# Greenhouse Gas: Long-Run Growth and Collapse

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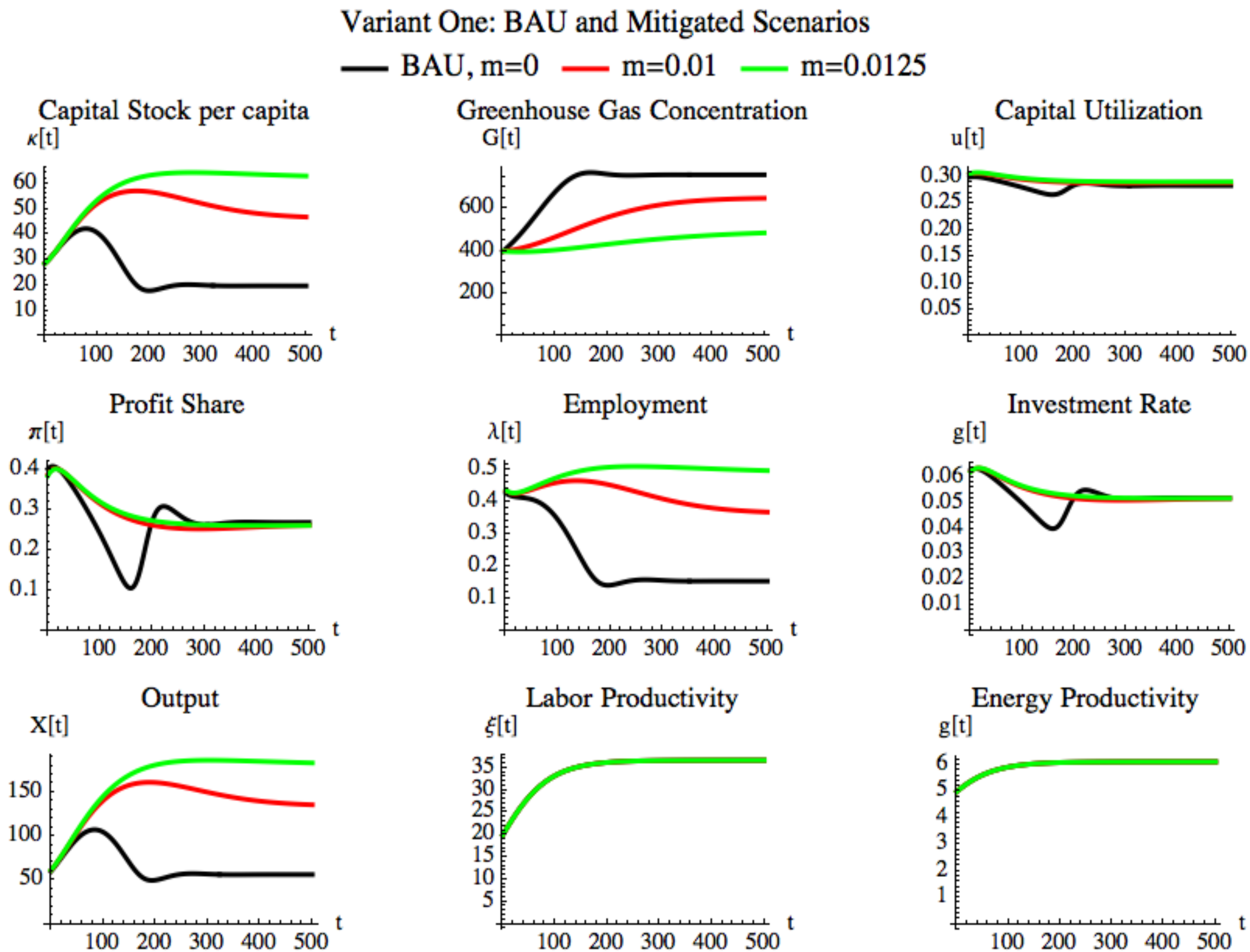
GDAE Leontief Prize presentation 23 March 2015

# Key results from demand-driven model of growth and climate change

In business as usual (BAU) scenario, both atmospheric $CO_2$ concentration ($G$) and the capital/population ratio ($\kappa = K/N$) swing up for 70-80 years.

Then $\kappa$ crashes and stabilizes at a low level (along with output $X$, employment $L$, etc.). $G$ stabilizes as economy stagnates.

