the Rest of the World. (a) Sweden's CO_2 emission trading balance with the EU (2000). Data given in Table 6, (b) Sweden's CO_2 emission trading balance with the EU (2009). Data given in Table 6, (c) Sweden's CO_2 emission trading balance with the rest of the world (2000). Data given in Table 6, (d) Sweden's CO2 emission trading balance with the rest of the world (2009). Data given in Table 6.

In 2009 there were particularly significant differences between EE in exports and imports with China and Russia (see Fig. 4c and d). In absolute terms, both China (−6407 kt) and Russia (−4609 kt) had a negative ETB with Sweden.

In 2000, the main countries responsible for EE in Swedish imports from the rest of the world included: Russia (RUS) (6609 kt), the United States (USA) (3079 kt), China (CHN) (2755 kt) and India (IND) (946 kt). In 2009, EE in Swedish imports came mainly from China (CHN) (8177 kt), Russia (RUS) (5005 kt) and the United States (3024 kt) (see Fig. 4c and d). For China in particular, the volume of EE in imports increased threefold between 2000 and 2009.

Our results suggest that the following sectors played a key role: 'Electricity, Gas and Water Supply', 'Basic Metals and Fabricated Metal', 'Inland Transport' and 'Mining and Quarrying' (see Tables A and B, Appendix A). Most EE in the 'Electricity, Gas and Water Supply' sector came from Russia (RUS), China (CHN), the United States (USA) and India (IDN). For the particular case of China, EE in imports from this sector increased from 1250 kt in 2000 to 4454 kt in 2009 (Tables A and B, Appendix A). The main reason for this is the fuel mix involved in the production of goods in these countries. A significant amount of goods and services that require electricity for their production are imported from countries with much higher carbon intensity than Sweden. The same argument applies to the 'Basic Metals and Fabricated Metal' sector. The 'Inland Transport' sector also generated a significant amount of EE in Swedish imports. This is due to EE in both land and oil transport via pipelines. Finally, EE in imports in the 'Mining and Quarrying' sector[11] were significantly higher than in exports. Most of this came from Russia, as Sweden meets around 37% of its primary energy needs through imports, which consist mainly of oil (84%) and solid fuels (12%). Russia is Sweden's main supplier of crude oil and Australia is the main supplier of hard coal.

Finally, our results showed that Sweden was a net exporter of CO_2 emissions in the 'Water transport[12]' and 'Basic Metals and Fabricated Metal' sectors. In the former, the figures are explained by the importance of the Swedish maritime trade and its relatively high CO_2 intensity. In the latter sector, results are consistent with those of trade with the EU; increased production is a response to growing demand from China, the United States and the rest of the world. This result is consistent with recent research about how international trade might influence negatively in the CO_2 reduction commitments [51].

4. Conclusion

Overall, our analysis led to the following concluding remarks. From the production side, CO_2 emissions reductions in Sweden are largely explained by substantial decreases in CO_2 intensity. Pre-1990 there was a sharp decarbonisation of Sweden's energy supply, with reductions (or reversals) in energy intensity, CO_2 intensity and energy use. Post-2000, reductions in energy intensity were mainly due to substantial increases in economic activity rather than absolute reductions in energy use. Consistent with the analysis of indicators, the econometric tests confirmed our initial hypothesis that CO_2 emission intensity of energy supply is the most highly correlated variable with CO_2 emissions. Combined with the energy supply intensity of GDP_{ppp}, these two variables explained most of the variability of CO_2 emissions in the period under analysis. From the consumption side (and complementing our understanding of the production side), estimates from the MRIO model showed that the Swedish Emissions Trading Balance with both the EU and the rest of the world was negative, i.e. CO_2 embodied emissions in imports were higher than embodied emissions in exports. Thus, in both cases Sweden was a net importer of CO_2 emissions and emissions generated by the global supply chain for imported products and services were higher than its territorial, production-based emissions. Therefore, from a production-consumption perspective, and with due limitations, these results also suggest that $C0_2$ emissions cuts in Sweden were cancelled out by imported goods – at least given the scope of our analysis. In all, our results suggest that Sweden has only seized the 'Green Energy Economy' opportunity from a production-based point of view. Sweden's low-carbon intensity electricity production appears to be a critical explanatory element in all three evaluation methods. Our findings strongly suggest that while domestic mitigation policies have been effective in decarbonising Sweden's energy-economy system (e.g. through bioenergy development), greater efforts need to be made to encourage low-carbon consumption in sectors with high embodied emissions in imports.

