Energy Abundance, trade, and Industry Location

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Trade driven by factor differences

- Corner stone trade theory: Quasi Heckscher-Ohlin prediction
  - countries capture larger shares of world production and exports in commodities that more intensively use the abundant factors
- Empirical literature on capital per labour
  - Leontief paradox (1954): US 1949 imports are 30% more capital intensive then exports. Replicated many times.
- But what matters is effective labour = labour x education
- and human capital per labour
  - Baldwin (1971/1979): US imports capital, but exports education
  - Romalis (2004): US imports for high-skilled sectors comes mainly from countries with high education levels.
- Conclusion: Quasi HO seems to hold: Factors → Trade

What about energy?

- major production factor (>5% of US expenditure)
- Large geo-political relevance
- Countries have vastly different endowments (Norway vs Italy)
- And different policies (EU vs US)
- Empirical Question: Do energy-intensive industries locate in and export from energy-abundant countries?
  - When controlling for capital and skills
  - Is energy an important production factor that drives part of trade?

Carbon leakage

- Can countries concerned with climate change reduce emissions (=making energy more expensive) without the energy-intensive firms moving abroad?
  - or will emissions 'leak away' when energy-intensive industries move to countries with lax policies?
- Intuition: yes, but to assess this question, keep in mind
  - Though political worries are about 'north-south' leakage, trade (competition) is mainly between similar countries (rich OECD).
  - Industries differ wrt energy-intensity
  - Industries differ wrt exposure to trade
  - Energy is one of many production factors: how to isolate its importance?
- Empirical Question: Do energy-intensive industries locate in and export from energy-abundant countries?
  - Consider rich OECD, consider differences between sectors
  - Our results do NOT extrapolate to rich-poor carbon leakage

Environment & Trade Literature

- Pollution Haven Hypothesis Polluting industries move to countries with lax environmental regulations when trade barriers decrease → overall pollution increases (Copeland & Taylor 1994, Antweiler et al. 2001, Copeland and Taylor 2003, Ederington and Minier 2003, Frankel and Rose 2005, Cole and Elliot 2003, Cole 2006, Managi et al 2009). PHH not true
- Pollution Haven Effect: Stricter environmental regulation will deter polluting industries that move abroad (Taylor 2005, Ederington and Minier (2003) and Ederington et al (2005): Ederington et al. (2005), Cole and Elliot (2005), Brown (2007) and Barajas et al (2007). PHE very weak evidence
- Carbon leakage: (i) Develop large CGE model of world economy & simulate policy scenario. Felder and Rutherford 1993, Burnieaux and Oliveira Martins 2000, Bohringer et al. 2000, Bollen et al 2000, and Paltsev 2001, Babiker 2001, 2005) Carbon leakage 2-25%

Research Question

- Question (empirical): Do energy-intensive industries locate in and export from energy-abundant countries?
- Method from Midelfart-Knarvik et al. (2000): Interact industry attribute (sector needs skills) with country characteristics (country has high education levels): multiply and use as independent variable explaining sector shares
- Romalis (2004): US imports; interaction skills per sector x education per exporting country
- Mulatu et al. (2009): Within EU, polluting industries tend to locate in environmentally lax countries (controlling for multiple factors)

Main Concept

- Method concept: energy-intensive industries locate in and export from energy-abundant countries

	Construction low energy intensity (–)	*Non-mineral Metals* High energy intensity (+)
Italy low energy abundance (–) = high energy costs	Export Large Sector (– x – = +)	Import Small Sector (– x + = –)
Norway High energy abundance (+) = low energy costs	Import Small Sector (+ x – = –)	Export Large Sector (+ x + = +)

- Method contribution: Energy is tradable commodity, make sure that cause-effect is not tautological, or reverse causation. Derive sector attribute & country abundance from sector panel data
- Checks: Control for trade-exposure & causality (instrument 'energy abundance' through Energy Self Sufficiency) & other factors

Model (Romalis 2004)

- Trade with varieties → bilateral trade
- Countries *i*, Sectors *s*, Firms *h*: each firm monopolist for its variety

$$TC_{i,s,h}(q_{i,s,h}) = (\alpha + q_{i,s,h}) a_i b_s r_i^{\alpha_s} v_i^{\beta_s} w_i^{1-\alpha_s-\beta_s}$$

- Production factors: capital (*r*), energy (*v*), labour (*w*)
- Factors are mobile within country: prices are same
  - For example: Norway has cheap energy, expensive labour
- Total Costs: fixed costs, constant marginal costs, Cobb-Douglas technology that is sector-specific
  - For example: Services has high capital intensity α, low energy intensity β.

Model (Midelfart-Knarvik et al. 2000)

- Interaction country x sector: Higher factor endowment (capital) → higher aggregate output and exports for factor-intensive sectors: $\gamma_f > 0$

$$Y_{is} \sim \sum_{f=1}^{F} \gamma_f (\theta_{f,i} - \bar{\theta}_f)(\pi_{f,s} - \bar{\pi}_f)$$

- With $\theta_{f,i}$ the country factor endowment (observed), $\pi_{f,s}$ the sector intensity of factor use (observed), and $\bar{\theta}_f$ and $\bar{\pi}_f$ the 'cutoff' levels (estimated)

$$Y_{is} = \sum_{f=1}^{F} (\gamma_f \theta_{f,i} \pi_{f,s} + \eta_f \theta_{f,i} + \chi_f \pi_{f,s}) + \alpha_i + \beta_s + \varepsilon_{i,s}$$

Model, extension I

- Estimate country factor abundance & sector factor intensity from first-order conditions for firms:

$$\ln\frac{K_{i,s}}{L_{i,s}} = \ln\frac{\alpha_s}{1-\alpha_s-\beta_s} - \ln\frac{r_i}{w_i} = \pi_{K,s} + \theta_{K,i} + \varepsilon_{i,s}$$

$$\ln\frac{E_{i,s}}{L_{i,s}} = \ln\frac{\beta_s}{1-\alpha_s-\beta_s} - \ln\frac{q_i}{w_i} = \pi_{E,s} + \theta_{E,i} + \varepsilon_{i,s}$$

Model, extension II

- Trade effect of factor-abundance-intensity interaction increases with trade exposure.
  - Midelfart-Knarvik et al. (2000) and Romalis (2004) do not differentiate between sectors with high vs low trade exposure.

