General Equilibrium Rebound from Efficiency Policies

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Policies to deal with climate change must be big.
Big policies have general equilibrium effects.

General equilibrium channels can be crucial to evaluations of large-scale policy interventions (Acemoglu, 2010).

Most formal analyses of rebound effects have focused on partial equilibrium settings with a fixed price of energy resources.

- Microeconomic settings have emphasized income and substitution effects (e.g., Borenstein, 2013).
- Neoclassical growth settings have emphasized analogous effects at the aggregate level (e.g., Saunders, 1992, 2000).

Computable general equilibrium models have suggested the potential for strong rebound effects through economy-wide channels.

- Grepperud and Rasmussen, 2004; Hanley et al., 2006, 2009; Allan et al., 2007, 2009; Barker et al., 2007a,b, 2009; Turner, 2009

I fill this gap in the theoretical literature by developing an analytically tractable GE framework for analyzing the implications of efficiency policies for resource extraction and emissions.

I show that GE rebound is always positive, contrary to some claims in the literature.

I provide both analytical and graphical decompositions of the forces determining GE rebound.

“Backfire” (>100% rebound) arises for a broader set of conditions than suggested by previous theoretical work.

Resource taxes and emission taxes can reduce the effectiveness of efficiency policies.

The potential for backfire increases as the energy resource becomes more depleted, which suggests that rebound effects may accumulate over time.

The two previous analytic GE frameworks did not explicitly represent energy supply.

Turner (2013) laments the lack of attention given to energy supply in analytic assessments of rebound.

Wei (2007) restricts attention to Cobb-Douglas functional forms and does not include a physical resource input to energy production.

Wei (2010) represents energy supply as a reduced-form, increasing function of its price, which means that energy supply does not compete with other sectors for scarce factors of production.

I use a more general CES form for final-good production and explicitly represent both the resource extraction sector and heterogeneity in resource quality.

This paper extends several recent literatures exploring the unintended consequences of environmental policies.

1) The green paradox literature considers how energy policies can backfire by changing extractors' incentives to conserve resources for the future (e.g., Sinn, 2008; Gerlagh, 2011).

- I abstract from dynamic considerations to focus on static, GE channels for backfire.

2) Intensity regulations can backfire because they include an implicit output subsidy (e.g., Helfand, 1991; Holland et al., 2009; Fullerton and Heutel, 2010; Lemoine, 2013).

- I explore the consequences of more common policies that directly incentivize the adoption of more efficient technologies.

This paper extends several recent literatures exploring the unintended consequences of environmental policies.

3) Other GE literature has explored the potential for leakage between sectors or regions (e.g., Copeland and Taylor, 2004; Baylis et al., 2014).

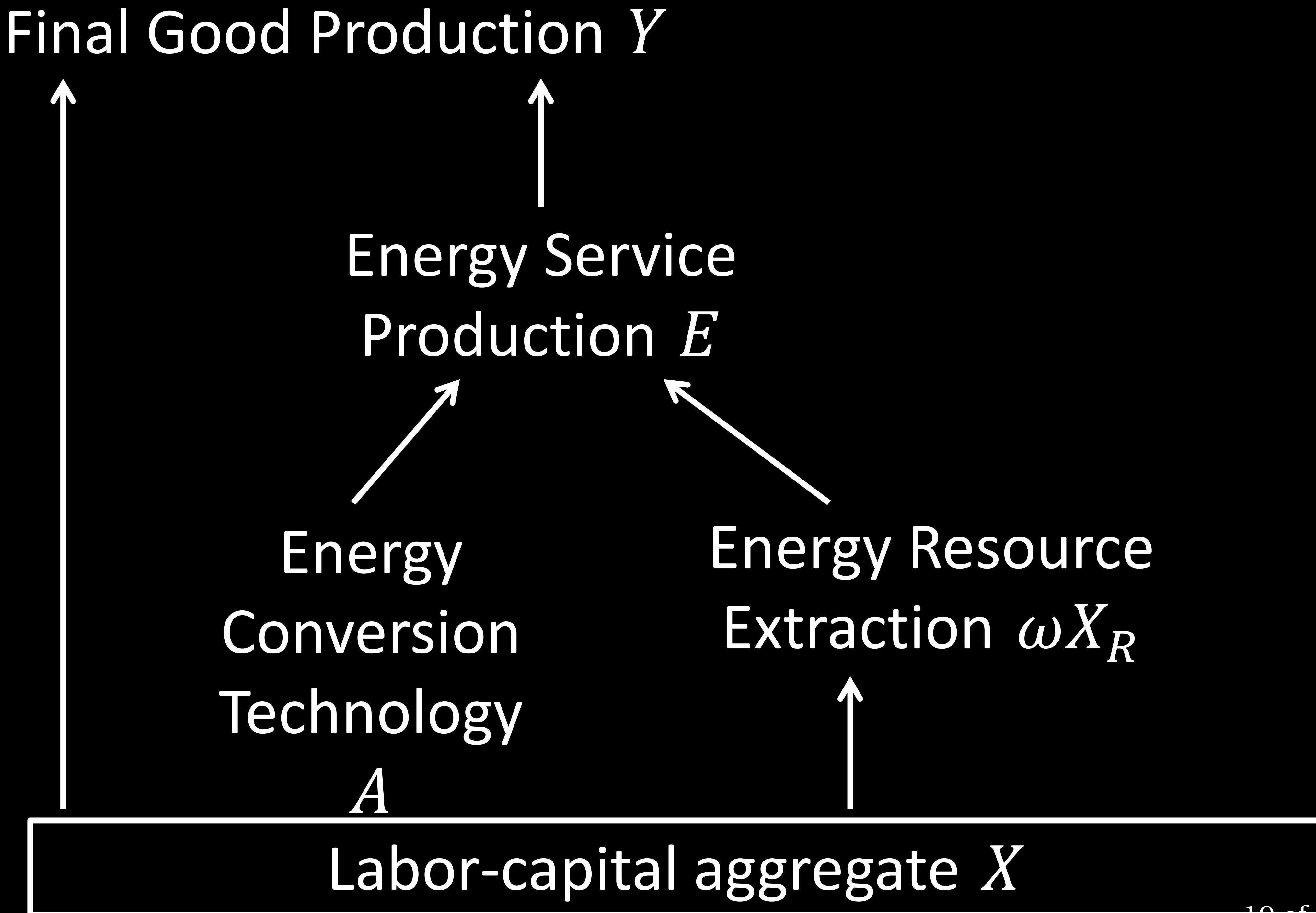
- I develop a more textured model of the energy system that allows me to answer questions about efficiency policies.

