The Impact of Carbon Price Policies on Industrial Output and Employment

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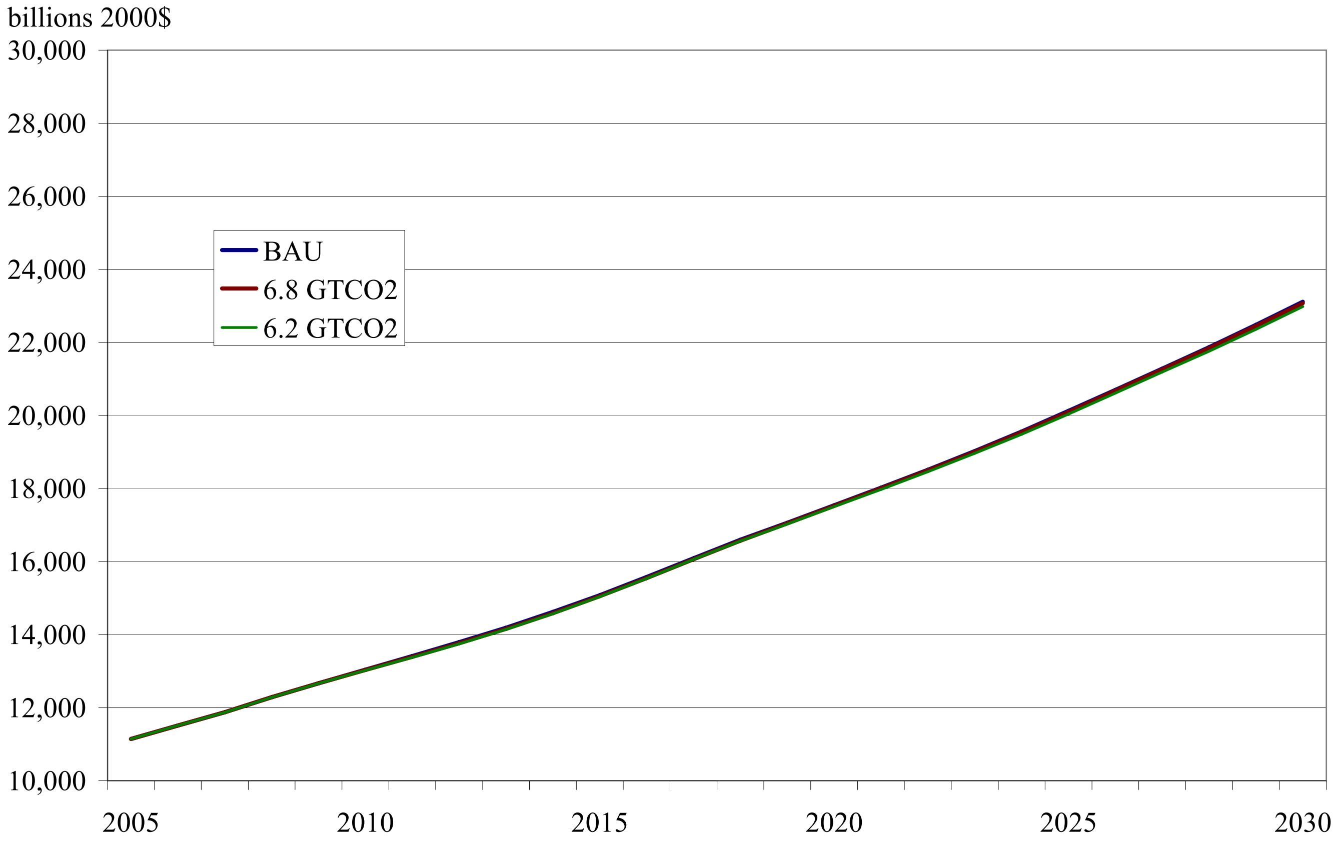
Issues Addressed

- Motivation for study
- Background on policy issues
- Overview of Literature
- Our Approach
- Results
- Conclusions

