Energy Abundance, Trade and Specialization

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ABSTRACT

Do countries with large energy endowments have larger energy-intensive sectors? We answer this question empirically using a panel with 14 high-income countries from Europe, America and Asia and 10 broad sectors, from 1970 to 1997. Energy-abundant countries have 7 to 10 percent higher employment and 13 to 17 percent higher net exports per value added in energy-intensive sectors vis-à-vis otherwise comparable countries. Conversely, energy-scarce countries specialize in non-energy-intensive sectors.

Keywords: Trade, Energy, Factor abundance

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1. INTRODUCTION

Do energy endowments affect industry location and trade flows? For energy-intensive manufacturing sectors such as metals and chemicals, access to low-cost energy is of crucial importance. Though oil, gas and coal are traded globally, national prices have not converged, since transport costs create a wedge between prices. Hence in the absence of policy intervention, we expect energy to be available more cheaply in energy-abundant countries. Moreover several OPEC members subsidize fossil fuel consumption below the world market price,[1] and industries in the coal-abundant U.S. face much lower coal and electricity prices than their European counterparts. Yet, taxes and subsidies could also counter the effect of local energy availability and whether on average energy endowments lead to lower prices is an empirical question.

In this paper, we test whether energy-intensive industries are overrepresented in and export more from energy-abundant countries. Using a panel data set of 14 OECD countries, we find support for both hypotheses. Energy-abundant countries have 7 to 10 percent higher employment and 13 to 17 percent higher net exports per value added in energy-intensive sectors vis-à-vis otherwise comparable countries. Conversely, energy-scarce countries have 7 to 10 percent higher employment and 13 to 17 percent higher net exports in energy-non-intensive sectors than otherwise comparable countries.

The rest of this paper is organized as follows. Section 2 reviews the theoretical and empirical literature and issues on determinants of industry location. Section 3 outlines the methodology.

1. World Energy Outlook, 2010.

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Section 4 describes the data. Section 5 presents the results, and section 6 concludes. The online appendix contains a description of data and a series of robustness checks.

2. LITERATURE REVIEW

The Heckscher-Ohlin model has established the relation between factor endowments and industry location and trade flows as one of the pillars of trade theory.[2] If energy, like final goods in the H-O model, is traded without friction in competitive markets, energy endowments have no effect on industry location. Indeed, most empirical work inspired by the H-O model does not include energy as a production factor (cf. Bowen et al. 1987, Trefler 1995). When energy trade is costly or countries use strategic trade policy, energy prices are lower in energy-abundant countries though. Romalis (2004) argues that factor price differences are an important mediator of the effect of factor endowments on industry location. We can thus expect energy abundance also to significantly affect industry location and trade flows.

Existing evidence on the location of energy-intensive industries is limited and focuses on the U.S. Assuming capital-energy complementarity, Hillman and Bullard (1978) find that the U.S. has a comparative advantage in labour-intensive sectors, and conversely a disadvantage in energy-intensive sectors. Ellison and Glaeser (1999) report that energy-intensive industries are overrepresented in U.S. states with low energy prices, and Gustavsson et al. (1999) find that energy-intensive sectors are more competitive in OECD countries with low energy prices. Hillman and Bullard (ibid) calibrate a modified version of the Heckscher-Ohlin model to aggregate U.S. import and export data, rather than performing an econometric estimation. Ellison and Glaeser (ibid) and Gustavsson et al. (ibid) interact energy prices with energy intensity but leave the direction of causality unsettled; they do not address the concern that energy prices may be endogenous to the industry structure. Our approach is more closely related to Michielsen (2013) who addresses this concern by directly estimating the effect of coal and gas resources on sector location, showing fuel resources are a major determinant of U.S. industry location. Grether et al (2013) apply a similar methodology to Chinese provinces over the period 1999–2009. They find that larger energy endowments are significantly correlated with larger production of energy-intensive sectors. Disaggregating across energy carriers shows that coal, the most costly energy carrier to transport, exhibits the strongest effect.

