

The impacts of energy prices on industrial foreign investment location: evidence from global firm level data

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Abstract

As countries pursue environmental protection at differing speeds, there is significant variation in energy prices across the world. This paper investigates whether the basic logic of comparative advantage can explain the patterns of industrial firms' investment location decisions, particularly focusing on the role of heterogeneous energy prices. To overcome the lack of global, disaggregated sector-level bilateral FDI data, we use an exhaustive Thomson-Reuters dataset of all cross-border M&A deals in the manufacturing sector across 41 countries, both OECD and non-OECD. Our final dataset includes close to 70,000 deals – of which 22,000 are cross-border – between 1995 and 2014 and covers 23 manufacturing subsectors. We specify a conditional logit model linking M&A activity to relative bilateral energy prices. To control for the large number of potential confounding factors, our identification strategy rests on within-country cross-sectoral energy price differentials. We then estimate our model using a custom PPML estimator, designed to accommodate our specific high-dimensional fixed effects structure. We find that industrial firms perform more cross-border investments when the differential between their domestic sectoral energy price and that of foreign countries increases. Specifically, we find that a 10% increase in the relative energy price differential between two countries is expected to increase by 2.3% the number of firms acquired in the lower energy price country by firms based in the more expensive country. This result has important implications for the adoption of environmental policies which affect energy prices. In particular, it suggests that uncompensated unilateral carbon taxation runs the risk of leading to offshoring and carbon leakage in industrial sectors.

Keywords: FDI; Mergers and Acquisitions; energy prices; environmental regulation stringency; firm location; competitiveness impacts; carbon leakage; output-based allocation.

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1. Introduction

There is a rising concern about the effect of environmental regulations on investment flows as globalisation has increased. As international trade costs continue to fall, a country's environmental and energy policies may become an important factor contributing to its comparative advantage. Assuming that firms are responsive to differences in environmental policy stringency across countries, the pollution haven hypothesis (McGuire, 1982) predicts that pollution intensive activity will tend to relocate towards regions with lax environmental control. Such companies may relocate production through foreign direct investment abroad, mergers with producers located in environmentally lenient countries, acquisition of assets in such countries, or through importing pollution intensive production inputs from foreign suppliers rather than producing those inputs domestically.

Empirically assessing the relationship between environmental policy and investment location choice faces a number of challenges. First, the existing literature highlights the importance of wide geographical coverage of the data, because the strongest effects observed tend to be found in studies with smaller geographical scope (which feature less variation in other determinants of production location). Second and relatedly, it is also understood that the data should be sufficiently spatially disaggregated in order to control for the multitude of confounding factors. In particular, the effect of stricter regulation is spatially heterogeneous and varies systematically on location specific attributes like unemployment levels. Third, disaggregated data is also important in order to address endogeneity issues – treating environmental regulation as endogenous is important, as an influx of FDI can lead to a change in environmental regulation. Forth, using aggregated FDI data poses a challenge to this type of analysis because it typically provides total inward or outward flows for a given country, without bilateral flows, thus preventing any differential analysis at the bilateral or sectoral

level. This is problematic because cross-border investment decisions under the pollution haven hypothesis may be driven by energy costs in *both* countries. Last but not least, variables capturing environmental regulation stringency of a particular location are often subject to measurement error, due to its multidimensional nature (Brunel and Levinson, 2016)¹.

This article contributes to the literature by exploiting global firm level M&A data which has not yet been used in this context. Specifically, we use the Thomson Reuters Mergers & Acquisitions database which provides a comprehensive listing of M&A deals since 1980 at a highly detailed sectoral level. We use this dataset to construct global, bilateral and sectoral microdata of cross-border investments between 1995 and 2014 across 41 countries – both OECD and non-OECD – and 22 industrial subsectors. This enables the coverage of the entire manufacturing sector across both developed and emerging economies over close to two decades, such that the results can be interpreted in a global context. We use a global industrial energy price index developed by Sato et al. (2015) to measure energy price at the sectoral level.

A rich theoretical and empirical literature has considered the general determinants of FDI and cross border M&A activity. Past studies have highlighted the importance of traditional gravity factors - geographical and cultural proximity, market size - (Bloningen and Piger, 2014), the role of stock market valuations and exchange rates in driving global cycles of mergers and acquisitions (Erel, 2012), or the relevance of tariff-jumping and trade costs in motivating the acquisition of foreign assets (Brainard, 1997). However, the impact of relative input costs such as cross-border variations in energy prices or environmental policy stringency has received less attention.