Motivation

- CO_2 price policy may cause decline in certain sectors (including output, jobs, profits), plus increase in imports and/or foreign production
- Energy intensive, import sensitive industries most vulnerable
- Why? Pricing of CO_2 increases firms' production costs, leading to market adjustments
- Issue not just political: if production shifts abroad to unregulated firms, emissions *leakage* could undermine policy goals, especially if foreign production is less efficient
- Btu tax, recent legislative proposals suggest need for transparent basis to identify true hardship cases

EIA GDP estimates through 2030 show small impacts overall



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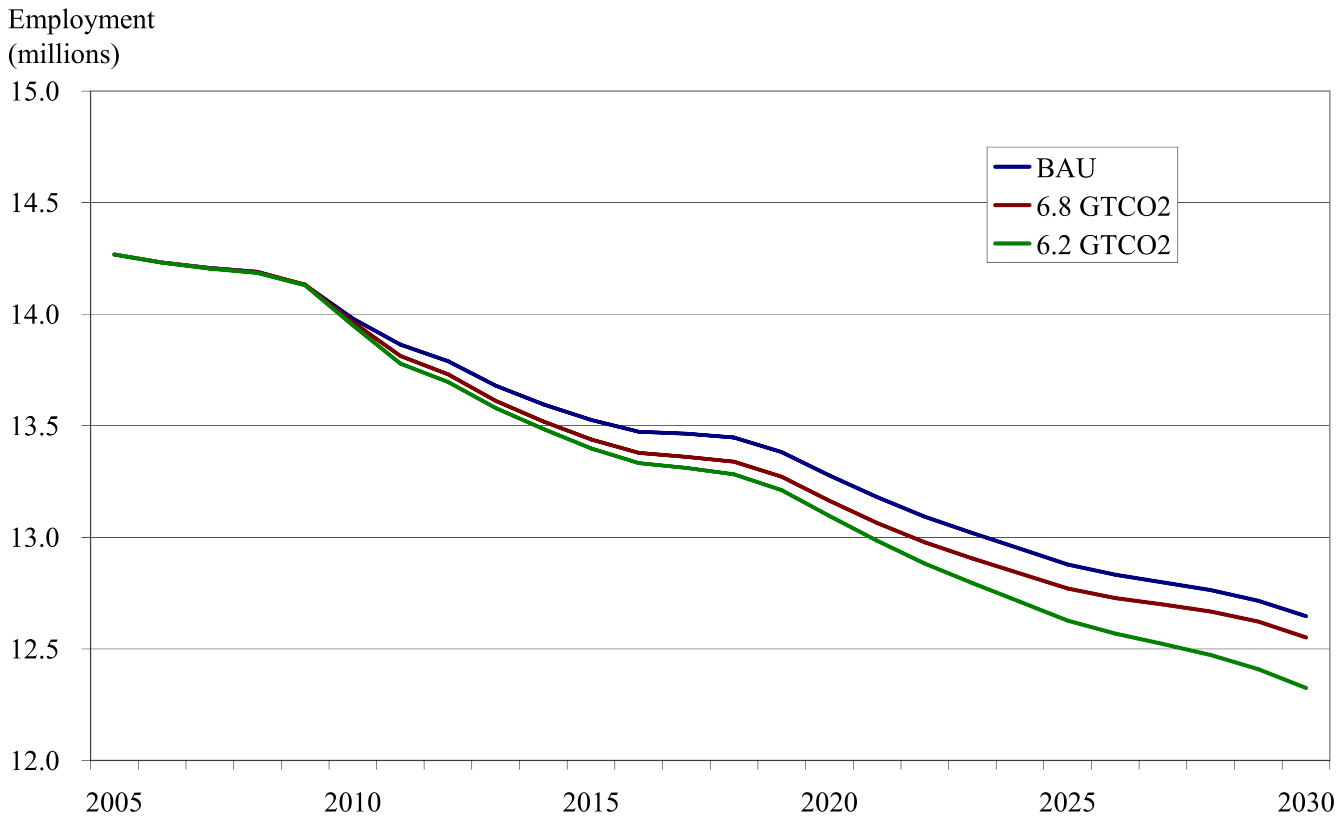
But some decline in manufacturing employment



