Centre for
Climate Change
Economics and Policy

An ESRC Research Centre

Energy efficiency gains from trade in intermediate inputs: firm-level evidence from Indonesia

Michele Imbruno and Tobias Ketterer

June 2016

Centre for Climate Change Economics and Policy
Working Paper No. 274

Grantham Research Institute on Climate Change and the Environment
Working Paper No. 244

Grantham Research Institute on Climate Change and the Environment

ESRC Economic & Social Research Council

University of Leeds

LSE The London School of Economics and Political Science

The Centre for Climate Change Economics and Policy (CCCEP) was established by the University of Leeds and the London School of Economics and Political Science in 2008 to advance public and private action on climate change through innovative, rigorous research. The Centre is funded by the UK Economic and Social Research Council. Its second phase started in 2013 and there are five integrated research themes:

1. Understanding green growth and climate-compatible development
2. Advancing climate finance and investment
3. Evaluating the performance of climate policies
4. Managing climate risks and uncertainties and strengthening climate services
5. Enabling rapid transitions in mitigation and adaptation

More information about the Centre for Climate Change Economics and Policy can be found at: http://www.cccep.ac.uk.

The Grantham Research Institute on Climate Change and the Environment was established by the London School of Economics and Political Science in 2008 to bring together international expertise on economics, finance, geography, the environment, international development and political economy to create a world-leading centre for policy-relevant research and training. The Institute is funded by the Grantham Foundation for the Protection of the Environment and the Global Green Growth Institute. It has nine research programmes:

1. Adaptation and development
2. Carbon trading and finance
3. Ecosystems, resources and the natural environment
4. Energy, technology and trade
5. Future generations and social justice
6. Growth and the economy
7. International environmental negotiations
8. Modelling and decision making
9. Private sector adaptation, risk and insurance

More information about the Grantham Research Institute on Climate Change and the Environment can be found at: http://www.lse.ac.uk/grantham.

Energy efficiency gains from trade in intermediate inputs: Firm-level evidence from Indonesia

Michele Imbruno [a] Tobias D. Ketterer [b]

Abstract

This paper investigates whether importing intermediate goods improves firm-level environmental performance in a developing country, using data from the Indonesian manufacturing sector. We build a simple theoretical model showing that trade integration of input markets entails energy efficiency improvements within importers relative to non-importers. To empirically isolate the impact of firm participation in foreign intermediate input markets we use 'nearest neighbour' propensity score matching and difference-in-difference techniques. Covering the period 1991-2005, we find evidence that becoming an importer of foreign intermediates boosts energy efficiency, implying beneficial effects for the environment.

JEL: F12, F14, F18, Q56

Keywords: Trade, Intermediate Inputs, Energy Efficiency, Environment and Indonesia

Acknowledgements. The authors would like to thank Sotiris Blanas, Antoine Dechezlepretre, Ana M. Fernandes, Beata Javorcik, Richard Kneller, Alessia Lo Turco, Daniela Maggioni, and all participants at the ETSG 2015 Conference in Paris and CSAE 2016 Conference at Oxford University for their helpful comments and suggestions. Michele Imbruno gratefully acknowledges financial support from the CrisisLab project funded by the Italian government. Tobias Ketterer gratefully acknowledges financial support from the ESRC Centre for Climate Change Economics and Policy. This paper reflects the views of the authors only and should not be attributed to the European Commission.

[a] IMT Institute for Advanced Studies, Lucca (Italy), and GEP, Nottingham (UK). E-mail address: michele.imbruno@imtlucca.it.
[b] Directorate-General for Economic and Financial Affairs, European Commission, Brussels. E-mail address: tobias.ketterer@ec.europa.eu.

1. Introduction

Globalisation and the formation of global supply chains have led to a substantial increase not only in the trade in final goods, but also in intermediate goods. Previous research has shown that access to cheaper imported inputs results in important productivity gains based on firms' access to a larger number of input varieties, a better input quality, and technology transfers (Ethier, 1982; Markusen, 1989; Grossman and Helpman, 1991).[1] Access to foreign input markets and with it enhanced learning, quality and variety effects, may lower the costs of innovation and generate sizable dynamic gains from trade with important consequences for firm-level product scope and firm efficiency. Previous empirical work shows that trade liberalisation in intermediate input markets represents a significant source of firm level productivity gains in Brazil (Schor, 2004), Indonesia (Amiti and Konings, 2008) and India (Goldberg et al., 2010; Khandelwal and Topalova, 2011); with productivity gains from intermediate input tariff reductions likely to exceed those stemming from tariff cuts for final goods.

At the same time, increasing international trade flows have sparked a vibrant debate featuring a growing concern over the impact of globalisation on the environment. Enunciated by the pollution haven hypothesis, the possibility of major trade reforms resulting in a shift of pollution-intensive activities to territories with weaker environmental standards raised fears of a global race to the bottom and increasing global pollution. Theoretical evidence on the link between trade and the environment, however, tends to be ambiguous and does not provide a clear verdict. Advanced by the seminal contributions of Pethig (1976) and McGuire (1982) the pollution haven hypothesis has also been put into perspective in studies considering that environmental policy may respond to changes in trade patterns (Copeland and Taylor, 1994, 1995), or when allowing for differences in income and factor abundance to jointly determine the patterns of trade (Antweiler et al., 2001).[2]

Empirical studies on the effect of trade and trade policy reform on environmental performance at the detailed firm level are scarce and mainly focus on firms' decision to

[1] A related literature highlights aggregate productivity gains stemming from new exporting opportunities and increasing competition following trade liberalisation (Melitz, 2003; Melitz and Ottaviano, 2008), and firm-level productivity gains associated with intra-firm reallocation of resources (Bernard, Redding and Schott, 2006).

