Virtual Seminar on Climate Economics

Federal Reserve Bank of San Francisco

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Business Cycles and Climate Policy

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Introduction

- Economists strive to identify "optimal" levels of pollution and environmental regulation
- Costs and benefits of environmental regulation will vary over the course of business cycles
  - Especially true for CO_2

CO_2 emissions are highly pro-cyclical

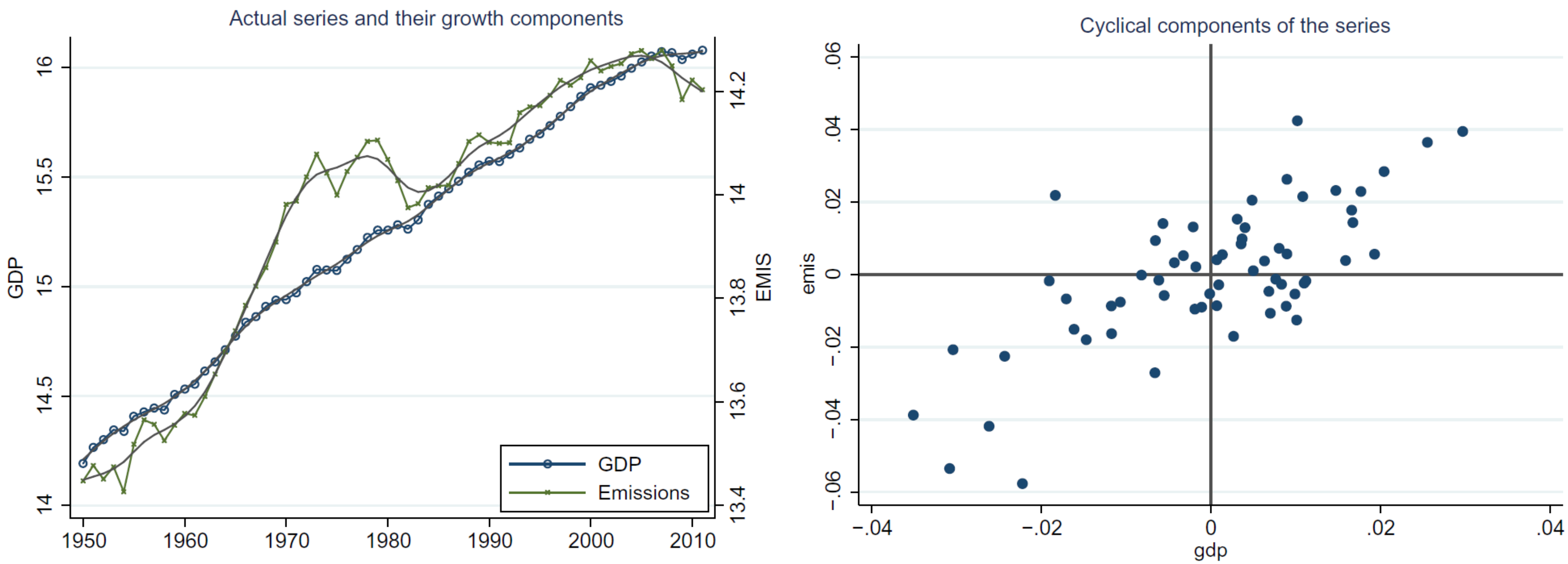
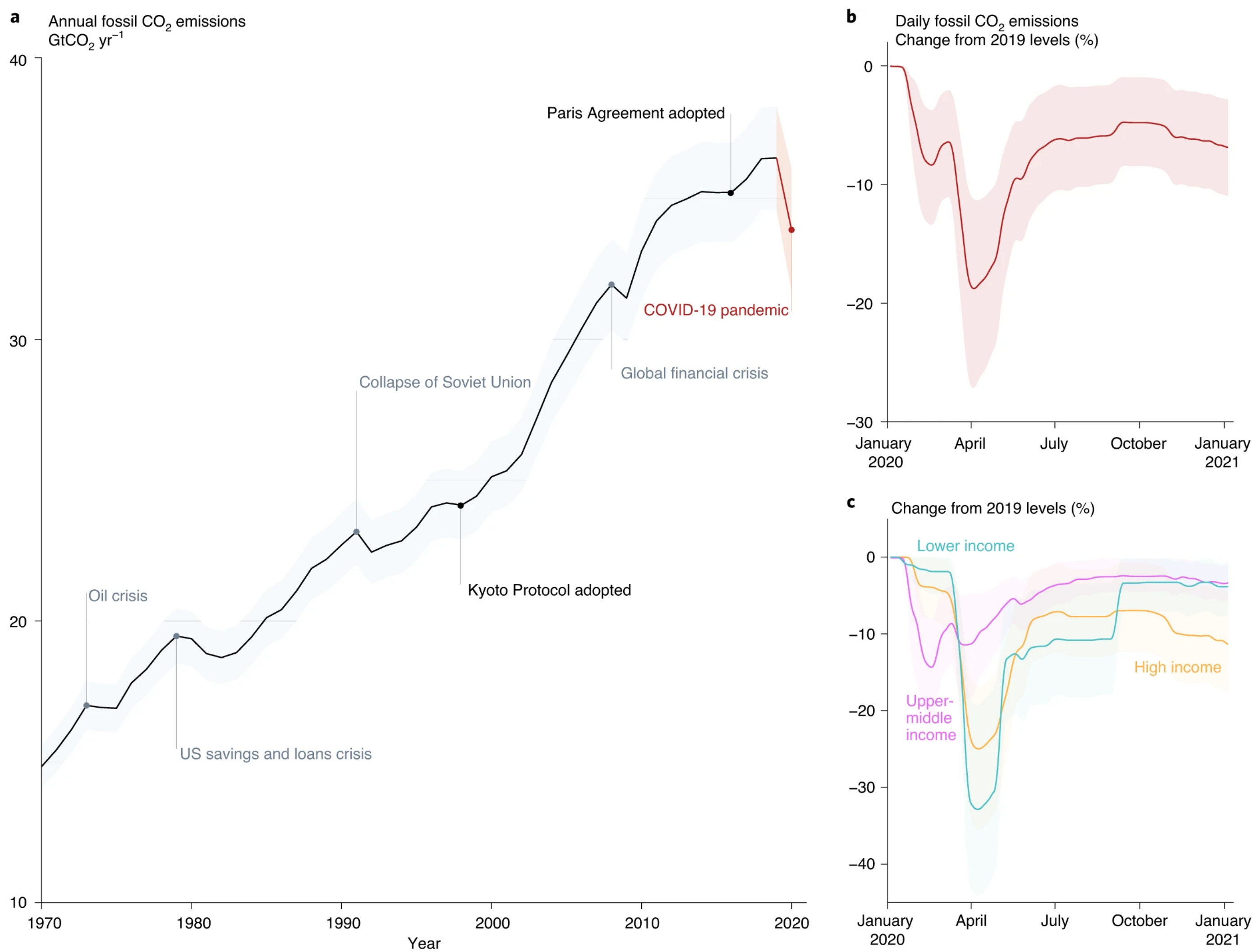


Fig. 1. Growth and cyclical components of GDP and emissions in the US.