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…the more narrowly focused the adverse impacts of a policy, the more politically difficult it is to sustain the policy

Mancur Olson, 1965

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First Look at Policy Options

- Weaker overall targets
- Partial/full exemptions for some industries
- Standards instead of market-based policies for some sectors
- Free allocation of permits
- Trade-based policies

Issues that influence modeling approach

- Level of industry detail
- Level of detail on changes in production processes
- Short run versus long run; adjustment processes
- Importance of international trade

Existing Literature (1)

- ‘bottom-up’ models contain technology detail (e.g., different ways to generate electricity in different regions), but do not explain prices/quantities as part of whole economy, e.g., MARKAL, NEMS
- ‘top-down’ models cover the whole economy and determine prices and quantities endogenously, but often do not have detailed industries, e.g., CGE models.

Table 1: Estimated cost increase under EU-ETS for various industries (% of total costs)

Industry	1	2	3	4	5	6
	McKinsey ($10/t$CO_2$)			Reinaud/IEA ($10/t$CO_2$)		
	Cost increase	Net of free allowances	Net of allowances and passthrough	Cost increase	Net of free allowances	Demand reduction
BOF Steel	6.2	1.0	0.6	5.9	0.6	0.8
EAF Steel	1.0	0.9	0.2	1.7	0.6	0.4
Cement	13.1	1.4	-0.6 to 1.4	14.5	1.8	0.3
Primary Aluminum	4.1	4.1	4.1	2.7	2.7	2.1
Secondary Aluminum	0.2	0.2	0.2			
Chemical Pulp/Paper	0.9	0.4	0.2 to 0.4			
Thermo-Mech. Pulp/Paper	2.7	2.2	1.7 to 2.2			
Average Process Petroleum Refining	7.4	0.9	-4.5 to -0.9			

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Existing Literature (2)

- Top-down models have different strengths, trading off regional detail, industry disaggregation, and time. Examples:

EPPA (MIT): 15 energy, 2 manuf, transport,…
    16 Regions; simple dynamics (simple savings function)
SGM (Batelle Lab): 7 energy sectors, 5 manuf,….;
    14 Regions; various expectations formulations, not dynamic eq.
ABARE-GTEM (Australia Bureau of Agri)
    5 mining, 7 manuf, …; Many Regions
G-cubed (McKibben et al)
    2 manuf, 2 utilities, 3 mining, …; 8 Regions; rich dynamics
USAGE-ITC (US Intl Trade Comm/Monash)
    514 industries; 1-country; various expectations formulations
AMIGA (Argonne): 200 industries; 1 country; simple dynamics
Goulder et al: 13 industries; 3 manuf, …; 1-country; rich dynamics
IGEM (Jorgenson et al): 21 manuf, total 35 indus; 1-country; dynamic equil.

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Our Analysis: Considers 4 different timeframes

I) IMMEDIATE HORIZON: ALL QUANTITIES FIXED

assume that quantities of output and inputs are fixed, fall in profits due to higher price of inputs from the carbon price.

II) SHORT TERM: ALLOWING FOR SALES ADJUSTMENT

assume inputs per unit output fixed, but sales decline when higher prices charged to cover the higher production costs drive substitution towards imported varieties and lower carbon alternatives.

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Our Analysis: (2)

III) MEDIUM TERM: CONSTRAINED GENERAL EQUILIBRIUM ANALYSIS

Allows input substitution, import substitution and general equilibrium effects, but assumes capital is frozen in each industry, i.e. higher energy prices lead to higher steel prices, and both lead to higher vehicle prices.

IV) LONG-RUN: FULL GENERAL EQUILIBRIUM ANALYSIS

A full GE analysis where capital is mobile and allowed to move out of sectors facing a fall in demand, and move into less energy intensive sectors.