Other studies with an international dimension use computable general equilibrium models to numerically simulate the movements of energy-intensive sectors in response to internationally differentiated energy prices (Felder and Rutherford 1993, Babiker 2005). The implementation of the Kyoto protocol has resulted in some recent empirical studies on 'carbon leakage' where the focus is on climate policy and energy abundance is not directly addressed (Aichele and Felbermayr 2012, 2013).

This paper contributes to the literature by investigating the effect of energy abundance on industrial activity and trade flows in several countries over an extended period of time. To the best of our knowledge, this is the first paper investigating the effect of energy abundance on trade flows and industry location in a panel of countries. Following the literature investigating the importance of factor endowments and to assure the robustness of our results, we use both sectoral production and sectoral trade flows as dependent variable (see for example Romalis 2004 using trade data and Midelfart-Knarvik et al. 2000 for production data as dependent variable).

2. See Baldwin (2008) for a review of the development and testing of the H-O model.

3. METHODOLOGY

Our methodology is closely grounded in theory and has been applied in several previous empirical studies (Midelfart-Knarvik et al., 2000; Crafts and Mulatu, 2005; Mulatu et al., 2010; Michielsen 2013). All other things being equal, all industries would be interested to locate in e.g. capital-abundant countries. However, desirable country characteristics increase location costs for the average firm in general equilibrium. Midelfart-Knarvik et al. (2000) and Romalis (2004) develop models to show that in equilibrium, the sectors that end up in capital-abundant countries are those that benefit most from capital abundance, i.e. capital-intensive sectors. Non-capital-intensive sectors move somewhere else, and therefore tend to locate in capital-scarce countries.

The model in Midelfart-Knarvik et al (2000) combines both comparative advantage and geographical elements. Countries differ in factor endowments and face transport costs when trading. Sectors use inputs to produce differentiated goods, which allows for positive trade flows and intra-industry trade even in the presence of transport costs. Linearizing the equilibrium relationships allows them to derive the econometric equation directly from their theoretical model.

We test whether the predictions from these models also hold for energy endowments. Our first hypothesis is hence that energy-abundant countries have larger energy-intensive sectors than countries that are scarcely endowed with energy. The latter countries specialize in non-energy-intensive sectors. We measure industrial activity by employment. This approach has the advantage, compared to using value added, that the industrial activity measure is not too sensitive to between-country differences in margins and factor prices related to consumer tastes. A disadvantage is that the measure might be affected by differences in labour intensity (for equal sectors) between countries. The Appendix contains a robustness check in which we use value added as the dependent variable. Our second hypothesis is that energy-abundant countries have a higher net export in energy-intensive sectors. Conversely, energy-scarce countries export more in non-energy-intensive sectors. Holding consumer tastes fixed, there is a close relation between industry location and trade flows (Midelfart-Knarnik et al. 2000, Romalis 2004). Our results concerning the influence of energy endowments on net exports in energy-intensive industries therefore provide a test whether the underlying theory can be confirmed. Closely following Midelfart-Knarvik et al. (2000), Mulatu et al. (2010) and Michielsen (2013), we estimate the following equations

$$\log L_{i,s,t} = \beta_1 EA_{i,t} EI_{s,t} + \sum_n \gamma_{1,s,n} Z_{i,n,t} + \zeta_{i,t} + \phi_{s,t} + \varepsilon_{i,s,t} \quad (1)$$

$$NE_{i,s,t} = \beta_2 EA_{i,t} EI_{s,t} + \sum_n \gamma_{2,s,n} Z_{i,n,t} + \zeta_{i,t} + \phi_{s,t} + \varepsilon_{i,s,t} \quad (2)$$

where $L_{i,s,t}$ and $NE_{i,s,t}$ are employment and net exports in country i and sector s at time t, $EA_{i,t}$ is country energy abundance and $EI_{s,t}$ is sectoral energy intensity, and $\gamma_{s,n} Z_{i,n,t}$ are sector-specific controls that absorb sector structure differences associated with a country's land size, population, income or savings ($Z_{i,n,t}$, $n = 1,\dots,4$).[3] That is, $Z_{i,n,t}$ are country-level attributes and $\gamma_{z,s,n}$ are sector-specific returns to these attributes. The population and land size controls capture a sector's tendency

