Oil and the World Economy: Some Possible Futures

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1 Introduction

There are two questions we really need to understand concerning oil:

- **The Outlook for Oil Itself:**
  - Question: What is the outlook for oil production and oil prices?
  - Our Answer: "The Future of Oil: Geology versus Technology", International Journal of Forecasting.
  - Summary of that paper: Over the medium term, oil prices will have to rise a lot to keep oil output growing.
- **The Implications for GDP:**
  - Question: How will oil scarcity affect output?
  - Scenario: Downward shift in trend growth rate of world oil production.
  - Answer: It depends on some key aspects of technology
    * Behavior of demand and supply elasticities.
    * Effects on technology.

- Three key questions for the oil-to-output link:
  1. Just how large will the **oil supply reduction** be, and when will it happen?
  2. What is the **output contribution** of oil?
     - Economists: Low, looking just at the cost share.
     - This paper: Technology Externality Scenario:
     (a) Oil is a critical enabler of key technologies (Bob Ayres).
     (b) Oil's benefits are external.
  3. What is the **elasticity** between oil and other factors?
     - Economists: Low in short run, much higher in long run.
     - This paper:
       * Growing Elasticity Scenario: Elasticity rises at very high oil prices.
       * Entropy Boundary Scenario: Elasticity falls at very low oil quantities.

- Objective of this work:
  - We systematically and rigorously think through channels whereby oil scarcity could affect output.
  - Without being limited by the very narrow interpretive framework of existing neoclassical economic models.
  - We attempt to broaden our horizon by drawing on information from the natural sciences.
  - We thereby hope to pave the way for future more useful empirical work.
  - We are very conscious of serious gaps in our knowledge, so all our conclusions are very tentative.

2 Daly's Critique of Neoclassical Production Theory

- Neoclassical treatments of natural resources in production functions:
  - Mostly natural resources are completely omitted.
  - Even if they are not omitted, the complementarity between natural resources and capital and labor is not recognized, e.g. by allowing capital and labor to be infinitely substituted for natural resources.
  - The equality between output elasticities and cost shares of resources is imposed by restricting attention to narrow classes of production functions that are analytically tractable and easier to calibrate using prices.

- Solution: Georgescu-Roegen (1971), but this is not readily incorporated into familiar economic models.

- We offer ways to incorporate some insights of Georgescu-Roegen and Daly into otherwise neoclassical DSGE models:
  - Strict complementarity between oil and capital/labor on the boundaries of the factor space (Stern (1997)), and very low substitutability elsewhere (Krusell et al. (2012), King (2012)).
  - Emphasis on realistic description of physical processes rather than on analytical tractability (Ayres and Warr (2005, 2010), Kümmel (2011)).

3 The Structure of GIMF-Oil

GIMF is a dynamic business cycle model developed at the IMF for policy and scenario analyses.

- Six regions: Oil exporters, US, euro area, Japan, emerging Asia, ROW.
- Each region has a fully specified output and factor market structure that is calibrated to replicate key national accounts magnitudes.
- Each region has fully specified fiscal and monetary policies, including a calibration of fiscal accounts to replicate regional characteristics.
- The trade linkages between all regions are modeled in detail, and the relative strength of trade links is calibrated using international trade data.
- The dynamic behavior of the model, which includes many nominal and real rigidities, has been studied in detail and broadly replicates empirically observed economic responses to standard shocks.
- Key today: Oil is an additional production input and consumption good.

3.1 Baseline Oil Demand

- Short-run price elasticity of demand: 0.02.

- Long-run price elasticity of demand: 0.08.

- Comparison with literature:
  - Towards the lower end of conventional VAR estimates.
  - But higher than the far more relevant estimate of Krusell et al. (2012), who look at the dynamics implied by CES production functions like ours under different elasticities.

- Cost share of oil in production: 2%-5% (data).

- Output contribution of oil in production: 2%-5% (model, under the restrictive and unrealistic assumption of a CES production function).

3.2 Baseline Oil Production

- Exhaustible resource:
  - Oil production is mostly an exogenous endowment.
  - Except for a small price elasticity of supply of 0.03.

- No spare capacity: Supply response only to lagged oil price.

- Extraction cost in the baseline:
  - Initially equal to 40% of oil revenue.
  - Thereafter growing at real 2% p.a.
  - Conservative: Recent growth rates in costs have been much higher.

3.3 Fiscal Sector Specification

- Oil rent = oil revenue minus oil extraction costs.

- Oil rent recipients in oil importers: Mainly the private sector.

- Oil rent recipients in oil exporters:
  - 90% goes to the government.
  - Government accumulates these funds in a US$ oil fund.
  - Only 3% per year of this fund is spent: Almost exactly like the Norwegian oil fund.
  - Oil price boom therefore causes a huge expansion of the oil fund.
  - Consequence: Higher world savings + lower world interest rate.