Doda, Baran. "Evidence on business cycles and CO_2 emissions." *Journal of Macroeconomics*, 40 (2014): 214-227.

Noticeable impacts of the pandemic



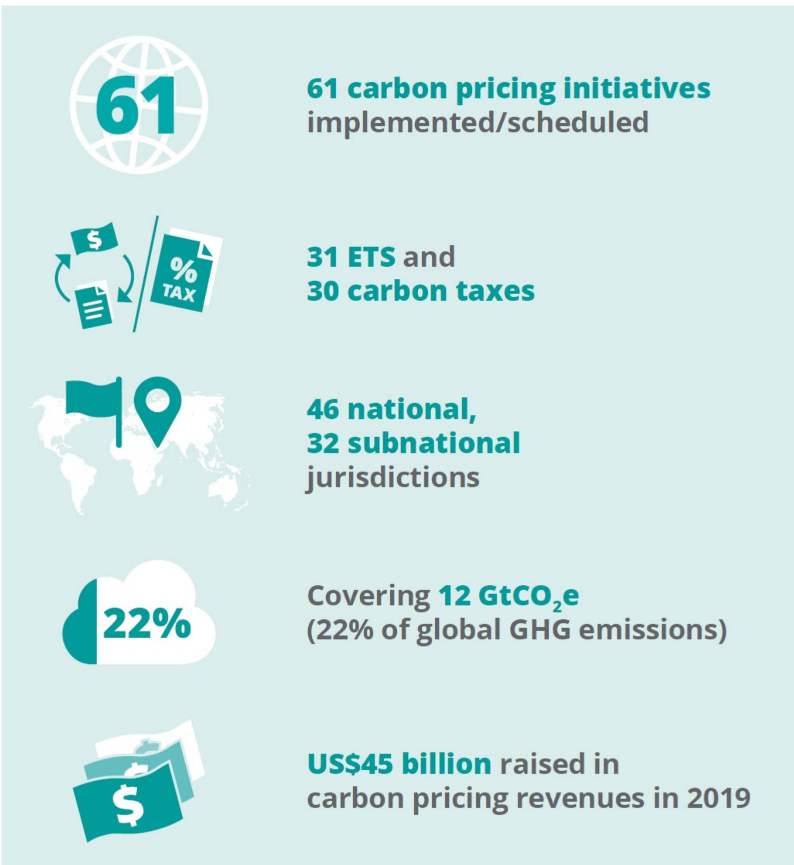
a, Annual emissions for 1970–2019 in $GtCO_2\ yr^{-1}$, including a projection for 2020 (in red) on the basis of the analysis of the Global Carbon Project[1] and their uncertainties (shading; Methods). **b**, Daily change in emissions in 2020 caused by COVID-19 restrictions, compared to a mean day in 2019, for the globe, updated from initial publication in May 2020 (ref. [3]). **c**, As in **b** but for three economic income groups: the Annex B country group of mostly high-income economies with emissions targets under the Kyoto Protocol; upper-middle-income economies (including China) as defined by the World Bank; and lower-middle-income economies and low-income economies (including India) as a single group. Global economic and energy crises are highlighted in **a**, along with key international policy dates.

Le Quéré, C. et al. "Fossil CO2 Emissions in the Post-COVID-19 Era." *Nature Climate Change* 11, no. 3 (2021): 197–99.

Introduction

- Economists strive to identify “optimal” levels of pollution and environmental regulation
- Costs and benefits of environmental regulation will vary over the course of business cycles
- Therefore, climate policy ought to adapt to the business cycle as well
  - Carbon taxes allow emissions to adjust, caps allow prices to adjust, but optimally both should vary
  - Few systems do so in practice

Existing landscape of carbon pricing



World Bank. "State and Trends of Carbon Pricing—2020." Washington, DC, 2020.

- Carbon taxes
  - Some scheduled increases paused in downturns (BC, UK)
- Emissions trading systems (ETS)
  - Some reserve prices
    - CA/QC, Korea
  - Some quantity adjustment
    - RGGI: price triggers
    - EU ETS: bank size triggers in Market Stability Reserve (MSR)
- Little automatic adjustment
  - None really targeted to business cycle conditions

Motivation for our review

- Literature on business cycles and climate policy is now 10 years old and has made a lot of progress
- The COVID-19 recession shows that the business cycle argument can be abused in reactive regulation
  - Excuse to weaken policies not matched with intent to strengthen climate policies in expansions
- Policy sphere has yet to take up many lessons from literature
  - Ideally, policies should not change *ex post* in response to cycles
  - Rather, adjustment rules should be set *ex ante* to remove politics and uncertainty from the process
- We want to inform policy design and identify important open questions

Overview

- How do climate policies influence business cycles, and how should they adapt?
- Review of the literature
  - Initial explorations using real business cycle models
  - New Keynesian extensions
  - Open-economy variations
  - Role of monetary policy
  - Financial regulations.
- Summarize main findings for policymakers
- Propose important remaining research questions

Preview of key policy lessons

- Climate policies influence volatility of outcomes over the business cycle
  - Cap-and-trade reduces while carbon tax exacerbates volatility
- Dynamically-efficient carbon price and quantity are *both* pro-cyclical
  - However, cap adjustments may be counter-intuitive: stringency increases during recessions and decreases during expansions
- Type of shock can matter for policy preference
  - E.g., aggregate productivity, energy efficiency, sector-specific
- Other policies—including monetary policy—and other distortions—e.g., labor or capital market frictions—can affect the efficient cyclicality of policy

Fischer and Springborn (2011)

Heutel (2012)

Angelopoulos et al. (2013)

BASIC REAL BUSINESS CYCLE (RBC) MODELS IN CLIMATE POLICY ANALYSIS

Basic RBC model

- **Representative agent** maximizes expected discounted lifetime utility choosing in each period:
  consumption c_t, **investment** i_t, and **leisure** l_t,
  with single-period utility function $U_t(c_t, l_t)$
- **Resource constraint** is $c_t + i_t = y_t$, where y_t is total output
- **Capital stock** follows $k_{t+1} = i_t + (1-\delta)\, k_t$
- Time (normalized to 1 each period) is allocated between **labor** (n_t) and leisure: $l_t + n_t = 1$
- **Production** based on labor and capital inputs along with a productivity shock: $y_t = a_t f(k_t, n_t)$
- **Productivity shock** a_t is exogenous and evolves according to an autoregressive process

Modified RBC model: incorporating pollution

- Option 1: include a **polluting input $\boldsymbol{m_t}$** choice variable in the production function: $y_t = a_t f(k_t, n_t, m_t)$. The polluting input is costly, so the resource constraint becomes $c_t + i_t + m_t = y_t$.
  - Fischer and Springborn (2011) method, similar to CGE models
- Option 2: let **emissions $\boldsymbol{e_t}$ be a byproduct** of production that can be **reduced through abatement spending $\boldsymbol{z_t}$**. Emissions are the product of an increasing function h of output and decreasing function g of abatement: $e_t = g(z_t)h(y_t)$. The resource constraint is then $c_t + i_t + z_t = y_t$.
  - Heutel (2012) method, based on DICE model (Nordhaus 1993, 2017)

