The ThreeME model

The economic effects of a decrease in GES emissions

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Outline

- Presentation of the ThreeME model
- Main behavioral equations
- Dynamic and long term properties: two short scenarios
- Hybridization and an example of energy transition scenario

Presentation of the ThreeME model

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Presentation of the ThreeME model

- **Multi-sector Macroeconomic Model for the Evaluation of Environmental and Energy policies**
  - Joint design between ADEME and OFCE since 2008
  - Macroeconomic multisectoral model of neo-keynesian inspiration
  - Comparable to models used in quarterly forecasting
    (MESANGE at INSEE and Finance Ministry, NEMESIS at Paris 1)
  - Versions developed for France, Mexico, Indonesia and the Netherlands
  - Model shared with the French energy ministry

- **Detailed sectoral disaggregation in 37 sectors, with a focus on energy (17 sub-sectors)**

- **This allows to analyze the effect of transfers of activities from one sector to another on:**
  - **Employment**, due to different labor intensity
  - **Investment**, due to different capital intensity
  - **Energy consumption**, due to different energy intensity
  - **Trade balance**, due to different propensity to import and export

Why a neo-keynesian model ?

For most walrassian CGEM; it is impossible to disconnect GES emissions and GDP

- Perfect flexibility of prices ensures the balance between supply and demand (static equilibium in all markets) there is no unsold product.

- Saving finance investment (The interest rate flexibility ensures the balance, money is neutral).

- All incomes are spent either for consumption or investment.

- Firms don't have any outlets constraints (JB SAY's law). Therefore, production is maximal. All the available supply factors are used. (capital, energy and labor) Supply determines the demand.

- There is a static equilibrium. GDP is over determined by the quantity of avalaible production factors.

- -from this point of view, a decrease in energy consumption leads to a recession

Carbon tax and dead weight losse

- For a given amount of saving, there is a crowding effect between investments.

- A carbon taxe has a cost (dead losses weight)

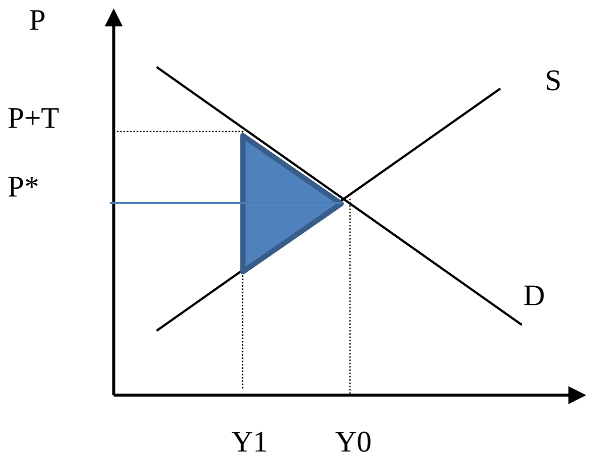
.

The substitution between energy and capital causes an increase in production costs, a decrease in profit, hence, in saving and therefore in global invesment.

The dead weight losse may be offset by :

- The carbon tax receipts recycling for reducing other distortive taxes.

- A decrease in energy imports.



The supply-demand dynamic : a double dividend

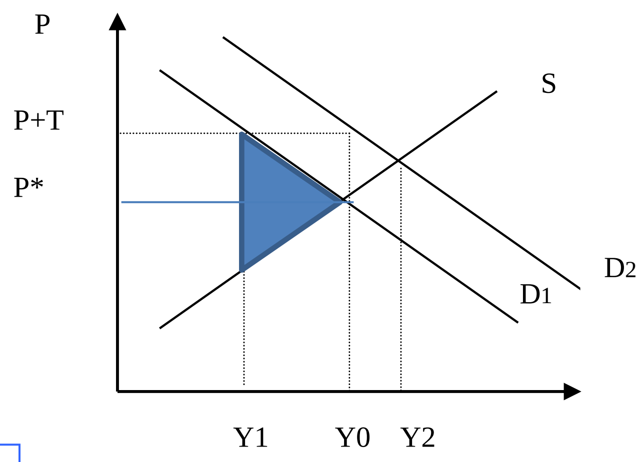
- In an oligopolistic world whith imperfect information, firms maximize their profits by adjusting quantities instead prices.
- Investment is not only financed by saving but loans, i.e money creation
- Interest rate does not balance saving and investment but the demand and supply of money (the crowding effect is limited).
- Credit supply depends on investment rentability, which is a function of demand.
- Since saving doesn't finance investment, it 's a kind of losse. There is an outlet constraint.
- Therefore supply depends on demand
- There are some possible cumulativ desequilibrium.
- Unvoluntary unemployment is possible, so the State intervention is justified.

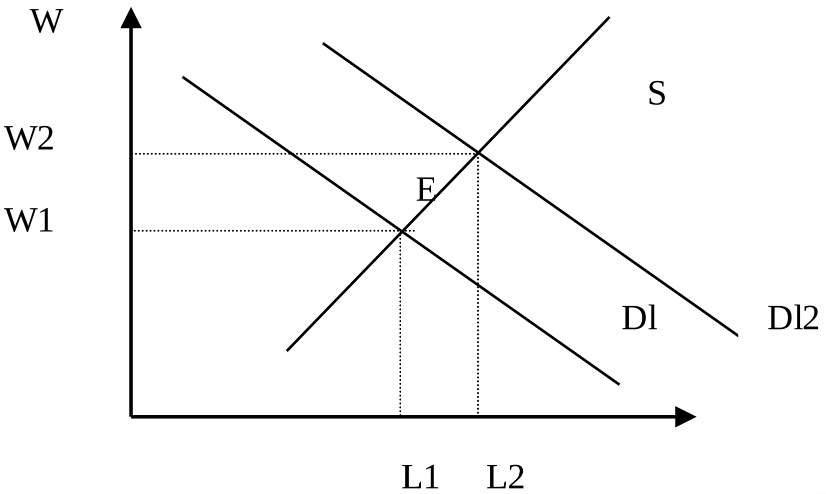
Green growth and employment

An increase in investment, financed by money creation, leads to an increase in economic activity and jobs creation.

The dead weight losse may be offset by :

- A reduction of the labor costs
- A decrease in energy imports.
- An investment growth and a capital stock expansion





ThreeME : A supply and demand Model

- The supply and demand interactions are taken into account.

- Investments are not only financed by saving but also banking loans (the capital amount is not determined)

- The crowding effect is limited.

  Ex : the increase in energy efficiency investments in dwellings doesn't lead to a same decrease in others housholds' spendings. The decrease in consumption is equal to the debt annuities less the energy bill reduction

- Investment (credit supply) depends on anticipated profitability and hence, on the demand level.

- In return, the supply and employment level depend on investment

- Jobs creations retro act on demand (consumption and investment).