This dismal scenario can be countered by "mitigation" of emissions with an outlay of around 1.25% of GDP


Variant One: BAU and Mitigated Scenarios
BAU, m=0
m=0.01
m=0.0125
Capital Stock per capita
κ[t]
Greenhouse Gas Concentration
G[t]
Capital Utilization
u[t]
Profit Share
π[t]
Employment
λ[t]
Investment Rate
g[t]
Output
X[t]
Labor Productivity
ξ[t]
Energy Productivity
g[t]
t

# Key Features I

Quick summary:

Higher capital per capita increases output which in turn increases the speed of $CO_2$ accumulation.

Higher atmospheric $CO_2$ concentration reduces output and growth of capital per capita.

So we have a variation on “typical” predator-prey dynamics – $G$ is the predator and $\kappa$ the prey. After an upswing of $\kappa$ for around eight decades, there is a crash ***of output and capital only***.

# Key Features II

That is, ***$CO_2$ concentration remains high***, blocking any chance of economic recovery. Contrary to familiar wolf-and-moose models, the decay rate of $CO_2$ in the atmosphere is *very* slow (the "wolf" is almost immortal).

In practice the system ***must*** converge to a **stationary state** with constant capital stock, $CO_2$ concentration, etc. Otherwise, $CO_2$ accumulation will overwhelm the economy.

# Key Features III

The model is set up to let output be determined by effective demand along Keynesian lines. Unemployment is possible, and shoots up after a climate-induced crash. Mainstream models assume full employment and Say's Law.

Medium-term adjustment is also "predator-prey"

Output & jobs $\uparrow \Rightarrow$ profits $\downarrow$. Profits $\downarrow \Rightarrow$ output & jobs $\downarrow$ as investment $\downarrow$ (for simplicity this Marx/Goodwin business cycle is suppressed).

# Key Features IV

Profits, investment, and output are also squeezed by rising $CO_2$ concentration $G$. Together with accounting equations for growth in $\kappa$ and $G$, this linkage determines dynamics of the model.

Mainstream models get a similar result by assuming that higher $G$ forces supply of output down directly (with constant employment).

# Energy Use and Productivity growth I

Simulations are set up to reach a stationary state at constant levels of population (initial level = 7 billion, final = 10), energy intensity $e = E/L$ (initial = 4 kilowatts per employed worker, final = 6) and labor productivity $\xi = X/L$ (initial = $20,000/worker, final = $35,000)