Methodology

ΔProfits= Δ Revenue- Δ Cost

$$\Delta\pi = (\Delta pX + p\Delta X) - \sum_i \Delta p_i B_i X - \sum_i p_i \Delta B_i X - \sum_i p_i B_i \Delta X - p^L B_L \Delta X$$

Immediate run:

$$\Delta\pi^{IM} = -\sum_i \Delta p_i B_i X$$

Short run:

$$\Delta\pi^{SR} = (\Delta pX + p\Delta X) - \sum_i \Delta p_i B_i X - \sum_i p_i B_i \Delta X - p^L B_L \Delta X$$

Intermediate run:

$$\Delta\pi^{MR} = (\Delta pX + p\Delta X) - \sum_i \Delta p_i B_i X - \sum_i p_i \Delta B_i X - \sum_i p_i B_i \Delta X - \ldots$$

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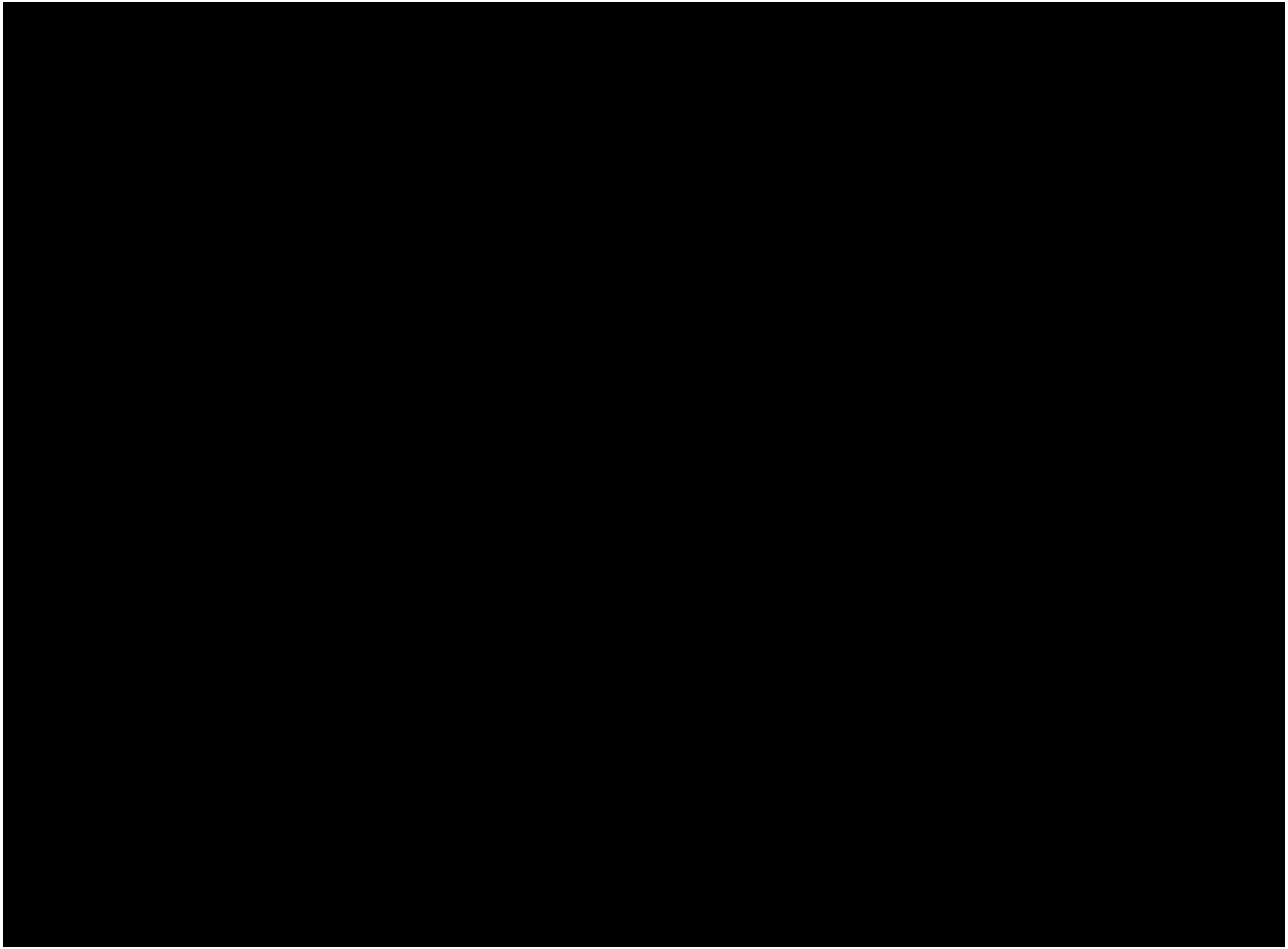
Our Analysis (3)

