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Structural decomposition analysis of CO_2 emissions in France from 1999 to 2005

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Résumé

Cette étude examine la variation des émissions de CO_2 provenant des activités économiques pour la France en utilisant l'analyse de décomposition structurelle pour la période 1999-2005. La variation des émissions de CO_2 a été décomposée selon cinq termes : coefficients d'émissions, changement technique, modification de la structure de la demande finale, changement du volume de la demande finale et croissance de la population nationale. Nous avons montré néanmoins que la croissance de la population ne pouvait être reliée avec l'ensemble des composantes de la demande finale, à savoir les exportations, la variation de stock et les objets de valeur.

Les résultats montrent que les efforts de réduction des émissions de CO_2 provenant de l'amélioration des coefficients d'émissions ne compensent pas entièrement l'augmentation des émissions provoquée par une hausse de la demande finale. Cette hausse est expliquée principalement par un effet volume et, d'une manière moins importante, par la croissance de la population. A contrario, le changement de la structure de la demande finale a un effet positif dans la réduction des émissions. En outre, la France a accru la responsabilité des émissions envers le reste du monde du fait de la substitution des produits domestiques vers les produits importés.

Mots clés : analyse de décomposition structurelle, modèle entrées-sorties environnemental, émissions de CO_2

Abstract

This paper examines the variation of CO_2 emissions from economic activities in France by using the structural decomposition analysis for the period 1999-2005. The variation of CO_2 emissions was decomposed according to five terms: change in emissions coefficients, technical change, change in the structure of final demand, change in the volume of final demand and national population growth. We show however that population growth cannot be linked to all the components of final demand, especially with exports, valuables and changes in inventories.

Results show that the efforts of reduction of CO_2 emissions from emissions coefficients improvement cannot entirely offset the increase in emissions caused by the increase in final demand. This rise is explained principally by a volume effect and by, in a lesser manner, the population growth. On the contrary, the changes in the structure of final demand have a positive effect in the emissions reduction. Moreover, France increases the responsibility of emissions toward the rest of the world by the substitution of domestic products to imported products.

Keywords: structural decomposition analysis, environmental input-output analysis, CO_2 emissions

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Classification JEL : C67, Q54

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1 Introduction

France is one of the lowest emitters of greenhouse gas (GHG) in the industrialized countries. It contributes to 1.1 % of the world GHG emissions whereas it represents 5.5 % of the world GDP (world resources institute, 2012). French GHG emissions were in 2010 at 473 $MtCO_2eq$ (CITEPA, 2012). Though it is a low carbon-economy, France has an ambitious target of GHG emissions reduction to contribute to limit the climate warming at 2 $^\circ$C during the 21st century. The target of France is to reduce by 23 % its GHG emissions in 2020 compared to 1990 level, and to divide by 4 its GHG emissions in 2050 compared to 1990 level (Ministère de l'Ecologie, du Développement durable, des Transports et du Logement, 2011). According to the baseline scenario, emissions in France will be at 551 $MtCO_2eq$ in 2020 ; i.e., a reduction of 2.5 % compared to 1990 level. To reach its target for 2020, France has implemented a climate plan within the framework of the Grenelle Environment Forum to avoid 116 $MtCO_2eq$/year in 2020 ; i.e., an emissions target of 435 $MtCO_2eq$.

The implementation of climate plans has begun since 2000 in France. The reduction of emissions was relatively moderate in the period 2000-2005 (-2.85 %) before a more important decrease in the 2005-2010 (-7.43 %). It will be interesting to decompose historical GHG emissions in France according to different terms by taking into account the complex interindustrial trade with disaggregated branches. This study will provide a better understanding of the evolution of GHG emissions process in France.

The analysis of structural decomposition is particularly well suited for this study. It is defined as "a method of distinguishing major shifts within an economy by means of comparative static changes in key sets of parameters" (Skolka, 1989). It is based on environmental input-output analysis, leading to incorporate both direct and indirect effects from changes in the structure or in the total value of final demand components. Besides, it overcomes the static characteristics of input-output analysis by dynamizing the technical coefficients (Rose and Miernyk, 1989) leading to take into account the technical change. It is so a pragmatic alternative to econometrics requiring a large number of temporal observations. Structural decomposition analysis requires at least only two input-output tables (IOT) (Casler and Rose, 1998).