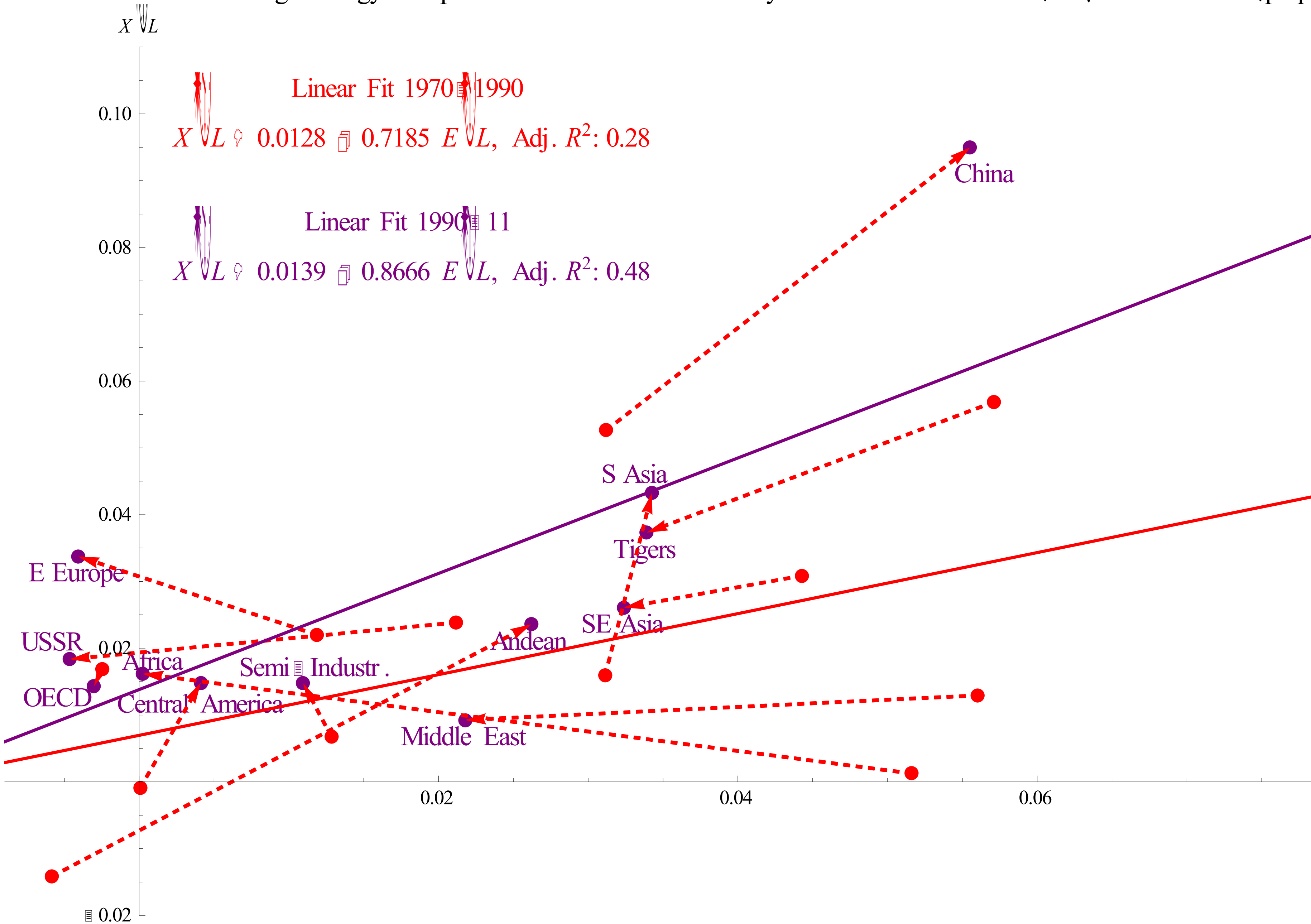
Productivity growth is key to increasing output. How is it determined?

# Energy Use and Productivity growth II

See next slide for empirical linkages between growth rates of $e$ and $\xi$ – strong relationships (due to Gregor Semieniuk) in both cross-section and time series. That is, higher $e$ can be interpreted as pushing up $\xi$.

This linkage is an ostinato theme in ecological economics (Boulding, Daly) and plays a key role in determining the model's results.

Evolution of Average Energy Use per Labor vs. Labor Productivity Growth from 1971-90 (red) to 1990-2011 (purp