- Construct 2002 input-output tables for US and ROW from BEA data and GTAP (Purdue Univ) data. Do at 50-industry level, 32 of which are manufacturing.
- Construct coal, oil, gas and electricity use data matching these 50 industries for 2002
- Apply methods in Morgenstern et al (2004) to estimate (I)
- Use Adkins-Garbaccio 2-region general equilibrium model based on GTAP data.
- Simulate GE model to estimate demand elasticities for output and inputs. (i.e. effect of prices on sales and input substitution). Use elasticities to estimate (II)
- Use GE model to estimate general equilibrium effect of a carbon tax, to implement (III) and (IV).



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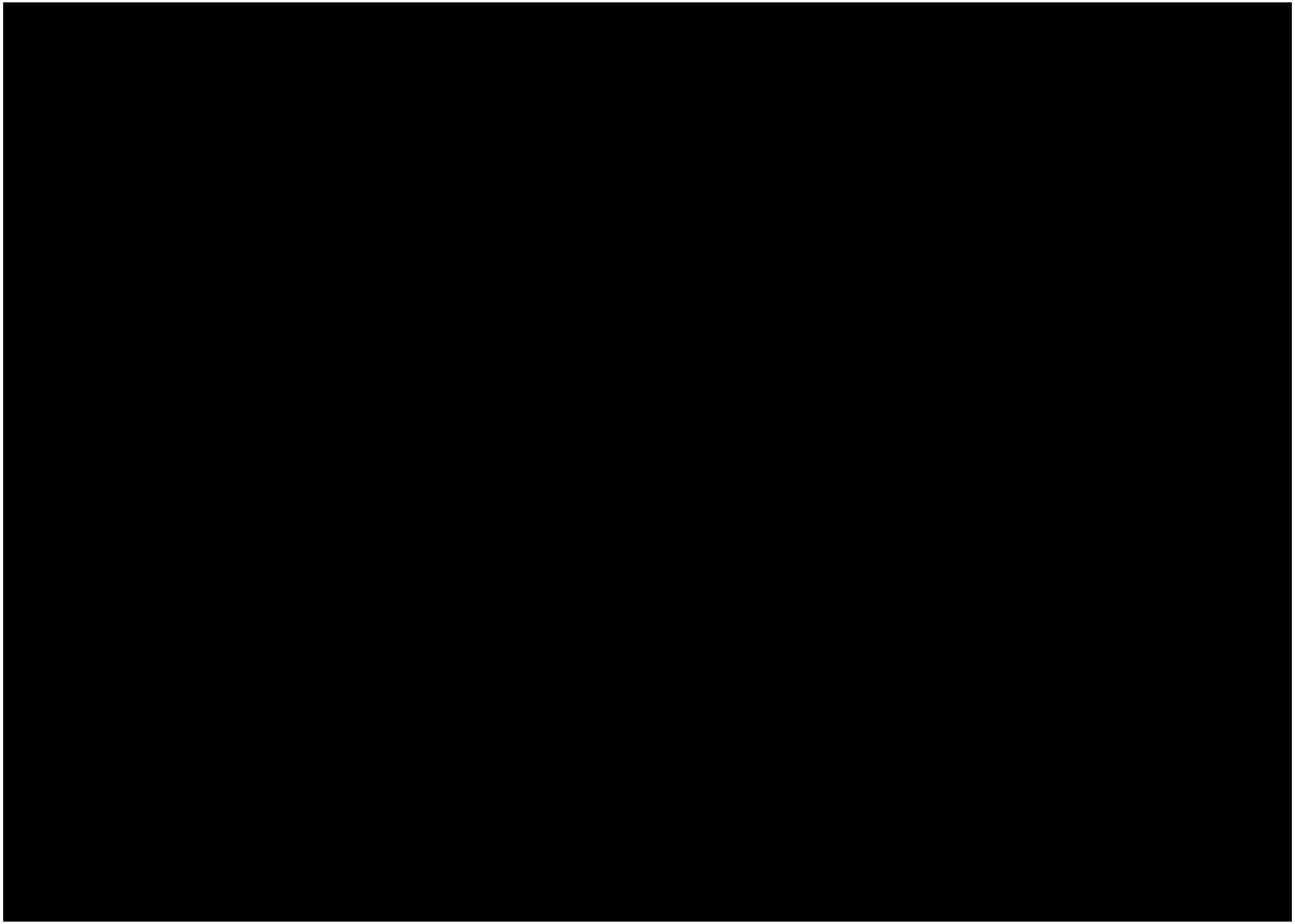