Although the structural decomposition analysis was used for a large number of countries to understand the variation of their GHG emissions, France has not been concerned with this work. The paper aims at using the structural decomposition analysis to select the main factors explaining the change in CO_2 emissions in France from 1999 to 2005.

We cite non exhaustive number of studies using this technique. Butnar and Llop (2011) decomposed GHG emissions in Spain for service sectors by using an input-output sub-system analysis in 2000-2005. Du et al. (2011) and Xu et al. (2011) evaluated the impact of exports on Chinese CO_2 emissions respectively in 2002-2007 and 2002-2008. Chang et al. (2011) analysed in Taiwan the change in CO_2 emissions from industry according to 11 factors between 1989 and 2004. Peng and Shi (2011) decomposed the change in emissions in China according to 4 factors in 1992-2005 : carbon intensity, technical change, domestic final demand and trade with the rest of the world. Yamakawa and Peters (2011) analyzed GHG emissions in Norway between 1990 and 2002 according to 5 terms : carbon intensity, technical change, structure of final demand, volume of final demand and population. Guan et al. (2008) decomposed GHG emissions in China in 2002-2010 according to the same terms of Yamakawa and Peters (2011). They then used these results to carry out some scenarios until 2030.

In this paper, we decompose CO_2 emissions between 1999 and 2005 in France according to the same terms of Yamakawa and Peters (2011), and Guan et al. (2008). However, we show that the population growth cannot explain the variation of all final demand components. The first section aims at presenting the structural decomposition applied in France whereas the second section exposes the main empirical results.

2 The structural decomposition analysis applied to France

We first expose the methodology of CO_2 emissions decomposition. We then explain the resolution of non-uniquess solution.

2.1 Decomposition of CO_2 emissions

We assume an economy composed of n branches and n products. The model assumes that a branch produces only one product, and branches and products are homogeneous.

The Leontief model uses the supply-demand balance of the different products i :

$$\mathbf{X} = \mathbf{Z}.\mathbf{i} + \mathbf{Y} \tag{1}$$

Where
$\mathbf{X}$: $(n \times 1)$ vector of output,
$\mathbf{Z}$: $(n \times n)$ matrix of intermediate consumptions,
$\mathbf{i}$: $(n \times 1)$ vector composed only of 1,
$\mathbf{Y}$: $(n \times 1)$ vector of final demand subtracting imports, composed of final consumption (**FC**), gross fixed capital formation (**GFCF**), the changes in inventories (**CI**), valuables (**VL**), exports (**E**) and imports (**M**).

The $(n \times n)$ matrix of technical coefficients, indicating the required monetary inputs i to produce one monetary unit of product j, is calculated as follows :

$$\mathbf{A} = \mathbf{Z}.\widehat{\mathbf{X}}^{-1} \tag{2}$$

The hat indicates a diagonal matrix.

By combining (2) into (1), and after transformation, we obtain :

$$\mathbf{X} = \mathbf{B}.\mathbf{Y} = (\mathbf{I} - \mathbf{A})^{-\mathbf{1}}.\mathbf{Y} \tag{3}$$

Where $\mathbf{B} \equiv (\mathbf{I} - \mathbf{A})^{-\mathbf{1}}$ is the $(n \times n)$ matrix of Leontief inverse. It indicates the required direct and indirect output to satisfy one unit of final demand for the product j.

The environmental Leontief model links economic data to emissions data through emissions coefficients. The $(n \times 1)$ vector of emissions coefficients, indicating emissions of branch j caused by a monetary unit of output of this branch, is calculated as follows :

$$\mathbf{c} = \mathbf{C}.\mathbf{P}^{-\mathbf{1}} \tag{4}$$

By combining (4) into (3), we find :

$$\mathbf{C} = \widehat{\mathbf{c}}.\mathbf{B}.\mathbf{Y} = \widehat{\mathbf{c}}.\mathbf{B}.(\mathbf{FC} + \mathbf{GFCF} + \mathbf{VL} + \mathbf{CI} + \mathbf{E} - \mathbf{M}) \tag{5}$$

Equation (5) breaks down, for a given year, domestic emissions according to final demand components subtracting imports (final consumption, gross fixed capital formation, changes in inventories, valuables, exports and imports).

