Do Energy Prices Drive Outward FDI? Evidence from a Sample of Listed Firms

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ABSTRACT

Affordable energy is often argued to be a vital condition for manufacturing industries to be able to compete on global markets. Consequently, the idea of introducing a (unilateral) carbon tax is usually opposed on the grounds of potential losses of competitiveness and leakage of economic activity abroad. In this paper, we shed light on one potential channel of such effects—the impact of energy prices on firms' outward FDI. Using an instrumental variable strategy we estimate the longer-term effects on a sample of listed firms from 9 manufacturing sectors in 24 OECD countries over 1995–2008. The results suggest that relative energy prices—that is the difference between domestic energy prices and prices in the potential FDI destination—are significantly and asymmetrically related to firms' outward FDI asset share. Only firms that faced increases in the relative energy prices have increased their international asset position and this effect was relatively small.

Keywords: Energy prices, FDI, Carbon leakage, Carbon tax

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I. INTRODUCTION

Foreign direct investment (FDI) has increased dramatically over the last four decades, both in developed and developing countries. In particular, developing countries have become a primary destination of FDI: in 2012, for the first time they received more than 50% of worldwide FDI.[1] A significant part of these investments has been made in the manufacturing sector. For example, in China, between 1997 and 2008, 70% of total FDI inflows were in the manufacturing sector for an amount of USD 388,679 million (Liu and Daly, 2011), making China the largest single FDI recipient already by 2002. Similarly in India, between 2000 and 2015, manufacturing FDI accounted for roughly 50% of total FDI inflows, amounting to USD 123,069 million (DIIP, 2015).

FDI has potentially large benefits, for both host and investor countries. Such benefits can range from more efficient production patterns, technology and know-how transfers and economic development (see for example De Mello, 1998; Saggi, 2002; OECD, 2002 for surveys on this issue). However, reasons for deciding to invest abroad may also be controversial. For example, outward FDI can be motivated by comparatively lax environmental regulation in the destination country. This is in line with a pollution haven effect type of argument, which leads to concerns about the

1. Historical series of FDI for developed and developing countries can be found on UNCTAD website: http://unctadstat.unctad.org/.

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deterioration of competitiveness in environmentally stringent countries—in particular for pollution intensive manufacturing—and pollution leakage.

Business associations, primarily in developed countries, often point out low energy costs and weak environmental regulation in developing countries as being partly responsible for these global FDI trends (Alliance for American Manufacturing, 2008, 2009). More generally, business leaders consider cheap energy as vital for manufacturing industries to compete on global markets.[2] High energy prices would arguably reduce industrial output and significantly reduce employment (Business for Britain, 2014). Consequently, such groups argue that the introduction of a (unilateral) carbon tax would have adverse effects on manufacturing industry activity (Morgan, 2012; Green, 2011; American Council for Capital Formation and National Association of Manufacturers, 2009; National Black Chamber of Commerce, 2015).

In this paper, we shed light on these claims by estimating the effect of energy prices on firm-level outward FDI. Our estimations are based on an instrumental variable strategy that removes endogenous firms' choices of fuel substitution from observed energy prices. We use a sample of listed firms from 9 manufacturing sectors in 24 OECD countries over the period 1995–2008. Results suggest that only *relative* energy prices—i.e. the difference between domestic energy prices and prices in the FDI destination—rather than *absolute* energy prices are significantly correlated with firm level FDI. Second, we also find that firms heterogeneously respond to variations in energy prices. Only firms that faced increases in relative energy prices increased their international assets as opposed to those that experienced a decrease in relative energy prices, which did not respond to it. Considering only firms that experienced an increase in (relative) energy prices, we find that, on average, a 1% increase in energy prices is associated with an increase of 0.71 percent in firms' international assets. Compared to total assets, this increase appears to be small in magnitude. Further results suggest that a 1% increase in relative energy prices is associated with a 0.54 percent increase in firms' international-to-total-assets ratio on average.

While listed firms represent only a fraction of total firms that are potentially involved in FDI, they are likely to be larger and more "internationalised" than other firms not included in our data set. Moreover, this data-driven approach is appealing in light of increasing evidence that movements in large firms help to explain major parts of aggregate fluctuations (see Gabaix, 2011, for evidence using US data). Our results are robust across various specifications.

Conceptually, the question of whether outward FDI is driven by cross-country differences in energy prices is closely linked to the pollution haven effect. In theory, countries with relatively laxer environmental policies can gain a comparative advantage in pollution intensive industries (Pethig, 1976; Siebert, 1977; Yohe, 1979). Thus, stringent environmental regulations provide firms with incentives to relocate some stages of production to countries with laxer environmental policies—investing in "pollution havens" (Siebert et al., 1980; McGuire, 1982; Merrifield, 1988). Similarly, countries with lower energy prices can gain an absolute competitiveness advantage or a comparative advantage in energy intensive industries. Provided that capital is sufficiently mobile, a variation in the competitiveness advantage can be "internalised" by firms in countries with stringent environmental regulation through relocating their production overseas.

From an empirical perspective, industrial energy prices can therefore be expected to have impacts similar to general emissions policies. Climate change mitigation policies through carbon pricing—carbon taxes, cap-and-trade mechanisms—are one obvious example but, in practice, even command and control instruments addressing climate or air pollution can ultimately increase energy

2. See for instance Chazan (2012), Clark (2014a, 2014b) in The Financial Times and Barton et al. (2014) in The Wall Street Journal.

prices.[3] Thus, estimating the effect of changes in energy prices on FDI improves our understanding of the impact of cross-country differences in climate policies on FDI and of the environmental efficacy of such policies. The main advantage of using energy prices in our analysis is that data are readily available and comparable for a large number of countries and a long time period.

Our findings support the pollution haven effect even though the latter appears to be quantitatively small. In a simple simulation exercise, we illustrate that only a very high carbon tax would have a sizeable effect on FDI. Nonetheless, given that these effects are stronger in energy-dependent sectors and presumably geographically localised, we anticipate the political economy of carbon taxation to be complicated.