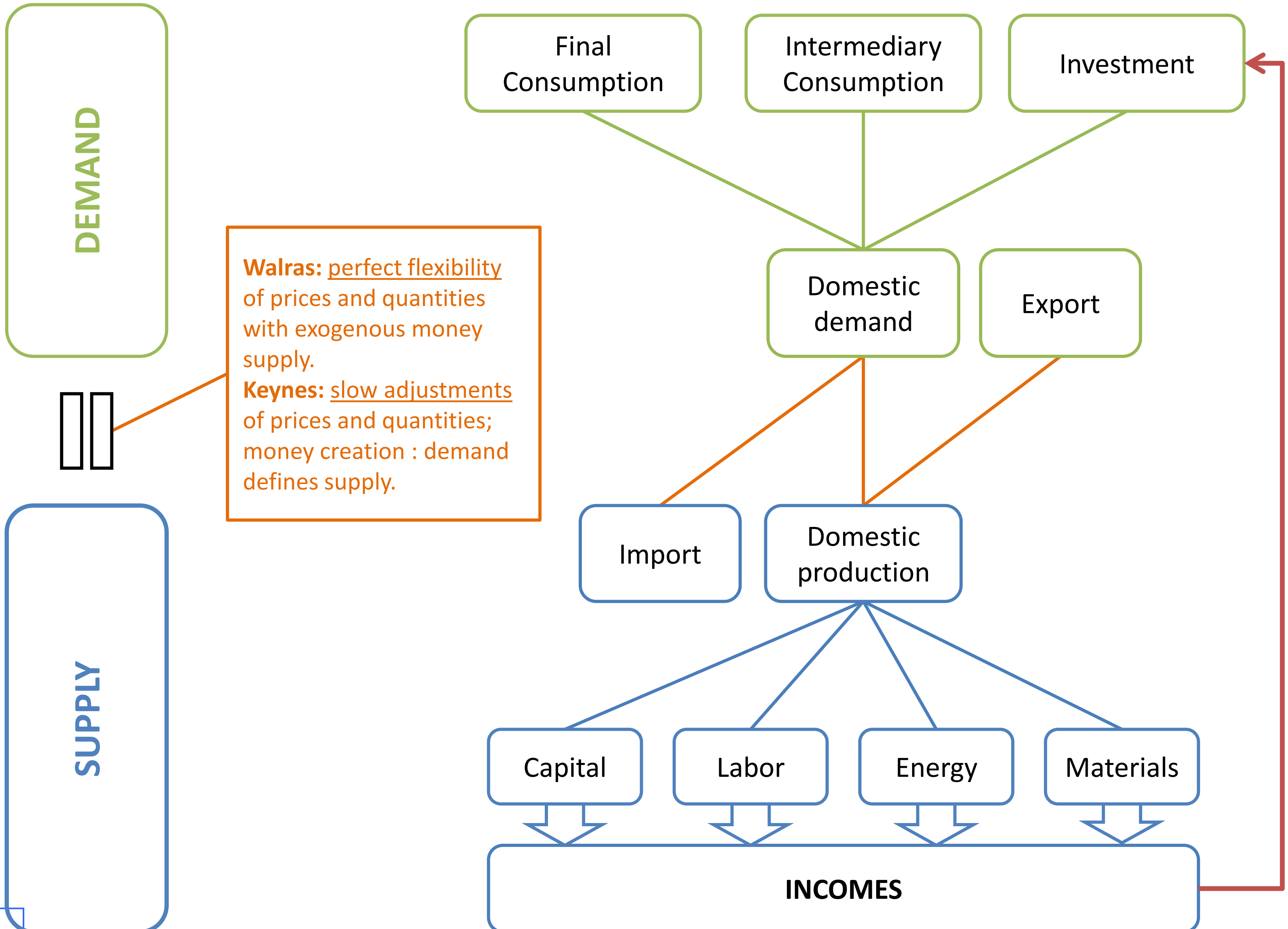
A green growth is possible

- One can show the double dividend existence

  ■Ex : an increase in investment in energy efficiency

  - Leads to a increase in global investment (limited crowding effect)
  - Which generates an growth in employment and consumption (demand is influenced by supply)
  - Which leads in return to an increase in production (supply is boosted by the demand)
  - And a decrease in unvoluntary unemployment

General structure of the ThreeME model



Main behavioral equations

Main features of the ThreeME model

- **Supply-demand model comparable to MESANGE (INSEE, Finance Ministry), but with a multisectoral disaggregation**
  - Prices do not balance supply and demand instantaneously – **it is therefore possible to obtain underemployment equilibria**
  - Firms apply a mark up on unit production costs
  - Wages are driven by price inflation, productivity and unemployment (WS curve)
  - Real interest rates are fixed by a taylor rule
  - Savings and investment depend on demand in addition to interest rates
  - Firms maximize their profits given demand (CES production function)

Markup and producers' margins

- **Notional production prices are determined in a bottom-up fashion**
  - Unit cost is first determined from the individual price of each production factor
  - A markup TM_t is then applied on unit costs

$$PY_t^n = CU_t(1 + TM_t)$$

- **The variation of notional markup TM_t^n is determined by the variation in production**

$$\Delta\ln(1 + TM_t^n) = \sigma^{TM}(\Delta\ln(Y_t) - \Delta\ln(Y_{t-1}))$$

- **An adjustment is then applied on the markup**

$$TM_t = \lambda^{TM}\ TM_t^n + (1 - \lambda^{TM})\, TM_{t-1}$$

Wage equation and Taylor rule

- *Wage equation*: ThreeME uses a flexible specification, that can be parametrized as either a Wage-Setting or a Phillips curve:

$$\Delta ln(W_t^n) = \rho_1^W + \rho_2^W \Delta ln(P_t^e) + \rho_3^W \Delta ln(PROG\_L_t) - \rho_4^W U_t - \rho_5^W \Delta U_t$$

- $\rho_4^W > 0$ **corresponds to a Phillips curve**
- $\rho_4^W = 0$ **corresponds to a Wage-Setting curve**

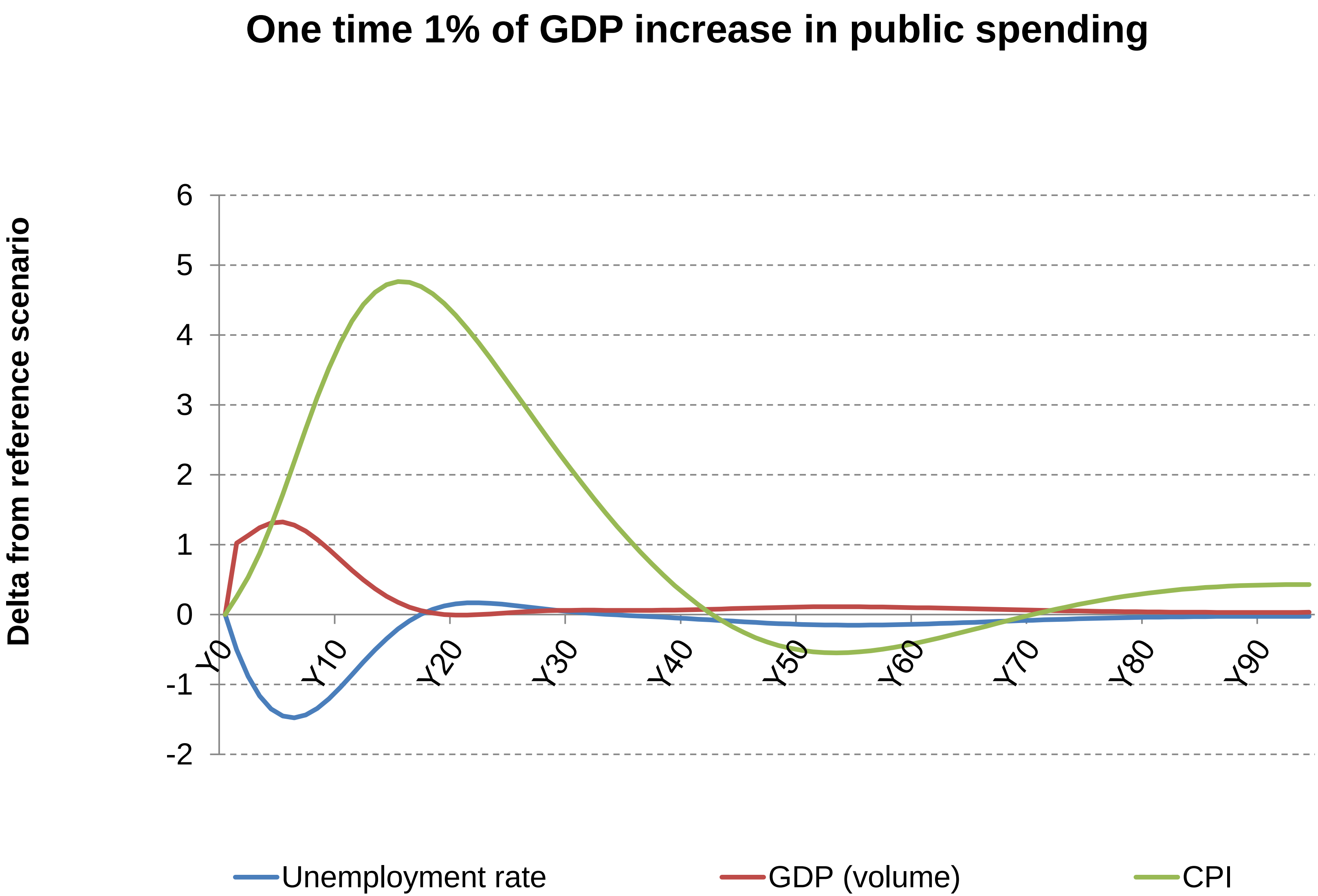
- ***Interest rate is determined by a Taylor rule*:**
  - It is fixed by the Central bank. It depends on inflation and variation of unemployment