4 The Scenarios

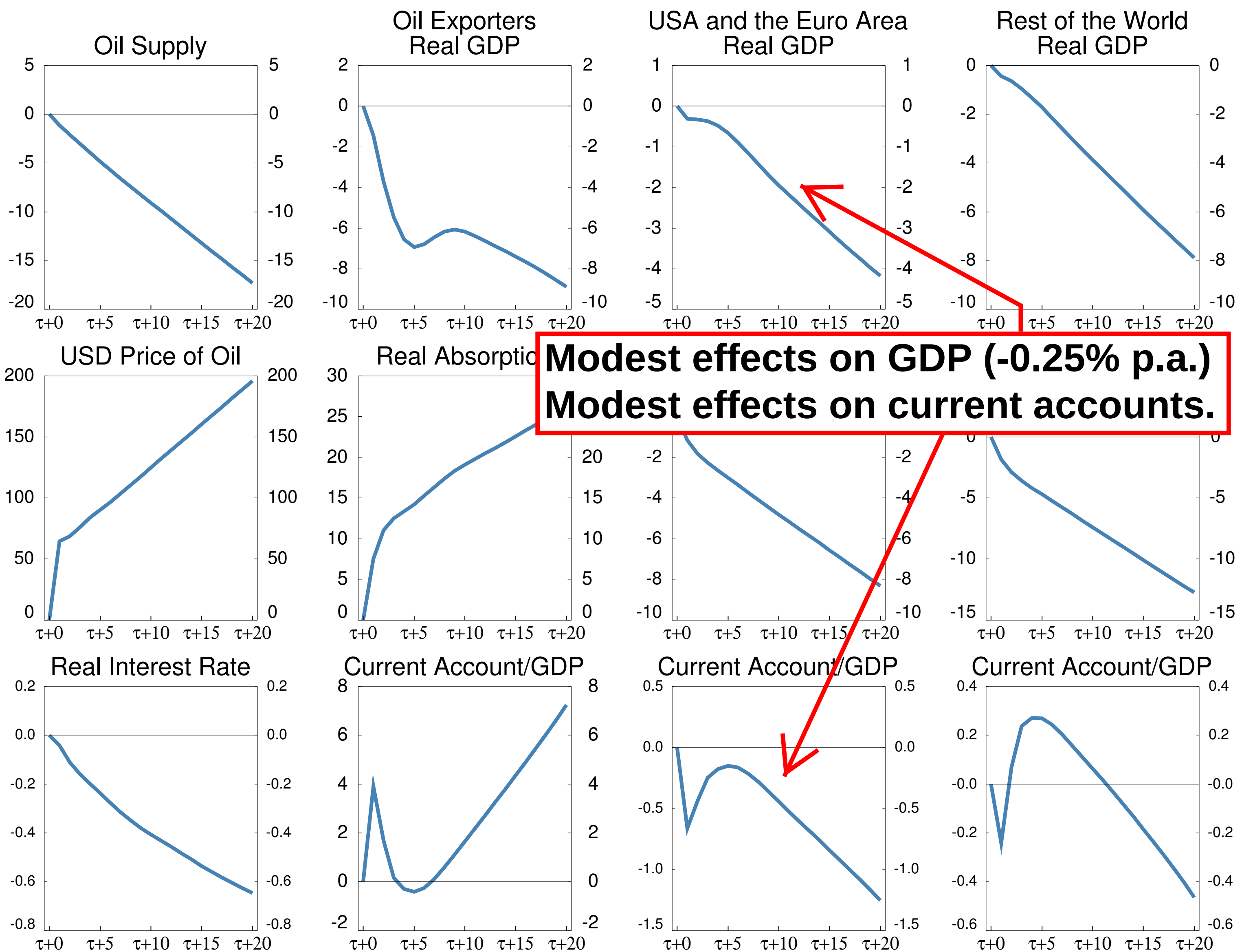
1. Baseline:

    (a) Modest reduction in oil output growth by 1% p.a. relative to trend.

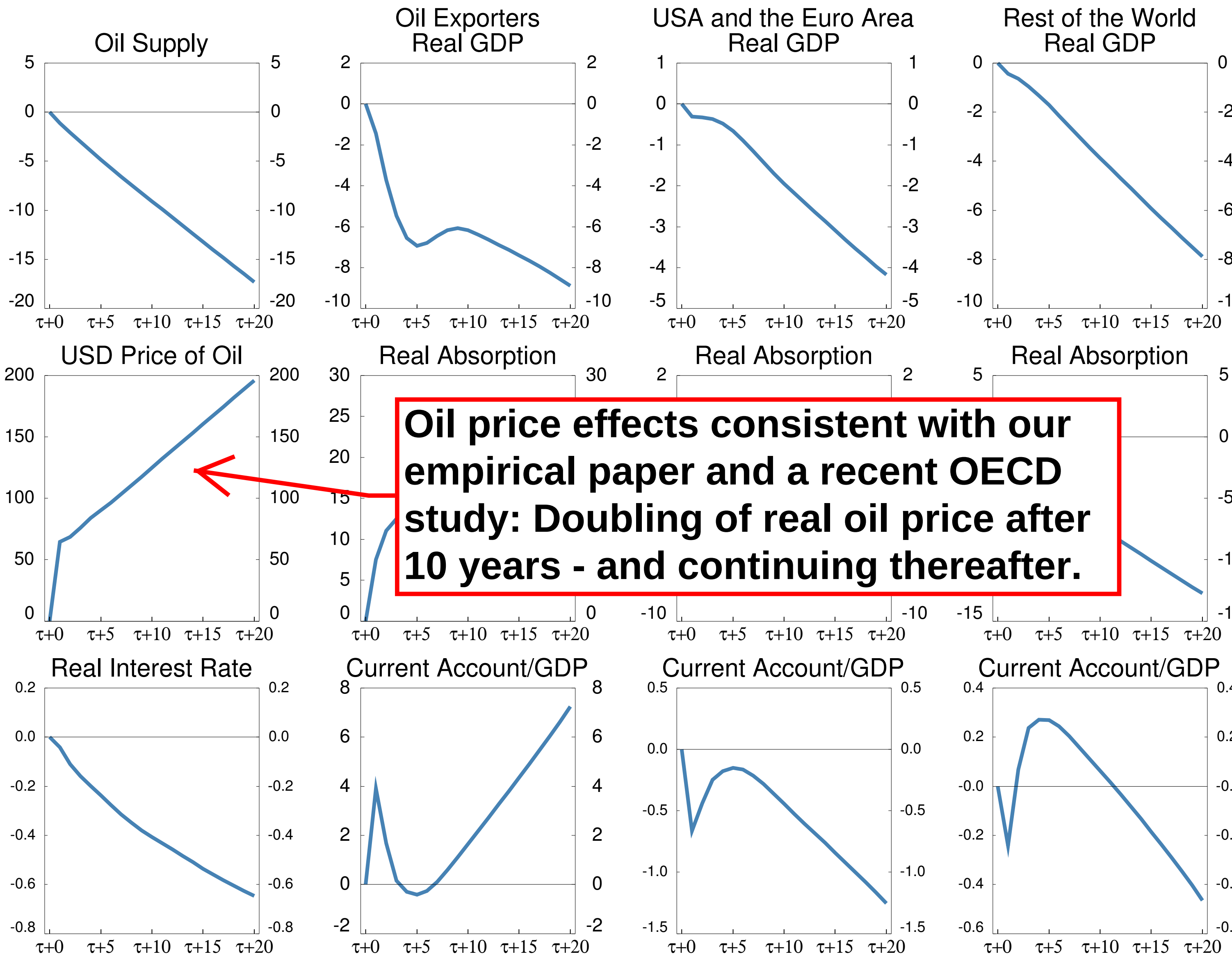
    (b) Conventional labor-capital-oil CES production functions:

    - Oil has a very low elasticity of substitution.
    - But it can still be infinitely substituted by capital and labor at very high oil prices.

