Impact on Greenhouse Emissions in the Aquitaine Region for the Cases of a Baseline Scenario and an Economic Crisis

MARTIN Jean-Christophe*, POINT Patrick†

Laboratory of Gretha, University of Montesquieu,
Avenue Leon Duguit, 33600 Pessac, France

Abstract

The region of Aquitaine, situated in the southwest of France, has put in place a climate plan with the goal of reducing greenhouse gas emissions by 10% for the period 2007-2013. Faced with the fact that regional accounting for this has been poorly developed, we constructed an input-output table, with an associated inventory, for emissions. The objective of this paper is to construct a baseline scenario for forecasting emissions for up to 2013. The primary contribution of this paper is development of a methodology for regionalizing national results as they derive from a structural decomposition analysis. We utilize the bootstrap method to produce forecasts in the case of a baseline scenario, taking into account uncertainty stemming from a standard deviation for annual variations. We thus estimated a density function for GDP as well as for emissions for 2013. We also simulated the effects of an economic crisis taking into account historical data to estimate its repercussions on emissions.

Keywords : Input-output analysis, structural decomposition analysis, regional economy, Bootstrap, greenhouse gas emissions, simulation, forecasting

*Doctoral Fellow
†Director of Research, National Centre for Scientific Research (CNRS)

1 Introduction

The region of Aquitaine has put in place for the period 2007-2013 a climate plan with the aim of reducing its greenhouse gas emissions by 10%. Yet the constitution of an effective climate plan presumes knowledge of the natural development of greenhouse gas emissions. This is the principle upon which construction of a baseline scenario is based. Thus the objective of this paper will be to estimate for 2013 greenhouse gas emissions for the region of Aquitaine assuming no new environmental policy is implemented.

This said, the cost of constructing a regional model is more often than not high, if not prohibitive (Catin, 1992). An input-output analysis is the most suitable method for such a regional study as it incorporates both specific statistical constraints on regional analysis and the fact of the complex nature of inter-industrial exchanges (West GR, 1995). Our previous work allowed for construction of an Input-output (IO) table for 47 sectors in the region of Aquitaine for 2001, with an inventory for energy consumption and associated emissions. The construction of a baseline scenario presumes use of a dynamic study, and thus the existence of data over a time series utilizable to produce forecasts concerning greenhouse gas emissions.

The structural decomposition analysis is often preferred for dynamic studies with a relatively rich and abundant literature. The objective of this analysis is to highlight and quantify the principal driving forces producing variation in production of emissions. It goes beyond the statistical features of the input-output model by incorporating the factor of technological change via the modification of technical coefficients as well as modification of the productive structure (A.Rose et S.Casler, 1996). B. Andreosso-O'Callaghan and Guoqiang Yue (2002) have studied the effects of economic reform in China on economic growth for the period 1987-1997 by estimating the contribution of various final demand components as well as the role of technological change. In regard to greenhouse gas emissions, S.D.Casler and A. Rose (1998) used the structural decomposition method to explain variation in CO_2 emissions for the United States for the period 1972-1982. In Denmark, we can cite the work of Wier M (1998) on carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) emissions for the period 1966 to 1988, and Chang et Lin (1998) for CO_2 emissions in Taiwan for the period 1981-1991.

Although a structural composition analysis may be used for historical studies, it can also be utilized for purposes of forecasting. In fact, according to Adam R (1996), the structural decomposition method is a pragmatic alternative to econometric estimates and is one that can be applied to a small number of observations in a time series. We can cite the work of Hoekstra R. and Van Den Bergh J.C. (2006), who give forecasts and create scenarios for up to 2030 for iron and steel and plastics production, applying IO tables, for 1990 and 1997. However, we may note the existence of a relatively meagre literature regarding regional forecasting using the structural decomposition method.

The first part of this paper is devoted to construction of a baseline scenario for estimating GDP, energy consumption and greenhouse gas emissions for the region of Aquitaine between 1999 and 2005. In the absence of regional IO tables and given inadequate regional accounting systems, we estimated the variations in production and emissions using the national IO table. We will present in the first section the methodology for regionalizing national results as derived from the structural decomposition method. This method permits estimation for each year of GDP, energy consumption and greenhouse gas emissions, in rapid manner and at low cost. It is impossible for us to estimate greenhouse gas emissions for prior to 1999 due to the fact of base change to the construction of national IO tables (from base 1995 to base 2000). The second section outlines the method for constructing a baseline scenario permitting estimation of GDP, energy consumption and greenhouse gas emissions for 2013 taking into account past observations. Due to a fairly small number of observations recorded, estimates using the econometric method, although advocated by Hoekstra and Van Den Bergh J.C. (2006), could not be applied. We are thus restricted to constructing linear growth hypotheses. However, it was possible to incorporate uncertainties stemming from standard deviation of variations observed and in production components by making use of the Bootstrap method. We will assume that uncertainties in results increase with standard deviation of variations observed. The advantage of the Bootstrap method is that it bypasses statistical problems as linked to a small sample number by performing a very high number of random resampling with replacements. We estimated density functions for GDP, energy consumption and greenhouse gas emissions for 2013.

This said, the baseline scenario assumes that future economic conditions will be reproduced under the same conditions as in the past. Yet we cannot ignore the economic crisis as arose beginning in 2007 stemming from the subprime fiasco coming out of the United States. While there exists a large number of uncertainties regarding forecasts pertaining to this crisis, the objective of the second section of this paper will be to show the value of a structural decomposition analysis in producing economic and environmental forecasts during the occurrence of an economic crisis, by using historical data. Employing certain hypotheses regarding the evolution of final demand components as well as of technological change and taking into account past trends, we simulated the effects of a crisis on greenhouse gas emissions.

2 Estimating Production Emissions for the Aquitaine Region for the Period 1999-2005

We first calculated the contribution of various final demand components, as well as of technological change, to variations in production for the period 1999-2005, before then regionalizing these national results.

2.1 Explanation of the Variation in French Production Using the Structural Decomposition Method

According to Skolka (1989), structural decomposition analysis can be defined as "a method for distinguishing the major changes of an economy by means of comparative statistical change within key parameters." It thus permits identification of the driving forces behind the variation in production comparing two given years. These driving forces are in essence components of final demand and of technological change. From a statistical point of view, production, according to an input-output analysis, is explained by final demand components. Thus, the production function can be written as follows:

$$P = B.HFC + B.FCA + B.GFC + B.GCF + B.X - B.M \quad (1)$$

Where B represents the Leontief inverse matrix, P the production vector, HFC the households final consumption vector, GFC general government final consumption vector, GCF gross capital formation vector, X the exports vector and M the imports vector. Note Y final demand vector, which is the sum of final consumption, gross capital formation, and exports net of imports.

By making Equation(1) dynamic, we obtain:

$$\Delta P = \Delta B.Y + B.\Delta HFC + B.\Delta GFC + B.\Delta GCF + B.\Delta X - B.\Delta M \tag{2}$$

Thus, Equation 2 describes the variation in production as dependent on technological change (through the modification of technical coefficients, and thus of the Leontief inverse matrix) as well as change in the various final demand components

We were able to obtain six IO tables for 114 sectors for France from 1999 to 2005. However the INSEE does not produce IO tables prior to 1999 with this level of sector detail due to the change in base (from base 1995 to base 2000). We calculated using the structural decomposition method the evolution of national production deriving from different final demand components and from technological change. However, certain difficulties had to be overcome in order to perform these calculations.

The IO table account for France is a "commodity-by-industry" IO table account. We had here to take into account transfers in order that production in rows equal production in columns. Furthermore, intermediate and final demands had to be converted from acquisition price to base price by reallocating transport and trade margins to the areas concerned, and subtracting taxes (Miller and Blair, 1985).