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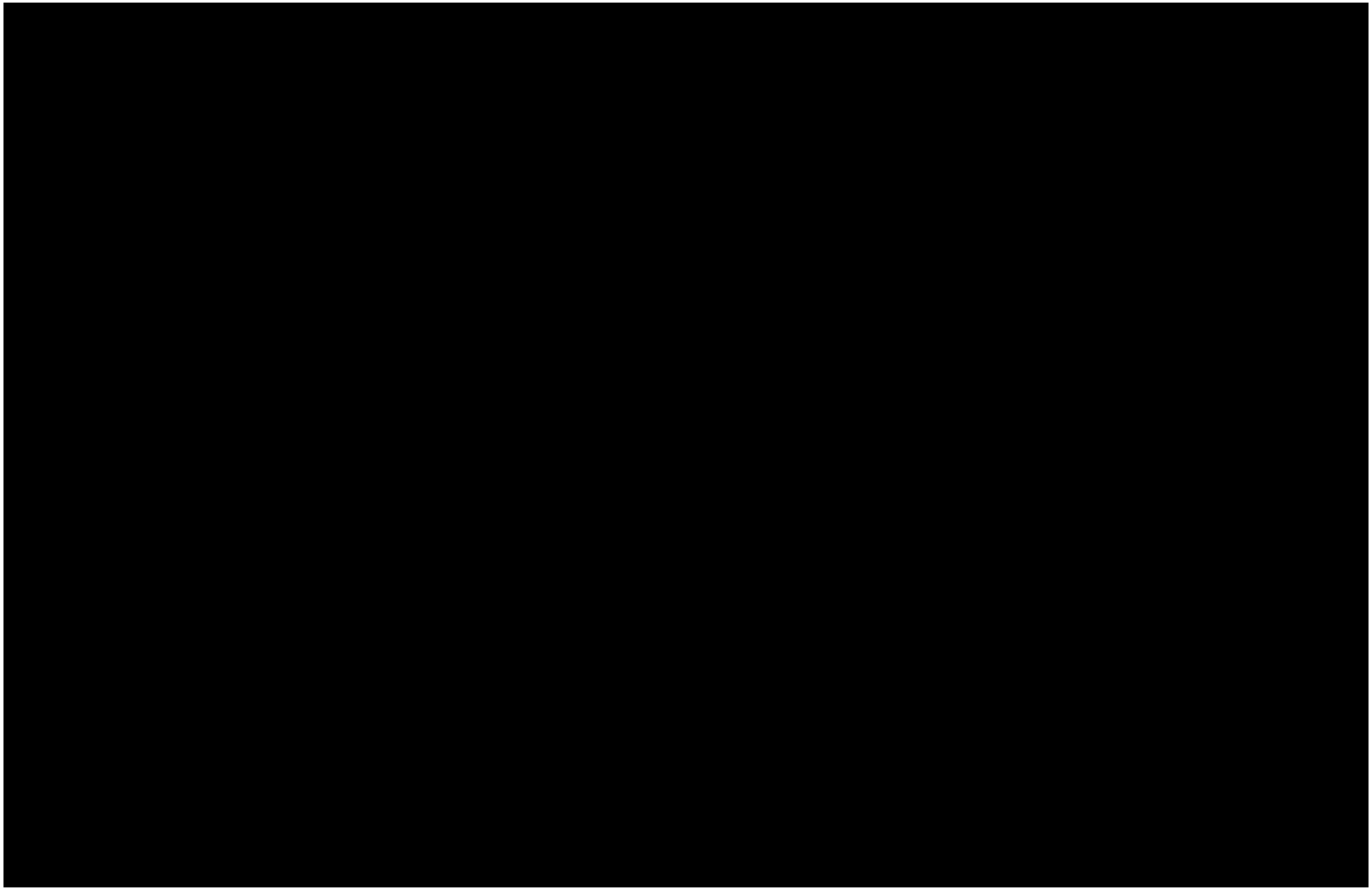