[2] Further theoretical contributions include, amongst others, Barret (1994), Markusen et al. (1995), Copeland and Taylor (1997), who additionally consider governments' strategic incentives, the location-specific character of pollution, and differences in factor endowments, respectively.

export in an industrialised country context.[3] Galdeano-Gómez (2010), for instance, considers the relationship between export orientation and environmental performance in the Spanish food industry, and provides evidence for a positive correlation. Girma et al. (2008) investigate environmental firm performance in a Melitz-type (2003) heterogeneous firms framework and provide evidence for exporting status being positively associated with the propensity to adopt newer and, hence, more advanced and environmentally-sound technologies, given exporters' larger ability to amortise fixed investment costs, relative to non-exporters. They provide empirical support for their theoretical predictions by using UK survey data showing that exporters tend to consider their innovations to be more energy-efficient and environmentally-sound. Batrakova and Davies (2012) extend the literature by looking at the impact of exporting status on actual energy use as a measure for environmental performance. Using a partial equilibrium framework and Irish firm-level data, they show that while exporting leads to energy efficiency losses for firms with low energy intensity because of predominant scale effects, high energy intensity firms are likely to become more energy efficient as they are pushed to invest in energy-saving technologies. [4]

Against the backdrop of a relatively limited firm-level literature on the international trade-environment nexus, this paper contributes to the existing literature by examining the impact of foreign intermediate inputs (rather than exports) on firms' productivity and environmental performance, in the context of a developing country. We begin by developing a simple theoretical framework, mainly based on Krugman (1980) and Ethier (1982), with two vertically-related sectors, where symmetric firms supply their varieties under monopolistic competition and in an autarkic regime. Firms in the downstream sector produce final good varieties, by mainly using energy and intermediate inputs, which are in turn manufactured by firms in the upstream sector. Next, we study the impact of trade integration of intermediate input markets across identical countries on firm-level energy intensity, in addition to productivity. We assume that only a given fraction of final good producers are able to import, whereas the other firms are not able to do so. We show that firms that enter intermediate input markets increase, on average, their performance, and reduce their energy intensity, compared with non-importing firms. In other words, through importing, firms have access to a larger range of differentiated intermediate inputs, which entails not only a more efficient usage of intermediates itself (productivity gains à la Ethier, 1982), but also a more

[3] More aggregate empirical work tends to provide evidence for trade encouraging the development of more environmentally sound production processes (Levinson, 2009; Dean and Lovely, 2008; Antweiler et al., 2001).
[4] Kaiser and Schulze (2003) examine the effect of export decisions on environmental expenses and find a positive correlation.

efficient usage of energy, implying beneficial effects for the environment (environmental gains from input varieties).[5]

We test the theoretical predictions by using firm-level data on manufacturing firms in Indonesia covering the time period 1991 to 2005. Using propensity-score matching and difference-in-difference techniques, the empirical findings support the results of our model by providing evidence for import-status being positively correlated with an increase in firm efficiency and a decline in firm-level energy intensities.[6] Accounting for export status and FDI status corroborates our findings for firm-level efficiency and environmental performance. Our results may hence carry important implication as they tend to suggest that trade liberalisation and access to foreign intermediate input markets may generate important economic but also environmental benefits for producers in emerging markets.

Our work can be considered one of the first attempts aiming to explore how importing intermediate inputs may affect firm-level energy efficiency. To our knowledge, a similar issue has only been addressed by Martin (2011). Using firm-level panel data, she examines changes in energy efficiency following trade, FDI and licensing reforms in India. Martin (2011) findings show that trade liberalisation in intermediate input markets entails, on average, within-industry energy efficiency gains based on within firm improvements only.[7]

Our analysis, however, contrasts with Martin's (2011), first, by providing an analytical framework which aims to show that firms starting to import intermediate inputs gain in energy efficiency compared with firms that remain non-importers. Second, we empirically quantify these energy efficiency gains from importing intermediate inputs, by directly comparing the change in energy intensity between import-starters and firms that remain non-importers with similar initial characteristics, to control for potential self-selection into importing activities.

The reminder of the paper is structured as follows. Section 2 outlines a very simple theoretical framework designed to focus and guide our empirical investigation. Section 3 introduces our empirical identification strategy, and provides a description of the data and the most salient sample characteristics. The empirical findings for the correlation between

[5] Note that in our theoretical set-up, we only allow for importing gains stemming from a larger set of input varieties. We, however, acknowledge that in reality gains from input importing may also arise through other channels, such as quality and/or learning effects (cf. Markusen, 1989; Grossman and Helpman, 1990).

[6] Since there is no pollution data available at the firm level, we use energy intensities, i.e. energy use divided by total output. This approach is similar to the strategy chosen by Eskeland and Harrison (2003) and Cole et al. (2008).

[7] She also documents that, while FDI liberalisation and delicensing leads to a reallocation of market shares from the least to the most energy-efficient firms, a reduction in tariffs on intermediate inputs results in a reallocation towards the least efficient firms instead.

intermediate input importing status and environmental firm performance are presented and discussed in section 4. Section 5 concludes.

2. Theoretical framework

In this section we present a very simple theoretical model, mainly based on both Krugman (1980) and Ethier (1982), to guide our empirical investigation. The purpose of this is to formulate some predictions on how importing intermediate inputs may affect energy efficiency at the firm-level. We first present a closed economy model with two sectors vertically related to each other, where symmetric firms supply their goods in monopolistic competitive markets. In particular, we assume that the downstream sector produces its final good varieties, by mainly using energy and intermediate inputs, which are, in turn, produced by the upstream sector. The upstream sector mainly uses labour. Material inputs are assumed to be horizontally differentiated, which is a common feature in the literature when investigating the effects of international trade on total factor productivity (cf. Ethier, 1982; Romer, 1990; Grossman and Helpman, 1991).

Next, we study how trade openness in the intermediate input markets may influence firm-level energy intensity, in addition to firm performance. We thereby assume that only a given fraction of final good producers are able to access foreign intermediate input market (i.e. importers), whereas the other firms are not able to do so (i.e. non-importers).[8]

2.1 Closed Economy

Final good sector. Consider a setting in which consumers supply labour *L* to firms at a wage rate *w*, and, at the same time, demand all available final differentiated varieties (*y*) produced by domestic firms. In particular, consumers are assumed to show CES preferences, so that the demand for each variety *y* is given by $q_y(y) = p_y(y)^{-\sigma} R_y P_y^{\sigma-1}$, where p_y represents the price of a single variety *y*, and $P_y = \left[\int_0^N p_y(y)^{1-\sigma} dy\right]^{\frac{1}{1-\sigma}}$ is the aggregate price index of all available final varieties *N*. R_y denotes aggregate revenue in the final goods

[8] For simplicity, we abstract from the underlying reasons. In our case, where firms are assumed to be symmetric in both sectors, it could be because of a random allocation of import licenses. But, in a more sophisticated case, where firms can be assumed to be heterogeneous in initial productivity, it could be because of a self-selection mechanisms: i.e. only the more productive firms are able to import (Gibson and Graciano, 2011, Imbruno, 2014).