3. Capital endowment data are not available for the whole time period and could hence not be included in the regressions. Figure 1 and Figure 2 in section 4 show that capital endowments are relatively homogeneously distributed among the sample countries. Also income and savings are highly correlated with capital endowments, so these variables capture most of the sector-specific comparative advantages that go through capital.

to locate in densely or sparsely populated areas. We use income per capita as a proxy for a country's human capital, and savings as a proxy for physical capital. Departing from Midelfart-Knarvik et al. (2000), we interact years of schooling and savings with a full set of sector dummies rather than with a single factor intensity variable, so we expect our results to be robust to the influence of human and physical capital. For these richer controls we sacrifice the ability to estimate a single, interpretable coefficient that captures the effect of physical and human capital on industry location; however, since we are primarily interested in energy this is an acceptable cost. In the interest of brevity, we do not report the $\gamma_{z,s,n}$ coefficients when presenting the results. Our hypotheses predict that the coefficients on the interaction terms β_1 and β_2 are positive. This would mean that energy-intensive sectors are expected to be larger in energy-abundant countries. We abstract from the possibility of factor reversal.

We estimate the models using fixed effects regressions with clustered standard errors. Country-year fixed effects $\zeta_{i,t}$ control for unobserved country-specific characteristics or trends that affect all sectors equally such as macroeconomic trends, other time varying endowments and institutional changes. Sector-year fixed effects $\phi_{s,t}$ absorb unobserved global sector characteristics or trends, such as technological progress or changes in consumer tastes. The fixed effects also perfectly absorb the linear terms $EA_{i,t}$ and $EI_{s,t}$, which are therefore excluded from the models. As our interaction term of interest is very persistent (energy abundance and energy intensity do not change much over time), we cannot employ a full (dynamic) panel data analysis: the (country-sector) fixed effects would be multicollinear with the interaction term, and the (country-sector) fixed effects would absorb most of the interaction effects. Instead we cluster error terms by country-sector pair. As a consequence, our analysis relies primarily on cross-sectional variation in industrial activity and net exports.[4]

Lastly, we perform two scaling and weighting procedures. To correct the dependent variables for country and sector size, we use the natural logarithm of employment as dependent variable in equation (1) and divide net exports by value added in country i and sector s at time t in equation (2).[5] Because trade-competing sectors are more sensitive in their location decisions (Ederington and Minier 2005), we weigh observations by the sector's trade intensity.[6] In the Appendix, we also present a robustness check without this weighting procedure.

We also consider the factor content of trade, to establish whether energy-abundant countries export embodied energy. We first construct gross exported (imported) embodied energy, and labour through:

$$E_{i,s}^{X} = E_{i,s}\frac{X_{i,s}}{Y_{i,s}},\ L_{i,s}^{X} = L_{i,s}\frac{X_{i,s}}{Y_{i,s}},\ E_{i,s}^{M} = E_{i,s}\frac{M_{i,s}}{Y_{i,s}};\ L_{i,s}^{M} = L_{i,s}\frac{M_{i,s}}{Y_{i,s}}$$

where (superscripts) $X_{i,s}$ ($M_{i,s}$) refer to exports (imports) of country i in sector s and $Y_{i,s}$ denotes total production at the country-sector level. We omit the time index for convenience. Relative energy intensity of exports (imports), $EI_i^X(,EI_i^M)$, is subsequently constructed through:

$$EI_i^X = \frac{\sum_s E_{i,s}^X}{\sum_s L_{i,s}^X},\ EI_i^M = \frac{\sum_s E_{i,s}^M}{\sum_s L_{i,s}^M}$$

4. Appendix 2 also reports results, where the coefficient on the interaction term is allowed to change over time.

5. Alternatively, one can divide net exports by total trade to correct for trade openness. We do this in the Appendix.

6. Observations are weighted by the square root of gross trade divided by value added. To avoid giving excessive weight to a small number of observations, the weights are restricted to lie between the 5th and 95th percentiles.