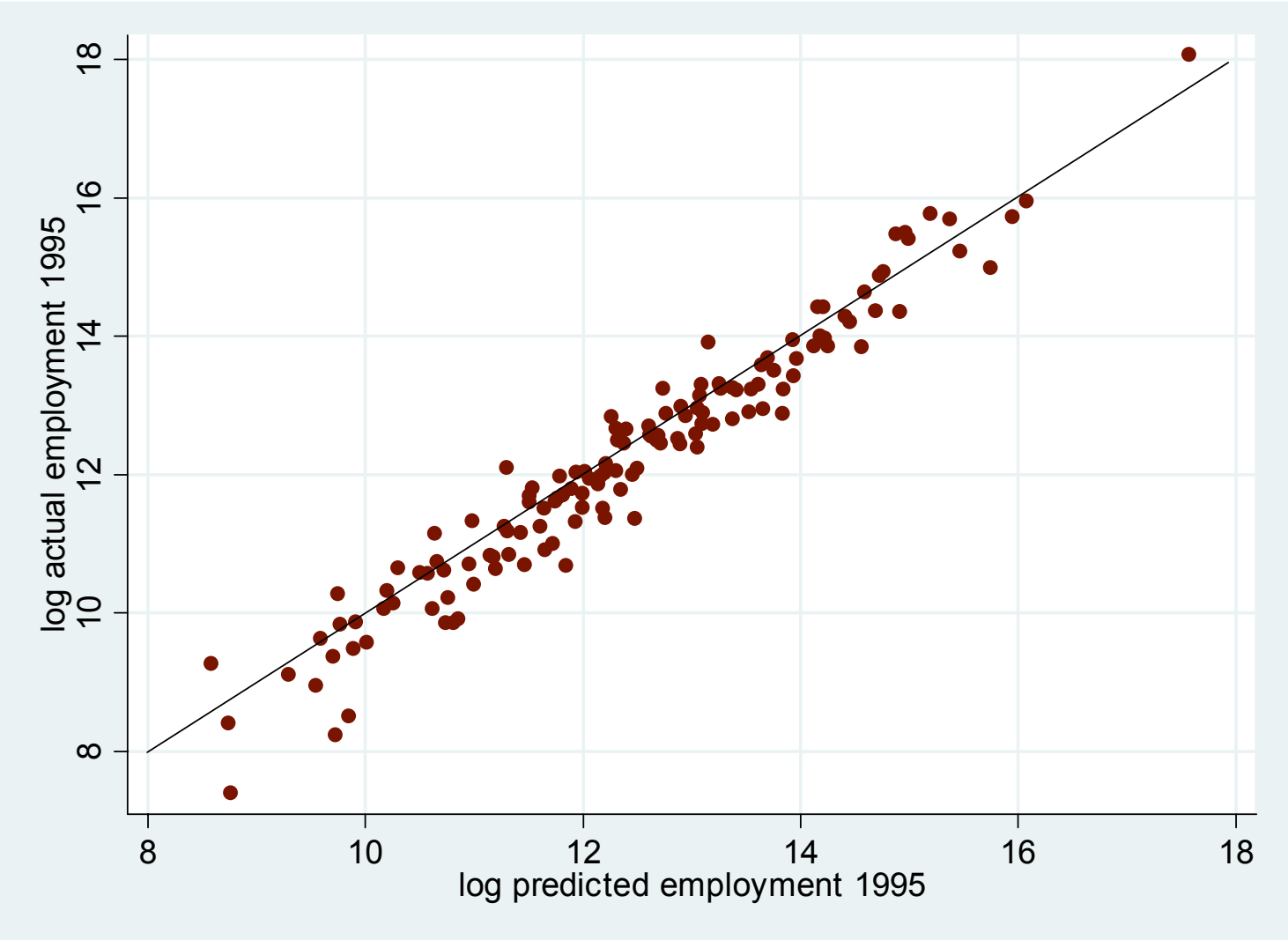
$$Y_{is} \sim \sum_{f=1}^{F} (\gamma_f + \eta_f TI_{i,s})(\theta_{f,i} - \bar{\theta}_f)(\pi_{f,s} - \bar{\pi}_f)$$

Data

- Main database: Peter Mulder (personal communication)
  - Mulder and de Groot (2007), *EARE* on convergence in energy and labour productivity
  - 14 OECD countries, 13 sectors, 1970-1997
  - Variables: VA, K, E, L, X, M, v, w
- Unbalanced data, weak on capital (also exchange rate sensitivity), fewer energy prices than energy use data
- Country sample of rich OECD countries
  - Advantage: (i) most trade is within rich OECD. These are relevant competitors. (ii) countries have comparable structure, less omitted variable bias
  - Disadvantage: (i) political fear is for losing jobs to poor non-Annex-I countries (China, India)
- Country data on primary energy production & use, land, population, saving, income

