Task-Level Fiscal Policy for the Green Transition:
Moving Beyond Binary Classifications

Shisham Adhikari (UC Davis)

July 27, 2025

Motivation: The Climate Transition Needs Better Tools

- Emissions must fall 45% by 2030, net-zero by 2050 to meet the 1.5°C goal [United Nations, 2023].
- Countries are deploying large-scale green subsidies (e.g., IRA, EU Green Deal).
- These raise three key macro questions:
  - How should subsidies be designed?
  - What trade-offs do they involve?
  - How should they be financed?
- Standard macro models treat sectors as either "green" or "dirty" — missing the complexity of real-world production.

Motivation: A Task-Based View of Green Production

- Production is a continuum of tasks with varying environmental footprints.
- Example: EV production spans mining to assembly — each task has different green potential.
- This paper:
  - Builds a GE model with a continuous greenness index.
  - Allows green vs. traditional input choice at the task level.
  - Captures task-level productivity and skill complementarity.
- **Goal:** Assess when green subsidies are effective, welfare-improving, and fiscally efficient.

Project Framework

1. Research Questions
   - How effective are green input subsidies in promoting the use of green inputs that improve environmental quality?
   - What are the welfare implications of green input subsidies?
     - Are green input subsidies always welfare-improving?
     - What is the least welfare-distorting method of financing these subsidies?

2. Methodology
   - Adapt Acemoglu and Restrepo [2018]'s task-based model for the green transition.
   - Calibrate the model to US labor market data.
   - Perform consumption-equivalent welfare analysis to equalize welfare across states.

3. Findings
   - The effectiveness of green input subsidies depends on the relative productivity of green versus traditional inputs.
   - For the subsidy to be welfare-improving, the positive externality from green inputs must be substantial (equivalent to a 4.3% increase in consumption).
   - Lump-sum tax is least distortionary, followed by capital income tax, and then labor income tax.

Literature and Contribution

1. Targeted Green Policies
   - *Taxes:* Nordhaus and Boyer [2000]; Angelopoulos et al. [2010]; Fischer and Springborn [2011]; Heutel [2012]; Golosov et al. [2014]; Hassler et al. [2016]; Fried [2018]; Barrage and Nordhaus [2023]; Traeger [2023].
   - *Subsidies:* Newell et al. [2019]; Palmer and Burtraw [2005]; Fischer and Newell [2008]; Hassler et al. [2020]; Casey et al. [2023]; Benkhodja et al. [2023].

   → *Contribution:* Relative productivity is relevant for green production/input subsidies' effectiveness.

2. Task-Based Models: Tools for Structural Transformation (Automation)
   - Key References: Acemoglu and Autor [2011]; Acemoglu and Restrepo [2018]; Hémous and Olsen [2021]; Vona et al. [2019]; Vona et al. [2018]; Vona [2021].

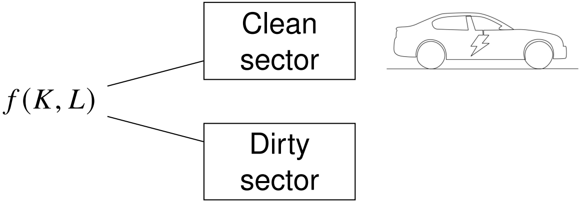
   → *Contribution:* Adapt the task-based framework for the green transition.

3. Green Transition and Labor Market
   - *Labor Productivity:* Zivin and Neidell [2012]; Fullerton et al. [2012]; Hsiang et al. [2017]; Zivin and Neidell [2013].
   - *Green Policies* $\implies$ *Labor:* Martinez-Fernandez et al. [2010]; Bowen and Kuralbayeva [2015]; Popp et al. [2020]; Vona et al. [2021].

   → *Contribution:* Focus on green labor input and labor market policy.

How to think of task-based model?

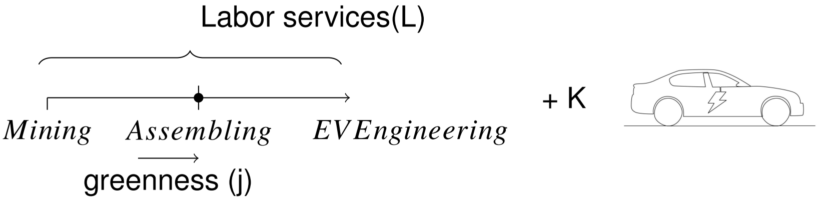
Binary sectoral approach



A task-based model offers:

- A continuous measure of greenness.
- Dynamic mapping between production tasks and productive factors.