It is also possible to decompose further emissions from final demand. Different studies (Yamakawa and Peters, 2011 ; Guan et al., 2008) decomposed these emissions according to the structure of final demand (structure effect), total value of final demand per head (volume effect) and population growth.

However, all final demand components cannot be explained by domestic population growth. It is the case for exports, changes in inventories and valuables. For the other final demand components (imports included), they can be linked to population growth.

The variation of final consumption can be explained by the population growth. By assuming the stability of consumption per head, an increase in population implies a rise in consumption for domestic products and so an increase in domestic emissions. Moreover, if we attribute emissions responsibility to consumers (Munksgaard and Pederson, 2001), national GHG emissions from domestic final demand can be linked to domestic population.

GHG emissions explained by final consumption are so decomposed as follows :

$$\mathbf{C_{FC}} = \widehat{\mathbf{c}}.\mathbf{B}.(\mathbf{FCs}.\mathbf{FCn}.\mathbf{N}) \tag{6}$$

Where **FCs** is the $(n \times 1)$ vector of the structure of final demand, **FCn** the total value of final consumption per head and **N** the number of domestic population.

Concerning gross fixed capital formation, Clark (1917) through accelerator effect links investment with the demand of products. As exposed above, the demand of products is explained by the population. An increase of population implies, all other things being equal, a rise in product demand. In order to face with this, firms increase the capital stock to rise productive capacity. CO_2 emissions from gross fixed capital formation are decomposed as follows :

$$\mathbf{C_{GFCF}} = \widehat{\mathbf{c}}.\mathbf{B}.(\mathbf{GFCFs}.\mathbf{GFCFn}.\mathbf{N}) \tag{7}$$

Where **GFCFs** is the $(n \times 1)$ vector of the structure of gross fixed capital formation, **GFCFn** the total value of gross fixed capital formation per head.

Concerning international products trade, imports and exports cannot be explained solely by domestic population. By retaining the principle of consumer responsibility (Munksgaard and Pederson, 2001), emissions from imports should be linked to domestic population whereas exports should be linked to population of the country where the exports are destined. It is so a mistake to link emissions from exports to domestic population because it has not responsibility for these emissions.

Emissions from imports can be linked to domestic population through the below equation :

$$\mathbf{C_M} = \widehat{\mathbf{c}}.\mathbf{B}.(\mathbf{Ms}.\mathbf{Mn}.\mathbf{N}) \tag{8}$$

Where **Ms** is the $(n \times 1)$ vector of the structure of imports, **Mn** the total value of imports per head.

On the contrary, exports cannot be explained by the domestic population. An increase of domestic population does not imply a rise of exports according to demand-driven Leontief model. Because of difficulties to account foreign population consuming French products, emissions from exports were linked to the total value of exports as indicated by this equation :

$$\mathbf{C_E} = \widehat{\mathbf{c}}.\mathbf{B}.(\mathbf{Es}.\mathbf{Ev}) \tag{9}$$

Where **Es** is the $(n \times 1)$ vector of the structure of exports, **Ev** the total value of exports.

Concerning the valuables, they do not depend on population, but rather on corporate strategies. Valuables are the buying of goods that do not serve neither output nor consumption, but used as a store of value. Emissions from valuables are assumed to be decomposed into the structure of valuables and the total value of valuables :

$$\mathbf{C_{VL}} = \widehat{\mathbf{c}}.\mathbf{B}.(\mathbf{VLs}.\mathbf{VLv}) \tag{10}$$

Where **VLs** is the $(n \times 1)$ vector of the structure of valuables, **VLv** the total value of valuables.

Concerning the changes in inventories, they depend mainly on the difference between the anticipated sales and actual sales, and also corporate strategies. Emissions from changes in inventories are assumed to be decomposed into the structure of change in inventories and the total value of change in inventories :

$$\mathbf{C_{CI}} = \widehat{\mathbf{c}}.\mathbf{B}.(\mathbf{CIs}.\mathbf{CIv}) \tag{11}$$

Where **CIs** is the $(n \times 1)$ vector of the structure of change in inventories, **CIv** the total value of change in inventories.

Equations from (5) to (11) decompose the CO_2 emissions for the year t according to different terms. They are then used for the structural decomposition analysis to explain the variation of CO_2 emissions between two years.