After having converted these national IO tables, it remained for us to estimate the variations in production deriving from technological changes and from final demand components. However application of Equation 2 proves to result in the all-too-common problem of a non-unique solution (Dietzenbacher and Los, 1998). We will illustrate this problem with an example. Let us consider a variation z representing the product of two variables x and y between two periods $t-1$ and t. The variation z ($\Delta z = z_t - z_{t-1}$) can be broken down as follows :

$$\Delta z = \Delta x.y_{t-1} + \Delta y.x_t \tag{3}$$

Or also as:

$$\Delta z = \Delta x.y_t + \Delta y.x_{t-1} \tag{4}$$

Equations 3 and 4 give the same result, but with different contributions from the variables x and y depending on the reference period in question. Yet there exists no theoretical reason to prefer one decomposition over another. The solution proposed is to produce an average for the contributions of each variable, between these two decompositions. In concrete terms, the contribution of the variables x and y to the variation of the variable z is calculated as follows :

$$\Delta z = \Delta x.\frac{y_{t-1} + y_t}{2} + \Delta y.\frac{x_{t-1} + x_t}{2} \tag{5}$$

This method is used in Equation 2 to estimate the contribution of different components of the final demand and of technological change to production variation.
We thus estimated for France, from 1999 to 2005, the contribution of the various components that explain the variations in production. It then only remained for us regionalize these contributions to estimate the variation in GDP and greenhouse gas emissions for this period.

2.2 Regionalization of National Structural Decomposition Results for Estimating Production

Utilizing the IO table for the Aquitaine region, we were able to estimate for 2001 the contribution of the various components of final demand to regional production. In order to dynamize the regional IO table, it is possible to regionalize variation in production components derived from the national IO tables. This regionalization must respond to a coherence requirement : that the sum of the variations in regional production, which is none other than the sum of variations in regional production deriving from its various components, must be equal to the variation in national production. However, regionalization of the national IO table poses a problem in that it does not integrate explicitly the variation in regional production stemming from interregional trade. We will explain in the second section how this problem can be overcome.

2.2.1 Regionalization of Variations in National Production Components (exclusive of interregional trade)

We will present the general method of regionalization of the variation in each component k of production between 1999 and 2005. k represents the various components of final demand (final consumption, gross capital formation, exports net of imports) and of technological change. We already know at the national level the variation in production deriving from the contribution of the component k. The key to dividing among the regions the variation in production stemming from the component k is accomplished based on regional contribution to national production deriving from this component k. Thus, the variation in regional production stemming from component k will be proportional to the contribution of the region to national production as deriving from component k. We then integrate a third factor, enabling dynamization of this regional contribution. However the integration of this third factor must not call into question the coherence condition as stated above. We will explain in detail this methodology, for each component k.

In regard to production as stemming from final consumption, our point of departure was the national variation in production stemming from final consumption on the date t between different sectors i ($\Delta P^{FR}_{FC,i,t}$).Moreover, we know from the national and regional IO table data for 2001 the respective contribution of production deriving from final consumption of each sector i for France ($B.P^{FR}_{FC,i}$) and Aquitaine ($B.P^{FR}_{FC,i}$). Thus we determined without difficulty the regional contribution to national production stemming from final consumption $\left(\frac{B.P^{AQUI}_{FC,i}}{B.P^{FR}_{FC,i}}\right)$. This contribution was dynamized according to gross disposable income. If the variation in gross disposable income (GDI) was greater at the regional level than at the national level, we should expect a greater increase in production deriving from final consumption in the region than in the nation as a whole. Thus, variation in production deriving from final consumption was calculated as follows :

$$\Delta P^{AQUI}_{FC,i,t} = \Delta P^{FR}_{FC,i,t}.\left(\frac{B.P^{AQUI}_{FC,i}}{B.P^{FR}_{FC,i}}.\frac{GDI^{AQUI}_{t}\Big/GDI^{AQUI}_{t-1}}{GDI^{FR}_{t}/GDI^{FR}_{t-1}}\right) \tag{6}$$

In regard to production stemming from gross capital formation, our point of departure was the national variation in production stemming from gross capital formation for each sector i for the date t ($\Delta P^{FR}_{GCF,i,t}$). Utilizing national and regional IO tables for 2001, we were able to determine the regional contribution to national production for each sector i as deriving from gross fixed capital formation $\left(\frac{B.P^{AQUI}_{GCF,i}}{B.P^{FR}_{GCF,i}}\right)$. This contribution was dynamized employing gross domestic product (GDP). If the variation in GDP was greater at the regional level than at the national level, we should expect a greater increase in production as stemming from gross capital formation in the region than in the nation as a whole. Thus, the variation in production stemming from gross capital formation was calculated as follows :

$$\Delta P_{GCF,i,t}^{AQUI} = \Delta P_{GCF,i,t}^{FR} \left(\frac{B.P_{GCF,i}^{AQUI}}{B.P_{GCF,i}^{FR}} . \frac{PIB_t^{AQUI} \Big/ PIB_{t-1}^{AQUI}}{PIB_t^{FR} / PIB_{t-1}^{FR}} \right) \tag{7}$$

In regard to production stemming from exports to the rest of the world (RoW), our point of departure was the national variation in production for each sector i stemming from exports for the date t ($\Delta P_{X,i,t}^{FR}$). Utilizing national and regional IO tables for 2001, we were able to determine the regional contribution to national production for each sector i stemming from exports to the rest of the world $\left(\frac{B.P_{X,i}^{AQUI}}{B.P_{X,i}^{FR}} \right)$. This contribution was dynamized based on quantity of exports to the rest of the world. If the variation in exports to the rest of the world was greater at the regional level than at the national level, we should expect a greater increase in production deriving from exports to the rest of the world in the region than in the nation as a whole. Thus, the variation in production stemming from exports to the rest of the world was found as follows :

$$\Delta P_{X,i,t}^{AQUI,RoW} = \Delta P_{X,i,t}^{FR} . \left(\frac{B.P_{X,i}^{AQUI}}{B.P_{X,i}^{FR}} . \frac{X_t^{AQUI} \Big/ X_{t-1}^{AQUI}}{X_t^{FR} / X_{t-1}^{FR}} \right) \tag{8}$$

In regard to production deriving from imports from the rest of the world (RoW), our point of departure was the national variation in production for each sector i stemming from imports for the date t ($\Delta P_{M,i,t}^{FR}$). Utilizing national and regional IO tables for 2001, we were able to determine the regional contribution to national production for each sector i stemming from imports from the rest of the world $\left(\frac{B.P_{M,i}^{AQUI}}{B.P_{M,i}^{FR}} \right)$. This contribution was dynamized based on quantity of imports from the rest of the world. If the variation in imports from the rest of the world was greater at the regional level than at the national level, we should expect a greater decrease in production deriving from imports from the rest of the world in the region than in the nation as a whole. Thus, the variation in production stemming from imports from the rest of the world was found as follows :

$$\Delta P_{M,i,t}^{AQUI,RdM} = \Delta P_{M,i,t}^{FR} . \left(\frac{B.P_{M,i}^{AQUI}}{B.P_{M,i}^{FR}} . \frac{M_t^{AQUI} \Big/ M_{t-1}^{AQUI}}{M_t^{FR} / M_{t-1}^{FR}} \right) \tag{9}$$

This is the method we used to regionalize the various national production components. It thus remains for us to elucidate and explain our approach to the issue of interregional trade.

2.2.2 Estimation of Variations in Regional Production Stemming from Interregional Trade

It is difficult to estimate interregional imports and exports as these are incorporated within the national IO table in the various components of domestic final demand. In fact, exports to other French regions feed domestic final demand of other French regions and imports coming from other French regions feed domestic final demand of the Aquitaine region. Due to the fact that regional accounting is poorly developed, there exist no data on French interregional trade. Thus, the evolution of interregional trade is estimated based on hypotheses. We perform two calculation steps to estimate interregional trade.