4) The double dividend literature has explored how interactions with pre-existing taxes can reduce or reverse the welfare gains from Pigouvian taxes (e.g., Bovenberg and Goulder, 1996).

- I show that emission taxes can themselves reduce the environmental benefits of a more common type of policy.

Outline

- Overview of setting
- Rebound: analytic decomposition
- Backfire, with graphical analysis


Final Good Production Y
Energy Service Production E
Energy Conversion Technology A
Energy Resource Extraction ωX_R
Labor-capital aggregate X

Rebound

The analysis shows that we can express rebound as

$$rebound = 100 * \left(1 + \frac{B}{\frac{\alpha}{1-\alpha}B + \frac{1}{1-\alpha}C}\right)$$

The term *B* describes how relative rents respond to an improvement in energy conversion technology.

$$B = -\frac{p_E}{p_E - t_E}\Pi_{R,Rev} + \sigma(1+\Theta)\Pi_{R,Rev} - \Theta\Pi_R$$

The increase in the supply of energy services reduces their price

The final-good firm shifts its input mix towards energy services, which works to raise their price

Households' opportunity cost of renting to the extraction sector increases

Proposition 1. Rebound is strictly positive.

$$rebound = 100 * \left(1 + \frac{B}{\frac{\alpha}{1-\alpha}B + \frac{1}{1-\alpha}C}\right)$$

Economic responses always undercut "engineering" savings. Contrary to claims in the literature, "super-conservation" does not occur. The terms in *C* ensure that rebound is always positive.

$$C = \frac{1}{X_Y}\left(\frac{p_E}{p_E - t_E}\Pi_{R,Rev} + \Theta\Pi_R\right) + \omega\frac{\partial\psi(X_R;Q)}{\partial X_R}\sigma\left[1+\Theta\right]X_R$$

Any decline in extraction must (mechanically) increase supply of the non-energy input X_Y, which increases the incentive to rent to the extraction sector.

Any decline in extraction decreases the expected cost of extraction.

The Potential for Backfire

Neoclassical growth models have suggested that backfire can occur for elasticities of substitution very close to 1 or larger than 1.

Much empirical work has shown that the elasticity of substitution between energy and non-energy inputs is less than 1.

However, a number of computable general equilibrium models have reported backfire in specific policy applications.

We will gain a better understanding of the conditions consistent with backfire, and establish that it is more empirically relevant than suggested by previous theoretical work.