From equation (5), the variation of CO_2 emissions is decomposed as follows :

$$\begin{aligned}\mathbf{\Delta C} = \; & \mathbf{\Delta}\widehat{\mathbf{c}}.\mathbf{B}.\mathbf{Y} + \widehat{\mathbf{c}}.\mathbf{\Delta B}.\mathbf{Y} + \widehat{\mathbf{c}}.\mathbf{B}.\mathbf{\Delta FC} + \widehat{\mathbf{c}}.\mathbf{B}.\mathbf{\Delta GFCF} + \widehat{\mathbf{c}}.\mathbf{B}.\mathbf{\Delta CI} + \widehat{\mathbf{c}}.\mathbf{B}.\mathbf{\Delta VL} + \widehat{\mathbf{c}}.\mathbf{B}.\mathbf{\Delta E} \\ & - \widehat{\mathbf{c}}.\mathbf{B}.\mathbf{\Delta}.\mathbf{M}\end{aligned} \tag{12}$$

The variation of CO_2 emissions ($\mathbf{\Delta C}$) is explained by the variation of emissions coefficients ($\mathbf{\Delta \widehat{c}.B.Y}$), technical change ($\mathbf{\widehat{c}.\Delta B.Y}$) and a change in final demand components ; i.e., final consumption ($\mathbf{\widehat{c}.B.\Delta FC}$), gross fixed capital formation ($\mathbf{\widehat{c}.B.\Delta GFCF}$), changes in inventories ($\mathbf{\widehat{c}.B.\Delta CI}$), valuables ($\mathbf{\widehat{c}.B.\Delta VL}$), exports ($\mathbf{\widehat{c}.B.\Delta E}$) and imports ($\mathbf{\widehat{c}.B.\Delta .M}$).

The variation of CO_2 emissions explained by final consumption, gross fixed capital formation, imports is further decomposed by a change in structure, the total value per head and population growth. The variation of CO_2 emissions explained by valuables, changes in inventories and exports is further decomposed by a change in structure and the total value.

However, the implementation of structural decomposition analysis poses the problem of non-uniqueness solution.

2.2 The problem of non-uniqueness solution

To explain the problem of non-uniqueness solution, the variation in output is decomposed by using equation (3) where the output ($\mathbf{X}$) is equal to the product of Leontief inverse matrix ($\mathbf{B}$) to the final demand vector ($\mathbf{Y}$).

Assuming two time periods : year 0 and year 1 (0 earlier than 1).

$$\mathbf{X^0 = B^0.Y^0} \quad (13)$$

$$\mathbf{X^1 = B^1.Y^1} \quad (14)$$

The variation of output between the years 0 and 1 is equal to :

$$\mathbf{\Delta X = B^1.Y^1 - B^0.Y^0} \quad (15)$$

The variation of Leontief inverse matrix and final demand are respectively defined :

$$\mathbf{\Delta B = B^1 - B^0} \quad (16)$$

$$\mathbf{\Delta Y = Y^1 - Y^0} \quad (17)$$

There are 4 possible decompositions of output variation by combining equations (16) and (17) into (15). These 4 alternatives were used in different structural decomposition studies. For a presentation of these different alternatives, see Dieztenbacher and Los (1998), and Miller and Blair (2009). Dieztenbacher and Los (1998) conclude that the average of decomposition of 2 alternatives indicated below is often an acceptable approach.

In the first alternative, we pose :

$$\mathbf{B^0 = B^1 - \Delta B} \quad (18)$$

$$\mathbf{Y^1 = \Delta Y + Y^0} \quad (19)$$

By combining (18) and (19) into (15), and after transformation, the variation of output is decomposed as follows :

$$\mathbf{\Delta X = B^1.\Delta Y + \Delta B.Y^0} \quad (20)$$

In the second alternative, we pose :

$$\mathbf{B^1} = \mathbf{\Delta B} + \mathbf{B^0} \tag{21}$$

$$\mathbf{Y^0} = \mathbf{Y^1} - \mathbf{\Delta .Y} \tag{22}$$

By combining (21) and (22) into (15), and after transformation, the variation of output is decomposed as follows :

$$\mathbf{\Delta X} = \mathbf{B^0.\Delta Y} + \mathbf{\Delta B.Y^1} \tag{23}$$

Equations (20) and (23) are two correct alternatives of output decomposition although the contribution of different factors (technical change and final demand) differs. Dietzenbacher and Los (1998) advocate to make an average of the contribution of these factors :

$$\mathbf{\Delta X} = \frac{\mathbf{1}}{\mathbf{2}}.(\mathbf{B^0} + \mathbf{B^1}).\mathbf{\Delta Y} + \frac{\mathbf{1}}{\mathbf{2}}.(\mathbf{Y^0} + \mathbf{Y^1}).\mathbf{\Delta B} \tag{24}$$

