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PRESENTATION OF THE THREE-ME MODEL: MULTI-SECTOR MACROECONOMIC MODEL FOR THE EVALUATION OF ENVIRONMENTAL AND ENERGY POLICY

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Presentation of the Three-ME model: Multi-sector Macroeconomic Model for the Evaluation of Environmental and Energy policy

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Abstract

This paper presents the structure and the main properties of Three-ME. This new model of the French economy has been especially designed to evaluate the medium and long term impact of environmental and energy policies at the macroeconomic and sector levels. To do so Three-ME combines two important features. Firstly, it has the main characteristics of neo-Keynesian models by assuming a slow adjustment of effective quantities and prices to their notional level. Compared to standard multi-sectors CGEM, this has the advantage to allow for the existence of under-optimum equilibriums such as the presence of involuntary unemployment. Secondly, production and consumption structures are represented with a generalized CES function which allows for the elasticity of substitution to differ between each couple of inputs or goods. This is an improvement compared to the standard approach that uses nested CES functions which has the disadvantage to impose a common elasticity of substitution between the goods located in two different nested structures.

Key word: neo-Keynesian model, macroeconomic modeling, energy and environmental policy modeling

JEL code: E12, E17, E27, E37, E47, D57, D58

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Contents

I Introduction

At the country level, there are generally two types of model able to evaluate of the economic impact of environmental and energy policy: Computable General Equilibrium Models (CGEM) and neo-Keynesian macroeconomic models. Widely used to analyze a large range of economic problems, CGEM have the advantage to combine tractability with a high level of detail, being able to distinguish different countries, goods, type of consumer, etc[1]. Particularly important for the analysis of the economic impact of environmental and energy policy, they often account for an important number of sectors: *e.g.* GREEN has 11 sectors (Burniaux et al., 1992), GEMINI-E3 has 18 sectors of which 5 energy sectors (Bernard and Vielle, 2008), GEM-E3 has 14 sectors (Capros et al., 1997), IMACLIM-S has 10 sectors (Ghersi and Thubin, 2009). But CGEM have the drawback to rely on very restrictive assumptions relative to the functioning of the economy especially in the short and medium run. CGEM are supply models where the hypothesis of perfect price flexibility often insures the full and optimal use of production factors and thus rule out permanent or transitory under-optimum equilibrium such as the presence of involuntary unemployment.

Neo-Keynesian macroeconomic models try to give a more realistic representation of the actual functioning of the economy taking explicitly into account slow adjustments of prices and quantities, thus allowing for permanent or transitory under-optimum equilibrium. This effort seems to have a cost in terms of the detail of the disaggregation which is often limited to a small number. This is typically the case for currently running macroeconomic models for the French economy: *e.g.* MESANGE of the French ministry of Economy has three sectors (Allard-Prigent et al., 2002), E-Mod of the OFCE (Chauvin et al., 2002) and MASCOTTE of the French central bank (Baghli et al., 2004) have only one. However, earlier versions of theses model in the 1980’s and 1990’s had a higher level of disaggregation, between 6 and 8 products (see Economie et Prévision, 1998). But still, neo-Keynesian macroeconomic models generally do not distinguish between the different types of energy or of transport which are particularly important for the assessment of environmental and energy policy[2]. They are thus likely to neglect the effect of activity transfers in terms of growth and employment from high to low intensive energy sectors.

[1] For a survey on CGEM see Böhringer and Löschel (2006).

[2] NEMESIS is an exception with 30 sectors covering 16 European countries (Brécard et al., 2006; Zagamé et al., 2010)

Three-ME (Multi-sector Macroeconomic Model for the Evaluation of Environmental and Energy policy) is a new model of the French economy developed by ADEME, OFCE and IVM. Its main purpose is to evaluate the impact of environmental and energy policy measures on the economy at the macroeconomic and sectoral levels. Having the general structure of neo-Keynesian macroeconomic models, Three-ME seems more realistic than the standard CGEM for describing the actual dynamic of the economy at least in the short and medium run. Disaggregated in 24 sectors with an explicitly distinction between four types of energy and five types of transports, it allows for the neo-Keynesian short term macroeconomic modeling approach to catch-up with the most advanced CGEM in terms of sectoral analysis.

Moreover, Three-ME aims to overcome the restriction imposed by nested Constant Elastiscity of Substitution (CES) functions by assuming a more flexible form of the production function. This is a clear difference with most CGEM where the technology is generally represented by a series of nested CES production function (e.g. Bernard and Vielle, 2008; Burniaux et al., 1992). Nested CES functions proposed by Sato (1967) have the advantage to allow for different elasticity of substitutions between production factors that are not in the same nested structure. But within the same CES, the elasticity of substitution is common to all factors. For instance, if several energy inputs are represented within the same CES, the elasticity of substitution is the same between all these energy inputs. This may be a very strong assumption in some cases. Three-ME does not impose this restriction by assuming a generalized CES function where the elasticity of substitution is not necessary common between all the inputs of the same nested structure. This allows changing easily the hypotheses about the value of elasticity of substitutions without having to change the structure of the nest. This flexible form is also assumed to represent the substitutability possibilities between the different investment and consumption goods.

Section 2 presents an overview of the model by summarizing its main characteristics. Section 3 describes the demand and supply equilibrium. Section 4 describes the supply side and shows how we derive a simple specification of the production factor demand from a generalized CES function. Section 5 and 6 presents respectively the household and the labor market equations. In each sectors, the wage equation is an augmented Phillips curve including possible hysteresis phenomena. Under the assumption of full hysteresis, this specification has the same properties as a Wage Setting (WS) curve in level. Section 7 presents the external trade equations. Section 8 describes the price structure and how firms in each sector determine their production price. The behavior of the European Central Bank (ECB) about the determination of the interest rate is presented in Section 9. Section 10 treats the public administrations equation block. Section 11 deals with the specification of CO_2 emissions of sectors and households by type of fossil energy. Section 12 looks at the dynamic properties of the model by simulating the macroeconomic and sectoral impact of various shocks such a positive demand shock via the increase in public spending, a positive supply shock via the decrease in the employer social security rate, and the increase in the oil price and in the labor participation rate.

II Overview of the model

The overall structure of the model is schematized in Figure 1. In the short term, Three-ME has the main characteristics of a standard neo-Keynesian macroeconomic model of demand in an open economy. An important one is that demand determines supply. The demand is composed of (intermediate and final) consumption, investment and export whereas the supply comes from imports and the domestic production. As a feed-back with eventually some lags, the supply affects the demand through several mechanisms. The level of production determines the quantity of inputs used by the firms and thus the quantity of their intermediate consumptions and investment which are two components of the demand. It determines the level of employment as well and consequently the households' final consumption. Another effect of employment on demand goes through the wage setting via the unemployment rate which is also determined by the active population. The active population is mainly determined by exogenous factors such as the demography but also by endogenous factors: because of discouraged worker effects, the unemployment rate may affect the labor participation rate and thus the active population.

The unemployment rate is an important determinant of the wages dynamic which is defined by a Phillips curve. The inflationary property of the model is determined by the feedback loop between wages, production cost and prices. Prices are assumed to adjust slowly to their optimum level that corresponds to a mark-up over marginal costs. Consequently, wages, which affect production costs, affect directly prices. Prices have in return an impact on wages because of they are indexed on the consumer price. Production costs are also directly affected by prices via the cost of intermediate consumptions and of investment.

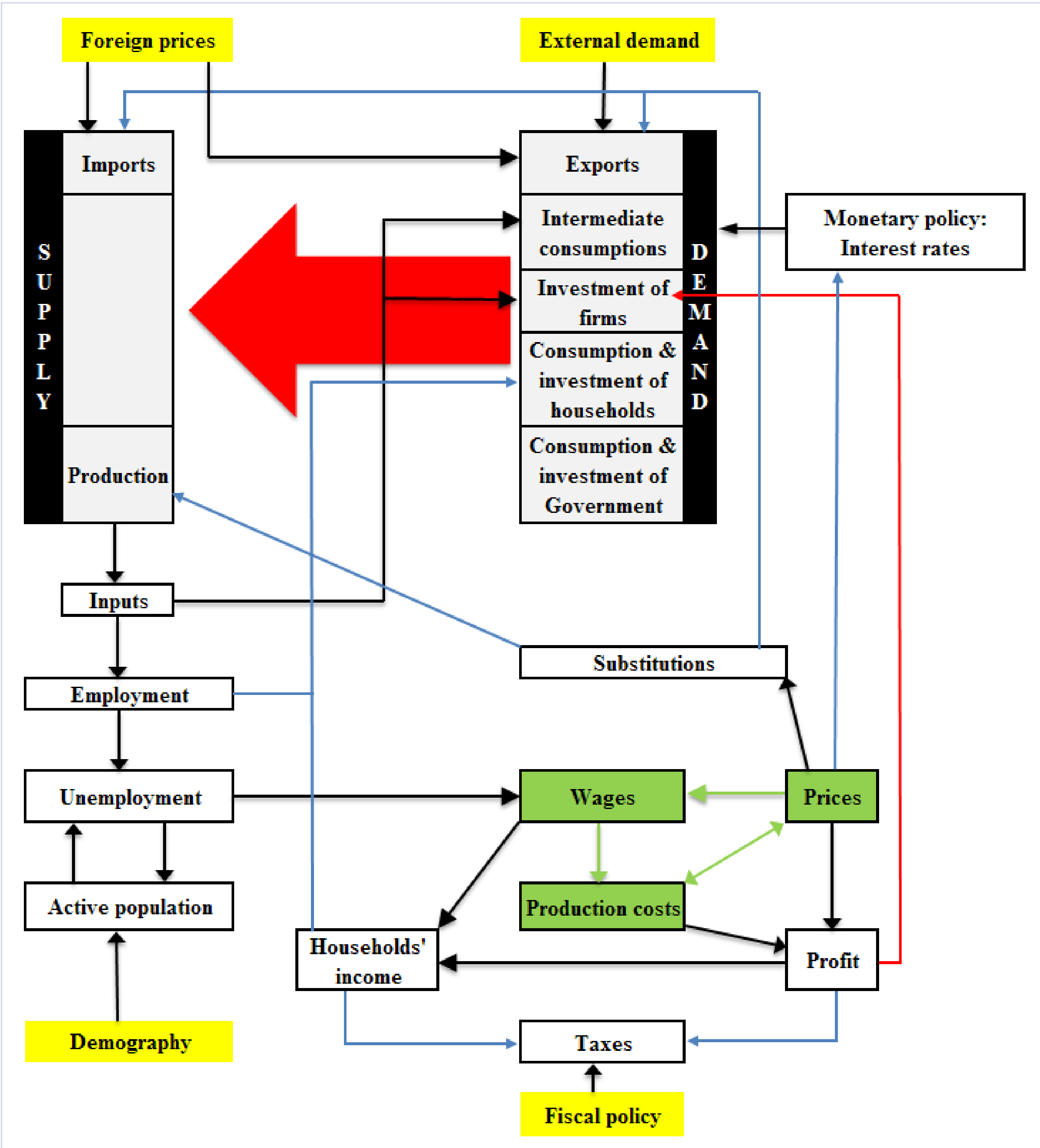
This dynamic between wages, cost and prices affects the demand through several canals. Wages affect the household consumption because they are an important part of their income. Prices and cost affect profits and thus sectors' debts level. But they affect the households' consumption and investment too because they finance a part of the private debt of the economy. Another canal is the monetary policy which is defined by a Taylor rule. The European central bank determines the interest rate level based on the European level of inflation and unemployment. This has an effect on the demand via the negative effect of the real interest rate on consumption and investment.

The dynamic of prices is the driver of the substitution mechanisms of the model. The evolution of relative prices between imported and domestic goods defines the repartition between imported and domestic products to satisfy the internal (consumption and investments) and external (export) demand. The evolution of relative prices between types of goods and services defines the structure of consumption of the economy. Importantly for the analysis of environmental and energy policies, it defines the share of each energy and transport into (intermediate and final) consumptions.

Three-ME explicitly distinguishes between five types of transports and four types of energy (resp. red and yellow lines in Table 1). Energy intensity was the main criterion for the selection of the 24 sectors (see Appendix C). This relatively high level of disaggregation is important to capture the complexity of the substitution mechanisms involved after a change in the relative price between energies. For instance, an increase in the oil price tends to lead to substitution from oil to the other energy in several ways. In addition to direct substitutions by producer and consumer, indirect effects occur via the increase of the production price of oil intensive sectors. This leads to intermediate and final consumptions structure less oil intensive. The decrease of the use of transport by road would be the most typical example.

Three-ME accounts also for endogenous energy efficiency and sobriety effects. In contrast with the substitution mechanisms, the reduction of a given energy consumption does not imply the increase of the use of another energy. Sobriety consists in refraining from consuming energy by for instance staying home during the weekend instead of taking the car or by lowering the heating temperature in the house. In general, sobriety leads to a decrease in the welfare of the consumer. In contrast, in the case of efficiency, the same welfare is achieved with a lower quantity of energy. Energy efficiency implies an investment in a more efficient technology by for instance switching from a high to a low oil consumption car or by using more efficient insulation techniques for the house. In the current version of model, endogenous efficiency phenomena are introduced through an explicit distinction between two types of housing and automobile investments: energy saving housing and "comfort" housing investments; low and high oil consumption cars.

Figure 1 Overall structure of Three-ME



In Three-ME, efficiency and sobriety phenomena decrease the consumer price since the share of energy into consumption decreases (see Section V). This allows for directly capturing the so-called “rebound effect” in consumption behaviour often observed at the micro level (Bentzen, 2004; Sorrell and al., 2009). There is a rebound effect when the effective energy saving from an investment in energy efficiency is less than the energy saving expected ex ante because the consumer uses a part of the reduction of her energy bill to increase her energy consumption. A typical example is the case of certain poor households who live in badly insulated houses and set a low heating temperature to reduce their energy bill. After an insulation investment, they will have the tendency to increase the heating temperature of their house keeping their energy bill more or less constant. This effect is explicitly taken into account in the model: an energy efficiency investment decreases the consumer price and thus increases the real income which leads to a higher level of (energy) consumption.

The short and medium run dynamic is largely driven by the demand side through multiplier and accelerator mechanisms. Because of the slow adjustment of price and quantity to their optimal value, the allocation of production factors is sub-optimal in the short and medium run. The long term is driven by the supply constrain. All adjustment processes are achieved: there is no error of anticipation and the effective quantities coincide with the optimal ones. The prices are fully adjusted and all markets are in equilibrium. The unemployment reaches its structural level. The economy thus converges toward a stable equilibrium growth path à la Solow (1956) where all real variables grow at the same rate defined as the sum of the growth rates of the technical progress and of the population. Per capita real variables grow thus at the same rate as the technical progress. All prices grow at the rate of inflation which is defined by the exogenous rate of inflation in the rest of the world. The endogenous dynamic of the model is determined by capital accumulation of households and firms, the specification of the anticipation and of the adjustment dynamic.

Three-ME model is programmed on the E-views 7 package software and simulated with the Broyden algorithm.

Table 1 Sectoral disaggregation in Three-ME

Index	Sectors	NAF 118 code
1	Agriculture, forestry and fishing	GA01-03
2	Manufacture of food products and beverages	GB01-06
3	Manufacture of motor vehicles, trailers and semi-trailers	GD01-02
4	Manufacture of glass and glass products	GF13
5	Manufacture of ceramic products and building materials	GF14
6	Manufacture of articles of paper and paperboard	GF32-33
7	Manufacture of inorganic basic chemicals	GF41
8	Manufacture of organic basic chemicals	GF42
9	Manufacture of plastics products	GF46
10	Manufacture of basic iron and steel and of ferro-alloys	GF51
11	Manufacture of non-ferrous metals	GF52
12	Other industries	GC11-12, GC20, GC31-32, GC41-46, GE11-14, GE21-28, GE31-35, GF11-12, GF21-23, GF31, GF43-45, GF53-56, GF61-62, GG12-14, GG22
13	Construction of buildings and Civil engineering	GH01-02
14	Rail transport (Passenger and Freight)	GK01
15	Passenger transport by road	GK02
16	Freight transport by road and transport via pipeline	GK03
17	Water transport	GK04
18	Air transport	GK05
19	Business services	GJ10, GJ20, GJ30, GK07-08, GK69, GL01-03, GM01-02, GN10, GN21-25, GN31-34, GN4A, GP10, GP21, GP2A, GP2B, GP31-32, GQ1A, GQ2A, GQ2C, GQ2D
20	Public services	GN4B, GQ1B, GQ2B, GQ2E, GR10, GR20
21	Mining of coal and lignite	GG11
22	Manufacture of refined petroleum products	GG15
23	Electric power generation, transmission and distribution	GG2A
24	Manufacture and distribution of gas	GG2B

III Demand and supply equilibrium

The model assumes that the French economy uses 24 products (goods or services) which can be imported or produced domestically by the 24 sectors[3]. The supply for imported and domestics products is determined by demand. Consequently, the demand and supply equilibriums for domestic *(d)* and imported *(m)* products written in vector form are:

[3] If each sector produces only one good, the production of sector *j* is equal to the production of product *i* (once one account for transport and commercial margins and subsidies and taxes on product). In practice, national accounts statistics do not respect this equality because sectors generally produces more than one good (e.g. see Piriou, 2008). Published input-output tables are generally too aggregated to identify the exact quantities transferred between one sector to another. To respect the accountancy equilibrium, one would have to made hypotheses about the direction of these transfers. To avoid this complication and since transfers are relatively small, we have merge them with the changes in inventories.

$$Y_t = IC_t^d + C_t^d + G_t^d + I_t^d + \Delta S_t^d + X_t^d \qquad [1]$$

$$M_t = IC_t^m + C_t^m + G_t^m + I_t^m + \Delta S_t^m + X_t^m \qquad [2]$$

where $Y_t = \begin{pmatrix} Y_{1t} \\ \vdots \\ Y_{24t} \end{pmatrix} = (Y_{it})$ and $M_t = \begin{pmatrix} M_{1t} \\ \vdots \\ M_{24t} \end{pmatrix} = (M_{it})$ are respectively a vectors of the domestic and imported production of product *i*, $IC_t = (IC_{it})$ the intermediate consumptions of product *i*, $C_t = (C_{it})$ the households' final consumption, $G_t = (G_{it})$ the public spending (general government final consumption), $I_t = (I_{it})$ the investment (gross fixed capital formation of households, general government and sectors), $\Delta S_t = (\Delta S_{it})$ the changes in inventories and $X_t = (X_{it})$ the exports[4].

The domestic and imported demand and supply equilibriums are expressed in purchaser's price and thus include taxes and subventions on products as well as transportation and commercial margins. The base year 2006 has been calibrated on the input-output tables and resources and uses tables of the French national accounts (available on www.insee.fr) (see the Appendix E for the French economy structure at the base year).

Domestic and imported intermediate consumptions can be expressed as a function of the domestic production of each product:

$$IC_t^z = \mathrm{A}_t Y_t \qquad \text{with } z = \{d;m\}$$

$$\mathrm{A}_t = \begin{pmatrix} \alpha_{1,1t}^z & \cdots & \alpha_{1,24t}^z \\ \vdots & \ddots & \vdots \\ \alpha_{24,1t}^z & \cdots & \alpha_{24,24t}^z \end{pmatrix} = (\alpha_{ijt}^z) = (IC_{ijt}^z / Y_{it}) \qquad [3]$$

[4] In this paper, lower-case variables are in logarithm. Variables in first difference and in growth rate are respectively referred to as $\Delta X_t = X_t - X_{t-1}$ and $\dot{X}_t = X_t / X_{t-1} - 1 \approx \Delta x_t$. X' is the transpose of matrix *X*. The *t* as an index is the time operator. All parameters written in Greek letter are positive. The constant of every equation written in log form is omitted.

where IC^z_{ijt} is the quantity of product *i* (domestic if *z* = *d* or imported if *z* = *m*) consumed by sector *j*. $\alpha^z_{ijt} = [0;1]$ is this same quantity expressed in proportion of the production of product *i*, that is the share of the intermediate consumption of sector *j* in the total production of *i*. As we shall see in Section IV , this share is determined by the specification of the demand for input and may thus vary because of technical progress and substitution mechanisms between inputs. A is the matrix of these technical coefficients and the sum of the parameters of a matrix A's column, $\sum_{\substack{i=1 \\ z=d,m}}^{24} \alpha^z_{ijt}$, corresponds to the share of the total intermediate consumption in the production of sector *j*.

Defining an import share matrix, the domestic and imported components of the final uses defined to the right of equation [1] and [2] can conveniently be expressed as a function of the aggregated final use:

$$V^d_t = (\mathbb{I}_{24,24} - \mathrm{B}^v_t)V_t \quad \text{with } \mathrm{B}^v_t = \begin{pmatrix} \gamma^v_{1t} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \gamma^v_{24t} \end{pmatrix} \qquad [4]$$

$$V^m_t = \mathrm{B}^v_t V_t$$

where the vector $V_t = (V_{it}) = \{C_t; G_t; I_t; \Delta S_t; X_t\}$ refers to the various final uses that composes the demand (final consumption, investment, change in inventories, export), $V_{it} = V^d_{it} + V^m_{it}$ is the sum of the domestic and imported final use of product *i*. $\mathbf{B}^v_t$ is the diagonal import share matrix of the final use *V*, $\gamma^v_{it} = V^v_{it} / V_{it}$ being the import share of product *i*. $\mathbb{I}_{24,24} = \begin{pmatrix} 1 & \dots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1 \end{pmatrix}$ is the identity matrix with a 24×24 dimension.

Box 1 Numerical illustration of the final use multiplier

Let us assume an economy with two sectors with following matrix of technical coefficients $\mathrm{A}_t = \begin{pmatrix} 0.1 & 0.1 \\ 0.1 & 0.1 \end{pmatrix}$. In a closed economy, the import share in the final consumption of household is zero: $\mathbf{B}_t^C = \begin{pmatrix} 0.0 & 0.0 \\ 0.0 & 0.0 \end{pmatrix}$. The Leontief matrix is thus: $\left[\mathbb{I}_{2,2} - \mathrm{A}_t\right]^{-1} = \begin{pmatrix} 1.13 & 0.13 \\ 0.13 & 1.13 \end{pmatrix}$.

If households increase their consumption of each goods by 1 unit, $\Delta C_t = \begin{pmatrix} 1 \\ 1 \end{pmatrix}$, the increase in production, $\Delta Y_t = \begin{pmatrix} 1.25 \\ 1.25 \end{pmatrix}$, is higher than the increase in consumption. The increase in value added is equal to production minus intermediate consumption: $\Delta VA_t = \begin{pmatrix} 1.25 \times (1-0.2) \\ 1.25 \times (1-0.2) \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \end{pmatrix}$ and correspond exactly to the increase in consumption.

In open economy, the multiplier effect is lower because some products are imported: the increase in consumption does not benefit only to domestic producers. For example, with an openness of 10%, $\mathbf{B}_t^C = \begin{pmatrix} 0.1 & 0.0 \\ 0.0 & 0.1 \end{pmatrix}$, the Leontief matrix becomes $\left[\mathbb{I}_{2,2} - \mathrm{A}_t\right]^{-1}\left[\mathbb{I}_{2,2} - \mathbf{B}_t^C\right] = \begin{pmatrix} 1.0 & 0.1 \\ 0.1 & 1.0 \end{pmatrix}$ and the increase in production and value-added are lower than in the previous case: $\Delta Y_t = \begin{pmatrix} 1.1 \\ 1.1 \end{pmatrix}$ and $\Delta VA_t = \begin{pmatrix} 0.88 \\ 0.88 \end{pmatrix}$. Increasing the import shares would lower production and value-added even more. When the degree of openness becomes higher than 17%, the increase in domestic production become even lower than the initial impulse, that is lower than the increase in consumption.

Combining Equations [1], [2], [3] and [4] allows to express the domestic production directly as a function of the final use quantities :

$$\begin{aligned} Y_t = & \left[\mathbb{I}_{24,24} - \mathrm{A}_t\right]^{-1}\Big(\left[\mathbb{I}_{24,24} - \mathbf{B}_t^C\right]C_t + \left[\mathbb{I}_{24,24} - \mathbf{B}_t^G\right]G_t \\ & + \left[\mathbb{I}_{24,24} - \mathbf{B}_t^I\right]I_t + \left[\mathbb{I}_{24,24} - \mathbf{B}_t^{\Delta S}\right]\Delta S_t + \left[\mathbb{I}_{24,24} - \mathbf{B}_t^X\right]X_t\Big) \end{aligned} \quad [5]$$

Equation [5] allows the calculation of the increase of production that follows the increase of a given final use. The matrix $\left[\mathbb{I}_{24,24} - \mathrm{A}_t\right]^{-1}\left[\mathbb{I}_{24,24} - \mathbf{B}_t^v\right]$, generally referred as Leontief matrix, can be interpreted as the final use multiplier: for instance, an increase of each consumption goods by 1 unit leads to an increase of each sector production by $\left[\mathbb{I}_{24,24} - \mathrm{A}_t\right]^{-1}\left[\mathbb{I}_{24,24} - \mathbf{B}_t^C\right]$ units. With a positive value of A_t, characteristic of the multi-sector models, the final demand multipliers are higher. This propriety illustrates the advantage of a multi-sector model over an aggregate macroeconomic model for the evaluation of an economic policy. The numerical illustration presented in Box 1 shows that the importance of this multiplier depends to a great extend to the degree of openness of the economy.

In order to calculate the Gross Domestic Product (GDP), it is useful to express the value-added (*VA*) as a function of the level of production:

$$VA_t = (VA_{jt}) = Y_{jt}(1 - \sum_{i=1}^{24} \alpha_{ijt}^D) = Y_t.(\mathbb{I}_{24,1} - \mathrm{A}_t'\mathbb{I}_{24,1}) \qquad [6]$$

Where . is the Hadamard product (or product component by component) of two matrices of same dimensions, $\mathbb{I}_{24,1} = \begin{pmatrix} 1 \\ \vdots \\ 1 \end{pmatrix}$ is matrix with a 24×1 dimension composed of 1.