Baseline


Oil Supply
Oil Exporters Real GDP
USA and the Euro Area Real GDP
Rest of the World Real GDP
USD Price of Oil
Modest effects on GDP (-0.25% p.a.)
Modest effects on current accounts.
Real Interest Rate
Current Account/GDP
Current Account/GDP
Current Account/GDP
τ+0
τ+5
τ+10
τ+15
τ+20

Baseline

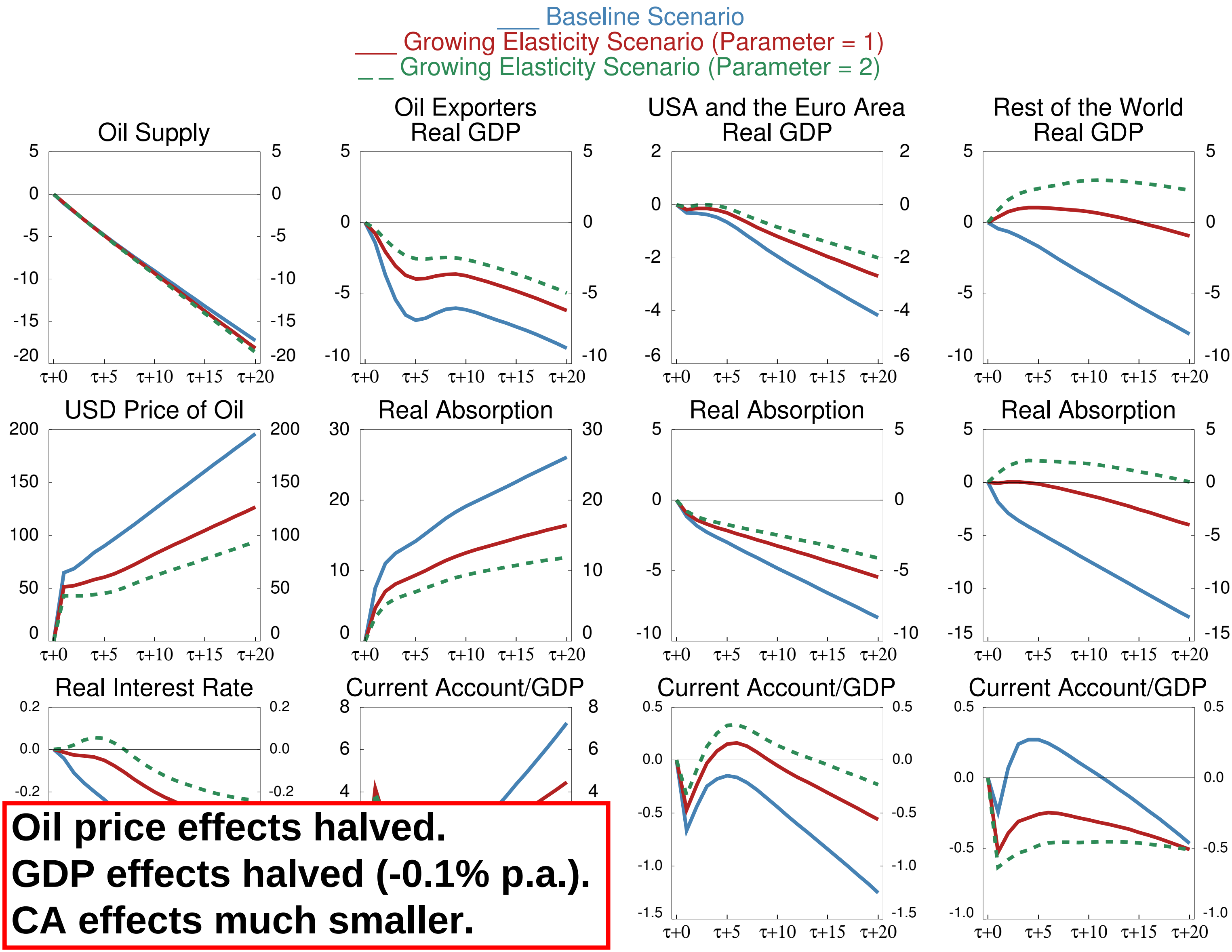


Oil Supply
Oil Exporters Real GDP
USA and the Euro Area Real GDP
Rest of the World Real GDP
USD Price of Oil
Real Absorption
Real Absorption
Real Absorption
Real Interest Rate
Current Account/GDP
Current Account/GDP
Current Account/GDP
τ+0
τ+5
τ+10
τ+15
τ+20
Oil price effects consistent with our empirical paper and a recent OECD study: Doubling of real oil price after 10 years - and continuing thereafter.

2. Growing Elasticity Scenario:

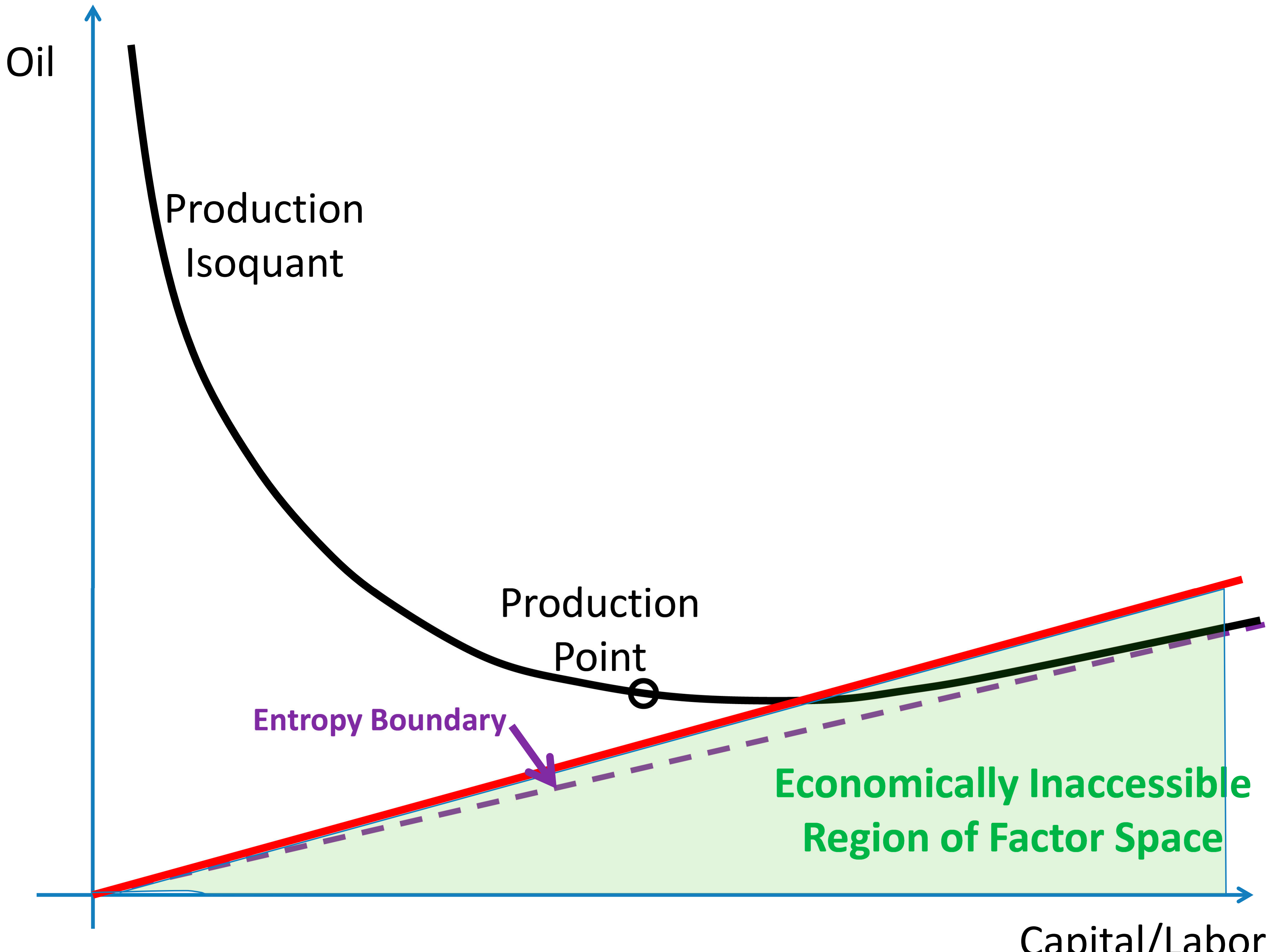
- **Elasticity of substitution grows with high oil prices.**
- This reflects more urgent substitution away from oil at very high oil prices.