$$R_t^n = \rho_1^R + \rho_2^R \Delta ln(P_t^e) - \rho_3^W \Delta U_t$$

- **Interest rate is not determined by the balance between savings and investment.**
  - Investment is not only financed by saving but also by bank's credit
  - Investments and credit supply depend on their profitability, and therefore on the demand
- **There is some money creation. The capital amount is endogenous**
- **The eviction effect is limited.**

Dynamic and long term properties

One-time increase in public investment by 1% of GDP



One-time increase in public investment by 1% of GDP

		ThreeME (WS)				
		Year 1	Year 3	Year 5	Year 10	Year 35
GDP (volume)	(a)	1.02	1.24	1.32	0.79	0.06
Household consumption	(a)	0.09	0.66	1.06	0.96	0.33
Investment	(a)	8.25	8.68	8.74	7.61	1.48
Balance of trade	(c)	-0.21	-0.31	-0.35	-0.33	-0.19
Employment	(d)	127	275	324	206	5
Unemployment rate	(b)	-0.50	-1.16	-1.45	-1.04	-0.01
CPI	(a)	0.26	0.88	1.72	3.89	1.08
Real wage	(a)	0.05	0.69	1.30	1.65	0.14
Real labor costs	(a)	0.03	0.61	1.14	1.29	0.01
Primary balance	(c)	-0.87	-0.46	-0.31	-0.36	-0.07

Note: (a) Delta from reference scenario (in % of reference scenario)
(b) in percentage points, (c) in % of GDP, (d) in thousands.

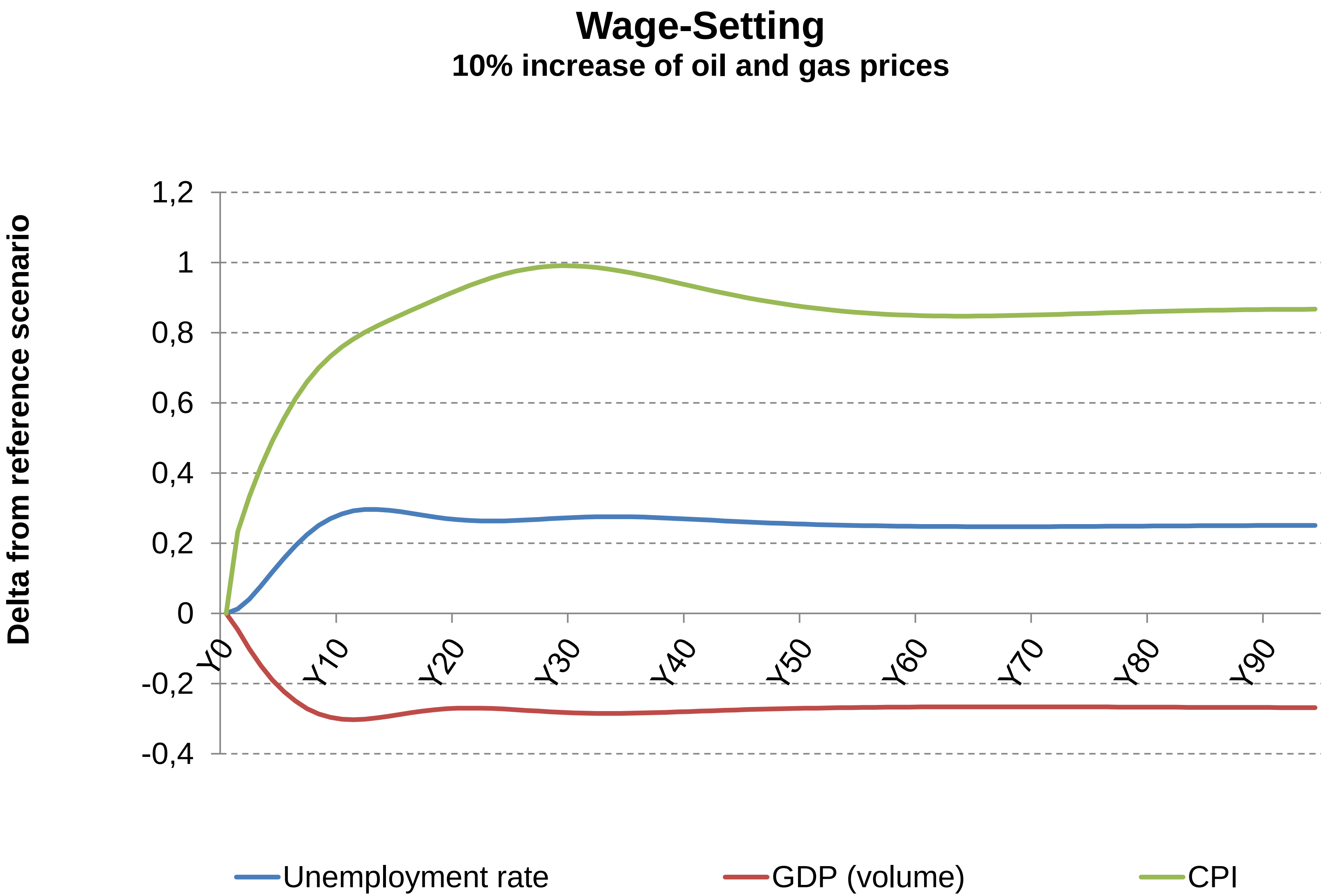
Permanent 10% increase of oil and gas prices: comparison with MESANGE

		ThreeME (WS)			MESANGE		
		Year 1	Year 3	Year 5	Year 1	Year 3	Year 5
GDP (volume)	(a)	-0.04	-0.11	-0.15	-0.02	-0.13	-0.20
Household consumption	(a)	-0.10	-0.26	-0.34	-0.05	-0.20	-0.30
Investment	(a)	-0.01	-0.05	-0.08	-0.04	-0.17	-0.25
Balance of trade	(c)	-0.22	-0.16	-0.14	-0.20	-0.26	-0.27
Employment	(d)	-3	-14	-24	-2	-27	-43
Unemployment rate	(b)	0.01	0.06	0.10	0.01	0.11	0.18
CPI	(a)	0.17	0.23	0.27	0.15	0.39	0.48
Real wage	(a)	-0.24	-0.33	-0.37	-0.08	-0.16	-0.27
Real labor costs	(a)	-0.14	-0.23	-0.28	0.07	0.15	0.07
Primary balance	(c)	-0.04	-0.11	-0.14	-0.02	-0.11	-0.16