¹Regulations target different pollutants arising from different media such as air, water and land, different polluters such as industry and households, and can take many forms such as pollution reduction targets and technology standards.

In this paper, we first present a simple model to examine the impact of energy prices on cross-border investment flows, based on Head and Ries's (2008) dartboard model founded in discrete choice theory applied to the firm location problem. We use this theoretical framework to derive an empirical model reminiscent of the gravity models commonly encountered in the trade literature. We then exploit the new, extensive M&A dataset and a custom Poisson Pseudo-Maximum Likelihood (PPML) estimator to examine the determinants of cross-border investment flows, in the context of the pollution haven hypothesis.

We derive new and interesting results, using our unique data and model specification. We find evidence that relative industrial energy prices have an impact on the cross-border investment activity of industrial firms. Specifically, firms tend to engage in more cross-border mergers and acquisitions when they face high energy prices relative to that of other countries. These results are robust to a wide variety of tests including alternative specifications, various levels of clustering and an examination of different controls. We also find other intriguing results. We find that the impact of energy prices is not larger when acquiring or target firms operate in highly energy-intensive sectors. This is similar to previous findings in the literature and may be explained by the large capital intensity of energy-intensive sectors reducing their cross-border mobility.

These results have a number of potential implications. First, they support the argument for complementing environmental policies with measures to prevent pollution leakage in industrial activities. For examples, in carbon emissions trading systems across the world (e.g. California, European Union, New Zealand, South Korea and the Chinese pilot schemes) regulated firms in industrial sectors deemed to be exposed to the risk of carbon leakage (relocation) are typically granted compensation in the form of free emission allowances. Our results indicate that such anti-leakage measures indeed appear justified, so long as they are

targeted correctly to those companies that are genuinely exposed to that risk.

This paper is structured as follows. Following a review of the previous related literature, Section 3 develops a theoretical framework to develop our empirical analysis. Section 4 describes the econometric methodology and 5 provides a comprehensive description of our M&A dataset, along with our covariates. We then present the results of our estimations in section 6 and conclude.

2. Related literature

Recent empirical work finds some support for the pollution haven hypothesis, through examining the role of environmental regulation on industrial activity location. This literature broadly examines two distinct questions. First is whether relatively lax environmental policies is a pull factor in attracting incoming manufacturing investments. The second is whether stringent policies is a push factor that influences the decision on outward investment flows or relocation decisions.

On the first question, the evidence is still inconclusive. Wagner and Timmins (2009) examines the impact of environmental stringency (measured by the World Economic Forum (WEF)'s Executive Opinion Survey) on German manufacturing industries's outward FDI flows to 163 destination countries during the period 1996-2003, accounting for agglomeration effects. Of the 6 sectors studied, they find a statistically significant relationship between environmental regulation and FDI flows in the chemical industry. Kellenberg (2009) also uses the WEF index of environmental stringency and explores if it affects production volumes of majority owned U.S. multinational affiliates in 50 countries, for the period 1999 to 2003. Out of the 9 industries studied, they find that production is negatively and significantly influenced by stronger environmental policy in food, machinery and electrical equipment, and

that 8.6% of US affiliate value added growth was attributable to falling environmental stringency. Raspiller and Riedinger (2008) instead uses the EF index (Dasgupta et al 1995) as a proxy for environmental stringency and a dataset on French firms' foreign subsidiaries that re-export to France. They find no significant effect on the location behavior of French firms. Ben Kheder and Zugravu (2012) also study the location choice of French investments in 74 countries between 1996 to 2002. They construct their own measure of environmental regulation stringency based on the number of ratified multilateral environmental agreements, number of international NGOs and energy efficiency levels. They find evidence that lax policy in the host country attracts French investment but only if the host country is a developed country, an emerging economy or Central and Eastern European country. For French investments destined to developing countries, the effect is opposite - stringent regulation attracts investment. Manderson and Kneller (2012) test if UK multinational companies with high environmental compliance costs are more likely to locate subsidiaries in countries with lax environmental policy (measured by the WEF index) but find no evidence, to support this, once controlling for a range of interaction terms between environmental costs and host country characteristics such as availability of skilled labour and high quality infrastructure.