Task-based approach



Summary of the Paper

1. Adapt Acemoglu and Restrepo [2018]'s task-based approach to analyze the green transition.
    - A continuum of tasks, ordered by a greenness index [Vona et al., 2018], is required to produce a good.
    - Each task can be performed using either green (labor) input or traditional (labor) input, with relative productivity varying across tasks [Vona et al., 2019].
2. Environmental quality improves when green inputs are used:

   $$u(C, L^n, L^g) = \ln C + \eta \ln(1 - L^g - L^n) + \ln E \quad E = e^{\psi \int_{N-1}^{N} l_j^g \, dj}, \quad \psi > 0$$ [1]
3. Characterize the misallocation of green (labor) inputs by comparing the competitive equilibrium (CE) to the social planner's problem (SPP).
4. Evaluate the effectiveness of subsidizing the cost of using green (labor) input.
5. Calibrate the model to analyze how productivity schedules impact subsidy effectiveness.
6. Conduct welfare analysis of the subsidy and explore various funding mechanisms.

[1] Aghion et al. 2024 uses a similar externality from underlying technology.

Task-based Modelling Choices

- *Core Concept:* Tasks are fundamental units of productivity; skills enable task performance.
- *Production:* Divided into tasks; labor with varying skills competes for tasks.
- *Green Tasks:* Measured by Vona et al. [2018] using O*NET data.

$$\text{Greenness}_k = \frac{\#\text{green specific tasks}_k}{\#\text{total specific tasks}_k}$$

  - High Greenness: Environmental Engineers
  - Low Greenness: Mining

- *Green skills :* Based on General Green Skills measured by Vona et al. [2019].

Model Structure

- Firms: $Y = K^{\alpha} L^{1-\alpha}$, $L = \left(\int_{N-1}^{N} t_j^{\frac{\chi-1}{\chi}} \, dj \right)^{\frac{\chi}{\chi-1}}$, and $t_j = \gamma_j^n l_j^n + \gamma_j^g l_j^g$.
- Everything else standard except in task-based model,

$$L = \left(\left(\int_{N-1}^{J} (\gamma_j^n)^{\chi-1} \, dj \right)^{\frac{1}{\chi}} (L^n)^{\frac{\chi-1}{\chi}} + \left(\int_{J}^{N} (\gamma_j^g)^{\chi-1} \, dj \right)^{\frac{1}{\chi}} (L^g)^{\frac{\chi-1}{\chi}} \right)^{\frac{\chi}{\chi-1}}.$$

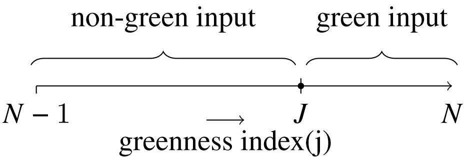
Factor share influenced by J is endogeneously determined.

- *Key Assumption:* $\frac{\gamma_j^g}{\gamma_j^n}$ is continuously differentiable and increasing in j.[2]

[2] Definition of green skills based on Vona et al. [2019] are based on the skills required for green jobs in Vona et al. [2018].

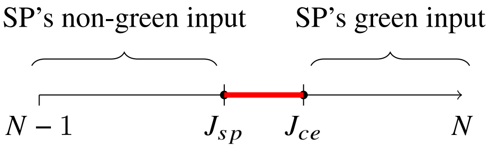
Competitive equilibrium vs. Social Planner's Task Allocation J

- Market allocates tasks based on relative effective costs $J : \frac{\gamma_J^g}{\gamma_J^n} = \frac{W_g}{W_n}$.



- There exists an environmental benefit of using green inputs on performing tasks:

  Households: $u(C, L^n, L^g) = \ln C + \eta \ln(1 - L^g - L^n) + lnE \quad E = e^{\psi \int_{N-1}^{N} l_j^g dj}, \quad \psi > 0.$
- *Given externality*, a Social Planner allocates more tasks to green input than what a CE would.