The first step consists in assuming that, for each year t and each sector i, the relative variation in production stemming from exports $\left(\frac{\Delta P^{AQUI,R}_{X,i,t}}{P^{AQUI,R}_{X,i,t}}\right)$ and imports $\left(\frac{\Delta P^{R,AQUI}_{M,i,t}}{P^{R,AQUI}_{M,i,t}}\right)$ is equal to the relative variation in national production stemming from final demand $\left(\frac{\Delta P^{FR}_{Y,i,t}}{P^{FR}_{Y,i,t}}\right)$

We thus assume in the first calculation step, the following:

$$\frac{\Delta P^{AQUI,R}_{X,i,t}}{P^{AQUI,R}_{X,i,t}} = \frac{\Delta P^{R,AQUI}_{M,i,t}}{P^{R,AQUI}_{M,i,t}} = \frac{\Delta P^{FR}_{Y,i,t}}{P^{FR}_{Y,i,t}} \tag{10}$$

This hypothesis enables us to differentiate the variation in production deriving from interregional trade between different sectors. Naturally, this hypothesis of identical relative variation for each sector for imports and exports between different French regions is too strong and will be dropped in the second step.

The second step consists in taking into consideration regional differences regarding relative variations in imports and exports of each sector i and each year y. As stated above, exports from the Aquitaine region to other French regions depend on the final demand of the other French regions, just as imports coming from other French regions into the Aquitaine region are dependent on the final demand of the Aquitaine region. As the INSEE gives no information on amounts for regional final demand, one must first find an alternative indicator that traces the evolution of final demand between the different French regions. Gross disposable income (GDI) is an indicator that may be of use as it corresponds to the amount of revenue that allows for consumption (feeding final demand) and for saving. But however the share consumed of gross disposable income may vary and thus there is no inevitable correlation with final demand. However, according to Keynes (1936), average propensity to consume remains stable. In order to verify this assertion, we performed an econometric estimate between final demand and gross disposable income by volume between 1959 and 2007. Graph 1 shows clearly a strong correlation between GDI and final demand with a high correlation coefficient ($R^2 = 0.99$), permitting validation of Keynes' hypothesis for the French regions.

< Insert graph 1 >

Thus, according to these results, it is acceptable to assume that relative variation in gross disposable income is identical to relative variation in national final demand. Thus, to estimate the relative variation of exports for each sector i and for each year t, we will weight relative variation of national final demand using the evolution of gross disposable income of the other French regions. Thus, the relative variation in exports to other French regions is calculated as follows :

$$\frac{\Delta P_{X,i,t}^{AQUI,R}}{P_{X,i,t}^{AQUI,R}} = \frac{\left(GDI_t^{AQUI} \big/ GDI_{t-1}^{AQUI}\right)}{\left(GDI_t^{FR}/GDI_{t-1}^{FR}\right)} . \frac{\Delta P_{Y,i,t}^{FR}}{P_{Y,i,t}^{FR}} \tag{11}$$

In identical fashion for imports coming from other French regions for each sector i and each year t, we will weight relative variation for final demand with the gross disposable income for the Aquitaine region. Thus, the relative variation of imports to other French regions is calculated as follows:

$$\frac{\Delta P_{M,i,t}^{AQUI,R}}{P_{M,i,t}^{AQUI,R}} = \frac{\left(GDI_t^{R}/GDI_{t-1}^{R}\right)}{\left(GDI_t^{FR}/GDI_{t-1}^{FR}\right)} . \frac{\Delta P_{Y,i,t}^{FR}}{P_{Y,i,t}^{FR}} \tag{12}$$

We were thus able to estimate the evolution of each component of regional production between 1999 and 2005. We can estimate the production amount and added value per region and thus calculate the rate of economic regional growth.

2.3 Estimation of Production of Regions and of Regional GDP

We know for each year from 1999 to 2005 and for each sector the evolution of production deriving from its different components. By adding these, we obtain the evolution of regional production by sector.

$$\Delta P_{i,t}^{AQUI} = \Delta P_{B,i,t}^{AQUI} + \Delta P_{FC,i,t}^{AQUI} + \Delta P_{GCF,i,t}^{AQUI} + \Delta P_{X,i,t}^{AQUI,RdM} + \Delta P_{X,i,t}^{AQUI,R} + \Delta P_{M,i,t}^{AQUI,RdM} + \Delta P_{M,i,t}^{AQUI,R} \tag{13}$$

Due to the fact that we know for each sector and for each year, the evolution of regional production between 1999 and 2005 and the amount of production for 2001, we can estimate the amount of production for each sector between 1999 and 2005.

Gross added value is calculated by finding the product of production and added value per unit produced. Due to the fact that we assumed during construction of our regional IO table that the productive structure was identical for France and for the region, this hypothesis involves assuming that the added value per unit produced (indicator of productive efficiency) is identical for nation and region. National IO table indicates the amount of added value per unit produced. It suffices to multiply by regional production to obtain added value for each sector.

$$VAB_{it}^{AQUI} = v_{it}.P_{i,t}^{AQUI} \tag{14}$$

We obtained an estimate for regional GDP by adding the added value of all sectors between 1999 and 2005. We could thus determine growth in GDP by volume for the Aquitaine region for this period.

It was possible to compare our estimates with INSEE data as INSEE estimates regional GDP by volume from 1999 to 2005. We are thus able to obtain an estimate for errors produced during regionalization for variations in national production. The comparison of the two rates of growth for GDP can be seen in Graph 2.

< Insert graph 2 >

Seen in graphic form, we observe a pretty clear correlation between the two growth rates. We can observe strong growth (around 5%) for 1999-2005 with a reduction in growth rate up to 2003, with zero or indeed negative growth rate for that year, and then a recovery for the period 2004-2005 (around 2.5$/year). By calculating the linear correlation coefficient, we obtain a value of 0.74. Said otherwise, the variation in GDP derived from our estimate explains 74% of real variation in GDP. Although this coefficient is rather high, it also indicates a non-negligible error as our model does not succeed in explaining 26% of variations in GDP. These errors are quite significant for two periods: 2000-2001 and 2002-2003. For the period 2000-2001, our growth rate estimated is largely undervalued compared to that observed: we estimated a growth rate of 1.5% while in reality it was slightly higher than 4%. For the period 2002-2003, we estimated a very weak rate of growth, indeed zero growth, while in reality the region experienced a recession with a reduction in GDP of 1%. We can however concede that the errors are acceptable when compared to the hypotheses produced to regionalize the national variations.

After having estimated production for the Aquitaine region, we can calculate the evolution of energy consumption and greenhouse gas emissions for the Aquitaine region.

2.4 Estimation of Energy Consumption and Greenhouse Gas Emissions for the Aquitaine Region for the Period 1999-2005

Due to the fact that emissions depend on the combustion of fossil fuels, it is important to calculate the evolution of energy consumption during these periods through the calculation of variations in energy intensity using a technical coefficients matrix. The values for emission coefficients will enable estimation of greenhouse gas emissions for the Aquitaine region during this period.

2.4.1 Estimation of Energy Consumption and Energy Intensity for the Aquitaine Region

Energy consumption deriving from companies and that deriving from households should be separated. Let us first look at energy consumption deriving from the business sector.

The technical coefficient matrix is an indicator of energy intensity as it indicates for different energy sectors the monetary amount of energy consumption required to produce one monetary unit. Due to the fact that evolutions are by volume, we can calculate the evolution of energy intensity for France. Based on the hypothesis of an identical productive structure for both France and the Aquitaine region, the technical coefficients, as well as their variation, are identical between nation and region. Said otherwise, energy intensity varies identically between nation and region. We calculated for France the variation in technical coefficients for different energy sectors in the following manner:

$$\Delta A_{t/t-1}.\alpha = A_t.\alpha - A_{t-1}.\alpha \tag{15}$$

In the above equation, the matrix A represents the technical coefficients matrix and the coefficient α is a vector permitting selection of different energy sectors. It is thus equal to 1 for the different energy sectors and 0 for the other sectors. Due to the fact that we estimated for each year and each sector production and technical coefficients, the amount of energy consumption expressed as a monetary unit was calculated easily by multiplying technical coefficients matrix with production vector.

$$CI.\alpha = A.P.\alpha \tag{16}$$

To convert the monetary data to physical data, it remains simply to multiply by the inverse of the shadow prices calculated in our regional IO table for 2001. In fact, as the IO tables for 1999 to 2005 are indicated by volume (in terms of 2001 constant prices), the shadow prices are assumed to be constant. Thus, we were able to estimate energy consumption as expressed in ktoe for the Aquitaine region for 1999 to 2005.