# Stationary states with profit squeeze from both high employment and $CO_2$ concentration I

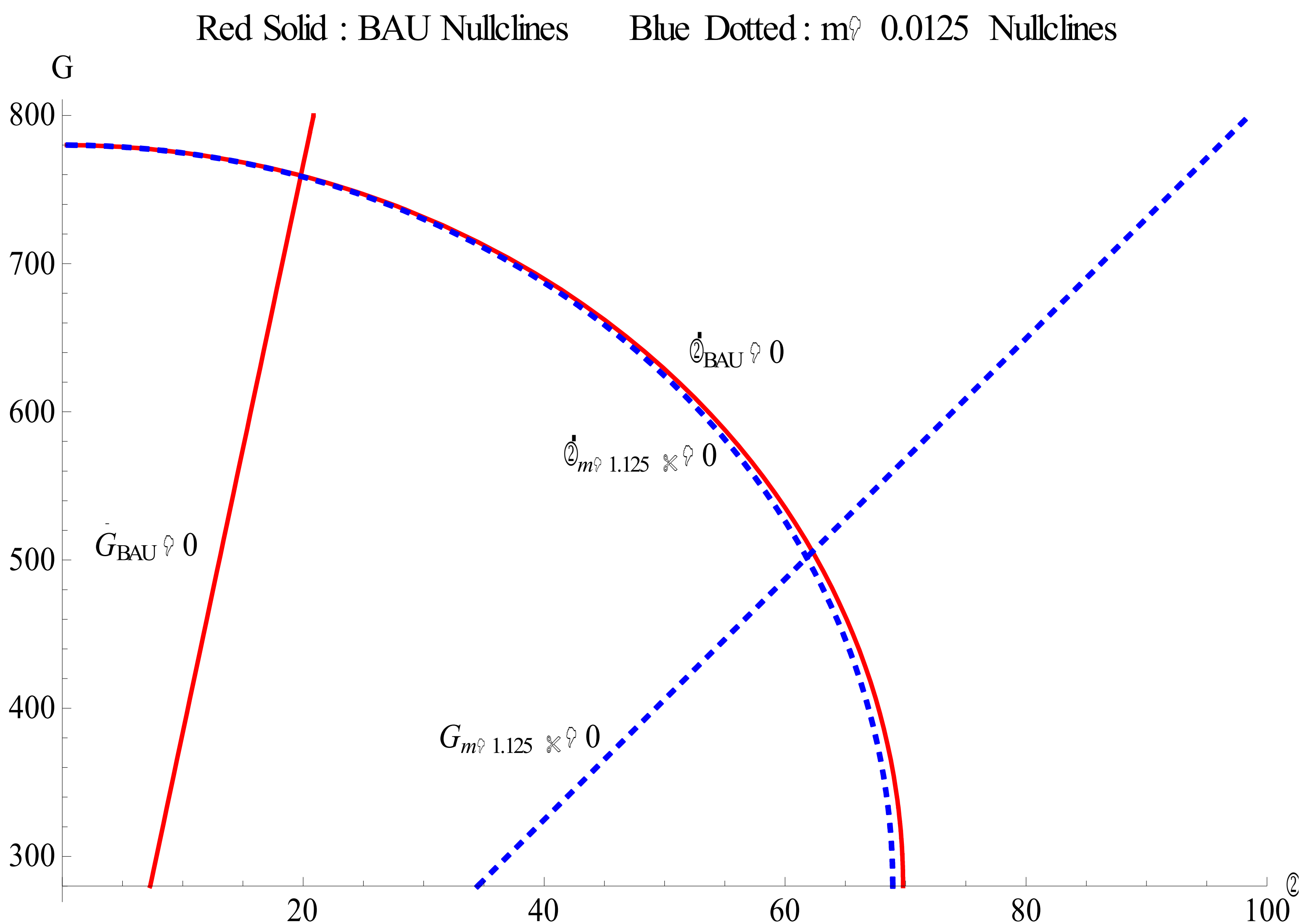
In the stationary state, capital formation is needed only to make up for depreciation at rate $\delta$, i.e.

$$g = I/K = \delta.$$

$G$ and $\kappa$ both push $g$ down so they must trade off along a "nullcline" to hold $g$ constant.

There is also a nullcline for $(\kappa, G)$ combinations that hold $G$ constant. Its slope is sensitive to mitigation $m$ as a share of GDP. A sufficiently high value of $m$ can steer the system away from a dismal BAU steady state.

# Nullclines for per capita capital stock and $CO_2$ concentration (G) when the profit share decreases with both and



# Stationary states with profit squeeze from both high employment and $CO_2$ concentration II

- With no mitigation, $\kappa < 20$ and $G = 759$ in BAU stationary state (Initial values are $\kappa = 28.57$ and $G = 400$.)
- Mitigated stationary state $G = 486$ might correspond to $2.5°\mathrm{C}$ of global warming over the pre-industrial baseline – more than the currently accepted "red line"; BAU steady state with $G = 759$ would mean 5 or 6°C of warming.

# Levels of Key Variables in Steady States

| Profit share decreases with both $\kappa$ *and* $G$ | | | |
|---|---|---|---|
| | Initial value | BAU | Mitigated |
| $G$ | 400 | 759.4 | 486.2 |
| $\kappa$ | 28.6 | 19.8 | 63.0 |
| $X/N$ | 8.6 | 5.6 | 18.3 |
| $\lambda$ | 0.429 | 0.153 | 0.5 |
| Higher $G$ increases depreciation rate | | | |
| $G$ | 400 | 698.6 | 464.7 |
| $\kappa$ | 28.6 | 20.3 | 57.3 |
| $X/N$ | 8.6 | 6.6 | 17.2 |
| $\lambda$ | 0.429 | 0.181 | 0.468 |

# Transient paths to steady state – BAU dynamics I

We set up simulations to track model dynamics toward a steady state. Growth trajectories are affected by assumed rates of increase of population, labor productivity, and energy intensity.