The rest of the paper is organised as follows. Section 2 summarises the literature on the PHH debate. Section 3 explains our empirical strategy. Section 4 reports the main estimation results and discusses them. Section 5 provides a simulation of the effect of a carbon tax on FDI. Section 6 concludes.

II. EMPIRICAL LITERATURE ON POLLUTION HAVENS AND FOREIGN DIRECT INVESTMENT

The debate on the pollution havens through FDI is based primarily on the empirical evidence from single-country effects,[4] mostly due to the dearth of relevant bilateral FDI data.[5] A large number of existing studies use US inward or outward FDI data (List and Co, 2000; List, 2001; Keller and Levinson, 2002; Xing and Kolstad, 2002; Eskeland and Harrison, 2003; Fredriksson et al., 2003; List et al., 2004; Cole and Elliott, 2005; Kellenberg, 2009; Hanna, 2010). Other studies use outward FDI from U.K. (Manderson and Kneller, 2012), Japan (Kirkpatrick and Shimamoto, 2008; Elliot and Shimamoto, 2008), France (Ben Kheder and Zugravu, 2012), Germany (Wagner and Timmins, 2009) and Korea (Chung, 2014). Another set of studies relied on inward FDI into China (Di, 2007; Dean et al., 2009), or Mexico (Waldkirch and Gopinath, 2008).

Overall, results are mixed with some papers finding strong evidence that FDI decisions are significantly influenced by weaker environmental regulations (Hanna, 2010; Chung, 2014) or not affected at all (Eskeland and Harrison, 2003; Kirkpatrick and Shimamoto, 2008; Manderson and Kneller, 2012). Others find that the effect depends on industries' ability to relocate, proxied by capital intensity (Cole and Elliot, 2005; Kellenberg, 2009). The effects are also found to depend on the characteristics of the parent countries (Dean et al., 2009) or characteristics of the host countries (Ben Kheder and Zugravu, 2012). Conducting a meta-analysis over this literature, Rezza (2015) suggests that differences among results can be explained by different choices in the definition of FDI as a dependent variable or the use of different proxies for environmental stringency. The Table A1 in Appendix A1 summarises the main results of this literature.

3. Sato et al. (2015) also develop this argument and show that there exists a high correlation between energy prices and a series of alternative measures of climate stringency. In particular, they show that there is a significant correlation of 0.77 between their energy prices index and the industry-adjusted intensity (IAEI) measures, arguably a good proxy for climate and energy policies stringency.

4. One exception is Javorcik and Wei (2004) who use firm-level FDI data from 25 developed and emerging countries over the 1989–1994 period. However, their analysis focusses on FDI in post-Soviet transition economies as a destination.

5. Although less directly related to this paper, some papers have also addressed the pollution haven hypothesis trough patterns of international trade. Examples are Ederington et al. (2004), Ederington et al. (2005), Levinson and Taylor (2008) or Koźluk and Timiliotis (2016). Closer to our paper, Aldy and Pizer (2011), Gerlagh and Mathy (2011) and Sato and Decheleprêtre (2015) investigate the link between energy prices and trade patterns.

These studies suffer from at least two drawbacks that our paper attempts to address. First, given the single-country focus of this research, one can hardly generalize these results. Second, the tabulated overview of the related literature in Table A1 in Appendix A1 shows that these studies mostly relied on indexes derived from surveys, abatements expenditures or authorized pollution as proxies for environmental regulations, all of which are flawed with identification issues (Botta and Kozluk, 2014). In surveys for instance, respondents might perceive environmental regulation as more or less stringent depending on the business cycle. Abatement expenditures capture effects from non-environmental policies—such as technology and innovation policies—or firms' decisions (e.g. energy efficiency profit seeking investments that also improve environmental performance). Authorized pollution does not capture to what extent environmental regulations are enforced. That is, countries vary in the vigor of their law enforcement, which results in some discrepancy between the legal (*de jure*) and the actual (*de facto*) stringency of their environmental policies.

The contribution of this paper is therefore twofold. First, we provide the first cross-country analysis at the firm level on the response of FDI to energy prices. Second, our estimates of FDI elasticity of energy prices allow for a better understanding of the effect of some important environmental policies, such as climate change mitigation policies. In practice, most upstream policy instruments addressing climate or air pollution—carbon taxes, cap-and-trade mechanisms and even command and control instruments—ultimately increase energy prices. Thus, the effect of changes in energy prices on FDI can be viewed as an approximation of the impact of an increase in the stringency of, at least some key types of, climate policies. Unlike the latter, the main advantage of using energy prices is that data are readily available and comparable for a large number of countries and a long time period.

We acknowledge the conceptual limitations of this approximation however. First, we only implicitly measure the effect of the policy instruments that have an impact on energy prices. These include climate policies, air pollution and transport regulations. Moreover, deliberate policy action, such as a carbon tax introduction, could have a more salient effect than equivalent market price changes (Rivers and Schaufele, 2015).

III. EMPIRICAL STRATEGY

Methodology

To estimate the firm-level FDI elasticity of energy prices, we consider the following equation:

$$\log(FDI\ )_{ijct} = \alpha + \beta \log\left(EP\right)_{jct} + \gamma X_{ijct} + \mu_i + \lambda_{ct} + \varepsilon_{ijct} \tag{1}$$

where FDI_{ijct} is the international assets of firm i. in sector j in country c at time t, EP_{jct} is the domestic energy prices of sector j in country c at time t, X_{ijct} is a set of firm-level control variables, μ_i is a firm fixed-effect, λ_{ct} is a country-year dummy variable that captures country-year specific effects on firms' decisions on FDI and ε_{ijct} is the idiosyncratic error term.