The relative energy content of trade considers the ratio between EI^X and EI^M. If this ratio exceeds one, then the country exports in sectors that are more energy-intensive compared to the sectors it imports from. We take logs and call the variable the energy embodied in trade index. If the index is positive, the country 'exports' energy through trade. If the index is negative, the country 'imports' energy through trade. We test whether energy-abundant countries tend to be net exporters of embodied energy by estimating the following equation

$$\log\left(\frac{EI^X_{i,t}}{EI^M_{i,t}}\right) = \beta_3 EA_{i,t} + \sum_n Z_{i,n,t} + \eta_t + \varepsilon_{i,t} \tag{3}$$

4. DATA

We use the International Sectoral Database with Energy (ISDB-E), which contains data on 14 OECD countries and 10 sectors over the period 1970–1997. This database combines economic data from the International Sectoral Database (ISDB) and the Structural Analysis database (STAN), published by the OECD with energy data from the Energy Balances (IEA). In addition we use data from the World Bank Development Indicators and the International Database from the U.S. Census Bureau[7] Appendix 1 offers a full description of the data and sources.[8] The countries in our data cover more than 60% of international trade during our sample period. Furthermore, as they are comparable in terms of economic, cultural and political structure, the risk of omitted variable bias is minimal. A disadvantage of our dataset is that we cannot be sure whether our results also apply to developing economies.

We measure energy intensity by energy consumption per labourer, averaged over countries. This definition also depends on labour inputs, so a similar caveat applies as to our choice of left-hand variable. As shown in a working paper version of this paper (Gerlagh and Mathys 2011, Table 2), the relative energy-intensity of sectors vis-a-vis each other is largely consistent between the countries of our sample. We use two proxies for energy abundance. The first is the ten-year lagged primary energy production per capita.[9] This measure is not as exogenous as energy reserves per capita, but data on reserves are not available for the full length of our sample period. By taking lags, we preserve weak exogeneity. Still, the coefficient on the energy interaction term might be positively biased when using this measure. The second proxy is the self-sufficiency ratio (domestic energy production divided by domestic energy use). If countries with large energy-intensive sectors produce more energy, they will have a lower self-sufficiency ratio. Reverse causality thus negatively biases the energy interaction coefficient when we use this measure. We obtain similar results when using both proxies, suggesting that the results are not driven by endogeneity of energy abundance.

In Appendix 4, we exploit the variation in energy use per sector across countries to decompose energy use per labourer into a country and a sector effect. We show that countries that use more energy per labourer in all sectors compared to other countries also have higher value added in energy-intensive sectors. The country component of energy use can be interpreted as an inverse measure of energy abundance, and the sector effect as a measure of energy intensity. By letting the data inform us about country abundance and sector intensity, this analysis addresses

7. We measure total trade flows and not trade flows within the sample.

8. We are grateful to Peter Mulder and Henri de Groot for providing us with the database. A limited version of the dataset is available at: www.henridegroot.net

9. We implicitly assume that population is exogenous to energy abundance.

Table 1: Correlations for 1980–1984, for Geometric Country Averages

	energy production	self sufficiency	energy per labour	energy price
Energy production (log 10 yrs lagged)	1			
Energy self-sufficiency (log)	0.826***	1		
Energy per labour (log)	0.715***	0.733***	1	
Energy price (log)	−0.578**	−0.665**	−0.748***	1

Note: ** significant at 5%, *** significant at 1%.

potential criticisms that the definitions in the main text are arbitrary. Because the country component of energy use is possibly influenced by industrial policy or other endogenous factors, we instrument it with the measures of energy abundance that we use in the main text; the first-stage results suggest that energy-abundant countries also use more energy-intensive production methods within each sector.[10]

We transform the country energy abundance variables by taking logs and 5-year averages to smooth out short-term fluctuations. For ease of interpretation, we then normalize energy abundance and energy intensity by imposing a zero mean over countries or sectors per period, and a unit standard deviation, over all periods. For a typical energy-abundant country, the energy abundance variable has value $+1$; for a typical energy-scarce country, the energy abundance value is -1. Similarly, a typical energy-intensive sector has an energy-intensity of $+1$ and the typical energy-non-intensive sector has an energy-intensity of -1. In additional specifications, we discretize energy intensity so that it is equal to $+1$ for sectors that are more energy-intensive than average, and -1 for sectors that are less energy-intensive than average, following Kee et al. (2010).