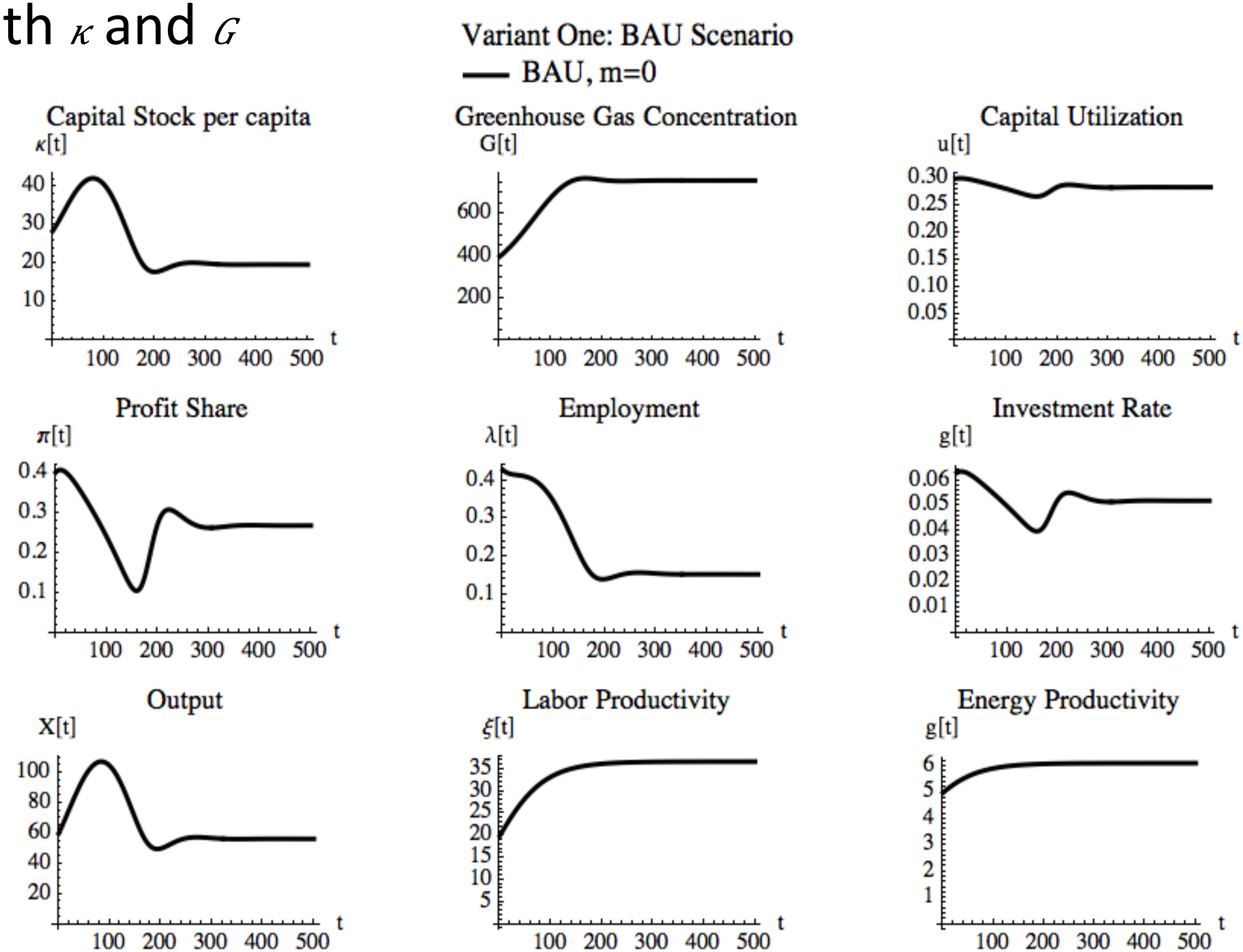
# Transient paths to steady state – BAU dynamics II

Cyclical growth with crashes in capital per capita and output after around 8 decades.

$CO_2$ concentration *stabilizes* at well over 700 ppmv, so an atmospheric temperature increase of 5-6˚ Celsius. Output cannot recover.

Output stabilizes near its initial level of $60 trillion so output per capita falls by around 35% at a final population level of 10 billion.