Permanent 10% increase of oil and gas prices: comparison with MESANGE

		ThreeME (WS)		MESANGE	
		Year 10	Year 35	Year 10	Year 35
GDP (volume)	(a)	-0.17	-0.16	-0.20	-0.17
Household consumption	(a)	-0.37	-0.30	-0.31	-0.33
Investment	(a)	-0.11	-0.04	-0.19	-0.20
Balance of trade	(c)	-0.13	-0.16	-0.30	-0.28
Employment	(d)	-33	-33	-34	-28
Unemployment rate	(b)	0.15	0.13	0.14	0.12
CPI	(a)	0.30	0.42	0.43	0.23
Real wage	(a)	-0.44	-0.39	-0.40	-0.45
Real labor costs	(a)	-0.34	-0.31	-0.08	-0.08
Primary balance	(c)	-0.16	-0.14	-0.15	-0.15

Comparison between Wage-Setting and Phillips curve



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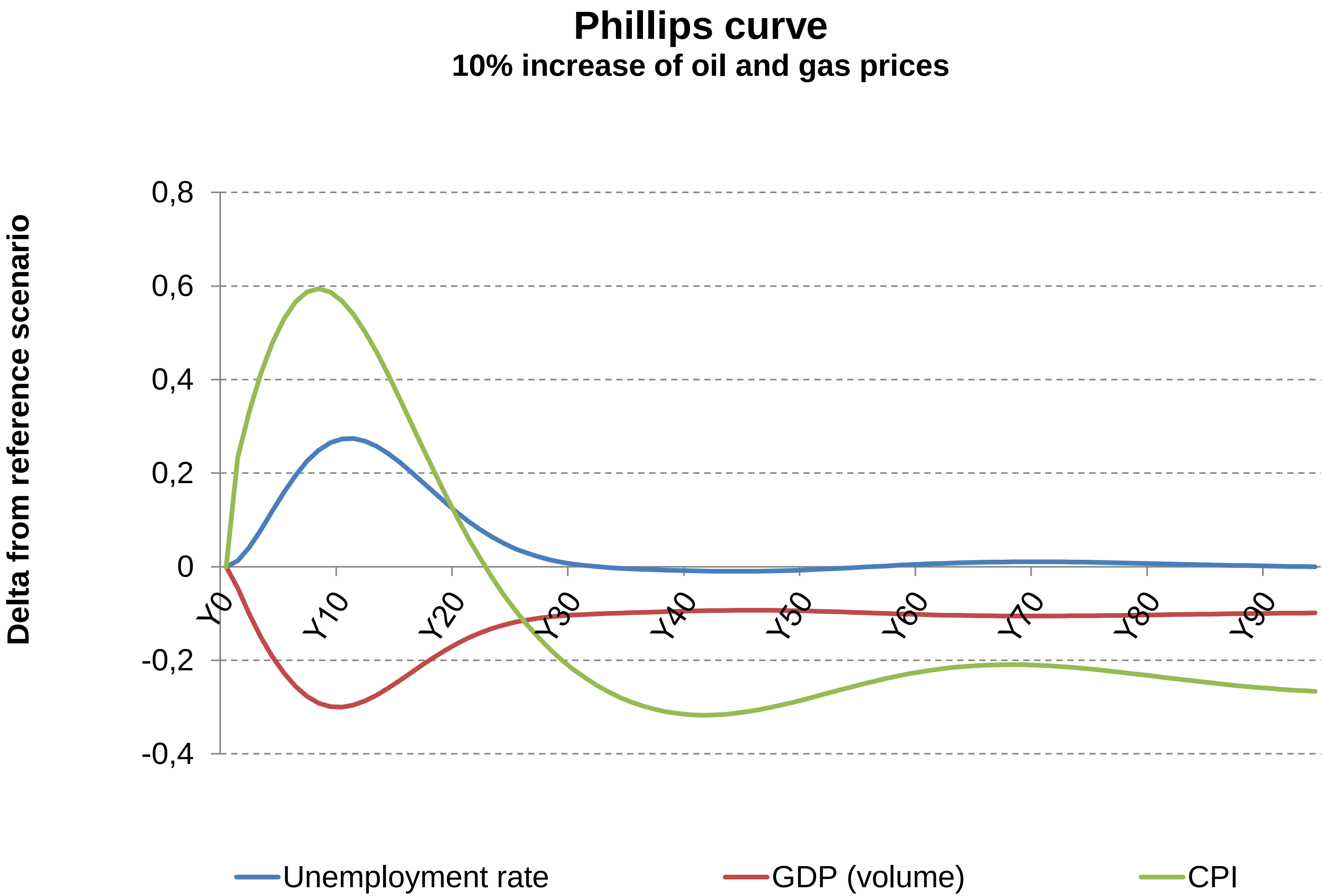
Comparison between Wage-Setting and Phillips curve



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Hybridization and an example scenario

Hybridization

- **For the ThreeME model, we have developed several hybrid modeling for different sectors/uses**

- The flux defines the stock evolution, and the stock determines the energy consumption.
- There is a Hybridization between bottom up ant top down approach.
  - Representation of the housing stock across seven energy classes (A through G)
    - Linked with energy consumption per m^2
  - Representation of the private vehicles' stock across seven energy classes
    - Linked with energy use per km
  - Representation of energy production across several energy technologies (e.g. renewables)
    - Linked with energy production in MWh