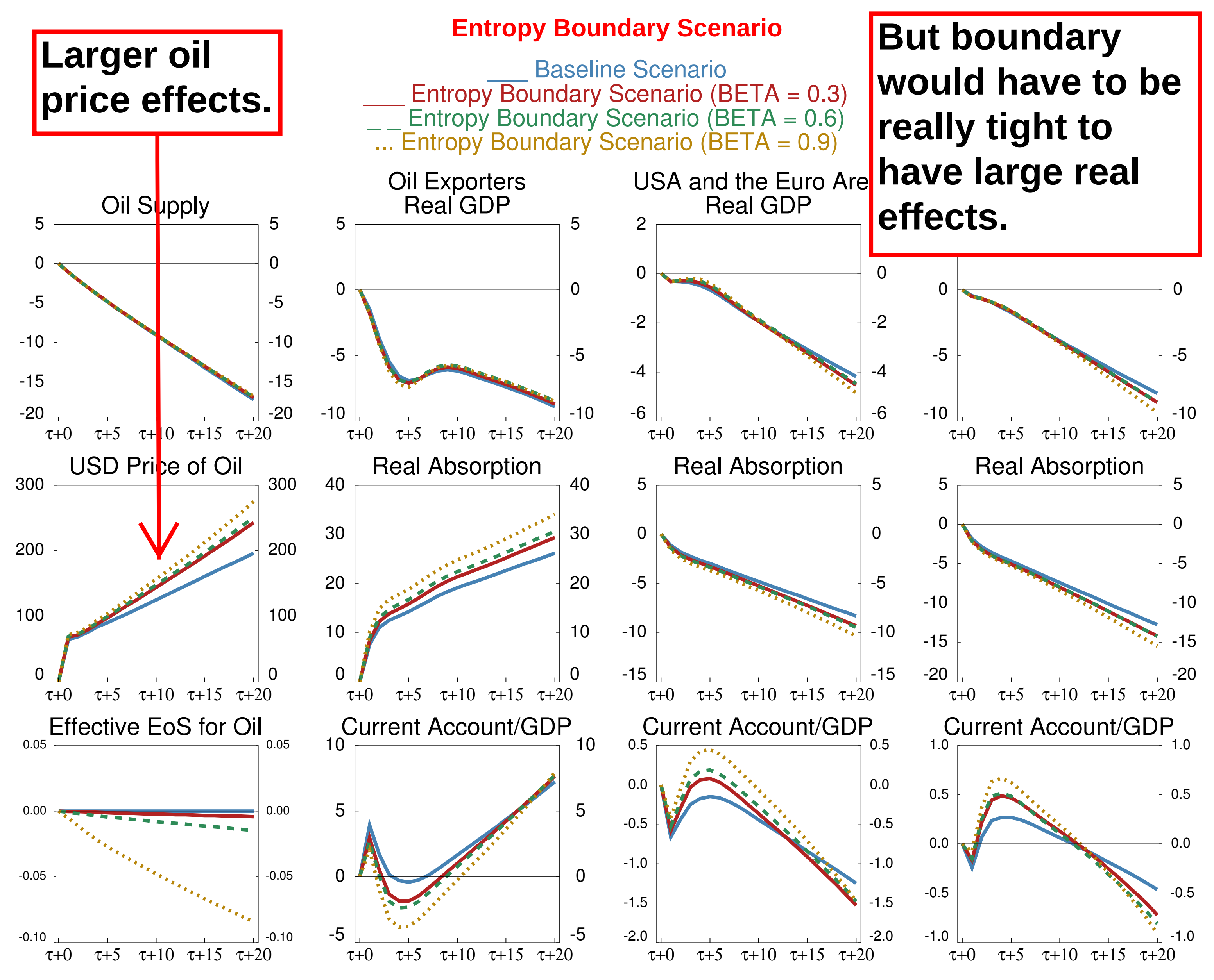
Growing Elasticity Scenario



Oil price effects halved.
GDP effects halved (-0.1% p.a.).
CA effects much smaller.

3. Entropy Boundary Scenario:
    - Minimum amount of oil required per unit of output.
    - Otherwise entropy (=energy dissipation) will degrade capital.
    - **Elasticity of substitution drops with low oil quantities.**
    - The modified production function features a lower boundary: Input combinations with oil use below that boundary are not feasible.
    - The production function is a mathematical representation of the graphical intuition in Stern (1997) and Reynolds (2002).
    - Substitution by other forms of energy must be doubtful:
        - Many have future supply limitations of their own. More research is urgently needed here.
        - Technical substitutability for oil is in many cases very limited. More research is needed here, too. This would have to go into a lot of technical detail to be useful.