Pollution dynamics

- Nearly all consider stock pollutants, like GHGs, either as
- **Pollution stock** that accumulates with emissions:

$$x_{t+1} = \eta x_t + e_t + e_t^{exog},$$

where η is a pollution depreciation rate and e_t^{exog} is the exogenous level of emissions from other jurisdictions
  - Heutel (2012)
- **Environmental quality stock** variable Q_t that is degraded by emissions and improved by abatement spending:

$$Q_{t+1} = (1 - \delta^q)\bar{Q} + \delta^q Q_t - e_t + \nu z_t,$$

where $\bar{Q}$ is environmental quality without any pollution and δ^q is a pollution persistence parameter
  - Angelopoulos et al. (2013)

Pollution damages

- Pollution can negatively affect utility **directly** via environmental quality Q_t:

$$U_t(c_t, l_t, Q_t)$$

  - Angelopoulos et al. (2013)
- or **indirectly** via output or productivity:

$$y_t = \big(1 - d(x_t)\big)a_t f(k_t, n_t),$$

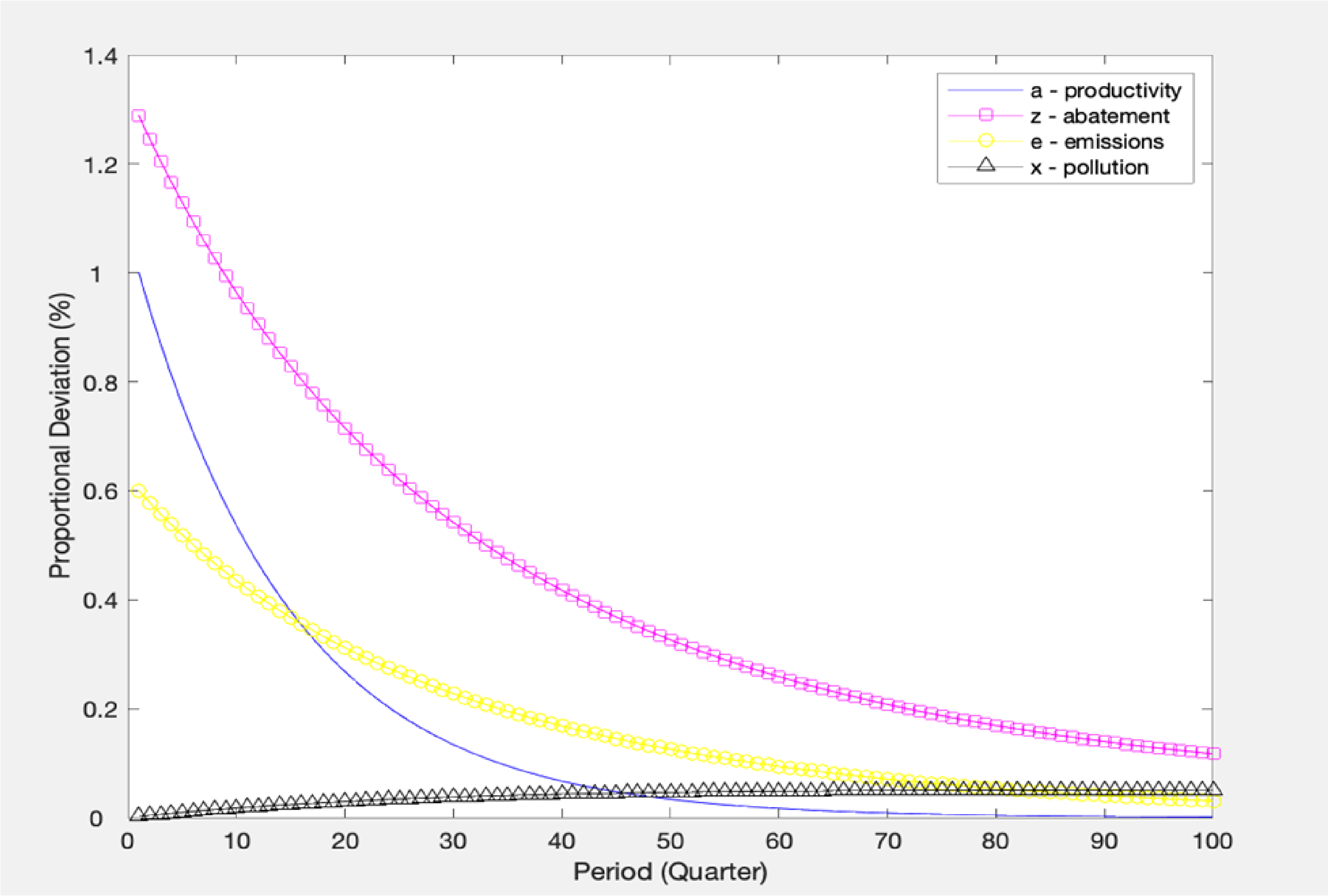
  where d is a damage function that relates the level of the pollution stock x_t to a reduction in output.
  - Heutel (2012)
  - Technique used in many integrated assessment models like DICE