On the question about the impact of environmental policy on outflows of investment activity, the evidence is also mixed. Cole and Elliott (2005) finds evidence that US manufacturing FDI outflows positively vary with abatement costs. This result is confirmed by Hanna (2010) who uses firm level data to examine the foreign production decisions of US-based multinational firms, exploiting the exogenous variation in environmental regulation stringency created by the Clean Air Act Amendment (CAAA). She finds evidence that during the period 1966-1999, the legislation caused multinationals to increase foreign assets in polluting industries by 5.3% and foreign output by 9%. However, Manderson and Kneller

(2012) use UK firm level data to explicitly account for heterogeneous firm behavior, and find no evidence that firms with high environmental compliance costs are more likely to establish foreign subsidiaries than those with low environmental compliance costs.

3. Theoretical framework

In this section, we derive a simple model of cross-border M&A inspired by Head and Ries's (2008) dartboard model, in turn inspired by the application of McFadden's (1974) discrete choice theory to the firm location problem. We also draw from applications of this model by Hijzen et al. (2008) and Coeurdacier et al. (2009), who study the impact of trade costs and the European integration on FDI respectively.

In the following, we propose a model for the choice of investment location conditional on the decision to invest. We consider the firm's investment decision as a two step process: first, the firm decides whether to invest in another firm, and second it chooses its target. We are only concerned with the second step of this decision process, which determines the location of the investment.

Let g be a firm operating in sector $k \in \mathcal{S}$ and country $i \in \mathcal{C}$, with \mathcal{S} the set of all sectors and \mathcal{C} the set of all countries. Consider now a second firm h , $h \neq g$, operating in sector l and country $j - (j, l) \in \mathcal{C} \times \mathcal{S}$. The special cases of domestic ($i = j$) and horizontal ($k = l$) investments are encompassed in this framework. We are interested in deriving the probability that g acquires h conditional on g having decided to invest in another firm.

Let π_h be the profit that firm g can expect if it acquires h , with π_h a reduced function of the sectoral and locational characteristics of h , X_{jl} . X_{jl} can include covariates such as sectoral energy prices or labor costs. We have:

$$\pi_h \equiv \sum_c \beta_c \log X_{c,h} + \varepsilon_h = \sum_c \beta_c \log X_{c,jl} + \varepsilon_h \quad (1)$$

Under the assumption that the perturbation term ε_h is distributed as a Type I extreme value, we have from discrete choice theory the following familiar expression for the probability $P_{g,h}$ that g acquires h :

$$P_{g,h} = \frac{\exp(\pi_h)}{\sum_{h'} \exp(\pi_{h'})} \quad (2)$$

Aggregating at the target sectoral and country levels, we get the probability that g acquires a firm in country j and sector l :

$$P_{g,jl} = \frac{n_{jl} \exp(\pi_{jl})}{\sum_{j' \in \mathcal{C}, l' \in \mathcal{S}} n_{j'l'} \exp(\pi_{j'l'})} \quad (3)$$

Summing over all firms in acquiring country i and sector k , we can express the number of deals m_{ijkl} observed between country-sector pairs (i, k) and (j, l) :

$$m_{ijkl} = \frac{n_{ik} n_{jl} \exp(\pi_{jl})}{\sum_{j' \in \mathcal{C}, l' \in \mathcal{S}} n_{j'l'} \exp(\pi_{j'l'})} \quad (4)$$

Since $i \in \mathcal{C}$ and $k \in \mathcal{S}$, we finally get:

$$m_{ijkl} = \frac{n_{ik} n_{jl} \exp(\pi_{jl} - \pi_{ik})}{\Omega_{ijkl}} \quad (5)$$

with $\Omega_{ijkl} \equiv n_{ik} + \sum_{(j', l') \in \mathcal{C} \times \mathcal{S} \setminus (i, k)} n_{j'l'} \exp(\pi_{j'l'} - \pi_{ik})$.

This expression is reminiscent of the gravity equation commonly used in the trade literature (Silva and Tenreyro, 2006). Ω_{ijkl} is an indicator of the financial attractiveness of a given sector in a given country - and therefore the difficulty to acquire one of its targets: the more

profitable targets in a given country-sector pair are, the larger this denominator, the smaller the probability for potential acquirers to out compete the rest of the world and achieve a deal.

Importantly, injecting equation (1) into (5), we get:

$$m_{ijkl} = \frac{n_{ik}n_{jl} \prod_c \left(\frac{X_{c,jl}}{X_{c,ik}} \right)^{\beta_c}}{\Omega_{ijkl}} \quad (6)$$

In the case of sectoral energy prices, (6) implies that the number of deals is directly related to the ratio of energy prices between the target and host countries, thus to the sectoral energy price of the target country *relative* to that of the host country. A decrease (resp. increase) in this ratio is thus expected to cause an increase (resp. decrease) in the number of deals observed between the country pair considered. This result is intuitive: when energy prices in country j become cheaper relative to those of country i , firms in country i are expected to be incentivized to invest in country j .