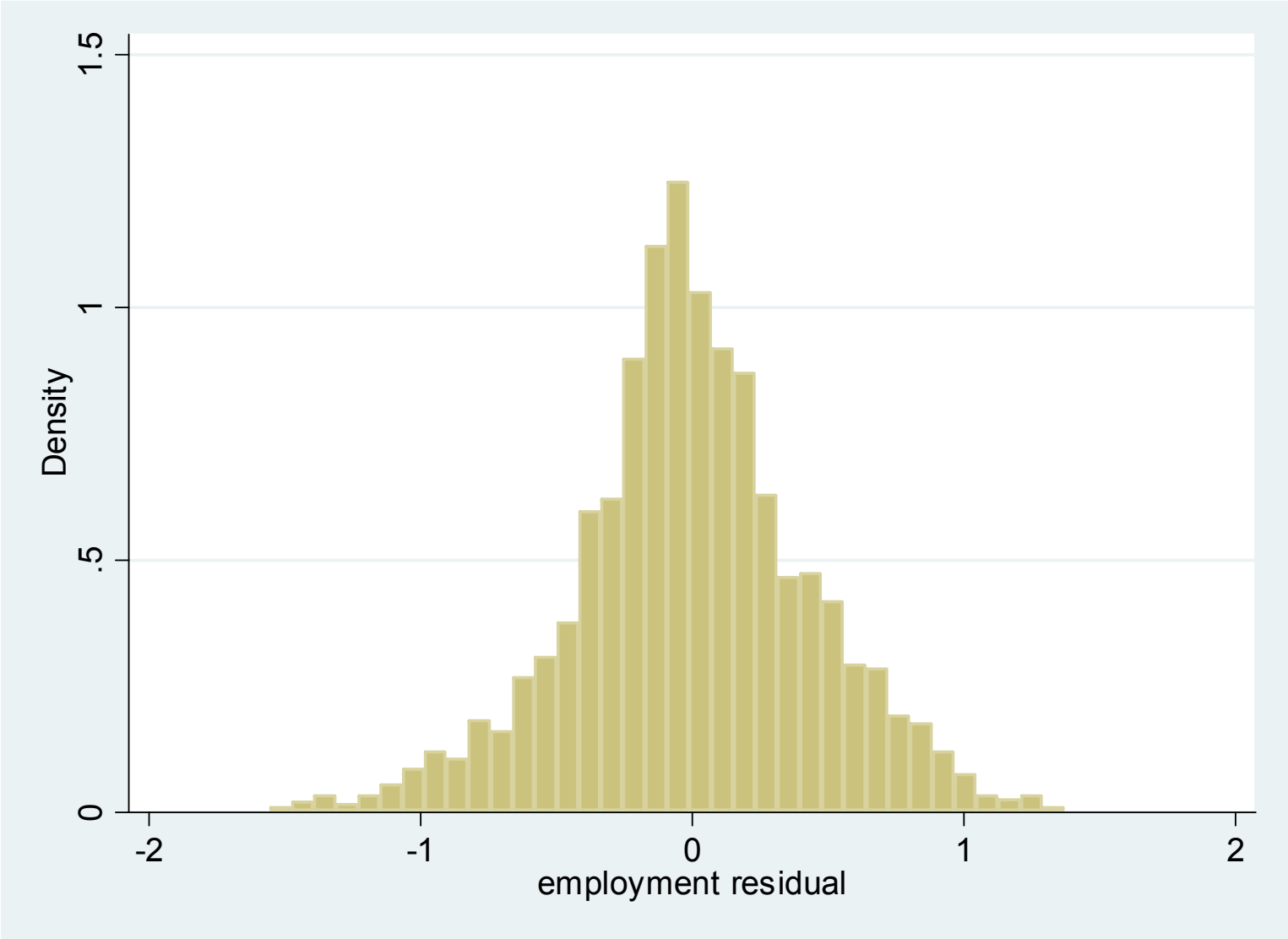
Results in Graphs

- Country population size + typical sector size (dummies) explains most variation in Employment (equal sector shares)



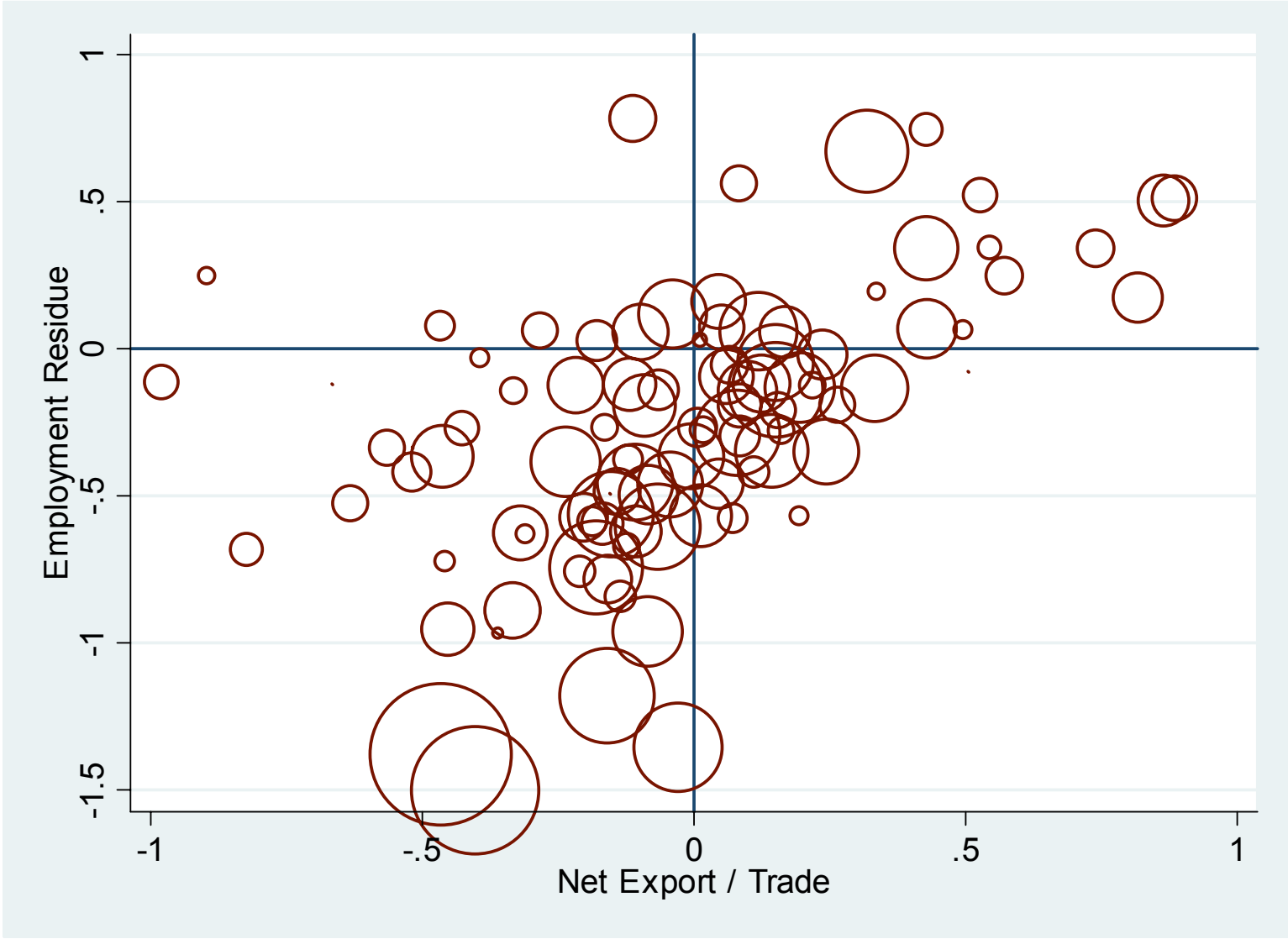
Employment Residuals

- But residuals are substantial: where do these come from?