The actual sector production (Y_{jt}) is expressed at basic price and thus exclude transportation and commercial margins (M_{jt}^{ar}), net taxes (*i.e.* taxes minus subventions) on products (PR_{it}^{tax}). For all sectors except the commercial sector (19) and the transport sectors (14 to 18), margins enter with a negative sign since they must be deducted from the production expressed in purchaser's price. On the contrary, for the commercial and transport sectors (14 to 18), transportation and commercial margins enter with a positive sign since they are a production of these sectors[5]. Let us conveniently index commercial and transport

[5] Conceptually commercial and transportation margins could be treated as intermediate consumption that increase the production of the commercial and transport sectors when the production of the other sector increases. As such they intervene in the calculation of the Leontief matrix. By convention they are not treated as

margins (14 to 19) with *i* and the all the other products with *i'*. The actual sector production is thus:

$$Y_{jt} = Y_{it} + M^{ar}_{jt} - PR^{tax}_{it} \qquad \text{for } j = i = \{14;15;16;17;18;19\}$$
$$Y_{j't} = Y_{i't} - M^{ar}_{j't} - PR^{tax}_{i't} \qquad \text{for } j' = i' \neq i \qquad [7]$$

For the commercial and the transport sectors and for the others sectors, margins are respectively:

$$M^{ar}_{jt} = \sum_{i'} M^{ar}_{i'jt} \qquad \text{for } j = i = \{14;15;16;17;18;19\}$$
$$M^{ar}_{j't} = \sum_{i} M^{ar}_{ij't} \qquad \text{for } j' = i' \neq i \qquad [8]$$

where $M^{ar}_{ij't}$ is the quantity of commercial or transport product *i* used as a margin by the (non-commercial or non-transport) sector *j'*. By definition the sum of the margins received by the commercial and transports sectors is equal to the sum of the margins paid by the other sectors:

$$\sum_{j} M^{ar}_{jt} = \sum_{j'} M^{ar}_{j't} \qquad [9]$$

IV The producer

IV.1 Demand for production factors

As shown in Figure 2, the production structure is decomposed in 3 levels. The first level assumes a technology with four production factors (or inputs) sometimes referred as a KLEM (Capital, Labor, Energy, Material) technology, thus splitting intermediary consumptions into energy and material. Compared to most existing models, we do not necessarily assume a Constant Elastiscity of Substitution (CES) between these factors. For instance the elasticity of substitution between capital and labor may differ from the one between capital and energy. To do so we use a generalized CES (GCES) function. We added a fifth element at the level one:

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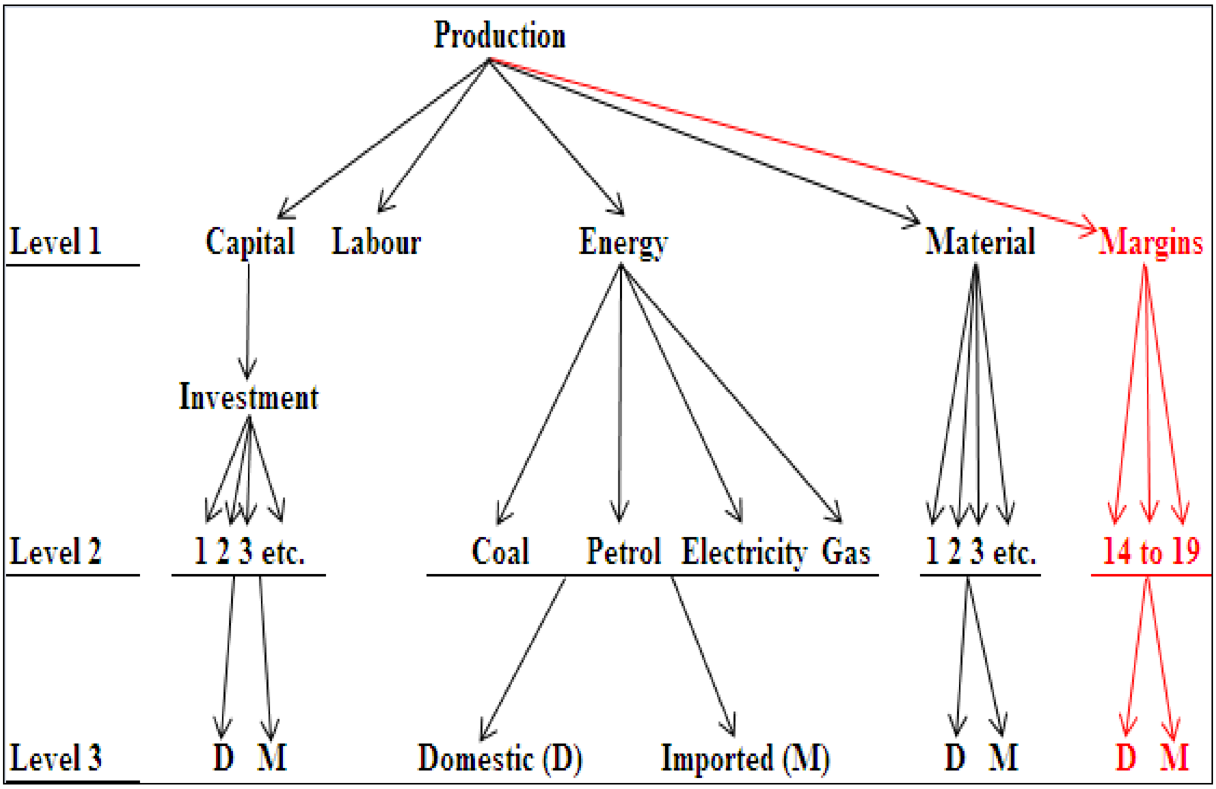
an intermediate consumption by national account statistics because margins are not incorporated in the product or destroyed during the production process.

the transport and commercial margins. Stricto sensu, they cannot be considered as production factors since they intervene after the production process. Thus they are not substitutable with the production factor. But they are closely related to the level of production since once a good has been processed, it has to be transported and commercialized. At the second level, the investment, energy, material and margins aggregates are further decomposed. The investment level is determined by the capital stock assuming a constant depreciation ratio.

At the third level, the demand for each factor or margin is either imported or produced domestically. The generalized CES function is also used to capture substitutions effect at the level 2 and 3. Moreover, we assume at each level a degree 1 homogenous function that a constant return-to-scale technology.

Figure 2 Production structure of Three-ME



Appendix B shows that the cost minimizing program of the firm in the case of a constant return-to-scale GCES technology leads to the following notional production factors (or) demand (Equation [102]):

$$i_{hjt}^{nput\_n} = y_{jt} - p_{hjt}^{rog} - \sum_{\substack{h'=1 \\ h' \neq h}}^{H} \eta_{hh',j} \varphi_{h'j}^{val} (p_{hjt}^{Input} - p_{h'jt}^{Input}) \quad \text{with } \varphi_{h'jt}^{val} = \frac{P_{hjt}^{Input} I_{hjt}^{nput}}{\sum_{h=1}^{H} P_{hjt}^{Input} I_{hjt}^{nput}} \qquad [10]$$

where I_{hjt}^{nput} and $I_{hjt}^{nput\_n}$ is the effective and notional demand of input *h* in sector *j*, $\eta_{hh',j}$ the elasticity of substitution between the production factors *h* et *h'* in sector *j*, P_{hjt}^{rog} the technical progress of input *h* in sector *j*, φ_{hjt}^{val} the value share of input *h* into the production of sector *j*. The superscript *n* refers to the adjective "notional" as opposed to "effective" as defined by neo-Keynesian disequilibrium theory (e.g. see Benassy, 1975). The notional demand is the optimal demand of the firm derived from its maximization program. We may also use the adjective "desired" since it would be the demand the firm would like to achieve immediately if there were no constrains such as adjustment costs. Moreover relation [10] can be interpreted as the equation of the Leontief technical coefficients which corresponds to the input to production ratio ($I_{hjt}^{nput\_n} / Y_{jt}$). Unlike the Leontief model, they may here vary over time because of substitution mechanisms between inputs and of the technical progress.

In coherence with the real observations of nominal and real rigidities, Three-ME assumes that effective prices and quantities adjust slowly to their notional value according to an Error Correction Model (ECM):

$$\Delta x_t = \alpha_1 \Delta x_{t-1} + \alpha_2 \Delta x_t^n - \alpha_3 (x_{t-1} - x_{t-1}^n) \qquad [11]$$

where *X* and X^n are respectively the effective and notional value of a given variable *X*. Section 4 of Appendix A shows that the use of ECM has important implication for the calibration of the long run steady state. If one does not constrain $\alpha_1 + \alpha_2 = 1$, a gap between the effective and notional quantities remains even at the steady state. The base year notional value should then be calibrated accordingly.

Equation [10] is used to model the demand factors for the three levels described in Figure 2. For illustration purposes, we derive explicitly the first level which assumes a KLEM four-production-factors function: $I_{ijt}^{nput} = \left[K_{jt}; L_{jt}; E_{jt}; M_{jt}^{at} \right]$ referring respectively to capital, labor, energy and material. As Three-ME assumes a Harrod-neutral technical progress, the technical progress appears only in the labor demand:

$$\begin{cases} k_{jt}^{n} = y_{jt} - \eta_{j}^{KL} \varphi_{jt-1}^{Val\_L} (p_{jt}^{K} - p_{jt}^{L}) - \eta_{j}^{KE} \varphi_{jt-1}^{Val\_E} (p_{jt}^{K} - p_{jt}^{E}) - \eta_{j}^{KM^{at}} \varphi_{jt-1}^{Val\_M^{at}} (p_{jt}^{K} - p_{jt}^{M^{at}}) \\ l_{jt}^{n} = y_{jt} - p_{jt}^{rog} - \eta_{j}^{KL} \varphi_{jt-1}^{Val\_K} (p_{jt}^{L} - p_{jt}^{K}) - \eta_{j}^{LE} \varphi_{jt-1}^{Val\_E} (p_{jt}^{L} - p_{jt}^{E}) - \eta_{j}^{LM^{at}} \varphi_{jt-1}^{Val\_M^{at}} (p_{jt}^{L} - p_{jt}^{M^{at}}) \\ e_{jt}^{n} = y_{jt} - \eta_{j}^{KE} \varphi_{jt-1}^{Val\_K} (p_{jt}^{E} - p_{jt}^{K}) - \eta_{j}^{LE} \varphi_{jt-1}^{Val\_L} (p_{jt}^{E} - p_{jt}^{L}) - \eta_{j}^{EM^{at}} \varphi_{jt-1}^{Val\_M^{at}} (p_{jt}^{E} - p_{jt}^{M^{at}}) \\ m_{jt}^{at,n} = y_{jt} - \eta_{j}^{KM^{at}} \varphi_{jt-1}^{Val\_K} (p_{jt}^{M^{at}} - p_{jt}^{K}) - \eta_{j}^{LM^{at}} \varphi_{jt-1}^{Val\_L} (p_{jt}^{M^{at}} - p_{jt}^{L}) - \eta_{j}^{EM^{at}} \varphi_{jt-1}^{Val\_E} (p_{jt}^{E} - p_{jt}^{M^{at}}) \end{cases} \quad [12]$$

Where $\eta_{j}^{hh'}$ is the elasticity of substitution between input h and h' with $h,h' = \left[K;L;E;M^{at}\right]$.

As explained previously, the effective production factor demand adjust slowly to the notional one according to the ECM [11]:

$$\begin{cases} \Delta k_{jt} = \alpha_{1}^{K} \Delta k_{jt-1} + \alpha_{2}^{K} \Delta k_{jt}^{n} - \alpha_{3}^{K} (k_{jt-1} - k_{jt-1}^{n}) \\ \Delta l_{jt} = \alpha_{1}^{L} \Delta l_{jt-1} + \alpha_{2}^{L} \Delta l_{jt}^{n} - \alpha_{3}^{L} (l_{jt-1} - l_{jt-1}^{n}) \\ \Delta e_{jt} = \alpha_{1}^{E} \Delta e_{jt-1} + \alpha_{2}^{E} \Delta e_{jt}^{n} - \alpha_{3}^{E} (e_{jt-1} - e_{jt-1}^{n}) \\ \Delta m_{jt}^{at} = \alpha_{1}^{M^{at}} \Delta m_{jt-1}^{at} + \alpha_{2}^{M^{at}} \Delta m_{jt}^{at\_n} - \alpha_{3}^{M^{at}} (m_{jt-1}^{at} - m_{jt-1}^{at\_n}) \end{cases} \quad [13]$$

The investment in sector j (I_{jt}) is calculated by inverting the capital accumulation equation assuming a constant depreciation rate (R_{j}^{dep}) of capital:

$$I_{jt} = \Delta K_{jt} + R_{j}^{dep} K_{jt-1} \quad [14]$$

The depreciation rate is calibrated on national account data by inverting Equation [14], using the net fixed capital stock data for capital and the gross fixed capital formation data for investment.

Because of access restriction to National account investment data disaggregated by sector, it is not possible to identify different investment patterns between the different private sectors[6]. Consequently, we assumed the same substitution behaviour between investment goods across private sectors by first calculating the aggregate private investment (I_t^s)[7]:

$$I_t^s = \sum_{\substack{j=1 \\ j\neq 20}}^{24} I_{jt} \qquad [15]$$

Then the notional demand equations for private investment in good *i* results from the producer optimization program described in Appendix B. For a given desired volume of aggregate private investment, the producer minimize the cost of investment subject to GCES technical constraint; The notional investment demand for each good thus depends on the aggregate private investment [15] and substitution effects:

$$i_{it}^{s\_n} = i_t^s - \sum_{\substack{i'=1 \\ i'\neq i}}^{I} \eta_{ii',j} \varphi_{i'j}^{val} (p_{it}^I - p_{i't}^I) \quad \text{with } \varphi_{ij}^{val} = (P_{it}^I I_{it}^s) / \sum_{i=1}^{I} P_{it}^I I_{it}^s \qquad [16]$$

Because of data availability, the investment general government (Sector 20) is treated separately:

$$i_{20t}^{g\_n} = i_t^g - \sum_{\substack{i'=1 \\ i'\neq i}}^{I} \eta_{ii',20} \varphi_{i'20}^{val} (p_{i20t}^I - p_{i'20t}^I) \qquad [17]$$

The index *i* could refer to every product produced by each sector. In practice however, only the goods produced by the sectors 1, 3, 5, 12, 13 and 19 of Table 1 are used as investment by the private and public sectors.

In current version of the model, labor is assuming homogenous inside each sector, and is thus not disaggregated further[8]. On the contrary, the aggregate of energy and material

[6] Such a disaggregation is now possible and will be included in a future version of Three-ME.

[7] The exponents *s, h* and *g* refer respectively to sectors, household and public administrations.

[8] On the contrary, the JULIEN model (Laffargue, 1996) applied to the French economy distinguishes two types of worker qualification. As suggested by econometric studies (e.g. Shadman-Mehta and Sneessens, 1995), this would allows to reproduce more accurately the recent evolution in the industry sector by accounting for different

inputs are disaggregated in a second level of production structure assuming a GCES function. The notional demand for energy i and material i are respectively:

$$e_{ijt}^{n} = e_{jt} - \sum_{\substack{i'=1 \\ i' \neq i}}^{I} \eta_{ii',j} \varphi_{i'j}^{val} (p_{ijt}^{E} - p_{ijt}^{E}) \quad [18]$$

$$m_{ijt}^{at\_n} = m_{jt}^{at} - \sum_{\substack{i'=1 \\ i' \neq i}}^{I} \eta_{ii'j} \varphi_{i'j}^{val} (p_{ijt}^{M^{at}} - p_{i'jt}^{M^{at}}) \quad [19]$$

In both cases, the demand for each type of energy and material is the function of the aggregates defined in the first level by Equations [13] and [12] and of the relative prices between type of energy and material.

Finally, in the third level, each type of investment products, energy and material can be domestically produced or imported. As in Armignton (1969), a CES function is used to describe the possibilities of substitutions between imported and domestic goods.

IV.2 Debt in the private sector

The dynamic of the debt in the private sector (D_t^s) is determined by the accumulation equation [20], which depend on the gap between the private investment spending and the Gross Operating Surplus (GOS_t^s) :

$$D_t^s = D_{t-1}^s (1 + R_t^s) + P_t^{inv} I_t^s - GOS_{jt}^s + FP_t^{tax} \quad [20]$$

$$GOS_t^s = P_t^{VA} VA_t + SUB_t^Y - TAX_t^Y - L_t W_t (1 + R_t^{em\_cont}) \quad [21]$$

substitution pattern between each kind of labor and capital, and biased technical progress in favor of less qualified labor.

where SUB_t^Y and TAX_t^Y are respectively the subvention and tax on production. W_t is the gross wage and R_t^s the interest rate paid by the private sector. FP_t^{tax} is the total firms profit tax, $R_t^{em\_cont}$ the apparent rate of employer social security contribution.

V The household's behaviour

Assuming that all households are homogenous with respect to incomes and allocation of resources, the current version of Three-ME has one "macroeconomic" household with a gross disposable income $\left(I_t^{disp}\right)$ consisting of net labor revenue, a net financial wealth earnings and government transfers $\left(T_t^{ransf\_h}\right)$:

$$I_t^{disp} = \left(\sum_{j=1}^{24} (L_{jt} W_{jt} * (1 - R^{esc})) + FW_{t-1}^{net\_h} . R_t^h + T_t^{ransf\_h} \right) * (1 - R^{i\_tax}) \qquad [22]$$

where $FW_t^{net\_h}$ corresponds to the household's net financial wealth, defined as the difference between financial assets and liabilities, R_t^h is the average rate of return[9] deduced from the ratio between the net property revenues and the net financial wealth. It is composed of the net interests (interests received minus interests paid) and of the dividends received by household. R^{esc} and R^{i_tax} are respectively the average rates of the employee social contribution and of the income tax.

Figure 3 summarizes the household's optimization behaviour. In the first level, the household chooses the respective shares of the gross disposable income going to expenditure and to savings. In Three-ME, these shares are stable at long term when the economy is on its stationary state. They may depend on the real interest rate if one wants to account for eviction effect on households demand: households tend to increase their savings share when the interest rate increases. These shares may also depend on the ratio between the national

[9] Symmetrically to the private sector, we do not differentiate between the possible forms of financial assets which is equivalent to assuming the same rate of return for all assets.

(government and private) debt and the household's financial wealth. This allows accounting for Ricardian effects in saving behaviours: when the national debt increases faster than their financial wealth, households may increase their savings anticipating a future increase in taxes:

$$\begin{aligned} & exp_t^h = (i_t^{disp} - p_t) - \beta_1 (R_t^h - \dot{P}_t) - \beta_2 \left((D_t^s + D_t^g) / FW_t^{net\_h} \right) \\ & with\ P_t.EXP_t^h = I_t^{disp} - S_t^h \end{aligned} \qquad [23]$$

where EXP_t^h are the volume of total expenditures of the household, P_t their price and S_t^h the households' saving. The unitary elasticity between the real total expenditures of households and their real income guarantees the long-run stability of the expenditures to income ratio.

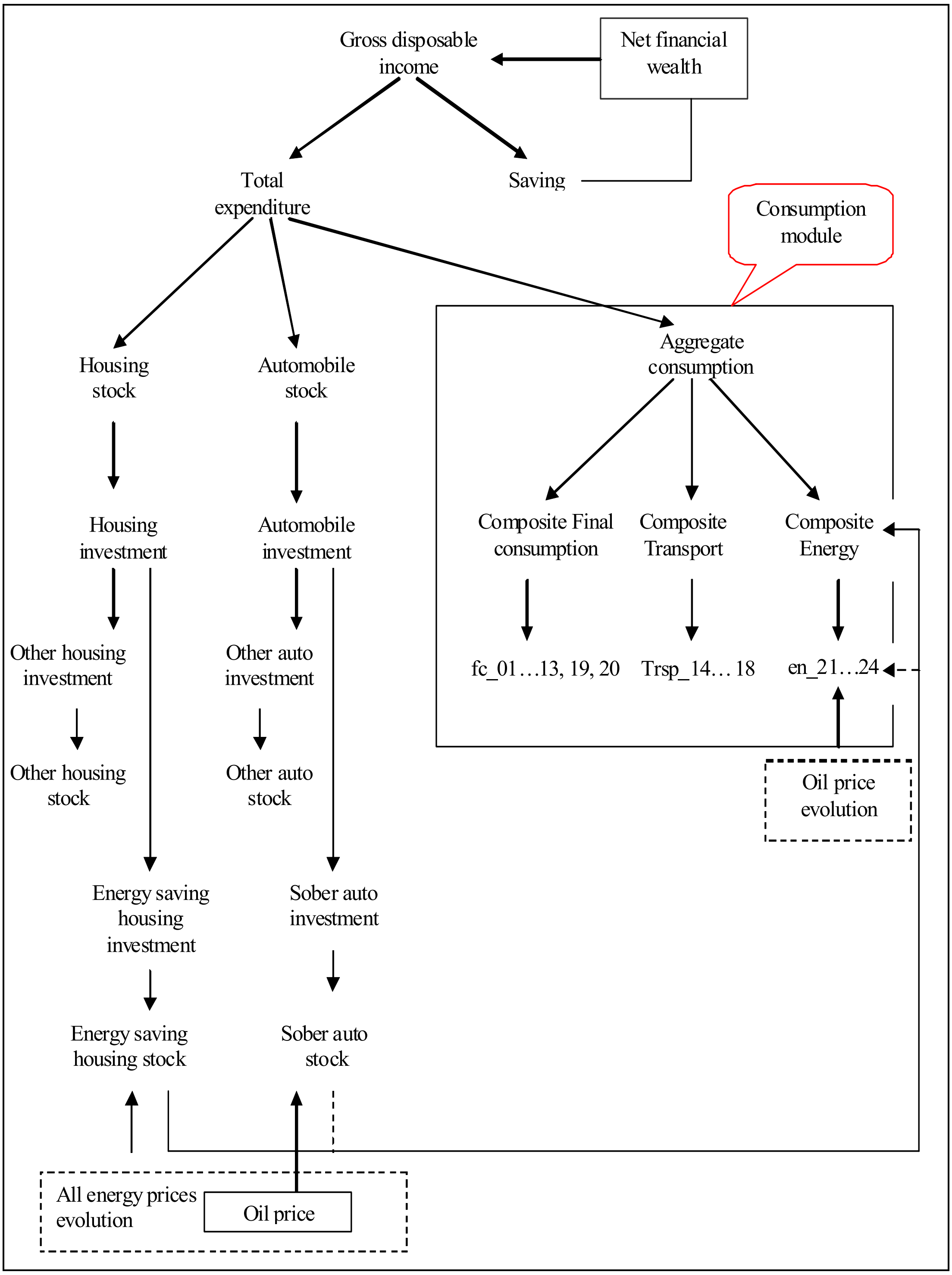
At the second level, the household allocates these expenditures between the final consumption (Section V.1) and the capital stock accumulation of automobile and housing (Section V.2) by maximizing a GCES utility function subject to a budget constraint:

$$\begin{aligned} & \underset{C_t, AUTO_t, HOUS_t}{\text{Max}} U_t \left(C_t, AUTO_t, HOUS_t \right) \\ & \text{st } P_t^c C_t + P_t^{auto} AUTO_t + P_t^{hous} HOUS_t = P_t.EXP_t^h \end{aligned} \qquad [24]$$

where C_t is the aggregate consumption of goods, $AUTO_t$ and $HOUS_t$ the automobile and housing stocks, P_t^c, P_t^{auto}, P_t^{hous} their respective price.

In a third level, following the same logic, the optimizer household allocates the aggregate consumption to three types of composite consumption goods: transport, energy and other final consumption goods. In a fourth level of consumption structure, these three types of final consumption are further disaggregated between different sorts of transport, energy and other final consumption. Following the producer's behaviours, the substitution mechanisms are described with a GCES in each step of the consumer structure. The adjustment process of effective to notional values is also specified as an ECM (according to Equation[11]).

Figure 3   Households' behaviour structure



Household investments in housing and automobile are determined by the desired stock level assuming a constant rate of depreciation. Then in order to account for energy efficiency effects, two types of housing and automobile investments are explicitly distinguished (Figure 3). In the first case, depending on the energy aggregated price, the household arbitrates between energy saving housing and "comfort" housing investments. In the second case, depending on the oil price, the household chooses between low and high oil consumption cars. This in return reduces the energy consumption.

V.1 Consumption

Appendix B shows that the resolution of the optimization program [24] gives the following notional demand for each type of expenditures in volume ($EXP_t^{h\_e\_n}$):

$$exp_t^{h\_e\_n} = exp_t^h - \sum_{e,e'} \eta^{e\_e'}.\varphi_t^{val\_e'}(p_t^e - p_t^{e'}) \qquad e = e' = c, auto, hous \qquad [25]$$

P_t^e and $P_t^{e'}$ are the consumer prices (resp. the user cost of automobile and housing) if $e = e' = c$ (resp. $auto, hous$) . $\eta^{e\_e'}$ and $\varphi_t^{val\_e}$ are the elasticities of substitution between two given expenditure and the share in value of a given expenditure. The adjustment process of effective to notional expenditures is specified as an ECM (according to Equation[11]). This slow adjustment reflects the inertia observed empirically in consumption pattern. As households' expenditures are strongly influenced by past habits, one generally observes that consumption fluctuates less than income during the business cycle. Indeed households tend to use their saving to damper the fluctuation of their consumption.

Assuming again a GCES utility function at the first level of the consumption module (see Figure 3), the aggregate consumption is decomposed into three composite consumptions with the following notional demand:

$$c_{ct}^n = c_t - \sum_{c,c'} \eta_{cc'}.\varphi_{c'}^{val}.(p_{ct}^c - p_{c't}^c) \qquad c = fc, trsp, c' = fc, trsp, en \qquad [26]$$

$$c_{en,t}^{n} = c_t - \sum_{c,c'} \eta_{en,c'} . \varphi_{c'}^{val} . (p_{en,t}^{c} - p_{c't}^{c}) - \eta^{hous} . \left(hous_t^{eff} - hous_t \right) \qquad c' = cf, trsp \qquad [27]$$

Where p_{ct}^{c} is the price of the composite good consumption *c*. *fc*, *trsp* and *en* are respectively the composite of final consumption[10], transport and energy. $hous_t$ and $hous_t^{eff}$ are respectively the total housing capital stock and the energy saving housing capital stock.

The energy demand defined in Equation [27] includes, in addition to the revenue and substitution effects, an endogenous energy efficiency effect related to the household's investment in energy efficiency. The sensibility of the aggregate energy demand to the share of energy saving housing capital stock in the total housing capital stock is measured by the positive parameter η_{en}. This effect was calibrated using the recent ADEME (2011)[11] micro simulation studies on the effect of measures taken during the *Grenelle de l'environnement*[12].