4. Empirical strategy

We now proceed with the estimation of our model. In the absence of a good estimate of the potential number of acquiring and target companies in the countries and sectors considered, we make the assumption that the number of entities n_{ik} and n_{jl} in each country-sector pair is proportional to the respective sectoral GDP in each country.

In the reduced form profit function, we include our main regressors of interest, the ratio of energy prices in the host countries of the acquiring and target companies. The index we use for industrial energy prices is described in more details in the following section.

To control for confounding factors that may influence firms' choice of investment location and for the financial attractiveness term, we integrate a rich set of fixed effects, as is common

in the gravity literature (Arvis and Shepherd, 2013). We notably include country pairs, which account for the time invariant characteristics often considered in gravity models (*e.g.* distance, language, system of law) and origin and destination sector. We also include country-time fixed effects, which account for the country-specific macroeconomic environment and any regressor which vary at the country-time granularity; this includes environmental regulations, exchange rates, labor costs, environmental regulation, or stocks valuation, which have been observed in the M&A literature to be correlated with the number of deals between two given countries, independently of their respective market size (Di Giovanni, 2005). Further, country-time fixed effects also encompasses time fixed effects, which control for the highly cyclical nature of global merger and acquisition flows (Erel et al., 2012). Finally, we also control for the existence of free-trade agreement between a given country pair.

Our final model specification is therefore:

$$m_{ijkl} = \exp(\beta_1 \log(GDP_{ik,t}) + \beta_2 \log(GDP_{jl,t}) + \beta_3 \log(e_{ijkl,t}) + \beta_5 \text{fta}_{ij,t} + \alpha_{0,ij} + \alpha_{1,it} + \alpha_{2,k} + \alpha_{3,l} + \alpha_{4,jt}) + \epsilon_{ijklt} \quad (7)$$

where for each country-sector pair ik (acquirer) or jl (target), $GDP_{ik,t}$ is the sectoral GDP, $\text{fta}_{ij,t}$ is a dummy indicating the presence of a free-trade agreement between countries i and j , and $e_{ijkl,t}$ is defined as the relative energy prices between the acquiring and target country-sector pairs (i, k) and (j, l) – see below for the definition of FEPI:

$$e_{ijkl,t} = \frac{FEPI_{jl,t}}{FEPI_{ik,t}} \quad (8)$$

To keep the estimation computationally manageable, we aggregate the original sectoral breakdown, available in our dataset at the 4-digit SIC level, down to the 2-digit level. Given our focus on industrial cross-border investment, this brings the number of sectors down to 22.

Still, despite this reduction in sectoral detail, our overall scope of 40 countries over a period 18 years yields close to 14 million potential observations. Data availability reduces this sample size to slightly more than 5 million observations.

It should be noted that most of the country-sector pairs in our sample have never registered a single deal over the period of observation. Indeed, as is often the case in gravity-like models, most observations in the sample are zeros. This raises an estimation challenge, as there is a risk of overdispersion in the data. This would violate the distributional assumptions of the simple Poisson estimator *a priori*, which require that the variance of the dependent variable be equal to its mean.

To overcome this restriction we use the Poisson Pseudo-Maximum Likelihood estimator (PPML) with heteroskedasticity-consistent standard errors proposed by (Silva and Tenreyro, 2006), which offers a consistent framework to handle the potential overdispersion observed in our sample. However the size of the dataset makes a traditional maximum likelihood estimation intractable. Instead, we implement a custom estimator based on an iterated reweighted least square (IRLS) implementation of the PPML estimator, extending Guimaraes (2017) to an arbitrary number of fixed effects. We further implement one-way and multi-way clustering, building on Zylkin (2017). This custom estimator makes the estimation of our model feasible in a reasonable amount of time on modern hardware.

5. Data

5.1. *The Mergers and Acquisitions dataset*

Our main dataset is the Thomson-Reuters Mergers and Acquisitions database, which in its entirety lists more than 700,000 deals globally, across both OECD countries and emerging economies, since 1980. Each deal is accounted for by a rich set of variables describing both acquiring and target companies and the nature of the deal. In particular, the dataset includes

for each party in a given deal its country of origin along with its main sector of activity identified at the 4-digit SIC classification level.