sector, which is equal to aggregate consumer income (*wL).* The wage rate *w* represents our *numeraire* (i.e. *w*=1). $\sigma > 1$ denotes the elasticity of substitution between final good varieties. We model final good firms' output production, q_y, by means of the following Cobb-Douglas technology function:

$$q_y = \varphi_y X_e^{\alpha} X_m^{1-\alpha}, \quad \text{with } X_m = \left[\int_0^M x_m(m)^{\frac{\sigma-1}{\sigma}} dm\right]^{\frac{\sigma}{\sigma-1}}$$

where φ_y denotes the firm-level Hicksian productivity, X_e stands for energy consumption *e*, and X_m denotes CES consumption in intermediate inputs *m*. α and $(1-\alpha)$ represent the factor shares of production. Notice that firm-level aggregate consumption in intermediates is a function of the total number of all symmetric intermediate input varieties (M), the quantity consumed of each input variety (x_m), and the elasticity of substitution between them ($\sigma > 1$), as in Ethier (1982). Thus, firm-level demands in energy and intermediate inputs can respectively be written as:

$$X_e = \frac{q_y}{\varphi_y}\left(\frac{\alpha}{1-\alpha}\right)^{1-\alpha}\left(\frac{P_m}{P_e}\right)^{1-\alpha} \qquad X_m = \frac{q_y}{\varphi_y}\left(\frac{1-\alpha}{\alpha}\right)^{\alpha}\left(\frac{P_e}{P_m}\right)^{\alpha}$$

Firm-level demand of a single intermediate input variety *m* is given by $x_m = (p_m/P_m)^{-\sigma} X_m$, where $p_m(m)$ represents the price of intermediate variety *m*, $P_m = \left[\int_0^M p_m(m)^{1-\sigma} dm\right]^{\frac{1}{1-\sigma}}$ the aggregate intermediate input price, and P_e denotes the aggregate energy price. It is worth pointing out that, while P_m is considered to be endogenous, P_e is modelled to be exogenous as energy is assumed to be in-elastically supplied within a country (similarly to labour).[9]

Under profit maximisation, each firm will charge a price equal to $p_y = \frac{\sigma}{\sigma-1}\gamma(P_e)^{\alpha}(P_m)^{1-\alpha}(1/\varphi_y)$,where $\gamma = (\alpha)^{-\alpha}(1-\alpha)^{-(1-\alpha)}$. Domestic firms' profit may, hence, be expressed as $\pi_y = \frac{\gamma(P_e)^{\alpha}(P_m)^{1-\alpha}}{(\sigma-1)\varphi_y} q_y$, which alternatively can also be written as $\pi_y = \frac{R_y}{\sigma N}$.

[9] Larch and Wanner (2015) make a similar assumption. The authors argue that a constant energy price is quite plausible, by considering the oil market characteristics and the important role played by OPEC, which may have incentives to adjust the oil supply to keep oil prices stable.

Taking into account that each firm faces labour-intensive fixed costs to enter the market (f_e), and considering the free entry condition ($\pi_y = f_e$),we can determine the equilibrium firm-level output which is equal to $q_y = \frac{f_e(\sigma-1)\varphi_y}{\gamma(P_e)^{\alpha}(P_m)^{1-\alpha}}$, and the mass of final good firms (i.e. the number of available final varieties) $N = \frac{R_y}{\sigma f_e}$, whose the price index can be written as $P_y = N^{\frac{1}{1-\sigma}}\left(\frac{\sigma}{\sigma-1}\frac{\gamma(P_e)^{\alpha}(P_m)^{1-\alpha}}{\varphi_y}\right)$.

Intermediate good sector. Since final good producers are symmetric, the total demand for each intermediate input variety can be expressed as $q_m = Nx_m = p_m(m)^{-\sigma} R_m P_m^{\sigma-1}$, where R_m denotes aggregate revenue in the intermediate goods sector. Notice that R_m turns out to be equal to the aggregate revenue in the final goods sector decreased by the mark-up $\left(\frac{\sigma-1}{\sigma}\right)R_y$.

Input suppliers use a linear production function $q_m = \varphi_m l_m$, where φ_m stands for suppliers' Hicksian productivity, and l_m is the number of employed labour units.

Under profit maximisation each input supplier will set a price $p_m(\varphi_m) = 1/(\rho\varphi_m)$, yielding the profit $\pi_m = \frac{1}{(\sigma-1)\varphi_m} q_m$, which can be alternatively written as $\pi_m = \frac{R_m}{\sigma M}$.

Similar to the final good sector, input suppliers face fixed costs of entry f_e. Taking into account the free entry condition ($\pi_m = f_e$), we determine both the equilibrium output produced by each supplier, which equals $q_m = (\sigma-1)\varphi_m f_e$, and the mass of domestic suppliers (i.e. the number of input varieties available in the closed economy) $M = \frac{R_m}{\sigma f_e}$, whose the price index equals $P_m = \left(\frac{\sigma}{\sigma-1}\right)\frac{M^{\frac{1}{1-\sigma}}}{\varphi_m}$.

Final good firms' Ethier productivity and energy intensity. A final good firm's productivity (à la Ethier, 1982) is defined by total output over the linear consumption in intermediate inputs, expressed as:

$$\varphi_y^{Ethier} = \frac{q_y}{X_e^{\alpha}\left(Mx_m\right)^{1-\alpha}} = \varphi_y M^{\frac{1-\alpha}{\sigma-1}} \tag{1}$$

Equation (1) suggests that a firm's productivity is a function of the range of employed intermediate inputs, as well as a firm-specific productivity shock. Turning to energy efficiency, a final good firm's energy intensity is defined by total energy consumption in energy over the output produced, which may be written as:

$$\varepsilon_y = \frac{X_e}{q_y} = \frac{1}{\varphi_y}\left(\frac{\alpha}{1-\alpha}\right)^{1-\alpha}\left[\frac{1}{P_e}\left(\frac{\sigma}{\sigma-1}\right)\frac{1}{\varphi_m}\right]^{1-\alpha} M^{\frac{1-\alpha}{1-\sigma}} \tag{2}$$

Equation (2) highlights that the energy intensity is negatively related to the mass of input varieties used by the firm. In other words, both firm-level performance and energy efficiency turn out to be increasing in the number of intermediate varieties.