Implementation and Effectiveness

1. *Implement* $J_{sp} < J_{ce}$ using the following task-specific green input subsidy:[3]

$$\tau_j^g = \begin{cases} 0 & \text{if } j \le J_{sp} \\ 1 - \frac{Y_{L^n}}{Y_{L^g}} \frac{\gamma^n(j)}{\gamma^g(j)+\psi} \ge 0 & \text{if } j > J_{sp} \end{cases}$$

2. *Effectiveness* of the subsidy depends on the relative productivity schedule:

$$J : \frac{\gamma_J^g}{\gamma_J^n} = \frac{W_g}{W_n} \implies d\ln J = \frac{1}{\epsilon_{\bar{\alpha},J}}(d\ln\omega), \quad \text{where } \epsilon_{\bar{\alpha},J} = \frac{d\ln\left(\frac{\gamma_J^g}{\gamma_J^n}\right)}{d\ln J}.$$

[3] Intuition: The subsidy increases the cost-competitiveness of green labor for tasks where it's less productive than non-green labor, capturing the added environmental benefits.

Model Calibration: Parameters

- Standard RBC parameters: $\alpha = 0.33$, $\beta = 0.99$, $\delta = 0.025$, $\eta = 1$; other key parameters:

Parameter	Value	Description	Source
χ	1.5	Substitution elasticity between green and traditional input	Papageorgiou et al. [2017], Casey et al. [2023]
ψ	0.4	Externality weight[4]	Angelopoulos et al. [2010]

- Relative productivity schedule formulation: $\frac{\gamma_j^g}{\gamma_j^n} = \frac{A \cdot j^{\nu g}}{B \cdot (1-j)^{\nu n}}$; normalize $\gamma_j^n = 1 \implies \frac{\gamma_j^g}{\gamma_j^n} = A \cdot j^{\nu}$.
- Calibration based on:
  - Vona et al. [2018] findings that green occupations are, on average, *higher-skill* and *less routine-intensive* than non-green occupations.
  - Productivity elasticity $\nu = 2.12$ for routine intensity (in line with Acemoglu et al. [2020]) and $\nu = 0.67$ for skill intensity (in line with Marczak et al. [2022]).
- Parameters chosen to match:
  - Green employment estimate of 19.4% [Bowen et al., 2018].
  - Green wage premium of 2% [Shibata et al., 2022].

[4] Higher bound typically assigned to public goods in related utility functions; $\equiv 1.4\%$ increase in consumption.

Simulation Results: Effectiveness of Green Input Subsidy

Goal: Subsidize green input cost to allocate more tasks to green inputs, i.e. decrease J

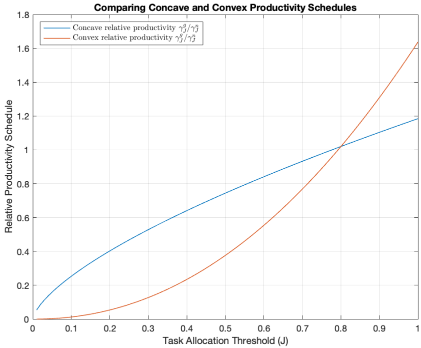


Fig 1: Relative productivity between green and trad. inputs across tasks

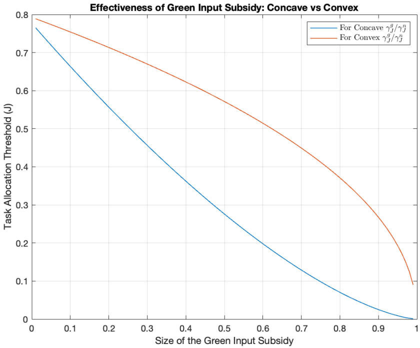


Fig 2: Effectiveness of subsidy in decreasing J

Key Findings: The effectiveness of green input subsidies depends critically on the relative productivity of green versus traditional inputs and the initial task allocation threshold, J.

Welfare analysis: productivity vs. environmental benefits tradeoff

$$\underbrace{\frac{\partial W}{\partial J}}_{\text{total welfare effect}} = \underbrace{\frac{\partial Y}{\partial J}}_{\text{productivity effect}} \underbrace{- \frac{\eta}{1 - L^n - L^g}\left[\frac{\partial L^g}{\partial J} + \frac{\partial L^n}{\partial J}\right]}_{\text{labor reallocation effect}} + \underbrace{\psi \cdot \frac{\partial L^g}{\partial J}}_{\text{environmental benefit}}$$

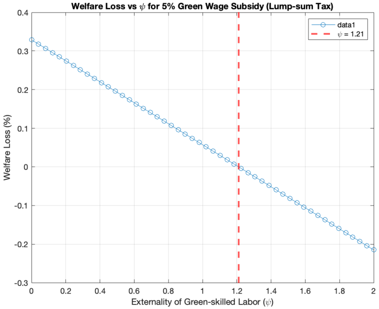


Fig 3: Welfare for different values of externality parameter ψ

Main takeaway: $\exists$ productivity and environmental benefit tradeoff; the positive externality needs to be greater than $\psi = 1.21 (\equiv 4.3\% \uparrow$ in $C)$ to be welfare-improving.