Energy prices indexes EP_{jct} are constructed by weighting country-level prices of four different types of fuel—oil, gas, coal and electricity—by their relative consumption in each country-sector-year. Formally,

$$EP_{jct} = \sum_k \frac{F^k_{jct}}{\sum_k F^k_{jct}} . P^k_{ct} = \sum_k w^k_{jct} . P^k_{ct}$$

where F^k_{jct} is input consumption of fuel k for industrial sector j, in country c at time t, and P^k_{ct} is the price of fuel k in country c at time t.

Estimating equation (1) by OLS is likely to provide biased results. Endogeneity problems arise as unobservable industry-level factors could explain both trends in observed energy prices and FDI outflows. For example, technological changes or other industry-specific shocks on output demand could affect the sector-level distribution of fuel consumption and, consequently, energy prices (Linn, 2008). These very same factors may also have an influence on FDI decisions at the firm-level. For instance, an energy-efficiency technology innovation can make firms rely more on a particular fuel while also delaying investments in foreign countries.

To circumvent this issue, we follow Linn (2008) and Sato and Dechezleprêtre (2015) by adopting an instrumental variable (IV) strategy, using an energy prices index based on the aforementioned four fuels, but weighted with constant weights—i.e. where $F^k_{jct} = F^k_{jc0}$. Keeping sector-level weights constant while allowing national fuel prices to vary across time provides an instrument that removes the effects of technological change or other industry-specific shocks on fuel substitution in EP_{jct}.

While our instrument relies on national fuel prices, the latter may be correlated with other factors that may also explain FDI developments. Fuel prices are driven by global energy commodity prices and domestic factors such as transportation costs and energy policies. Sato et al. (2015) find that the cross-country variation in energy taxation explains 80% to 90% and 50% to 80% of the variation in coal and oil prices respectively. For electricity, this is around 60% while the explanatory power of taxes for the variation in gas prices is approximately 20% because gas prices are strongly conditioned on the geography of transport infrastructure.

We use country-time fixed-effect parameters λ_{ct} in equation (1) to control for any "general" confounding factors that are not industry specific. These can include changes in institutional settings at the country level, allowing countries to have their own specific trends in FDI outflows. For example, they allow for each country to react differently to global shocks such as China's accession to WTO or aggregate demand shocks in one particular country in one particular year.[6] Furthermore, these coefficients capture the effects on FDI outflows from movements in exchange rates or changes in trade patterns.

Next, firms in a given sector might not pay the industry-wide energy prices. For example, large firms may be able to negotiate special agreements. Because these special contracts are not prone to frequent modifications, we capture the potential firm-level differences in price levels through firm fixed effects μ_i. Importantly, country and sector fixed effects are also included in this parameter. Therefore, time-invariant unobservable characteristics at the country and sector levels are captured by this variable.

Finally, we control for firms' size by the number of employees and total assets, and international openness by the amount of international sales. These variables are potential confounding factors at the firm level. Bigger companies might have an easier access to international markets and therefore enjoy lower transactions costs when engaging in FDI. Furthermore, some firms might just be more internationally oriented by the nature of their business and therefore find it easier to adjust to energy prices changes through FDI.

6. Intuitively, by using country-year dummies, we allow for common shocks' responses to be differentiated across countries. If these responses were not different across countries, country-year dummies would simply have similar (i.e. non-significantly different) coefficients for every given year. These coefficients will therefore capture common shocks with respect to a baseline year.

We estimate equation (1) by two-stage least squares (2SLS) with a fixed-weight energy prices index as an instrumental variable. In this panel data setting, we use the time variation between the first and the last year of observation of each firm consequently exploiting the accumulation of (net) energy prices increase over time and its effect on FDI outflows.[7] This approach has the advantage that we focus on longer term changes in energy prices therefore limiting the influence of temporary shocks that fade away over the period of analysis. Furthermore, in order to avoid estimating a large number of firm fixed-effect parameters μ_i, we estimate equation (1) in deviations from means within each firm.[8] We report clustered standard errors both at the country-sector-year and country-sector levels to account for potential autocorrelation in the error term.

One limitation of this approach is that we do not estimate the effect of an increase in domestic prices relative to foreign prices.[9] Such an exercise requires the use of firm-level data of bilateral FDI that are, to our knowledge, not available. An alternative is to use the difference between domestic and Chinese energy prices to proxy for relative prices. Over the period of analysis, China has the lowest energy prices on average which makes it an attractive destination for firms seeking lower energy prices. Additionally, China had become increasingly open to international trade and, as explained above, has received significant amount of FDI. In any case, our estimation strategy relies on the assumption that, as firms respond to energy prices increases, outward FDI goes to countries with lower energy prices.

Data

All firm-level data come from the Worldscope database that provides balance-sheet information on listed companies worldwide. Our concept of foreign direct investment is the Thomson Reuters Worldscope definition of international assets: identifiable assets of foreign operations before adjustments and eliminations, which are effectively for-profit assets held abroad by the company that can be identified and priced.

Although listed firms represent only a fraction of total firms that potentially do FDI, they are likely to be larger and more "internationalised" than other firms not included in the Worldscope database. Since building up production facilities abroad requires shouldering high fixed costs (Greenaway et al. 2007), firms who face lower financial constraints, ceteris paribus, tend to have a greater propensity to outsource via FDI. Listed firms face less financial obstacles through a combination of broader access to equity markets and reduced informational asymmetries due to higher requirements to the disclosure of firm activity (Beck et al. 2006) and thus likely engage more easily in outsourcing as compared to private firms.

While data-driven, the choice to focus on listed firms is also appealing in light of increasing evidence that movements in large firms help to explain major parts of aggregate fluctuations.[10] Furthermore, the data on international assets is based on comparable balance-sheet information resulting from legal disclosure requirements as opposed to voluntary potentially incomplete reporting.

As the main objective of this paper is to estimate the FDI elasticity of energy prices, our sample includes firms that report some positive values for international assets. As a result, we only

7. The first and last years of observation for each firm do not necessarily correspond to the first and final years of our period of analysis as we have an unbalanced panel data of observations.