As mentioned earlier, the three types of consumption goods (transport, energy and other final consumption goods) are further disaggregated assuming a GCES substitution pattern. We assume further a zero-elasticity of substitution between all components of the other final consumption goods. In addition to substitution effect between energies, the demand for oil (en_{22}) depends on the real oil price and on the share of low energy consumption cars:

$$en_{22t}^{n} = c_{en,t} - \sum_{i} \eta_{22,i} . \varphi_{it}^{val} . (p_{22t}^{c} - p_{it}^{c}) - \eta_{22}^{en} . (p_{22t}^{c} - p_t) - \eta^{auto} . \left(auto_t^{eff} - auto_t \right) \qquad [28]$$

with $i = 21, 23, 24$

[10] Our definition of the final consumption is slightly different from the real final consumption of national accounting which includes the public administration services provided free of charge and an estimation of the pseudo-rent paid by house owner households. Here we only take into account the marketed consumption goods.

[11] These studies are not published yet. For more results, you could contact Gaël Callonnec from ADEME.

[12] The *Grenelle de l'environnement* translated as *Grenelle Environment Round Table process* is the open debate held during summer 2007 in France. The aim of the debate was to define a coherent public policy on ecology and sustainable development issues. It led to a series of political measures (see www.legrenelle-environnement.fr). For instance, concerning the housing sector, the generalization of low consumption standards in the new housing and the setting-up of economic incentives in favor of energy efficiency were adopted.

where P_{22}^{c} is the oil price, P the price of the total expenditures of households, $AUTO^{eff}$ the stock of low consumption (energy efficient) automobiles and $AUTO$ the total stock of automobiles. η_{22}^{en} and η^{auto} measure respectively the sobriety and efficiency effects which lead to an endogenous decrease in the trend of the share of the oil consumption into the energy consumption ($en_{22t}^{n} - c_{en,t}$). For the calibration of their magnitude, we used two recent studies of the ADEME (2011)[11]. According to the first one, a 1% increase of the real oil price, leads to a decrease of 0.33% $\left(=\eta_{22}^{en}\right)$ of the French household's oil demand. The direct oil effect price reflects sobriety effect or the development of environmental friendly household behaviours and not substitution between energies: the consumption of the other kind of energy is not affected. The household change its way of leaving in order to consume less energy by, for instance, reducing the heating temperature of the house or choosing hobbies that does not involve the use of the car.

The second effect captures the energy efficiency improvement that results from the investment strategy of the household. A second study of ADEME relating to the effect of the Bonus-Malus car systems shows that the dynamic of household oil demand is closely related to the increase of the share of low consumption cars. An increase of 1% of this share would lead to a decrease of 0.20% $\left(=\eta^{auto}\right)$ of the share of the oil consumption into the energy consumption.

V.2 Investment

From the optimal stocks of automobile and housing defined by Equation [25], it is possible to derive the equation of investment in automobile and housing (as we did for the business sector, Equation [14]) from a standard equation of capital stock accumulation:

$$I_{hous,t}^{h} = \Delta HOUS_{t} + HOUS_{t-1}.R_{hous}^{dep} \quad [29]$$

$$I_{auto,t}^{h} = \Delta AUTO_{t} + AUTO_{t-1}.R_{auto}^{dep} \quad [30]$$

where I^h and R^{dep} are respectively the annual investment flows and the specific depreciation rate.

For each of these investments, we assume two types of investment: the investment improving the energy efficiency and the other investment. Concerning the housing investment, depending on the relative prices of oil, electricity and gas, the household is assumed to arbitrate between an investment that reduces the energy bill and an investment that improves the house comfort. In the other hand, the household could also choose to invest in sober cars[13] depending on the real oil price:

$$i^h_{hous\_eff,t} = i^h_{hous,t} + \sum_{i=22}^{24} \eta_i.(p^c_{it} - p_t) \quad [31]$$

$$i^h_{auto\_eff,t} = i^h_{auto,t} + \eta_{22}.(p^c_{22t} - p_t) \quad [32]$$

$$i^h_{hous\_oth,t} = i^h_{hous,t} - i^h_{hous\_eff,t} \quad [33]$$

$$i^h_{auto\_oth,t} = i^h_{auto,t} - i^h_{auto\_eff,t} \quad [34]$$

Equations [31] and [32] describe the "green" household investment in housing $\left(i^h_{hous\_eff}\right)$ and in automobile $\left(i^h_{auto\_eff}\right)$. The other types of investment ($i^h_{hous\_oth}$, $i^h_{auto\_oth}$) are deduced as a difference between the aggregate investment and the green investment (Equations [33] and [34][14]). The stocks of "green" housing and cars are derived from a standard capital accumulation equation:

$$HOUS^{eff}_t = (1 - R^{dep}_{hous})HOUS^{eff}_{t-1} + I^h_{hous\_eff,t} \quad [35]$$

$$AUTO^{eff}_t = (1 - R^{dep}_{auto})AUTO^{eff}_{t-1} + I^h_{auto\_eff,t} \quad [36]$$

[13] The sober cars correspond to the cars with a A, B or C classification that is characterized by a lower level of CO_2 emissions (< 140 g/km).

[14] Supposing one producer sector of the « green » and « no green » investment goods in both kind of household investments, the disaggregated and aggregated prices are equal and the equalities in volume (Equations [33] and [34]) are respected.

V.3 Saving and financial wealth

The household's financial saving $\left(S_t^h\right)$ is given by the following equation:

$$S_t^h = I_t^{disp} - \sum_{i=1}^{13,19,20} P_{it}^c.FC_{it} - \sum_{i=14}^{18} P_{it}^c.TRSP_{it} - \sum_{i=21}^{24} P_{it}^c.EN_{it} - \sum_{i=auto,hous} P_{it}^{inv\_h}.I_{it}^h \qquad [37]$$

where $P_{it}^{inv\_h}$ is the price of investment.

The stock of the net household financial wealth is determined by a standard accumulation formula:

$$FW_t^{net\_h} = FW_{t-1}^{net\_h} + S_t^h \qquad [38]$$

Box 2 Stability condition in household behaviours' structure

If we assume that the dynamic homogeneity hypotheses are respected by the ECM adjustment equations, the long term notional quantities of household consumption and investment are equal to their effective levels. Given unitary income elasticity, consumption and investment are fixed shares $(\varphi_t^c, \varphi_t^{inv})$ of the real disposable income (I_t^{disp} / P_t). These shares can be defined as the marginal propensities to consume and to invest. They depend positively on relative prices and a scale parameter.

$$C_t = \varphi_t^c.I_t^{disp} / P_t \qquad [39]$$

$$I_{hous,t}^h = \varphi_t^{inv\_hous}.I_t^{disp} / P_t \qquad [40]$$

$$I_{auto,t}^h = \varphi_t^{inv\_auto}.I_t^{disp} / P_t \qquad [41]$$

In this box, the small letters with accent refer to the per capita variables expressed in real efficient unit (deflated by inflation and technical progress) and "χ" refer to the growth rate of nominal variables defined as $\chi = (1+\mu).(1+\pi) - 1$, where μ and π are respectively the growth rate of real variables and the inflation rate. Dividing all the variables demanded by household (Equation [39] to [41]) by the effective employment, the real per capita variables are constants (noted without the index *t*) along a stationary growth path and the household equations system can be rewritten as:

$$\hat{i}^{disp\_real} = \left(\sum_{j=1}^{24} (\hat{w}_j * (1 - R^{esc})) + \frac{\widehat{fw}^{net\_h}}{(1+\chi)} . R^h + \hat{t}^{ransf} \right) * (1 - R^{i\_tax}) \qquad [42]$$

$$\hat{c} = \varphi^c . \hat{i}^{disp} \qquad [43]$$

$$\hat{i}^h_{auto} = \varphi^{inv\_auto} . \hat{i}^{disp} \text{ with } \varphi^{inv\_auto} = \varphi^{auto} . \left(\frac{\mu + R^{dep}_{auto}}{1+\mu} \right) \qquad [44]$$

$$\hat{i}^h_{hous} = \varphi^{inv\_hous} . \hat{i}^{disp} \text{ with } \varphi^{inv\_hous} = \varphi^{hous} . \left(\frac{\mu + R^{dep}_{hous}}{1+\mu} \right) \qquad [45]$$

$$\hat{s} = \hat{i}^{disp} - \hat{c} - \sum_{i=auto,hous} \hat{i}^h_i \qquad [46]$$

$$\widehat{fw}^h = \frac{(1+\chi)}{\chi} . \hat{s} \qquad [47]$$

where φ^{auto} and φ^{hous} are the ratios between the automobile and housing stocks to the gross real disposable income. The marginal propensities to invest depend also on the exogenous depreciation rate, i.e. the intensity of investment is affected by the life duration of equipments.

Thus, the reduced form of the previous system corresponds to the single following equation of household financial wealth accumulation:

$$\widehat{fw}^{net\_h} = \frac{\varphi^s . (1+\chi)}{\chi - R^h . \varphi^s} . \left(\left(\sum_{j=1}^{24} \hat{w}_j * (1 - R^{esc}) + \hat{t}^{ransf} \right) * (1 - R^{i\_tax}) \right) \qquad [48]$$

where $\varphi^s = \frac{S_t}{I^{disp}_t} = 1 - \varphi^c_t - \sum_{i=auto,hous} \varphi^{inv\_i}$ is the constant long term saving rate.

Equation [48] show that the stability condition of the system is $\chi > R^h \varphi^s$, which is largely respected by the parameterization of Three-ME. For a saving rate equal to 1, the per capita financial wealth is positive only if the rate of economic growth is higher than the interest rate. When the saving rate is smaller than 1, the constraint on the rate of economic growth is less tied. With a low saving rate, the interest rate can lie above the growth rate of the nominal production. Consequently, the per capita household consumption and investment demand equations are:

$$\widehat{c} = \varphi^{c}.\left(\frac{\chi}{\chi - R^{h}.\varphi^{s}}\right).\left(\left(\sum_{j=1}^{24}\widehat{w}_{j} * (1-R^{esc}) + \widehat{t}^{\,ransf}\right) * (1-R^{i\_tax})\right) \qquad [49]$$

$$\widehat{i}^{\,h}_{auto} = \varphi^{inv\_auto}.\left(\frac{\chi}{\chi - R^{h}.\varphi^{s}}\right).\left(\left(\sum_{j=1}^{24}\widehat{w}_{j} * (1-R^{esc}) + \widehat{t}^{\,ransf}\right) * (1-R^{i\_tax})\right) \qquad [50]$$

$$\widehat{i}^{\,h}_{hous} = \varphi^{inv\_hous}.\left(\frac{\chi}{\chi - R^{h}.\varphi^{s}}\right).\left(\left(\sum_{j=1}^{24}\widehat{w}_{j} * (1-R^{esc}) + \widehat{t}^{\,ransf}\right) * (1-R^{i\_tax})\right) \qquad [51]$$

In the long run, the wage per efficient unit is stable and the household's consumption and investment depend on the economic policy parameters: the variation in the tax rate or in government transfers requires a variation more than proportional in consumption and investment for the stability condition to hold.

Box 3 Sustainability condition of domestic debt

Assuming that the long-run external account of the economy is in equilibrium, the total domestic debt is financed entirely by the net financial wealth of households. The total domestic debt is composed by the private (or sector) debt D^{s}_{∞} and the gross public debt D^{g}_{∞} (excluding the financial and real estate assets that are not accounted for in the model):

$$FW^{net\_h}_{\infty} = D^{s}_{\infty} + D^{g}_{\infty} \qquad [52]$$

The sustainability of the domestic debt requires that the ratio between the deficit and the financial wealth respects the following condition:

$$\frac{B^{s}_{t} + DEF^{g}_{t}}{FW^{net\_h}_{t}} = 1 - \frac{1}{1+\chi} \qquad [53]$$

For a higher level of nominal growth rate "χ" due to a higher potential of economic growth or a higher inflation rate, the ratio between the flows to domestic debts and the stock of household wealth can be maintained at a higher level which means that the economy can accumulate larger debt in period of high activity or inflation.

Such a long term constraint can be incorporated in the model by assuming that the households' consumption and investment adjust such as that the debt can be reimbursed by the nation (Ricardian effect). When the domestic debt is growing faster than the financial household's wealth, for a given value of "χ", the household demand tends to decrease. This increases the saving and financial wealth until the ratio [53] returns to its equilibrium level.

In the case of an open economy characterized by the accumulation of an external commercial deficit $\left(DEF_t^x\right)$ (e.g. the French economy), a part of the debt is financed by the rest of the world and the sustainability condition becomes:

$$\frac{B_t^s + DEF_t^g - DEF_t^x}{FW_t^{net\_h}} = 1 - \frac{1}{1+\mu} \quad [54]$$

VI The labor market

We assume that the average gross wage (that is including employee social security contributions) in sector j (W_{jt}) is determined by a Phillips curve. Wages may be indexed on the consumer price inflation ($\rho_{2j} > 0$) and on productivity gains of the sector j ($\rho_{3j} > 0$). Trade unions may accept lower wage increases in case of a degradation of the terms of trade, that is in case of competitiveness losses ($\rho_{4j} > 0$). In addition to the level of unemployment (U_t), the variation of unemployment may influence the Phillips curve ($\rho_{6j} > 0$), because wages can be affected not only by the level but also by the evolution of employment (Phillips, 1958; Lipsey, 1960) or due to hysteresis phenomena[15]. Finally, it is possible that the wage dynamic differs across sectors because of differences in employment situation ($\rho_{7j} > 0$).

$$\Delta w_{jt}^n = \rho_{1j} + \rho_{2j}\Delta p_t + \rho_{3j}\Delta p_{jt}^{rog} - \rho_{4j}\Delta(p_{jt}^m - p_{jt}^y) - \rho_{5j}U_t - \rho_{6j}\Delta U_t + \rho_{7j}\Delta(l_{jt} - l_t) \quad [55]$$

The parameter ρ_{1j} reflects the labor market tensions and the bargaining power of trade unions. L_t is the aggregated employment:

$$L_t = \sum_j^{24} L_{jt} \quad [56]$$

[15] Hysteresis occurs when the long-term unemployed workers exert no influence on wage-setting (Blanchard and Summers, 1986; Lindbeck, 1993). However, some authors contest the use of the term hysteresis to describe this phenomenon (Cross, 1995).

It can be shown that the WS curve in level is a particular case of the Phillips curve [55]: the case of full hysteresis (Reynès, 2010) that is the case where the level of unemployment does not have any effect on the wage setting ($\rho_{5j} = 0$). Moreover, we assume a slow adjustment of wages: the effective wage growth adjusts to its notional level defined in [55] according to the ECM [11].

The unemployment rate is calculated according to its conventional definition:

$$U_t = (P_t^{op\_act} - L_t) / P_t^{op\_act}$$
$$P_t^{op\_act} = \kappa_t P_t^{op} \qquad [57]$$

where $P_t^{op\_act}$ is the active population which is by definition the product between the labor participation ratio (κ_t) and the total population (P_t^{op}) assumed to be exogenous.

Since the seminal works of Strand and Dernburg (1964) and Dernburg and Strand (1966), several studies have observed that the labor force participation depends on the labor market situation in particular because of a discouraged-worker effect. Thus, the labor participation ratio may be endogenous and depend negatively on the unemployment rate:

$$\kappa_t = \psi_1 - \psi_2 U_t \qquad [58]$$

where ψ_1 is a constant term and ψ_2 is the discouraged-worker effect parameter.

VII External trade

The external trade in Three-ME is treated with a relatively high level of detail. On the one hand, import behaviours are specific for each economic actor and each product. On the other hand, the model integrates explicit external demand functions of both the domestic production and the importations with a constant price elasticity.

VII.1 **Imports**

Following the Armington's (1969) approach, the international trade is justified by the differentiation of products between regions of the world. This explanation assumes implicitly the imperfect substitutability between domestic and imported products. To determine the volume of imports by product, each economic actor minimizes the purchasing costs under the constraint of a predetermined absorption level and a CES substitution pattern. This can be formulated as:

$$Min\left\{P_{it}^{a}.A_{it} = P_{it}^{m-a}.M_{it}^{a} + P_{it}^{q-a}.D_{it}^{a}\right\}$$

$$\text{st} \quad A_{it} = Z_{i}^{a}.\left[\varphi_{i}^{vol\_a}.\left(M_{it}^{a}\right)^{(1-\eta_{i}^{a})/\eta_{i}^{a}} + \left(1-\varphi_{i}^{vol\_a}\right).\left(D_{it}^{a}\right)^{(1-\eta_{i}^{a})/\eta_{i}^{a}}\right]^{\eta_{i}^{a}/(1-\eta_{i}^{a})} \qquad [59]$$

$$\text{with A, } a = M_{j}^{at-s}, EN_{j}^{s}, I_{j}^{nv-s}, X_{j}^{s}, CF_{i}^{h}, TRSP_{i}^{h}, EN_{i}^{h}, I_{i}^{h}, G_{i} \;;\; i,j = 1,...,24$$

where A_{it} represents the demand of each composite product by each Armington agent and P_{it}^{a} its price, M_{it}^{a} and D_{it}^{a} are the import and domestic product quantities demanded by agent A, and P_{it}^{m-a} and P_{it}^{q-a} their respective prices. These prices are different between products but common between agents except for households who have to pay the value-added tax. Z_{i}^{a} and $\varphi_{i}^{vol\_a}$ are the scale and absorption parameters. η_{i}^{a} is the Armignton elasticity of substitution between domestic and foreign goods and services. The import bloc is quite flexible since the elasticity of substitution can potentially be different for each type of use of a given product (such as intermediary consumption, investment, consumption, public spending, export, etc). The solution of the optimization program [59] gives the optimal demand for domestic and imported goods:

$$m_{it}^{a^n} = a_{it} - \eta_i^a.(p_{it}^{m\_a} - p_{it}^a)$$
$$d_{it}^{a^n} = a_{it} - \eta_i^a.(p_{it}^{q\_a} - p_{it}^a) \quad [60]$$

VII.2 Exports

In the same logic, exports are determined by the external demand for domestic products and the ratio between the export and world prices assuming constant price elasticity. In other words, under the hypothesis of a "small open economy", the external demand and the export price are negatively related for a given world price[16]. The functional form for the export demand $\left(x_{it}\right)$ for each product in Three-ME is a logarithm transformation of the one derived by Wilcoxen (1988):

$$x_{it} = wd_{it} - \eta_i^x.\left(p_{it}^x - p_{it}^w\right) \quad [61]$$

where wd_{it} is the world demand and p_{it}^w its price expressed in national currency. p_{it}^x is the exports price that depends on the production cost and reflects the price competitiveness of domestic products. Finally, η_i is (the absolute value of) the price elasticity assumed constant. The unit elasticity between export and the world demand guarantees the long run stability the export market shares.

In Three-ME, part of the exports comes from imported products (re-exports). The repartition between domestic and imported products results from the minimization by foreign clients of the value of their imports from France (i.e. of French export)[17]:

[16] An alternative approach which is using frequently in CGEM, but less realistic, consists in assuming an infinite price elasticity between exports and the production of foreign competitors and that domestic producers do not have any difficulty to sell their products on the foreign market as long as the domestic price does not differ from the international price. In this case, the volume of exports is limited by supply (Shoven and Whalley, 1992).

[17] The optimization program is: $\begin{array}{ll} Min & P_{it}^x.X_{it} = P_{it}^q.X_{it}^d + P_{it}^m.X_{it}^m \\ Subject\ to & X_{it} = CES(X_{it}^d, X_{it}^m) \end{array}$.

$$x_{it}^{d} = x_{it} - \eta_{d,m}^{x}.(p_{it}^{q} - p_{it}^{x})$$
$$x_{it}^{m} = x_{it} - \eta_{d,m}^{x}.(p_{it}^{m} - p_{it}^{x}) \quad [62]$$

where x_{it}^{d} and x_{it}^{m} are the optimal level of domestic and import products that are exported. $\eta_{d,m}^{x}$ is the elasticity of substitution between domestic and imported products.

As the exchange rate is exogenous in the model, the external balance $\left(DEF_{t}^{x}\right)$ may differ from zero:

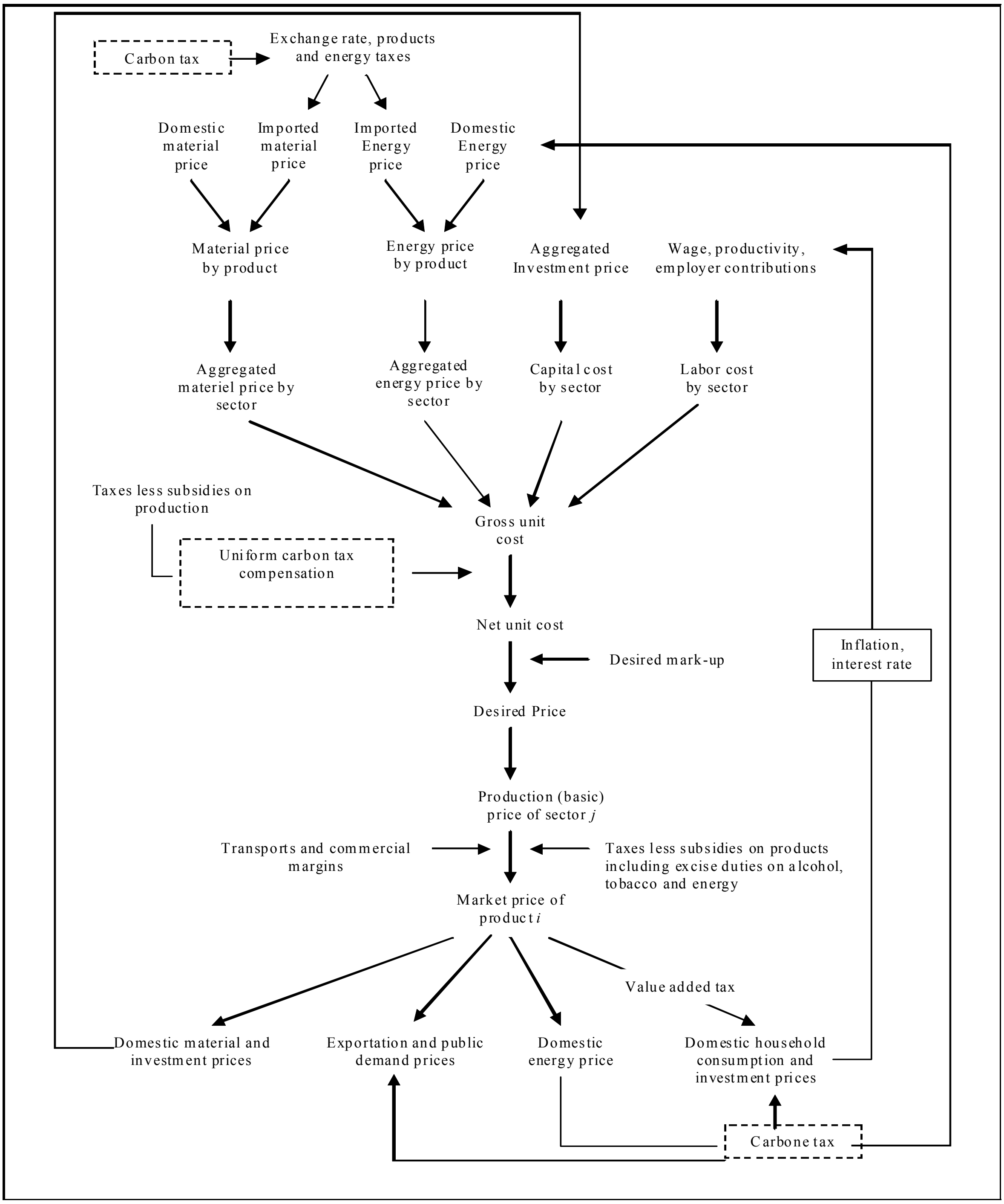
$$DEF_{t}^{x} = \sum_{i} P_{it}^{m}.M_{it} - \sum_{i} P_{it}^{x}.X_{it} \quad [63]$$

with P_{it}^{m} as the import product price (see equation[68]).

VIII Prices structure

The prices in TRHEE-ME follow a bottom-up structure, where the prices of all intermediate levels are calculated as weighted average (Figure 4).

Figure 4 Prices structure



VIII.1 Production prices

In order to describe as clearly as possible the construction of prices in Three-ME, we begin with the production prices fixed by firms. With the import prices, the system of production prices is the key element in the price structure since all other prices are derived from them by adding taxes or/and deducting subsidies according to the destination of each product.

In the case of imperfect competition, firms choose the price that maximizes their profit as a mark-up $\left(R_j^{mu}\right)$ over the unit cost of production:

$$DP_{jt}^{Y} = NUC_{jt}.\left(1 + R_{jt}^{mu}\right) \quad [64]$$

where DP_{jt}^{Y} is the optimal (or desired or notional) production price. NUC_{jt} is the net unit cost of production calculated by adding over the gross level all taxes on production and deducting operating subsidies. The mark-up rate is calibrated so that the growth of the effective price is constant by inverting Equation [65] at the stationary state.

The effective price adjusts slowly the desired level according to an ECM:

$$\Delta p_{jt}^{y} = \alpha_1^{py}.\Delta p_{jt-1}^{y} + \alpha_2^{py}.\Delta dp_{jt}^{y} - \alpha_3^{py}.(p_{jt-1}^{y} - dp_{jt-1}^{y}) \quad [65]$$

This price is calibrated to unity in the base year for all model sectors. Considering that the public services sector does not optimize financial profits, we assume that the mark-up is null and that the production price adjusts to the net unit cost instantaneously.

The steps that lead to the calculation of the gross unit cost $\left(GUC_{jt}\right)$ are described in Figure 4. It follows a bottom-up approach starting from the most disaggregated price levels to reach the most aggregated one by determining the prices of composite factors in intermediate steps. At the bottom of the price structure, we calculate the composite prices for each energy and material in each sector according to their geographic origins. These prices depend on the domestic $\left(P_{ijt}^{q}\right)$ and import $\left(P_{ijt}^{m\_a}\right)$ prices including taxes, and a volume share parameters $\left(\varphi_{ijt}^{vol}\right)$:

$$P_{ijt}^{mat} = \varphi_{ijt}^{vol}.P_{ijt}^{q} + \left(1-\varphi_{ijt}^{vol}\right).P_{ijt}^{m\_mat}$$
$$P_{ijt}^{en} = \varphi_{ijt}^{vol}.P_{ijt}^{q} + \left(1-\varphi_{ijt}^{vol}\right).P_{ijt}^{m\_en} \qquad [66]$$

At the upper level, we calculate the prices for each composite factor in each sector:

The composite materiel price in sector *j*: $P_{jt}^{mat} = \sum_{i=1}^{20} \varphi_{it}^{vol}.P_{ijt}^{mat}$

The composite energy price in sector *j*: $P_{jt}^{en} = \sum_{i=21}^{24} \varphi_{it}^{vol}.P_{ijt}^{en}$

The user capital cost per unity produced in sector *j*: $P_{jt}^{k} = P_{t}^{inv\_s}.\left(R_{j}^{decl} + R_{t}^{s} - \dot{P}_{t}^{inv\_s}\right)$

where:

- $P_{t}^{inv\_s}$: The investment price common to all sectors[18];
- R_{t}^{s} : The long-run nominal interest rate.