The variation of output is equal to the sum of the change in final demand $[\frac{\mathbf{1}}{\mathbf{2}}.(\mathbf{B^0} + \mathbf{B^1}).\mathbf{\Delta Y}]$ and technical change $[\frac{\mathbf{1}}{\mathbf{2}}.(\mathbf{Y^0} + \mathbf{Y^1}).\mathbf{\Delta B}]$.

It is also possible to extend the decomposition according to more than 2 terms by using the same principles explained above. For instance, the equation (5) is decomposed as follows :

$$\begin{aligned} \mathbf{\Delta C} = \quad & \tfrac{\mathbf{1}}{\mathbf{2}}.\widehat{\mathbf{c}}.(\mathbf{B^0.Y^0} + \mathbf{B^1.Y^1}) + \\ & \tfrac{\mathbf{1}}{\mathbf{2}}(\widehat{\mathbf{c}}^{\mathbf{0}}.\mathbf{\Delta B.Y^1} + \widehat{\mathbf{c}}^{\mathbf{1}}.\mathbf{\Delta B.Y^0}) + \\ & \tfrac{\mathbf{1}}{\mathbf{2}}(\widehat{\mathbf{c}}^{\mathbf{0}}.\mathbf{B^0} + \widehat{\mathbf{c}}^{\mathbf{1}}.\mathbf{B^1}).\mathbf{\Delta Y} \end{aligned} \tag{25}$$

The variation of CO_2 emissions is decomposed according to changes in emissions coefficients (first term), technical coefficients (second term) and final demand (third term). This decomposition can be extended to different terms for the components of final demand : structure, total value per head and population growth for the final consumption, the gross fixed capital formation and the imports ; structure and total value for the other final demand components.

After presenting the theory, we carry out the implementation for French CO_2 emissions.

3 The empirical results

We first present the used database for France by explaining the required transformation for a structural decomposition analysis. We present then the main empirical results.

3.1 The used database

The use of environmental structural decomposition analysis requires IOTs in volume expressed in the price in the same year and also environmental data associated with economic data.

Concerning IOTs, the French institute for statistics (INSEE) sent us IOTs in value and IOTs in volume expressed in the price of the previous year. These IOTs were disaggregated in 114 branches (NES 114) in 1999-2005 according the base 2000. The IOTs before 1999 and after 2007 are not comparable because they are expressed in different bases (respectively to the bases 1995 and 2005) without a conversion in the same base. We cannot find IOT in volume after 2005. Besides, these IOTs in value and in volume are "Industry x Commodity" IOTs. They are not symmetric. They are not operational to input-output analysis (Miller and Blair, 2009).

INSEE sent us "Commodity x Commodity" IOTs operational to input-output analysis. From non symmetric IOTs in value and in volume, a deflator was calculated to select only volume effects in 1999-2005.

On the supply side of IOTs, the supply of goods and services is distinguished between the domestic and imported origins. Deflators were calculated between the years t and t+1 in 1999-2005 for each product i by distinguished domestic origin corresponding to domestic output ($\mathbf{X}$) and imports ($\mathbf{M}$).

The variation of price for each product i from domestic output between t and $t+1$ is calculated as follows :

$$\dot{p}^X_{i,t/t+1} = \frac{p^X_{i,t+1} \cdot q^X_{i,t+1}}{p^X_{i,t} \cdot q^X_{i,t+1}} \tag{26}$$

Where $p^X_{i,t}$ is the price of domestic product i at date t and $q^X_{i,t}$ the quantity of domestic product i at date t .

We carry out the same calculations for the variation of imported products price :

$$\dot{p}^M_{i,t/t+1} = \frac{p^M_{i,t+1} \cdot q^M_{i,t+1}}{p^M_{i,t} \cdot q^M_{i,t+1}} \tag{27}$$

where $p^M_{i,t}$ is the price of imported product i at date t and $q^M_{i,t}$ the quantity of imported product i at date t .