8. This estimation technique is called the "within estimator" and is common practice for panel data estimations.

9. Under the pollution haven theory, this deteriorates domestic competitiveness and firms would have more incentives to increase their holdings abroad.

10. See Gabaix (2011) for evidence using US data.

work with firms from the moment they start reporting positive values of FDI. The question of whether energy prices push firms to engage in FDI (extensive margin) should be modelled differently and is left for future research.

We focus our analysis on a subset of OECD countries for which we have decent data coverage. OECD countries are more advanced in terms of environmental policies and their policymakers tend to be more concerned about industry flight. Therefore, OECD countries are likely to be an FDI origin rather than a destination for firms trying to avoid higher energy prices. A downside of the Worldscope database is that the information on the FDI destination is not available in a usable fashion, not allowing an analysis of bilateral FDI. Hence, the analysis focuses on the effects of domestic energy prices increases on international assets held.

Energy prices come from the database in Sato et al. (2015). Energy prices indexes are constructed for 12 sectors in 48 countries over 1995–2008. Fuel prices of oil, gas, coal and electricity, and their respective sectoral consumption shares come from the IEA Energy End-Use Prices database, which provides details on the domestic end-use energy prices paid by industrial users in manufacturing sectors. Energy prices are 12-month averages and include taxes paid by industry (in particular excise and environmental taxes) but exclude VAT and recoverable taxes and levies. The prices are deflated and converted to constant 2010 USD for tonnes of oil equivalent (TOE).

Sato et al. (2015) provide two versions of the index with different weighting. The Variable-weight Energy Price Level (VEPL) uses the actual industry fuel consumption shares that vary over time, making it representative of the actual energy prices paid by industry and suitable for level comparisons across countries and industries at different points in time. The Fixed-weight Energy Price Level (FEPL) can be used as an instrumental variable for the VEPL. It is constructed using fixed weights from the baseline year 1995. Hence, the variation in the FEPL comes solely from the changes in domestic energy prices and not from the changes in consumption shares.

Our sample covers the following manufacturing sectors: chemicals and petrochemicals, food and tobacco, iron and steel, machinery, non-ferrous metals, non-metallic minerals, paper and print, textile and transport. We drop construction, mining and quarrying and, wood products as these sectors are unlikely to respond to energy prices through FDI. Construction is a genuinely local business and mining and wood industries investments in foreign countries mainly respond to natural resources availability.

The final sample is an (unbalanced) panel of 3,364 companies from 24 OECD countries[11] and 9 industries over the period 1995–2008. Because of data on Chinese energy prices go only up to 2008, the 2009 financial crisis period is excluded from our sample of analysis. In any case, such a global shock has been highly disruptive in terms of investment decisions. Therefore, FDI patterns might have been affected by systemic factors that are likely to create noise and contaminate our estimates. Table A2.1 and Table A2.2 in Appendix provide the ISIC codes that define the manufacturing sectors and countries sample weight respectively.

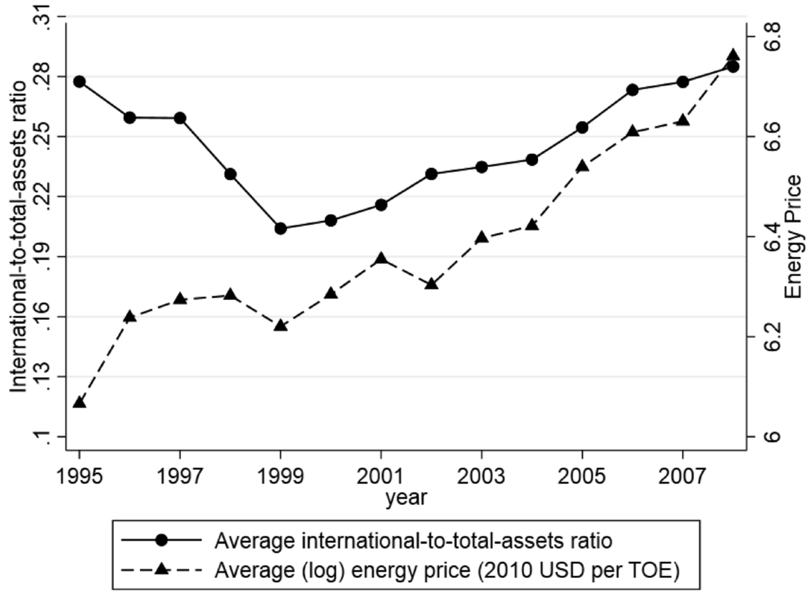
Table A2.3 reports summary statistics of our sample for firms in their last year of observation. On average, firms have 8,238 employees (with a median of 2,000) and make around USD 3.3 million in international sales (median is USD 346,686). The sample averages of international and total assets are USD 2.5 million and USD 7.2 million respectively (medians are USD 169,740 and USD 963,849 respectively). The average international-to-total-assets ratio is 26% (with a median

11. Countries are Australia, Austria, Belgium, Canada, Switzerland, Czech Republic, Germany, Denmark, Finland, France, the United Kingdom, Greece, Hungary, Italy, Japan, Korea, the Netherlands, New Zealand, Poland, Portugal, Slovakia, Sweden, Turkey, and the United States.

of 19%). Finally, firms face energy prices of USD 786.2 per TOE (with a median of USD 608.3 per TOE).

Figure 1 displays the yearly firm-average international-to-total-assets ratio and (log) real energy prices. For most of the analysis period, the average FDI ratio has been increasing in line with energy prices faced by firms included in the sample. This suggests that the latter is potentially a driver of FDI and motivates the more detailed analysis provided in the next section.

Figure 1: FDI and energy prices trends



Source: Authors calculations.

