



CENTRE  
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ET LE DÉVELOPPEMENT

# Capital dynamics in energy transition models

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# Overview

- Foreword on IMP activities
- Macroeconomics of energy transitions
- The ‘Capital’ of multisector, dynamic macroeconomic models
- Illustration of modelling issues with runs of KLEM-FRA
- Discussion

# Macroeconomics of energy transitions (some!)

# Energy systems embedded in economic systems

- Energy transition triggers **structural change**
  - Energy expenses are substituted **Investment** & non-E consumption under adjusted budget constraints
  - Displaced output feedbacks on activity *via* the Input-Output structure, which loops to equilibrium
- Energy transition impacts **relative prices**
  - Relative energy-intensity and energy-flexibility of activities rank cost impacts
  - ...Under public policy constraints... including price administration
  - Input-Output structure propagates direct effects including *via* primary factor markets
- Energy transition modifies **investment structure** and +/- **crowds out** other I
- Three effects loop to convergence through **input-output relationships** between activity sectors

# Impacts on distribution of income

- Unclear impact on **relative primary factor payments** (L, K, rents)... except shrinking fossil rent?
  - Structural change induces factor demand shifts that retroact on factor prices... under constraint of labour market policies
- Impact on **secondary distribution of income** including via public policies
  - E transition policies are mixes of market incentives, pricing policies and regulations
  - Indirect effects on fiscal resource via structural change and relative price shifts
  - Distribution of aggregate gains or losses hanging on budget closure rule
- Impact on public involvement in economic activity?

...induce shifts of aggregate Investment and Savings behavior

# Economies embedded in globalized markets

- At all levels of domestic consumption potential trade-off between domestic and imported goods with varying degrees of exposition
- Direct impacts of relative price shifts on **competitiveness** mitigated by energy transitions of trading partners and own influence on international energy markets
- Indirect impacts via nominal exchange rate shifts
  - Considering **trade balance dynamics**
  - Under constraint of **currency exchange** policy
- Domestic structural change can position on
  - Global E-transition **technology markets** with high opportunities
  - Global markets of the **untapped fossil resources** (!)

# Induced financial flows

- Long term **balance of payment equilibrium** means that trade deficit/surplus prompts capital inflows/outflows
  - Capital inflows: foreign loans, Foreign Direct Investment
  - Capital outflows: foreign equities and bonds
- For net energy importers, energy transition may free up financial capacity to invest into foreign economies
  - Increasing part of growth depending on foreign economic performance
  - Geopolitical consequences
- ... And the opposite for large energy exporters

# Developing economies are transforming rapidly

- Changing **lifestyles** i.e. **saving and consumption patterns**
  - Rising living standards, further urbanization, ageing
- For many economies, **investment challenge**
  - Ageing/limited infrastructure requires investment hike to maintain and extend economic service
- For the more successful, economic activity climbing up the value-chain
  - **Higher value-added** intensity of domestic activity to the point of relocation of lower value-added activity in neighboring emerging economies via FDI
  - ⇒ End of export-oriented economy
- In both cases, modification of **investment versus private consumption shares in GDP**



The 'Capital' of multisector, dynamic  
macroeconomic models

# 'Capital' in economics

- 'Capital' is output of human activity **immobilized into productive capacity**: transportation and communication networks, plants, factories and office buildings, machines, patents...
- Not land or natural resources, which are not produced, nor homes or personal cars, which are not used directly as productive capacity
- The **complement of Labour**, which is the physical and intellectual effort put by individuals into the production process — although labour productivity improvements through schooling, training or experience are also termed as 'human capital' improvements
- **Investment** is the process of immobilization, it is the building-up flow of which Capital is the stock
- '**Depreciation**' is the process of degradation of the Capital stock: the speed at which Capital wears down to the point of not being usable anymore

# Capital dynamics

- Capital, investment and depreciation are linked via the **perpetual inventory** method

$$K_{t+1} = (1 - \delta) K_t + I_t$$

With  $K_t$  the capital stock during period  $t$

$\delta$  the depreciation rate: the share of  $K$  wearing off from one period to the next

$I_t$  the investment flow over period  $t$

- $I_t$  calibrated on constant-currency (real) Gross Fixed Capital Formation (investment) statistical series
- $\delta$  connected to the lifetime of equipment
- $K_t$  estimated using  $I$  series and  $\delta$  through the perpetual inventory method

# Capital in national accounting

Bn EUR	Non-E	E	C	G	I	X	Uses
Non-E	2 242	32	1 525	703	635	700	5 836
E	91	44	94	-	-	26	255
L	772	9					
K	992	25					
R	5	-					
M	751	87					
T	984	58					
Resources	5 836	255					

Economic flows in money unit  
for one given year

2-sector (non-energy, energy) IOT of 2014  
France, Source: GTAP and POLES

# Capital in national accounting

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Non-E	2 242	32	1 525	703	635	700	5 836
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## Uses

Market structure of goods and services

# Capital in national accounting

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## Resources

Cost structure of domestic production + imports M + market taxes T

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## Input-Output matrix

Interdependence of cost structures  
through intermediate consumptions:  
channel of propagation of price variations

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## Final uses

- C Households consumption
- G Public consumption (no E...)
- I Immobilisations (no E...)