The labor cost per unity produced in sector *j*: $P_{jt}^{l} = W_{jt}.(1+R_{jt}^{em\_cont}) / P_{jt}^{rog}$

where:

- W_{jt} : The average gross wage;
- $R_{jt}^{em\_cont}$: The employer social security contributions.

Finally, the gross unit cost of production in sector *j* is equal to[19]:

$$GUC_{jt} = \varphi_{jt}^{vol\_mat}.P_{jt}^{mat} + \varphi_{jt}^{vol\_en}.P_{jt}^{en} + \varphi_{jt}^{vol\_k}.P_{jt}^{k} + \varphi_{jt}^{vol\_l}.P_{jt}^{l} \qquad [67]$$

[18] The published French Input-Output table describes only the repartition investment by product only for one aggregated sector of production.

[19] The sum of volume shares is not equal to one since the prices of capital and labour are different from one and since the sum of the volumes of the production factors do not equal the volume of production.

VIII.2 Import market prices

The import prices are different between products and Armignton agents. The import product price of each commodity is calculated as the weighted average of the world price (expressed in national currency) and the transportation and commercial margins prices (evaluated at the market price): Equation [68]. The import price including taxes is then different for each Armignton agents: Equation [69].

$$P_{it}^{m} = \left(P_{it}^{w} . \left(1 - \sum_{i'=14}^{19} \varphi_{ii't}^{mar} \right) + \sum_{i'=14}^{19} \varphi_{ii't}^{mar} P_{i't}^{m\_a} \right) \qquad [68]$$

$$P_{it}^{m\_a} = P_{it}^{m} .(1 + R_{i}^{va\_tax\_a} + R_{i}^{pr\_tax}) + R_{i}^{en\_tax\_a} \qquad [69]$$

where $R_{i}^{va\_tax\_a}$, $R_{i}^{pr\_tax}$ and $R_{i}^{en\_tax\_a}$ are respectively the rate of value-added tax, the tax rate of other products and the one of energy (the two last taxes are proportional to volumes). $\varphi_{ii't}^{mar}$ is the share of each sort of margin in the total imports by product.

VIII.3 Domestic market prices

Similarly to import market prices, the production price of each commodity $\left(P_{it}^{y}\right)$ is equal to the weighted average of the sector production price $\left(P_{jt}^{y}\right)$, the transportation and commercial margins prices: Equation [70]. The domestic market prices $\left(P_{it}^{q}\right)$ vary depending on the product destination because they include taxes on products net of subsidies: Equation [71].

$$P_{it}^{y} = P_{jt}^{y} . \left(1 - \sum_{i'=14}^{19} \varphi_{ii't}^{mar} \right) + \sum_{i'=14}^{19} \varphi_{ii't}^{mar} P_{i't}^{y} \qquad [70]$$

$$P_{it}^{q} = P_{it}^{y} .(1 + R_{i}^{va\_tax} + R_{i}^{pr\_tax}) - R_{i}^{pr\_sub} + R_{i}^{en\_tax} \qquad [71]$$

where $R_i^{pr\_sub}$ is the apparent rate of public product subsidy applied on the volume of product.

VIII.4 Consumer price index

The consumer price index (P_t) is defined as a weighted average of prices of all total expenditure household components:

$$P_t = \varphi_t^{vol\_c}.P_t^c + \varphi_t^{vol\_auto}.P_t^{auto} + \varphi_t^{vol\_hous}.P_t^{hous} \quad [72]$$

where $P_t^c = \sum_{\substack{i=1 \\ i \neq 3;13}}^{24} \varphi_{it}^{vol\_c}.P_{it}^c$ is the aggregate consumer price with $P_{it}^c = \varphi_{it}^{vol\_q} P_{it}^q + (1-\varphi_{it}^{vol\_q}) P_{it}^{m\_c}$ the consumption price of each commodities calculated as a weighted average between the domestic and import price.

The household user cost of automobile and housing stocks is:

$$P_t^i = P_{it}^{inv\_h}.\left(R_i^{decl} + R_t^h - \dot{P}_{it}^{inv\_h}\right) \qquad i = auto, hous$$

with $P_{it}^{inv\_h} = \varphi_{it}^{vol\_q} P_{it}^q + (1-\varphi_{it}^{vol\_q}) P_{it}^{m\_inv}$ the household investment price (also calculated as a weighted average between the domestic and import price).

IX Interest rate

In Three-ME, money supply is endogenous. The interest rate is determined at the euro area (EA) level according to a reaction function à la Taylor. We assume that the European Central Bank (ECB) sets the short-term interest rate taking into account inflation and the situation on the labor market in the euro area:

$$
\begin{aligned}
&R_t^s = \varsigma_0 + \varsigma_1(\dot{P}_t^{ea} - \dot{P}_t^{ea*}) - \varsigma_2(U_t^{ea} - U_t^{ea*}) \\
&\dot{P}_t^{ea} = \sum_{e=1}^{E} \sigma_e \dot{P}_t^e \\
&U_t^{ea} = \sum_{e=1}^{E} \sigma_e U_t^e
\end{aligned}
\qquad [73]
$$

Where R_t^s is the nominal short run interest rate, $\dot{P}_t^{ea}$ the inflation rate within the EA, $\dot{P}_t^{ea*}$ the ECB inflation target, U_t^{ea} the unemployment rate in the EA and U_t^{ea} the ECB unemployment rate target. $\dot{P}_t^e$, U_t^e et σ_e are respectively the inflation rate, the unemployment rate and the GDP weight of country *e* in the EA. We assume further that the long-term interest rate adjusts slowly to the short-term interest rate according to a ECM [11].

X Public administrations behaviour

According to the French national accounts, public administrations refer to the central and regional government services and social security administration. In Three-ME, we have aggregated these three components in order to focus on transfers between public administrations, household and sectors. These transfers are accounted for in the government's resources $\left(RES_t^g\right)$ and expenditures $\left(EXP_t^g\right)$:

$$RES_t^g = \left(Y_{20t}.NUC_{20t}\right) + VA_t^{tax-c} + VA_{it}^{tax} + PR_t^{tax} + EN_t^{tax} + Y_t^{tax} + SC_{jt} + W_t^{tax} + FP_t^{tax} \qquad [74]$$

$$EXP_t^g = G_t + SUB_t^g + T_t^{ransf\_h} + I_t^g + PFD_t^g + D_{t-1}^g.R_t^g \quad [75]$$

with:

- The marketed part of public administrations production is evaluated at its net production cost: $Y_{20t}.NUC_{20t}$;
- The household's consumption value-added tax : $VA_t^{tax\_c} = \sum_i \left(P_{it}^y.D_{it}^c + P_{it}^m M_{it}^c\right).R_i^{va\_tax}$;
- The household's investment value-added tax: $VA_{it}^{tax} = \sum_{i=auto,hous} \left(P_{it}^y.I_{it}^{h\_d} + P_{it}^m.I_{it}^{h\_m}\right).R_i^{va\_tax}$;
- In contrast with the value-added tax which is calculated only on the household consumption and investment, the taxes on products net of subsidies are applied to all components of demand: $PR_t^{tax} = \sum_i \left(P_{it}^y.Q_{it} + P_{it}^m.M_{it}\right).R_i^{pr\_tax} - \sum_i Q_{it}.R_i^{pr\_sub}$;
- The energy tax : $EN_t^{tax} = \sum_{i=21}^{24} \left(Q_{it} + M_{it}\right).R_i^{en\_tax}$;
- The production taxes net of operating subsidies : $Y_t^{tax} = \sum_{\substack{j=1 \\ j\neq 20}}^{24} Y_{jt}.\left(R_j^{y\_tax} - R_j^{y\_sub}\right)$;
- Employer and employee social security contributions: $SC_{jt} = \sum_{\substack{j=1 \\ j\neq 20}}^{24} L_{jt}.W_{jt}.\left(R_j^{esc} + R^{ssc}\right)$;
- The income tax : $I_t^{disp\_tax} = I_t^{disp}.R^{i\_tax} / \left(1 - R^{i\_tax}\right)$;
- The total firm profit tax : $FP_t^{tax} = \left(\sum_{\substack{j=1 \\ j\neq 20}}^{24} GOS_{jt-1}^s - FD_{t-2}^{net\_s}.R^s\right).R^{FP\_tax}$, GOS_{jt-1}^s is the total gross operating profit and $FD_{t-2}^{net\_s}$ the total net financial debt of firms ;
- Total public expenditures : $G_t = \sum_i \left(P_{it}^q.G_{it}^d + P_{it}^{m\_g}.G_{it}^m\right)$;
- Total public investment : $I_t^g = \sum_i P_{it}^{inv\_g}.I_{it}^g$;

- The total demand of production factors:

  $PFD_t^g = \left(C_{20t}.P_{20t}^k\right) + \left(L_{20t}.P_{20t}^l\right) + \left(EN_{20t}.P_{20t}^{en}\right) + \left(M_{20t}^{at}.P_{20t}^{mat}\right)$;

- Public subventions to sectors consist of subventions on production and products. Both types are applied on volume[20] which means that changes in price caused by a shock do not affect the amount of subsidies: $SUB_{it}^g = \left(R_i^{pr\_sub} + R_i^{y\_sub}\right).Y_{it}$

The public deficit $\left(DEF_t^g\right)$ and debt $\left(D_t^g\right)$ accumulation equations are written as follows:

$$DEF_t^g = EXP_t^g - RES_t^g \quad [76]$$

$$D_t^g = D_{t-1}^g + DEF_t^g \quad [77]$$

XI CO_2 emissions

In France, the anthropogenic CO_2 emissions represent about 70% of the total gross greenhouse gases (GHG). They come from the burning of fossil fuels and decarbonation process. The modeling of the demand for fossil energy in Three-ME is detailed by economic agent, by kind of fossil energy and by procedure of emissions. This allows for a precise estimation of the variation in the national CO_2 emissions. The calculation of emissions level consists in multiplying the fossil energy demand by the corresponding emission coefficients. These coefficients are specifics for each economic actor, each sector and each energy sources depending on their carbon intensity.

The CO_2 emissions due to the combustion of fossil energy by sectors and households are calculated according to the following equations:

$$\begin{aligned} CO2_{en,j,t}^s &= \xi_{en,j}^s.E_{en,j,t}^s \\ CO2_{en,t}^{hh} &= \xi_{en}^{hh}.E_{en,t}^{hh} \end{aligned} \quad [78]$$

[20] At the stationary state, we assume that all taxes or subsidies rates applied on volume quantity grow at the rate of inflation.

The coefficients of CO_2 emissions intensity, $\xi^{s}_{en,j}, \xi^{hh}_{en}$, are specific for each fossil energy *(en)* but also for each sector *(s)* and households *(hh)*, and are calibrated by inverting Equation [78] in the base year.

Finally, CO_2 emissions from decarbonation during production process in glass and ceramic sectors are assumed proportional to the quantity of intermediate raw material used in the production process *(M^{at})* :

$$CO2^{s}_{j,t} = \xi^{s}_{j}.M^{at}_{j,t} \qquad j = 4,5 \qquad [79]$$

XII Analytical scenarios

In this section, we conduct several analytical scenarios in order to test the properties of the model. In particular we look how the main macroeconomic and sectoral indicators react after standard shocks such as an expansionary policy, a tax decrease or an increase in the oil price. Analytical scenarios are sometimes referred by modeler as "naïve" scenarios in the sense that they do not integrate the most realistic feature of the model. Typically here, we assume a reference scenario where all variables grow at a constant rate at every period which implies some constraint that may not be realistic. For instance, the share of oil into the final consumption is assumed stable over time which is in contradiction with empirical fact: in reality, the share of energy consumption tends to decrease with economic development since energy is generally a necessity good. With this hypothesis, the model tends to exaggerate the increase in GHG emissions of any policy that increases the revenue of households. Avoiding this problem is particularly important when one wants to evaluate for instance the impact of a carbon tax. This requires the use of a "realistic scenario" that assumes that the elasticity between oil consumption and revenue is lower than one. Another necessary constraint to have a stationary reference scenario from the base year onwards is the assumption that the unemployment rate is at its equilibrium level at the base year (above 8% in 2006). The interpretation of any analytical scenario should keep in mind such hypothesis. If there are good reasons to believe that the equilibrium rate of unemployment is below 8%, this simulation tends to exaggerate the inflationary pressure of any policy that reduces the unemployment rate.

Despite this caveat, analytical scenarios provide useful information on the long term and dynamic properties of the model. In particular, they allow for testing the dynamic stability of the model after a given shock and to control if the specification of the model insures the convergence to the long term equilibrium. In general, after a shock all the variables converge towards their long term value following a damped cyclical dynamic. The second cycle is generally very close to the long term values. This cyclical dynamic comes mainly from the interaction between the Keynesian multipliers (in particular of investment due to the specification of the equation of capital accumulation) and the inflation dynamic. In a first phase, the investment multiplier accentuates the effect of any favorable shock. This tends to decrease the unemployment rate below its equilibrium level. The subsequent increase in inflation reduces the internal and external demand bringing back the economy below its long term trend. This brings the unemployment rate above its equilibrium value. When inflation is low enough, the favorable phase of the cycle starts again. The length of the cycle is determined by the delay in the adjustment process of the effective prices and quantities toward their notional values. Because all the adjustment process follows an ECM, effective values reach their notional values only asymptotically. To measure how fast, this adjustment process is, is it useful to define the adjustment delay as the length time it takes to reach a 90% adjustment. Under this definition, the calibrated adjustment delays are 3 years for the production prices and wages, 4 years for the production factors, 2 years for consumption, and 2 years for energy.

XII.1 Expansionary policy: one GDP point-increase of public spending

We first simulate the medium and long term impact of an expansionary policy: a one GDP point-increase of public spending. Since, government spending at the base year accounts for about one quarter of the GDP, this shock corresponds to an increase of 4% of public expenditure. The repartition of this impulse in terms of products is proportional to the base year public consumption:

Tableau 2 Structure of public consumption by product in 2006

Public consumption by product	Percentage
G_12	6.10
G_14	0.04
G_15	0.37
G_16	0.00
G_19	19.37
G_20	74.12
G_24	0.00

In the short and medium term, this impulse has a positive effect on the economy. Because of the consumption and investment Keynesian multipliers, during the first ten year the GDP increase is higher than the original impulse (Tableau 3). The decrease of the unemployment leads to an increase in inflation and in the interest rate which slowly interrupt this favorable dynamic. The increase in inflation degrades the external position by decreasing exports and increasing imports. The increase in the interest rate degrades further the investment dynamic. This loss in domestic revenues gradually brings back the economy to its long term path and the favorable effect in terms of employment and GDP vanishes. Because of this eviction effect, the long term Keynesian multipliers are zero and after 30 years the public debt has increased by more than 8 points. The path of employment and production at sector level exhibit a similar profile than the one at the aggregate level. A restrictive policy through a contraction of public spending gives an opposite and symmetric effect.

Tableau 3 Macroeconomic effect of a one GDP point-increase of public spending

	Level at 2006	1 year	2 years	3 years	4 years	5 years	10 years	20 years	30 years
GDP	1 763 774 *	1.70	1.70	1.60	1.51	1.45	1.05	0.36	-0.01
Private Sectors GDP	1 478 578 *	1.26	1.32	1.23	1.14	1.07	0.61	-0.18	-0.60
Production	3 232 382 *	1.16	1.36	1.40	1.40	1.36	0.95	0.22	-0.18
Private Sector Production	2 855 640 *	0.86	1.08	1.14	1.13	1.09	0.63	-0.19	-0.62
Public sector production	376 742 *	3.44	3.44	3.43	3.43	3.42	3.37	3.25	3.15
Consumption	963 871 *	0.09	0.25	0.40	0.54	0.65	0.67	0.02	-0.47
Household Investment									
Automobile	1 883 *	0.40	0.72	0.90	0.98	0.99	0.50	-0.12	-0.39
Housing	93 561 *	0.14	-0.04	-0.11	0.04	0.31	0.78	-0.44	-1.22
Productive Investments	385 789 *	4.37	4.63	3.99	3.27	2.66	0.84	0.04	-0.06
Private Sector Investments	338 712 *	2.96	3.56	3.27	2.73	2.20	0.37	-0.49	-0.56
Public Sector Investments	47 077 *	14.51	12.29	9.21	7.18	6.00	4.27	3.79	3.58
Exports	488 019 *	0.00	0.00	-0.02	-0.06	-0.12	-0.68	-1.42	-1.75
Imports	571 023 *	0.79	1.07	1.18	1.21	1.22	1.12	0.85	0.70
Employment	22 476 184	0.48	0.92	1.23	1.44	1.56	1.46	0.71	0.25
Unemployment rate	8.1%	-0.44	-0.84	-1.13	-1.32	-1.43	-1.34	-0.65	-0.23
Inflation rate	2.0%	0.07	0.13	0.14	0.14	0.14	0.13	0.08	0.04
Average gross wage deflated by Value-Added Price	30 365.74 **	0.08	0.23	0.36	0.46	0.54	0.77	1.01	1.19
Real Disposable Income	1 179 497.89 *	0.17	0.34	0.48	0.59	0.66	0.60	-0.02	-0.48
Interest rate	4%	0.02	0.05	0.09	0.12	0.14	0.18	0.10	0.04
Public Deficit (% of GDP)	3%	0.78	0.70	0.66	0.62	0.59	0.50	0.51	0.56
Public Debt (% of GDP)	65%	-0.23	0.49	1.13	1.65	2.08	3.85	6.17	8.44
Trade Deficit (% of GDP)	5%	0.18	0.27	0.29	0.29	0.27	0.08	-0.18	-0.31

*** Million Euros; ** Euro**

Tableau 4 Sectoral effect of a one GDP point-increase of public spending

	Sectors	Variables	Level at 2006	1 year	2 years	3 years	4 years	5 years	10 years	20 years	30 years
1	Agriculture, forestry and fishing	Production (Y)	77 956	0.2	0.3	0.4	0.4	0.5	0.2	-0.6	-1.1
		Employment (L)	390 189	0.0	0.1	0.2	0.3	0.3	0.2	-0.7	-1.3
		Production price (PY)	1	0.0	0.1	0.2	0.3	0.4	1.4	2.9	3.6
2	Manufacture of food products and beverages	Y	121 773	0.1	0.3	0.4	0.5	0.6	0.3	-0.6	-1.2
		L	484 066	0.0	0.1	0.2	0.3	0.4	0.3	-0.7	-1.4
		PY	1	0.0	0.0	0.1	0.2	0.3	1.3	2.8	3.5
3	Manufacture of motor vehicles, trailers and semi-trailers	Y	90 738	1.2	1.4	1.3	1.1	0.9	-0.2	-1.1	-1.5
		L	209 964	0.4	0.7	0.9	1.0	0.9	-0.1	-1.3	-1.9
		PY	1	0.0	-0.1	-0.1	0.0	0.1	1.1	2.1	2.6
4	Manufacture of glass and glass products	Y	6 645	0.3	0.5	0.6	0.6	0.6	-0.1	-1.1	-1.6
		L	37 597	0.1	0.2	0.3	0.4	0.4	0.0	-1.2	-1.8
		PY	1	0.0	0.0	0.1	0.2	0.3	1.4	2.8	3.4
5	Manufacture of ceramic products and building materials	Y	19 667	1.0	1.7	1.9	1.8	1.7	1.0	0.0	-0.6
		L	84 480	0.3	0.7	1.1	1.4	1.5	1.0	-0.1	-0.8
		PY	1	0.0	-0.1	-0.1	0.0	0.1	1.3	2.7	3.4
6	Manufacture of articles of paper and paperboard	Y	19 280	0.2	0.4	0.6	0.6	0.6	0.0	-1.0	-1.5
		L	72 927	0.1	0.2	0.3	0.4	0.4	0.1	-1.1	-1.9
		PY	1	0.0	0.0	0.1	0.1	0.2	1.1	2.3	2.9
7	Manufacture of inorganic basic chemicals	Y	5 976	0.1	0.2	0.3	0.3	0.3	-0.4	-1.4	-2.0
		L	13 672	0.0	0.1	0.2	0.2	0.2	-0.3	-1.6	-2.3
		PY	1	0.0	0.0	0.1	0.2	0.3	1.1	2.2	2.7
8	Manufacture of organic basic chemicals	Y	23 286	0.1	0.1	0.2	0.2	0.1	-0.3	-1.0	-1.4
		L	18 657	0.0	0.1	0.1	0.1	0.1	-0.3	-1.2	-1.7
		PY	1	0.0	0.0	0.1	0.1	0.2	0.7	1.4	1.7
9	Manufacture of plastics products	Y	25 454	0.3	0.6	0.8	0.8	0.7	0.1	-0.9	-1.3
		L	153 969	0.1	0.3	0.4	0.5	0.6	0.1	-1.0	-1.7
		PY	1	0.0	0.0	0.0	0.1	0.2	1.1	2.2	2.7
10	Manufacture of basic iron and steel and of ferro-alloys	Y	24 196	0.2	0.4	0.5	0.5	0.4	-0.4	-1.4	-1.9
		L	37 599	0.1	0.2	0.3	0.3	0.3	-0.3	-1.6	-2.3
		PY	1	0.0	0.0	0.1	0.1	0.2	1.0	2.0	2.4
11	Manufacture of non-ferrous metals	Y	11 506	0.1	0.2	0.2	0.2	0.2	-0.4	-1.2	-1.6
		L	14 268	0.0	0.1	0.1	0.1	0.1	-0.4	-1.5	-2.1
		PY	1	0.0	0.0	0.1	0.1	0.2	0.8	1.6	1.9
12	Other industries	Y	449 449	0.6	0.9	0.9	0.9	0.8	0.1	-0.8	-1.3
		L	2 036 834	0.2	0.4	0.6	0.7	0.7	0.2	-1.0	-1.6
		PY	1	0.0	0.0	0.0	0.1	0.2	1.2	2.6	3.2
13	Construction of buildings and Civil engineering	Y	247 504	3.2	3.1	2.6	2.2	2.0	1.4	0.5	0.0
		L	1 498 411	1.0	1.7	2.0	2.1	2.0	1.5	0.4	-0.2
		PY	1	-0.1	-0.3	-0.3	-0.2	0.0	1.4	3.1	3.8
14	Rail transport (Passenger and Freight)	Y	10 033	0.4	0.5	0.6	0.6	0.6	0.2	-0.6	-1.0
		L	96 348	0.1	0.3	0.4	0.5	0.6	0.3	-0.8	-1.5
		PY	1	0.1	0.2	0.5	0.7	0.9	1.9	3.1	3.7
15	Passenger transport by road	Y	17 137	0.8	1.1	1.3	1.4	1.5	1.4	0.8	0.4
		L	184 850	0.2	0.5	0.8	1.0	1.2	1.4	0.8	0.3
		PY	1	0.0	0.0	0.0	0.1	0.3	1.7	3.6	4.5
16	Freight transport by road and transport via pipeline	Y	36 670	0.4	0.6	0.7	0.7	0.7	0.2	-0.7	-1.2
		L	328 404	0.1	0.2	0.4	0.5	0.5	0.2	-0.8	-1.4
		PY	1	0.0	0.0	0.1	0.1	0.3	1.4	2.9	3.5
17	Water transport	Y	10 138	0.1	0.1	0.2	0.1	0.1	-0.5	-1.3	-1.7
		L	16 833	0.0	0.1	0.1	0.1	0.1	-0.4	-1.4	-1.9
		PY	1	0.0	0.0	0.1	0.1	0.2	1.2	2.5	3.1
18	Air transport	Y	17 992	0.1	0.1	0.2	0.2	0.1	-0.4	-1.3	-1.8
		L	66 244	0.0	0.1	0.1	0.1	0.1	-0.4	-1.4	-2.0
		PY	1	0.0	0.0	0.1	0.2	0.3	1.3	2.6	3.2
19	Business services	Y	1 521 601	0.7	1.0	1.1	1.2	1.2	0.8	0.1	-0.4
		L	10 355 121	0.2	0.5	0.7	0.9	1.0	0.9	-0.1	-0.6
		PY	1	0.0	0.0	0.1	0.3	0.4	1.6	3.2	3.9
21	Mining of coal and lignite	Y	35	0.9	1.8	2.4	2.8	2.9	0.1	-4.0	-5.3
		L	599	0.3	0.7	1.3	1.8	2.2	1.0	-3.6	-5.4
		PY	1	0.0	0.0	0.0	0.0	0.1	1.7	3.7	4.2
22	Manufacture of refined petroleum products	Y	49 658	0.2	0.5	0.6	0.7	0.8	0.7	0.4	0.2
		L	13 640	0.1	0.2	0.3	0.4	0.5	0.7	0.2	0.0
		PY	1	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.6
23	Electric power generation, transmission and distribution	Y	46 120	0.3	0.5	0.7	0.8	0.9	0.8	0.2	-0.1
		L	95 291	0.1	0.2	0.4	0.6	0.7	0.7	0.0	-0.4
		PY	1	0.0	0.1	0.1	0.2	0.4	1.3	2.7	3.3
24	Manufacture and distribution of gas	Y	22 826	0.3	0.5	0.8	0.9	1.0	1.1	0.7	0.6
		L	27 958	0.1	0.2	0.4	0.6	0.7	1.0	0.6	0.4
		PY	1	0.0	0.0	0.0	0.0	0.0	0.4	1.0	1.2