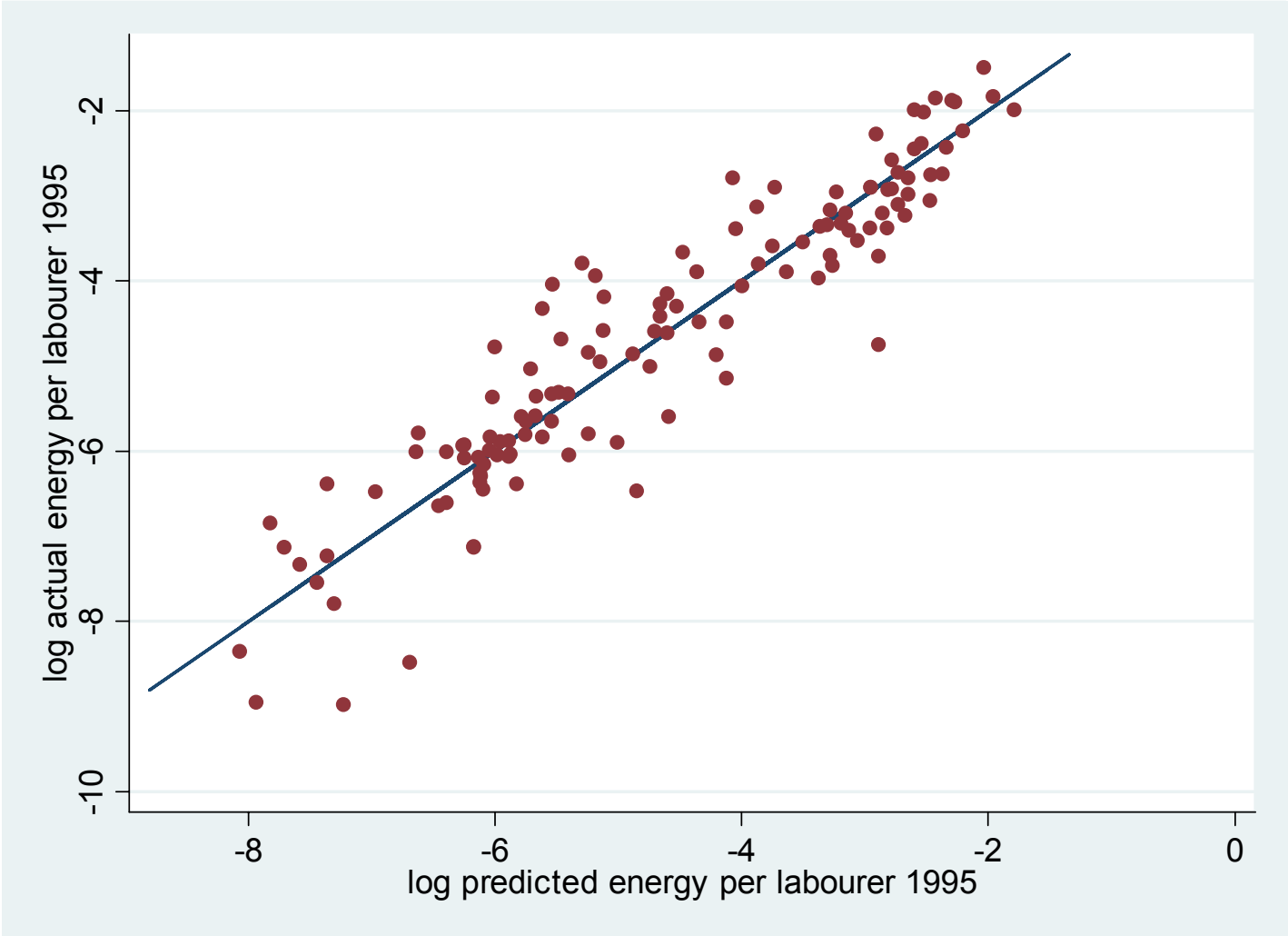
Employment & Trade

- Export success brings employment



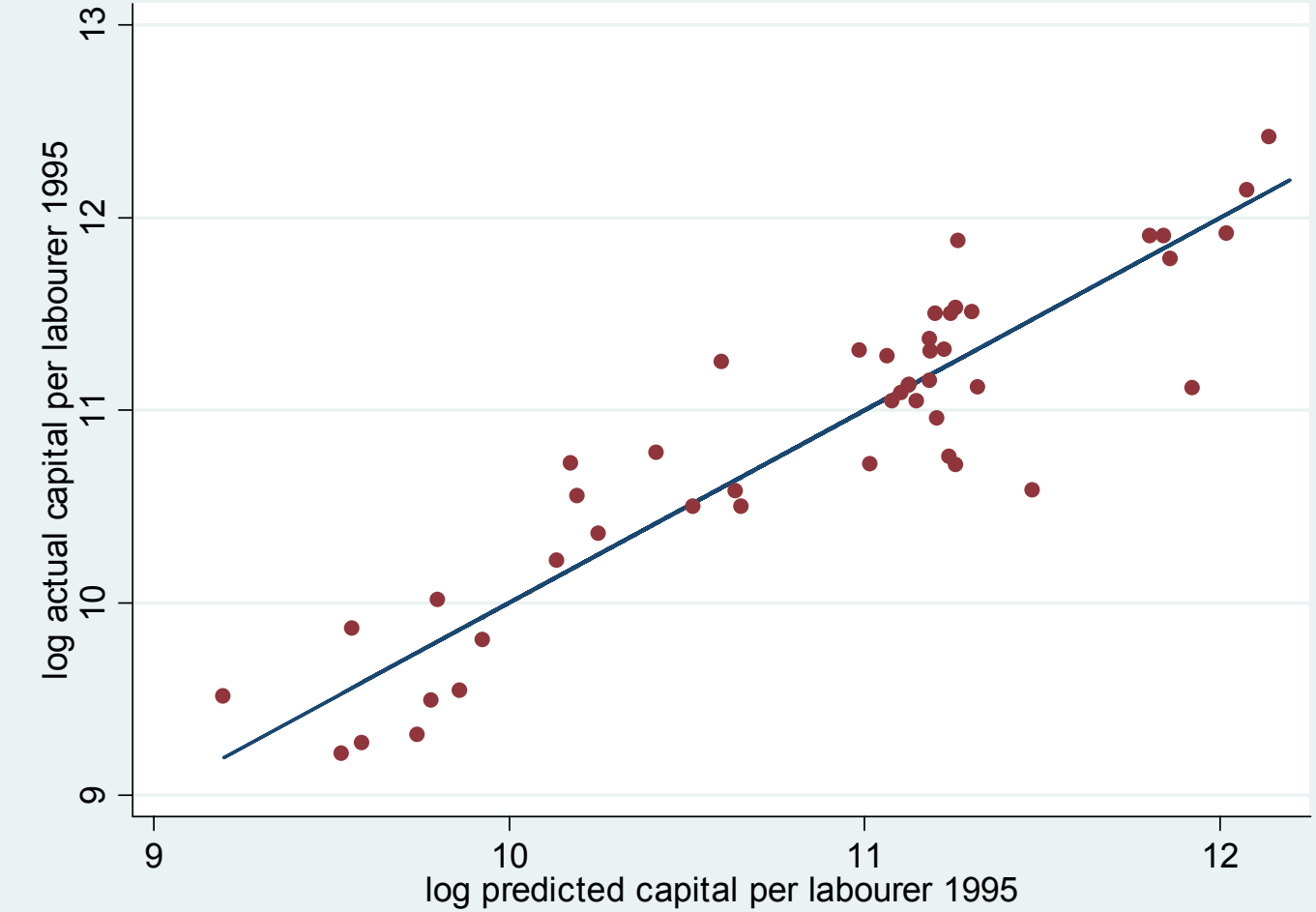
Explaining Energy Use

- Country energy abundance + sector energy share explains