4.1. Further implications

Given Sweden's 'Climate Roadmap 2050', which sets a target of zero net emissions of greenhouse gasses and the goal of making the country's vehicle fleet independent of fossil fuels by 2030, bioenergy will inevitably become a more important energy carrier. Thus, cost-effective policies to encourage the sustainable supply of bioenergy are very likely to become crucial in reducing Sweden's CO_2 intensity. In addition, once the databases used in this paper are updated in the near future, our research might be revised in light of new empirics (e.g. to contrast the performance of Sweden's energy-economic system pre and post economic crisis).

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Appendix A

See Tables A and B.

[11] This sector includes following divisions: 'the extraction of solid mineral fuels through underground or open-cast mining', 'the production of crude petroleum, the mining and extraction of oil from oil shale and oil sands and the production of natural gas and recovery of hydrocarbon liquids' and 'the mining for metallic minerals (ores), performed through underground or open-cast extraction'.

[12] According to the statistical classification of economic activities in the EU (NACE), the water transport sector, corresponding to NACE Division 61, covers all water transport activities, including both sea and coastal and maritime transport (NACE Group 61.1) and inland water transport (NACE Group 61.2).

Table A
Sweden's CO_2 emissions embodied in international trade by sector in 2000 (kt).

	Total emissions			Region *u* (Sweden)			Region *r* (EU area)			Region *w* (Rest of the World)		
	Prod. Effect	Carbon Footprint	ETB	Prod. Effect	Carbon Footprint	ETB	Prod. Effect	Carbon footprint	ETB	Prod. Effect	Carbon footprint	ETB
Agriculture, Hunting, Forestry and Fishing	2486	2400	87	1529	1529	0	462	634	−171	495	237	258
Mining and Quarrying	598	2378	−1779	231	231	0	166	707	−541	201	1440	−1238
Food, Beverages and Tobacco	973	1177	−204	752	752	0	108	365	−257	114	60	53
Textiles and Textile Products	115	517	−402	17	17	0	71	226	−155	27	274	−247
Leather, Leather and Footwear	5	30	−26	0	0	0	3	15	−13	1	14	−13
Wood and Products of Wood and Cork	233	175	57	64	64	0	61	72	−11	108	39	69
Pulp, Paper, Paper , Printing and Publishing	2525	1210	1315	750	750	0	976	269	707	800	192	608
Coke, Refined Petroleum and Nuclear Fuel	2360	2914	−554	817	817	0	1068	1435	−367	475	662	−187
Chemicals and Chemical Products	1483	2717	−1234	283	283	0	595	1467	−872	605	967	−362
Rubber and Plastics	129	230	−101	30	30	0	47	128	−81	52	72	−20
Other Non-Metallic Mineral	3720	3945	−224	1940	1940	0	772	1276	−504	1008	729	279
Basic Metals and Fabricated Metal	6554	6571	−17	1796	1796	0	2289	2674	−385	2469	2101	368
Machinery, Nec	204	300	−96	43	43	0	68	161	−92	93	96	−3
Electrical and Optical Equipment	76	378	−301	12	12	0	24	221	−197	40	145	−104
Transport Equipment	299	431	−132	91	91	0	98	203	−105	109	136	−27
Manufacturing, Nec; Recycling	155	204	−49	55	55	0	56	108	−52	44	41	3
Electricity, Gas and Water Supply	6574	17858	−11284	5326	5326	0	581	5651	−5070	666	6881	−6215
Construction	1835	1690	145	1635	1635	0	82	42	40	117	13	104
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	1609	1105	503	1048	1048	0	197	42	155	364	15	348
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	0	252	−252	0	0	0	0	148	−148	0	104	−104
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	0	193	−193	0	0	0	0	103	−103	0	90	−90
Hotels and Restaurants	91	143	−53	79	79	0	5	16	−11	7	48	−42
Inland Transport	3361	4677	−1316	1996	1996	0	538	1201	−662	827	1480	−653
Water Transport	6028	2276	3752	618	618	0	797	1243	−446	4614	415	4198
Air Transport	2725	3167	−442	1207	1207	0	577	1562	−985	940	398	542
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	318	413	−96	154	154	0	62	137	−75	102	123	−21
Post and Telecommunications	155	216	−61	107	107	0	23	52	−29	25	57	−32
Financial Intermediation	53	112	−59	35	35	0	8	32	−24	10	45	−35
Real Estate Activities	505	494	11	458	458	0	19	22	−3	28	13	15
Renting of M&Eq and Other Business Activities	709	905	−197	367	367	0	130	227	−97	212	311	−99
Public Admin and Defence; Compulsory Social Security	1258	1213	45	1183	1183	0	30	10	20	46	20	25
Education	142	149	−7	137	137	0	2	9	−7	3	3	0
Health and Social Work	178	181	−3	176	176	0	1	4	−3	1	1	0
Other Community, Social and Personal Services	394	566	−173	345	345	0	23	95	−72	26	126	−100
Private Households with Employed Persons	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	47849	61187	−13338	23282	23282		9938	20554	−10616	14629	17351	−2723

Table B
Sweden's CO_2 emissions embodied in international trade by sector in 2009 (kt).