When the coefficient on the interaction term is 0.1, a one standard deviation increase in energy abundance increases (decreases) employment or net exports in energy-intensive (non-intensive) sectors by 10%. An alternative interpretation is that energy-abundant countries have 10% larger energy-intensive sectors than otherwise comparable countries, and 10% smaller energy-non-intensive sectors than otherwise comparable countries.

Table 1 reports correlations between our two measures of energy abundance, the use of energy per labourer (logs of geometric mean over sectors) and energy prices. The two abundance measures are highly correlated. The third row shows that energy-abundant countries use more energy-intensive technologies in all sectors. Moreover, energy prices are lower in countries with high energy production. This indicates that causality runs from production to prices, not the other way around. If causality would run from prices to production, there would be a positive correlation between the two variables, as higher prices would incentivize more energy production.

5. RESULTS

5.1. Main Results

Table 2 presents the main results for industrial activity as measured by employment. Energy abundance has a positive and significant effect on the location of energy-intensive industries. A one standard deviation increase in energy abundance increases (decreases) employment in energy-in-

10. An alternative interpretation is that energy-abundant countries specialize in more energy-abundant subsectors within each sector.

Table 2: Coefficients on Energy Interaction Term in Regression Eqn (1); Dependent Variable: Log Employment

	log L	log L	log L	log L
Lagged production × Intensity (cont)	0.104***			
Lagged production × Intensity (dummy)		0.101***		
Self sufficiency × Intensity (cont)			0.0774***	
Self sufficiency × Intensity (dummy)				0.0763***
R^2 adjusted	0.631	0.627	0.622	0.618
N	955	697	955	697
N clusters	172	126	172	126

Notes: all variables in logs, * significant at 10%, ** significant at 5%, *** significant at 1%. Error terms are clustered by country-sector pair. All regressions include country-time and sector-time fixed effects and a full set of sector dummies interacted with country savings, income, land area and population.

Table 3: Coefficients on Energy Interaction Term in Regression Eqn (2); Dependent Variable: Net Exports Scaled by Value Added

	NE	*NE*	*NE*	*NE*
Lagged production × Intensity (cont)	0.172***			
Lagged production × Intensity (dummy)		0.152***		
Self sufficiency × Intensity (cont)			0.135***	
Self sufficiency × Intensity (dummy)				0.130***
R^2 adjusted	0.677	0.674	0.667	0.671
N	712	712	712	712
N clusters	124	124	124	124

Notes: all variables in logs, * significant at 10%, ** significant at 5%, *** significant at 1%. Error terms are clustered by country-sector pair. All regressions include country-time and sector-time fixed effects and a full set of sector dummies interacted with country savings, income, land area and population.

tensive (non-intensive) sectors by 7.7 to 10 percent, depending on the metric used. Alternatively, the typical energy-abundant country has 7.7 to 10 percent larger (smaller) energy-intensive (non-intensive) sectors than otherwise comparable countries. As we expected, the coefficient is larger when we proxy energy abundance by lagged production. When countries with large energy-intensive sectors produce more energy, the interaction coefficient may be positively biased if we use lagged production, and negatively biased if we use the self-sufficiency ratio.

We replicate the results for value added in the appendix, and find significant and larger coefficients than in the main specification. The difference between employment and value added suggests that not only are energy-intensive sectors larger in energy-abundant countries than in energy-scarce countries, but that energy-intensive sectors are also able to accrue more rents in energy-abundant countries. This conjecture is consistent with our earlier observation that energy prices are lower in energy-abundant countries.

Table 3 reports the results with net exports per dollar of value added as dependent variable. Energy-abundant countries also have a higher net export in energy-intensive sectors than otherwise comparable countries. A one standard deviation increase in energy abundance increases (decreases) net exports per dollar of value added in energy-intensive (non-intensive) sectors by 13 to 17 percent.