most of variation in energy per labour use



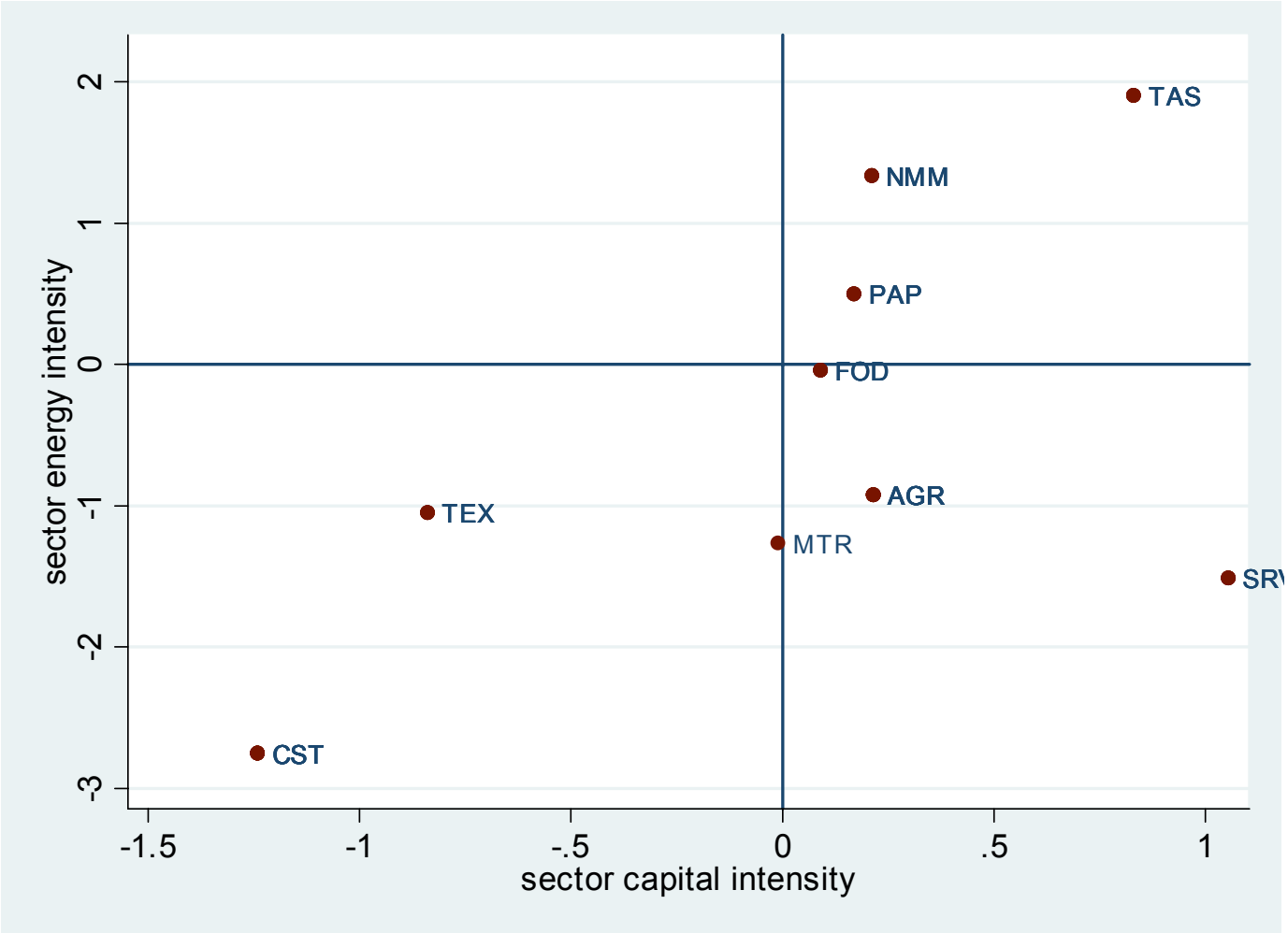
Explaining Capital Use

- Country capital abundance + sector capital share explains most of variation in capital per labour use