In regard to energy consunption deriving from households, we will assume that regional evolution for households final consumption for fossil fuels is identical to the national trend. As we had already calculated the relative variation for final consumption at the national level, we will assume that this variation is identical at the regional level. We thus obtained an estimate for final consumption for fossil fuels for the Aquitaine region for the period 1999-2005 expressed as a monetary unit. To convert this to a physical unit, we multiplied by the inverse of the price calculated in the IO table of 2001. We thus obtained an estimate for energy consumption, expressed in ktoe deriving from households for the period 1999-2005.

To obtain total energy consumption for the Aquitaine region, it suffices to add energy consumption deriving from the activity sectors with that deriving from households. For the period 1999-2005, total energy consumption increased on average by 0.68%/year with a significant increase for the period 1999-2000 (+4.7%) and a reduction for the period 2001-2002 (-2.7%). Refer to Graph 3 for the evolution in energy consumption by type of fossil fuel for the Aquitaine region.

< Insert graph 3 >

Consumption grows in effect for gas fuels (+2%/year), and to a lesser degree for liquid fuels fuel oils included (+0.5%/year). On the other hand, wood and solid fuel consumption decreases (-1.4% and 1.5% respectively). For wood, the trend is particularly affected as a consequence of the storm, named Martin, of 1999. The increase in wood consumption for the period 1999-2001 corresponds to the dispersal of wood stocks. After 2001, due to the fact that wood stocks were reduced, consumption was decreased.

We also calculated the evolution of energy intensity, being the relationship between total energy consumption and GDP. Refer to the results as shown in Graph 4.

< Insert graph 4 >

We can observe for the Aquitaine region an overall trend towards an improvement in energy intensity. However, it is worth noting that, during the period of economic growth, energy intensity has a tendency, by contrast, to deteriorate.

Estimates of energy consumption and of production permit an estimate for greenhouse gas emissions.

2.4.2 Estimates for Greenhouse Gas Emissions for the Region of Aquitaine

Greenhouse gas emissions are related to energy consumption and to production via emission coefficients. These are calculated during the construction of IO tables and of inventory emissions for 2001. We assume that emission coefficients remain stable. We were thus able to estimate greenhouse gas emissions for the Aquitaine region for each year of the period from 1999 to 2005 and for each sector. To calculate total greenhouse gas emissions for the Aquitaine region, it is sufficient to add together greenhouse gas emissions for each sector.

We calculated using the structural decomposition method the evolution of rate of growth of greenhouse gas emissions compared to the evolution of rate of economic growth. The results can be viewed in Graph 5.

< Insert graph 5 >

Greenhouse gas emissions increased on average by 1.04%, i.e., less rapidly than production. This shows that emission intensity improved during this period. From our graph it can be seen that emissions trends follow that of production but during these years emissions growth was always lower than economic growth, except for 2003-2004. Emissions even went down for the periods 2000-2001 and 2003-2004.

With these estimates, we can construct by extrapolation the baseline scenario.

3 Construction of the Baseline Scenario Using the Extrapolation Method to Estimate GDP and Emissions for the Aquitaine Region for 2013

Construction of the baseline scenario using the extrapolation method consists in assuming that evolution of GDP and and of greenhouse gas emissions follow the same trends as in the past, assuming that no new policy or that no shock event affects production during this period. Hoekstra and Van Den Bergh (2006) advocate the use of econometric tools for the construction of the baseline scenario. But in concrete terms the use of these tools is quite a difficult matter due to the small number of IO tables by volume. In our case, we need IO tables for 114 sectors in order to be compatible with our specific nomenclature, thereby permitting the relation of economic data to environmental data. The INSEE does not estimate IO tables with this level of historical detail prior to 1999 due to change in base. Thus, six observations are not sufficient to calculate an econometric estimate. Hoekstra and Van Den Bergh (2006), only having in their possession two IO tables, assume a linear variation in production from 1990 to 2030 ! This method is not appropriate as it does not incorporate the uncertainties that stem from such a strong hypothesis. The Bootstrap method seems more suitable for addressing our framed problem, as this incorporates the uncertainties that stem from differences of variation in time. We will lay out the method as follows. Bootstrapping consists in performing random resampling with replacements from observed data. This method is often well adapted to cases of small samples as its objective is to increase the number of observations in order to estimate function distribution. Yet however, the results of the Bootstrap method do not redress all problems, and still remain dependent on the quality of the data. We thus construct a Bootstrap matrix, as seen here below.

$$\begin{pmatrix} x \\ x_1^* \\ x_2^* \\ \vdots \\ x_B^* \end{pmatrix} = \begin{pmatrix} x_1 & x_2 & \cdots & x_n \\ x_{11}^* & x_{12}^* & \cdots & x_{1n}^* \\ x_{21}^* & x_{22}^* & \cdots & x_{2n}^* \\ \vdots & \vdots & \vdots & \vdots \\ x_{B1}^* & x_{B2}^* & \cdots & x_{Bn}^* \end{pmatrix} \tag{17}$$

Each line i corresponds to a bootstrap sample x_i^*, except for the first line, which corresponds to the observed sample x. We thus have $B + 1$ lines where B represents the number of resamples effected. It is important that B be a large number as the larger B is, the more the results converge and are stable. In our case, we have set B as equal to 50 000. Each bootstrap sample x_i^* is a random resampling with replacements from x. The number of columns corresponds to the number of observations in the sample. In our case, n=6. For each sample i, we will calculate its average corresponding to average annual growth in GDP between 2005 and 2013. We thereby obtain B possible average annual variation for GDP taking the observations into account. We can thus represent graphically along the X-axis the different amounts possible for GDP and along the Y-axis the frequency. We thus obtain a distribution function for GDP. It is important to note that the higher the standard deviation of variation in GDP for the period 1999-2005, the flatter the belle curve will be, and thus the higher the confidence interval for GDP for 2013, with a relative error risk of 5%, increases. This increase in confidence interval is interpreted as an increase in uncertainty stemming from the strong variation in growth in GDP in the period 2001-2005.

Graph 6 shows the density function for GDP without adjustment.

< Insert graph 6 >

We can observe strong variations in the density function due to the fact that these are discrete data and dependent on number of resampling. This function becomes increasingly smooth with the increase in number of resampling B. To overcome this problem, we will perfom a kernel-based method for non-parametric estimation so as to smooth the distribution function. See here below the method used for the estimation.

$$f_n\left(x\right)=\frac{1}{n.h}\sum_{i=1}^{n}K\left(\frac{x-X_i}{h}\right) \tag{18}$$

where X_i are the bootstrap samples, K the kernel density function ($K\left(t\right)\geq 0$ and $\int K\left(t\right).dt=1$)and h bandwidth (or smoothing) parameter ($h>0$).
The aim of the kernel-based method for non-parametric estimation is to find the optimal smoothing parameter h. A number h that is too low does not permit appropriate adjustment but an h that is too high reduces accuracy and increases the confidence interval. The optimal value for h will be found by experimentation.
Graph 7 shows the distribution function of GDP for 2013 after smoothing

< Insert graph 7 >

In taking relative error risk to be 5%, GDP for the Aquitaine region would be situated between € 816 M and € 116 M, i.e., an average annual increase between 0.96% and 2.57%. The amount of GDP that would have the highest probability for 2013 would be € 151 M, i.e., average annual growth of 1.73%.
Graph 8 shows the distribution function for greenhouse gas emissions for 2013.