Further, deals are categorized across different types based on the level of ownership of the acquirer in the target company. For the purposes of this paper, we consider a given deal as an M&A if the acquirer fulfills any of the following criteria:

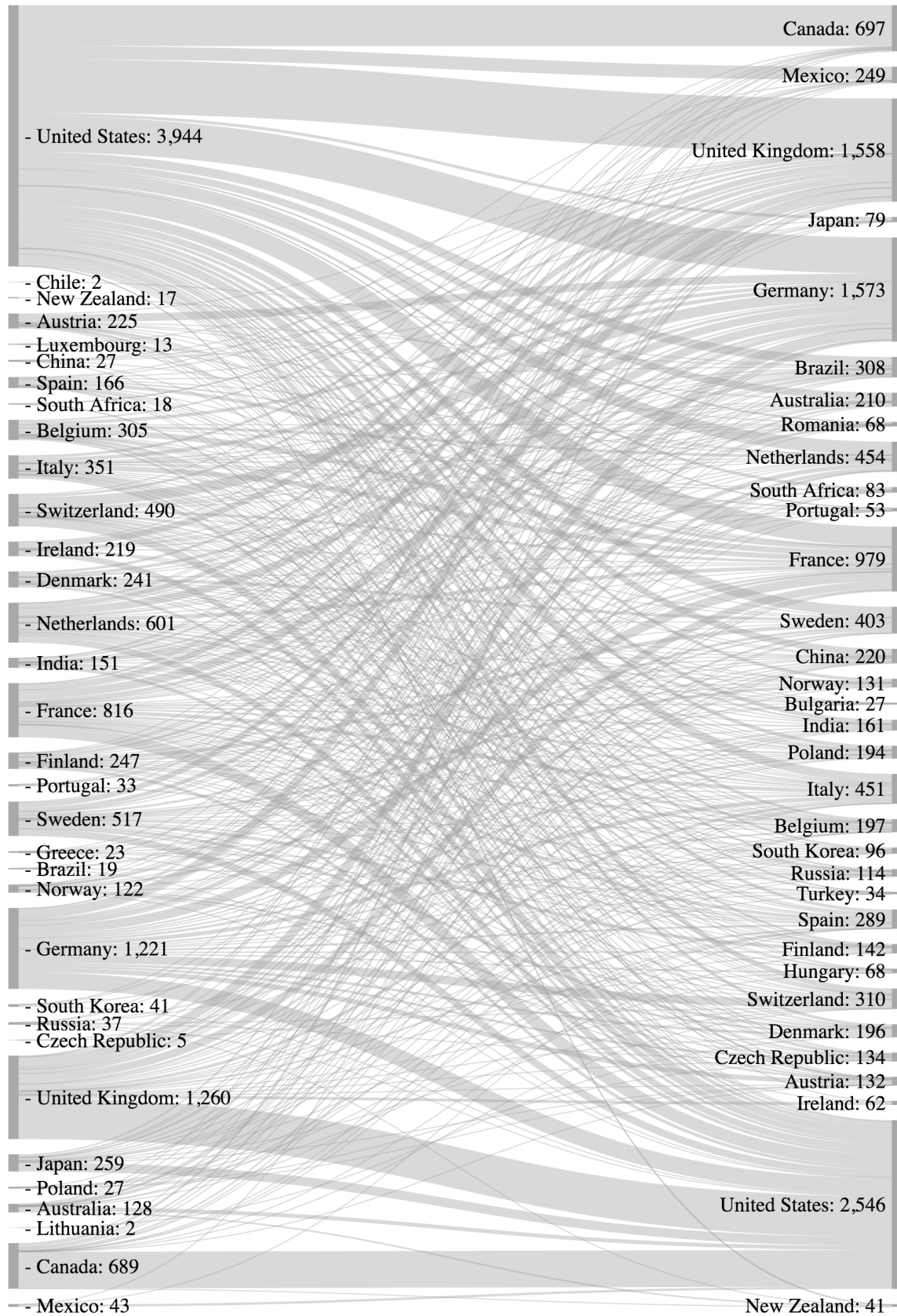
- full merger with the target company
- increase of its interest from below to above 50%
- acquisition of the remaining interest it does not already own ²

To complement this M&A category, we also include another subset of deals labeled “Acquisition of Assets”, whereby only a subset of a target company’s assets (pertaining to one of its division, branch or even a single plant) is acquired. It could be argued that this second category is more relevant for the original purposes of our inquiry, in that it offers a finer grained representation of cross-border investments that may be affected by the pollution haven hypothesis. We account for this in the following section by presenting results estimated on this specific subset.