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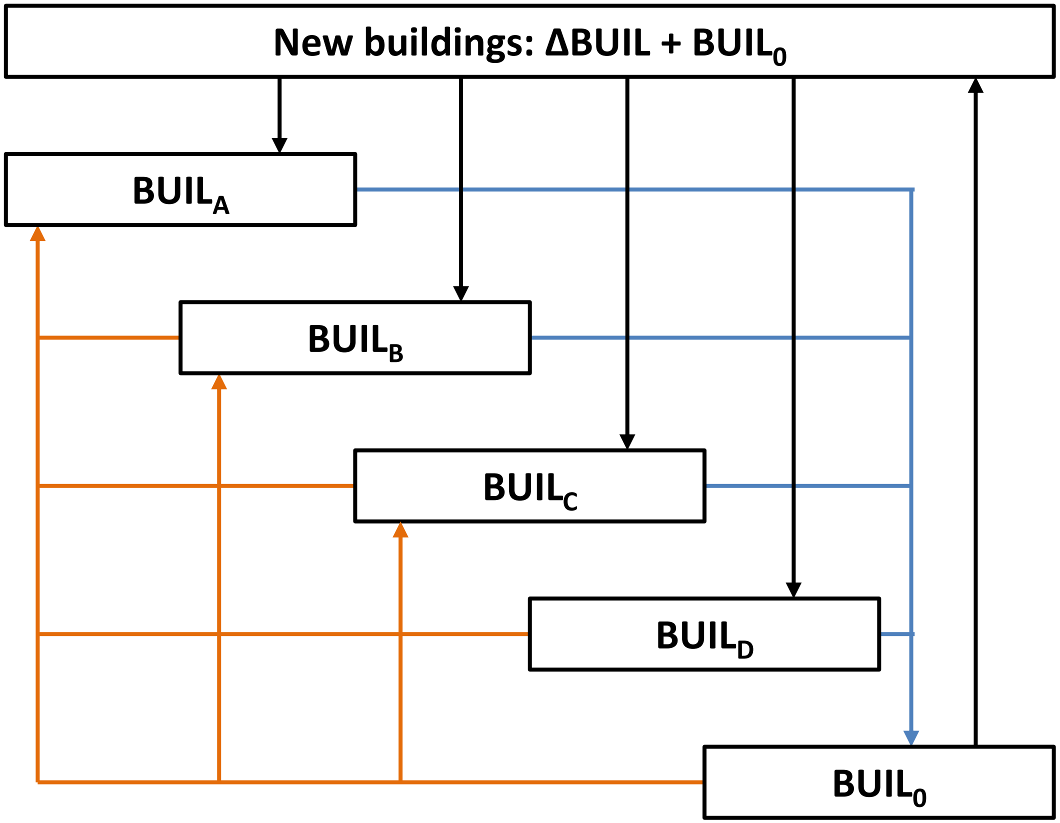
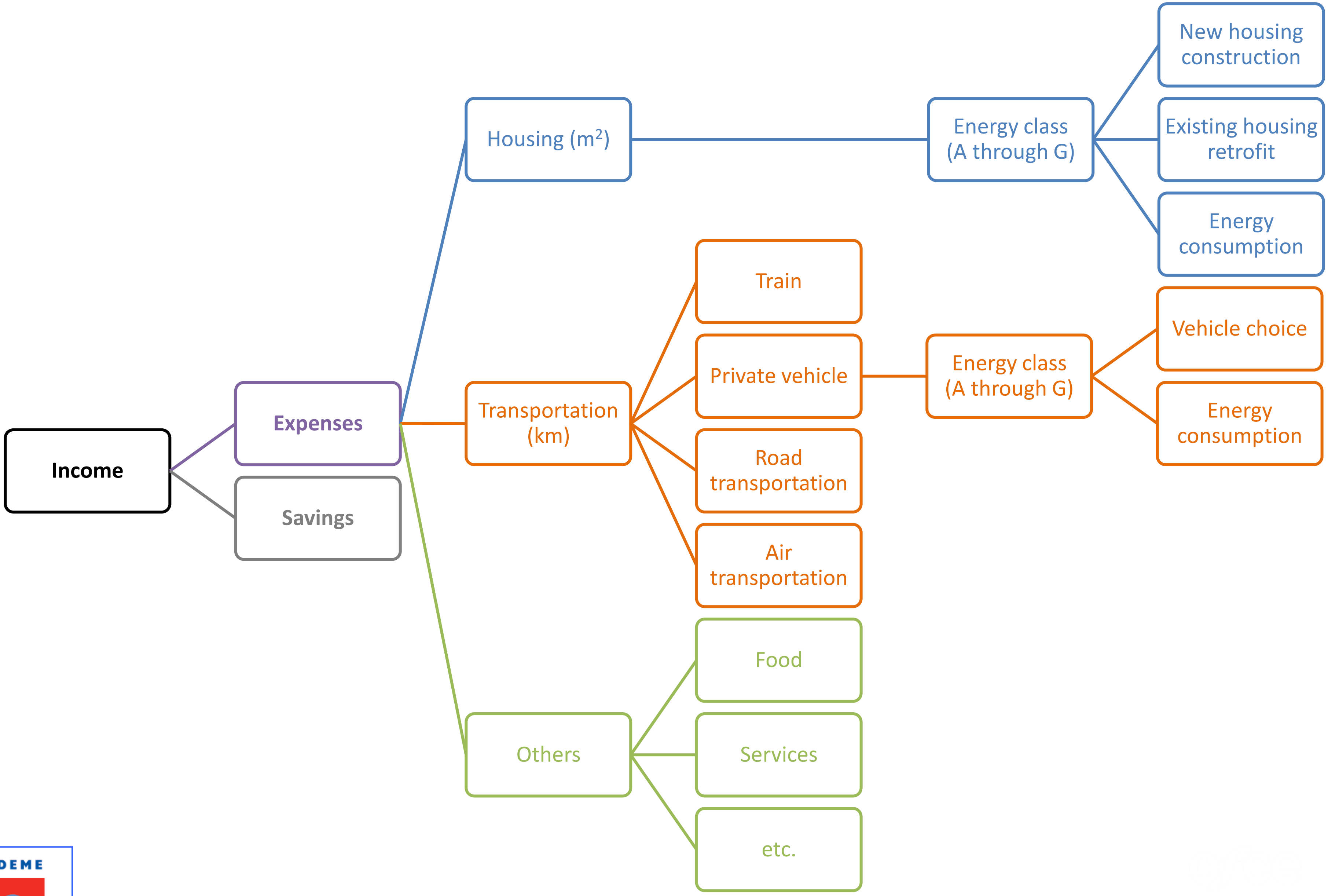
Hybridization: the housing stock example

- **Dynamic of the housing stock**
  - Blue lines represent old building demolition
  - Orange lines represent the energy retrofit of existing buildings



- **Each year, a share of the class *k* is retrofitted**

Integration of bottom-up elements into household consumption expenditures



Agents face several energy-related tradeoffs

- **Firms' investments are impacted by the tradeoff between capital and energy**
  - Substitution when the relative price of energy increases.
  - Substitution between energy sources
  - Endogenous technical progress (Energy Efficiency improves when the relative prices for energies increase).

- **Households choose between energy-intensive and energy-efficient investments**
  - 7 energy performances classes (A through G) for housing and private vehicles
  - Market shares evolve according to the user costs (purchase price net of public subsidies, and energy consumption actualized over the vehicles' lifecycle)
  - Penetration rate of electric vehicles is exogenous

- **Energy prices induce energy sufficiency**
  - Households reduce heating and gasoline expenditures when energy prices increase

Reference scenario assumptions

- **Results are estimated as deviations from a baseline scenario**

- **Features of the reference scenario**
  - The energy mix evolves as provisioned by current law
  - Existing instruments of climate change mitigation are maintained unmodified
  - CIDD, bonus-malus, domestic taxes on consumption, etc.
  - GDP growth stabilizes at 1,6% by 2035
    - Sum of productivity gains (1.2%) and demographic growth (0.4%)
  - Fossil fuel prices follow IEA forecast

- **The reference scenario only serves as a counterfactual. Its stability allows identifying the impacts of the scenario's implementation**

Estimation the macroeconomic impacts of the energy transition

- **Contribution of the French Environmental Agency: *Visions énergétiques 2030-2050***

  - Modeling assumptions

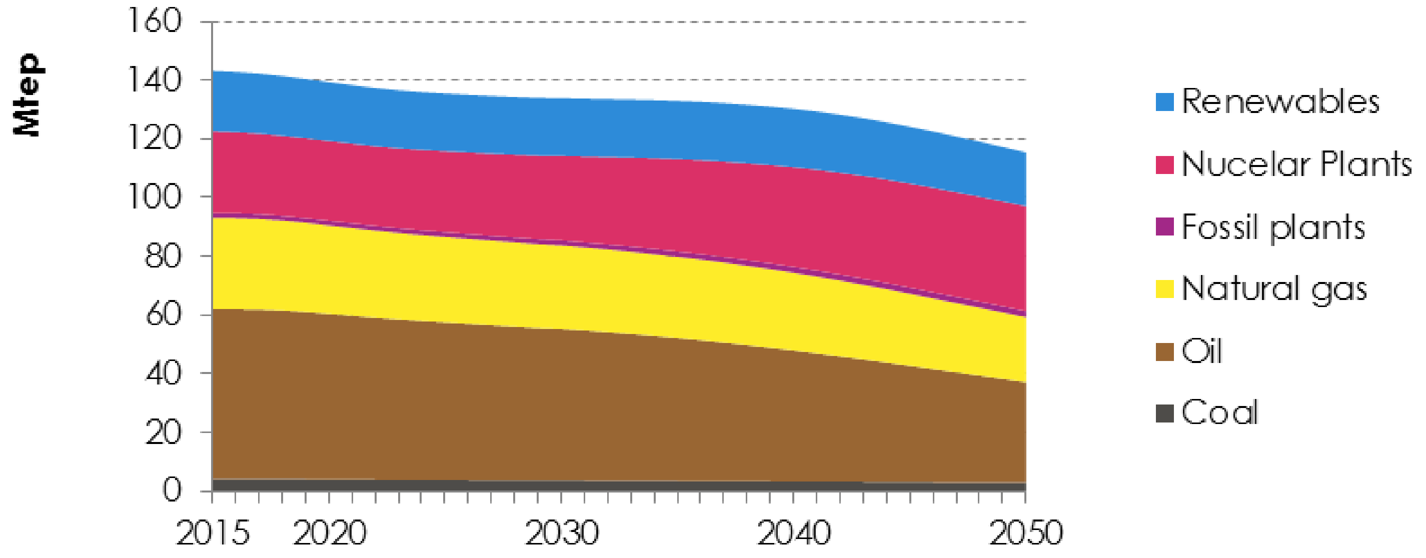
    - 1,6% of growth rate trend
    - Coal and fuel electric plants are closed in 2030
    - Energy demand is reduced by 2 in 2050
    - CO_2 emissions cut by 75% compared with 1990 in 2050