Since the use tables indicate the demand of the product without discriminating domestic and imported origins, a specific deflator was also calculated for the demand of each product. These deflators are a weighted average of domestic price and imported price of products.

We calculated then the deflators in 1999-2005 to have IOTs in volume expressed in the base year 1999 distinguishing domestic and imported origins :

$$\dot{p}^X_{i,1999/2005} = \dot{p}^X_{i,1999/2000} \cdot \dot{p}^X_{i,2000/2001} \cdots \dot{p}^X_{i,2004/2005} \tag{28}$$

$$\dot{p}^M_{i,1999/2005} = \dot{p}^M_{i,1999/2000} \cdot \dot{p}^M_{i,2000/2001} \cdots \dot{p}^M_{i,2004/2005} \tag{29}$$

From equations (28) and (29), a specific deflator was also calculated for the demand of products.

“Commodity-by-Commodity” IOTs expressed in the price of 1999 were constructed in 1999-2005.

Data of CO_2 emissions have been downloaded from the EUROSTAT website. CO_2 emissions are expressed according to NACE rev 1. By aggregating IOT to NACE rev. 1, data of CO_2 emissions are properly linked to economic data.

3.2 The empirical results

The analysis of empirical results is carried out in two stages. In the first stage, the contribution of the principal components of CO_2 emissions is studied. This will go further in the second stage with a decomposition of CO_2 emissions for each final demand component according to structure, volume and population growth. The simulation was carried out according to 58 branches. To clarify the presentation, the results were aggregated into 12 branches according to the classification of NACE rev.1

Contribution of main components of final demand, technical change and emissions coefficients in the variation of national CO_2 emissions.
The table 1 gives the contribution of different components of CO_2 emissions (emissions coefficients, technical change, final consumption, gross fixed capital formation, valuables, change in inventories, exports and imports) in France in 1999-2005.

< Insert Table 1>

The figure 1 shows the change in CO_2 emissions according to their different components in 1999-2005.

< Insert Figure 1>

From 1999 to 2005, CO_2 emissions from economic activities increase slightly in France by 0.77 % ; i.e., 2,222 ktCO_2.

The reduction of emissions coming from the improvement of emissions intensity (-29,340 ktCO_2) does not allow to offset the increase in emissions from the domestic final demand growth for domestic products (+49,952 ktCO_2), explained mainly by final consumption growth (+ 32,950 ktCO_2). The reduction of CO_2 emissions from the improvement of emissions intensity is mainly explained by manufacturing industry (-12,297 ktCO_2) and, in a lesser manner, by transports and communication (-7,431 ktCO_2). These branches explain also mainly the increase in emissions from final consumption (respectively +15,095 ktCO_2 and 4,831 ktCO_2 for manufacturing industry, and transport and communication).

The rise of these emissions was accentuated by technical change (+6,590 ktCO_2). The national producers increased the share of intermediate products having a domino effect to domestic CO_2 emissions ; i.e., electricity and gas (+5,597 ktCO_2) and, in a lesser manner, transports and communication (+1,809 ktCO_2). If the producers remain stable the share of their inputs in their production process, CO_2 emissions from economic activity decrease, all other things being equal, of 4,368 ktCO_2 ; i.e., -2 % in 1999-2005.

However, the increase of national CO_2 emissions was limited by a substitution from domestic products to imported products (-21,980 ktCO_2), explained by a large part by manufacturing products (-13,235 ktCO_2) and, in a lesser manner, by mining and quarrying (-7,086 ktCO_2). This result could be explained by a delocalization of pollutant industries. This result can be related to the article of Peters et al. (2011) stipulating that international trade has led to stabilizing emissions in developed countries to the detriment of developing countries. By assuming no substitution between domestic and imported products, national CO_2 emissions from economic activity increases, all other things being equal, of 24,202 ktCO_2 ; i.e., +8 % in 1999-2005.

We note that the contribution of final demand for valuables and changes in inventories to the variation of CO_2 emissions is relatively small (+2,724 ktCO_2), but sufficient to play the role of arbiter. Indeed, without an increase of emissions from changes in inventories, domestic CO_2 emissions decrease, all other things being equal, of 636 ktCO_2 in 1999-2005. The rise of emissions from changes in inventories is mainly explained by mining and quarrying (+1,848 ktCO_2) and, in a lesser manner, by manufacturing industry (+1,068 ktCO_2).

