Financing the Energy Transition and the search for sustainable growth:
the Paradoxical Role of Climate Confidence

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Prepared for the conference
Finance and the Macroeconomics of Environmental Policies

Thursday 10 April 2014
St Catharine's College, Cambridge, UK
Energy, Climate Change and the Three Domains of Sustainable Development

Michael Grubb with Jean-Charles Hourcade and Karsten Neuhoff

- Nature of the challenge
- The Three Domains and Three Pillars of Policy
- System key components
- Pillar I: Standards and Engagement
- Pillar II: Markets and Pricing
- Pillar III: Strategic investment for Innovation and Infrastructure
- Policy Integration
- Joint Benefits
- The Economics of Changing course
The “economic growth engine” draws on labour (L) and productive capital (K) to produce overall economic ‘product’ – GDP:

Production function: GDP = f(K, L).

The production can be either consumed (C), or invested (I) to increase income levels in the future: thus GDP = C + I.

Two areas of – interlinked – challenges:

(a) In its bare form, this predicts zero steady state growth and it does not match up to data – hence need the ‘Solow residual’ A(t):

Production function: GDP = A(t) * f(K, L).

A(t) normally ascribed to ‘innovation’ – exogenous productivity improvement

(b) Since GDP is sum of ‘value added’ and the inputs are homogenous, ‘intermediate consumption’ cancels on each side of the equation – hence, no notion of key resources
Following Ayres et al AER (1970) framework to track the physical interactions between the environment and the economy, expanded its model by adding energy (E): as a

$$GDP = A(t) \cdot F(K, L, E).$$

Sustainability relies on a technological optimism. Increasing the price of E relative to K and L allows to lower the energy content of production and the selection of low energy intensive techniques leaves the rate of technical change unchanged – but at cost of reduced growth.

Subsequent discussion between the so-called weak (Solow) and strong sustainability, ultimately relates to a judgment about the possibility of finding technical man made substitutes for irreplaceable assets.
Three Domains – an Economic Interpretation

1st Domain
“Satisficing” behaviour

2nd Domain
“Optimising” behaviour

3rd Domain
“Transforming” behaviour

1. Real-world individual and organisational decision-making

“Business as usual” innovation

Accelerated low carbon innovation

Purely carbon-price-driven innovation

Best practice frontier

Economic Output / Consumption

Resource Use / Energy & Emissions

Fig. 2 -3 b Resource trade-offs with the other two domains
The Three Domains link to debates about macroeconomic growth

- Neoclassical economic growth models have consistently found a ‘residual’ accounting for typically half of observed economic growth that cannot be explained by resource and capital accumulation (Ch.11 the “Dark Matter” of growth)

- Economic research points two broad areas for attention:
  - Persistent suboptimal performance of many economic actors and structures
  - Inadequate education, infrastructure and suboptimal rates of innovation

- ie. First and Third domain processes recognised as important for macroeconomic growth. Yet these remain
  - largely absent in global (or national) modelling
  - poorly charted in policy

- Energy is a particularly strong candidate because
  - Pervasive input to numerous production sectors
  - Fossil fuel markets are intrinsically unstable
  - Exceptionally low rates of innovation particularly electricity & construction
Under the hood of ‘innovation’ – beyond autonomy or self-optimisation

• *Learning by doing (Arrow 1962)*+. Knowledge and productivity increase with in line with growth in total investment => redirecting technical change is costless at least in long run

• *Labour productivity (Uzawa 1965)*+. Public investment in education and training, and human motivation, are important.

• *Product variety (Romer 1990) and quality (Aghion and Howitt 1992)* drive innovation intensity because these determine competitive incentives to innovate
Is the ‘Fordist’ growth engine faltering ... ?

• Possible reasons:
  – Saturation of traditionally expanding economies of scale in the aftermath of globalisation?
  – Delayed human and environmental consequences of consumption growth with inadequate environmental protection?
  – Energy vulnerability?
.. Which maps in interesting ways to energy/climate, where we seek radical innovation in some of the least innovative sectors of our economies

Fig. 9.3 R&D expenditure by top companies in different sectors as % of sales, 2011

INNOVATION INTENSITY AND THE BROKEN CHAIN

Highly innovating, close connection consumers and innovators
- 1st & 3rd Domains -
R&D intensity 5-15% (eg. IT, drugs)

Moderate innovation, mostly business to business connection
- 2nd & 3rd Domains -
R&D intensity 1-5% (eg. industrial & product engineering)

Low innovation, little connection between innovators and markets
R&D intensity < 1% (eg. energy & construction)

**Figure 9.7** Innovation intensity and the broken chain
Source: Authors
In *energy*, the macro debate is reflected in ...