	TOTAL EMISSIONS			Region *u* (Sweden)			Region *r* (EU area)			Region *w* (Rest of the World)		
	Prod. Effect	Carbon footprint	ETB	Prod. Effect	Carbon footprint	ETB	Prod. Effect	Carbon footprint	ETB	Prod. Effect	Carbon footprint	ETB
Agriculture, Hunting, Forestry and Fishing	2392	2225	166	1330	1330	0	583	682	−99	479	213	265
Mining and Quarrying	752	2380	−1628	140	140	0	271	531	−261	342	1709	−1367
Food, Beverages and Tobacco	644	973	−329	427	427	0	102	439	−337	116	108	8
Textiles and Textile Products	43	302	−259	1	1	0	33	106	−73	9	196	−186
Leather, Leather and Footwear	0	15	−15	0	0	0	0	8	−8	0	7	−7
Wood and Products of Wood and Cork	132	171	−39	51	51	0	34	67	−34	47	53	−5
Pulp, Paper, Paper , Printing and Publishing	1567	866	702	414	414	0	591	241	350	562	210	352
Coke, Refined Petroleum and Nuclear Fuel	3961	3220	741	493	493	0	1821	1789	32	1647	937	709
Chemicals and Chemical Products	1756	2802	−1046	149	149	0	783	1442	−659	824	1212	−387
Rubber and Plastics	82	199	−116	14	14	0	29	96	−67	39	88	−49
Other Non-Metallic Mineral	3545	3813	−268	1829	1829	0	671	1117	−446	1046	868	178
Basic Metals and Fabricated Metal	4939	5532	−593	909	909	0	1612	1870	−258	2418	2752	−335
Machinery, Nec	179	269	−89	23	23	0	58	142	−85	99	104	−5
Electrical and Optical Equipment	57	293	−236	8	8	0	17	162	−145	33	124	−91
Transport Equipment	241	341	−100	72	72	0	68	154	−86	101	115	−14
Manufacturing, Nec; Recycling	60	151	−91	13	13	0	27	104	−77	21	34	−13
Electricity, Gas and Water Supply	8958	20932	−11974	6858	6858	0	907	5363	−4456	1194	8711	−7517
Construction	1522	1442	80	1384	1384	0	50	44	5	88	13	75
Sale, Maintenance and Repair of Motor	2045	1280	765	1231	1231	0	240	39	201	574	10	564

(*continued on next page*)

Table B (*continued*)

	TOTAL EMISSIONS			Region *u* (Sweden)			Region *r* (EU area)			Region *w* (Rest of the World)		
	Prod. Effect	Carbon footprint	ETB	Prod. Effect	Carbon footprint	ETB	Prod. Effect	Carbon footprint	ETB	Prod. Effect	Carbon footprint	ETB
Vehicles and Motorcycles; Retail Sale of Fuel												
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	0	214	−214	0	0	0	0	127	−127	0	87	−87
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	0	162	−162	0	0	0	0	95	−95	0	67	−67
Hotels and Restaurants	93	155	−62	78	78	0	5	13	−8	10	64	−54
Inland Transport	3312	4966	−1654	1856	1856	0	510	1531	−1021	946	1579	−633
Water Transport	8452	2556	5896	583	583	0	1059	1003	56	6810	970	5840
Air Transport	4956	5897	−940	1926	1926	0	934	3020	−2086	2097	951	1146
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	162	422	−260	71	71	0	30	161	−131	60	189	−129
Post and Telecommunications	172	229	−57	113	113	0	28	51	−23	31	65	−34
Financial Intermediation	90	117	−27	60	60	0	10	24	−14	19	32	−13
Real Estate Activities	400	384	16	353	353	0	17	19	−3	31	12	19
Renting of M&Eq and Other Business Activities	1245	1150	95	548	548	0	219	212	7	477	389	88
Public Admin and Defence; Compulsory Social Security	373	374	−1	343	343	0	13	11	1	18	20	−2
Education	229	234	−6	221	221	0	3	8	−6	5	5	0
Health and Social Work	334	338	−4	329	329	0	2	3	−1	3	5	−3
Other Community, Social and Personal Services	550	692	−143	466	466	0	32	84	−52	51	142	−91
Private Households with Employed Persons	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL												

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