Oil
Production Isoquant
Production Point
Entropy Boundary
Economically Inaccessible Region of Factor Space
Capital/Labor


Entropy Boundary Scenario
Larger oil price effects.
But boundary would have to be really tight to have large real effects.
Baseline Scenario
Entropy Boundary Scenario (BETA = 0.3)
Entropy Boundary Scenario (BETA = 0.6)
... Entropy Boundary Scenario (BETA = 0.9)
Oil Supply
Oil Exporters Real GDP
USA and the Euro Are
Real GDP
USD Price of Oil
Real Absorption
Real Absorption
Real Absorption
Effective EoS for Oil
Current Account/GDP
Current Account/GDP
Current Account/GDP
τ+0
τ+5
τ+10
τ+15
τ+20

4. Technology Externality Scenario:

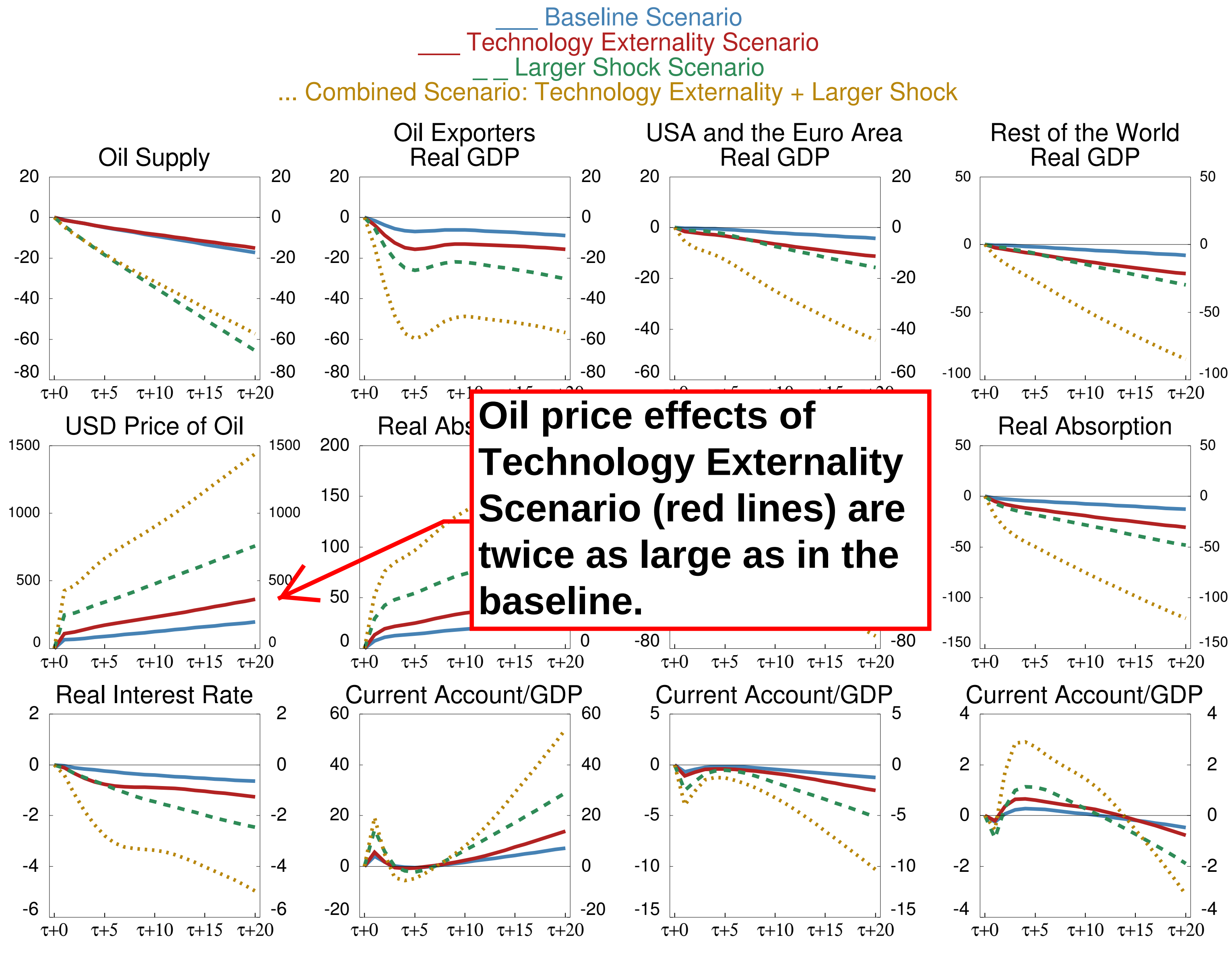
- **Oil acts like factor-augmenting technological progress.**

- Represents the critical role of oil in the viability of many key technologies (Ayres (1990)).

- **Effect is external and therefore not reflected in cost shares.**

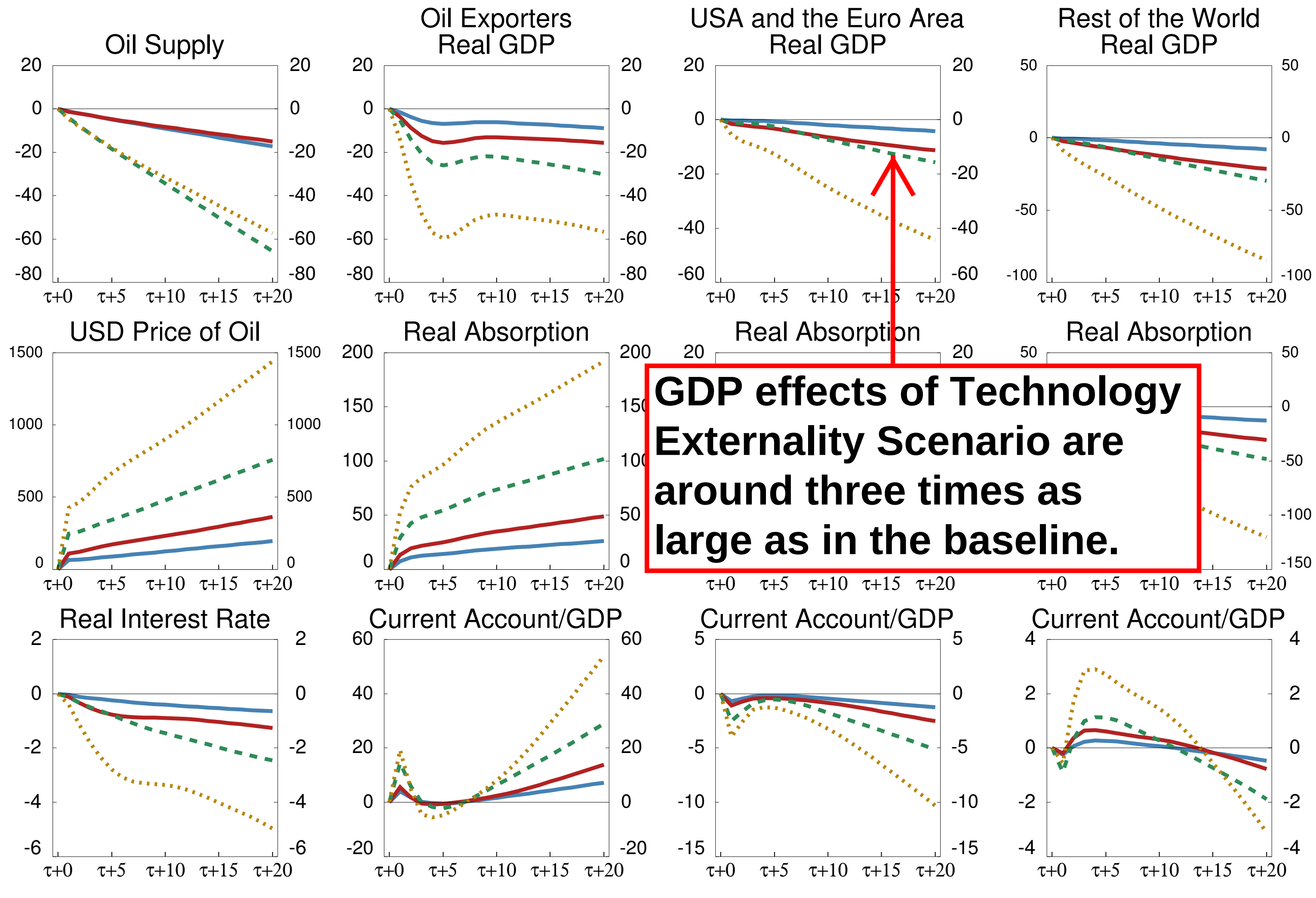
- Contribution of oil to output growth equals 20%-25%, not 2%-5%.