XII.2 Expansionary policy: decrease in the employer social security rate

The decline in employers' social contributions is another example of expansionist policy through the decrease of the labor cost. In the very short run the disinflationary impact and substitution mechanisms discourage investment and hence production. But very fast the rise in consumption (consecutive of the reduction in unemployment and the increase of the real income) and the improvement of competitiveness become the dominant effect and this measure is positive for the activity. After 10 years the effect tends to slowly vanish but is still present after 30 years. This important difference with the previous expansionary scenario comes from the permanent substitution effect in favor of employment and slightly from improvement of the competitiveness relatively to the rest of the world. If we assumed that French competitors adopt a similar policy, the impact would be less favorable in the long run. In order to ease the comparison with the previous scenario, we calibrated a shock of similar magnitude in terms of the expected ex ante increase in public deficit. Since the employers' social contributions amount for approximately 15% of the GDP in 2006, we simulated the impact of a 7% decrease of employers' social contributions. This decrease is spread across sectors proportionally to their weight into the total employers' social contributions:

Tableau 5 Employer social security rate by sector

Employer social security rate by sector	Rate in 2006 (a)	Rate after choc (b)	Rate reduction (a) - (b)
Tce_01	20%	19%	1.4%
Tce_02	41%	38%	2.8%
Tce_03	41%	38%	2.8%
Tce_04	41%	38%	2.9%
Tce_05	44%	41%	3.1%
Tce_06	42%	39%	2.9%
Tce_07	55%	51%	3.8%
Tce_08	50%	46%	3.5%
Tce_09	40%	38%	2.8%
Tce_10	44%	41%	3.1%
Tce_11	47%	44%	3.3%
Tce_12	43%	40%	3.0%
Tce_13	54%	50%	3.8%
Tce_14	43%	40%	3.0%
Tce_15	44%	41%	3.1%
Tce_16	37%	34%	2.6%
Tce_17	30%	28%	2.1%
Tce_18	43%	40%	3.0%
Tce_19	40%	37%	2.8%
Tce_20	26%	24%	1.8%
Tce_21	39%	36%	2.7%
Tce_22	58%	54%	4.1%
Tce_23	54%	51%	3.8%
Tce_24	54%	51%	3.8%

Tableau 6 Macroeconomic effect of a one GDP point- decrease of the employer social security

	Level at 2006	1 year	2 years	3 years	4 years	5 years	10 years	20 years	30 years
GDP	1 763 774 *	-0.06	0.10	0.29	0.45	0.58	0.99	0.95	0.65
Private Sectors GDP	1 478 578 *	-0.08	0.12	0.34	0.53	0.68	1.17	1.12	0.77
Production	3 232 382 *	-0.08	0.01	0.15	0.30	0.44	0.94	0.94	0.63
Private Sector Production	2 855 640 *	-0.09	0.01	0.17	0.34	0.50	1.06	1.06	0.71
Public sector production	376 742 *	0.00	0.00	0.01	0.01	0.02	0.04	0.05	0.04
Consumption	963 871 *	0.07	0.19	0.32	0.44	0.56	1.16	1.47	1.29
Household Investment									
Automobile	1 883 *	0.33	0.63	0.79	0.90	0.99	1.38	1.35	1.12
Housing	93 561 *	0.36	0.58	0.61	0.59	0.63	1.77	2.20	1.40
Productive Investments	385 789 *	-1.27	-0.94	-0.27	0.35	0.83	1.52	0.88	0.46
Private Sector Investments	338 712 *	-1.22	-0.82	-0.08	0.60	1.11	1.74	0.96	0.48
Public Sector Investments	47 077 *	-1.58	-1.75	-1.63	-1.41	-1.17	-0.07	0.35	0.32
Exports	488 019 *	0.09	0.22	0.35	0.45	0.53	0.68	0.39	0.02
Imports	571 023 *	-0.24	-0.26	-0.16	-0.03	0.10	0.59	0.76	0.70
Employment	22 476 184	0.04	0.10	0.18	0.28	0.38	0.87	0.92	0.61
Unemployment rate	8.1%	-0.04	-0.10	-0.17	-0.26	-0.35	-0.80	-0.85	-0.56
Inflation rate	2.0%	-0.20	-0.20	-0.14	-0.09	-0.06	0.00	0.05	0.05
Average gross wage deflated by Value-Added Price	30 365.74 **	0.23	0.46	0.62	0.74	0.85	1.34	1.76	2.03
Real Disposable Income	1 179 497.89 *	0.14	0.28	0.39	0.50	0.61	1.17	1.44	1.27
Interest rate	4%	-0.02	-0.03	-0.03	-0.02	-0.01	0.06	0.10	0.08
Public Deficit (% of GDP)	3%	0.77	0.72	0.73	0.73	0.72	0.66	0.59	0.59
Public Debt (% of GDP)	65%	1.11	1.88	2.57	3.22	3.82	6.61	9.17	10.72
Trade Deficit (% of GDP)	5%	-0.02	0.02	0.07	0.13	0.18	0.34	0.31	0.19

*** Million Euros; ** Euro**

Tableau 7 Sectoral effect of a one GDP point- decrease of the employer social security

	Sectors	Variables	Level at 2006	1 year	2 years	3 years	4 years	5 years	10 years	20 years	30 years
		Production (Y)	77 956	0.0	0.1	0.2	0.3	0.5	1.0	1.1	0.8
1	Agriculture, forestry and fishing	Employment (L)	390 189	0.1	0.1	0.2	0.3	0.4	1.0	1.1	0.8
		Production price (PY)	1	-0.1	-0.3	-0.5	-0.6	-0.8	-1.0	-0.5	0.2
		Y	121 773	0.1	0.2	0.3	0.5	0.6	1.2	1.3	1.0
2	Manufacture of food products and beverages	L	484 066	0.1	0.2	0.3	0.5	0.6	1.3	1.5	1.1
		PY	1	-0.2	-0.4	-0.7	-0.8	-1.0	-1.3	-0.7	0.0
		Y	90 738	-0.3	-0.1	0.2	0.5	0.7	1.2	0.8	0.3
3	Manufacture of motor vehicles, trailers and semi-trailers	L	209 964	0.0	0.0	0.2	0.4	0.6	1.3	1.0	0.4
		PY	1	-0.1	-0.3	-0.5	-0.7	-0.8	-1.0	-0.5	0.0
		Y	6 645	0.1	0.2	0.3	0.5	0.7	1.2	1.0	0.5
4	Manufacture of glass and glass products	L	37 597	0.1	0.2	0.3	0.4	0.6	1.2	1.2	0.6
		PY	1	-0.3	-0.6	-0.8	-1.0	-1.2	-1.3	-0.7	0.0
		Y	19 667	-0.1	-0.1	0.0	0.1	0.3	1.2	1.3	0.8
5	Manufacture of ceramic products and building materials	L	84 480	0.0	0.1	0.1	0.2	0.3	1.1	1.4	0.9
		PY	1	-0.2	-0.5	-0.7	-0.9	-1.1	-1.4	-0.8	0.0
		Y	19 280	0.0	0.1	0.3	0.4	0.6	1.1	1.0	0.5
6	Manufacture of articles of paper and paperboard	L	72 927	0.1	0.2	0.3	0.4	0.6	1.2	1.2	0.6
		PY	1	-0.2	-0.4	-0.6	-0.8	-0.9	-1.1	-0.6	0.0
		Y	5 976	0.1	0.2	0.3	0.5	0.6	1.1	0.9	0.4
7	Manufacture of inorganic basic chemicals	L	13 672	0.1	0.2	0.4	0.5	0.7	1.3	1.1	0.6
		PY	1	-0.2	-0.5	-0.7	-0.8	-0.9	-1.1	-0.6	-0.1
		Y	23 286	0.0	0.1	0.2	0.3	0.4	0.7	0.5	0.2
8	Manufacture of organic basic chemicals	L	18 657	0.1	0.2	0.3	0.4	0.5	0.9	0.7	0.3
		PY	1	-0.1	-0.2	-0.4	-0.5	-0.5	-0.7	-0.4	0.0
		Y	25 454	0.0	0.1	0.2	0.4	0.5	1.1	1.0	0.5
9	Manufacture of plastics products	L	153 969	0.1	0.2	0.3	0.4	0.5	1.2	1.2	0.6
		PY	1	-0.2	-0.5	-0.7	-0.8	-0.9	-1.1	-0.6	0.0
		Y	24 196	0.0	0.1	0.2	0.4	0.6	1.0	0.8	0.3
10	Manufacture of basic iron and steel and of ferro-alloys	L	37 599	0.1	0.2	0.3	0.5	0.6	1.2	1.0	0.4
		PY	1	-0.1	-0.3	-0.4	-0.6	-0.7	-0.9	-0.5	0.0
		Y	11 506	0.0	0.1	0.3	0.4	0.5	0.8	0.6	0.2
11	Manufacture of non-ferrous metals	L	14 268	0.1	0.2	0.4	0.5	0.6	1.0	0.8	0.3
		PY	1	-0.1	-0.2	-0.4	-0.5	-0.5	-0.7	-0.4	0.0
		Y	449 449	0.0	0.1	0.3	0.5	0.7	1.1	0.9	0.4
12	Other industries	L	2 036 834	0.1	0.1	0.3	0.4	0.6	1.2	1.1	0.6
		PY	1	-0.3	-0.5	-0.8	-1.0	-1.1	-1.3	-0.7	0.0
		Y	247 504	-0.4	-0.3	-0.1	0.1	0.3	1.3	1.4	0.9
13	Construction of buildings and Civil engineering	L	1 498 411	0.0	-0.1	0.0	0.1	0.3	1.2	1.5	1.0
		PY	1	-0.3	-0.7	-1.0	-1.3	-1.4	-1.8	-1.1	-0.2
		Y	10 033	0.1	0.2	0.3	0.4	0.5	0.9	1.0	0.7
14	Rail transport (Passenger and Freight)	L	96 348	0.1	0.3	0.5	0.6	0.8	1.3	1.3	0.8
		PY	1	-0.2	-0.4	-0.6	-0.6	-0.7	-0.8	-0.5	0.1
		Y	17 137	0.1	0.1	0.3	0.4	0.5	1.0	1.1	0.9
15	Passenger transport by road	L	184 850	0.0	0.1	0.2	0.3	0.4	0.9	1.2	1.0
		PY	1	-0.5	-1.1	-1.5	-1.7	-1.8	-1.9	-1.1	-0.2
		Y	36 670	0.0	0.1	0.3	0.4	0.6	1.1	0.9	0.5
16	Freight transport by road and transport via pipeline	L	328 404	0.0	0.1	0.2	0.3	0.5	1.0	1.1	0.6
		PY	1	-0.3	-0.6	-0.9	-1.1	-1.2	-1.4	-0.7	0.0
		Y	10 138	0.0	0.2	0.3	0.4	0.5	0.8	0.6	0.2
17	Water transport	L	16 833	0.1	0.2	0.3	0.4	0.5	0.9	0.7	0.2
		PY	1	-0.1	-0.3	-0.5	-0.7	-0.8	-1.1	-0.6	0.0
		Y	17 992	0.1	0.3	0.5	0.6	0.7	1.0	0.8	0.3
18	Air transport	L	66 244	0.1	0.2	0.4	0.5	0.7	1.1	0.9	0.4
		PY	1	-0.3	-0.6	-0.9	-1.0	-1.2	-1.3	-0.7	0.0
		Y	1 521 601	-0.1	0.0	0.1	0.3	0.5	1.0	1.1	0.8
19	Business services	L	10 355 121	0.1	0.1	0.2	0.4	0.5	1.1	1.3	0.9
		PY	1	-0.3	-0.6	-0.8	-1.0	-1.1	-1.3	-0.7	0.0
		Y	35	0.3	0.9	1.5	2.1	2.8	4.6	3.1	1.2
21	Mining of coal and lignite	L	599	0.2	0.5	0.9	1.3	1.9	4.4	3.6	1.6
		PY	1	-0.3	-0.7	-1.0	-1.3	-1.5	-1.8	-0.7	0.2
		Y	49 658	0.0	0.0	0.1	0.2	0.3	0.7	0.8	0.7
22	Manufacture of refined petroleum products	L	13 640	0.0	0.1	0.1	0.2	0.3	0.8	0.9	0.7
		PY	1	0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.1	0.0
		Y	46 120	0.0	0.1	0.2	0.3	0.4	1.0	1.0	0.8
23	Electric power generation, transmission and distribution	L	95 291	0.1	0.2	0.3	0.4	0.5	1.1	1.2	0.9
		PY	1	-0.2	-0.5	-0.7	-0.8	-0.9	-1.2	-0.8	-0.1
		Y	22 826	0.0	0.1	0.1	0.3	0.4	0.9	1.0	0.8
24	Manufacture and distribution of gas	L	27 958	0.0	0.1	0.1	0.2	0.3	0.8	1.1	0.9
		PY	1	-0.1	-0.3	-0.4	-0.5	-0.5	-0.6	-0.4	-0.1

XII.3 A 50% increase of the oil price

As expected, a 50% increase of the oil price has a negative impact on the economy through a reduction of all the components of the demand. The reduction of the real income reduces consumption which affects in return private investment. Moreover the increase in inflation degrades French exports because we assume that higher oil prices do not increase the world prices of other goods and services. This is quite unrealistic since most French competitors will also be affected by such a shock[21]. As an increase in the oil price is a shock on the world economy, its negative impact evaluated here are likely to be exaggerated.

Tableau 8 Macroeconomic effect of a 50% increase of the oil price

	Level at 2006		1 year	2 years	3 years	4 years	5 years	10 years	20 years	30 years
GDP	1 763 774	*	-0.82	-1.12	-1.25	-1.34	-1.43	-1.73	-1.44	-1.03
Private Sectors GDP	1 478 578	*	-0.97	-1.33	-1.48	-1.59	-1.69	-2.06	-1.72	-1.23
Production	3 232 382	*	-0.50	-0.80	-1.01	-1.17	-1.30	-1.71	-1.43	-0.99
Private Sector Production	2 855 640	*	-0.56	-0.91	-1.14	-1.32	-1.47	-1.93	-1.61	-1.11
Public sector production	376 742	*	-0.01	-0.02	-0.03	-0.04	-0.04	-0.06	-0.05	-0.04
Consumption	963 871	*	-0.38	-0.73	-1.03	-1.26	-1.44	-1.94	-1.74	-1.21
Household Investment										
Automobile	1 883	*	-1.88	-2.19	-2.13	-1.99	-1.88	-1.71	-1.25	-0.77
Housing	93 561	*	-5.25	-4.98	-3.39	-1.97	-1.16	-1.72	-1.90	-0.62
Productive Investments	385 789	*	-1.38	-1.97	-2.13	-2.19	-2.27	-2.22	-1.13	-0.66
Private Sector Investments	338 712	*	-1.53	-2.36	-2.66	-2.76	-2.82	-2.48	-1.19	-0.68
Public Sector Investments	47 077	*	-0.27	0.79	1.69	1.95	1.72	-0.36	-0.67	-0.52
Exports	488 019	*	-0.17	-0.45	-0.72	-0.93	-1.07	-1.09	-0.56	-0.17
Imports	571 023	*	-0.51	-0.84	-1.07	-1.25	-1.41	-2.05	-2.17	-2.04
Employment	22 476 184		-0.11	-0.28	-0.47	-0.63	-0.78	-1.24	-0.98	-0.50
Unemployment rate	8.1%		0.10	0.26	0.43	0.58	0.72	1.14	0.90	0.46
Inflation rate	2.0%		1.29	0.44	0.21	0.06	-0.01	-0.07	-0.06	-0.05
Average gross wage deflated by Value-Added Price	30 365.74	**	1.77	1.47	1.14	0.86	0.64	-0.03	-0.45	-0.69
Real Disposable Income	1 179 497.89	*	-0.77	-1.02	-1.21	-1.37	-1.49	-1.86	-1.67	-1.16
Interest rate	4%		0.12	0.13	0.10	0.06	0.01	-0.12	-0.11	-0.07
Public Deficit (% of GDP)	3%		0.15	0.38	0.41	0.42	0.44	0.77	1.22	1.53
Public Debt (% of GDP)	65%		0.96	1.03	1.14	1.37	1.71	5.09	12.81	20.81
Trade Deficit (% of GDP)	5%		1.01	0.73	0.54	0.41	0.33	0.16	0.26	0.39

*** Million Euros; ** Euro**

Because of the drop in demand, all sectors suffer from this shock (Tableau 9). The other energy sectors suffer less than the oil sectors, benefiting from the possibilities of substitution with oil.

[21] We suppose also that the recycling of the oil revenue of oil producing countries compensates exactly the decrease in demand of other commercial partners of France.

Tableau 9 Sectoral effect of a 50% increase of the oil price

	Sectors	Variables	Level at 2006	1 year	2 years	3 years	4 years	5 years	10 years	20 years	30 years
1	Agriculture, forestry and fishing	Production (Y)	77 956	-0.2	-0.5	-0.8	-1.1	-1.3	-1.8	-1.5	-0.9
		Employment (L)	390 189	-0.1	-0.2	-0.4	-0.6	-0.9	-1.6	-1.3	-0.7
		Production price (PY	1	0.8	1.8	2.6	3.2	3.5	3.6	2.6	1.9
2	Manufacture of food products and beverages	Y	121 773	-0.3	-0.6	-1.0	-1.2	-1.5	-2.0	-1.6	-1.0
		L	484 066	-0.1	-0.3	-0.5	-0.7	-1.0	-1.7	-1.5	-0.8
		PY	1	0.3	0.8	1.3	1.7	2.0	2.2	1.1	0.3
3	Manufacture of motor vehicles, trailers and semi-trailers	Y	90 738	-0.5	-0.9	-1.2	-1.4	-1.5	-1.6	-0.8	-0.2
		L	209 964	-0.2	-0.4	-0.7	-1.0	-1.2	-1.6	-0.8	-0.1
		PY	1	0.2	0.5	0.8	1.0	1.2	1.2	0.3	-0.2
4	Manufacture of glass and glass products	Y	6 645	-0.3	-0.6	-0.9	-1.2	-1.4	-1.7	-1.1	-0.5
		L	37 597	-0.1	-0.3	-0.5	-0.8	-1.0	-1.6	-1.1	-0.4
		PY	1	0.3	0.7	1.2	1.5	1.7	1.6	0.5	-0.3
5	Manufacture of ceramic products and building materials	Y	19 667	-0.8	-1.4	-1.6	-1.5	-1.4	-1.6	-1.4	-0.7
		L	84 480	-0.2	-0.6	-1.0	-1.2	-1.3	-1.5	-1.4	-0.6
		PY	1	0.4	1.0	1.6	1.9	2.1	2.0	1.0	0.3
6	Manufacture of articles of paper and paperboard	Y	19 280	-0.2	-0.5	-0.8	-1.1	-1.3	-1.7	-1.1	-0.5
		L	72 927	-0.1	-0.2	-0.4	-0.7	-0.9	-1.6	-1.1	-0.4
		PY	1	0.2	0.6	1.0	1.3	1.4	1.4	0.5	-0.1
7	Manufacture of inorganic basic chemicals	Y	5 976	-0.2	-0.6	-1.0	-1.4	-1.7	-2.1	-1.4	-0.8
		L	13 672	-0.1	-0.2	-0.5	-0.8	-1.1	-2.0	-1.4	-0.7
		PY	1	0.3	0.7	1.1	1.4	1.6	1.6	0.7	0.1
8	Manufacture of organic basic chemicals	Y	23 286	-1.1	-2.6	-3.8	-4.7	-5.2	-5.6	-5.1	-4.7
		L	18 657	-0.3	-0.9	-1.8	-2.7	-3.5	-5.2	-4.7	-4.2
		PY	1	2.7	5.7	7.9	9.3	10.0	10.0	9.2	8.8
9	Manufacture of plastics products	Y	25 454	-0.3	-0.7	-1.0	-1.3	-1.5	-1.9	-1.4	-0.8
		L	153 969	-0.1	-0.3	-0.5	-0.8	-1.0	-1.7	-1.3	-0.6
		PY	1	0.3	0.8	1.3	1.7	1.9	1.9	1.0	0.4
10	Manufacture of basic iron and steel and of ferro-alloys	Y	24 196	-0.2	-0.5	-0.7	-0.9	-1.1	-1.3	-0.7	-0.1
		L	37 599	-0.1	-0.2	-0.4	-0.7	-0.9	-1.3	-0.7	0.0
		PY	1	0.1	0.3	0.5	0.7	0.8	0.8	0.1	-0.4
11	Manufacture of non-ferrous metals	Y	11 506	-0.1	-0.3	-0.5	-0.7	-0.8	-0.9	-0.4	0.0
		L	14 268	-0.1	-0.2	-0.4	-0.5	-0.7	-1.0	-0.4	0.2
		PY	1	0.1	0.3	0.4	0.6	0.6	0.6	0.1	-0.3
12	Other industries	Y	449 449	-0.3	-0.6	-0.9	-1.1	-1.3	-1.5	-0.9	-0.4
		L	2 036 834	-0.1	-0.3	-0.5	-0.8	-1.0	-1.5	-0.9	-0.3
		PY	1	0.2	0.6	0.9	1.2	1.4	1.4	0.3	-0.4
13	Construction of buildings and Civil engineering	Y	247 504	-2.5	-2.5	-1.9	-1.3	-1.0	-1.6	-1.5	-0.7
		L	1 498 411	-0.8	-1.4	-1.6	-1.5	-1.4	-1.4	-1.4	-0.7
		PY	1	0.4	1.1	1.6	1.9	2.1	1.9	0.7	-0.2
14	Rail transport (Passenger and Freight)	Y	10 033	-0.3	-0.7	-0.9	-1.1	-1.2	-1.4	-1.1	-0.7
		L	96 348	-0.1	-0.3	-0.6	-0.8	-1.1	-1.6	-1.2	-0.5
		PY	1	0.4	0.8	1.0	0.9	0.8	0.4	-0.1	-0.7
15	Passenger transport by road	Y	17 137	-0.3	-0.6	-0.8	-1.1	-1.2	-1.6	-1.4	-1.0
		L	184 850	-0.1	-0.2	-0.4	-0.6	-0.8	-1.4	-1.3	-0.9
		PY	1	1.0	2.3	3.3	4.0	4.3	4.1	2.7	1.6
16	Freight transport by road and transport via pipeline	Y	36 670	-0.4	-1.0	-1.5	-1.8	-2.1	-2.5	-2.1	-1.6
		L	328 404	-0.1	-0.3	-0.6	-1.0	-1.3	-2.2	-1.9	-1.3
		PY	1	1.6	3.6	5.1	6.1	6.7	6.7	5.5	4.7
17	Water transport	Y	10 138	-0.5	-1.2	-1.8	-2.3	-2.6	-2.9	-2.4	-2.0
		L	16 833	-0.1	-0.5	-0.9	-1.3	-1.7	-2.7	-2.2	-1.7
		PY	1	1.0	2.4	3.4	4.2	4.7	4.7	3.7	3.0
18	Air transport	Y	17 992	-0.6	-1.4	-2.1	-2.7	-3.0	-3.2	-2.6	-2.1
		L	66 244	-0.2	-0.5	-1.0	-1.5	-2.0	-3.1	-2.5	-1.8
		PY	1	1.3	2.9	4.1	4.9	5.3	5.2	4.0	3.3
19	Business services	Y	1 521 601	-0.3	-0.6	-0.9	-1.1	-1.2	-1.7	-1.3	-0.9
		L	10 355 121	-0.1	-0.3	-0.5	-0.7	-1.0	-1.7	-1.3	-0.7
		PY	1	0.4	0.8	1.2	1.4	1.5	1.3	0.3	-0.5
21	Mining of coal and lignite	Y	35	-0.3	-0.9	-1.8	-2.8	-3.8	-7.7	-9.9	-10.6
		L	599	-0.1	-0.4	-0.9	-1.5	-2.3	-6.6	-9.5	-10.3
		PY	1	0.2	0.6	1.0	1.3	1.5	1.7	0.4	-0.7
22	Manufacture of refined petroleum products	Y	49 658	-3.3	-4.6	-5.7	-6.4	-6.9	-8.7	-9.8	-10.2
		L	13 640	-0.7	-1.7	-2.7	-3.7	-4.5	-7.2	-8.6	-9.1
		PY	1	10.6	20.9	26.6	29.1	30.0	30.1	29.5	29.3
23	Electric power generation, transmission and distribution	Y	46 120	0.3	-0.2	-0.8	-1.5	-2.0	-4.3	-5.6	-6.0
		L	95 291	0.1	0.0	-0.3	-0.7	-1.2	-3.7	-5.4	-5.8
		PY	1	0.3	0.7	1.0	1.3	1.5	1.7	0.8	-0.1
24	Manufacture and distribution of gas	Y	22 826	-0.7	-1.5	-2.4	-3.2	-3.9	-6.6	-8.5	-9.3
		L	27 958	-0.2	-0.6	-1.2	-1.9	-2.6	-5.8	-8.2	-9.1
		PY	1	0.2	0.4	0.7	0.9	1.1	1.3	0.6	0.2

XII.4 A increase of one point of the labor participation ratio

An exogenous increase in the labor participation ratio consecutive for instance of an increase in the legal retirement age has a positive impact on the activity since it increases the potential output of the economy. However, as the adjustment process is slow, the unemployment rate increases. The subsequent decrease in inflation is favorable for the economic activity and thus decreases unemployment: the improvement of the external position leads to an increase of the exports, and the decrease of the interest rate is favorable to investment.