Policy Implications (1)

- Weaker overall targets
  - Greatest environmental impact
  - Least focused/easiest to implement
  - Trend is for *tougher* targets; but may be relevant for first step
- Partial/full exemptions for some industries
  - Provides greatest relief for affected industries
  - Most costly in terms of reduced efficiency
  - Raises equity concerns, contentious to implement
- Standards instead of market-based policies for some industries
  - Avoids price increases, provides some emission reductions
  - Also costly in terms of lost efficiency, difficult to implement
  - More difficult when includes 'embodied' carbon, but often favored by industry

Policy Implications (2)

- Free allocation of permits
  - Growing interest in reducing size of free share. Attention turning to allocation method
  - Grandfathering widely used in early programs. Now less popular due to inability to deter leakage, prevent windfall gains
  - Output based allocation creates incentives to expand production and reduce leakage, although some concerns about efficiency losses
- Trade-related policies
  - Goal: encourage policy action by others, level playing field
  - Risks retaliation; difficult to measure foreign embodied carbon
  - Major differences between border tax adjustments, performance standards
  - Trade lawyer bonanza

Final Thoughts

- Identifying/validating genuine hardships is very data intensive
- Preliminary results for \$10/ton CO2 charge:
  - Impacts generally decline over longer timeframes
  - A few industries suffer larger declines in long run than short run
  - A few industries actually gain
  - Immediate effects on production costs up to 7%; most less than 3%
  - Immediate impacts on profits up to 10%, but quickly declines below 1% as output prices rise
  - Short run impacts on output are quickly reduced to less than 2% for most industries as input mix changes
- Most affected industries in medium/long run (broad categories): Petroleum refining, chemicals and plastics, primary metals, nonmetallic minerals
- Most affected industries in immediate/short term (narrower categories): petrochemicals, other organic chemicals, cement, artificial/synthetic fibers, plastics and resin, fertilizer, alumina refining, inorganic chemicals, iron and steel, lime/gypsum
- No free lunch: all policy options entail higher emissions or social costs

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Methodology, cont.

B: Activity Matrix (input of i per unit of j output)
D: Make/Supply Matrix (share of i produced by j)

The amount of inputs of each type required by the economy to produce one unit of good i for Final Demand:

11) $\Delta Q^i = (\mathbf{I} - \mathbf{BD})^{-1}\mathbf{i}_i$

$$\Delta Q^i = \begin{bmatrix} \Delta Q^i_{farm} \\ \Delta Q^i_{oil} \\ \Delta Q^i_{gas} \\ \vdots \end{bmatrix}$$

The carbon content of 1 unit of good i:

13) $\Delta C_i = \theta_{coal} e_{coal} \Delta Q^i_{coal} + \theta_{oil} e_{oil} \Delta Q^i_{oil} + \theta_{gas} e_{gas} \Delta Q^i_{gas}$

The price change for good i due to carbon tax t^c:

$$\Delta p_i^Q = t^C \Delta C_i$$

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