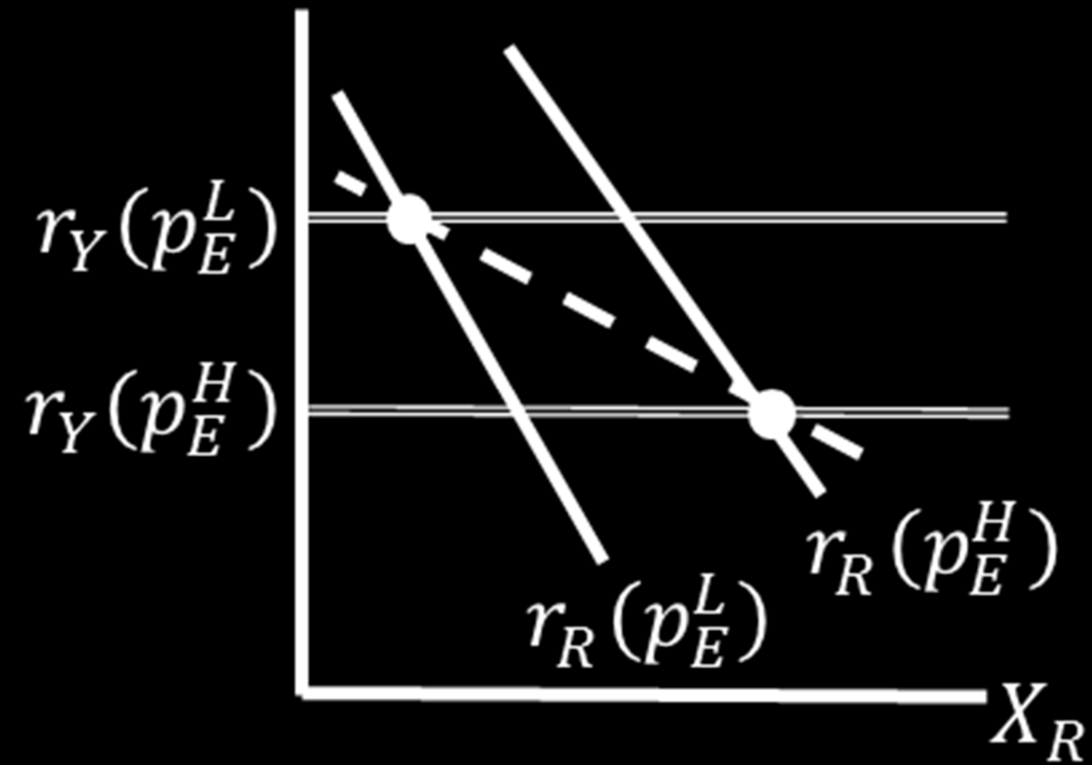
First, as in neoclassical growth settings, we have that backfire occurs for sufficiently large elasticities of substitution. And as long as energy services are either untaxed or subsidized, the critical value is < 1.

Proposition 2. *For any interior equilibrium* z*, there exists* $\hat{\sigma}_z > 0$ *such that* $\mathrm{d}X_R^*/\mathrm{d}A > 0$ *if and only if* $\sigma > \hat{\sigma}_z$*. If* $t_E \leq 0$*, then* $\hat{\sigma}_z < 1$*.*

I now develop graphical intuition for rebound and backfire.

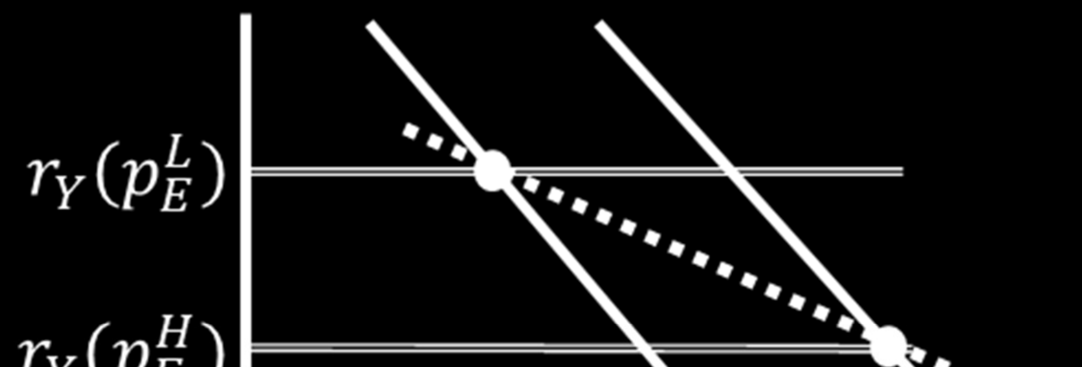
First, note that profit-maximization and the final-good firm's zero-profit condition together require that the rent r_Y paid for the non-energy input decreases in the price of energy services.

$$r_Y = \left(\frac{1 - \kappa^{\sigma} [p_E]^{1-\sigma}}{(1-\kappa)^{\sigma}} \right)^{\frac{1}{1-\sigma}}$$