Tableau 10 Macroeconomic effect of a 1 point of the labor participation ratio

	Level at 2006	1 year	2 years	3 years	4 years	5 years	10 years	20 years	30 years
GDP	1 763 774 *	0.25	0.42	0.49	0.51	0.52	0.79	1.33	1.73
Private Sectors GDP	1 478 578 *	0.29	0.50	0.58	0.60	0.62	0.93	1.56	2.04
Production	3 232 382 *	0.16	0.31	0.41	0.46	0.50	0.80	1.36	1.79
Private Sector Production	2 855 640 *	0.19	0.36	0.46	0.52	0.57	0.91	1.54	2.02
Public sector production	376 742 *	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.05
Consumption	963 871 *	0.00	0.00	0.02	0.06	0.12	0.47	1.03	1.54
Household Investment									
Automobile	1 883 *	0.31	0.55	0.66	0.67	0.66	0.68	1.08	1.42
Housing	93 561 *	2.18	3.58	3.84	3.48	2.92	1.13	1.66	2.43
Productive Investments	385 789 *	0.76	1.24	1.31	1.17	0.99	0.99	1.43	1.66
Private Sector Investments	338 712 *	0.77	1.30	1.43	1.32	1.18	1.22	1.73	1.98
Public Sector Investments	47 077 *	0.70	0.82	0.47	0.03	-0.31	-0.72	-0.71	-0.68
Exports	488 019 *	0.04	0.12	0.25	0.39	0.54	1.21	1.91	2.35
Imports	571 023 *	0.10	0.16	0.15	0.11	0.05	-0.04	0.06	0.19
Employment	22 476 184	0.04	0.10	0.18	0.26	0.33	0.70	1.30	1.78
Unemployment rate	8.1%	2.02	1.96	1.89	1.83	1.76	1.43	0.89	0.46
Inflation rate	2.0%	-0.31	-0.35	-0.31	-0.26	-0.22	-0.12	-0.09	-0.06
Average gross wage deflated by Value-Added Price	30 365.74 **	-0.15	-0.28	-0.37	-0.44	-0.49	-0.85	-1.30	-1.60
Real Disposable Income	1 179 497.89 *	0.03	0.07	0.12	0.17	0.23	0.55	1.07	1.57
Interest rate	4%	-0.09	-0.16	-0.20	-0.23	-0.23	-0.19	-0.13	-0.07
Public Deficit (% of GDP)	3%	-0.06	-0.13	-0.15	-0.13	-0.10	0.10	0.29	0.42
Public Debt (% of GDP)	65%	-0.10	-0.12	-0.07	0.02	0.12	0.95	3.12	5.58
Trade Deficit (% of GDP)	5%	0.04	0.10	0.14	0.17	0.20	0.34	0.55	0.71

*** Million Euros; ** Euro**

Tableau 11 Sectoral effect of a 1 point of the labor participation ratio

	Sectors	Variables	Level at 2006	1 year	2 years	3 years	4 years	5 years	10 years	20 years	30 years
1	Agriculture, forestry and fishing	Production (Y)	77 956	0.0	0.1	0.2	0.3	0.4	0.9	1.6	2.1
		Employment (L)	390 189	0.0	0.0	0.1	0.2	0.3	0.9	1.9	2.6
		Production price (PY)	1	-0.1	-0.3	-0.6	-0.9	-1.2	-2.5	-3.7	-4.6
2	Manufacture of food products and beverages	Y	121 773	0.0	0.1	0.2	0.3	0.4	1.0	1.8	2.4
		L	484 066	0.0	0.0	0.1	0.2	0.3	1.0	2.0	2.8
		PY	1	-0.1	-0.2	-0.5	-0.7	-1.0	-2.3	-3.7	-4.5
3	Manufacture of motor vehicles, trailers and semi-trailers	Y	90 738	0.3	0.5	0.6	0.7	0.8	1.3	2.1	2.6
		L	209 964	0.1	0.2	0.4	0.5	0.7	1.4	2.4	3.1
		PY	1	-0.1	-0.2	-0.4	-0.6	-0.8	-1.7	-2.7	-3.3
4	Manufacture of glass and glass products	Y	6 645	0.1	0.2	0.4	0.5	0.7	1.3	2.2	2.8
		L	37 597	0.0	0.1	0.2	0.3	0.5	1.3	2.4	3.2
		PY	1	-0.1	-0.3	-0.5	-0.8	-1.1	-2.3	-3.6	-4.3
5	Manufacture of ceramic products and building materials	Y	19 667	0.4	0.8	1.2	1.3	1.3	1.0	1.6	2.1
		L	84 480	0.1	0.4	0.6	0.9	1.1	1.2	1.8	2.5
		PY	1	-0.1	-0.3	-0.6	-0.9	-1.1	-2.2	-3.4	-4.2
6	Manufacture of articles of paper and paperboard	Y	19 280	0.1	0.2	0.3	0.5	0.6	1.4	2.2	2.9
		L	72 927	0.0	0.1	0.2	0.3	0.4	1.4	2.5	3.3
		PY	1	-0.1	-0.2	-0.4	-0.7	-0.9	-2.0	-3.0	-3.6
7	Manufacture of inorganic basic chemicals	Y	5 976	0.1	0.2	0.3	0.5	0.7	1.5	2.5	3.1
		L	13 672	0.0	0.1	0.2	0.3	0.5	1.5	2.7	3.5
		PY	1	-0.1	-0.2	-0.4	-0.7	-0.9	-1.9	-2.8	-3.4
8	Manufacture of organic basic chemicals	Y	23 286	0.0	0.1	0.2	0.4	0.5	1.0	1.6	2.0
		L	18 657	0.0	0.1	0.1	0.2	0.4	1.1	1.9	2.5
		PY	1	0.0	-0.1	-0.3	-0.4	-0.6	-1.2	-1.8	-2.2
9	Manufacture of plastics products	Y	25 454	0.1	0.3	0.4	0.6	0.7	1.2	2.0	2.5
		L	153 969	0.0	0.1	0.3	0.4	0.5	1.3	2.3	3.1
		PY	1	-0.1	-0.2	-0.4	-0.6	-0.8	-1.8	-2.8	-3.4
10	Manufacture of basic iron and steel and of ferro-alloys	Y	24 196	0.1	0.3	0.4	0.6	0.8	1.5	2.4	3.0
		L	37 599	0.0	0.1	0.2	0.4	0.6	1.6	2.8	3.6
		PY	1	-0.1	-0.2	-0.4	-0.6	-0.8	-1.7	-2.5	-3.1
11	Manufacture of non-ferrous metals	Y	11 506	0.1	0.2	0.3	0.5	0.6	1.2	1.9	2.4
		L	14 268	0.0	0.1	0.2	0.3	0.5	1.4	2.4	3.1
		PY	1	-0.1	-0.2	-0.3	-0.5	-0.7	-1.3	-2.0	-2.4
12	Other industries	Y	449 449	0.1	0.3	0.4	0.5	0.7	1.3	2.1	2.6
		L	2 036 834	0.0	0.1	0.3	0.4	0.5	1.3	2.3	3.0
		PY	1	-0.1	-0.2	-0.4	-0.7	-0.9	-2.1	-3.3	-4.0
13	Construction of buildings and Civil engineering	Y	247 504	1.2	1.9	2.1	1.8	1.5	0.7	1.1	1.6
		L	1 498 411	0.4	0.9	1.3	1.5	1.6	1.0	1.3	1.9
		PY	1	-0.1	-0.4	-0.7	-1.0	-1.3	-2.3	-3.8	-4.8
14	Rail transport (Passenger and Freight)	Y	10 033	0.1	0.2	0.4	0.6	0.7	1.2	2.0	2.5
		L	96 348	0.0	0.0	0.1	0.2	0.4	1.2	2.3	3.1
		PY	1	-0.3	-0.8	-1.2	-1.6	-1.9	-2.9	-4.0	-4.7
15	Passenger transport by road	Y	17 137	0.0	0.0	0.1	0.1	0.2	0.5	1.0	1.4
		L	184 850	0.0	0.0	0.0	0.1	0.1	0.4	1.0	1.5
		PY	1	-0.1	-0.3	-0.6	-0.9	-1.3	-2.9	-4.5	-5.6
16	Freight transport by road and transport via pipeline	Y	36 670	0.1	0.2	0.3	0.4	0.5	1.1	1.9	2.4
		L	328 404	0.0	0.1	0.2	0.3	0.4	1.1	2.0	2.7
		PY	1	-0.1	-0.3	-0.5	-0.8	-1.1	-2.3	-3.6	-4.4
17	Water transport	Y	10 138	0.0	0.1	0.2	0.4	0.5	1.2	2.0	2.4
		L	16 833	0.0	0.1	0.1	0.2	0.4	1.2	2.2	2.8
		PY	1	-0.1	-0.2	-0.4	-0.7	-0.9	-2.1	-3.2	-3.9
18	Air transport	Y	17 992	0.0	0.1	0.3	0.4	0.6	1.3	2.2	2.7
		L	66 244	0.0	0.1	0.1	0.2	0.4	1.3	2.3	3.0
		PY	1	-0.1	-0.2	-0.5	-0.7	-1.0	-2.2	-3.3	-4.1
19	Business services	Y	1 521 601	0.1	0.2	0.3	0.4	0.4	0.8	1.4	1.9
		L	10 355 121	0.0	0.1	0.1	0.2	0.3	0.8	1.6	2.2
		PY	1	-0.2	-0.5	-0.8	-1.1	-1.4	-2.7	-4.1	-5.0
21	Mining of coal and lignite	Y	35	0.2	0.6	1.2	1.9	2.6	5.9	8.6	10.4
		L	599	0.0	0.2	0.5	1.0	1.5	5.0	8.3	10.4
		PY	1	-0.1	-0.4	-0.8	-1.2	-1.6	-3.2	-4.4	-5.2
22	Manufacture of refined petroleum products	Y	49 658	0.0	0.0	0.0	0.1	0.1	0.2	0.4	0.5
		L	13 640	0.0	0.0	0.0	0.1	0.1	0.3	0.6	0.8
		PY	1	0.0	0.0	-0.1	-0.1	-0.2	-0.4	-0.6	-0.8
23	Electric power generation, transmission and distribution	Y	46 120	0.0	0.1	0.2	0.2	0.3	0.6	1.0	1.2
		L	95 291	0.0	0.0	0.1	0.1	0.2	0.7	1.2	1.6
		PY	1	-0.1	-0.4	-0.7	-0.9	-1.2	-2.3	-3.5	-4.2
24	Manufacture and distribution of gas	Y	22 826	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.3
		L	27 958	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.5
		PY	1	0.0	-0.1	-0.1	-0.2	-0.3	-0.8	-1.2	-1.5

Appendix A. Long term of the model

The long term steady state of the model is generally defined as a state where all variables grow at a constant rate. This state is coherent with the representation of a stable economy able to maintain a given configuration forever. This implies that rates such as the unemployment or labor participation ratios, tax rates are constant in the long run. This is coherent with the fact that these ratios lie by definition between 0 and 100% and thus cannot be affected by a trend forever.

Most shares should also be constant. For instance, the shares of investment or of consumption into GDP should be constant. Otherwise the effect of one these two determinants of the GDP vanishes over time. The same argument holds for the share of one sector in the total in terms of labor or production: we expect an economy where all sectors remains in the long run, which implies that some economic mechanisms guaranty stable share for each sectors.

Some exceptions are possible. As empirically observed, it seems realistic that the share of labor into the GDP decreases over time because of the technical progress. But the share of the efficient labor, that is including the technical progress, remains constant. Because of the globalization of the economy, the ratio between export and production may also increase permanently in the long run. But in the long run this effect is expected to be compensated by the increase in the ratio between import and production so that the share of the external balance into production remains constant.

In the long run, all relative prices are expected to be constant. This implies that all prices grow at the same rate. This guaranty that the economy is not affected by substitution mechanisms in the long run: firms do not want to change the share of each production factors into production and consumers are satisfied with share of each good into their aggregate consumption. It implies also that each agent is satisfied with their share of the global revenue: firms do not want to change the growth rate of their price whereas employees do not want to change the growth rate of their wage.

Assuming that ν, τ, μ, π and ω are the growth rates of the population, of the technical progress, of the real economy (i.e. of the GDP), of prices (i.e. inflation), and of wages, the long run value of these rate cannot be chosen independently. First, the growth rate of the real economy should be equal to the sum of the growth rate of the population and of the technical progress: $\mu = \nu + \tau$. This condition is a direct consequence of the hypothesis of constant return to scales (homogeneous of degree 1) of the production function. In the long run, relative price are constant and the labor demand [12] implies that production grows at the sum of the growth rates of labor and technical progress $\Delta y_{jt} = \Delta l_{jt} + \Delta p_{jt}^{rod}$. In addition, the stability of unemployment implies that labor grows at the same rate as the population (Equation[57]).

In the long run, the price equation implies that the growth rate of wages should be equal to the sum of inflation and of the growth rate of the technical progress $\omega = \pi + \tau$. This holds only if some economic mechanisms imply that the unemployment rate converge to the NAIRU. The latter depends on the parameter of the Phillips curve [55]:

$$U_{\infty} = \left(\rho_1 - (1-\rho_2)\pi - (1-\rho_3)\tau\right) / \rho_5 \qquad [80]$$

In the model several stabilizing equation guaranty that the economy return to stationary path after a shock. Inflationary shocks degrade the external position of France by decreasing export and increasing imports. In addition, the Taylor rule combined with the negative impact of the real interest rate on the demand prevents inflationary shock to lead to an explosive inflation dynamic. The negative impact of the real interest rate on the activity has several possible canals:

- Consumption: in coherence with a life-cycle model and the possibility of an intertemporal allocation of their resource, households may increase their savings when the real interest rate increases and thus reduces their consumptions. They may also have Ricardian behavior in the long run by internalizing the government and firms' budget constraints. They may thus adjust their consumption in such way that the ratio between their saving and the national debt is constant in order to insure the sustainability of the debt (see Box 3).
- Investment: firms may choose their investment level that is coherent with the stability of their debt into the value-added.
- Tax and public spending: the government is expected to choose the tax rate and public spending levels that are coherent with a stable debt into the GDP.

The consistency of a dynamic model with a stationary equilibrium requires long term constraints which depend on the type of mathematical equation. We briefly detailed the main cases that are encountered in Three-ME and how the model can be calibrated in order to be at the stationary state from the first period of the simulation onward.

Additive equations

In the model, many relations enter in an additive form:

$$Y_t = \sum_{i=1}^{I} X_{i,t} \qquad [81]$$

These are in general definitions such as the GDP decomposition or income, etc. In case of an additive equation [81], the variable Y grows at the rate μ from the first period onward if all its components X grow also at that rate:

$$Y_t = \left(\sum_{i=1}^{I} X_{i,0} \right) (1+\mu)^t = Y_0 (1+\mu)^t \qquad [82]$$

Moreover in that case all ratios between variables (X_i/Y and X_i/X_j) are constant over time. In the case of the GDP equation this seems a realistic long run property. Otherwise the share of each component in the GDP is not stable over time and the long run growth rate of the GDP corresponds to the component's highest growth rate. Indeed, if the X-variables do not grow at the same rate, the growth rate of Y (μ) converges to the highest X-variable growth rate. And the share of the X-variable with a lower growth rate tends toward zero.

This mathematical property may imply unrealistic constraint on the model if one wants to be at the steady states at the first period of the simulation. This is particularly true if one wishes to calibrate the model on real data. We can give 2 examples:

For instance, it is unrealistic to assume that a negative inventory change will decrease indefinitely because the level of inventories becomes at some point negative. One possibility is to amend the calibration in order to impose a zero-inventory change at the base years.

In the real world, most countries' imports and exports do not grow at the rate of the GDP but at a higher rate because of the trade globalization. In fact Equation [81] allows that several X-variables grow at a different rate than Y in the long run as long their sum grows at the same rate as Y. Consequently, imports and exports may grow faster that the GDP forever as long as their effect cancel out, that is as long as the foreign trade balance grows at the rate of the GDP. If the long run foreign trade balance is zero, imports and exports grow at the same rate. If not, they grow at the same rate asymptotically, the smallest (in absolute value) growing faster. This implies mechanism that imposes import and export to grow consistently.

The most common way is to assume that the exchange rate adjusts in order to reach the external balance objective.

Unit elasticity logarithm equations

Many relations in the model impose a unit-elasticity specified in logarithm form:

$$\ln(Y_t) = \ln(X_t) + \alpha \quad [83]$$

This specification is used for all production factor demand since we systematically assume a constant return-to-scale technology. If the coefficient α is calibrated in the initial period as a simple inversion of equation [83] and constant over time, this specification implies that *Y* always grows at the same rate as *X*.

In the production factors demand, *α* depends on the relative prices and thus may vary over time in case of shock or if they are not in equilibrium in the initial period. In that case, the growth rate of *Y* and *X* differs over time but they tend to converge toward each other provided that mechanisms in the price equation guaranty the long run stability of relative prices.

Accumulation equations

The model contains several accumulation equations: capital stock dynamic, public and private debt, household savings. All can be represented with the following equation:

$$Y_t = Y_{t-1}(1+\beta) + X_t \quad [84]$$

In the case of capital accumulation, *β* is the depreciation rate and is negative. In the case of debt or saving equation, *β* is the interest rate and is thus positive. Dividing both sides by Y_{t-1} give the growth rate of the stock variable:

$$\dot{Y}_t = \beta + X_t / Y_{t-1} \quad [85]$$

At the steady states, *X* should grow at the same rate as *Y* which is defined by Equation [85]. Consequently, being at the stationary states from the first period onward implies that *X* cannot be calibrated on real data. For the base year, X is calibrated as an inversion of Equation [84]:

$$X = \left(\frac{\mu - \beta}{1 + \mu} \right) . Y \qquad [86]$$

Error correction model (ECM) equations

All adjustment processes are assumed to follow an Error Correction Model (ECM) where the variable Y adjusts slowly to its target or notional value Y^n:

$$\Delta Y_t = \alpha_1 \Delta Y_{t-1} + \alpha_2 \Delta Y_t^n - \alpha_3 (Y_{t-1} - Y_{t-1}^n) \qquad [87]$$

This specification was used to specify the dynamic of prices and quantities and thus describe how effective values adjust to notional values. If the change in the target Y^n is constant, Equation [87] implies that in the long run change in Y is also constant: $\Delta Y_t = \Delta Y_t^n = \mu$. This property can be used to calibrate the initial period in order to be at the steady state from the first period onward. To do so, the initial target level should be:

$$Y_0^n = Y_0 + \mu.(1 - \alpha_1 - \alpha_2) / \alpha_3 \qquad [88]$$

Unless $\alpha_1 + \alpha_2 = 1$, the target is never reach even in the long run. For instance, the notional price becomes a function of inflation and the model is not super-neutral. This property is sometimes viewed as theoretically inconsistent (Allard-Prigent et al., 2002) but is frequently found empirically (Chagny et al., 2002).

One can notice that if $\alpha_1 = 0$ and $\alpha_2 = \alpha_3 = \alpha$, Equation [87] simplifies:

$$Y_t = \alpha Y_t^n + (1 - \alpha) Y_{t-1} \qquad [89]$$

If moreover the variables Y and Y^n are expressed in logarithm, Equation [89] is nothing else but a geometric adjustment process. This particular case has the advantage to allow only monotonous adjustment whereas the more general form of the ECM [87] may lead to cyclical adjustment. This generally arise when the autoregressive term has an important impact, that is when α_1 is high.

Appendix B. Generalized CES production function and factors demand

This appendix derives the optimality program of the producer and the consumer assuming a generalized CES (GCES) production and utility function. We show that the GCES function can be approximated in the neighborhood of the optimal stationary state by a Cobb-Douglas function for which the technical coefficients vary with the relative prices. This result greatly facilitates the deduction of linear demands functions for input and goods.

GCES production function and factors demand

Let us define a GCES production function as a H inputs-production function with different elasticities of substitution between each pair of input. We still assume a constant elasticity of substitution between 2 inputs along the isoquant. Let us assume that technology may be represented by a continuous and twice differentiable function, linearly homogeneous, strictly increasing ($Q_t^{'}(x_{ht}) > 0$) and concave ($Q_t^{''}(x_{ht}) < 0$) reflecting the law of diminishing marginal returns:

$$Q_t = Q(X_{ht}) \qquad [90]$$

Where X_{ht} is the quantity of input (or production factor) $h = [1;H]$ used to produce the quantity of production (or output) Q_t.

For algebraic simplicity, we assume a technology with constant returns to scale (*i.e.* the production function [90] is homogeneous of degree 1) and the absence of technical progress. We shall relax these constraints latter. Driven by maximizing profit behaviour, the producer chooses her demand for each input by minimizing her production cost [91] subject to the technical constraint [90]:

$$C_t = \sum_{h=1}^{H} P_{ht}^X X_{ht} \qquad [91]$$

Where P_{ht}^X is the price of input *h*. The Lagrangien to this problem is:

$$L_t = C_t - \lambda\left(Q_t - Q_t(X_{ht})\right) \qquad [92]$$

The necessary first order conditions are $L'(X_{ht}) = 0$ for all h and $L'(\lambda) = 0$. The second order conditions ensure that the optimum is a minimum is always verified because of the convexity of the cost function [91] and strict convexity of the isoquants formed by the production function [90] [22]. The well-known first order condition says that at the optimum, the ratio between marginal productivities of two inputs equals the one between their prices:

$$Q'(X_{ht}) / Q'(X_{h't}) = P_{ht}^{X} / P_{h't}^{X} \qquad [93]$$

The production function [90] can be linearized with the following first-order Taylor expansion:

$$\dot{Q}_t = \sum_{h=1}^{H} \frac{Q'(X_{ht}) X_{ht}}{Q(X_{ht})} \dot{X}_{ht} \qquad [94]$$

Euler's Theorem states that a function which is homogeneous of degree 1 can be express as the sum of its arguments weighted by their first partial derivatives:

$$Q(X_{ht}) = \sum_{h=1}^{H} Q'(X_{ht}) X_{ht} \qquad [95]$$

The fact that in equilibrium, the remuneration of the production factors must be equal to the value of the production provides another useful relation:

$$\sum_{h=1}^{H} P_{ht}^{X} X_{ht} = P_t^{Q} Q_t \qquad [96]$$

The combination of equations [93] to [96] gives at the neighbourhood of the stationary state a linear specification of the production function:

$$\dot{Q}_t = \sum_{h=1}^{H} \varphi_{ht} \dot{X}_{ht} \Leftrightarrow q_t = \sum_{h=1}^{H} \varphi_{ht} x_{ht} \qquad [97]$$

Where φ_{ht} is the share (in value) of input h in the production sometimes called Leontief technical coefficient:

$$\varphi_{ht} = P_{ht}^{X} X_{ht} / (P_t^{Q} Q_t) \qquad [98]$$

[22] According to the technological constraint [90], the strict convexity of the isoquant ($X''_{ht}(X_{h't}) > 0$) implies that $Q''(X_{ht}) < 2Q'(X_{ht})$. This condition is always verified since by assumption the left-hand side is negative ($Q''(X_{ht}) < 0$) while the right-hand side is positive ($Q'(X_{ht}) > 0$).

We have just shown that at the neighbourhood of the optimum any linearly homogeneous, twice differentiable, strictly increasing and concave production function can be approximated by a Cobb-Douglas with technical coefficients that varies over time. Moreover these technical coefficients correspond to the input share into production. They are stable in the long run because the specification of Three-ME guaranties the stability of ratios between prices and of input to production ratios.

Suppose further that the direct elasticity of substitution – in the sense of Hicks (1932) and Robinson (1933) – between inputs h and h' ($\eta_{hh'}$) is not necessarily the same between each couple of production factors. This elasticity measures the change in the ratio between two factors of production due to a change in their relative marginal productivity, i.e. in the marginal rate of substitution (in the slope of the iso-production curve):

$$-\eta_{hh'} = \frac{\partial \ln(X_{ht} / X_{h't})}{\partial \ln\left(Q'(X_{ht}) / Q'(X_{h't})\right)} \Leftrightarrow \partial \ln(X_{ht} / X_{h't}) = -\eta_{hh'} \partial \ln\left(Q'(X_{ht}) / Q'(X_{h't})\right) \qquad [99]$$

Integrating [99] with respect to time and then combining it with the optimality condition [93] gives:

$$X_{ht} / X_{h't} = \xi_{hh'} \left(P^X_{ht} / P^X_{h't}\right)^{-\eta_{hh'}} \qquad [100]$$

Where $\xi_{hh'}$ is the constant of integration which we calibrate to one for algebraic simplicity. Rewriting [100] in terms of input share, $\varphi_{ht} / \varphi_{h't} = \xi_{hh'} \left(P^X_{ht} / P^X_{h't}\right)^{1-\eta_{hh'}}$, gives the well-known result that the inputs share is constant over time only in case of unit elasticity of substitution between all factors of production (Cobb-Douglas technology).

The first order conditions [100] and the production function [97] constitute a system of H linearly independent equations and H unknowns. Its resolution give the demand for each factor as a positive function of output and negative function of relative prices between production factors:

$$x_{ht} = q_t - \sum_{\substack{h'=1 \\ h' \neq h}}^{H} \eta_{hh'} \varphi_{h't} (p^X_{ht} - p^X_{h't}) \qquad [101]$$

The introduction of technical progress and non constant return-to-scale is straightforward and does not alter the results. In the first case one can simply define $X_{ht} = I^{nput}_{ht} P^{rog}_{ht}$ as the efficient input, which includes the technical progress P^{rog}_{ht}, I^{nput}_{ht} being the effective input. In the second case, one can simply define production as an homogenous function of Q of degree θ : $Y_t = Q_t^{\theta}$. In case of a technology with increasing (resp. decreasing) return-to-scale, $\theta > 1$ (resp. < 1). Integrating technical progress and non constant return-to-scale leads to the following input demand:

$$i_{ht}^{nput} = \theta^{-1} y_t - p_{ht}^{rog} - \sum_{\substack{h'=1 \\ h' \neq h}}^{H} \eta_{hh'} \varphi_{h't} (p_{ht}^{X} - p_{h't}^{X}) \qquad [102]$$

Assuming constant return to scale, this log-linear specification has been recently estimated for the Euro area by Lemoine et al. (2010) using the Kalman filter to extract the trend of technical progress.

GCES consumer utility function and demand for goods

In Three-ME, the demand for goods is treated in a similar way as the demand for input. Let us assume that at a first stage the consumer divides (eventually via an intertemporal maximization program) her revenue between expenditures and savings. For a given level desired volume of expenditure Q, the consumer is then assumed to minimize the cost of this expenditure. The substitutability between the different consumption goods (or expenditures), X_h, is measured through a J goods-utility function having the same property as the production function defined in [90]. Formally the optimization program is the same as the one of the producer. It consists in minimizing the cost of expenditure [91] subject to the utility function constraint [90]. The demand for goods is thus [101].

Notice that minimizing the cost of expenditure subject to a utility function constraint give the same result as the standard approach which consists in maximizing the utility [90] subject to a budget constraint [103]:

$$\sum_{h=1}^{H} P_{ht}^{X} X_{ht} = P_t^{Q} Q_t \qquad [103]$$

The Lagrangien to this problem is:

$$L_t = Q_t - \lambda \left(\sum_{h=1}^{H} P_{ht}^{X} X_{ht} - P_t^{Q} Q_t \right) \qquad [104]$$

The necessary first order conditions ($L'(X_{ht}) = 0$ for all h and $L'(\lambda) = 0$) are the well-know conditions that the ratio between marginal utilities of two goods equals the one between their prices (Equation [93] and thus [100]) and the budget constraint (Equation [103]). Using a first-order Taylor expansion on Equation [103] (devided by P^Q) in the neighbourhood of the stationary equilibrium characterized by the stability of price ratios ($P_h^X / P_{h'}^X$, P_h^X / P^Q), allows for rewriting the budget constraint as [97]. As we have now the same system to solve as in the producer case (Equations [100] and [97]), the demand for good is thus [101].