Given the focus of our study, we restrict this extensive dataset to cross-border deals observed in the manufacturing sector. However, the model presented in section ?? encompasses both domestic and cross-border deals. Therefore, even though the emphasis is on identifying the impact of cross-border energy prices on cross-border investment behavior, we need to include both types of deals in the dataset. Table 1 provides an overview of our sectoral

²These correspond respectively to the categories labeled “Merger”, “Acquisition of Majority Interest” and “Acquisition of Remaining Interest” in the original Thomson-Reuters taxonomy.

Figure 1: Number of cross-border M&A deals in the manufacturing sector by acquiring and target country (1995-2012)



coverage and illustrates that about two-thirds of M&A deals observed in the manufacturing sector occur between companies located within the same country.

In addition, due to the limited availability of historical energy prices, we further limit our scope to the period from 1995 to 2014. After fully accounting for the availability of our other covariates, our final dataset includes a total of 69,979 deals, of which 22,241 are cross-border, covering 40 countries across 23 manufacturing subsectors (see Figure 1).

Table 1: Number of deals by manufacturing subsectors (1995-2014)

Manufacturing subsector	Within-country	Cross-border
Food products and beverages	5,657	2,224
Tobacco products	53	65
Textiles	1,443	699
Wearing apparel	773	193
Tanning and dressing of leather	206	90
Wood products	750	236
Paper products	1,258	617
Publishing and printing	4,673	998
Coke and refined petroleum products	2,201	1,073
Chemicals and chemical products	6,839	3,649
Rubber and plastics products	2,221	1,221
Other non-metallic mineral products	1,980	1,082
Basic metals	2,050	896
Fabricated metal products	2,456	1,253
Machinery and equipment	4,507	2,834
Office, accounting and computing machinery	814	333
Electrical machinery	1,808	1,021
Radio, television and communication equipment	1,772	710
Medical, precision and optical instruments	2,652	1,265
Motor vehicles, trailers and semi-trailers	1,620	1,000
Other transport equipment	942	358
Furniture	1,063	424

5.2. Energy prices

We make use of Sato et al.'s (2015) Fixed Weight energy Price Level Index (FEPI), constructed for each country-sector pair by weighting fuel prices for four carriers (oil, gas, coal and electricity) by the consumption of each fuel type in that country-sector. The FEPI

aims to capture the *within*-sector variation, of the change in energy price level over time for a specific country-sector. As such, it is suitable for use in time-series and panel data analysis.

The FEPI is available for 32 OECD and 16 non-OECD countries between 1995 and 2012. It provides energy price indexes across 12 industrial subsectors, plus a cross-sectoral average.

The fixed-weight price index is constructed for a given country i , sector k and year t , combination according to the following equation:

$$FEPI_{ikt} = \sum_j \frac{F_{ik}^j}{\sum_j F_{ik}^j} \cdot \log(P_{it}^j) = \sum_j w_{ik}^j \cdot \log(P_{it}^j) \quad (9)$$

where F_{ik}^j are the input quantity of fuel type j in tons of oil equivalent (TOE) for sector k in country i and P_{it}^j denotes the real TOE price of fuel type j for total manufacturing in country i at time t in constant 2010 USD. The weights, w_{ik}^j , applied to fuel prices are fixed over time. The same methodology is employed in the construction of the country level index. The prices P_{it}^j are transformed into logs before applying the weights so that the log of the individual prices enter linearly in the equation.³

The use of fixed weights in this index is particularly useful, as it alleviates the common endogeneity concern one faces when using energy prices at the sectoral level. Energy prices often vary with the amount of energy consumed and the choice of fuel types is an endogenous firm decision (Lovo et al., 2014). For example, technological change, fuel substitution or industry-specific shocks on output demand could potentially affect the distribution of fuel consumption within sectors and, ultimately, the sector-level energy prices (Linn, 2008). Instead, the use of fixed weights in the FEPI allows it to capture only energy price changes that come from variations in fuel prices, while ignoring changes in the mix of fuel inputs -

³Note that taking the exponential of the FEPI yields the weighted geometric mean of the different fuel prices, so Equation 9 is the log of the weighted geometric mean.

thereby removing this potential source of endogeneity.