2.2. Trade openness to intermediate inputs

We now examine how trade integration of intermediate input market across $(1+n)$ identical countries affects firm-level Ethier productivity and energy intensity, by considering that only a given fraction of firms in each country $\psi_y^M \in [0,1]$ is able to access additional intermediates from abroad (importers). Superscripts *M* and *D* refer to importers and non-importers, respectively. We assume that trade in final goods is not allowed, since the main purpose of our analysis is to explore the impact of importing intermediate goods at firm level. Thus, while non-importers keep having similar production and profit functions as those in the closed economy setting ($q_y^D = q_y$, $\pi_y^D = \pi_y$), importers' production and profit functions are, respectively, defined as:

$$q_y^M = \varphi_y X_e^{\alpha}\left(X_m^M\right)^{1-\alpha} \qquad \text{with } X_m^M = \left[\left(1+n\right)\int_0^M x_m\left(m\right)^{\frac{\sigma-1}{\sigma}} dm\right]^{\frac{\sigma}{\sigma-1}}$$

$$\pi_y^M = \frac{\gamma(P_e)^\alpha (P_m^M)^{1-\alpha}}{(\sigma-1)\varphi_y} q_y^M \qquad \text{with } P_m^M = \left[(1+n)\int_0^M p_m(m)^{1-\sigma} dm\right]^{\frac{1}{1-\sigma}}$$

,

It is worth noting that both importers' production and profit functions can be expressed in relative terms to those of non-importers – i.e. $q_y^M = (1+n)^{\frac{\sigma}{\sigma-1}(1-\alpha)} q_y^D$, and $\pi_y^M = (1+n)^{1-\alpha} \pi_y^D$.

Consequently, the average profit within the final good sector is given by $\tilde{\pi}_y = \left[(1-\psi_y^M) + \psi_y^M (1+n)^{1-\alpha}\right] \frac{\gamma(P_e)^\alpha (P_m^D)^{1-\alpha}}{(\sigma-1)\varphi_y} q_y^D$, which alternatively can also be written as $\tilde{\pi}_y = \frac{R_y}{\sigma N}$. As in Melitz (2003), we also assume that firms will only enter the market if the expected profit is higher than the fixed cost of entry f_e. Thus, using the free entry condition ($\tilde{\pi}_y = f_e$), we can determine both non-importer and importer output levels as:

$$q_y^D = \frac{f_e(\sigma-1)\varphi_y}{\gamma(P_e)^\alpha (P_m^D)^{1-\alpha} \left[(1-\psi_y^M) + \psi_y^M (1+n)^{1-\alpha}\right]} < q_y$$

$$q_y^M = \left[(1+n)\right]^{\frac{\sigma}{\sigma-1}(1-\alpha)} q_y^D = \left[\frac{\left[(1+n)\right]^{\frac{\sigma}{\sigma-1}(1-\alpha)}}{(1-\psi_y^M) + \psi_y^M (1+n)^{1-\alpha}}\right] \frac{f_e(\sigma-1)\varphi_y}{\gamma(P_e)^\alpha (P_m^D)^{1-\alpha}} > q_y$$

The resulting number of all domestic final good firms equals $N = \frac{R_y}{\sigma f_e}$, and the related price index amounts to $P_y = N^{\frac{1}{1-\sigma}} \left(\frac{\gamma(P_e)^\alpha (P_m^D)^{1-\alpha} \left[(1-\psi_M) + \psi_M (n+1)^{1-\alpha}\right]^{\frac{1}{1-\sigma}}}{\rho \varphi_y} \right)$.

Taking into account that firm-level demand for each input variety by non-importers and importers are, respectively, given by $x_m^D = \left(\frac{p_m}{P_m^D}\right)^{-\sigma} X_m^D$ and $x_m^M = \left(\frac{p_m}{P_m^M}\right)^{-\sigma} X_m^M$, total domestic demand for each intermediate variety is $q_m = (1-\psi_y^M) N x_m^D + \psi_y^M (1+n) N x_m^M$, which, through some rearrangements, can be written as: $q_m = (p_m)^{-\sigma} R_m (P_m^D)^{\sigma-1}$.

Since we consider a free trade scenario for intermediate goods, we implicitly assume that there are no additional costs to serve international markets. Therefore, all input suppliers exhibit the same profit function $\pi_m = \frac{1}{(\sigma - 1)\varphi_m} q_m^T$. In equilibrium ($\pi_m = f_e$), any input supplier will produce the same quantity of output as in the closed economy model – i.e. $q_m^T = (\sigma - 1)\varphi_m f_e$ – which will, however, be equally distributed across the world.

Notice that while the mass of domestic suppliers, i.e. the number of input varieties available for non-importers, remains unchanged $M^D = \frac{R_m}{\sigma f_e} = M$, the mass of all input suppliers competing within one country (i.e. both domestic and foreign ones), i.e the number of input varieties available for importers, increases to $M^M = (n+1)M^D > M$. Accordingly, while the price index of intermediates remains the same for non-importers $P_m^D = \frac{\sigma}{\sigma - 1} \frac{M^{\frac{1}{1-\sigma}}}{\varphi_m} = P_m$, the one for importers declines to $P_m^M = \frac{\sigma}{\sigma - 1} \frac{[(n+1)M]^{\frac{1}{1-\sigma}}}{\varphi_m} < P_m$.

As a result, we are able to show that following free trade for intermediate inputs, Ethier productivity increases (Eq. 3), while energy intensity decreases (Eq. 4), for importers with respect to their non-importing counterparts:

$$\varphi_y^{Ethier\_M} = \varphi_y [(n+1)M]^{\frac{1-\alpha}{\sigma-1}} > \varphi_y M^{\frac{1-\alpha}{\sigma-1}} = \varphi_y^{Ethier\_D} = \varphi_y^{Ethier\_Autarky} \tag{3}$$

$$\varepsilon_y^M = \frac{1}{\varphi_y} \left(\frac{\alpha}{1-\alpha} \right)^{1-\alpha} \left(\frac{1}{P_e} \frac{1}{\rho \varphi_m} \right)^{1-\alpha} [(n+1)M]^{\frac{1-\alpha}{1-\sigma}} < \frac{1}{\varphi_y} \left(\frac{\alpha}{1-\alpha} \right)^{1-\alpha} \left(\frac{1}{P_e} \frac{1}{\rho \varphi_m} \right)^{1-\alpha} M^{\frac{1-\alpha}{1-\sigma}} = \varepsilon_y^D = \varepsilon_y^{Autarky} \tag{4}$$