5.2. Robustness

To further deepen the analysis, we also investigate the effect of energy abundance on the energy content of trade and the possible transmission channel from energy abundance to industry

Table 4: Coefficients on Energy Abundance in Regression Eqn (3)

Lagged production	0.218***	
Self-sufficiency		0.204***
R^2 adjusted	0.536	0.488
N	69	69
N clusters	12	12

Notes: all variables in logs, * significant at 10%, ** significant at 5%, *** significant at 1%. Error terms are clustered by country. Regressions include time fixed effects and country savings, income, land area and population controls.

location though energy prices. We show that energy-abundant (scarce) countries tend to be net exporters (importers) of embodied energy, as an aggregate country-measure of sector bias. The results are shown in Table 4. A one standard deviation increase in energy abundance increases the energy embodied in trade index by about 20 per cent.

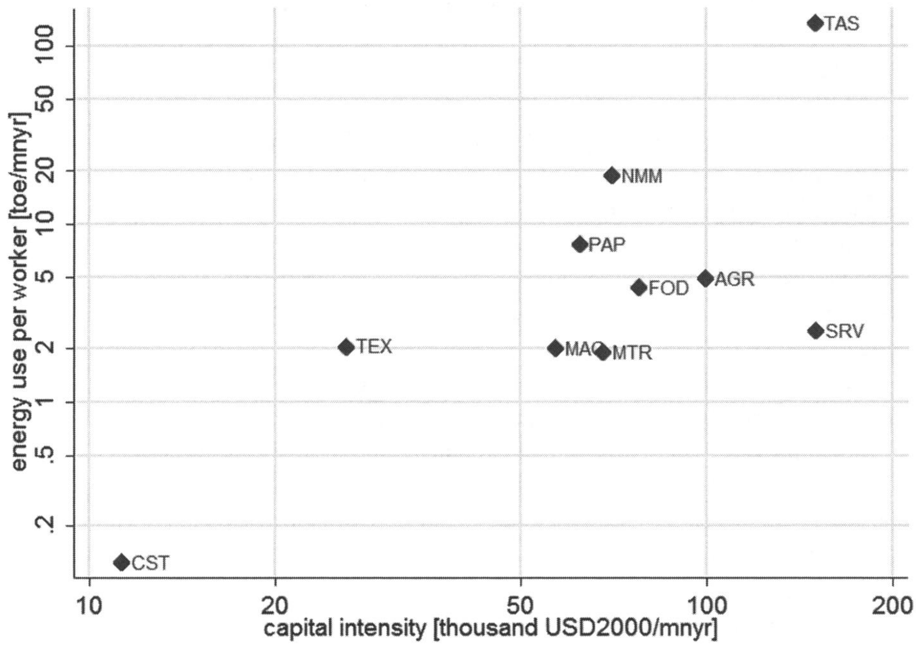
Trade theory suggests that energy prices are the most likely transmission channel for the effect of energy endowments on industry location and trade. In Appendix 3 we present additional analyses in which we include energy prices and instrument for them with energy abundance. The results support the hypothesis: energy-abundant countries have lower energy prices, and through this mechanism employment and net exports in energy-intensive industries are stimulated. These findings may indirectly contribute to the carbon leakage literature (cf. Aichele and Felbermayr 2012, 2013). If energy endowments attract energy-intensive industries because energy-abundant countries have lower energy prices, through the same mechanism climate policies that raise energy prices will lead to a relocation of employment in energy-intensive sectors towards countries without such policies. If, on the other hand, would not have found an energy endowment effect, it would also be less likely that energy policies lead to relocation.

5.3. Relative Importance of Energy and Capital

Figures 1 and 2 illustrate the importance of energy abundance and energy intensity relative to capital. Firstly, the variation in energy intensity across sectors is considerably larger (about a factor 20 to 30) than the variation in capital intensity (Figure 1). Being close to energy reserves can make more of a difference for energy-intensive industries than locating in capital-abundant countries for capital-intensive industries.[11] Secondly, the countries in our sample are more similar in terms of capital abundance than in terms of energy abundance (Figure 2), the variation differs by a factor 20 to 50. Gerlagh and Mathys (2011, Table 1) calculate that for a typical sector, the output elasticity for capital is between 4 and 5 times above the output elasticity for energy, substantially less than the differences between countries in capital and energy abundance. Combining the figures, we conclude that capital-intensive industries have access to large capital stocks in all countries in our sample, and might therefore let other considerations such as proximity to suppliers and customers take precedence in the location decision. For energy-intensive sectors however, there is a clear advantage to locating in Norway, Canada or Australia. In our sample, the comparative