IV. EMPIRICAL RESULTS

Main estimation results

Columns (1)–(4) of Table 1 provide OLS estimation results of equation (1) with domestic energy prices as the main independent variable. Reported coefficients are estimates of the FDI elasticity of energy prices. Their magnitude is similar across specifications and the full specification result of column (4) suggests that a 1% increase in energy prices is associated with a 0.68% increase in firm-level international assets. Next, columns (5)–(8) report point estimates of the FDI elasticity of the difference between domestic and Chinese energy prices. These estimations seem more robust as all coefficients are found to be statistically significant. Column (8)—the full specification—indicates that a 1% increase in relative energy prices is associated with a 0.70% increase in firm-level international assets. As these estimates might suffer from an endogeneity bias, we run IV regressions following the identification strategy explained in Section III.

Table 2 reports 2SLS results and display a quite different picture. Coefficients of columns (1)–(4) are now statistically insignificant. However, columns (6)–(8) report that a 1% increase in relative energy prices is associated with a significant increase of between 0.5% and 0.7% in firm-level international assets. Thus, these results suggest that relative energy prices are a driver of FDI as opposed to absolute energy prices. In addition, point estimates decrease in magnitude as we control for

Table 1: OLS estimation results

Dependent variable: Log(International assets)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log(energy price)	0.458	0.594	0.606*	0.676**				
	(0.374)	(0.437)	(0.336)	(0.328)				
Log(energy price)–					0.721***	0.851***	0.774***	0.704***
Log(CHN energy price)					(0.170)	(0.206)	(0.201)	(0.223)
Log(Number of employees)		0.850***	0.307**	0.192*		0.854***	0.314**	0.199*
		(0.140)	(0.132)	(0.113)		(0.140)	(0.133)	(0.114)
Log(Total assets)			0.835***	0.550***			0.829***	0.547***
			(0.078)	(0.066)			(0.078)	(0.067)
Log(International sales)				0.419***				0.416***
				(0.027)				(0.027)
Country-year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Observations	6,728	6,728	6,728	6,728	6,728	6,728	6,728	6,728
Number of firms	3,364	3,364	3,364	3,364	3,364	3,364	3,364	3,364
R-squared	0.189	0.319	0.385	0.442	0.192	0.324	0.389	0.444

Note: Columns (1)–(4) provide Ordinary Least Squares (OLS) estimation results of equation (1). Columns (5)–(8) OLS estimation results of equation (1) with relative prices as measured by the difference between domestic and Chinese energy prices. Firm-level control variables are the number of employees, total assets and international sales. All regressions include country-year fixed-effects. Robust standard errors clustered at the country-sector level in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

Table 2: 2SLS estimation results

Dependent variable: Log(International assets)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log(energy price)	0.344	0.779	0.841	0.625				
	(0.577)	(0.736)	(0.536)	(0.481)				
Log(energy price)–					0.332	0.701**	0.702***	0.510**
Log(CHN energy price)					(0.270)	(0.291)	(0.227)	(0.259)
Log(Number of employees)		0.850***	0.308**	0.192*		0.853***	0.314**	0.197*
		(0.137)	(0.130)	(0.111)		(0.138)	(0.131)	(0.112)
Log(Total assets)			0.835***	0.550***			0.830***	0.548***
			(0.077)	(0.065)			(0.077)	(0.065)
Log(International sales)				0.419***				0.417***
				(0.026)				(0.026)
Country-year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Observations	6,728	6,728	6,728	6,728	6,728	6,728	6,728	6,728
Number of firms	3,364	3,364	3,364	3,364	3,364	3,364	3,364	3,364
R-squared	0.001	0.161	0.242	0.312	0.003	0.166	0.246	0.315

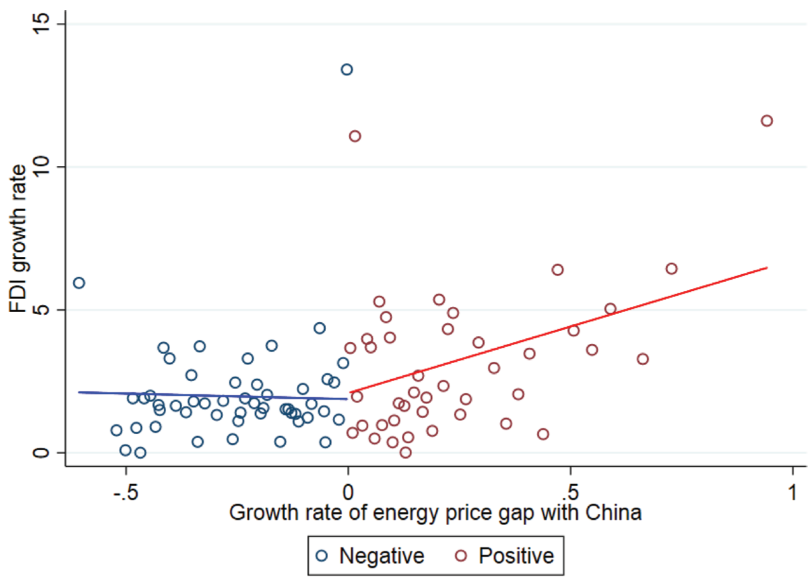
Note: Columns (1)–(4) provide Two Stage Least Squares (2SLS) estimation results of equation (1) using the FEPL index from Sato et al. (2015) as an instrument for observed energy prices. Columns (5)–(8) provide 2SLS estimation results of equation (1) with relative prices as measured by the difference between domestic and Chinese prices. The differences between the domestic and Chinese FEPL index from Sato et al. (2015) is used as an instrument for observed relative prices. Firm-level control variables are the number of employees, total assets and international sales. All regressions include country-year fixed-effects. Robust standard errors clustered at the country-sector level in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

the importance of international sales. Column (8) is therefore our preferred specification—including all firm-level controls and using IV. Importantly, coefficients of control variables have the expected signs and plausible magnitude and the fits of regressions are relatively high—around 31% for the full specification results of columns (4) and (8). Therefore, we believe that we use an appropriate econometric model and that reported elasticities are precisely estimated.