Welfare analysis: comparison of different financing methods

Calculate the necessary % change in initial consumption ω to equalize welfare across states.

$$\{[ln(\omega C) + \eta \ln(1 - L^g - L^n) + \psi L^g] - [ln(C') + \eta \ln(1 - L^{g'} - L^{n'}) + \psi L^{g'}]\} = 0, \quad W_l = (1 - \omega) * 100$$

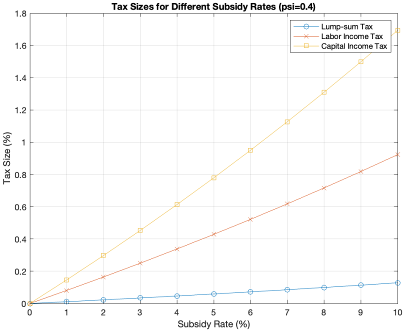


Fig 4: Tax Sizes for Different Subsidy Rates

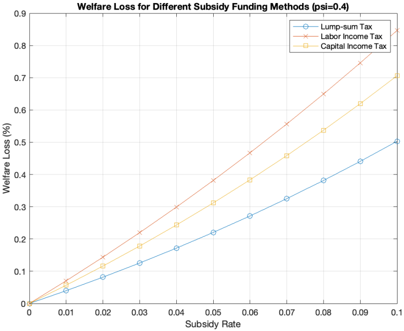


Fig 5: Welfare costs for financing methods

→ *Main takeaway:* Lump-sum tax is the least welfare-distorting financing tool.

Conclusion

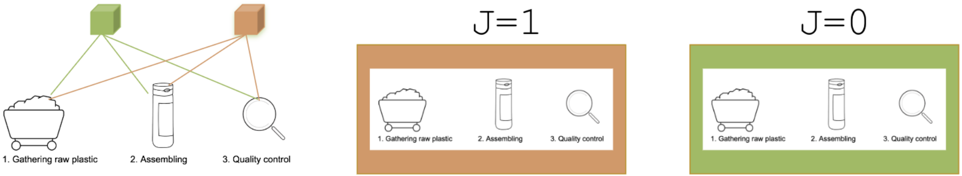
- Introduce a task-based GE model with a continuous greenness index.
- *Core insight:* Markets allocate too few green tasks $\Rightarrow$ need for corrective subsidies.

- **Policy findings:**
  - *Design:* Focus on sectors where green inputs are nearly as productive; support with R&D/infrastructure.
  - *Welfare:* A 5% subsidy raises welfare if $\psi > 1.2$; gains increase with task substitutability (χ).
  - *Financing:* Lump-sum taxes are least distortionary; labor taxes most.

- **Implication:** Well-targeted subsidies can green production without heavy fiscal cost.
- **Next steps:** Extend model to include capital, energy, and macro policy tools.

Understanding Endogeneous threshold

- Endogenous task-threshold: $J : \frac{\gamma_J^g}{\gamma_J^n} = \frac{W_g}{W_n} = \left(\frac{L^n}{L^g}\right)^{\frac{1}{\chi}} \left(\frac{\int_J^N (\gamma_j^g)^{\chi-1}\,dj}{\int_{N-1}^J (\gamma_j^n)^{\chi-1}\,dj}\right)^{\frac{1}{\chi}}$.



Understanding the endogenous threshold J.