# BAU simulation when the profit share decreases with both $\kappa$ and $G$



# Transient paths to steady state – Climate mitigation dynamics I

Now look at growth with mitigation at initial cost of \$160 per metric ton of carbon, or \$44 per ton of $CO_2$ (mid-range of current estimates).

With mitigation outlay of 1.25% of world output (\$60 trillion initially) $CO_2$ concentration can be stabilized. This outlay is around one-half of current level of defense spending and roughly twice the level of worldwide energy consumption subsidies.

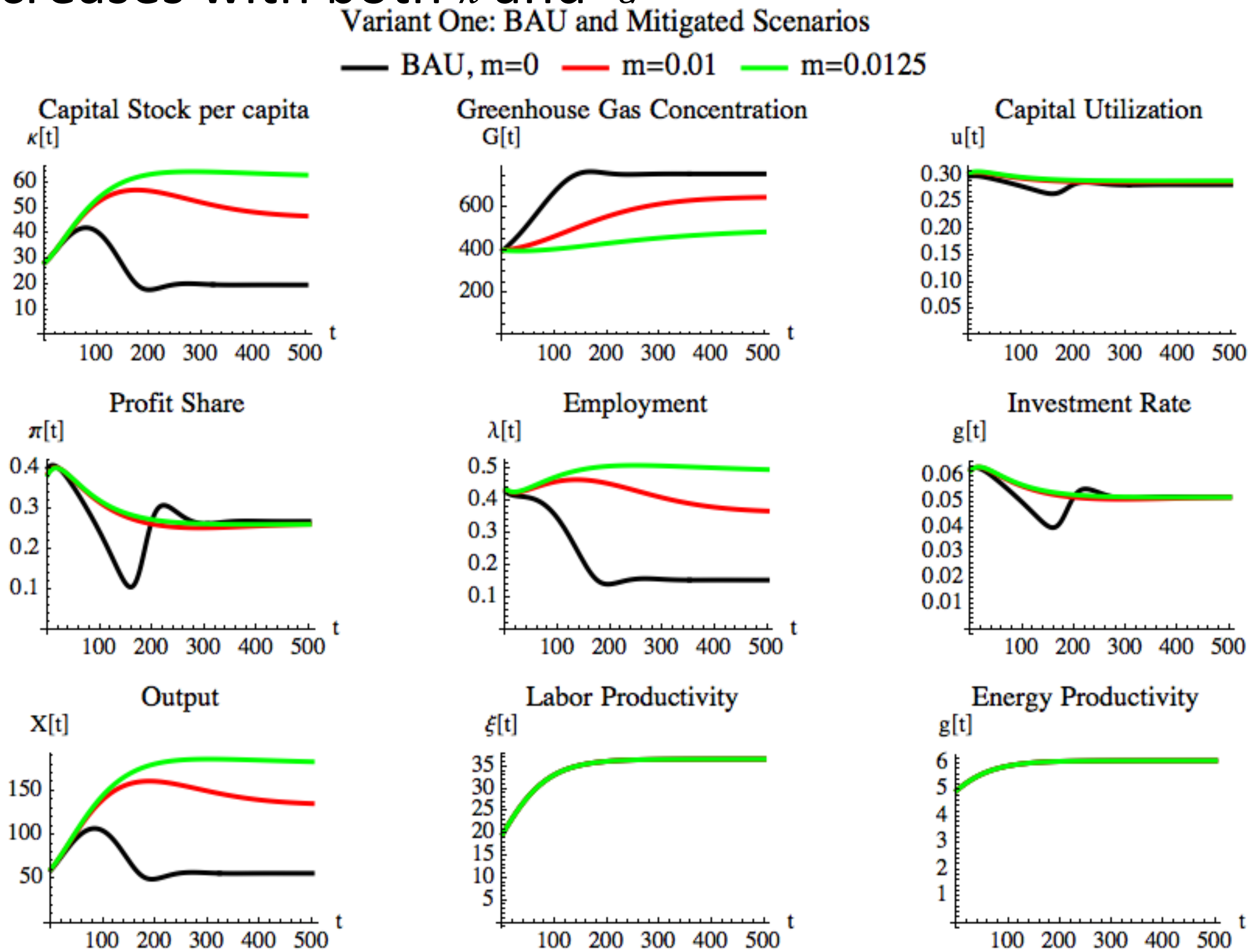
# Transient paths to steady state – Climate mitigation dynamics II

$\kappa$ and $X$ basically follow the growth path to a stationary state that would be observed in the absence of global warming.