< Insert graph 8 >

In taking relative error risk to be 5%, greenhouse gas emissions for the Aquitaine region would be situated between 22 121 ktCO_2eq and 27 505 ktCO_2eq, i.e., an average annual increase between -0.45% and 2.30%. The amount of emissions that would have the highest probability for 2013 would be 24 683 ktCO_2eq, i.e., an average annual growth of 0.92%.
Improvements in energy intensity levels will permit stabilization of emissions despite moderate economic growth. However, in the case of the baseline scenario, emission reduction targets such as those maintained by the regional council of Aquitaine will not be achievable. Thus, efforts will be required if the region wishes to attain its objectives.
This said, the period 2007-2013 was marked by the occurrence of a severe economic crisis, producing a break with the previous period of economic growth. Thus, this crisis throws in to question the validity of the results in the case of construction of a baseline scenario by extrapolation.

4 Forecasts for Greenhouse Gas Emissions for the Aquitaine Region up to 2013 via Simulation of a Crisis

The shock of the subprime fiasco in the United States in 2007 provoked a financial crisis resulting in a tightening of credit in the real economy. Europe was affected by this crisis with repercussions for the national regional economy. The growth by volume of GDP for France began to recede as of 2007 with growth of 2.1% for 2007 and 0.7% for 2008, with a recession expected for 2009. Yet, there exist still very strong uncertainties in regard to the evolution of the crisis. Although there exist some forecasts indicating a moderate recovery in economic growth starting in 2010 (IMF, OECD, European Commission), it is difficult to estimate the contribution of different production components to such a recovery. It is thus impossible to predict the evolution of production components for up to 2013. However, what interests us here is less a precise estimation of the effect of the crisis on the regional economy, and rather the capacity of the model to estimate the economic impact of such a crisis.

4.1 Methodology for Simulating an Economic Crisis

The first stage consists in estimating variations for final demand components by eclipsing variation for production stemming from technological change. Between 2005 and 2008, the INSEE gives variations for different final demand components (final consumption, gross capital formation, exports and imports), and thereby an estimate of variation of final demand components for 2009. We will use these data to predict production (exclusive of technological change) for the period 2005-2009. We will assume that regional variation of final demand components k is identical for France and the region of Aquitaine. Although we know the aggregated variation, we are not able to determine variation by sector. We thus employ historical data to perform these predictions. We will assume that relative variation of final demand components k of each sector i is proportional to relative overall variations of each component k taking into account past relative variations for each sector (between 2001 and 2005). We will first calculate relative rates of variation in necessary points so as to reach the target of variation of component k of final demand as indicated in the equation below :

$$\bar{\alpha}_{t+1,k} = \gamma_{t+1,k} - \gamma_{t,k} \tag{19}$$

where $\bar{\alpha}_{t+1,k}$ is the differential in total rate of variation by points of component k of final demand for the period $t+1$, corresponding to the difference between relative rate of variation of the final demand component k in the period $t+1$ ($\gamma_{t+1,k}$) and relative variation rate of component k of final demand in the period $t(\gamma_{t,k})$.

Taking this information into consideration, we can thus calculate the rate of variation for components of final demand for production stemming from final demand k of each sector i in the following manner :

$$\gamma_{t+1,i,k} = \gamma_{t,i,k} - \bar{\alpha}_{t+1,k} \tag{20}$$

We took as our point of departure (for the period 1999-2005) the average annual growth of the various final demand components, and we estimated the various production components by employing Equation 20 for up to 2013 iteratively.

This hypothesis implies an even higher decline for sectors experiencing difficulties if the crisis had not taken place without going out the market, and a slowing or decline for sectors experiencing growth attached to a period of expansion. The principal disadvantage of this method is that we are not here incorporating changes in consumption habits linked to the occurrence of the crisis. This hypothesis, although with its faults, seems to be the most realistic one for use taking into account the information in our possession [1]. We have therefore, for the year $t+1$, production values stemming from each final demand component. The second stage consists in estimating the average variation in production as stemming from technological change. We took as our base-line average annual variation in production exclusive of the effects of technological change. We assume that production deriving from technological change varies proportionally with the amount of total production deriving from final demand, thus assuming that efforts towards technological change remain unchanged despite the crisis.

We thus have an estimate for total production based on variations in final demand components. To estimate energy consumption, we calculated average annual variation of technological coefficients of different energy sectors for the period 2001-2005. We assume that the evolution of technological coefficients would follow the same trend as past data presents, due to the fact that we have no information in regard to evolution of energy intensity by sector. Said otherwise, it is assumed past efforts in regard to improvement in energy intensity will be reproduced in an identical fashion in the future. We thus have a monetary estimate for energy consumption. Energy consumption and greenhouse gas emissions were estimated based on the same method by extrapolation, assuming shadow prices and emissions coefficients that are constant.

4.2 Results of the Simulation of an Economic Crisis

In Table 1 can be seen hypotheses regarding variations in final demand components from 2005 to 2013.

$<$ Insert table 1 $>$

[1] The use of absolute variation would pose the problem of the disappearance of a large number sectors during a recession, which would be a completely an unrealistic and aberrant result

Between 2001 and 2005 these are average annual variations, between 2006 and 2009 observations and forecasts are from the INSEE, and between 2010 and 2013 our hypotheses as constructed for variations in production components are presented. It may be noted that the crisis has affected investment in particular (with a collapse in exports stemming from the reduction in world demand). Domestic demand has withstood the crisis relatively well, supported by demand coming from the public sector (via its stimulation packages) and to a lesser degree from households. We assume for the period 2010-2013 moderate growth in domestic demand, and a less dramatic reduction compared to 2009 for investment, imports and exports. The results regarding evolution of GDP and greenhouse gas emissions for the period 2002-2013 can be seen in Graph 9 :

< Insert graph 9 >

Trends between 2002 and 2005 are the same as in Graph 2 as these are the evolutions observed. However, trends as of 2005 are no longer linear. It can be seen that the occurrence of the economic crisis became manifest in 2009 with, according to the INSEE hypotheses in regard to the evolution of final demand components, a reduction in GDP by 1.7%. After 2009, a more moderate reduction in investment and international trade associated with growth in final consumption should permit an exit from the recession but with economic growth of essentially zero (0.2%). In this scenario, the growth in GDP should on average for the period 2007-2013 be -0.04%. At the same time, according to our hypotheses, the simulation shows a rate of growth in emissions lower than that of the growth rate for GDP. Beginning in 2008, emissions will come down, with a relatively significant reduction for 2009 (-1.8%), a result of the economic crisis. Between 2007 and 2013, emissions will fall by 2.5%, this being an average annual reduction of 0.4%. This reduction in emissions stems both from the crisis, with zero and negative growth for 2009, but also from efforts to improve energy intensity. Graph 10 shows trends in energy intensity for the period 2002-2013.

< Insert graph 10 >

Applying our hypotheses, energy intensity decreases, but at a decreasing rate.

The simulation of a crisis produces noteworthy results as compared to the baseline scenario. It demonstrates that the occurrence of a crisis, based on our hypotheses, allows for a reduction in emissions, but these are insufficient for attaining climate objectives. Thus, such a crisis notwithstanding, additional efforts will have to be undertaken in order to achieve emissions reduction.

5 Conclusion

We conclude that the structural decomposition method is a type of analysis that is suitable for dynamic regional studies, enabling construction of responses to concrete problems as faced by regional policy decision-makers. This paper suggests three interesting research paths: regionalization of national results using the structural decomposition method, the capacity to make forecasts given a small number of observations and the simulation of a crisis taking into account historical data.