Structural Estimation Equation of χ

$$
\begin{aligned}
d\ln s^*_{Lg} = &-\left[s^T_{Ln}\cdot(-(1-\chi)+s^f_K(1-\sigma))\right]d\ln\gamma^n-\left[(1-\chi)+s^T_{Lg}\cdot(-(1-\chi)+s^f_K(1-\sigma))\right]d\ln\gamma^g\\
&+\underbrace{\left[\frac{-\gamma_J^{(\chi-1)}}{\int_J^N(\gamma_j^g)^{\chi-1}\,dj}+\frac{1}{1-\chi}\cdot\frac{\left(\frac{W^n}{\gamma_J^n}\right)^{1-\chi}-\left(\frac{W^g}{\gamma_J^g}\right)^{1-\chi}}{P^L(i)^{1-\chi}}\cdot(-(1-\chi)+s^f_K(1-\sigma))\right]}_{\beta_1}dJ\\
&+\underbrace{\left[\frac{\gamma_N^{(\chi-1)}}{\int_J^N(\gamma_j^g)^{\chi-1}\,dj}+\frac{1}{1-\chi}\cdot\frac{\left(\frac{W^g}{\gamma_J^g}\right)^{1-\chi}-\left(\frac{W^n}{\gamma_J^n}\right)^{1-\chi}}{P^L(i)^{1-\chi}}\cdot(-(1-\chi)+s^f_K(1-\sigma))\right]}_{\beta_2}dN\\
&+\underbrace{\left[s^T_{Ln}\cdot(-(1-\chi)+s^f_K(1-\sigma))\right]}_{\beta_3}dW^n+\underbrace{\left[\frac{1-\chi}{W^g}+s^T_{Lg}\cdot(-(1-\chi)+s^f_K(1-\sigma))\right]}_{\beta_4}dW^g-\underbrace{\left[s^f_K(1-\sigma)\right]}_{-\beta_5}d\ln R.
\end{aligned}
$$

Here, similar to Baek and Jeong [2023], $\sigma = 1+\frac{\hat{\beta}_5}{s^f_K}$ $\quad \chi = \frac{\hat{\beta}_3+\hat{\beta}_5 s^T_{Ln}}{s^T_{Ln}}$.

References I

United Nations. Net-zero coalition, 2023. URL https://www.un.org/en/climatechange/net-zero-coalition.

Daron Acemoglu and Pascual Restrepo. The race between man and machine: Implications of technology for growth, factor shares, and employment. *American Economic Review*, 108(6): 1488–1542, 2018.

William D. Nordhaus and Joseph Boyer. *Warming the World: Economic Models of Global Warming*. MIT Press, Cambridge, MA, 2000.

Konstantinos Angelopoulos, George Economides, and Apostolis Philippopoulos. What is the best environmental policy? taxes, permits and rules under economic and environmental uncertainty. 2010.

Carolyn Fischer and Michael Springborn. Emissions targets and the real business cycle: Intensity targets versus caps or taxes. *Journal of Environmental Economics and Management*, 62(3):352–366, 2011.

References II

Garth Heutel. How should environmental policy respond to business cycles? optimal policy under persistent productivity shocks. *Review of Economic Dynamics*, 15(2):244–264, 2012.

Mikhail Golosov, John Hassler, Per Krusell, and Aleh Tsyvinski. Optimal taxes on fossil fuel in general equilibrium. *Econometrica*, 82:41–88, 2014.

John Hassler, Per Krusell, and Anthony A. Smith Jr. Environmental macroeconomics. In *Handbook of Macroeconomics*, volume 2, pages 1893–2008. Elsevier, Amsterdam, 2016.

Stephie Fried. Climate policy and innovation: A quantitative macroeconomic analysis. *American Economic Journal: Macroeconomics*, 10(1):90–118, 2018.

Lint Barrage and William D. Nordhaus. Policies, projections, and the social cost of carbon: Results from the dice-2023 model. 2023.

Christian P Traeger. Ace—analytic climate economy. *American Economic Journal: Economic Policy*, 15(3):372–406, 2023.

References III

Richard G. Newell, William A. Pizer, and Daniel Raimi. Us federal government subsidies for clean energy: Design choices and implications. *Energy Economics*, 80:831–841, 2019.

Karen Palmer and Dallas Burtraw. Cost-effectiveness of renewable electricity policies. *Energy Economics*, 27:873–894, 2005.

Carolyn Fischer and Richard G. Newell. Environmental and technology policies for climate mitigation. *Journal of Environmental Economics and Management*, 55:142–162, 2008.

John Hassler, Per Krusell, Conny Olovsson, and Michael Reiter. On the effectiveness of climate policies. Working paper, 2020.

Gregory Casey, Woongchan Jeon, and Christian Traeger. The macroeconomics of clean energy subsidies. 2023.