  - Three distinct versions of the scenario, differing by the share of nuclear power in the electric mix by 2050:

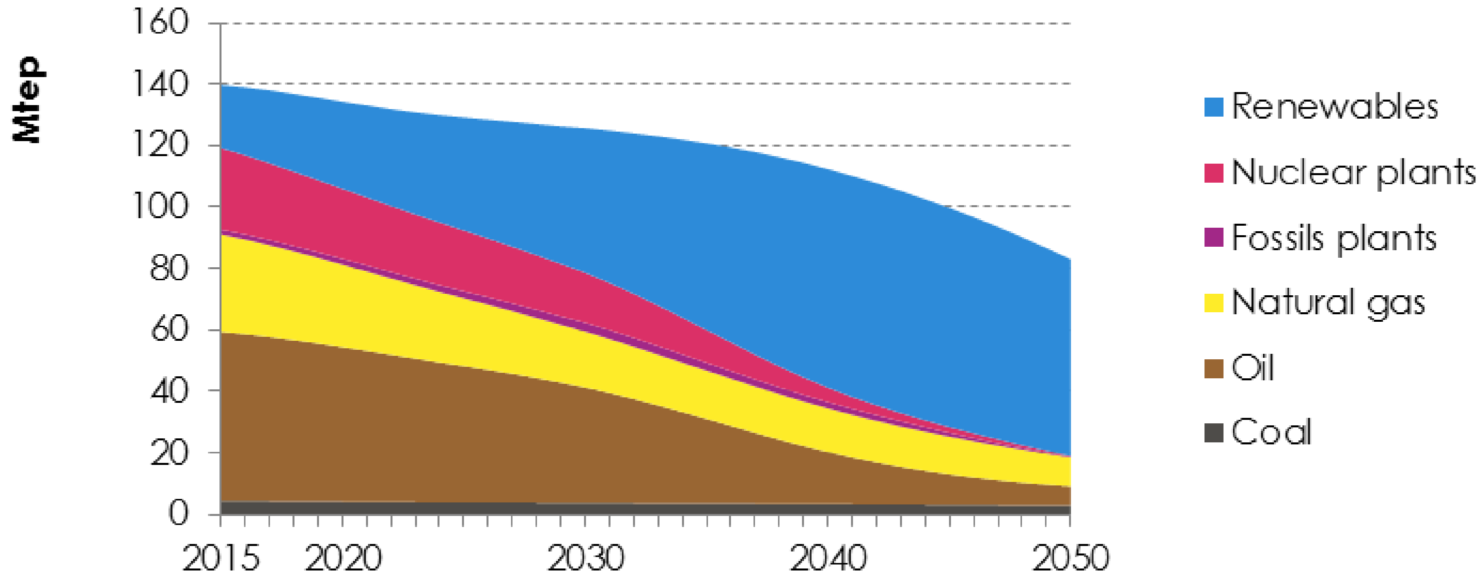
    - *ADEME bas*, aiming for 18% of nuclear electricity by 2050
    - *ADEME médian*, 25% of nuclear electricity by 2050
    - ***ADEME haut*, which assumes a constant 50% share of nuclear electricity from 2030 to 2050**

  - *ADEME haut* is the most coherent with the latest policy choices

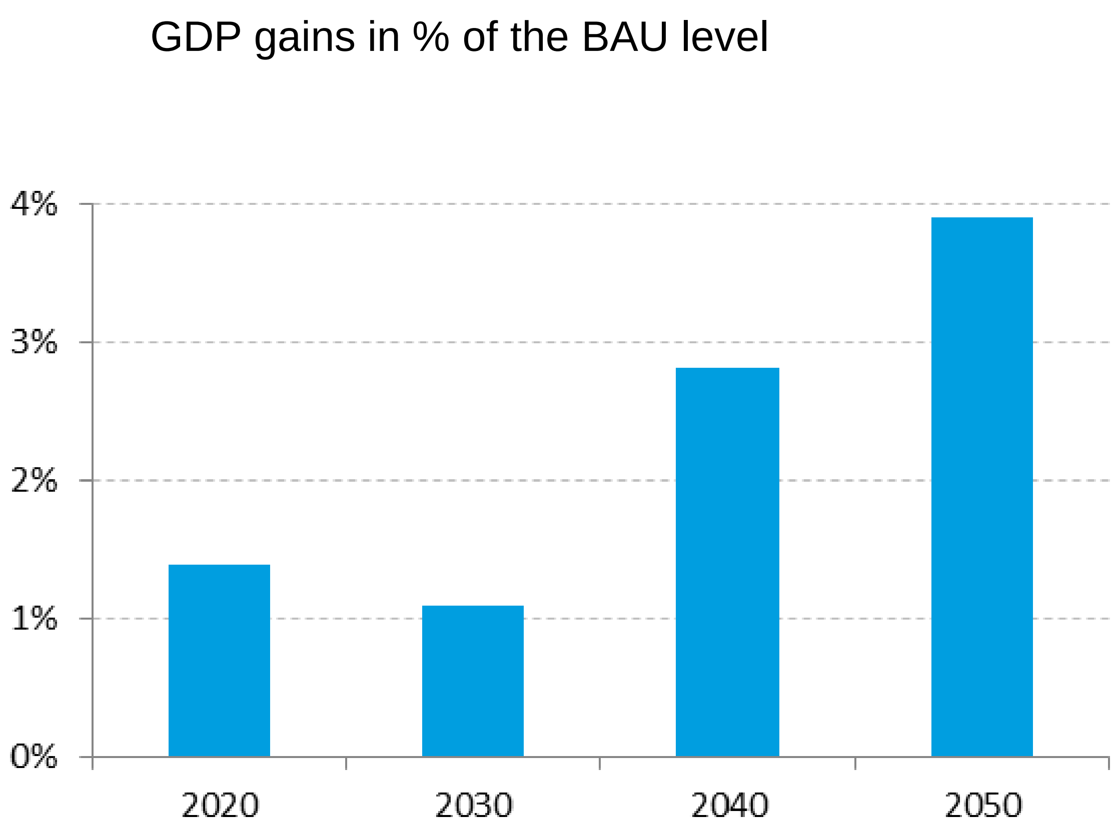
Reference energy mix (2010-2050)



Energy mix after the energy transition (2010-2050)