Technology Externality and Larger Shock Scenarios

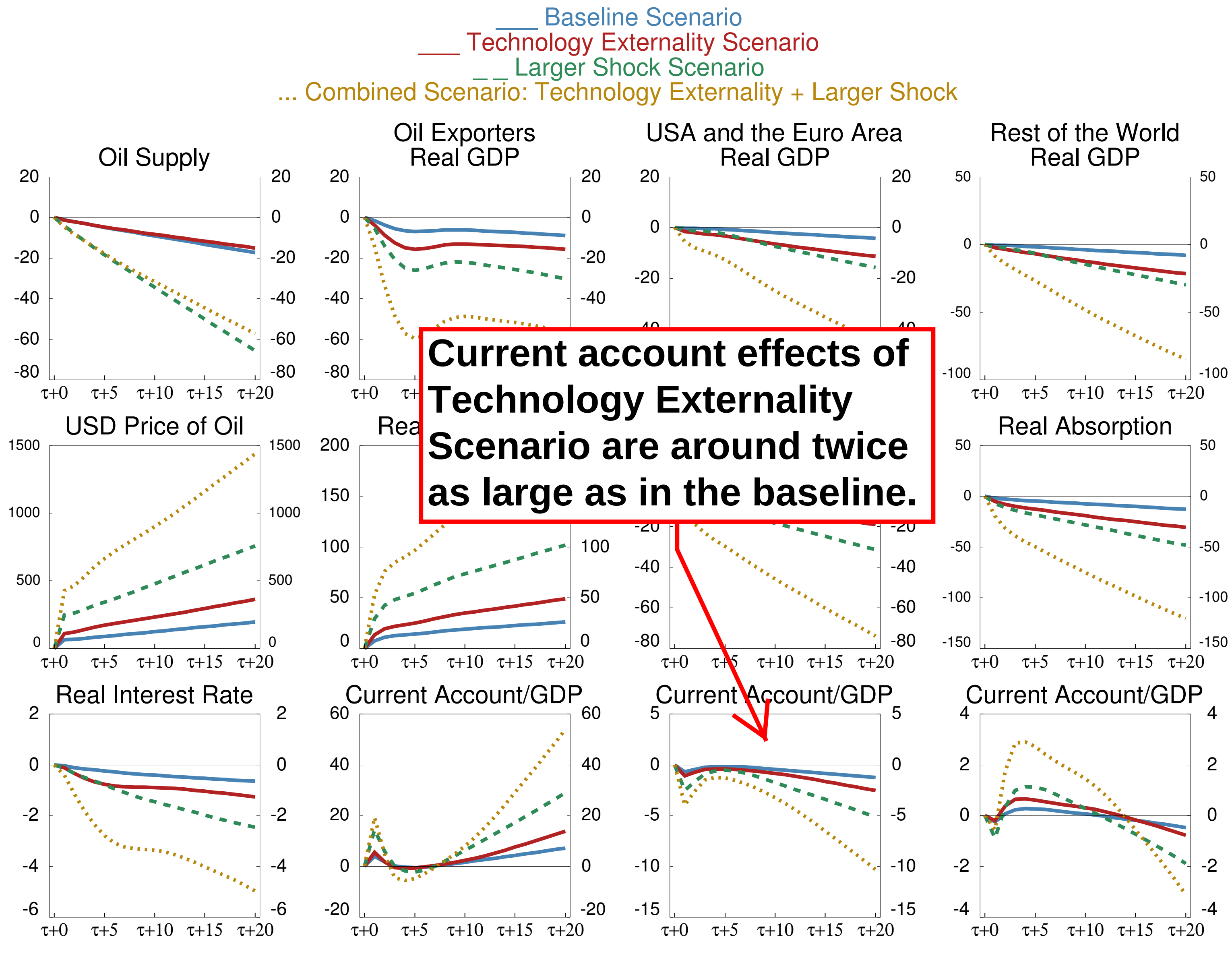


Technology Externality and Larger Shock Scenarios

___ Baseline Scenario
___ Technology Externality Scenario
_ _ Larger Shock Scenario
... Combined Scenario: Technology Externality + Larger Shock