Standard E-DSGE model implementation

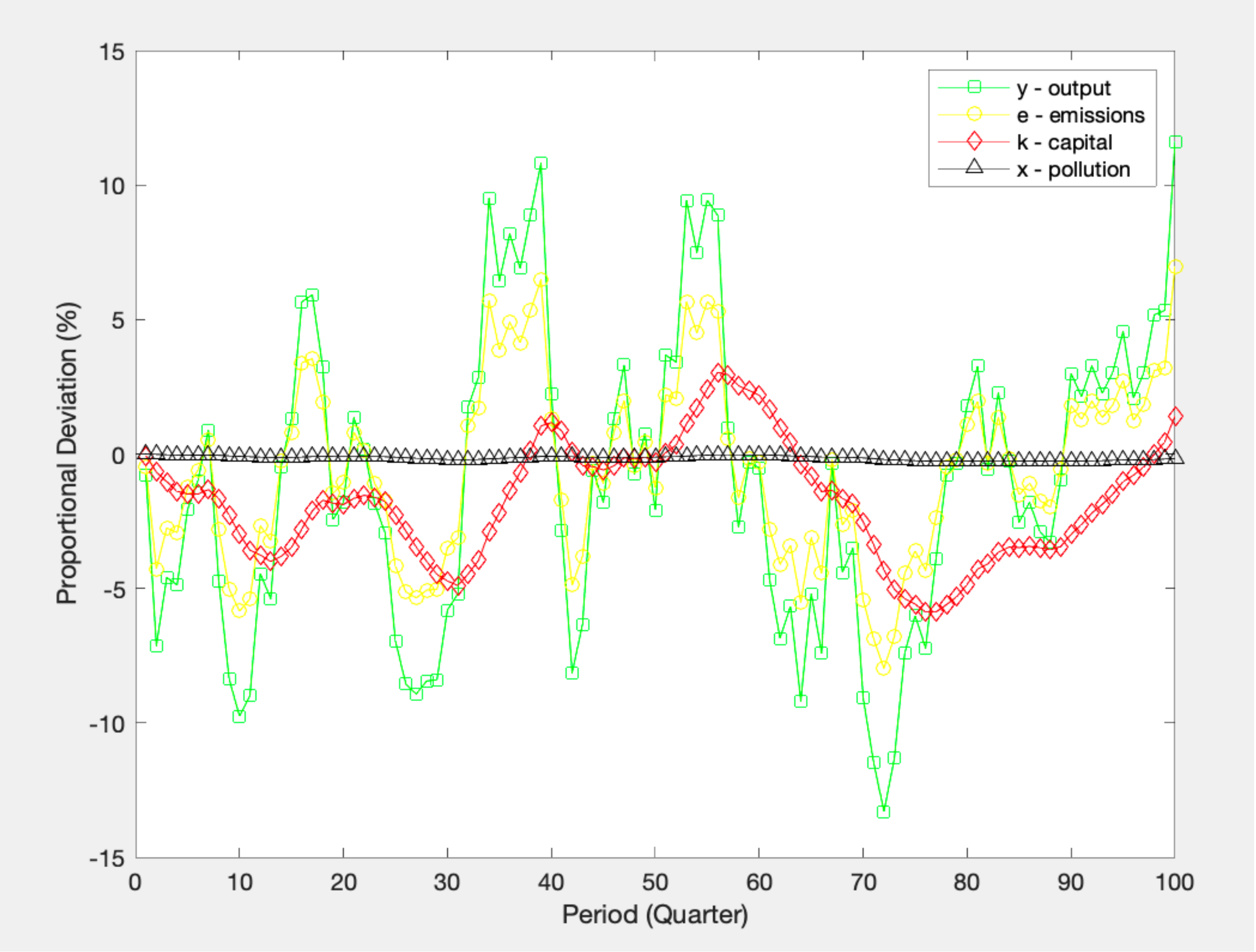
- Solved as planner problem
- Assumptions and implications
  - No involuntary unemployment
  - Prices and wages are completely flexible
  - Neutrality of money, even in the short term
  - Economy continuously at optimum, even during recessions
- Numerical solution
  - Productivity factor evolves according to a first-order autoregressive process that includes i.i.d. random shocks each period.
  - Parameterized with plausible values from the macro literature

Impulse response functions in efficient model

(one-time productivity shock at $t = 0$)



Business cycle simulations
(centralized model, no policy)



Simulations from E-DSGE model in Heutel (2012) with updated calibration

Policy constraints in a decentralized model

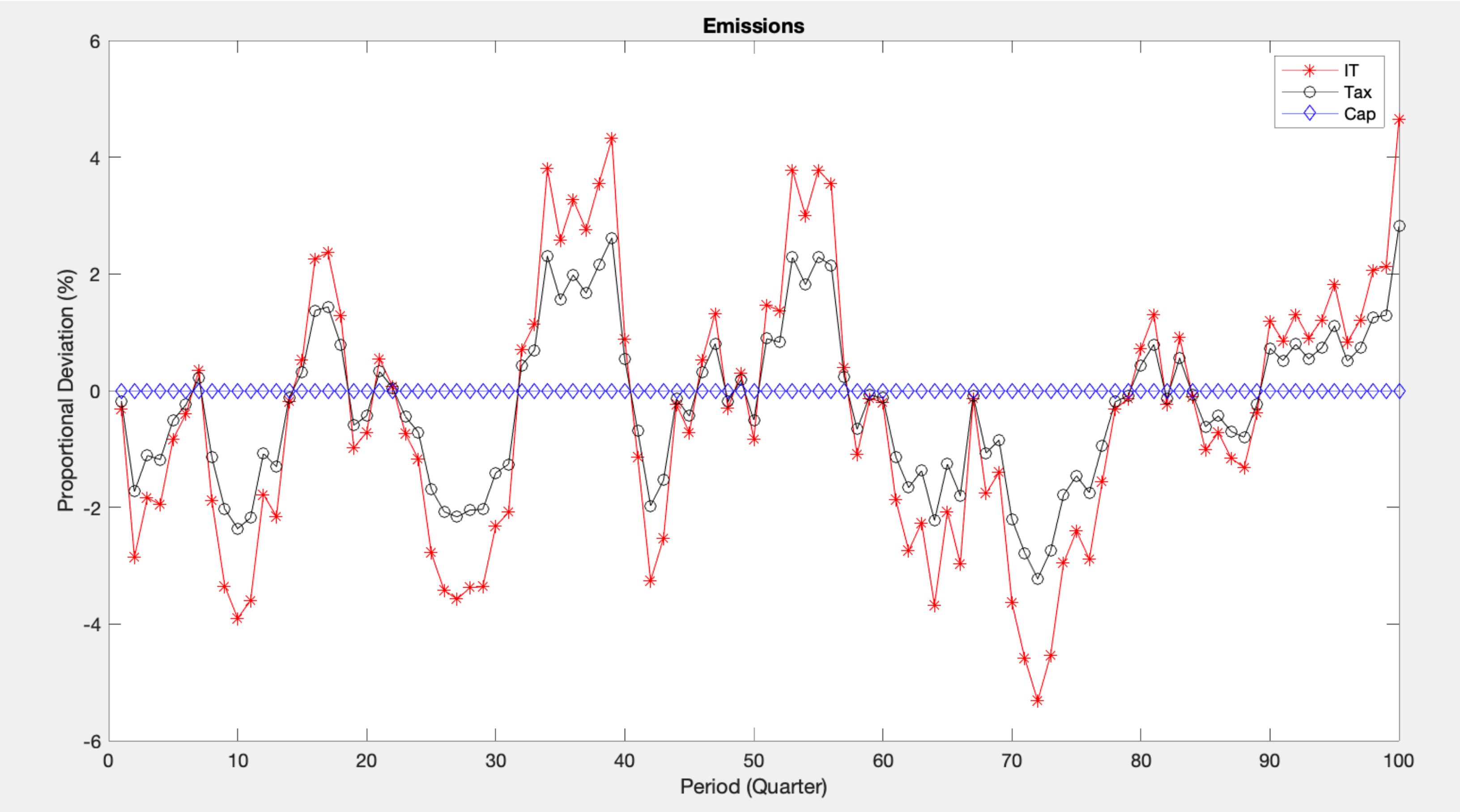
- Emissions cannot exceed pollution allocation, A:

  $$(e_t - A_t(Y_t))\ \phi_t = 0$$

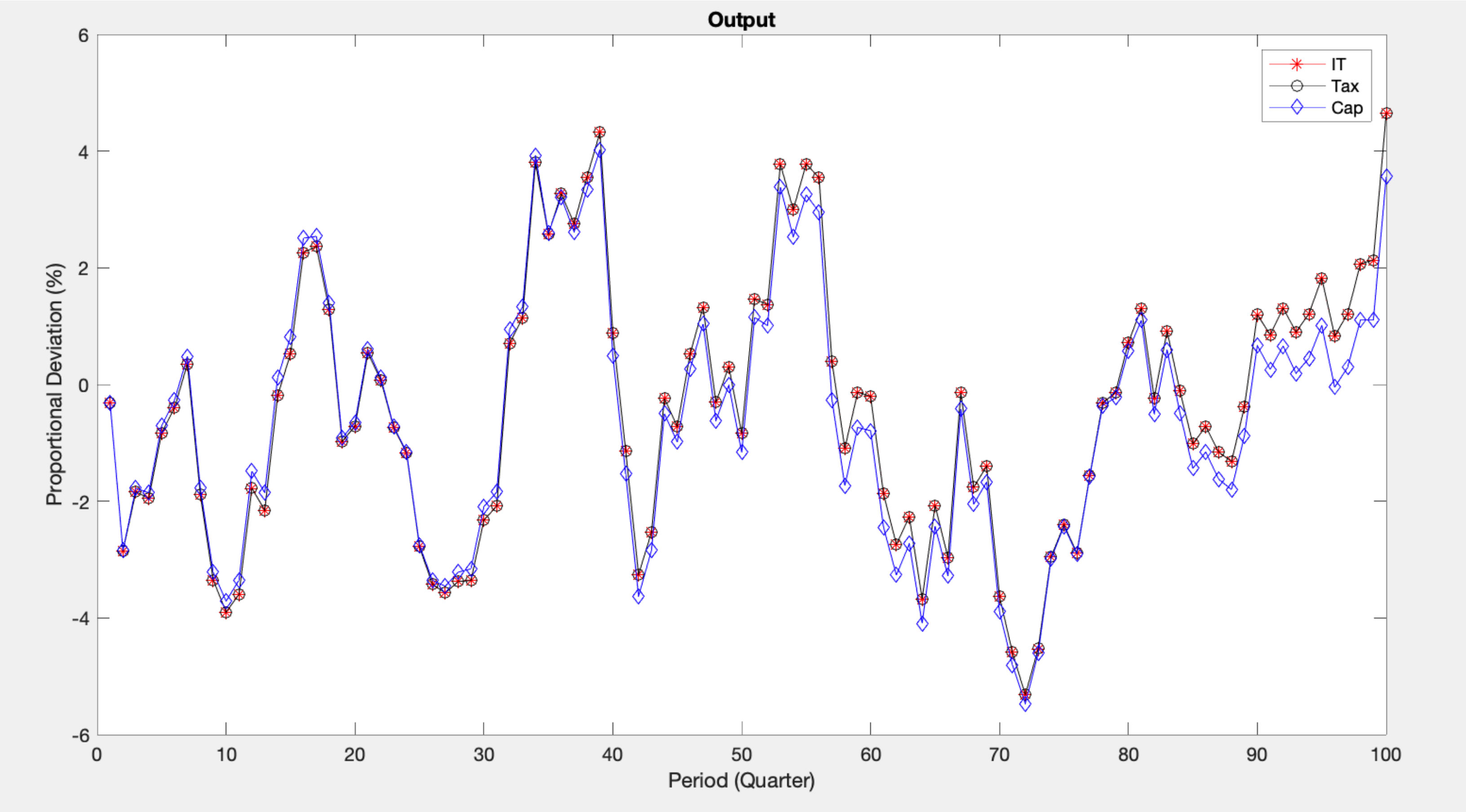
  where ϕ is the shadow value of the constraint
- **Emissions cap**: $A_t(Y_t) = A_{Cap}$
- **Emissions tax**: $\phi_t / \lambda_t = \tau$
  where λ is resource constraint shadow value
- **Emissions intensity target** (IT): $A_t(Y_t) = \mu Y_t$

- As in Fischer and Springborn (2011)

Business cycle simulations: CO_2
(decentralized model, *ex ante* policies)



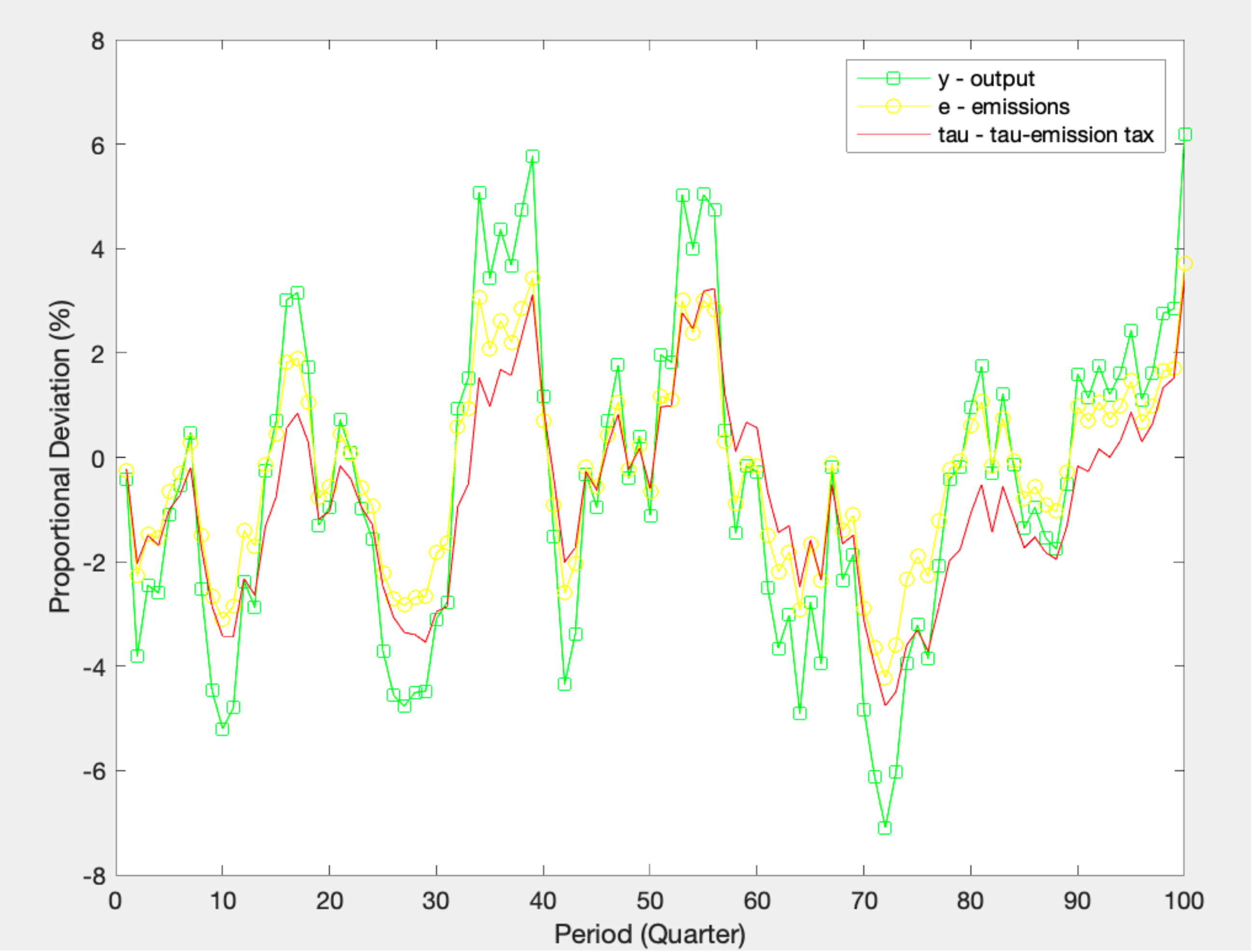
Business cycle simulations: Output (decentralized model, *ex ante* policies)