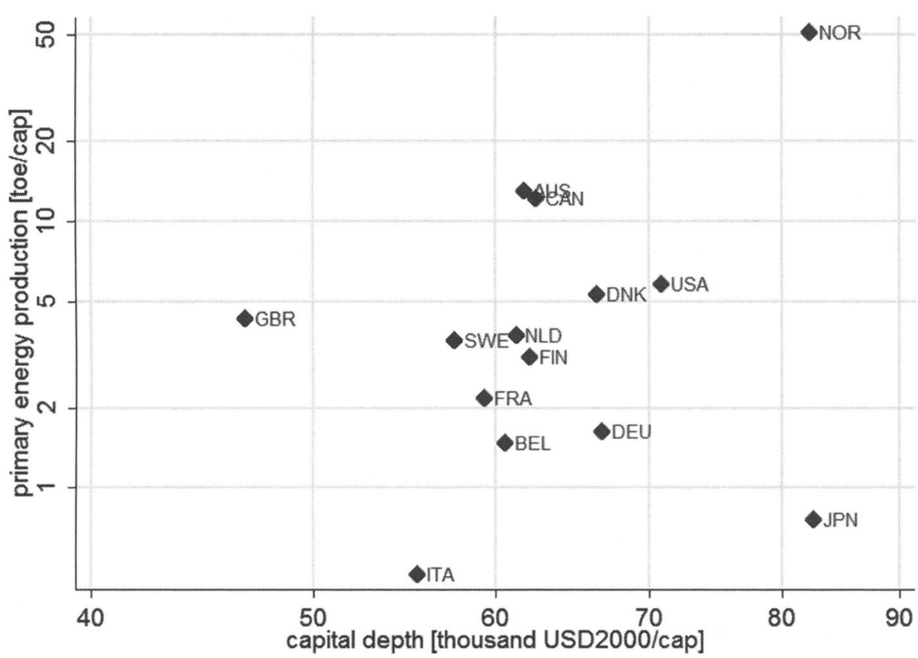
11. In the working paper version of this paper (Gerlagh and Mathys 2011) we have shown that capital and energy (relative to unskilled labour) seem to be complements in our sample.

Figure 1: Relative Capital and Energy Intensity



Note: capital data are missing for four sectors. The data for this Figure are for 1994 for availability reasons.

Figure 2: Relative Capital and Energy Abundance



Note: The data for this Figure are for 2002 for availability reasons.

advantage for energy intensive sectors in energy abundant countries therefore most likely exceeds the comparative advantage for capital intensive industries in capital abundant countries.

6. CONCLUSION AND DISCUSSION

This paper identifies the impact that energy abundance has on trade and industry location in 14 OECD countries. All other things equal, energy-abundant countries tend to have 7 to 10 percent higher employment in energy-intensive sectors and 13 to 17 percent higher net exports per dollar of value added in energy-intensive sectors. Conversely, energy-scarce countries have larger energy-non-intensive sectors. Energy turns out to be a major determinant for industrial activity among the sample of OECD countries. The results are robust to different measures of industrial activity and energy abundance.

Though the empirical analysis does not look into energy policy as such, our results contribute indirectly to the carbon-leakage hypothesis. Energy prices are the main candidate as a transmission variable through which energy endowments affect industry location. More energy endowments lower energy prices, and this attracts energy intensive industries. Climate policies, on the other hand, will increase energy prices and energy-intensive industries will move to countries with laxer policies. Our analysis therefore indirectly supports the carbon leakage hypothesis. We cannot directly estimate the effect of prices on industry location, as the coefficients will be biased due to reverse causality (endogeneity). A possible route for future work will be to identify good instruments for energy prices (Michielsen 2013). Future work will also extend the data to a broader set of countries and sectors.

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