In regard to the regionalization of national results, this methodology allows for estimate at the sector level and in a regional framework of the evolution of emissions and of production taking account of a context wherein regional accounting systems are poorly developed. Due to the fact that local decision-makers play an important role in the putting in place of an effective climate action plan, these are the most frequently confronted with a lack of data on past sector-level evolution of emissions and production. This analysis allows therefore a highlighting of the main driving forces explaining emissions evolution by sector at the level of the region.

This survey work permits, beyond this, emissions forecasts, assuming that various forces accounting for these emissions will be reproduced in identical fashion in the future. This is the principle behind construction of a baseline scenario. These results thus permit, for the regions, determination of the natural evolution of emissions assuming no new policy decisions are implemented. These can even be made to go further by simulating the impact of an economic shock event or more generally a shock event affecting one of the final demand components, or of technological change, on greenhouse gas emissions.

Acknowledgements and Thanks

This paper was made possible thanks to financial support from the ADEME and the regional council of Aquitaine.

References

Andreosso-O'Callaghan B., Yue G. (2002) Sources of output change in China: 1987-1997: application of a structural decomposition analysis, *Applied Economics*, 34, pp. 2227-2237

Bosq D., Lecoutre J.P. (1987) *Théorie de l'estimation fonctionnelle*, Économica

Braibant M.,*Elaboration d'un tableau des entrées intermédiaires pour les années de base 2000*, INSEE

Casler S.D. et Rose A. (1998) Carbon Dioxide Emissions in the U.S. Economy: A Structural Decomposition Analysis, *Environmental and Resource Economics*, 11 (3-4), pp. 349-363

Catin M. (1992) *La modélisation régionale dans P.H DERYCKE Espace et dynamiques territoriales*, Economica.

Chang Y.F., Lin S.J. (1998) Structural decomposition of industrial CO2 emission in Taiwan: an input-output approach, *Energy Policy*, 26(1), pp 5-12

Dietzenbacher E., Los B. (1998) Structural Decomposition Techniques: Sense and sensitivity,*Economic Systems Research* , 1998, 10(4), pp. 307-323.

Efron B., Tibshirani R.J. (1993) *An introduction to the bootstrap*, Chapman & Hall

Fonds monétaire international (2009) *Perspectives de l'économie mondiale : Turbulence finan-*

cière, ralentissements et redressements

Hoekstra R., Van Den Bergh J.C. (2006) The Impact of Structural Change on Physical Flows in the Economy,*Land Economics*, 82(4), pp 582-601

Lin X.; Polenske K.R. (1995) Input-Output Anatomy of China's Energy Use Changes in the 1980s, *Economic Systems Research*, 7(1), pp. 67-84

Miller, R.E., Blair, P.D. (1985) *Input-Output Analysis: Foundations and Extensions*, Prentice-Hall International, New Jersey

Mette W. (1998) Sources of Changes in Emissions from Energy: A Structural Decomposition Analysis, *Economic systems research*, 10 (2), pp 99-112

Organisation de coopération et de développement économiques (2009) : *Perspectives économiques intermédiaires de l'OCDE*

Rose A., Casler S. (1996) Input-Output structural decomposition analysis: a critical appraisal, *Economic Systems Research*, 8(1), pp. 33-62

West G.R. (1995) Comparison of input-output, input-output econometric and computable general equilibrium impact,*Economic Systems Research* , 7(2), pp.209-228

A Table

Table 1 : Hypotheses for Variation in final demand Components between 2005 and 2013

Years	FC	GCF	X_r	X_{fr}	M_r	M_{fr}
2001-2005	2,18%	1,71%	2,16%	2,14%	2,10%	3,76%
2006	2,50%	5,00%	2,50%	5,60%	2,50%	6,50%
2007	2,50%	4,90%	2,50%	3,20%	2,50%	5,90%
2008	1,30%	0,30%	1,30%	1,00%	1,30%	2,00%
2009	0,60%	-6,20%	0,60%	-10,20%	0,60%	-5,60%
2010	1,11%	-3,00%	1,00%	-4,00%	1,00%	-2,00%
2011	1,11%	-3,00%	1,00%	-4,00%	1,00%	-2,00%
2012	1,11%	-3,00%	1,00%	-4,00%	1,00%	-2,00%
2013	1,11%	-3,00%	1,00%	-4,00%	1,00%	-2,00%

FC : Final Consumption

GCF : Gross capital formation

X_r : Exports to other French regions

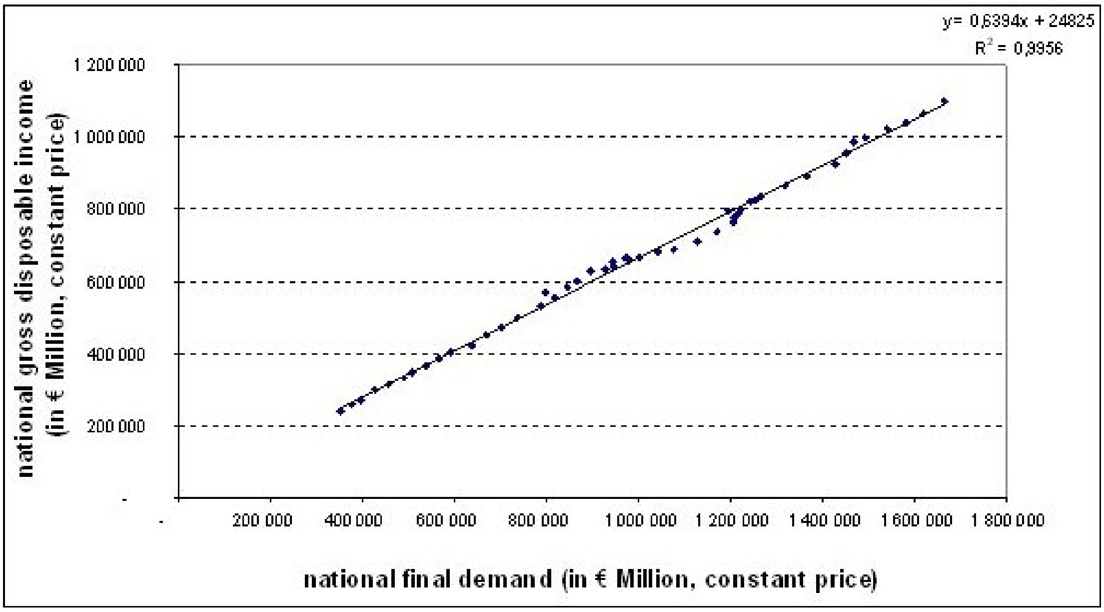
X_{fr} : Exports to the rest of the world

M_r : Imports coming from other French regions

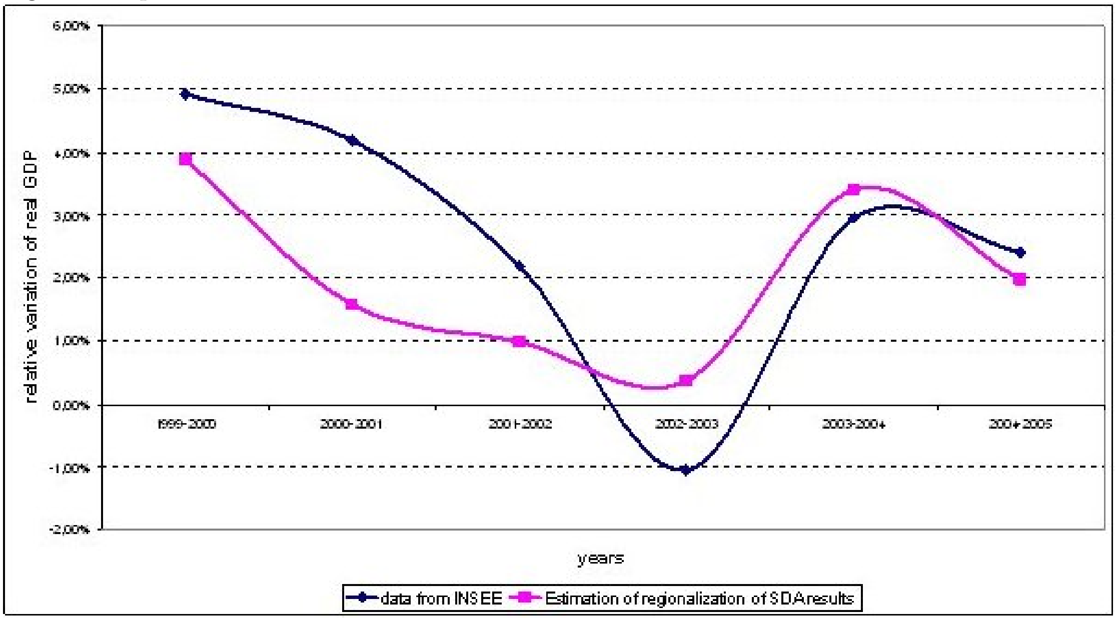
M_{fr} : Imports coming from the rest of the world