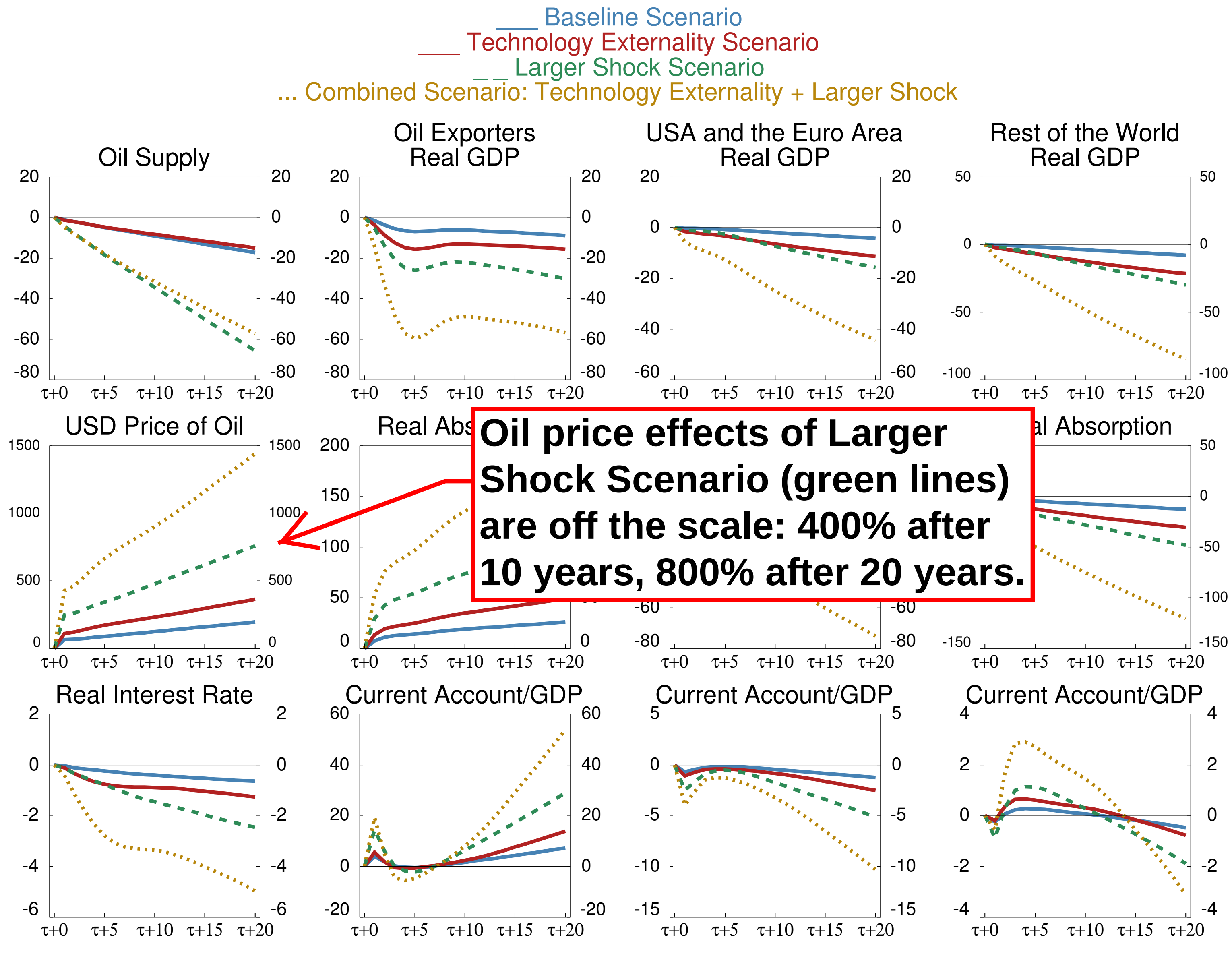
Technology Externality and Larger Shock Scenarios



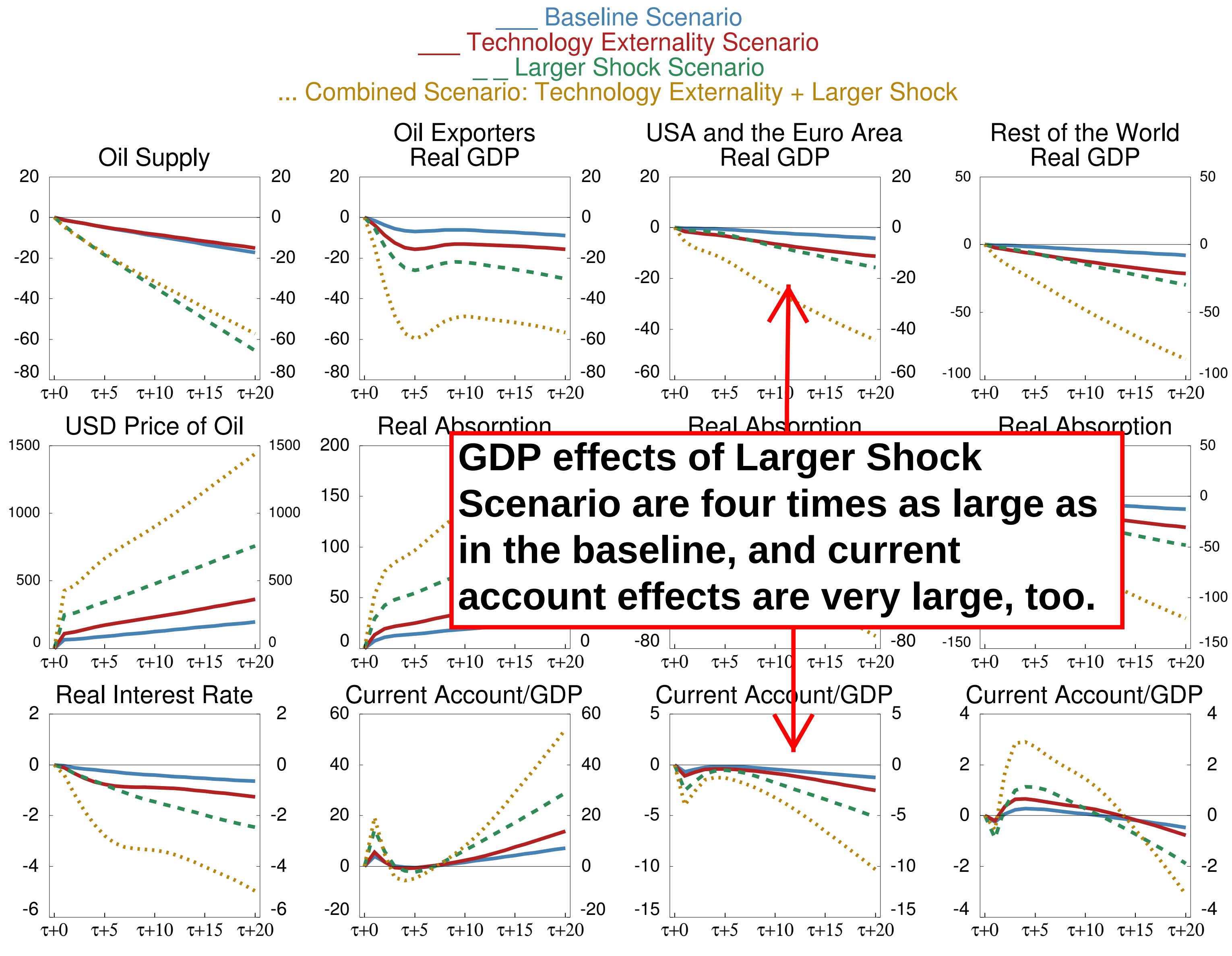
5. Larger Shock Scenario:

- **Reduction in oil output growth by 3.8% p.a. relative to trend** (absolute decline of 2% p.a.).
- Consistent with several papers in the natural sciences.