The difference in OLS and 2SLS results seem indicate that the former suffer from an upward bias. As explained in Section III, this bias may occur because unobservable shocks (e.g. technological changes) can affect the sector-level distribution of fuel consumption as well as FDI decisions at the firm-level. For instance, it may be that technological changes related to sector-specific industrial processes allowed for switching to cheaper fuels—therefore decreasing energy prices through a change in the fuel mix—and simultaneously reduced the incentives of investing in foreign countries where this technology was not yet available. A naïve correlation between energy prices and firm-level international assets would therefore provide biased estimates, which are corrected by our IV strategy.

In addition, while Table 2 results provide the average effect of energy prices on international assets, firms in our sample may heterogeneously respond to variations in energy prices. In particular, firms experiencing an increase in the domestic prices relative to the prices of energy in China may be prone to relocate their activities, while firms that observe a decrease in the energy prices gap with China may not choose to repatriate their assets. Figure 2 supports the possibility of this asymmetric effect. It plots the FDI growth rate against the growth rate in the domestic-Chinese energy prices gap. A linear fit line is added to visualize the relationship between two variables. We observe that the correlation is lower and close to zero in the case for negative growth rates of energy prices gap with China.

Figure 2: Effect of energy prices on FDI appear stronger for positive increases



Note: This figure provides a scatter plot of the firm-level FDI growth rate against the growth rate domestic-Chinese energy prices gap. Fitting lines represent the unconditional correlation between the two variables and are presented for two subgroups: firms that experienced negative and positive increase in the domestic-Chinese energy prices gap. For better data visualization of these relationships, the means of the x-axis and y-axis variables for equal-sized bins of 100 observations are plotted.

We formally test this hypothesis by estimating equation (1) with asymmetric effects of energy prices—interacting the energy prices variable (absolute or relative, depending on the specification) with additional dummies indicating whether firm *i* faced a decrease or an increase in (either absolute or relative) energy prices over the period of observation.

Point estimates reported in Table 3 confirm that absolute prices play no role in firm-level FDI decisions as energy prices coefficients reported in columns (1)–(4) are all statistically non-significant. Coefficient in columns (5)–(8) show that firms that faced an increase in energy prices relative to China responded by a significant increase in international assets unlike firms that experienced a decrease in such relative prices, which did not significantly respond. Column (8) shows that, on average, a 1% increase in energy prices is associated with an increase of 0.71 percent in firms' international assets. Therefore, results reported in Table 3 suggest that the statistical significance of the effects found in Table 2 can be attributed to the firms that faced an increase in relative energy prices.

Table 3: 2SLS estimation results with interaction terms

Dependent variable: Log(International assets)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log(energy price)*Dummy_Positive	0.396	0.805	0.882*	0.613				
	(0.544)	(0.697)	(0.526)	(0.483)				
Log(energy price)*Dummy_Negative	0.185	0.697	0.717	0.659				
	(0.622)	(0.825)	(0.546)	(0.500)				
[Log(energy price)–Log(CHN en. pr.)]*D_p					1.178**	1.375***	1.347***	0.711**
					(0.493)	(0.436)	(0.394)	(0.326)
[Log(energy price)–Log(CHN en. pr.)]*D_n					–0.081	0.370	0.385	0.412
					(0.377)	(0.396)	(0.278)	(0.302)
Log(Number of employees)		0.850***	0.307**	0.192*		0.851***	0.311**	0.196*
		(0.137)	(0.129)	(0.111)		(0.138)	(0.129)	(0.111)
Log(Total assets)			0.835***	0.550***			0.831***	0.550***
			(0.076)	(0.065)			(0.074)	(0.065)
Log(International sales)				0.420***				0.415***
				(0.026)				(0.027)
Country-year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Observations	6,728	6,728	6,728	6,728	6,728	6,728	6,728	6,728
Number of firms	3,364	3,364	3,364	3,364	3,364	3,364	3,364	3,364
R-squared	0.001	0.161	0.243	0.312	0.001	0.165	0.246	0.314

Note: Columns (1)–(4) provide Two Stage Least Squares (2SLS) estimation results of equation (1) using the FEPL index from Sato et al. (2015) as an instrument for observed energy prices. Columns (5)–(8) provide 2SLS estimation results of equation (1) with relative prices as measured by the difference between domestic and Chinese prices. The differences between the domestic and Chinese FEPL index from Sato et al. (2015) is used as an instrument for observed relative prices. Firm-level control variables are the number of employees, total assets and international sales. All regressions include country-year fixed-effects. Robust standard errors clustered at the country-sector level in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

How does FDI elasticity of energy prices compare to total investment?

So far, we have estimated the FDI elasticity of energy prices. To give our results some perspective—comparing with the total asset stocks, we estimate equation (1) with the international-to-total-assets ratio as a dependent variable.

Results are reported in Table 4 and, again, they suggest that relative prices as opposed to absolute prices play a role in driving firm-level FDI decisions (columns (4)-(6)). The full specification in column (6) suggests that a 1% increase in the domestic-Chinese energy prices gap is associated with an increase of 0.54% in the international-to-total-assets ratio. In terms of percentage points, this corresponds to a small increase: the average FDI ratio in our subsample of firms that face an increase in relative energy prices is 28% in their last year of observation. If for each of these firms, we subtract the effect due to relative energy prices increases over the period of observation as predicted by estimates of column (6) in Table 4, we calculate that this ratio would have been around 25%, that is, 3 percentage points lower.