Proposition. *Firms that enter the import market of intermediate inputs on average improve their productivity on the one hand, and decrease their energy intensity on the other hand, compared with firms that keep using only domestic intermediate inputs. In other words, importing foreign intermediate inputs leads to energy efficiency gains in addition to productivity gains, implying beneficial effects for the environment.*

3. Empirical methodology

3.1 Identification Strategy

It is worth noting that by using equations (3) and (4), productivity and energy gains of importers relative to non-importers may be respectively expressed as: $\frac{\varphi_y^{Ethier\_M\_after}}{\varphi_y^{Ethier\_M\_before}} \Big/ \frac{\varphi_y^{Ethier\_D\_after}}{\varphi_y^{Ethier\_D\_before}} = (n+1)^{\frac{1-\alpha}{\sigma-1}} > 1$ and $\frac{\varepsilon_y^{M\_after}}{\varepsilon_y^{M\_before}} \Big/ \frac{\varepsilon_y^{D\_after}}{\varepsilon_y^{D\_before}} = [(n+1)]^{\frac{1-\alpha}{1-\sigma}} < 1$. By taking logs, our expectations to be empirically tested become:

$E\left[\Delta \ln \varphi_y^{Ethier\_M} - \Delta \ln \varphi_y^{Ethier\_D}\right] > 0$ (5), and $E\left[\Delta \ln \varepsilon_y^{M} - \Delta \ln \varepsilon_y^{D}\right] < 0$ (6)

Both equations (5) and (6) highlight that to isolate the effect of importing (treatment) on firm-level economic and environmental performance (outcomes), we need to compare the change in performance over a given period for firms that entered the input import market (treated group), with the performance change for non-importing firms with similar characteristics in the pre-entry period (control group). Therefore, our empirical strategy aims at evaluating the causal effect of first-time foreign input market entry on firm-level productivity and energy intensity, through employing a matched difference-in-difference approach. [10]

Using matching techniques represents a valid strategy to isolate the economic and environmental performance indicators of input importers and may lead to more robust and reliable results than more standard techniques which treat all non-input importers as a suitable control group (Bernard and Jensen, 1999; Greenaway et al., 2005; Greenaway and Kneller, 2008). In order to reduce the heterogeneity between new input-importers and non-input importers we use information on observable characteristics at the firm level in the pre-market entry period. We then control for time-invariant unobserved differences in firm characteristics by combining the matching approach with a difference-in-difference technique.

To see how this is formally applied let $IM_{it} \in \{0,1\}$ represent an indicator variable of whether firm i entered the input import market in year t for the first time or remained outside. Further, let y_{it+s}^1 denote firm i's outcome at time t+s. Δy_{it+s}^1 represents the change in the respective outcome variable over a given period for firms that entered the input import market, while Δy_{it+s}^0 denotes firm i's change in the respective outcome variable had the firm

[10] Following Eskeland and Harrison (2003), as well as Cole et al. (2008) we assume that, if energy use rises net pollution too will rise. More micro-econometric information on the matched difference-in-difference methodology can be found in Heckman et al. (1997) and Blundell and Dias (2000).

not entered the input-import market. The causal effect of firm i's input-import market entry on its economic and environmental performance may hence be described as the difference between the respective outcome variable if market entry occurred, and the outcome variable had the entry not occurred. The average expected treatment effect may be expressed as:

$$E\{\Delta y^1_{it+s} - \Delta y^0_{it+s} | IM_{it}=1\} = E\{\Delta y^1_{it+s} | IM_{it}=1\} - E\{\Delta y^0_{it+s} | IM_{it}=1\} \quad (7)$$

Since the environmental performance experienced by firm i, had it not entered the input-import market, is unobservable, we construct a counterfactual by identifying firms with similar observable attributes in the pre-entry period, and which were not involved in foreign input importing. Taking into account the constructed control group, which is needed to establish causal interference, Eq. (7) becomes $E\{\Delta y^1_{it+s} | IM_{it} = 1, X\} - E\{\Delta y^0_{it+s} | IM_{it} = 0, X\}$, with X denoting a control vector of observable firm characteristics. Hence, our empirical approach aims to first match first-time input importers and non-importers on a number of pre-entry firm characteristics which makes them likely to become input importers at time t, and then to compare the environmental performance of the treated and the constructed control group. In order to match the importing and non-importing groups, we use propensity score matching assigning each firm a certain probability value, to become an input importer at time t, based on the observed covariates (Rosenbaum and Rubin, 1983).[11] This technique rests on the assumption of conditional interdependence by assuming that selection into treatment (i.e. input-import market entry) is completely conditional on and determined by the observed variables. To satisfy this assumption we identify the probability of input-importing by running a probit model including a set of covariates suggested by economic theory and previous empirical evidences. Our probit estimations, employed to generate the afore mentioned propensity score, include pre-entry information on energy intensity, productivity, output, worker compensation (i.e. wages), relative skill intensity (i.e. share of production to non-production workers), capital stock, foreign ownership, and the full set of 3-digit ISIC industry, province, and time effects. The probit model is defined as:

$$Pr(IM_{it}=1) = F\Big(\text{Energy intensity}_{it-1}, \text{Productivity}_{it-1}, \text{Output}_{it-1}, \text{Wages}_{it-1}, \text{Share of production workers}_{it-1},$$

(8)

[11] By creating a single probability index we match firms across several dimensions.

Predicting the probability of input-import market entry, the probit estimations are also used to obtain the firm-level propensity scores. All firms i that become an input-importer are then matched to a similar non-importing firm j based on these propensity scores.[12] The method chosen for selecting the appropriate match is the nearest neighbour caliper matching method, where the minimum distance in terms of the calculated propensity scores is smaller than a pre-specified value (i.e. caliper).[13] We further limit the possibilities of matching to the space of common support restricting the selection into similar treated and untreated firms to the area between the lowest and highest propensity scores that fall in the propensity score distribution for both of the respective groups.[14] The chosen matching algorithm assigns only one neighbour to each of the treated firms based on their proximity in calculated propensity scores. Upon the identification of the matched pairs, we ensure the validity of the matching exercise by analysing whether the pre-entry firm characteristics of the treated and the control group are sufficiently similar (Caliendo and Kopeinig, 2008). To test for pre-treatment similarity we examine whether treatment and control group differences are statistical significant (balancing property test). Following Blundell and Costa Dias (2000) we use a difference-in-difference strategy which contrasts growth rates of both treated and control group firms. The advantage of this approach is that it allows us to account for additional unobserved, time-constant factors that may influence firm performance. Moreover, we compare firm performance across the entry and first three post entry periods. The performance indicators are measured in growth relative to the pre-entry period (i.e. the period before switching the trading status).