Notice that the particular case of a CES function ($\eta_{hh'} = \eta$), [101] simplifies. To see this, let us first use a first-order Taylor expansion on Equation [103] (devided by Q_t) in the neighbourhood of the stationary equilibrium characterized by the stability of ratios between volumes ($X_h/X_{h'}$, X_h/Q). This conveniently allows expressing the consumer price as a weighted average of the prices of goods, the weight being the share into consumption (Equation [98]):

$$\dot{P}_t^Q = \sum_{h=1}^{H} \varphi_{ht} \dot{P}_{ht}^X \Leftrightarrow p_t^Q = \sum_{h=1}^{H} \varphi_{ht} p_{ht}^X \qquad [105]$$

Assuming a constant elasticity of substitution ($\eta_{hh'} = \eta$) between goods and combining the price equation [105] to [101], the demand for goods simplifies and depends only on the relative price between the price of goods and the consumer price:

$$x_{ht} = q_t - \eta(p_{ht}^X - p_t^Q) \qquad [106]$$

Not surprisingly this relation is the same as the one deduced from a direct maximization of CES utility function subject to a budget constraint (see Blanchard and Fischer, 1989; Blanchard and Kiyotaki, 1987; Dixit and Stiglitz, 1977). The only difference is that the consumer price index (P_t^Q) is a linear approximation of the Dixit-Stiglitz index which is a CES function of the price of goods. As demonstrated by Arrow et al. (1961), Leontief and Cobb-Douglas functions are particular cases of a CES function where η tends to 0 and 1 respectively.

Appendix C. Glossary of terms used

Index and exponents

a	Armington economic agent (sectors, consumers and public administrations)
auto	Automobile
c	Consumption
d	Domestic
e	Country
eff	Efficient
en	Energy
ea	Euro area
fc	Final consumption
g	Public administration
h	Input (capital, labor, energy, material); or euro area country
hh	Household
hous	Housing
i, i’	Product varying between 1 and 24
inv	Investment
j	Sector varying between 1 and 24
m	Import
n	Notional or optimal
real	Real
s	Sector
sub	Subsidies
t	Time
tax	Taxes
trsp	Transport
val	Value
vol	Volume
x	Export
y	Production

Volume variables

$AUTO_t$	Household automobile stock
C_t	Aggregate consumption
$C_{it}\left(\subset C_t\right)$	Subset of aggregate consumption with i=cf, trsp, en
$CO2_{en,t}$	CO_2 emissions by energy source
D_{it}^{a}	Domestic demand by product and by Armington agent
$FC_{it}\left(\subset C_{cf,t}\right)$	Subset of aggregate final consumption demand with i = 1…13, 19, 20
E_{jt}	Energy demand by sector
$EN_{it}\left(\subset C_{en,t}\right)$	Subset of household aggregate energy demand with i = 21… 24
G_t	Total government demand
$G_{it}\left(\subset G_t\right)$	Government demand by product
$HOUS_t$	Household housing stock
I_t	Investment
I_{ijt}^{nput}	Production input (or factor) *i* in sector *j*
K_{jt}	Capital stock by sector
L_t	Total employment
$L_{jt}\left(\subset L_t\right)$	Employment by sector
M_{it}^{a}	Import demand by product and by Armington agent
M_{it}^{ar}	Transport and commercial margins
M_{jt}^{at}	Material demand by sector
P_t^{op}	Total population
$P_t^{op\_act}\left(\subset P_t^{op}\right)$	Active population
$TRSP_{it}\left(\subset C_{trsp,t}\right)$	Subset of household aggregate transport demand with i = 14… 18
VA_{jt}	Value-added by sector
X_{it}	Export demand
$X_{it}^{d}\left(\subset X_{it}\right)$	Export of domestic product
$X_{it}^{m}\left(\subset X_{it}\right)$	Export of import product

Y_{jt}	Production by sector

Value variables

B^s	Sector financing-needs
D^g	Public debt
D^s	Sector (or private) debt
DEF^g	Public deficit
DEF^x	External commercial deficit
EN_t^{tax}	Energy taxes
EXP_t^g	Government total expenditures
EXP_t^h	Household total expenditures
$FD_{t-2}^{net\_s}$	Total firms net financial debt
FP_t^{tax}	Total firm profit tax
$FW_{t-1}^{net\_h}$	Net financial wealth of household
GOS_{jt-1}^s	Total gross operating profit
I_t^{disp}	Gross disposable income
PFD_t^g	Total demand of production factors
PR_t^{tax}	Product taxes net of subsidies
RES_t^g	Government total resources
S_t^h	Financial private saving
SC_{jt}	Employer and employee social security contributions
SUB_{it}^g	Total public subsidies
$T_t^{ransf\_h}$	Government social transfers to household
VA_t^{tax}	Value-added tax
$I_t^{disp\_tax}$	Income tax
Y_t^{tax}	Production taxes net of operating subsidies

Prices

P_t	Consumer price index
DP_{jt}	Desired production price by sector
I_t^r	Interest rate of the Central bank
GUC_{jt}	Gross unit cost of production by sector
NUC_{jt}	Net unit cost of production by sector
P_{it}	Price by product
P_{it}^c	Consumption price by product
P_t^{auto}	Unitary cost of automobile stock
P_t^{hous}	Unitary cost of housing stock
P_{it}^{inv}	Price of investment
P_{jt}^K	Unitary cost of capital by sector
P_{jt}^L	Unitary cost of labor by sector
P_{it}^W	External price by product
P_{jt}^Y	Production price by sector
P_{it}^q	Production market price by product
W_{jt}	Wage by sector
WD_{it}	World demand by product

Parameters and rates

U_t	Unemployment rate
R_t^h	Apparent earning rate of the household net financial wealth
R^{esc}	Apparent employee social security rate
R^{i_tax}	Apparent income tax rate
$R_i^{va\_tax}$	Apparent value-added tax rate by product
$R_i^{pr\_tax}$	Other apparent product tax rate by product
$R_i^{pr\_sub}$	Apparent product subvention rate by product

$R_i^{y\_sub}$	Apparent production subvention rate
$R_i^{en\_tax}$	Apparent energy tax rate by type of energy
R^{dep}	Depreciation rate of capital stock
R_{jt}^{mu}	Mark-up rate by sector
$R_{jt}^{em\_cont}$	Apparent rate of employer social security contribution
R^{FP_tax}	Apparent rate of firms profit rate
φ_{ht}^{val}	Value share of input *h*
φ_{ht}^{vol}	Volume share of input *h*
φ_t^{c}	Marginal propensity to consume
φ_t^{inv}	Marginal propensity to invest
φ_t^{auto}	Ratio of household automobile stock to her disposable income
φ_t^{hous}	Ratio of household housing stock to her disposable income
$\varphi_{ii't}^{mar}$	Share of transports and commercial margins by product
α_1	ECM parameter: measures the sensitivity to the past dynamic of effective variables
α_2	ECM parameter: measures the sensitivity to the dynamic of notional variables
α_3	ECM correcting force parameter: measures the sensitivity to the gap between effective and notional variables
$\eta_{ii',j}$	Substitution elasticity between two products or productions factors by sector
η^{hous}	Sensitivity parameter of household energy demand to the share of efficiency housing equipments
η_{22}^{en}	Sensitivity parameter of household oil demand to the oil price
η_i	Sensitivity parameter of household investments to the energy prices
η_i^{auto}	Sensitivity parameter of household oil demand to the share sober cars
η_i^{a}	Armington substitution elasticity
η_i^{a}	Export price elasticity
p_{jt}^{rog}	Productivity by sector
ρ_{1j}	Constant in the Phillips curve

ρ_{2j} Sensitivity parameter of nominal wage growth to inflation

ρ_{3j} Sensitivity parameter of nominal wage growth to productivity

ρ_{4j} Sensitivity parameter of nominal wage growth to the terms of trade

ρ_{5j} Sensitivity parameter of nominal wage growth to the unemployment level

ρ_{6j} Sensitivity parameter of nominal wage growth to the unemployment variation

ρ_{7j} Sensitivity parameter of nominal wage growth to labor market evolution in sector j

κ_t Labor participation ratio

ψ_1 Constant in labor participation equation

ψ_2 Flexion effect parameter

τ Growth rate of technical progress

ν Growth rate of population

μ Growth rate of real variables

π Growth rate of price index of consumption

χ Growth rate of nominal variables

ω Growth rate of wage

ξ CO_2 emissions coefficient of conversion

Appendix D. The choice of the sectorial disaggregation

Le choix du niveau de désagrégation sectorielle varie fortement d'un modèle à l'autre. Par exemple, les modèles de Shoven et Walley (1992) et Harrison et Rutherford (1997) retiennent respectivement 2 et 117 secteurs productifs. Ce choix dépend des spécificités du modèle (modèle statique versus dynamique ; la nature des politiques à évaluer, avec ou sans coûts d'ajustements, etc.), des objectifs du modélisateur et de la disponibilité des données. Dans la perspective d'un modèle macroéconomique multisectoriel destiné à quantifier les effets des politiques économiques structurelles, le rôle joué par le niveau de désagrégation sectorielle est très important dans la mesure où les prédictions et les enseignements qui en découlent dépendent largement du niveau de décomposition du tissu productif retenu. Des lors, un arbitrage doit être fait entre d'une part, le désir de disposer d'un modèle le plus détaillé possible afin de gagner en réalisme, et d'autre part, la lourdeur de construction et de chiffrage d'un gros modèle. Face à ce dilemme, Schubert (1993) propose d'adopter une stratégie de désagrégation permettant de mettre en avant les branches d'activités qui rentrent en jeu dans les questions auxquelles le modélisateur tente de répondre.

Il parait donc primordial de définir d'une manière claire les critères de la désagrégation sectorielle. Ces derniers doivent permettre d'identifier les canaux de transmission d'une politique économique sur les différentes grandeurs macroéconomiques afin d'identifier les perdants et les gagnants d'une telle politique. Etant donné que notre modèle a pour objectif d'étudier les effets de la fiscalité environnementale sur la consommation de combustibles fossiles, la croissance et l'emploi, quatre critères ont été privilégiés dans le choix de la désagrégation :

L'intensité énergétique *relative* du secteur : ce critère permet de distinguer les secteurs selon le poids de leur consommation énergétique dans le niveau total et selon leur participation aux émissions de $CO2$[23].

La possibilité de bénéficier d'une exonération de taxe : dans un cadre d'analyse des répercussions de la mise en place d'une taxe carbone, il s'avère important d'identifier les secteurs qui sont susceptibles de bénéficier d'une exonération fiscale totale ou partielle, afin de pouvoir estimer les différents scénarios possibles. Ces secteurs seront désignés selon les

[23] Dans notre analyse, nous ne retenons que les émissions de $CO2$ d'origine anthropique.

critères prévus par les directives européennes sur l'énergie. *A priori*, il s'agit de la branche « énergie », des secteurs industriels qui consomment des combustibles à double usage (comme la sidérurgie et la chimie), des secteurs de production de biens minéraux non métalliques, ainsi que les secteurs soumis au Système Européen d'Echange de Quotas de CO2 (SEEQ).

Le degré d'ouverture à la concurrence internationale : ce critère permet d'estimer les effets d'une nouvelle contrainte environnementale sur la compétitivité des secteurs. Il est d'autant plus important que la politique environnementale est mise en œuvre par le pays de manière unilatérale. Ainsi, Farmer et Steininger (1999) justifient le choix de ce critère de désagrégation en faisant valoir que les trois secteurs les plus pollueurs en Autriche sont ceux qui sont les plus exposés à la concurrence internationale.

L'homogénéité du secteur : C'est un critère primordial à respecter pour toute décomposition des activités économiques. Il est nécessaire de regrouper au sein d'un même secteur les activités productives qui ont des comportements énergétiques et un niveau d'émission de CO2 semblables. Un tel regroupement présente l'avantage de réduire la taille du modèle tout en préservant son pouvoir explicatif. Ce critère assure la cohérence globale de la structure de production dans le modèle, en distinguant les principaux grands secteurs de la comptabilité nationale. Outre les secteurs et sous secteurs énergivores et ceux bénéficiant d'une exonération fiscale, nous allons aussi distinguer l'agriculture des autres secteurs industriels (hors ceux retenus selon les deux premiers critères cités plus haut), le Bâtiment et Travaux Publics (BTP), les transports et les services. Ce critère conduit à désagréger le secteur des transports entre le transport routier, ferroviaire, aérien et maritime. S'agissant des services, la différence sera faite entre les services publics et privés.

Sur la base de ces quatre critères, nous avons procédé à une décomposition en groupes et sous-groupes de secteurs permettant d'éviter toute juxtaposition entre un secteur dont le comportement aura une grande incidence sur les résultats, et ceux qui auront un rôle marginal. Pour cela, la stratégie suivie consiste à scinder d'abord l'ensemble des secteurs en sous-groupes en fonction de leurs intensités énergétiques et de leurs niveaux d'émissions de CO2 respectives, tout en isolant les secteurs susceptibles de bénéficier d'une exonération. Par la suite, le troisième et le quatrième critère seront introduits afin d'évaluer la pertinence de la désagrégation obtenue sur la base des deux premiers critères.

Les première et deuxième parties justifient la désagrégation retenue dans l'industrie manufacturière et le secteur énergétique. La troisième décrit les bases de données utilisées, tandis que la quatrième conclut et résume la désagrégation finalement retenue et expose ses limites.

Industrie manufacturière

Pour l'année 2005, les émissions de CO2 provenant des secteurs de l'industrie manufacturière (hors production d'énergie) représentent environ 22% des émissions hors puit de l'ensemble des secteurs productifs en France. Tandis que sa part dans la consommation énergétique finale[24] est d'environ 39%. Cet écart entre le poids de l'industrie manufacturière dans la consommation énergétique totale et les émissions de CO2 est dû au fait que les émissions liées à la consommation d'électricité sont imputées à la branche productrice de cette énergie, afin d'éviter le double enregistrement de ces flux. Du coup l'utilisation de l'électricité dans toute branche d'activité, hors la branche qui la produit, ne peut être considérée comme source d'émissions[25].

Sachant que la répartition de la consommation énergétique finale et des émissions de CO2, entre les différents secteurs, sous-secteurs et branches d'activités composants l'industrie manufacturière, est très hétérogène, il est nécessaire de les ventiler au sein de catégories homogènes distinctes, afin d'évaluer de manière pertinente les effets sectoriels d'une nouvelle contrainte environnementale.

Pour cela, nous avons repris le niveau 5 de la Nomenclature d'Activités Françaises (NAF) contenant 712 postes dont 345 relevant de l'industrie manufacturière afin de faire correspondre à chaque poste la consommation énergétique par type de combustible qui lui revient. Ensuite, nous avons estimé leurs émissions de CO2 en appliquant à chaque combustible un coefficient d'émission propre, commun à tous les secteurs et sous-secteurs. Les sous-secteurs de l'industrie manufacturière du modèle qui sont les plus énergivores et/ ou qui sont les plus émetteurs sont clairement identifiés.

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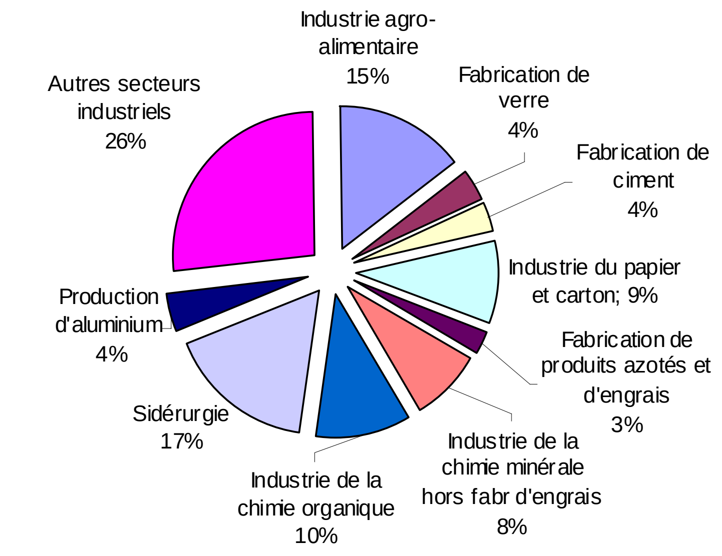
[24] Il s'agit de la consommation totale d'énergie diminuée de la consommation primaire du secteur « énergie ».

[25] Ce qui est d'ailleurs ordonné par le Système National d'Inventaires des Emissions de Polluants Atmosphériques (SNIEPA) qui prévoit que les émissions polluantes ne sont calculées que pour les secteurs qui les produisent.

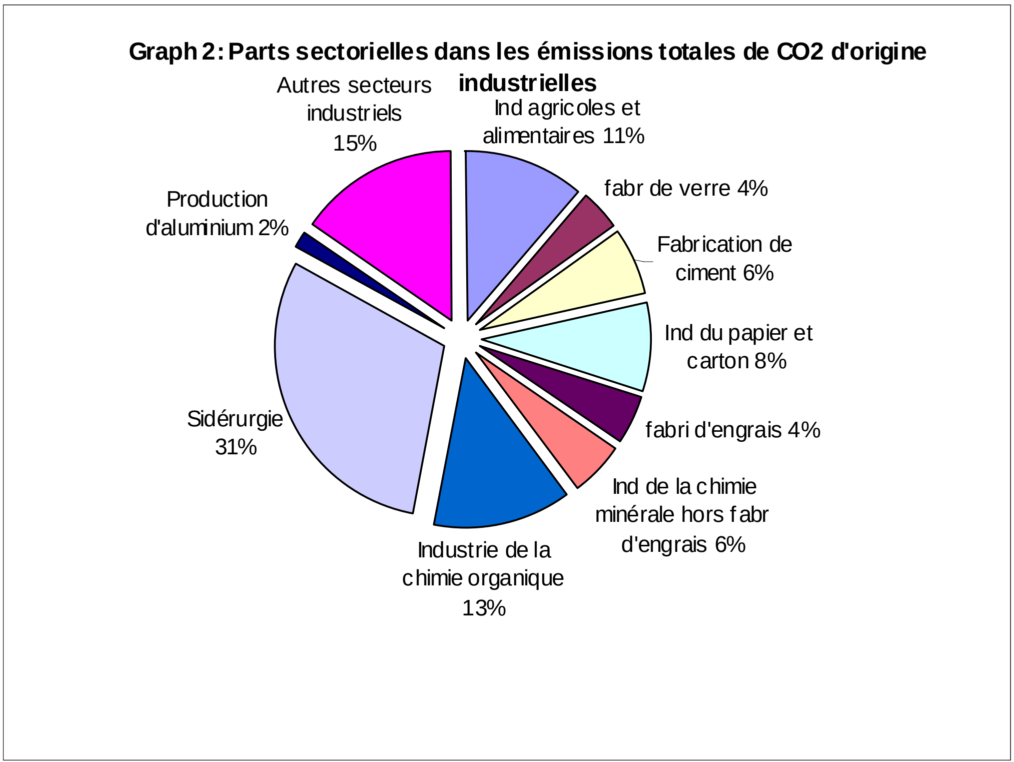
A la fin de cette procédure, les secteurs et sous-secteurs de l'industrie manufacturière ont été segmentés de la manière suivante : Industrie agro-alimentaire, Fabrication de verre, Fabrication de ciment, Industrie du papier et carton, Fabrication de produits azotés et d'engrais, Industrie de la chimie minérale hors fabrication d'engrais, Industrie de la chimie organique, Sidérurgie et Production d'aluminium, Autres industries.

La plupart des secteurs et sous-secteurs identifiés se caractérisent par de fortes intensités à la fois énergétique et carbone. Toutefois, elles ne sont pas toujours proportionnelles ; par exemple, la participation de la sidérurgie aux émissions totales de l'industrie manufacturière s'élève à 31% tandis que sa consommation énergétique dans la consommation totale ne dépasse pas 17%, (cela s'explique par la nature de son mix-énergétique : il s'agit principalement de la consommation de houille et du coke de houille, intensive en carbone, qui est responsable de ce taux élevé dans ce sous-secteur). Contrairement à la sidérurgie, l'industrie agro-alimentaire a une part d'émissions (11%) inférieure à sa part de consommation d'énergie (15%), car elle utilise beaucoup d'électricité. Les graphiques 1 et 2 présentent respectivement les parts dans la consommation énergétique totale et les émissions de CO_2 des catégories de secteurs et sous-secteurs retenues dans le modèle, selon la nature de leur intensité énergétique et de leur mix-énergétique.

Graph 1: Parts sectorielles dans la consommation énergétique industrielle



Les caractéristiques de l'offre des produits et de la demande des facteurs de production dépendront donc des comportements des dix segments de secteurs et sous-secteurs qu'on a choisi jusqu'à maintenant. Ils doivent avoir une intensité énergétique et des émissions relativement homogènes, afin de pouvoir capter un maximum de réactions sectorielles pour simuler de manière réaliste leurs répercussions sur les indicateurs macroéconomiques. Pour vérifier la pertinence de notre choix, l'intensité carbone de chaque secteur et sous-secteur a été comparée à celle de l'ensemble des autres composantes de l'industrie manufacturière regroupées dans le poste « autres secteurs industriels ».



Le tableau 1 montre que tous les secteurs et sous-secteurs retenus présentent bien une structure homogène en ce qui concerne la quantité d'émissions en tonnes de CO2 par unité d'énergie consommée. En effet, leur intensité carbone dépasse largement celle des « autres secteurs industriels ». A ce niveau, une désagrégation basée sur un tel critère mène à séparer les industries fortement sensibles à une politique environnementale de celles qui le sont moins.

Un examen du ratio des émissions de chaque industrie manufacturière sur leur production en volume (colonne 5 du tableau 1), confirme le choix de la segmentation retenue. Ce rapport illustre les caractéristiques environnementales de la technologie de production utilisée dans chacune de ces industries. Il reflète aussi le degré de contraste chez les industriels entre leur participation au bien être social par le biais de la production et les externalités négatives qu'ils font subir aux citoyens en émettant du dioxyde de carbone. Ainsi, ce ratio donne une idée de ce qu'on peut appeler l'« efficacité environnementale » d'un processus de production.

Le poste « Autres secteurs industriels » a un indicateur d' « efficacité environnementale » de 0.02, qui est le plus faible de l'ensemble des catégories de secteurs et sous-secteurs retenues. Ce qui veut dire que pour une participation de ce groupe de secteurs et branches d'activités de 1000 euros à la production nationale, les émissions de CO2 qui en découlent ne sont que de 0.02 tep. Pour les autres postes du tableau 1, cet indice reste largement supérieur de celui des « autres secteurs industriels ». Le modèle distingue donc bien d'un côté le poste des « autres industries manufacturières », qui sera relativement peu impacté par la politique environnementale et de l'autre, le reste des secteurs et sous-secteurs énergivores et émetteurs, listés dans le tableau 1, dont le comportement aura un effet déterminant sur la dynamique macroéconomique du modèle.

Tableau 12 L'intensité carbone dans l'industrie manufacturière en France (en 2005)

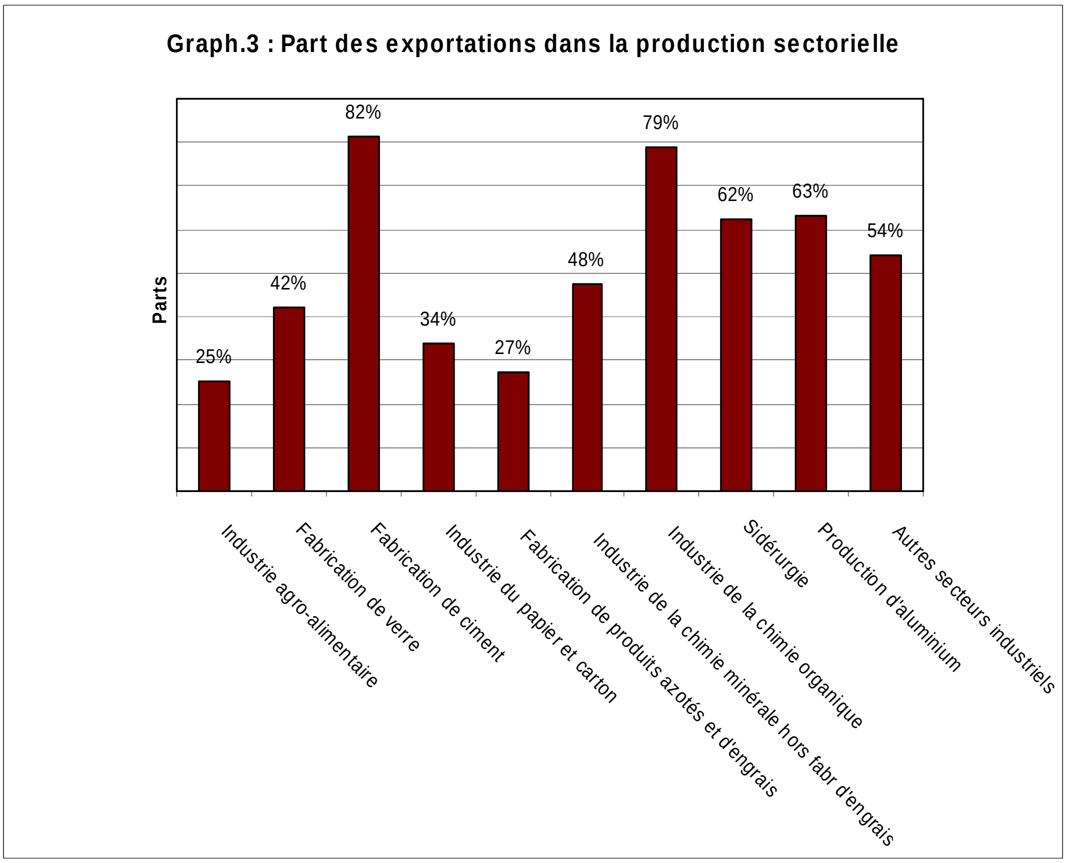
Secteurs retenus selon NES	Conso.énerg. Hors éléct (en tep) (a)	Emissions en t de co2 (b)	Intensité carbone (b)/(a)	Emissions / Production (en milliers d'euros)
Industrie agro-alimentaire	3 362 349,42	9 154 565,48	2,72	0,08
Fabrication de verre	1 117 948.00	3 046 568,88	2,72	0,48
Fabrication de ciment	1 332 730.00	5 071 750,06	3,80	1,86
Industrie du papier et carton	2 049 403.00	6 591 251,37	3,22	0,35
Fabrication de produits azotés et d'engrais	1 452 145.00	3 488 804,46	2,40	1,77
Industrie de la chimie minérale hors fabrication d'engrais	1 457 580,99	4 381 960,31	3,01	1,09
Industrie de la chimie organique	3 821 954,00	10 244 119,48	2,68	0,48
Sidérurgie	6 281 176.00	24 068 084,12	3,83	1,07
Production d'aluminium	416 708,00	1 259 591,61	3,02	0,29
Autres secteurs industriels	6 607 529,35	12 308 289,43	1,86	0,02
Total	**25 898 946,92**	**79 614 985,16**	**3,07**	**0,11**

S

ource: Calculs de l'auteur

Sachant qu'en économie ouverte, une modification de la compétitivité relative a une forte incidence sur les équilibres macroéconomiques ; sachant que l'économie française est très ouverte sur l'Europe et que la politique fiscale environnementale ne sera pas sans effet sur la compétitivité des entreprises françaises ; il est essentiel de discriminer les secteurs en fonction de leur exposition à la concurrence internationale. Leur degré d'ouverture doit donc être considéré comme un troisième critère de désagrégation déterminant. Cette approche est importante puisque les pays industrialisés ne sont pas soumis aux mêmes contraintes de réduction des Gaz à Effet de Serre (GES).