- Modelling assumptions of ‘Autonomous energy intensity improvement’ (AEEI)
  - which has been demonstrated to be clearly not autonomous
- ‘Induced energy productivity trends’
  - Which prove to be highly variable according to methodology, country and timescale of measurement, *ie.* fail stability tests
Innovation and ‘crowding out’: a judgement on spillovers

• If innovation is a finite, fungible factor optimally deployed - self-optimising by construction – accelerating or orienting innovation in energy is at cost of innovation elsewhere in the economy

• But innovation is also known to be highly subject to spillovers including across sectors – a foundation and amplifier of growth in wholly unpredictable ways
Figure 11.5 Waves of Innovation

Macro modelling: Global GDP in mid Century has little or nothing to do with global mitigation ...

20 GtCO2 = halving of global CO2 emissions by mid Century

Figure 11.4 Gross World Product in 2050 (excluding environmental benefits) from a wide range of models

Energy & related sectors are ‘complex sociotechnical systems’, with big evolutionary & lock-in characteristics

• Progress in clean energy industries impressive, but heavily dependent on public policy
• .. and so far outweighed by ‘carbon entanglement’
• Consider response to oil price rises
• .. and study the policy implications of evolutionary economics:
  – Niche accumulation
  – Hybridisation strategies
• Industrial strategy is unavoidable
• … with the positive side being macroeconomic version of “Porter’s kick”
What would we like to represent?

Overall productivity
Demographic dynamics
Savings, capital flows and funding of the welfare system
Globalisation: inward vs outward oriented development strategies

Growth Engine

Consumption Styles

Energy, food, land, real estate markets

Technological Paradigm

Localisation Patterns

C

T

L
A research agenda in six components for describing the growth engine of the new capitalism

Capturing the transition issues through growth models with disequilibrium, non-neutral money and finance et endogenisation of technical and institutional inertia:

a) ‘hybridation’ of models to represent the interactions between C, T, L and growth dynamics, and the technical and institutional inertia in a context of uncertainty and imperfect foresight

b) Linking behavioral models to institutional conditions: need of models of ‘endogenous preferences’ symmetrical to models of ‘endogenous technical change’

c) Decision models under a ‘shareholder value’ business regime’ instead of a managerial regime; how this changes technical choices of industry and trade-offs between industrial and speculative investments?

d) Beyond the Iceberg model of international competition: capturing economies of scales, dimension and variety and their limits, capturing the value chains and logistics costs

e) Endogeneisation of growth dynamics and income distribution

f) Beyond the disputes between weak and strong sustainability: represent scarcity rents generated by mis-anticipation of environmental and resources constraints
An integrating approach to climate policy

Three Domains
and the
First Pillar of Sustainable Development

- Nature of the challenge
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- Joint Benefits
- The Economics of Changing course
Experience and theoretical reasoning on each pillar shows ...

- Only approaches that integrate across all three domains have clear potential to generate ‘Green Growth’
- There are multiple lines of evidence that in context of transforming the global energy system over a few decades, all three domains are of comparable importance
- The dominant neoclassical ‘Second Domain’ theories emphasise instrument (pricing) that maximises political opposition unless it is nested in the complementary triad
- First and Third pillar policies can (and have) delivered multiple benefits, but ....
No pillar on its own can credibly solve the problem – nor offers a politically stable basis for policy

- Energy efficiency policy on its own limited by:
  - Scale of intervention required
  - Growing scale satisficing behaviour
  - . . . Leading to large Rebound effects

- Pricing on its own limited by:
  - Blunt nature of impacts First and Third Domain impacts
  - Rising political resistance to rising fuel bills
  - .. and competitiveness concerns

- Innovation on its own limited by:
  - Lack of demand pull incentives
  - Scale & risks of investment costs
  - Political failures in absence of rising market feedbacks
Changing course requires a sustained package - the key is to integrate and synergise across all three domains.
There are potential co-benefits in each domain

<table>
<thead>
<tr>
<th>Domain and Pillar</th>
<th>Co-Benefits</th>
<th>A New Framework</th>
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<tr>
<td>Standards &amp; Engagement for Smarter Choices</td>
<td>Enhance efficiency, Indoor and Local health subsidy removal ..</td>
<td>Climate Policy potential to Motivate Stabilise Coordinate Finance for efficiency growth innovation for long-run security</td>
</tr>
<tr>
<td>Prices and markets for cleaner products and processes</td>
<td>Stabilise investor confidence, revenues, air pollution &amp; energy security</td>
<td></td>
</tr>
<tr>
<td>Strategic investment for Innovation &amp; Infrastructure</td>
<td>Accelerate Innovation in weak sectors, coordinate supply chain &amp; infrastructure</td>
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An integrating approach to climate policy