Mohamed Tahar Benkhodja, Vincent Fromentin, and Xiaofei Ma. Macroeconomic effects of green subsidies. *Journal of Cleaner Production*, 410:137166, 2023.

References IV

Daron Acemoglu and David Autor. Skills, tasks and technologies: Implications for employment and earnings. In *Handbook of labor economics*, volume 4, pages 1043–1171. Elsevier, 2011.

David Hémous and Morten Olsen. The rise of the machines: Automation, horizontal innovation and income inequality. *American Economic Journal: Macroeconomics*, 2021. In press.

Francesco Vona, Giovanni Marin, and Davide Consoli. Measures, drivers, and effects of green employment: Evidence from us local labor markets, 2006–2014. *Journal of Economic Geography*, 19(5):1021–1048, 2019.

Francesco Vona, Giovanni Marin, Davide Consoli, and David Popp. Environmental regulation and green skills: An empirical exploration. *Journal of the Association of Environmental and Resource Economists*, 5(4):713–753, 2018.

References V

Francesco Vona. *Labour Markets and the Green Transition: a practitioner's guide to the task-based approach*. Publications Office of the European Union, Luxembourg, 2021. ISBN 978-92-76-42260-0. doi: 10.2760/65924. JRC126681.

Joshua S. Graff Zivin and Matthew Neidell. The impact of pollution on worker productivity. *American Economic Review*, 102(7):3652–3673, 2012.

Don Fullerton, Garth Heutel, and Gilbert E. Metcalf. Does the indexing of government transfers make carbon pricing progressive? *American Journal of Agricultural Economics*, 94(2):347–353, 2012.

Solomon Hsiang, Robert Kopp, Amir Jina, James Rising, Michael Delgado, Shashank Mohan, D.J. Rasmussen, Robert Muir-Wood, Paul Wilson, Michael Oppenheimer, Kate Larsen, and Trevor Houser. Estimating economic damage from climate change in the united states. *Science*, 356(6345):1362–1369, 2017.

Joshua S. Graff Zivin and Matthew Neidell. Environment, health, and human capital. *Journal of Economic Literature*, 51(3):689–730, 2013.

References VI

Cristina Martinez-Fernandez, Carlos Hinojosa, and Gabriela Miranda. Greening jobs and skills: labour market implications of addressing climate change. 2010.

Alex Bowen and Karlygash Kuralbayeva. Looking for green jobs: the impact of green growth on employment. *Grantham Research Institute Working Policy Report. London: London School of Economics and Political Science*, pages 1–28, 2015.

David Popp, Francesco Vona, Giovanni Marin, and Ziqiao Chen. The employment impact of green fiscal push: evidence from the american recovery act. Technical report, National Bureau of Economic Research, 2020.

Francesco Vona et al. *Labour markets and the green transition: a practitioner's guide to the task based approach*, volume 126681. Publications Office of the European Union, 2021.

Chris Papageorgiou, Marianne Saam, and Patrick Schulte. Substitution between clean and dirty energy inputs: A macroeconomic perspective. *Review of Economics and Statistics*, 99 (2):281–290, 2017.

References VII

Daron Acemoglu, Andrea Manera, and Pascual Restrepo. Does the us tax code favor automation? NBER Working Paper 27052, National Bureau of Economic Research, April 2020. URL https://www.nber.org/papers/w27052.

Martyna Marczak, Thomas Beissinger, and Franziska Brall. Technical change, task allocation, and labor unions. IZA Discussion Paper 15632, Institute of Labor Economics (IZA), October 2022. URL https://econpapers.repec.org/RePEc:iza:izadps:dp15632.

Alex Bowen, Karlygash Kuralbayeva, and Eileen L. Tipoe. Characterising green employment: The impacts of 'greening' on workforce composition. *Energy Economics*, 72:263–275, 2018. ISSN 0140-9883. doi: https://doi.org/10.1016/j.eneco.2018.03.015. URL https://www.sciencedirect.com/science/article/pii/S0140988318300963.

Ippei Shibata, Rui Mano, and Katharina Bergant. From polluting to green jobs: A seamless transition in the u.s.? *IMF Working Papers*, 2022:1, 07 2022. doi: 10.5089/9798400215094.001.

References VIII

Seungjin Baek and Deokjae Jeong. Automation, human task innovation, and labor share: Unveiling the role of elasticity of substitution. 2023.