Macroeconomic impacts of the *ADEME 100% RE Scenario*



Macroeconomic impacts of the *ADEME Scenario*: details

		2020	2030	2040	2050
GDP in volume	(a)	1,40	1,10	2,83	3,91
Consumption	(a)	2,01	1,92	4,29	6,66
Investments	(a)	5,06	6,06	11,52	16,52
Trade balance	(b)	-0,14	0,28	1,62	2,67
Unemployment rate	(c)	-1,38	-0,75	-2,48	-3,61
Employment	(a)	1,25	0,66	2,27	3,23
Real wages	(a)	1,69	1,53	4,25	7,05
Price index	(a)	2,24	5,60	8,46	12,12
Interest rate	(c)	0,00	0,00	0,00	0,00
Public Debt	(d)	-5,19	-10,33	-22,09	-43,66
Public deficit	(d)	-0,59	-0,40	-1,41	-2,97
GDP (2006=100)		120	141	166	196
Emissions	(a)	-7	-22	-43	-58
Emissions (2006=100)		76	60	40	25

(a) gap in % to the BAU scenario, (b) Gap in % to the BAU GDP

(c) in %, (d) in GDP %

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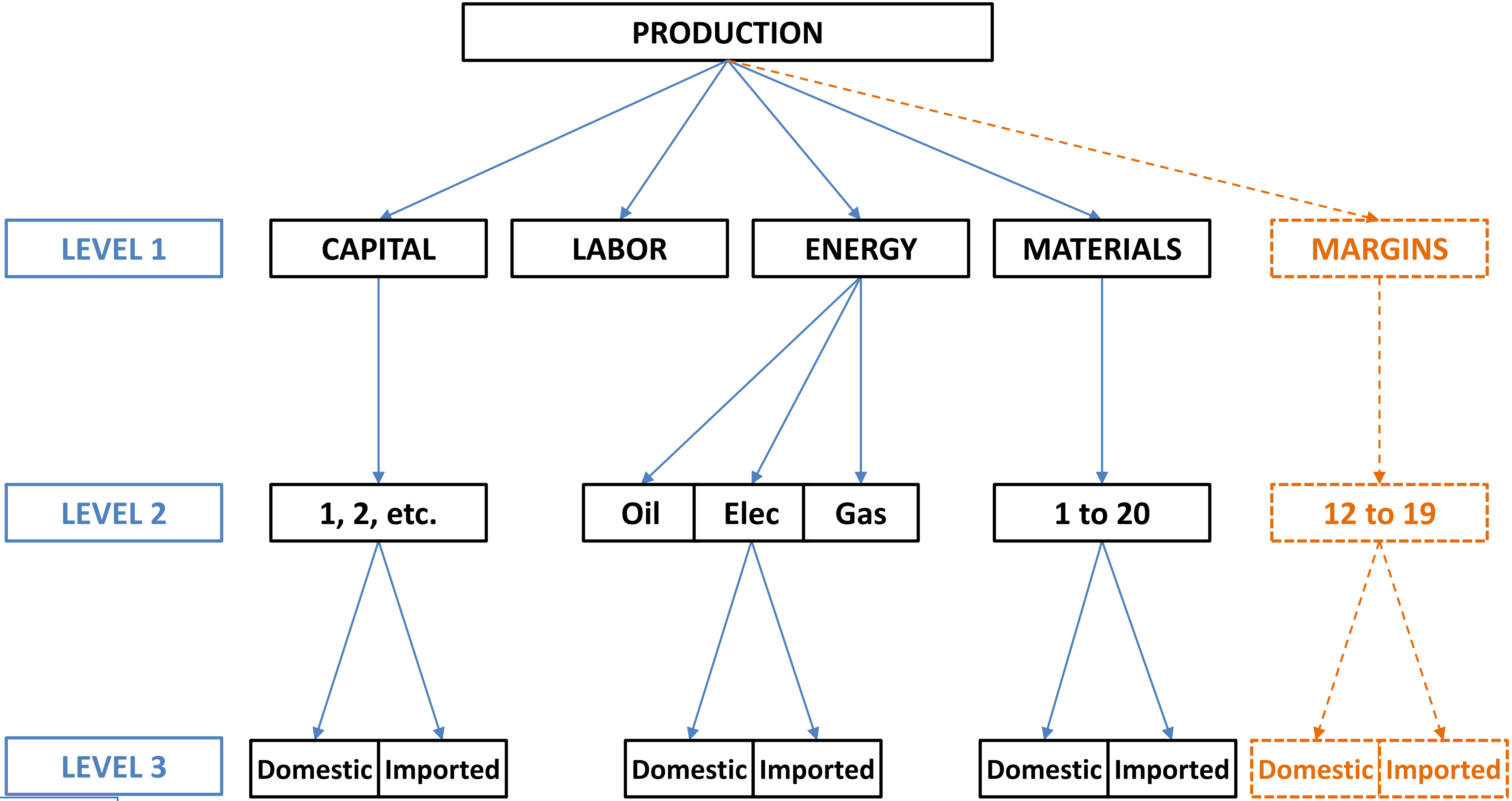
Annex

Production function and demand for production factors

- The production function is divided into three successive levels:



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The KLEM production function

- The first level is a production function with 4 factors of production:
  - Capital
  - Labor
  - Energy
  - Materials

- Solving the producer's program, we obtain the following *notional* demands for production factors:

$$\Delta \ln\left(PF_{j,t}^{n}\right) = \Delta \ln(Y_t) - \Delta \ln\left(PROG\_PF_{j,t}\right) + \Delta SUBST\_PF_{j,t}$$

$$\Delta SUBST\_PF_{j,t}^{n} = -\sum_{\substack{j'=1 \\ j' \neq j}}^{J} \eta_{j,j'}\, \varphi_{j',t-1}\, \Delta \ln\left(C_{j',t}^{PF} / C_{j,t}^{PF}\right))$$

$$\varphi_{j,t-1} = \frac{C_{j,t}^{PF} * PF_{j,t-1}}{\sum_j C_{j,t}^{PF} * PF_{j,t-1}} \quad \text{and} \quad j \in \{K, L, E, M\}$$

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Production function (continued)

- **Producers can also substitute among (level 2):**
  - **Materials used** (deformation of the technical coefficients in the Leontief matrix)
  - **Energy carriers** (oil, electricity, natural gas or coal)
  - **Transportation vectors** (road, rail, waterways or air transportation)
  - **Capital goods** in which they invest

- **Finally, ThreeME also implements imperfect substitution between domestic and imported goods (level 3)**

$$\Delta \ln\left(X^{D}_{c,t}\right) = \Delta \ln\left(X_{c,t}\right) + \Delta SUBST\_XD_{c,t}$$

$$\Delta SUBST\_XD^{n}_{c,t} = \eta^{X}_{c} \, \Delta \ln\left(P^{XD}_{c,t} / P^{XM}_{c,t}\right) \frac{P^{XM}_{c,t-1} * X^{M}_{c,t-1}}{P^{X}_{c,t-1} * X_{c,t-1}}$$

$$X^{M}_{c,t} = X_{c,t} - X^{D}_{c,t}$$

- **where η^{X}_{c} is the Armington elasticity for variable X and commodity c**

Investment and capital specifications

- Investment depends on anticipations of production, of substitutions between capital and other production factors, and of the difference between the real and notional stocks of capital

$$\Delta\ln(IA_t) = \theta_1^{IA}\ \Delta ln(IA_{t-1}) + \theta_2^{IA}\ \Delta\ln(Y_t^e) + \theta_3^{IA}(\ln(K_{t-1}^n) - ln(K_{t-1})) + \Delta SUBST\_K_t$$

- The real stock of capital is then obtained from the investment equation

$$K_t = (1 - \delta^K)K_{t-1} + IA_t$$

- This specification allows to reproduce realistic short-term dynamics, while ensuring convergence towards the notional long term

Adaptive adjustments specification

- **ThreeME takes into account the slow adjustment of prices and quantities (of production factors and consumption) towards their *notional* level**
  - The introduction of adjustments is motivated by the existence of physical or temporal limitations on factors uses uncertainty and adjustment costs

- **The notional level is the optimal value that prices and quantities would have if adjustments were instantaneous**
  - Under this specification, **underemployment equilibria** is possible