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## GDP

- L Labour payments
- K Capital payments
- R Rent on land and natural resources
- T Taxes

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Trade balance

Exports X – Imports M

# From national accounting to macro modelling through price/volume disaggregation

Bn EUR	Non-E	E	C	G	I	X	Uses
Non-E	2 242	32	1 525	703	$p_I I$	700	5 836
E	91	44	94	-	-	26	255
L	772	9					
K	$r K_Q$	$r K_E$					
R	5	-					
M	751	87					
T	984	58					
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Investment expense the product of price  $p_I$  and volume  $I$

Capital payments the products of single 'rental price'  $r$  and sectoral capital stocks  $K_i$

$K_i$  homogeneous so that  $K = K_Q + K_E$

Through normalisation of prices?

# Illustration of modelling issues with runs of KLEM-FRA

# Starting specifications

- KLEM as ‘textbook’ neoclassical model... with exogenous energy demands and trade and prices
  - Inputs of  $K$  and  $L$  into non-E and E productions functions of wages  $w$  and rental price of capital  $r$
  - Factor payments  $w$  and  $r$  adjust to set  $L_i$  and  $K_i$  demands at exogenous  $L$  and  $K$  endowments
  - Exogenous saving rate  $s_D$  and trade balance ratio to GDP  $s_B$
- Applied to ‘textbook dynamics’
  - Constant growth of labour supply and labour productivity: constant ‘potential growth’ of ‘efficient labour’
  - Constant saving rate  $s_D$  and trade balance ratio to GDP  $s_B$
  - Constant energy prices, energy volumes growing at ‘potential growth’ rate

...Expectation of a ‘stable growth path’

# Runs 1 to 3 – Calibration of the Capital stock

- Run 1: initial Capital stock  $K_0$  calibrated on national accounting statistics
- Run 2: initial Capital stock  $K_0$  half its national accounting statistics, as sensitivity analysis
- Run 3:  $K_0$  calibrated so that initial investment flow  $I_0$  increases the stock in strict parallel to ‘efficient labour’, solving  $K_1 = (1 + g_1) K_0 = (1 - \delta) K_0 + I_0$  with  $g_1$  the growth rate of efficient labour
  - Homothetic growth of the two factor endowments induces constant relative primary factor prices
  - Exogenous energy consumptions growing at the same ‘potential growth’ pace and stable exogenous energy prices warrant that the relative economic cost of the energy system (services) is stable
  - Exogenous constant trade balance ratio to GDP warrants that domestic prices remain constant relative to international prices
  - **Stable growth path**: all volumes grow at potential growth pace, all prices constant except wage, which grows as labour productivity i.e. Constant energy prices, energy volumes growing at ‘potential growth’ rate

# Runs 4 to 7 – Change of energy system conditions

- Run 4: 100% energy price hike in 2020 increases  $K$  demand of energy sector
  - Rental price  $r$  increases relative to wage  $w$  to accommodate  $K$  scarcity
- Run 5: 100% energy price hike with ‘neo-Keynesian’ imperfect labour market
  - ‘Wage curve’ decreases wage relative to other prices when unemployment increases i.e. partially substitutes unemployment increase to wage decrease
- Run 6: Calibrating the investment trajectory to stabilise unemployment under constraint of the hike
  - Change from positive to normative stance: what investment effort required to remediate  $K$  scarcity?
  - Technically: substitution of stable  $u$  constraint to  $K$  constraint, while maintaining the neo-Keynesian constraint on the labour market i.e. the wage curve  $\Rightarrow$  the  $K$  stock adjust freely to stabilise  $u$
  - The ‘normative’ investment trajectory is inferred from this adjusted  $K$  stock through the perpetual inventory

## Runs 4 to 7 (cont'd)– Change of E system conditions

- Run 6 determined the investment trajectory that allows stabilising unemployment despite the 100% energy price hike from 2020 on
- Run 7 injects the investment trajectory inferred from Run 6 with restored  $K$  constraint
  - Not 100% unemployment, GDP match of Run 6 because of first period inertia:  $K_1$  is constrained by  $K_0$  and  $I_0$  through the restored perpetual inventory accumulation
  - By assumption, increased investment effort financed by increased domestic savings i.e. lower consumption



# Run 8 – Financing investment through foreign debt

- Run 6 determined the investment trajectory that allows stabilising unemployment despite the 100% energy price hike from 2020 on
- Run 7 injected this investment trajectory into the restored model (with  $K$  constraint) and assumed that increased domestic savings i.e. decreased domestic consumption finance it
- Run 8 is identical to Run 7 except that it assumes that capital inflows, rather than additional domestic savings, are the source of the investment increase
  - Technically, close the savings and investment balance on the trade balance rather than on the domestic saving rate
  - The cumulated additional trade deficit is the extra cumulated foreign debt... not including interest payments
  - Domestic consumption is spared the investment effort at the cost of this cumulated foreign debt

# Thank you for your attention

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Presentation, model files, recordings will be uploaded shortly and a download link circulated