Table 4: 2SLS estimation results (International-to-total-assets ratio)

Dependent variable: Log(International-to-total-assets assets)	(1)	(2)	(3)	(4)	(5)	(6)
Log(energy price)	0.751	0.854*	0.695			
	(0.464)	(0.506)	(0.432)			
Log(energy price)–Log(CHN energy price)				0.614***	0.702***	0.547**
				(0.208)	(0.224)	(0.253)
Log(Number of employees)		0.200***	–0.044		0.203***	–0.040
		(0.076)	(0.067)		(0.076)	(0.067)
Log(International sales)			0.340***			0.337***
			(0.024)			(0.024)
Country-year fixed effects	YES	YES	YES	YES	YES	YES
Observations	6,728	6,728	6,728	6,728	6,728	6,728
Number of firms	3,364	3,364	3,364	3,364	3,364	3,364
R-squared	0.001	0.012	0.080	0.006	0.018	0.084

Note: Columns (1)–(3) provide Two Stage Least Squares (2SLS) estimation results of equation (1) with the international-to-total-assets ratio as a dependent variable and using the FEPL index from Sato et al. (2015) as an instrument for observed energy prices. Columns (4)–(6) provide 2SLS estimation results of equation (1) with the international-to-total-assets ratio as a dependent variable and with relative prices as measured by the difference between domestic and Chinese prices. The differences between the domestic and Chinese FEPL index from Sato et al. (2015) is used as an instrument for observed relative prices. Firm-level control variables are the number of employees and international sales. All regressions include country-year fixed-effects. Robust standard errors clustered at the country-sector level in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

How would a carbon tax introduction affect firm-level FDI?

The estimated results can be extended to assess the impact of a uniform and unilateral carbon tax on all upstream carbon emissions of a country. This is a simple back-of-the-envelope simulation exercise, subject to many caveats. In particular, our simulations are based on average effect estimates and do not provide lower or upper bounds of this effect.

Economies have different carbon intensity in energy use and hence carbon tax effects will be heterogeneous across countries. Therefore, we calculate the effect of a carbon tax introduction as follows. First, we match a country-year carbon intensity measure for energy use—which accounts for the number of tonnes of CO_2 (tCO_2) emitted per ton of oil equivalent (TOE)—with our firms dataset.[12] Next, for each firm, we calculate the hypothetic energy prices including the carbon tax by: (i) multiplying the carbon intensity measure (tCO_2/TOE) with the hypothetical carbon tax (USD/tCO_2), which provides the carbon price per TOE (USD/TOE); (ii) adding this carbon price (USD/TOE) to the observed price (USD/TOE) faced by firms. Finally, by multiplying the (log) percentage increase in energy prices due to the carbon tax and our estimated coefficients, we obtain the effect of carbon pricing on the FDI ratio in percentage points.[13]

We assume that energy prices increase in the countries of our sample only (and not everywhere else, especially in developing countries where FDI could take place). We consider two scenarios: (i) a carbon tax of USD 15/tCO_2, which is calculated by Rezai and van der Ploeg (2015) to be the global optimal price of carbon; (ii) a carbon tax of 55 USD/tCO_2, which is an estimate of the necessary EU carbon price for European countries to achieve their GHG reduction objectives by 2030 (Sato and Dechezleprêtre, 2015).

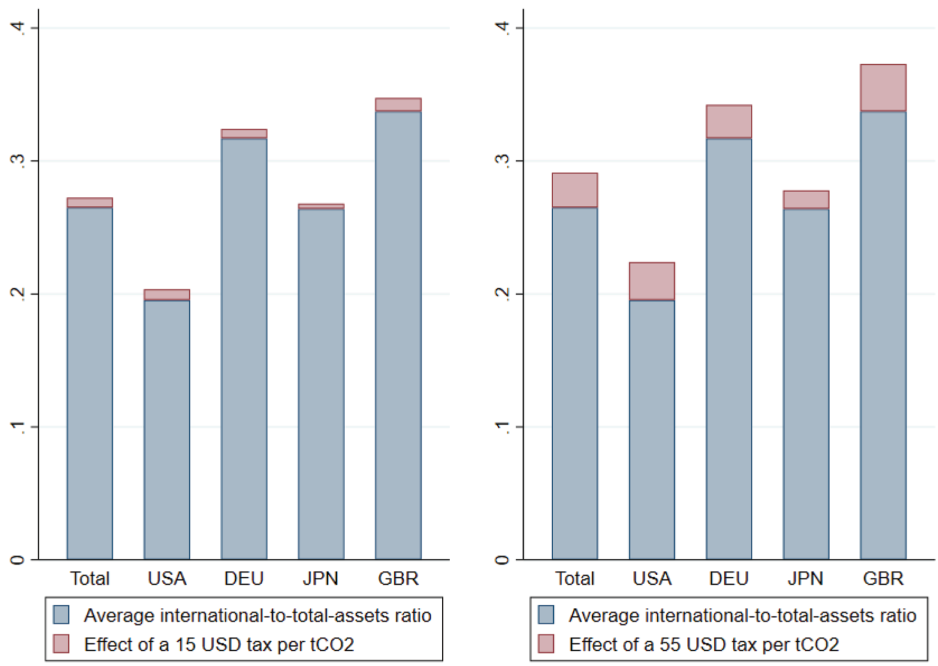
12. The dataset on carbon intensity is available from the World Bank: http://data.worldbank.org/indicator/EN.ATM.CO2E.EG.ZS?end=2011&start=1995.

13. We use the 2SLS estimation result of column (6) in Table 4.

Figure 3 reports the simulated last year of observation firm-level average FDI ratio for our entire sample and for the countries most represented in the latter (the U.S., Germany, Japan and the United Kingdom). Heavily relying on nuclear energy within our sample, Japan has a low CO_2 intensity (tCO_2 generated by TOE). Therefore, the introduction of a uniform carbon tax on all carbon emissions does not affect energy prices as much as in countries that rely on fossil fuels.

In the 15-USD scenario (panel A), energy prices increase by 5% on average, with the highest impact in the U.S (around 7%) and the lowest in Japan (around 2.5%). This translates into an increase of 0.74 percentage points in the FDI ratio (0.81 pp for the U.S. and 0.38 pp for Japan). The 55-USD scenario (panel B) implies a 20% increase in energy prices on average (28% for the U.S. and 10% for Japan). This translates into an increase of 2.6 percentage point in the FDI ratio (2.8 pp for the U.S. and 1.3 pp for Japan).