5.3. Other covariates

We complement energy prices with two additional covariates. First, we approximate the size of the potential pool of acquirer or target companies in a given country-sector pair using sectoral industrial activity as measured by sectoral GDP. We obtain this data from the INDSTAT2 database provided by UNIDO, which reports the value added by ISIC Rev. 3 industrial sector at the 2-digit level. Second, we also control for the existence of a free-trade agreement between each country pair, obtained from the CEPII gravity dataset.

6. Results

6.1. Main results

Our main results are shown in Table ?? and cover deals over the period 1995 to 2014. To control for unobserved heterogeneity, all estimates include the basic controls (sectoral GDP in country i and sector k , and in country j and sector l), country-pair fixed effects, acquirer country-time and target country-time dummies, sector dummies and year dummies. This rich set of fixed effects also control for a wide range of other variables that may vary at the country-time level, including unit labor costs, corporate tax levels, stocks valuation, or environmental regulations.

We find evidence that relative industrial energy prices have an impact on the cross-border investment activity of industrial firms. Specifically, firms tend to engage in more cross-border mergers and acquisitions when they face high energy prices relative to that of other countries. Conversely, a country with low energy prices relative to those of its competitors can expect an increase in investments targeting its domestic firms. With an elasticity of -0.25 in our main specification, a 10% increase in the relative industrial energy price differential between two

countries is expected to increase by 2.5% the number of firms acquired in the lower energy price country by firms based in the more expensive country.

The controls enter with expected signs. The log of GDP in both the acquirer and target countries have a positive effect on M&A. The coefficient on the acquirer country's GDP tends to be larger, indicating that the majority of cross-border M&A is initiated by firms located in large economies.

Table 2: Main results

	Main (1)	Lagged energy prices (2)	Labor costs (3)	Horizontal deals (4)
$\log(e_{ijkl,t})$	-0.249*** (0.071)		-0.215*** (0.076)	-0.356*** (0.100)
$\log(e_{ijkl,t-1})$		-0.226*** (0.082)		
$\log(l_{ijkl,t})$			-0.254*** (0.058)	
Controls				
$\log(GDP_{ik,t})$	0.691*** (0.020)	0.688*** (0.023)	0.704*** (0.020)	0.664*** (0.024)
$\log(GDP_{jl,t})$	0.646*** (0.016)	0.644*** (0.022)	0.660*** (0.016)	0.628*** (0.018)
Free-trade agreement	Yes	Yes	Yes	Yes
Country-pair fixed effects	Yes	Yes	Yes	Yes
Country-time fixed effects	Yes	Yes	Yes	Yes
Sectoral fixed effects	Yes	Yes	Yes	Yes
Observations	5,307,776	4,273,215	4,170,498	721,375

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All standard errors clustered by country pairs.

Note: Results from the estimation of equation (7) using our custom Poisson Pseudo-Maximum Likelihood (PPML) estimator, with robust standard errors. Country-pair, time, country-time and sector fixed effect dummies are included in all specifications, but are not reported.

These findings remain consistent under a number of robustness checks. All standard errors reported in the results table are clustered by country-sector pairs. Our main coefficients remain statistically significant and exhibit smaller standard errors when clustered at the country pair level, and when using a robust HAC variance-covariance matrix to control for heteroskedasticity. We therefore choose to conservatively report the SEs resulting from country-sector pairs clustering.

One area of concern is the potential endogeneity of current-period energy prices in both acquirer and target countries. Indeed, cross-border investments may increase activity in countries on the receiving end of foreign investments while potentially reducing it on the acquiring side. This in turn would impact energy demand, and therefore energy prices, on both sides of any given deal – leading to an endogeneity problem between cross-border activity and energy prices. We control for this by using the one-year lag of energy prices in specification (2), with very similar results to that of our main specification.

Still, the effect of sectoral relative energy prices may actually be capturing the price effect of another factor of production – with labor costs appearing as a prime candidate in the context of firm location decisions. In specification (3), we thus include relative unit labor costs l_{ijkl} , with ULC measured as the ratio of total sectoral labor costs to real sectoral output:

$$l_{ijkl} = \frac{ulc_{jl}}{ulc_{jk}} \text{ where } ulc_{ik} = \frac{L_{ik}}{Y_{ik}}$$

The elasticity of the number of deals to relative energy prices remains highly significant albeit slightly smaller, at -0.215, confirming that this coefficient captures the impact of energy prices.