- **Formally, we use the following *adaptive adjustments* specification:**

$$\ln(X_t) = \lambda_0^X \ln(X_t^n) + (1 - \lambda_0^X)(\ln(X_{t-1}) + \Delta \ln(X_t^e))$$

$$\Delta\ln(X_t^e) = \lambda_1^X \Delta\, ln(X_{t-1}^e) + \lambda_2^X \Delta\ln(X_{t-1}) + \lambda_3^X \Delta\ln(X_t^n)$$

where X_t is the actual value of variable X, X_t^n its notional value and X_t^e its expected value. To ensure that X_t converges towards X_t^n, we enforce $\lambda_1^X + \lambda_2^X + \lambda_3^X = 1$

- **Substitutions between production factors also adjust slowly over time:**

$$SUBST\_X_t = \lambda_4^X\ SUBST\_X_t^n + (1 - \lambda_4^X) SUBST\_X_{t-1}$$

Correspondence between adaptive anticipations and ECM

- **The adaptive anticipations specification used in ThreeME for adjustments has a directly equivalent specification as an Error Correction Model**

- **Thus, the following system:**

$$\ln(X_t) = \lambda_0^X * \ln(X_t^n) + (1 - \lambda_0^X) * (\ln(X_{t-1}) + \Delta \ln(X_t^e))$$

$$\Delta\ln(X_t^e) = \lambda_1^X * \Delta\, ln(X_{t-1}^e) + \lambda_2^X * \Delta\ln(X_{t-1}) + \lambda_3^X * \Delta\ln(X_t^n)$$

can be rewritten simply under ECM form as:

$$\Delta \ln(X_t) = \alpha_1 * \Delta\ln(X_{t-1}) + \alpha_2 * \Delta \ln(X_t^n) - \alpha_3 * \ln\left(\frac{X_{t-1}}{X_{t-1}^n}\right)$$

provided we impose the following constraints on λ^X:

$$\lambda_0^X = \alpha_3,\ \lambda_1^X = 0,\ \lambda_2^X = \alpha_1/(1 - \alpha_3),\ \lambda_3^X = (\alpha_2 - \alpha_3)/(1 - \alpha_3)$$

Household consumption

- ***Household consumption*** **is modelled through a Linear Expenditure System (LES) utility function with a non-unit elasticity of substitution between goods**
  - Goods are split into essential and non-essential goods. Only the non-essential goods consumption is governed by LES

$$(EXP_c^n - NEXP_c)PEXP_c = \beta_c^{EXP}\left[(1 - MPS)\ DISPINC\_VAL - \sum_c PEXP_c\ NEXP_c\right]$$

$$\Delta\beta_{c,t}^{EXP} = (\ 1 - \ \eta^{LES\_CES})\ \Delta\frac{PEXP_{c,t}}{PEXP_t^{CES}}$$

$$PEXP_t^{CES} = \left(\sum_c \beta_{c,0}^{EXP}\ \ PEXP_{c,t}{}^{(1- \eta^{LES\_CES})}\right)^{\frac{1}{1- \eta^{LES\_CES}}}$$

Permanent 10% increase of oil and gas prices

		ThreeME (WS)				
		Year 1	Year 3	Year 5	Year 10	Year 35
GDP (volume)	(a)	-0.05	-0.15	-0.22	-0.30	-0.28
Household consumption	(a)	-0.11	-0.33	-0.45	-0.53	-0.39
Investment	(a)	0.00	-0.05	-0.10	-0.20	-0.14
Balance of trade	(c)	-0.32	-0.24	-0.20	-0.19	-0.24
Employment	(d)	-3	-19	-37	-63	-67
Unemployment rate	(b)	0.01	0.08	0.16	0.28	0.28
CPI	(a)	0.23	0.42	0.56	0.76	0.97
Real wage	(a)	-0.24	-0.33	-0.38	-0.49	-0.46
Real labor costs	(a)	-0.14	-0.23	-0.30	-0.42	-0.41
Primary balance	(c)	-0.05	-0.17	-0.22	-0.26	-0.23

Note: (a) Delta from reference scenario (in % of reference scenario)
(b) in percentage points, (c) in % of GDP, (d) in thousands.

Permanent 1% increase of VAT rate

		ThreeME (WS)				
		Year 1	Year 3	Year 5	Year 10	Year 35
GDP (volume)	(a)	-0.36	-0.59	-0.74	-0.96	-0.85
Household consumption	(a)	-0.72	-1.17	-1.39	-1.69	-1.44
Investment	(a)	-0.20	-0.48	-0.66	-1.03	-0.97
Balance of trade	(c)	0.12	0.21	0.26	0.30	0.26
Employment	(d)	-34	-101	-148	-215	-203
Unemployment rate	(b)	0.13	0.42	0.64	0.97	0.83
CPI	(a)	1.45	1.57	1.78	1.98	2.01
Real wage	(a)	-1.52	-1.16	-1.16	-1.49	-1.45
Real labor costs	(a)	-0.07	0.28	0.26	-0.09	-0.05
Primary balance	(c)	0.61	0.40	0.29	0.17	0.25

Note: (a) Delta from reference scenario (in % of reference scenario)
(b) in percentage points, (c) in % of GDP, (d) in thousands.

Comparison with MESANGE: Permanent decrease of employers' social taxes by 1% of GDP

		ThreeME (WS)			MESANGE		
		Year 1	Year 3	Year 5	Year 1	Year 3	Year 5
GDP (volume)	(a)	0.04	0.27	0.52	0.25	0.87	1.06
Household consumption	(a)	0.03	0.30	0.59	0.35	1.37	1.45
Investment	(a)	-0.04	0.05	0.26	0.61	1.02	1.16
Balance of trade	(c)	-0.03	-0.08	-0.12	-0.12	-0.24	-0.14
Employment	(d)	11	63	129	84	265	268
Unemployment rate	(b)	-0.04	-0.26	-0.55	-0.35	-1.09	-1.09
CPI	(a)	-0.34	-0.97	-1.48	-0.24	-1.27	-1.61
Real wage	(a)	-0.08	-0.10	0.00	0.37	1.21	1.52
Real labor costs	(a)	-1.66	-1.54	-1.38	-2.12	-1.42	-1.01
Primary balance	(c)	-0.13	-0.15	-0.07	-0.84	-0.32	-0.30

Comparison with MESANGE: Permanent decrease of employers' social taxes by 1% of GDP

		ThreeME (WS)		MESANGE	
		Year 10	Year 35	Year 10	Year 35
GDP (volume)	(a)	0.90	0.77	1.18	1.43
Household consumption	(a)	0.94	0.65	1.54	1.82
Investment	(a)	0.77	0.67	1.10	1.46
Balance of trade	(c)	-0.13	-0.03	-0.01	0.05
Employment	(d)	248	244	257	276
Unemployment rate	(b)	-1.11	-0.99	-1.05	-1.13
CPI	(a)	-2.14	-1.91	-1.93	-1.98
Real wage	(a)	0.44	0.46	1.95	2.43
Real labor costs	(a)	-0.89	-0.91	-0.45	0.01
Primary balance	(c)	0.10	0.03	-0.30	-0.18

Top-down and bottom-up approaches

- **Bottom-up: "From the detailed to the aggregate level"**
  - Advantages: realism and high level of details
  - Drawbacks: neglect indirect effects, feedback

- **Top-down: "From the aggregate to the detailed level"**
  - Advantages: accounts for interactions & feedbacks
    - Rebound effects
    - Carbon leakage
  - Drawbacks: lack of details, unrealistic representation of certain economic behaviors such as energy consumption

- **Hybridization seeks to overcome the respective drawbacks of each approach by combining them**
  - Necessary to emphasize more realistic representation of energy use