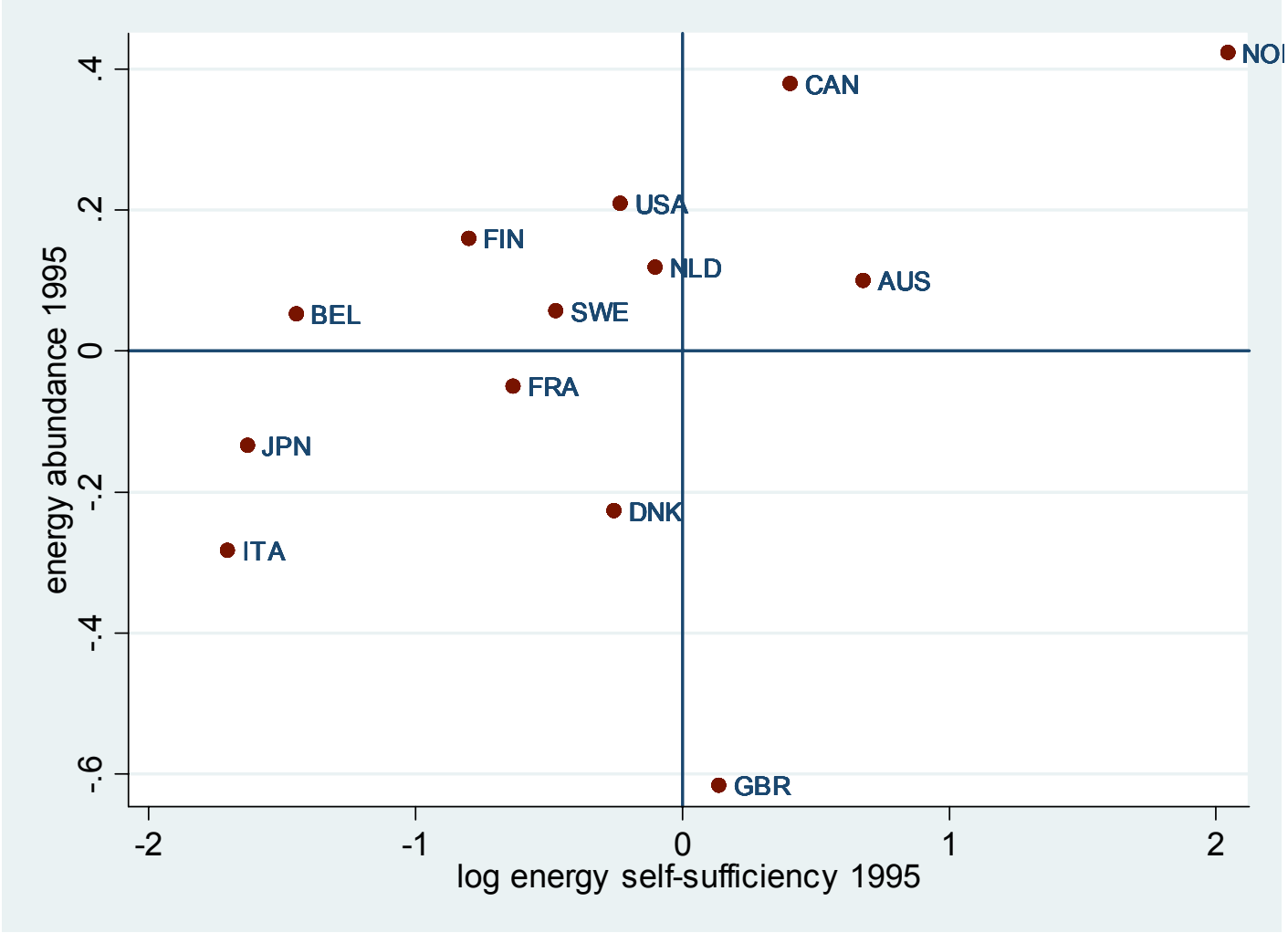
Capital-Energy complementarity

- Capital intensive sectors are also energy intensive (exc Services)
- Variation energy intensity exceeds variation capital intensity by 2