Une mesure de la part des exportations dans la production des segments industriels identifiés dans le modèle, montre qu'une grande partie des retombées d'une taxe environnementale sur la compétitivité des entreprises industrielles sera captée et quantifiée. Le graphique 3 montre que la moitié des groupes de secteurs et sous-secteurs retenus vendent plus de 50% de leur production sur le marché mondial.



En se référant au deuxième critère de désagrégation sectorielle annoncé dans l'introduction, tous les secteurs susceptibles de bénéficier d'une exonération partielle ou totale sur leurs émissions polluantes apparaissent déjà dans les segments distingués sur la base du critère de l'intensité énergétique et carbone, à l'exception des secteurs de « Fabrication des produits céramiques et de métaux de construction hors le ciment », de « Transformation des matières plastiques » et de « Production de plomb et de zinc ». Ce dernier ne sera pas désagrégé des « autres industries », puisque sa contribution aux émissions totales de CO2 est quasi nulle et que toute nouvelle politique environnementale n'aura vraisemblablement que des effets directs secondaires sur ce secteur.

Les critères de désagrégation sectorielle définis plus haut nous ont permis de réaliser une ventilation en secteurs et sous-secteurs de l'industrie manufacturière française cohérente avec l'objectif de notre exercice de modélisation. Le tableau 2 liste les secteurs et sous-secteurs représentant l'industrie manufacturière du modèle, selon qu'ils peuvent bénéficier ou non d'une exonération.

Tableau 13 L'industrie manufacturière dans le modèle

Secteurs et sous-secteurs du modèle	**Partiellement /totalement exonérés**
Industrie agro-alimentaire	Non
Fabrication de verre	Oui
Fabrication de ciment	Oui
Fabrication de produits céramiques et de métaux de construction hors le ciment	Oui
Industrie du papier et carton	Oui
Fabrication de produits azotés et d'engrais	Oui
Industrie de la chimie minérale hors fabr d'engrais	Oui
Industrie de la chimie organique	Non
Transformation des matières plastiques	Oui
Sidérurgie	Oui
Production d'aluminium	Oui

Outre l'industrie manufacturière, le bloc de production dans le modèle devrait expliciter les comportements d'autres secteurs et tout particulièrement le secteur de l'énergie, des transports et des BTP.

Producteurs et distributeurs de l'énergie

Etant donné que le modèle a pour objectif de répondre à des problématiques environnementales, énergétiques et fiscales, il est primordial de spécifier finement l'offre d'énergie, car il est important de prendre en compte les effets macroéconomiques de la substituabilité entre l'énergie et les autres facteurs de production, mais aussi de la substituabilité des différents produits énergétiques entre eux. Cette distinction est essentielle puisque l'intensité carbone des divers sources d'énergie n'est pas la même et que la consommation d'électricité peut faire l'objet d'une exonération fiscale.

Ainsi, la production d'énergie provient de cinq secteurs (Tableau 3), à l'intensité carbone très variable. La différenciation retenue permet d'étudier de manière satisfaisante les éventuelles substituabilités qui pourraient s'opérer entre les sources d'énergie suite à la variation de prix relatifs causée par une nouvelle taxe environnementale.

Comme le montre le tableau 3, la production et la distribution d'électricité occupent le premier rang dans la consommation énergétique et les émissions qui en découlent. Elles représentent respectivement 57% et 65% des quantités totales d'énergie consommées et des émissions totales ; suivie par le raffinage de pétrole avec des pourcentages de 24% et 17%. La production de combustibles minéraux solides et le secteur d'électricité ont une intensité carbone parmi les plus élevées de la branche, bien supérieure à l'intensité moyenne de toutes les sources d'énergie confondues. Ceci s'explique par l'utilisation dans leur processus de production de gaz hautement émetteurs de CO2. Il s'agit du gaz des hauts fourneaux pour le premier secteur et du gaz sidérurgique pour le deuxième. En revanche, pour une unité d'énergie consommée dans le secteur de production et distribution de gaz naturel, les émissions de CO2 ne sont que de 0.19 tonne. Ce résultat n'est pas étonnant dans la mesure où la production nationale en gaz naturel ne dépasse pas les 2% de la consommation nationale de ce type d'énergie et qu'environ 92% de l'énergie qu'il consomme provient d'électricité dont les émissions ne leurs sont pas imputées.

Tableau 14 Intensité carbone par source d'énergie

Sources d'énergie	Consommation énergétique en tep	émissions de CO2 en tonne	Intensité carbone
Production de combustibles minéraux solides	1 279 280,48	8 856 605,41	6,92
Raffinage de pétrole	6 208 180,75	16 351 680,80	2,63
Production et distribution d'électricité	14 732 552,56	60 601 341,18	4,11
Production et distribution de gaz naturel	537 905,63	101 886,66	0,19
Chauffage urbain	3 206 742,96	8 014 811,91	2,50
Total	**25 964 662,37**	**93 926 325,97**	**3,62**

Source: calcul de l'auteur

Conclusion sur la désagrégation sectorielle

La segmentation retenue permet d'analyser de manière pertinente les effets macroéconomiques des politiques fiscales environnementales. Elle est représentée par l'ensemble des secteurs et sous-secteurs listés dans le Tableau 1 de la section 2.

Il est important de noter que cette décomposition sectorielle présente plusieurs limites. En particulier, elle ne permet pas de répondre à certaines questions importantes pour l'analyse des enjeux de la protection de l'environnement à long terme. Il s'agit principalement des questions liées au progrès technique induit par une taxe environnementale. Dans quelle direction une taxe environnementale peut affecter le changement technologique ? Avec quelles mesures économiques peut-on encourager les industriels à faire plus d'efforts dans l'activité de recherche et développement en faveur de l'environnement ? Il est difficile de répondre à ce genre de questions avec une modélisation de type *top-down* et une structure sectorielle qui ne fait pas apparaître les secteurs innovants en la matière comme l'industrie automobile.

Une deuxième faiblesse provient du fait que la production d'énergie renouvelable n'a pas été isolée des autres secteurs producteurs d'énergie. Par ailleurs, il pourrait se révéler utile d'incorporer d'autres raffinements. Par exemple, le modèle *Mégapestes* de Beaumais (1995) scinde le bloc de production en deux, avec d'un côté des secteurs qualifiés de « verts » et d'un autre des secteurs dits « standards ». Cette différentiation est introduite pour pouvoir modéliser l'offre des produits « verts » dans l'objectif d'analyser le comportement des consommateurs français suite à un changement de prix relatifs en faveur de ces derniers.

Sources de données utilisées lors de la désagrégation

Pour le choix d'un niveau d'agrégation sectorielle compatible avec les objectifs du modèle, nous avons été amenés à construire une base de données contenant la consommation énergétique par type de combustible de l'ensemble des activités productives en France et à en calculer par la suite les émissions de CO2 pour chacune de ces activités.

A ce stade, nous avons gardé le même niveau de détail pour les combustibles considérés que dans l'Enquête Annuelle sur la Consommation d'Energie dans l'Industrie (EACEI)[26]. Quant aux acteurs économiques, nous nous sommes basés sur la présentation la plus fine (niveau 5) des activités économiques en France de la comptabilité (NAF) datant de 2005 et contenant 712 activités productives[27].

Le modèle a été calibré sur la base de l'année 2005. C'est l'année pour laquelle nous disposions des données détaillées les plus récentes, à la fois sur le plan énergétique et macro-économique, au moment où on débutés nos travaux. Le contenu de la base énergétique provient de plusieurs sources différentes, qui sont parfois divergentes. Les regrouper dans un seul cadre cohérent nécessite un travail minutieux de consolidation. Différentes sources ont été utilisées:

Les données sur la consommation d'énergie par type de combustible dans les secteurs producteurs de l'énergie émanent du Centre d'Etudes et recherches économiques sur l'énergie (CEREN), de la base Pégase de l'observatoire de l'énergie et du CITEPA qui lui-même se base, entre autres, pour ses inventaires des émissions polluantes, sur les données de l'observatoire de l'énergie ;

Les données pour les secteurs de l'industrie manufacturière proviennent de l'Enquête annuelle sur la Consommation d'Energie dans l'Industrie (EACEI) menée par le ministère de l'économie, de l'industrie et de l'emploi ;

[26] Il s'agit du gaz naturel, autres gaz, houille, gaz de pétrole liquéfié, lignite coke de houille, coke de pétrole, fioul lourd, fioul domestique, liqueur noire, autres produits pétroliers et de l'électricité.

[27] Une nouvelle version révisée de la NAF est entrée en vigueur le 01 janvier 2008, elle comprend 732 postes.

Pour l'agriculture, les données proviennent du Service Central des Enquêtes et Etudes Statistiques (SCEES) du ministère de tutelle ;

Les données relatives aux secteurs des transports et du tertiaire sont tirées principalement de la base Enerdata du CEREN et du ministère de transport pour le premier secteur.

Appendix E. The structure of the French economy in the model base and calibration values of the elasticities of substitution

Tableau 15 The supply and demand structure in the base year (in %)

Supply					Demand			
Production	**Import**	**Margins**	**Product taxes off subsidies**	**Products**	**Total consumption**	**Total investment**	**Export**	**Stock variation**
82	**13**		**5**	**All sectors**	**77**	**10**	**12**	
2	2	7	-1	Agriculture, forestry and fishing	3		2	51
4	10	22	12	Manufacture of food products and beverages	7		7	-4
3	27	7	6	Manufacture of motor vehicles, trailers and semi-trailers	2	14	10	-1
	23			Manufacture of glass and glass products			1	
1	11	3		Manufacture of ceramic products and building materials	1			3
1	25	2		Manufacture of articles of paper and paperboard	1		1	1
	35	1		Manufacture of inorganic basic chemicals			1	
1	39	1		Manufacture of organic basic chemicals	1		4	
1	23	1		Manufacture of plastics products	1		1	
1	32	1		Manufacture of basic iron and steel and of ferro-alloys	1		3	1
	45	1		Manufacture of non-ferrous metals	1		2	6
13	25	50	17	Other industries	18	18	43	43
7			11	Construction of buildings and Civil engineering	2	45		
	15	-1	-1	Rail transport (Passenger and Freight)				
1			-1	Passenger transport by road				
1	38	-10		Freight transport by road and transport via pipeline			1	
	48	-1		Water transport			2	
1	36			Air transport	1		2	
49	4	-89	33	Business services	43	22	15	6
10				Public services	11			
	83			Mining of coal and lignite				-1
2	34	5	18	Manufacture of refined petroleum products	4		3	-4
1	1		3	Electric power generation, transmission and distribution	2		1	
1	26		1	Manufacture and distribution of gas	1			

Source: INSEE, National Accounts

Tableau 16 Structure of total consumption in the base year (in %)

Products	Total consumption		
	final consumption	Public consumption	intermediate consumption
All sectors	**31**	**15**	**54**
Agriculture, forestry and fishing	3		3
Manufacture of food products and beverages	15		4
Manufacture of motor vehicles, trailers and semi-trailers	2		2
Manufacture of glass and glass products			
Manufacture of ceramic products and building materials			2
Manufacture of articles of paper and paperboard			1
Manufacture of inorganic basic chemicals			1
Manufacture of organic basic chemicals			2
Manufacture of plastics products	1		2
Manufacture of basic iron and steel and of ferro-alloys			2
Manufacture of non-ferrous metals			1
Other industries	18	6	20
Construction of buildings and Civil engineering	1		3
Rail transport (Passenger and Freight)			
Passenger transport by road	1		
Freight transport by road and transport via pipeline			1
Water transport			
Air transport	1		1
Business services	48	19	46
Public services	1	74	
Mining of coal and lignite			
Manufacture of refined petroleum products	4		6
Electric power generation, transmission and distribution	2		2
Manufacture and distribution of gas	1		2

Source: INSEE, National Accounts

Tableau 17 Structure of total investment in the base year (in %)

Products	Total investment		
	Household invest	Sector invest	Public Invest
Repartition by post	**55**	**32**	**13**
Agriculture, forestry and fishing	1		0
Manufacture of food products and beverages			
Manufacture of motor vehicles, trailers and semi-trailers	10	28	4
Manufacture of glass and glass products			
Manufacture of ceramic products and building materials			
Manufacture of articles of paper and paperboard			
Manufacture of inorganic basic chemicals			
Manufacture of organic basic chemicals			
Manufacture of plastics products			
Manufacture of basic iron and steel and of ferro-alloys			
Manufacture of non-ferrous metals			
Other industries	30		11
Construction of buildings and Civil engineering	24	72	72
Rail transport (Passenger and Freight)			
Passenger transport by road			
Freight transport by road and transport via pipeline			
Water transport			
Air transport			
Business services	37		14
Public services			
Mining of coal and lignite			
Manufacture of refined petroleum products			
Electric power generation, transmission and distribution			
Manufacture and distribution of gas			

Source: INSEE, National Accounts

Tableau 18 Structure of intermediate consumption by sector at the base year * (in %)

		Intermediate consumption by sector																							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Agriculture, forestry and fishing	**1**	32	33				2						1	1							1			1	
Manufacture of food products and beverages	**2**	14	30				1		2				1					1	2	4	4				
Manufacture of motor vehicles, trailers and semi-trailers	**3**			34		1										1	2	1	1	1					
Manufacture of glass and glass products	**4**	1	1	1	8	1				1			1												
Manufacture of ceramic products and building materials	**5**			1	12	29	1	1			1		1	14		1	1								
Manufacture of articles of paper and paperboard	**6**		2		5	1	44	1	1	3			2							1	1				
Manufacture of inorganic basic chemicals	**7**	7			5		1	34	6	1	1	1	1												
Manufacture of organic basic chemicals	**8**			1	1	1	5	2	23	47			3										2		
Manufacture of plastics products	**9**	1	3	5	1	1	2	3	2	10		1	3	3						1			1	1	
Manufacture of basic iron and steel and of ferro-alloys	**10**			5		2				1	40		4	2											
Manufacture of non-ferrous metals	**11**			1	3	1		2			4	52	3	1											
Other industries	**12**	20	5	35	18	27	12	18	9	11	26	22	51	24	1	4	3	10	14	9	26			17	
Construction of buildings and Civil engineering	**13**	1			1	1						1	1	23	1	1		2	1	2	7		1	9	1
Rail transport (Passenger and Freight)	**14**														1						1				
Passenger transport by road	**15**															7					2				
Freight transport by road and transport via pipeline	**16**															1	18			1	1				
Water transport	**17**																	21							
Air transport	**18**																		21	1					
Business services	**19**	13	22	17	33	27	23	18	13	22	20	18	27	28	81	55	47	52	38	75	49	77	9	25	7
Public services	**20**				1																				
Mining of coal and lignite	**21**										2											14		3	
Manufacture of refined petroleum products	**22**	9	1	1	2	4	1	2	36	1			1	3	3	25	28	13	22	3	2		85	2	1
Electric power generation, transmission and distribution	**23**	2	1	1	4	2	4	7	2	2	3	3	1		11	3				1	3	9		40	1
Manufacture and distribution of gas	**24**		1		5	2	3	11	4		2	1			1	1					2			2	90

*The sum of each column equals to 100%. The diagonal of the matrix represents the auto-consumption in the sectors.

Source: INSEE, National Accounts

Tableau 19 Structure of margins by sector in the base year (in %)

Sectors	Commercial Margins	Transport Margins	Transport Margins repartition			
			Rail transport	Freight transport	Water transport	Air transport
Agriculture, forestry and fishing	93	7	6	85	9	1
Manufacture of food products and beverages	90	10	2	94	3	1
Manufacture of motor vehicles, trailers and semi-trailers	90	10	11	83	3	3
Manufacture of glass and glass products	52	48	7	84	7	2
Manufacture of ceramic products and building materials	88	12	7	84	7	2
Manufacture of articles of paper and paperboard	77	23	7	84	7	2
Manufacture of inorganic basic chemicals	53	47	7	84	7	2
Manufacture of organic basic chemicals	81	19	7	84	7	2
Manufacture of plastics products	66	34	7	84	7	2
Manufacture of basic iron and steel and of ferro-alloys	73	27	7	84	7	2
Manufacture of non-ferrous metals	84	16	7	84	7	2
Other industries	90	10	7	84	7	2
Construction of buildings and Civil engineering						
Public services						
Mining of coal and lignite	53	47	9	71	19	
Manufacture of refined petroleum products	85	15	9	71	19	
Electric power generation, transmission and distribution						
Manufacture and distribution of gas		100	9	71	19	

Source: Ministry of Transports, Transport Accounts

Tableau 20 Product taxes and subsidies by sectors at the base year (in %)

	Product taxes and subsidies						
	Oil tax	Electricity tax	Natural gas tax	Coal tax	Other products tax	Value add tax	Subsidy
All sectors	**13**	**1**			**24**	**68**	**-6**
Agriculture, forestry and fishing						1	24
Manufacture of food products and beverages					29	8	5
Manufacture of motor vehicles, trailers and semi-trailers					1	8	
Manufacture of glass and glass products							
Manufacture of ceramic products and building materials							
Manufacture of articles of paper and paperboard						1	
Manufacture of inorganic basic chemicals							
Manufacture of organic basic chemicals							
Manufacture of plastics products						1	
Manufacture of basic iron and steel and of ferro-alloys							
Manufacture of non-ferrous metals							
Other industries					5	24	
Construction of buildings and Civil engineering					2	16	1
Rail transport (Passenger and Freight)							15
Passenger transport by road						1	28
Freight transport by road and transport via pipeline							
Water transport							1
Air transport					1		1
Business services					58	29	12
Public services							
Mining of coal and lignite				100			
Manufacture of refined petroleum products	100				1	7	
Electric power generation, transmission and distribution		100			3	2	13
Manufacture and distribution of gas			100			1	

Source: INSEE, Ministry of Finances

Tableau 21 Import shares by sectors in the base year (in %)

Products		Intermediate consumption by sector																								Final consumption	Investment	Export
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24			
Agriculture, forestry and fishing	1	6	7				7		35				7	6				39		16	6			6		37	44	
Manufacture of food products and beverages	2	9	17	23	26	23	11	26	28	24	25	24	18	18	21	16	14	13	19	20	18		24	25	20	20		
Manufacture of motor vehicles, trailers and semi-trailers	3	48	49	49	48	49	49	49	49	49	48	49	82	49	49	49	49	50	49	48	39		48	48	49	52	53	
Manufacture of glass and glass products	4	36	36	36	36	36	36	36	36	36	36	36	36	36	36	0	36	36	36	31	60					25		7
Manufacture of ceramic products and building materials	5	16	16	16	16	16	16	16	16	16	16	16	17	16	16	16	16	16		15	16		16	16		36	13	4
Manufacture of articles of paper and paperboard	6	21	31	43	38	40	45	38	39	25		37	37	37		42	48	47	21	38	20		40	44	49	33		
Manufacture of inorganic basic chemicals	7	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	48	93		51		51	50		
Manufacture of organic basic chemicals	8		72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	71	79		72	72	72	68		
Manufacture of plastics products	9	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	26	27		27	27	27	66		
Manufacture of basic iron and steel and of ferro-alloys	10	46		46	46	46			46	46	46	46	46	46	46		46	46	46	45			46	46	46			8
Manufacture of non-ferrous metals	11		70	70	70	70	70	70	70	70	70	70	70	70						70			70			68		
Other industries	12	42	28	31	31	25	32	24	39	45	37	55	37	31	34	38	30	16	34	35	30		33	18	28	51	46	10
Construction of buildings and Civil engineering	13																											
Rail transport (Passenger and Freight)	14	13	13	13	13	13	13	13	13	13	13	13	15	13	13	13	13	13	13	12	14		13	13	13	8		
Passenger transport by road	15																		0	0	0							
Freight transport by road and transport via pipeline	16	10	10	10	10	10	10	10	10	10	10	10	30	10	10	10	10		10	10	10		10	10	10	10		
Water transport	17																	12		3	11					28		20
Air transport	18	43	43	43	43	43	43	43	43	43	43	43	18	43	43	43	43	43	43	33	49		43	43	43	37		
Business services	19	4	4	5	5	5	5	5	4	4	5	5	6	5	5	4	4	6	5	4	5	2	6	6	5	1	4	
Public services	20																											
Mining of coal and lignite	21					93	93	93	93		93		93							92	93	93		93	93	93		
Manufacture of refined petroleum products	22	30	30	30	30	30	30	34	34	30			30	30	30	30	30	30	30	30	30		90	30	80	30		7
Electric power generation, transmission and distribution	23																									1		
Manufacture and distribution of gas	24							7	7														86		61			

Source: INSEE

Tableau 22 Weight and composition of Value-Added by sector in the base year (in %)

	Value Added by sector	Value added sectors composition			
		Employemnt cost	Gross operating profit	Production tax	Production subvention
All sectors	**100.00**	**57.95**	**38.81**	**4.67**	**-1.43**
Agriculture, forestry and fishing	2.06	26.73	90.90	4.43	-22.07
Manufacture of food products and beverages	1.78	57.73	35.66	7.36	-0.75
Manufacture of motor vehicles, trailers and semi-trailers	0.82	73.73	19.19	8.00	-0.92
Manufacture of glass and glass products	0.15	70.16	22.61	7.92	-0.69
Manufacture of ceramic products and building materials	0.40	58.42	34.23	7.80	-0.45
Manufacture of articles of paper and paperboard	0.28	71.90	18.77	9.79	-0.46
Manufacture of inorganic basic chemicals	0.05	127.76	-43.88	17.94	-1.82
Manufacture of organic basic chemicals	0.24	45.77	42.19	12.72	-0.67
Manufacture of plastics products	0.46	75.55	17.30	7.71	-0.56
Manufacture of basic iron and steel and of ferro-alloys	0.29	48.01	44.57	7.83	-0.41
Manufacture of non-ferrous metals	0.12	44.96	47.39	8.10	-0.45
Other industries	8.27	69.97	25.02	6.22	-1.21
Construction of buildings and Civil engineering	6.17	54.41	43.19	2.84	-0.44
Rail transport (Passenger and Freight)	0.38	79.44	15.37	6.73	-1.54
Passenger transport by road	0.72	65.72	31.14	6.63	-3.49
Freight transport by road and transport via pipeline	1.12	63.63	32.28	4.62	-0.53
Water transport	0.12	38.91	57.43	4.02	-0.36
Air transport	0.41	73.93	23.37	3.75	-1.06
Business services	56.87	49.07	47.13	4.77	-0.98
Public services	17.66	85.07	13.43	2.68	-1.18
Manufacture of refined petroleum products	0.15	26.69	55.09	19.56	-1.33
Electric power generation, transmission and distribution	1.17	36.65	52.53	11.06	-0.23
Manufacture and distribution of gas	0.31	39.53	54.41	6.50	-0.44

Source: INSEE

Tableau 23 Elasticities of substitutions between production factors

	Values
Substitution elasticities between:	
Capital-Labor	0.3
Capital-Aggregate Energy	0.06
Capital-Intermediate Consumption	0
Labor-Aggregate Energy	0.04
Labor-Intermediate Consumption	0.15
Aggregate Energy-Intermediate Consumption	0.17
Substitution elasticities between intermediate consumptions	0
Substitution elasticities between product investments of sectors	0
Armignton Elasticity	0.6

Source: Own estimates, Reynès and Tamsamani (2010) , Cochard and Blot (2008).

Tableau 24 Elasticities of substitutions between energies

	Substitution elasticities between:					
	Coal-Oil	Oil-Electricity	Coal-Natural Gas	Oil-Electricity	Electricity-Natural Gas	Oil-Natural Gas
Agriculture, forestry and fishing				0.35		2.29
Manufacture of food products and beverages				0.13		0.61
Manufacture of motor vehicles, trailers and semi-trailers				0.14		0.78
Manufacture of glass and glass products				0.13		0.56
Manufacture of ceramic products and building materials	0.68	2.29		0.20		0.87
Manufacture of articles of paper and paperboard	1.95	1.17		0.10		0.50
Manufacture of inorganic basic chemicals	1.39	0.86		0.07		0.29
Manufacture of organic basic chemicals	0.39			1.11		1.16
Manufacture of plastics products				0.08		0.74
Manufacture of basic iron and steel and of ferro-alloys		0.67				0.29
Manufacture of non-ferrous metals						0.21
Other industries	0.80	1.56		0.14		0.80
Construction of buildings and Civil engineering				0.44		2.87
Rail transport (Passenger and Freight)				0.07		0.91
Passenger transport by road				0.63		3.63
Freight transport by road and transport via pipeline						
Water transport						
Air transport						
Business services	0.49	2.60		0.23		1.39
Public services	1.06	1.29		0.11		0.61
Mining of coal and lignite		0.76				
Manufacture of refined petroleum products						
Electric power generation, transmission and distribution		0.33		0.03		0.19
Manufacture and distribution of gas						0.05

Source: Blanc and Callonnec (2009).

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