B Graphs

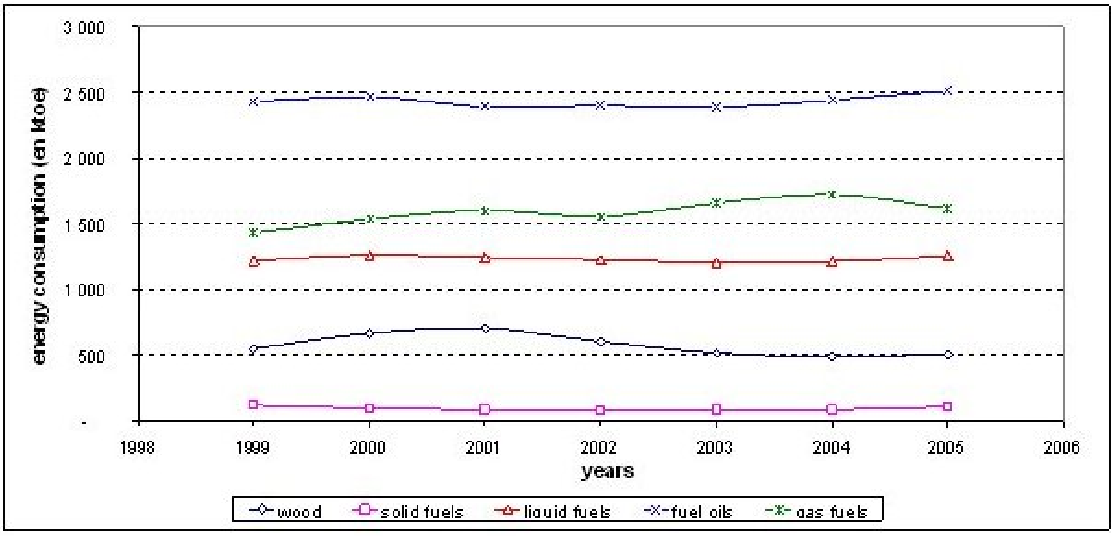
Graph 1 : GDP growth rate from our results and data from INSEE for the region of Aquitaine



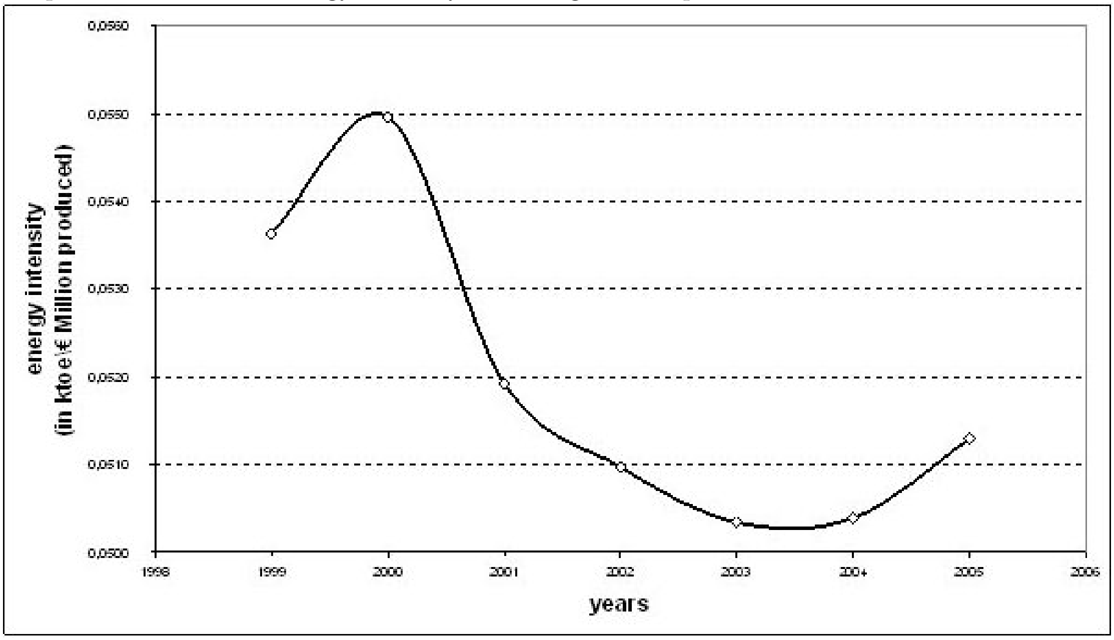
Graph 2 : comparison of GDP growth rate from our results and data from INSEE for the region of Aquitaine



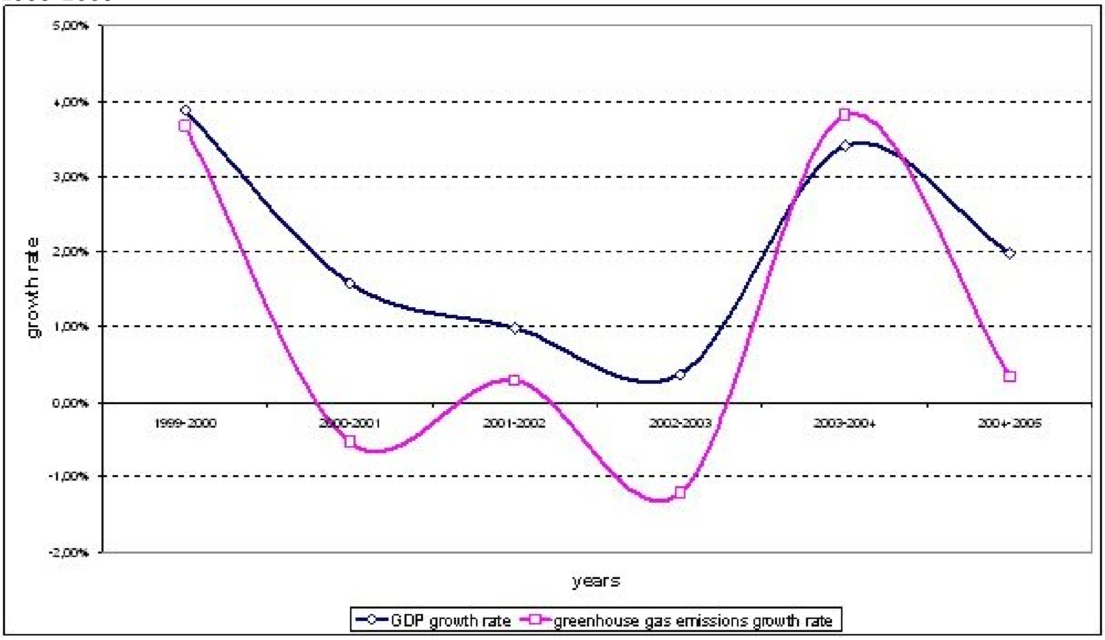
Graph 3 : Evolution of energy consumption of the region of Aquitaine