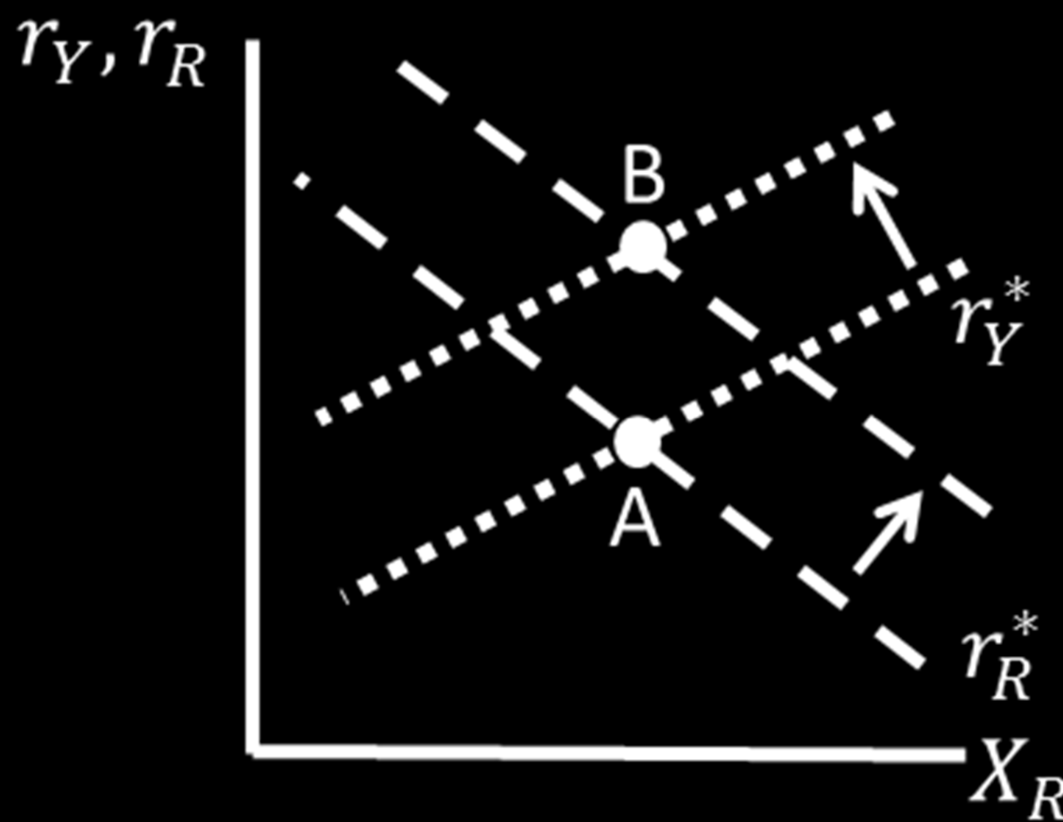
The final-good firm's demand for the non-energy input X_Y is steeper the smaller is σ.

The extraction sector's rent r_R decreases in the quantity of extraction.



$$r_R = \omega \underbrace{(1-\alpha)(\omega X_R)^{-\alpha}[p_E - t_E] A^\alpha}_{p_R} - \omega\, \psi(X_R; Q) - \omega\, t_R$$

Backfire from efficiency policies occurs when the labor demand curve is relatively flat (i.e., for high elasticities of substitution).



Improving efficiency technology increases the marginal productivity of energy resources.

This channel increases the revenue from extraction and so tends to increase extraction.

But the increased availability of energy services also increases the value of the non-energy input in f-g production. This is a substitution channel.

The outward shift in the final-good firm's non-energy demand pulls X away from the extraction sector, reducing extraction.

Proposition 3: Backfire occurs only if the efficiency policy increases the price of energy resources.

An efficiency policy always decreases the price of energy services. Backfire occurs only if the price of energy resources nonetheless increases.

An increase in the resource price p_R is not sufficient for backfire because the rent r_Y to the non-energy input always increases, raising households' opportunity cost of renting to the extraction sector.

This necessary condition for backfire may provide a means of empirically testing for backfire or for market expectations of backfire.

Conclusion

We have seen that GE rebound is positive, and the paper shows that it can become more problematic as depletion progresses and as externalities are internalized.

We should not argue against the plausibility of backfire simply by appealing to the elasticity of substitution being less than 1.

Computable general equilibrium models report large rebound effects through economy-wide channels. We see that the supply side of energy may be an important part of the story.

Large-scale efficiency policies have been advocated as one means of meeting the challenge of climate change. Cost-benefit analyses of these policies should pay attention to GE effects.

Empirical work may be able to explore market expectations of rebound by considering how commodity futures respond to policy announcements, provided a surprise can be found.