BAU and 1.25% mitigation scenarios broadly correspond to the highest and lowest damage paths in the IPCC 2013

"Front-loading" mitigation leads to more favorable results ($G \approx 400$) – a "climate policy ramp" would be harmful.

# BAU and mitigation simulations when the profit share decreases with both $\kappa$ and $G$



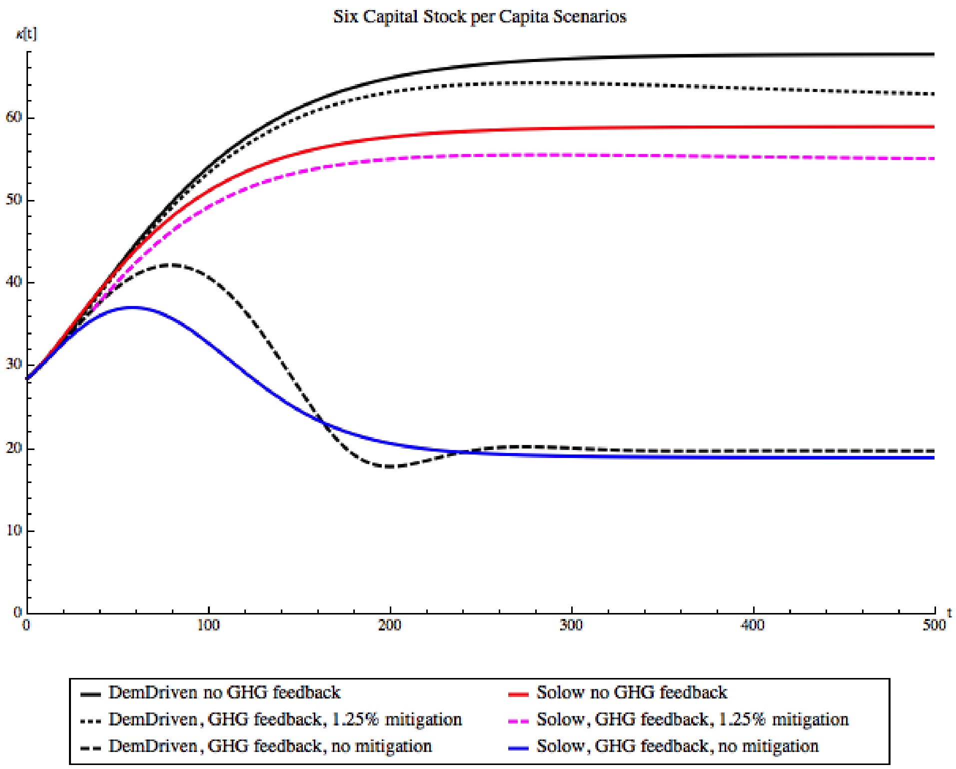
# Transient paths to steady state – Climate mitigation dynamics III

These results are largely driven by convergence dynamics of $\kappa$ and $G$ to stationary levels.

Same basic pattern appears under variant medium-run adjustments, e.g. higher $CO_2$ concentration reduces profitability *or* leads to capital destruction via faster depreciation *or* shifts down a neoclassical aggregate production function in a supply-driven full employment Solow growth model.

# Demand-driven and neoclassical dynamics

**Dynamics of $\kappa$ for demand-driven and neoclassical growth spcifications.**



# Transient paths to steady state – Impacts on labor

BAU stationary state employment/population ratio $\lambda$ is 65% below its initial value due to high $G$, stagnating $X$ and increases over time in $\xi$ and $N$. $\lambda$ rises in mitigated solution.

Wage share = Real wage/Productivity

The wage share stabilizes so that the real wage can rise over time roughly in line with labor productivity.

So BAU gives a high wage (per unit labor) and low employment long run. Mitigated solution is high wage, high employment.

# Acknowledgements

Research supported by the Institute for New Economic Thinking (INET) under a grant to the Schwartz Center for Economic Policy Analysis, New School for Social Research. Thanks to Nelson Barbosa, Jonathan Cogliano, Gregor Semieniuk, Rishabh Kumar, Codrina Rada, Özlem Ömer, and Armon Rezai for invaluable contributions.