3.2 Data and sample characteristics

Annex Tables 1 and 2 provide a detailed overview over the main variables used in the analysis, and provide some summary statistics. In this section we report the most salient features of the dataset. We use microeconomic firm-level data from the Indonesian Manufacturing Census, which includes information on around 48,000 different firms,

[12] When defining the control group of non-importers we focus on firms that never imported during the whole sample period. The treatment group, on the other hand, includes firms that imported for at least two consecutive time periods, and that did not import before (import) market entry. When looking at firms that imported at least for three consecutive periods we obtain qualitatively similar results for our main variables of interest. These results are available upon request.

[13] In case there is no control-group match for a treated firm for which the propensity score distance is smaller than the specified caliper, the respective treated firm is excluded from the sample.

[14] We allow non-importers to be selected more than once as an appropriate match for an input-importing firm.

covering the period 1991 to 2005. The manufacturing census categorises firms into HS 5-digit ISIC Rev. 2 industries and is published by the Indonesian Statistical Agency (Badan Pusat Statistic, BPS).[15] The Indonesian Manufacturing Survey is an annual census of all manufacturing firms with at least 20 employees and includes plant-level information on output, intermediate inputs, labour, capital, foreign ownership, exports and imports and energy consumption. Price deflators were used for all output, input and investment data,[16] and capital stocks were calculated based on a perpetual inventory method and using depreciation rates from Arnold and Javorcik (2009).[17] Environmental performance is defined as a firm's energy intensity (i.e. energy consumption over total output),[18] while total factor productivity has been calculated using the Levinsohn and Petrin (2003) methodology. Based on Solow's (1957) growth decomposition model, it is assumed that a plant-level linearly homogeneous production functions can be subdivided into the growth rates of the individual input factors and the growth rate of an unexplained growth residual. Since the estimation of production functions tends to suffer from simultaneity concerns, given that inputs tend to be chosen based on an observed level of productivity we follow Levinsohn and Petrin (2003) and use intermediate inputs as a proxy to unobserved productivity shocks.

Table 1: Importing status, import sourcing and ownership

	(1)	(2)	(3)	(4)	(5)
	Total	Foreign ownership	Domestic Private ownership	Domestic Public ownership	Import share
		FORsh	*DOMPRIVsh*	*DOMPUBsh*	*IMPsh*
Import-starters (*IM*)	0.074	0.081	0.757	0.163	0.191
Never-importers (*NIM*)	0.926	0.013	0.837	0.150	0

Notes: The values reported reflect mean values over the time period 1991 to 2005. Our final data sample includes 1,512 different import starters, over the whole time period considered, and 20,303 non-input importers (Column 1). Columns 2-4 indicate on average the firm-level capital shares owned by foreign, domestic-private or domestic-public investors, respectively. Column 5 shows on average the firm-level import share of intermediate inputs.

---

[15] At the moment there are 33 Indonesian provinces, seven of which have been created since 2000.To ensure consistency over the considered time horizon (i.e. 1995-2005) we re-grouped all newly created provinces back to their original provinces, which resulted in 26 provinces considered in this study. The Manufacturing Census does not include information on the province Sulawesi Barat.

[16] We are grateful to Rodriguez-Pose et al. (2013) for providing us with the deflators. The authors constructed a value-added deflator for input and output information including exports and intermediate imports, as well as an investment price deflator for net investment flows. The value added deflator was constructed by dividing the value added in current prices by the value added in 1995 prices, while the investment price deflator was calculated by dividing current-priced gross capital formation by 1995 prices.

[17] Arnold and Javorcik (2009) use 20% for transport equipment, 10% for machinery and equipment, and 3.3% for buildings, while land is not depreciated.

[18] Batrakova and Davies (2012), and Martin (2011), also use energy intensities as an indicator of firm level environmental performance and argue that the use of energy is positively correlated with firm level pollution.

Table 1 provides some basic statistics on the distribution of import starters and their never-importing counterparts included in our estimating sample.[19] New input importers account for around 7.4% of all firms in our dataset, and feature on average a foreign equity holding of about 8.1 %. On average new input importers' equity is to about 75.7% privately owned, and to around 16.3% by the government. Input importers tend to import, on average, 19.1% of their inputs from abroad and source, on average, around 80.9% of all used inputs domestically.

Table 2 reports some basic firm characteristics of import-starters and non-importers. Input importers are shown to be less energy intensive and more productive compared to the group of non-input importing firms. Moreover, foreign input market entrants are also found to be larger, in terms of both output and employment, and to pay higher wages.

Table 2: Input importer versus non-input importer firm characteristics

	(1)	(2)	(3)	(4)	(5)
	Energy intensity	Productivity	Output	Employment	Wages
	$\ln(\varepsilon)$	$\ln(\varphi)$	$\ln(q_y)$	$\ln(L)$	$\ln(w)$
Import-starters (*IM*)	0.93	6.34	21.67	5.07	13.19
Never-importers (*NIM*)	1.09	5.56	19.67	3.92	11.54

Notes: Table 2 reports mean values over the time period 1991 to 2005. The number of import starters in our sample amounts to 1,512, while the number of never-importers amounts to 20,303. Energy intensity is defined as total energy consumption over total output, while productivity is defined as total factor productivity based on calculations using the Levinsohn and Petrin (2003) methodology. All monetary values are expressed in local currency and have been deflated using a value added deflator. All values are expressed in log.

4. Empirical results

4.1 Foreign input market entry, firm productivity and energy intensity

To identify pre-importing firm characteristics which determine the probability to enter foreign input markets, we run a probit model measuring the selection into input importing in year t based on firm characteristics in year t-1, as illustrated in Eq. (8).[20] The estimation outcome in Annex Table 3 shows no evidence for less energy-intensive firms self-selecting into input importing. However, we find that more productive firms self-select to become input importers. This is in line with some earlier evidence providing support for the

[19] The reported statistics are expressed in means over the considered time horizon.