The results show that the CO_2 emissions growth arises from final demand. It is important to carry out a further analysis to select the main effects explaining this evolution (structure effect, volume effect or population growth).

Decomposition of national CO_2 emissions from the different final demand components.
Table 2 indicates the contribution of different final demand components to national CO_2 emissions.

< Insert table 2 >

Concerning emissions from final consumption and gross fixed capital formation, the rise of CO_2 emissions is mainly explained by a volume effect with an increase of final consumption per head (+25,636 ktCO_2) and gross fixed capital formation per head (+9,395 ktCO_2). In a lesser manner, the population growth explains the increase of emissions (+11,393 ktCO_2 and +2,717 ktCO_2 respectively for final consumption and gross fixed capital formation).

However, the change in the structure of final consumption and gross fixed capital formation limits this rise (respectively 4,080 ktCO_2 and 834 ktCO_2). The reduction of CO_2 emissions from the decrease of the part of final demand for the products of mining and quarrying (-2,559 ktCO_2), and agriculture, hunting and forestry (-1,136 ktCO_2) offset largely the increase of emissions from the rise of the part of final demand for the product of manufacturing industry (+906 ktCO_2) and community, social and personal service activities (+386 ktCO_2).

The increase of emissions from exports is mainly explained by a volume effect (+35,874 ktCO_2). It is interesting to mention that a change in exports structure contributes to a rise of emissions (+1,460 ktCO_2), explained by a more important part devoted to mining and quarrying (+2,694 ktCO_2). Concerning the reduction of emissions from imports, it is mainly explained by an increase of imports per head (-65,414 ktCO_2).

An increase of emissions from domestic final demand is so explained mainly by a wealth effect ; i.e., an increase of consumption per head (final consumption, gross fixed capital formation). The national population growth explains only a part of the rise of CO_2 emissions from domestic final demand for domestic products.

4 Conclusion

A structural decomposition analysis was performed in France in 1999-2005 to select main factors explaining the change in CO_2 emissions. Emissions were decomposed according to 5 terms : emissions coefficients, technical change, structure of final demand components (imports included), volume of final demand components (imports included) and population growth. We show that some final demand components (valuables, changes in inventories and exports) cannot be linked with the population growth.

Results for France show that the efforts of CO_2 emissions reduction from the improvement of emissions coefficients do not offset the rise of emissions from the increase of domestic final demand for domestic products, explained mainly by a volume effect and, in a lesser manner, by population growth. The change in the structure of inputs contributes to an increase of CO_2 emissions. However, this rise is limited by international trade at the detriment to the emissions of the rest of the world.

From these results, we carry out different scenarios to determine the impacts of one component change by assuming all other things being equal. These scenarios can help the decision-makers to a better understanding of the change in emissions in their territory by incorporating interindustrial trade and international trade.

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List of tables

Table 1 : Variation of CO_2 emissions in France according to its different components in 1999-2005 (in $ktCO_2$).

	ΔC	ΔB	ΔFC	ΔGFCF	ΔVL	ΔCI	ΔE	ΔM	TOTAL
Agriculture, hunting, forestry, fishing	-128	-226	735	108	-2	-2	57	-735	-193
Mining and quarrying	1147	-1541	3400	1566	-19	1848	9062	-16148	-686
Manufacturing	-12297	-2025	15095	5958	-116	1068	20239	-33474	-5551
Electricity, gas and water supply	-6296	5597	3540	630	-3	20	2053	-2636	2905
Construction	544	164	131	1031	0	17	50	-76	1862
Wholesale and retail trade	-1527	484	986	228	6	-5	397	-606	-38
Hotels and restaurants	-200	34	303	26	0	0	46	-72	137
Transport and communication	-7431	1809	4831	1019	0	-85	4320	-3838	624
Financial intermediation and real estate	-727	645	941	361	0	1	558	-838	942
Public administration	-455	0	236	0	0	0	0	0	-219
Education, health and social work	-948	18	686	25	0	1	65	-101	-254
community, social and personal service activities	-1021	1631	2066	325	-1	-6	488	-790	2693
TOTAL	-29340	6590	32950	11279	-134	2858	37335	-59315	2222