Figure 3: Simulated effect of unilateral carbon tax on outward FDI



Note: These figures report the simulated effect of the introduction of a carbon tax on the FDI ratio using the estimation result of column (3) in Table 3. We consider two scenarios: a USD 15 carbon tax (panel A) and a USD 55 carbon tax (panel B).

V. CONCLUDING REMARKS

Overall, our results indicate that energy prices are not a main driver of FDI. Our estimates show that the FDI elasticity of energy prices is significantly different from zero for a sample of firms that experienced an increase in the domestic energy prices relative to Chinese energy prices. However the magnitude is relatively small. Our preferred estimate suggests that a 1% increase in relative energy prices is associated with an increase of 0.71% in international assets on average.

As a result, even the unilateral introduction of a substantial carbon tax of 55 USD/tCO_2 would have a limited impact on the international-to-total-assets ratio. A carbon price of 34 USD/tCO_2 is considered by OECD (2015a, 2015b) as a lower-end estimate of the social climate cost of carbon emissions. The same studies also recall the urgent need for action in implementing carbon prices as roughly 90% of CO2 emissions in OECD countries and key emerging market economies are priced below this level. In line with other recent results on the pollution haven effect via the trade channel (Koźluk and Timiliotis, 2016; Sato and Dechezleprêtre, 2015), we conclude that our findings suggest that concerns regarding the effect of stricter environmental rules on economic activity and carbon leakages via FDI are likely overstated. Future research could however test the robustness of these results expanding geographic and time coverages once data become available.

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APPENDIX A1: SUMMARY OF LITERATURE REVIEW

Table A1.1: Summary of literature review

Paper	Parent Country	Host country	Period	Level of analysis	Type of FDI	Type of data	Proxy for environmental policy stringency	Evidence of pollution haven effect
Ben Kheder and Zugravu (2012)	France	74 countries	1996–2002	Firm	Establishment location decision	Cross-section	Index	MIXED
Chung (2014)	South-Korea	Rest of the world	2000–2007	Firm	Flows	Panel data	Survey	YES
Cole et al. (2005)	USA	Brazil and Mexico	1989–1994	Sector	Stock	Panel data	Abatement cost	MIXED
Dean et al. (2009)	Rest of the world	China	1993–1996	Firm	Establishment location decision	Cross-section	Abatement cost	MIXED
Di (2007)	Rest of the world	China	1992–1995	Firm	Establishment location decision	Cross-section	Authorized pollution	YES
Elliot and Shimamoto (2008)	Japan	3 South-East Asian countries	1986–1998	Sector	Flows	Panel data	Abatement cost	NO
Eskeland and Harrison (2003)	USA	4 developing countries	1977–1990	Sector	Outward investment	Panel data	Abatement cost	NO
Fredriksson et al. (2003)	Rest of the world	USA	1977–1987	Sector	Flows	Panel data	Abatement cost	YES
Hanna (2010)	USA	Rest of the world	1966–1999	Firm	Stock (foreign assets)	Panel data	Authorized pollution	YES
Javorcik and Wei (2004)	25 countries around the world	20 countries in Eastern Europe and former Soviet Union	1989–1994	Firm	Establishment location decision	Cross-section	International treaties, index, observed pollution	NO
Kellenberg (2009)	USA	50 countries	1999–2003	Sector	Value added of US multinational affiliates	Panel data	Survey	YES
Keller and Levinson (2002)	Rest of the world	USA	1967–1994	Aggregate FDI in US states	Stock (foreign assets)	Panel data	Abatement cost	YES
Kirkpatrick and Shimamoto (2008)	Japan	Rest of the world	1992–1997	Firm	Establishment location decision	Cross-section	International treaties	NO
List (2001)	Rest of the world	USA	1983–1992	Firm	Establishment location decision	Cross-section	Authorized pollution	NO
List and Co (2000)	Rest of the world	USA	1986–1993	Firm	Establishment location decision	Cross-section	Index	YES
List et al. (2004)	Rest of the world	USA	1980–1990	New plants in US counties	Establishment location decision	Panel data	Authorized pollution	NO
Manderson and Kneller (2012)	UK	Rest of the world	2005	Firm	Establishment location decision	Cross-section	Abatement cost	NO
Wagner and Timmins (2009)	Germany	Rest of the world	1996–2003	Sector	Flows	Panel data	Survey	YES
Waldkirch and Gopinath (2008)	Rest of the world	Mexico	1994–2000	Sector	Flows	Cross-section	Authorized pollution	YES
Xing and Kolstad (2002)	USA	Rest of the world	1985–1990	Aggregate FDI	Flows	Cross-section	Authorized pollution	MIXED

APPENDIX A2: DATASET ADDITIONAL INFORMATION

Table A2.1: SIC codes used in manufacturing industries

	SIC codes
Chemicals and petrochemicals	28
Food and tobacco	20, 21
Iron and steel	331, 332
Machinery	34, 35, 36, 38
Non-ferrous metal	333, 334, 335, 336
Non-metallic minerals	32
Paper and printing	26, 27
Textile	22, 23, 31
Transport equipment	37

Table A2.2: List of countries included in the full sample

Country	Share of observations (in %)
AUS	2.71
AUT	0.74
BEL	0.74
CAN	4.43
CHE	2.73
CZE	0.03
DEU	5.17
DNK	0.92
FIN	1.37
FRA	2.65
GBR	11.41
GRC	0.42
HUN	0.12
ITA	1.58
JPN	17.03
KOR	1.10
NLD	1.25
NZL	0.12
POL	0.09
PRT	0.06
SVK	0.03
SWE	1.69
TUR	0.24
USA	43.37

Table A2.3: Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Median
International assets (2010 USD)	3,364	2,472,438	1.68e+07	169,740
Number of employees	3,364	8,238	16,248	2,100
International sales (2010 USD)	3,364	3,299,401	1.40e+07	346,686
Total assets (2010 USD)	3,364	7,234,834	3.56e+07	963,849
International-to-total-assets ratio	3,364	0.265	0.240	0.195
Energy prices (2010 USD per TOE)	3,364	786.2	398.0	608.3