Three Domains:
A modelling exploration and generic policy implication

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Mainstream economic models are weak in the dynamics of energy systems

- The vast majority of economic models assume a cost function in relation to the degree of abatement from ‘reference projection’ at time $t$
- This has no underlying history ⇒ eg. DICE equations
  Inertia, pathway etc effects have been introduced through
- Capital stock lifetimes (many models)
- Endogenous technological change (increasing numbers of models but mostly in academia)
A simplifying approach with links to 3 domains

• Cost may also be represented in relation to both the *degree* and the *rate* of abatement
  – First is the classical representation
  – Second (rate dependent) represents inertia
  – Ratio represents adaptability - *transitional costs with enduring pathway impacts*

• This enables link to the 3 domains:
  – *Most First Pillar gains do not reverse:* they have the characteristic of regulatory or behavioural innovation which saves costs
  – *Most Third Pillar gains do not reverse:* infrastructure endures and innovation generally moves forward, not backwards
The ‘global optimal trajectory’ is radically different for an adaptive energy system, given ‘typical’ damage & discounting assumptions.

- Both First and Third pillar policies – which can be broadly characterised as regulatory and technological systems innovation – are adaptive in nature (i.e., transitional cost with enduring benefit).
- A significant degree of direct response to prices may also be adaptive.
Measures which steadily adjust the pathway are optimal at much higher ‘cost of carbon’

- For an adaptive system (characterised by transitional costs with enduring benefits, early efforts have much higher benefit than just emission reductions
- eg. Optimal investment c. $1tn/yr can cut annual costs (abatement + damage) towards end of century by at least 5 times as much
Key policy implication of the numerical analysis

- The value of measures which *adjust the pathway* is several times that of measures which just save CO2
- Useful to think of a ’base’ carbon price as that which can be implemented today reflect the assumed damage of CO2 emissions
- Measures in the First and Third Domains may well justify a “cost of carbon” well above this base carbon price
- A rising base carbon price can also enhance in particular strategic investments & leverage *long term institutional finance*
Thought for discussion: ‘First among Equals?’

• A rising **base** carbon price is an instrument that contributes across *all* domains:
  I. Attention effect and funding for 1st Domain responses
  – rising steadily enables efficiency to keep pace and stop much rise in *total bills*
  II. Price differential will steadily reduce use of coal in power generation, and help to move renewables on from transitional subsidies into mainstream market
  III. Facilitates increased investment stability and funding for innovation, infrastructure and tech transfer programmes

• Embedding in an international agreement would enhance stability and credibility
Some research challenges

• Better mapping the boundaries of the relevant Domains
• Fleshing out the synergies between Pillars, and in particular how different structures and linkages of carbon prices may help to form more stable and politically appealing packages
• Digging deeper into the ‘co-benefits’ and how these vary between regions and economic circumstances, and for different pillar designs
• The role of international cooperation in the Three Domains and the politics of a ‘base price’ agreement
• Exploring sensitivities and other representations of ‘the Economics of Changing Course’
Launch meetings

- **UCL London 28th Jan:**
  - Pre-launch seminar, deeper look at Pillar I
- **Paris 21st Feb:**
  - Internal presentations to OECD and IEA
- **Brussels 27th Feb:**
  - Policy launch at Bruegel Institute
- **Cambridge Kings College 10th March**
  - Academic launch: architecture, integration and modelling
- **London LSE Annual Energy Conference 11th March**
  - Economic focus on carbon pricing (Pillar II) and interactions
- **London Imperial College Grantham Institute, 12 March**
  - Seminar, deeper look at Pillar III
Planetary Economics:
Energy, climate and the Three Domains of sustainable development

1. Introduction: Trapped?
2. The Three Domains

Pillar 1
• Standards and engagement for smarter choice
  • 3: Energy and Emissions – Technologies and Systems
  • 4: Why so wasteful?
  • 5: Tried and Tested – Four Decades of Energy Efficiency Policy

Pillar II
• Markets and pricing for cleaner products and processes
  • 6: Pricing Pollution – of Truth and Taxes
  • 7: Cap-and-trade & offsets: from idea to practice
  • 8: Who’s hit? Handling the distributional impacts of carbon pricing

Pillar III
• Investment and incentives for innovation and infrastructure
  • 9: Pushing further, pulling deeper
  • 10: Transforming systems
  • 11: The dark matter of economic growth

12. Conclusions: Changing Course

Routledge/Taylor & Francis, Published 2014