Effects of non-responsive policies

- While cap and tax can produce equivalent outcomes in expectation, tax may exacerbate volatility
- Cap functions as an automatic stabilizer
  - price increases with unexpected increases in productivity and decreases with unexpected economic cooling
  - labor variance 35% lower (Fischer and Springborn 2011)
- Intensity neither dampens nor exacerbates the business cycle
  - IT allows for greater economic growth
  - allocation of additional permits serves as an inducement for additional production

Business cycle simulations: Efficient policy



Efficient policy responses

- Both the emissions cap and tax are procyclical
- Cyclicality of stringency is different
  - During an expansion, tax should increase, which is an *increase* in stringency
  - Efficient emissions cap also increases, which is a *decrease* in stringency.
- Efficient emissions tax is more procyclical than the efficient emissions cap

EXTENSIONS TO THE BASIC RBC MODEL

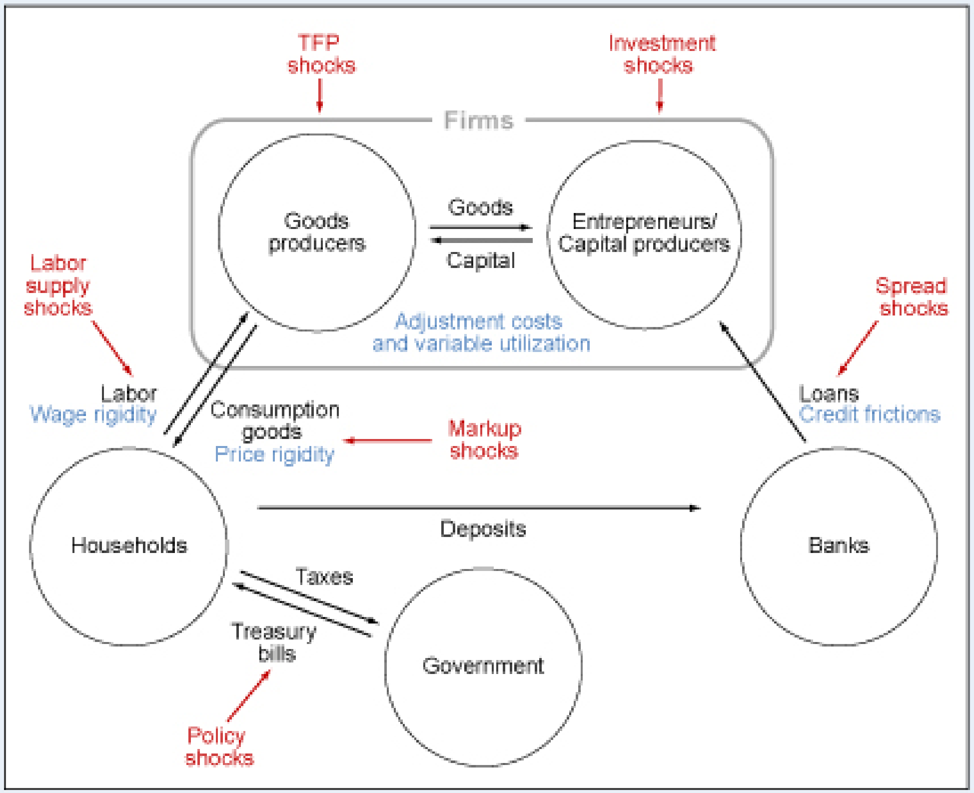
Differentiated sectors:
Dissou and Karnizova (2016)

- Sector-specific productivity shocks
  - 1 services sector, 2 manufacturing (low- and high-energy intensity), and 3 energy sectors (coal, oil&gas, electricity)
- More channels for abatement:
  1) shift from fossil-fuel to cleaner energy;
  2) reduction of the use of energy in production;
  3) substitution of energy for other production inputs
- Smaller aggregate impact of a carbon mitigation policy
- Cap leads to lower volatility than carbon tax
  - but ***only* significantly for productivity shocks in energy sectors**
- Cap is *more costly* in terms of welfare than the cap
  - When cap not binding, permit price is zero → asymmetry between negative and positive shocks, lower mean benefit

Extensions to include different shocks and frictions

A Stylized Description of the Model

---- Frictions ---- Shocks



Note: Chart from Bianca DePaoli, Argia Sbordone, and Andrea Tambalotti, "A Bird's Eye View of the FRBNY DSGE Model," Federal Reserve Bank of New York *Liberty Street Economics* blog, September 23, 2014.

Differentiated technology shocks:

Khan, Metaxoglou, Knittel, and Papineau (2019)

- Emissions response to different shocks is procyclical
- Positive investment shock raises opportunity cost of capital for pollution abatement
  - Abatement becomes more expensive during expansions
- Explaining emissions variation empirically:
  - Investment-specific > technology-neutral shocks
  - Anticipated > unanticipated shocks
  - Government spending / monetary policy shocks: <1%
  - Unidentified structural shock: ~2/3

Labor market frictions:
Gibson and Heutel (2020)

- Job search involves congestion externalities
  - Each job seeker
    - (–) reduces the probability of a match for other unemployed
    - (+) increases match probability for all hiring firms
  - Each vacancy
    - (+) increases the match probability for unemployed workers
    - (–) reduces it for other firms
- If not offsetting
  → labor market inefficiency
  - in addition to emissions externality

Policy response depends on net search congestion externality

Excess vacancies	Excess unemployment

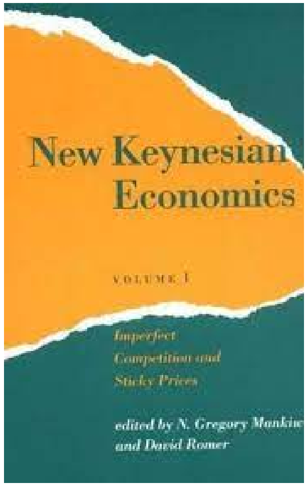
Optimal policy = carbon tax +…

- **tax** on vacancy creation
- **subsidy** to vacancies

If vacancy tax not available, 2nd best carbon tax is…

- much **higher** than 1st best
- **Less** volatile
- **Lower** than 1st best
- **More** responsive to business cycle fluctuations

New Keynesian frictions:
Annicchiarico and Di Dio (2015)