Table 2 : decomposition of CO_2 emissions explained by final demand components in 1999-2005 (in $ktCO_2$)

	ΔFC			ΔGFCF			ΔVL		ΔCI		ΔE		ΔM		
	ΔFCs	ΔFCn	ΔN	ΔGFCFs	ΔGFCFn	ΔN	ΔVLs	ΔVLv	ΔCIs	ΔCIv	ΔEs	ΔEv	ΔMs	ΔMn	ΔN
Agriculture, hunting, forestry, fishing	-1136	1293	578	-76	142	42	-2	0	749	-751	-899	956	1060	-1559	-235
Mining and quarrying	-2559	4135	1824	-105	1309	362	-8	-12	989	859	2694	6368	10779	-23558	-3370
Manufacturing	906	9813	4376	-488	5000	1447	-70	-46	-325	1393	390	19849	2410	-31251	-4633
Electricity, gas and water supply	-865	3065	1340	-25	514	141	-1	-2	32	-13	-163	2216	472	-2721	-388
Construction	-38	117	53	-83	859	254	0	0	-111	128	5	45	8	-74	-11
Wholesale and retail trade	-49	716	318	-20	192	56	7	0	-8	4	-108	505	-40	-493	-73
Hotels and restaurants	-70	258	115	1	20	6	0	0	0	0	0	46	0	-62	-9
Transport and communication	324	3111	1397	-85	849	256	2	-2	-91	6	-543	4863	883	-4091	-630
Financial intermediation and real estate	105	576	259	13	268	80	0	0	-16	17	63	495	16	-742	-112
Public administration	-523	529	231	0	0	0	0	0	0	0	0	0	0	0	0
Education, health and social work	-543	856	374	1	19	6	0	0	0	2	10	55	7	-95	-14
community, social and personal service activities	368	1168	530	33	223	68	0	0	-1	-5	12	476	97	-769	-119
TOTAL	-4080	25636	11393	-834	9395	2717	-71	-63	1218	1640	1460	35874	15694	-65414	-9595

List of figure

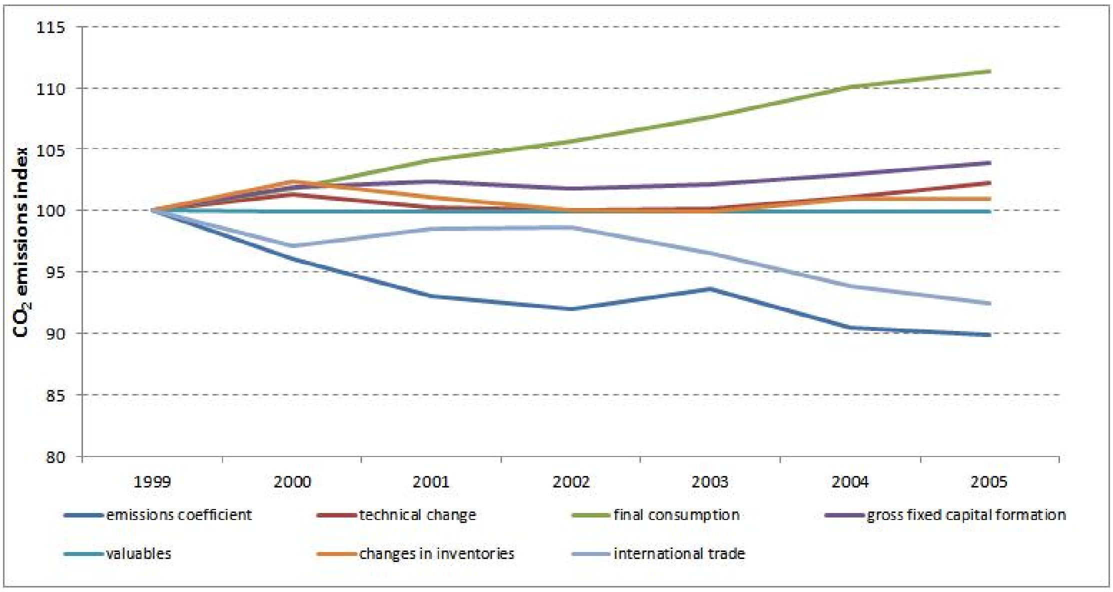

Figure 1 : CO_2 emissions index according to main terms in 1999-2005.