In specification (4), we estimate our model on the subset of our dataset concerning hor-

horizontal deals only – that is deals occurring between firms operating in the same subsector (using industrial subsectors defined along the IEA classification). We may hypothesize that an acquiring firm would enter a horizontal deal as a way to offshore part of its production to the target company, making it the most sensitive to energy costs. Indeed, we find in column (4) that the impact of the energy price ratio is larger for horizontal deals than in the general case by more than one standard error, at -0.356, indicating a higher sensitivity to energy prices.

6.2. Heterogeneity

We also explore the potential heterogeneity of the impact with respect to sectoral energy intensity. In particular, theory predicts that foreign investment decisions in energy intensive sectors where energy costs represent a higher share of overall production costs would be more affected than non energy intensive sectors. In Table 3 we thus add an interaction term between relative energy prices and a dummy indicating whether the *target* sector is highly energy intensive.

We test two definition of energy intensity: physical energy intensity in columns (5) and (6), defined as the ratio of energy consumption physical units (kWh) to total output in dollars, and cost energy intensity in column (7), defined as the ratio of energy costs to total output, both in dollars.

We do not find a statistically significant difference in the sensitivity of high-energy intensity sectors with respect to relative energy prices. This results holds for both definitions of energy intensity (columns 5 and 7), and when restricting the sample to horizontal deals only (column 6). A similar finding is reported by ? when analyzing German multinational firms' location choices faced with the EU-ETS. One potential explanation is the higher capital intensity of high energy intensity activities, which make them more difficult to relocate – the

Table 3: Heterogeneity across sectoral energy intensity

	All deals (5)	Horizontal deals (6)	High energy cost to VA ratio (7)
$\log(e_{ijkl,t})$	-0.251*** (0.077)	-0.321*** (0.107)	-0.244*** (0.072)
$\log(e_{ijkl,t}) * intensive_{jl}$	0.006 (0.068)	-0.085 (0.076)	-0.026 (0.075)
Controls			
$\log(GDP_{ik,t})$	0.691*** (0.020)	0.665*** (0.024)	0.691*** (0.020)
$\log(GDP_{jl,t})$	0.646*** (0.016)	0.628*** (0.018)	0.646*** (0.016)
Free-trade agreement	Yes	Yes	Yes
Country-pair fixed effects	Yes	Yes	Yes
Country-time fixed effects	Yes	Yes	Yes
Sectoral fixed effects	Yes	Yes	Yes
Observations	5,307,776	721,375	5,307,776

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All standard errors clustered by country pairs.

so-called "footlooseness" argument.

7. Conclusion

A third of mergers and acquisitions bring together firms from two different countries. As world economies become increasingly integrated and countries compete for new investments in productive capacities, there is a greater need to identify the factors that drive or deter cross border deals.

In this paper, we have combined a rich firm level dataset on cross-border mergers and acquisitions with a dataset on industry level energy prices. This is a key area of concern for policy makers in the environmental, energy and climate areas. It represents the first analysis in this context to focus on the role of energy prices as possible determinants of cross border

M&As. It builds on previous work using FDI data to explore the role of these factors in driving foreign investments.

We find evidence that relative industrial energy prices have an impact on the cross-border investment activity of industrial firms. Specifically, firms tend to engage in more cross-border mergers and acquisitions when they face high energy prices relative to that of other countries. These results are robust to a wide variety of tests including alternative specifications, various levels of clustering and an examination of different controls. We also find other intriguing results. We find that the impact of energy prices is not larger when acquiring or target firms operate in highly energy-intensive sectors. This is similar to previous findings in the literature and may be explained by the large capital intensity of energy-intensive sectors reducing their cross-border mobility.

These results have a number of potential implications. First, they support the argument for complementing environmental policies with measures to prevent pollution leakage in industrial activities. For examples, in carbon emissions trading systems across the world (e.g. California, European Union, New Zealand, South Korea and the Chinese pilot schemes) regulated firms in industrial sectors deemed to be exposed to the risk of carbon leakage (relocation) are typically granted compensation in the form of free emission allowances. Our results indicate that such anti-leakage measures indeed appear justified, so long as they are targeted correctly to those companies that are genuinely exposed to that risk.

Our analysis can be extended in several directions. One extension would be to move beyond the number of deals and to gather data on the value of the mergers and acquisitions. Regressing this as the dependent variable enables testing if energy prices and environmental policies affect cross-border investment volumes in terms of transaction value. This and other extensions are left for future work.

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