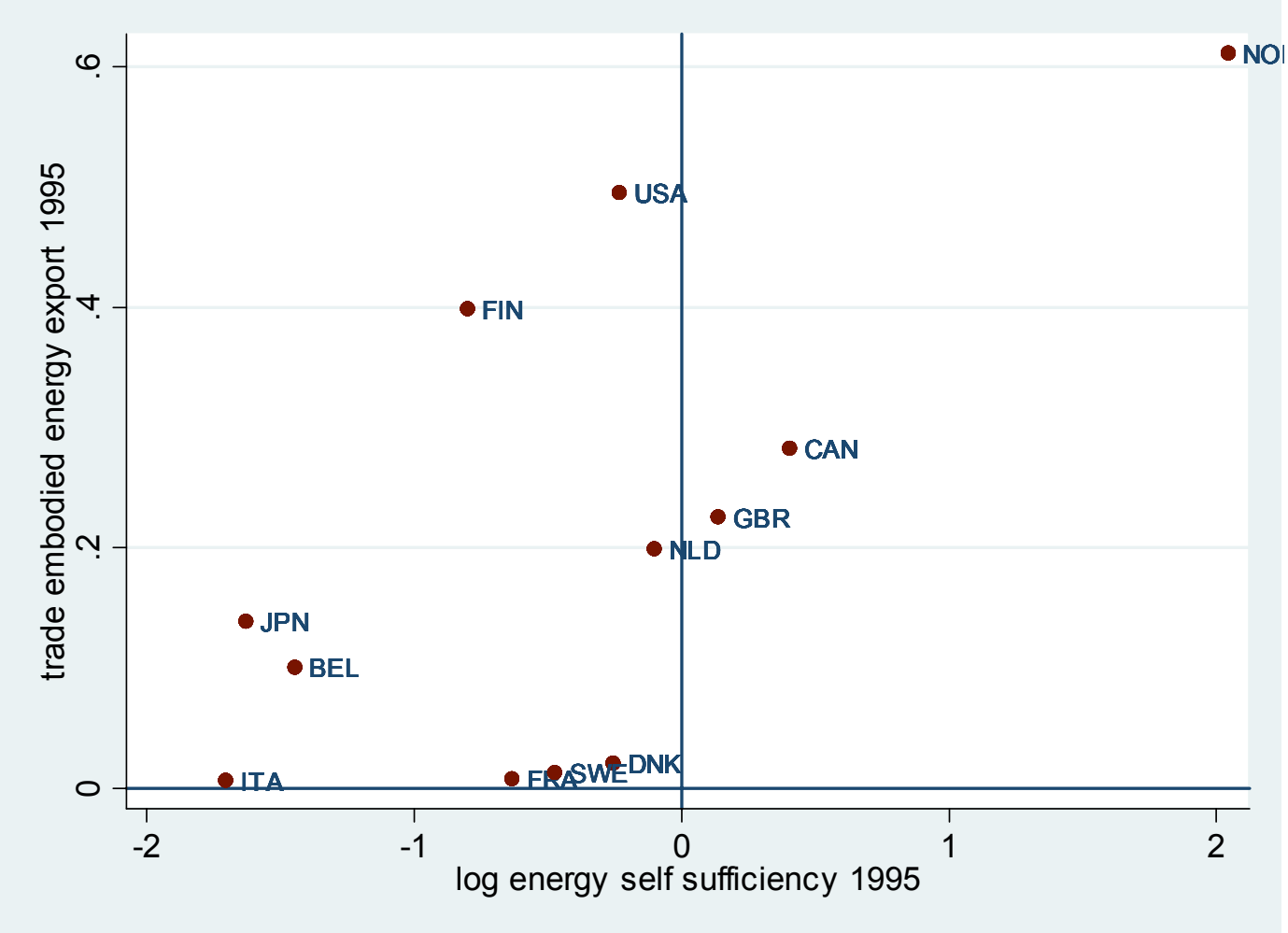
Country energy abundance

- Energy self sufficiency is instrument for energy abundance



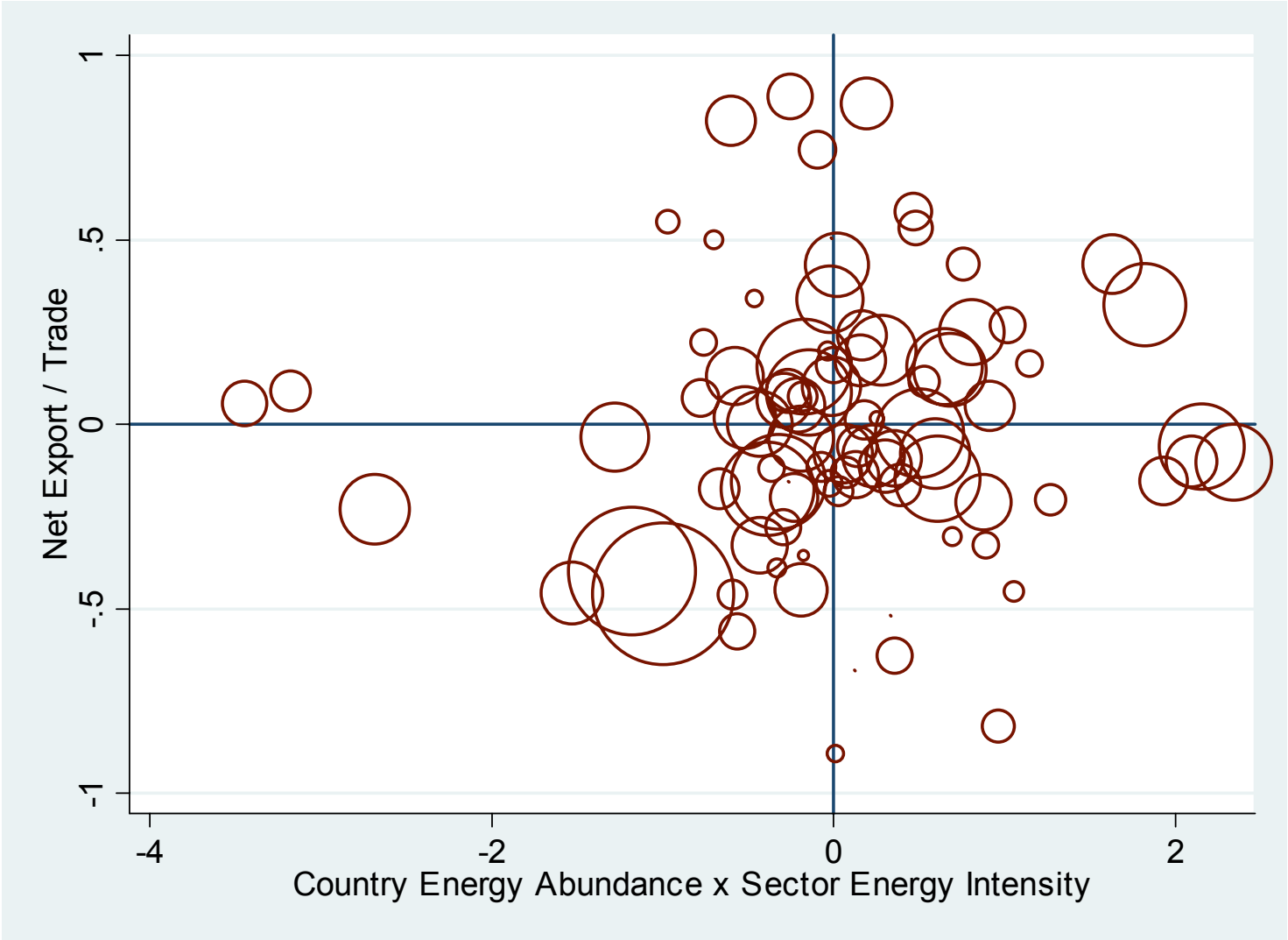
Energy abundance & trade

- Countries that export energy commodities, also export more embodied energy in their products



Energy abundance → Trade

- Countries that are energy abundant export more of energy-intensive sectors (too much noise)



Econometrics

- Data
- Preview results
- Hypotheses
- Stage 0: Basic checks on factor-output elasticity, energy-price elasticity
- Stage I: Decompose energy (capital) intensity in country energy-abundance and sector energy-coefficient
- Stage II: use of decomposition to analyze interaction
  - Aggregate level: trade embodied energy & capital
  - Sector level: propensity to for sector *s* to export from & locate in country *i*