Technology Externality and Larger Shock Scenarios



Technology Externality and Larger Shock Scenarios

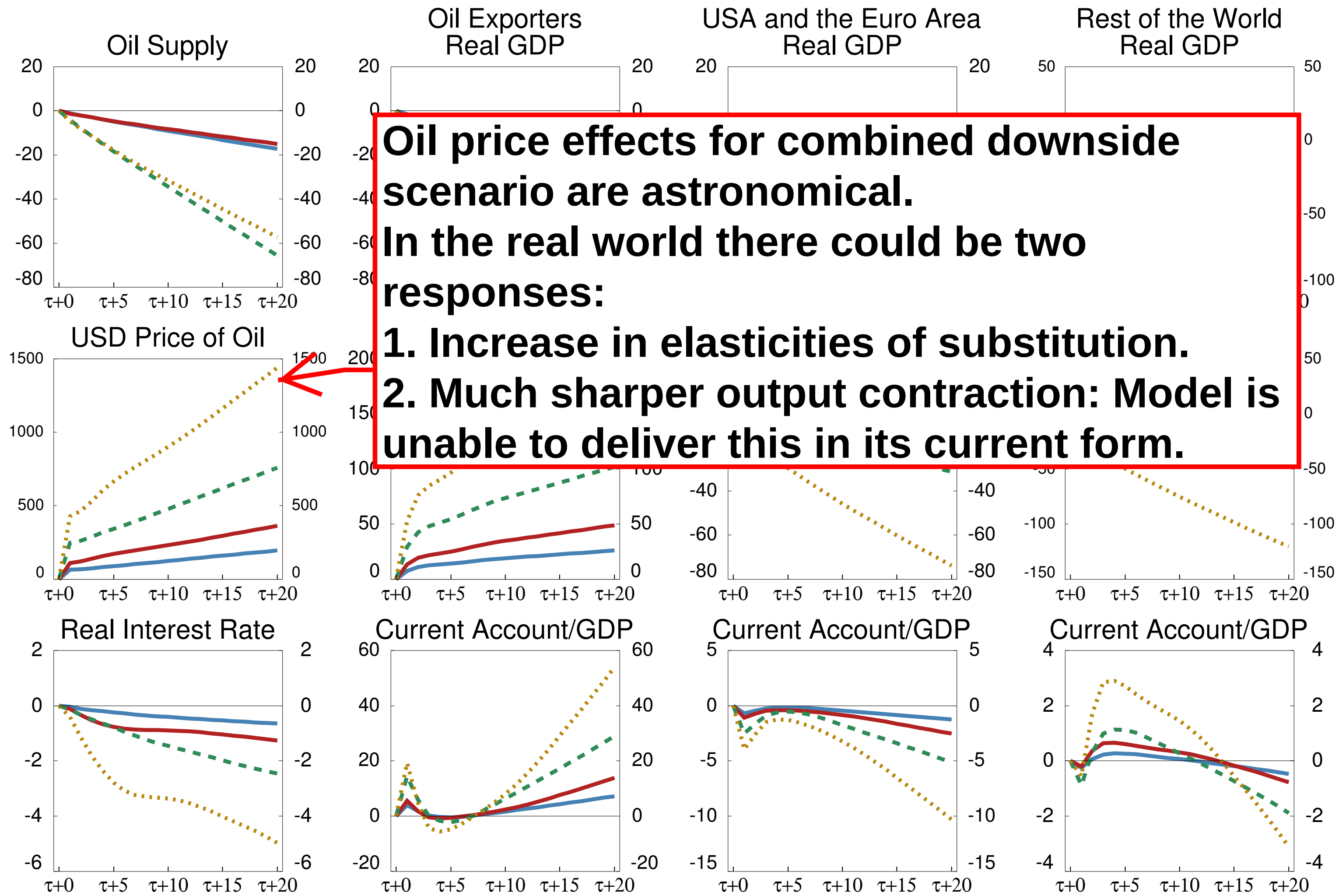


6. Combined Downside Scenario:

- Technology Externality Scenario $+$
- Larger Shock Scenario.

Technology Externality and Larger Shock Scenarios

___ Baseline Scenario
___ Technology Externality Scenario
_ _ Larger Shock Scenario
... Combined Scenario: Technology Externality + Larger Shock



Oil price effects for combined downside scenario are astronomical.
In the real world there could be two responses:
1. Increase in elasticities of substitution.
2. Much sharper output contraction: Model is unable to deliver this in its current form.

5 Weaknesses in Assumptions

5.1 Unitary Income Elasticity

- Model: Unitary income elasticity of oil demand implied by balanced growth.
- Data: World income elasticity of oil is well below one.
- When oil is plentiful this is nice.
- But when oil is scarce this is bad news: Together with low price elasticities it could nearly triple the output effects.

5.2 Smooth Reallocation

Do we really expect smooth reallocation after very large price shocks?

- Efficient intermediation of large net capital flows from oil exporters? Think about the 1980s third world debt crisis.
- Increased labor market flexibility? There may be a limit to how much workers are willing to take.
- Free sale of oil to the highest bidder? If oil exporters withhold oil for domestic use, net exports decline much faster than output. This is happening today.
- Smooth reallocation among inputs and across sectors?
  - Some key industries are highly vulnerable.
  - Credit market interdependencies.
  - Bottleneck effects are critical. Assessment requires highly detailed knowledge of industrial processes.

6 Conclusion

- Oil price effect in the benchmark simulation is similar to our empirical paper.
- Output and current account effects of lower oil output in the benchmark are modest.
- Alternative assumptions could lead to much larger effects:
  1. Larger decline in oil output.
  2. Higher output contribution of oil.
  3. Lower elasticity of substitution as oil use is reduced to a minimum.
- Output effects get much larger but are still not enormous.
- But the oil price effects are enormous.
- Key question: At what level does output response to higher oil prices become highly nonlinear in the real world (nonlinearities are limited in the model)?