[20] The specification and setting up of the probit model has been guided by economic theory as well as by considerations of specification quality when using propensity score matching techniques.

hypothesis that firm productivity has a positive effect on the decision to import (Vogel and Wagner, 2010; Castellani et al., 2010).[21] The results also show that firms that are more capital-intensive and skill-intensive (in terms of higher wages, but not in terms of lower share of production to non-production workers) are characterised by a higher probability to source inputs from abroad. In addition, the regression results also suggest that foreign-owned firms are more likely to start importing, confirming that they are more likely to outsource their intermediate inputs through their multinational network.

These probit estimations are used to obtain the firm-level propensity scores required for matching our constructed treated group with the related control group, and the results of the balancing property test, aimed at evaluating the quality of the matching are reported in Annex Table 4. They confirm that for each of the treated group, a control group has been identified with similar pre-treatment firm characteristics (i.e. the mean differences in the variables introduced to calculate the propensity scores between the two groups are statistically not significant).

Table 3 reports the findings for the post-entry effects. To establish the consequences of importing on energy intensity and a series of alternative firm characteristics we compare the outcome variables of matched importers and non-importers as illustrated in section 3.1.[22] The change in energy intensity is reported to be some 11.6% smaller in the entry year than in the time period before, having controlled for energy intensity changes of firms that did not begin to import. There is also evidence for the persistency of this entry effect of up to two years following the decision to import, bringing about a decline in energy intensity of up to some 14.1 percentage points two years following import market entry. These findings hence suggest a positive link between the ability to access intermediate input markets and firm-level energy efficiency, and may point to a beneficial effect of an increasing integration of intermediate input markets on the environment.

[21] While Vogel and Wagner (2010) analyse importing activities and firm productivity for a selection of German firms, Castellani et al. (2010) examine the productivity importing nexus for a sample of Italian firms.

[22] We acknowledge the possibility that a shock in unobserved firm characteristics may affect input import market participation, as well as firm-level environmental and economic outcomes.

Table 3: Post entry energy intensity effects: Difference in difference analysis of new input importers and non-importers for the matched sample of firms

	(1)	(2)	(3)	(4)	(5)
Dependent variable (growth)	Energy intensity	Productivity	Output	Employment	Wages
	$\ln(\varepsilon)$	$\ln(\varphi)$	$\ln(q_y)$	$\ln(L)$	$\ln(w)$
Entry effect	-0.116**	0.220***	0.434***	0.222***	0.368***
	(0.057)	(0.052)	(0.088)	(0.058)	(0.103)
1st year of importing	-0.102**	0.272***	0.368***	0.137***	0.252***
	(0.048)	(0.050)	(0.044)	(0.023)	(0.050)
2nd year of importing	-0.141***	0.257***	0.378***	0.120***	0.327***
	(0.048)	(0.053)	(0.047)	(0.024)	(0.056)
3rd year of importing	-0.062	0.232***	0.346***	0.137***	0.350***
	(0.052)	(0.055)	(0.050)	(0.026)	(0.061)

Notes: Standard errors are in parentheses below all coefficients. *, **, *** respectively denote the 10%, 5%, 1% significance levels.

Table 3 further shows that input import market entry also tends to be associated with positive productivity, employment, output and wage growth premiums. Statistically significant evidence is found for total factor productivity growth in the entry period, as well as in the first, second and third period following market entry, with additional productivity premiums of up to some 27% (in the year following market entry). Positive employment effects are shown to be economically relevant from the period of market entry up until three years following the decision to access foreign intermediate goods markets. The results reported in Table 3 also point to a positive and highly persistent impact of the decision to import on output and real wage growth, for importing firms relative to their never-importing counterparts.

4.2 Robustness checks

Input market exposure, exporting and FDI

In the context of previous empirical studies, which find that learning and competition effects are most likely to occur for firms' most involved in exporting activities (cf. Greenaway and Kneller, 2008; Damijan et al., 2007; Castellani, 2002), we also investigate whether the extent of foreign input market exposure matters for firm-level energy intensity and total factor productivity. We consider the level of exposure to foreign intermediate input markets as an essential driver of firm level efficiency gains. We hence combine foreign input market entry with a significant input-import share indicator variable taking the value one if the imported total input ratio assumes values above the 25th percentile. The results complement previous findings on the exposure to export markets, as they show a significant growth premium in energy efficiency upon beginning to import (Column 1, Table 4), and a substantial gain in total factor productivity following the decision to import (Column 2, Table 4). The effects on energy and total factor efficiency are in magnitude significantly larger than those reported in our baseline specifications in Table 3 (Columns 1 and 2).

In light of the strong focus on exporting status and environmental performance in previous firm-level studies (cf. Galdeano-Gomez, 2010; Girma et al., 2008; Batrakova and Davis, 2012), and to address the potential concern that our results may be driven by firm exports rather than imports, we reduce the firm total population to the sub-sample of non-exporting firms - i.e. we contrast non-exporting importers with firms that neither imported nor exported (i.e. never-traders), over the considered time. The estimation results reported in Table 4 (Column 3) tend to confirm previous findings as the parameter estimates for the entry, as well as first and second post-entry periods are statistically highly significant at the usual thresholds, however at somewhat reduced magnitudes (showing values of -0.010, -0.018 and -0.015, respectively). These findings suggest a significant but reduced impact on energy efficiency for firms that only import intermediates and do not export at the same time. Regarding total factor productivity growth, the results reported in Table 4 (Column 4) also point to a statistically significant premium for pure input importers when contrasting them to their never-trading counterparts, although at slightly smaller magnitudes (relative to your baseline estimations).

Table 4: Post entry effects: Input market participation , Exporting, FDI

	Foreign input market participation (25%)		Non-exporting input importers		Non-FDI & non-exporting importers	
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable (growth)	Energy intensity	Productivity	Energy intensity	Productivity	Energy intensity	Productivity
	ln(ε)	ln(φ)	ln(ε)	ln(φ)	ln(ε)	ln(φ)
Entry effect	-0.143**	0.279***	-0.010**	0.212***	-0.005	0.229***
	(0.071)	(0.065)	(0.006)	(0.077)	(0.005)	(0.077)
1st year of importing	-0.161***	0.363***	-0.018***	0.142**	-0.023***	0.146**
	(0.063)	(0.066)	(0.004)	(0.078)	(0.008)	(0.077)
2nd year of importing	-0.172***	0.343***	-0.015***	0.222***	-0.018**	0.237***
	(0.063)	(0.068)	(0.004)	(0.085)	(0.008)	(0.082)
3rd year of importing	-0.107***	0.250***	-0.010	0.0756	-0.005*	0.164
	(0.063)	(0.070)	(0.008)	(0.091)	(0.006)	(0.087)

Notes: Standard errors are in parentheses below all coefficients. *, **, *** respectively denote the 10%, 5%, 1% significance levels.