Hypotheses

- Hypothesis 1 (agg. trade): Energy (capital) abundant countries export more embodied energy (capital) than they import
- Hypothesis 2 (trade): Energy (capital) abundant countries export more than they import in sectors that are energy (capital) intensive
- Hypothesis 3 (location): ~ higher activity ~
- Hypothesis 4 (trade exposure): H3 increases with trade exposure
- Target variables
  - Aggregate embodied energy in exports – imports (country x years)
  - Net export (country x sectors x years)
  - Sector activity (country x sectors x years)

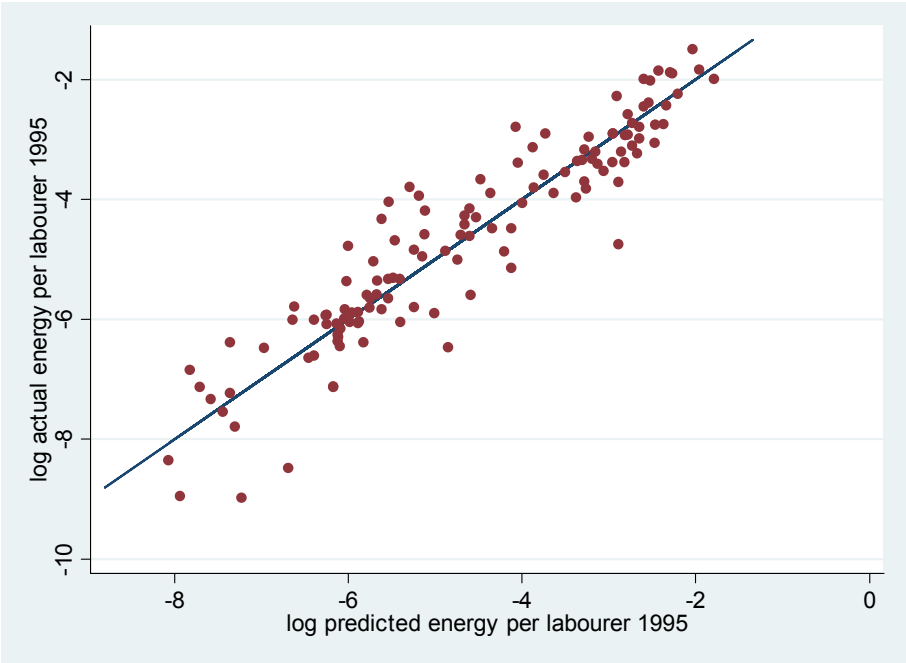
Stage 0: basic checks

- Capital-output elasticity is much higher than energy elasticity
  - All variables as residues

	ln(VA)	
ln(K)	**0.13**	***
ln(E)	**0.01**	*
ln(L)	**0.77**	***
N	1738	
FE (ct + st)	266 + 246	
R^2	.76	

Stage I: decomposition

- FOC relative factor use: $\ln \frac{E_{i,s,t}}{L_{i,s,t}} = \ln \frac{\beta_s}{1-\alpha_s-\beta_s} - \ln \frac{v_{i,t}}{w_{i,t}}$
- estimate: $\ln \frac{E_{i,s,t}}{L_{i,s,t}} = \pi_{E,s} + \theta_{E,i,t} + \varepsilon_{E,i,s,t}$



- Generate $\hat{\pi}_{E,s}, \hat{\theta}_{E,i,t}$ as proxies for
  - sector energy intensities and
  - country energy abundance

Constructed variables summary

- Decomposition explains most of variation
- (not because of time trend)
- Variation of energy interaction = 2x2 capital interaction

	N	*sd*	*sd* between countries	*sd* between sectors	*sd* residual
ln(E/L)	4902	1.72	.26	1.54	.65
ln(K/L)	1869	.80	.16	.67	.27

- Can variation in energy fingerprint correct for low energy-output-elasticity as determinant for trade & location?

Stage II: embodied factors in trade

- Energy abundance increases embodied capital & energy export
- Leontief paradox? Instruments work o.k.

Net Energy Embodied in Export / Import

	OLS	OLS	IV: EP	IV: SSR
E-abund	**0.67** ***	**0.51** ***	**1.65** ***	**2.12** ***
K-abund	**–0.27** ***			
Controls	no	yes	yes	yes
N	204	319	319	319
FE (t)	26	26	26	26
R^2	0.54	0.33	0.62	0.52

- beta-coefficients

Energy abundance & trade

- Trade Exposure: normalized (X+M)/Y
- Energy endowed countries export in energy-intensive sectors.
  - Energy abundance drives about 10-30% of trade variation

Interaction	(X–M)/Y	(X–M)/(X+M)
Energy-interaction	**.13** ***	**.08** ***
Trade x Energy-interaction	**.33** ***	**.07** ***
Controls: per sector land, pop, income, savings	yes	yes
N	3088	3088
FE (c + s,t)	283	283
R^2	.51	.70

Industry Location

- Problem: value added = price * volume; factors ↑ ⇒ price ↓ & voluem price ↑ ⇒ VA ~
- Use employment instead

	ln(employment)			
Energy	**.11**	***	**.04**	***
Trade x Energy-interaction	**.08**	***	– .05	
(X–M)/Y			**0.31**	***
(X–M)/(X+M)			**0.36**	***
Controls: per sector land, pop, ..	yes		yes	
N	3088		3088	
FE (c + s,t)	283		283	
R^2	.67		.80	

Conclusions I

- Output elasticity for capital >> output elasticity for energy
- Capital & energy are complements within and between sectors, but not between countries
- Remarkably large differences between rich OECD countries in energy-abundance (sd=0.26).
- Differences in energy-intensity are much larger compared to differences in capital-intensity, both between sectors & countries
- Evidence for Energy Haven Effect, i.e., energy abundance drives much of net trade & location (residual), especially for exposed sectors
- No support for capital as location driver (factor endowment effect)

Conclusions II (carbon leakage)

- Within rich OECD countries, harmonizing energy markets among rich OECD can reap substantial climate benefits
  - Reduce energy use in Canada & Norway ⇒ move energy-intensive industries to more energy-saving countries
  - Example: Electricity market integration (power cable between Norway – Netherlands) will probably raise energy prices in Norway. Norway will see value of hydro resources increase substantially.
- Between rich OECD and developing countries, capital may play more important role → subject for future research
  - Sector energy data for developing countries are difficult to obtain