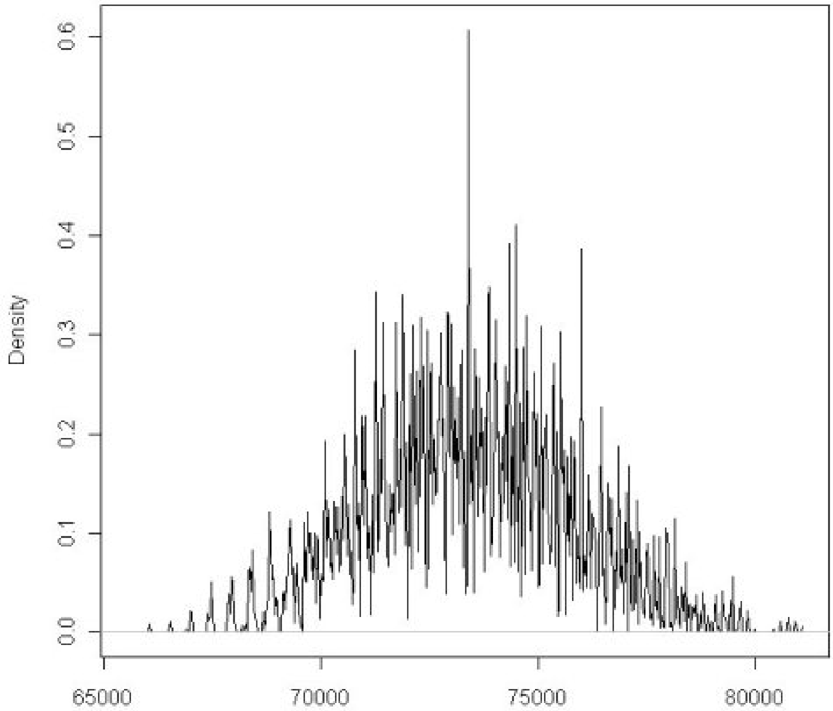
Graph 4 : Evolution of energy intensity of the region of Aquitaine



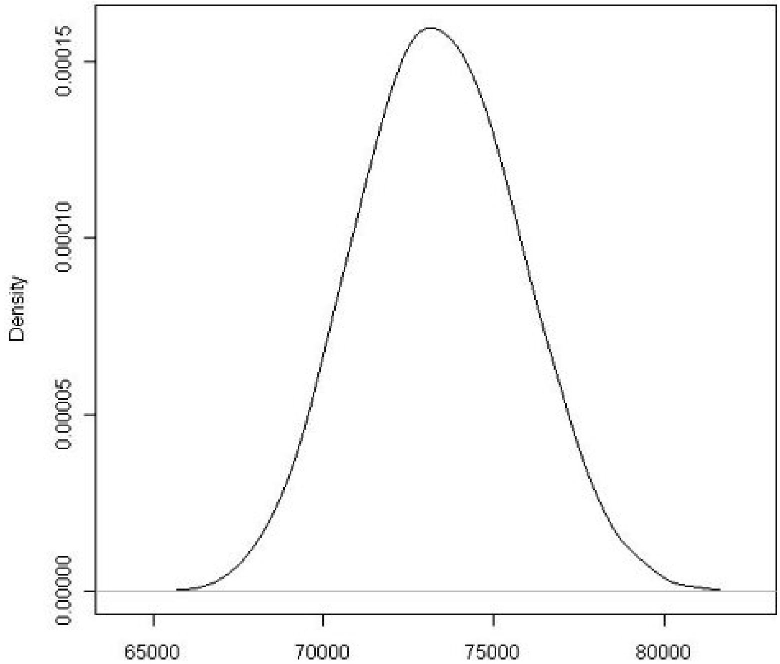
Graph 5 : GDP and greenhouse gas emissions growth rates for the region of Aquitaine for 1999-2005



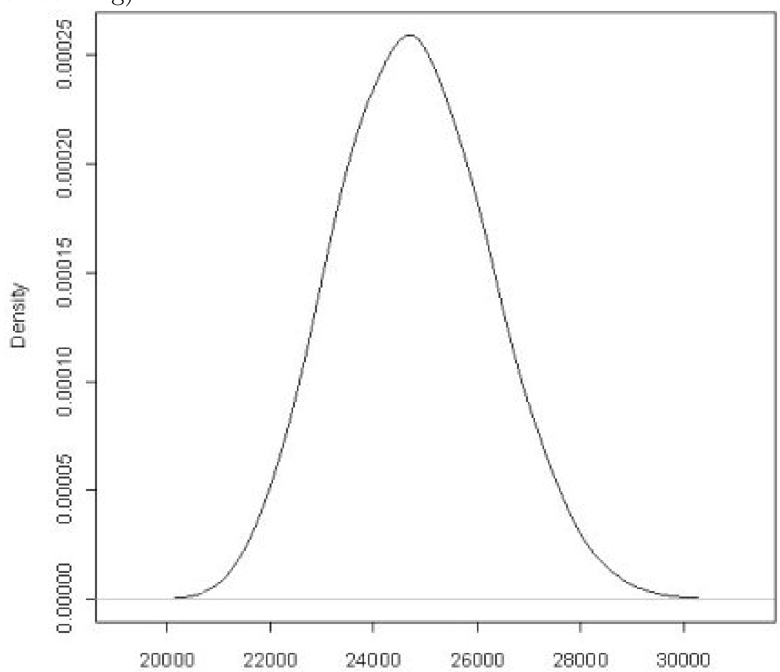
Graph 6 : GDP density function for 2013 in the region of Aquitaine (before smoothing)



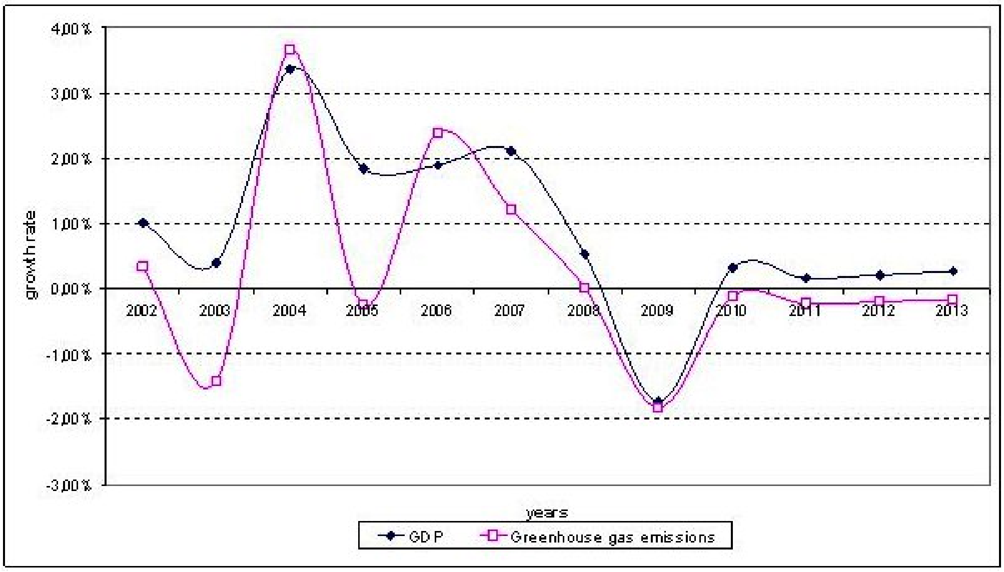
Graph 7 : GDP density function for 2013 in the region of Aquitaine (after smoothing)



Graph 8 : Greenhouse gas emissions density function for 2013 in region of Aquitaine (with smoothing)



Graph 9 : Results for Simulation of an Economic Crisis: Comparison of GDP and Emissions Growth Rates



Graph 10 : Evolution of Energy Intensity for Simulation of a Crisis