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 CO₂
CO$_2$ emissions are highly pro-cyclical

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

Noticeable impacts of the pandemic

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

- Carbon taxes
  - Some scheduled increases paused in downturns (BC, UK)

- Emissions trading systems (ETS)
  - Some reserve prices
    - CA/QC, Korea
  - Some quantity adjustment
    - RGGEI: price triggers
    - EU ETS: bank size triggers in Market Stability Reserve (MSR)

- Little automatic adjustment
  - None really targeted to business cycle conditions

61 carbon pricing initiatives implemented/scheduled
31 ETS and 30 carbon taxes
46 national, 32 subnational jurisdictions
Covering 12 GtCO₂e (22% of global GHG emissions)
US$45 billion raised in carbon pricing revenues in 2019

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 \textit{ex post} in response to cycles
  - Rather, adjustment rules should be set \textit{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** $m_t$ 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 $e_t$ be a byproduct of production that can be **reduced through abatement spending** $z_t$. 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 $c_t + i_t + z_t = y_t$.
Pollution dynamics

- Nearly all consider stock pollutants, like GHGs, either as

- **Pollution stock** that accumulates with emissions:

  \[ x_{t+1} = \eta x_t + e_t + e_t^{\text{exog}}, \]

  where \( \eta \) is a pollution depreciation rate and \( e_t^{\text{exog}} \) 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 \( \delta^q \) 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:
  \[ y_t = (1 - d(x_t))a_tf(k_t, n_t), \]
  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 $\phi$ is the shadow value of the constraint

- **Emissions cap:** $A_t(Y_t) = A_{Cap}$

- **Emissions tax:** $\phi_t / \lambda_t = \tau$
  where $\lambda$ 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 \(\rightarrow\) asymmetry between negative and positive shocks, lower mean benefit
Extensions to include different shocks and frictions

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

Optimal policy = carbon tax +…

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

Excess unemployment

If vacancy tax not available, 2\textsuperscript{nd} best carbon tax is…

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

- 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
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 countercyclical 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)
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

- 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...

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

- 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

Figure E5.4 / Carbon price, share of emissions covered and carbon pricing revenues of implemented carbon pricing initiatives

Biden EPA SCC = $51/tonCO₂

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!