- NK model features
  1) imperfectly competitive markets
  2) **nominal price rigidities** (à la Calvo 1983)
  3) non-neutrality of monetary policy (interest-rate rule)
- Nominal rigidities amplify business cycles
- Optimal emissions tax is **more procyclical** with a higher degree of nominal rigidities
- Stabilizing properties of the **emissions cap** are welfare-improving

Open economies:

e.g., Annicchiarico and Diluiso (2019)

- **International transmission** of the business cycle

  - "**demand channel**" (change in domestic expenditure)
  - "**competitiveness channel**" (changes in relative prices of domestic / foreign production)
- **Cross-border spillover effects** of RBC and monetary shocks are **stronger under a carbon tax**
  - both the demand and competitiveness channels are stronger
- **Linking** cap-and-trade regimes mitigates asymmetric shocks
  - home and foreign outputs move in opposite directions
- **Degree of openness, trade patterns, exchange rate regime** (i.e. currency union or flexible exchange rates) affect the conditioning role of environmental regulations in the transmission of shocks

Small open economies

- Holladay et al. (2019): Canada
  - **cap-and-trade** regulation **mitigates business cycle effects on the trade balance** by reducing imports during a recession and exports during an expansion
- Economides and Xepapadeas (2019): Greece
  - **Negative climate shocks entail significant deterioration** in competitiveness, external balance, and output
  - Underlying exchange rate regime has little influence, so **autonomous monetary policy does not help** manage climate change

Climate change and financial markets

- Systemic risks
  1) Physical: damages to assets
  2) Liability: exposure to legal action
  3) **Transition**: abrupt devaluation of carbon-intensive assets
- Disorderly transition could lead to stranded assets
  - Unanticipated changes in policies, technologies or public sentiment
  - **Could trigger broader procyclical market dynamics**
- Empirical support
  - Carbon-intensive stocks make up substantial portion of portfolios
    - e.g. Battiston et al. 2017
  - Stock markets not internalizing transition, but rather short-term changes in probability of ambitious climate policy
    - Ramelli et al. 2018, Carattini and Sen 2019, Barnett 2020, Sen and von Schickfus 2020

Credit market imperfections

- More ambitious environmental policies lower profits and undermine borrowing capacity of firms
- In a recession, **credit constraints** are more binding, requiring a further reduction of the carbon tax
  – van den Bijgaart and Smulders (2018)

- Collateral constraints on borrowing can lead to **credit amplification**: sudden fall in value of carbon-intensive assets may precipitate a fire sale across the economy, triggering a recession
  – Comerford and Spiganti (2017), à la Kiyotaki and Moore (1997)

Green financing and financial market frictions

- **Differentiated capital requirements**
  - can help to sustain green investments, while lowering the volatility of business cycle fluctuations (Punzi 2018)
- **Green biased quantitative easing** policies
  - useful short-term countercylical tool
  - less so for structural change (Benmir and Roman 2020)
  - Effective but no better at reviving the economy than market-neutral programs (Diluiso et al. 2020; Ferrari and Nispi Landi 2020)
- Macroprudential options **no substitute for carbon pricing**
  - Alone not very effective at reducing greenhouse gas emissions
  - Can limit the risk of a recession from the abrupt implementation of carbon taxes, thus clearing the way for ambitious policies
    - Carattini et al. (2021)

POLICY LESSONS

Pro-cyclical climate policies

- Optimal carbon price is pro-cyclical, more so when
  - unemployment is inefficiently high
  - prices are sticky
  - trade is more open
  - credit is constrained
- Accommodation can mitigate these extra needs to adjust
- Comparing options: cap-and-trade programs reduce volatility, but their price adjustment overshoots optimal
  - May still be better aligned than fixed tax
    - Contrast to Weitzman-inspired literature, which tends to favor taxes
  - Still unclear how large welfare differences are, esp. for stock pollutants
    - Lintunen and Vilmi (2013); Heutel (2012)

Automating adjustments

- Needs credible, transparent rules, set in advance
  - help stabilize expectations and reduce uncertainty
- Taxes
  - Perception advantage: stringency loosens in recessions
  - Manual adjustment impossible: set by legislation
  - Could index to consumption
- Emissions trading systems
  - Flexibility mechanisms exist; could be adjusted for a business-cycle based trigger
  - Intertemporal trading may also help
- Intensity standards automatically scale with output

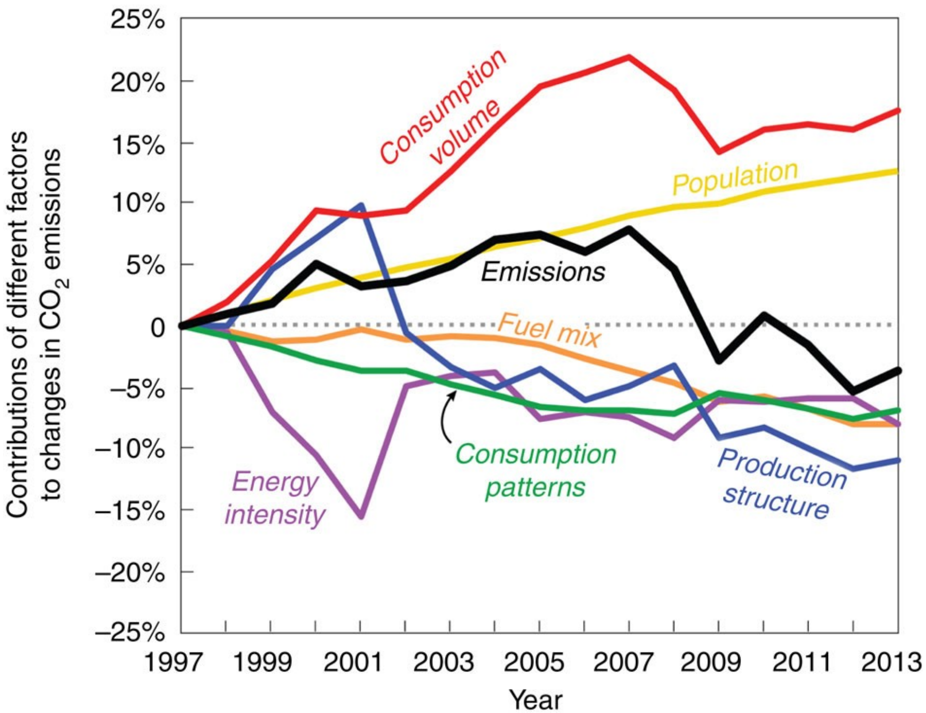
FUTURE RESEARCH OPPORTUNITIES

Heterogeneity, equity, and distributional concerns

- **Households** differ
  - **Equity**: cyclical adjustments affect revenues available for redistribution
  - Distribution of **employment** impacts
  - Intergenerational **wealth** reallocation

- **Firms** differ
  - **Entry and exit** of heterogeneous firms shape aggregate fluctuations and job creation/destruction
  - Climate policy affects firm dynamics and composition of sectors and the economy

Different kinds of shocks



https://www.nature.com/articles/ncomms8714/figures/1

- Many factors influence emissions and may respond differently to shocks
- Energy-efficiency shocks
  - can lead to negative correlation between output and emissions
    (Jo and Karnizova 2021)
- Monetary policy
- Financial
- Demand
- Sector specific…

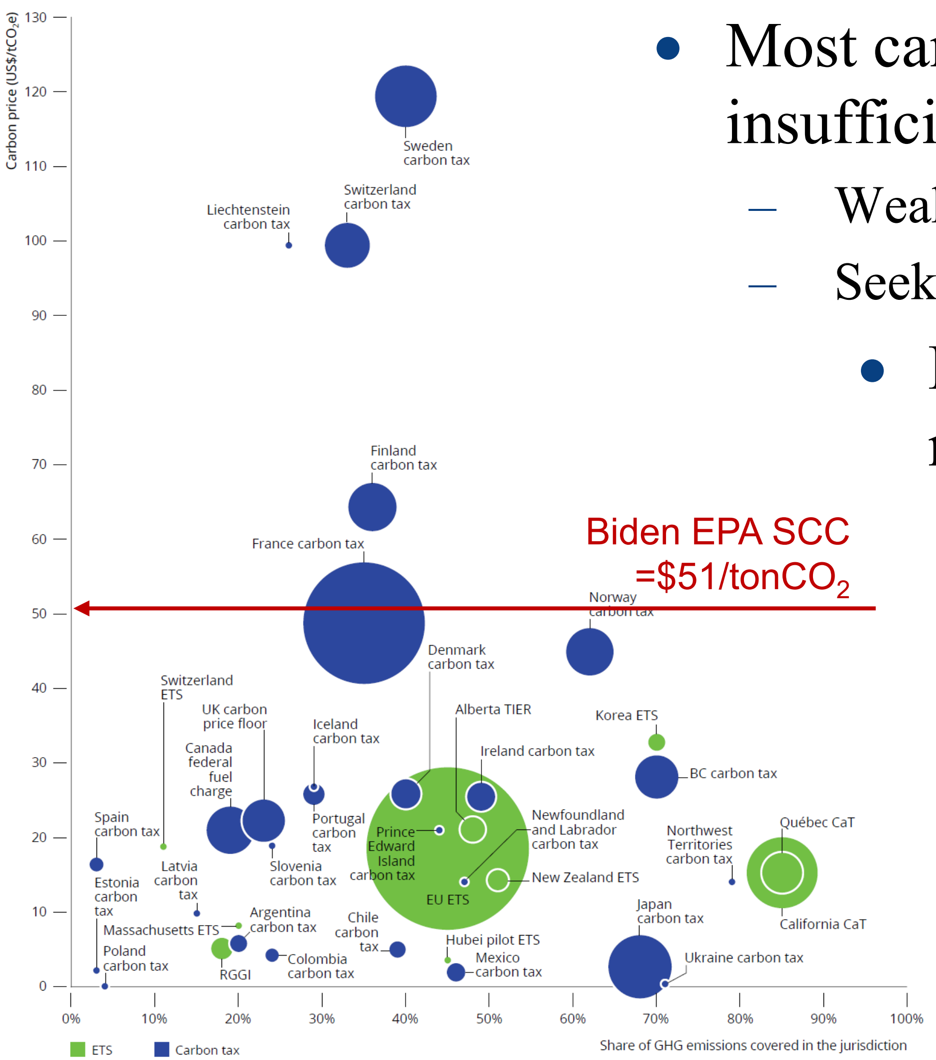
Policy interactions

- Fiscal policies
  - Carbon revenue recycling and tax distortions
  - Green stimulus
- Regulatory mandates
  - Energy efficiency
  - Renewable or clean energy standards
  - Electrification of vehicles

- Trade and carbon border adjustment mechanisms
- Green macroprudential tools
  - brown-penalizing and green-supporting capital requirements
  - green-biased liquidity regulation
  - differentiated reserves requirements

Adjustments to suboptimal policies

Figure ES.4 / Carbon price, share of emissions covered and carbon pricing revenues of implemented carbon pricing initiatives

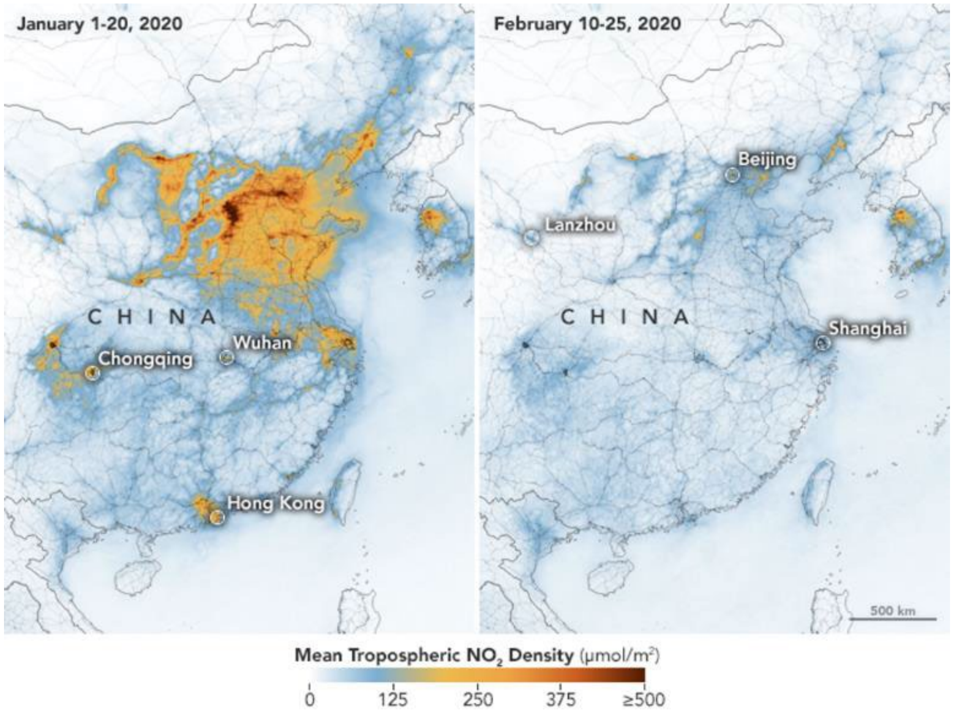


- Most carbon pricing policies are insufficiently stringent
  - Weakens case for adjusting to cycles?
  - Seek asymmetric adjustments?
- Role of other flexibility mechanisms?
  - Banking and borrowing, expectations and transmission of shocks (Pizer and Prest 2020)
  - Auction reserve prices
  - Carbon levy top-ups
  - Market stability reserve
- Non-pricing policies

https://openknowledge.worldbank.org/bitstream/handle/10986/33809/211586figures.pdf

Other pollutants

- Conventional air pollutants can be even more cyclical than CO_2
  - Flow pollutants
- They also affect labor productivity



- Stronger rationales for self-adjusting policies?
- Reverse effects: climate change and pollution as a *source* of macroeconomic shocks

Thanks!

- This paper is prepared for the NBER's *Environmental and Energy Policy and the Economy* conference and publication.

- Comments welcome!