Accounting for the possibility that foreign-owned firms may gain easier access to foreign produced intermediate inputs through their multinational networks, and may benefit from a direct transfer of better and more environmentally-friendly technologies by their parent companies, we additionally aim to clean the import premium from both exporting and FDI status. We thus compare non-exporting and non-foreign owned import starters with non-foreign owned never-traders. The results, presented in Table 4 (Column 5), confirm the significant positive relationship between energy efficiency and import-status also for purely domestically-owned firms (for the post-entry periods), but show, in magnitude, a significantly smaller effect of input-import status on firm-level energy efficiency growth, compared to our main findings in Table 3. This may, indeed, point to an important influence of foreign direct investment on the impact of input importing, and may support existing findings in favour of a positive effect of foreign ownership on environmental firm performance in the host country (Albornoz et al., 2009; Cole et al. 2006, 2008; Kaiser and Schulze, 2003). As for the growth in total factor productivity, the results in Table 4 (Column 6) confirm, by and large, our baseline findings showing statistically significant import premiums for the entry, first and second post entry periods.

Alternative matching approach

In addition to the pooled matching technique reported above, we also implement the matching on a cross-section by cross-section basis, and hence require the matching algorithm to select matches that occur in the same time period. This reduces the risk of comparing firms that had to deal with remarkably different macroeconomic conditions. After the selection of matched pairs of treated and untreated firms we pool these observations to construct a panel dataset that we use for our analysis.

As in the previous section, we use a difference-in-difference strategy following Blundell and Costa Dias (2000), and we compare firm performance across the entry and first three post entry periods. The results are reported in Annex Tables 5 and 6, and by and large confirm our previous findings. The former table shows that switching import status leads to a lower energy intensity growth of about 13.6% in the market entry year compared to the period before; this effect persists also in the three years following import market entry, although at different levels of magnitude.[23] These findings corroborate the hypothesis that the

[23] For the1st, 2nd, and 3rd post entry periods our results show lower energy intensities of around 11.6%, 13.7%, and 10.2%, respectively, relative to the pre-entry period.

ability to access intermediate input markets and to integrate into international supply chains may have a positive effect on company-level energy efficiency.[24]

Moreover, using the cross-section-by-cross section firm matching strategy provides further support for positive productivity, output, employment, and wage growth premiums. Our findings show statistically highly significant coefficients for total factor productivity growth in the entry, and the first three periods following market entry, with an additional productivity increase of up to some 30% (in the second year following market entry), compared to the pre-entry period. Positive and highly persistent premiums are also reported for new input importers' size growth (in terms of both output and employment) for the period of market entry up until three years following the decision to access foreign intermediate goods markets. The results reported in Annex Table 5 also point to a positive and statistically significant impact of the decision to import on real wages growth, for importing firms relative to their never-importing counterparts.

Turning to the impact of a higher exposure to foreign input markets on learning, competition, and hence productivity and energy intensity, but also to take into account effects linked to exporting and foreign direct investment, we repeat the above sensitivity analysis when employing cross-section-by-cross-section matching. The results for firms that import more inputs from abroad are reported in Annex Table 6 (columns 1 and 2). They show statistically significant coefficients for energy intensity for the entry and first post entry period. Regarding total factor productivity, the coefficients are statistically highly significant and are, on average, of a similar magnitude compared to the baseline results shown in Annex Table 5. Excluding exporting firms from the sample (Annex Table 6, columns 3 and 4) confirms these results for energy intensity, showing coefficients whose magnitude even exceeds those of the baseline specification. Dropping exporters from the sample, however, also results in still highly significant and, in magnitude, slightly larger productivity premiums. Finally, the findings are also robust to the exclusion of exporters and foreign-owned (i.e. FDI) firms, showing statistically significant energy intensity and productivity growth parameter estimates for all periods (columns 5 and 6).

[24] To control for the possibility that our findings may be driven by individual industry characteristics we also include industry fixed effects at the ISIC 3-digit level in a separate set of cross-section by cross-section regressions. The intuition behind this is that some sectors might be relatively more energy-intensive or subject to a higher number of energy-saving environmental policies than other sectors. Annex table 7 reports the results for the energy intensity and productivity variable and shows very similar parameter estimates compared to our baseline specification.

5. Conclusions

A main concern over international trade and increasing global market integration is its impact on the environment. This is particularly true and important for developing nations, where presumably lower environmental standards have been linked to adverse environmental effects and increasing pollution. This paper contributes to this debate by focusing on the link between participation in foreign intermediate goods markets and firm-level environmental performance in a developing country.

The theoretical and empirical findings in this paper demonstrate significant evidence that imported intermediate goods enhance firms' economic efficiency with an important positive effect on environmental performance. Our results show that by switching from being a non-input importer to an input importer of foreign intermediate materials, a company is likely to improve its economic efficiency and reduce its energy intensity. Our baseline estimates indicate a positive effect of around 22.0% and 11.6% on economic efficiency and energy efficiency growth, respectively, immediately upon entry, and a statistically significant and persistently positive impact of around 25.7% and 14.1%, respectively, two years following market entry. Our findings may hence carry important implications for both government policies and firm level strategies, as they suggest that there are important economic and environmental efficiency gains to be realised when enabling developing country producers to gain access to foreign intermediate good markets. Our results may also be understood as a call for more research on the trade – environment nexus, in particular regarding the effect of importing intermediate inputs on a firm’s propensity to directly invest in cleaner technologies.

REFERENCES

Amiti, M., Konings J., 2007, Trade Liberalization, Intermediate Inputs, and Productivity: Evidence from Indonesia, *American Economic Review*, 97(5), 1611-1638.

Albornoz, F., Cole, M. A., Elliott, R. J. R., Ercolani, M. G., 2009, In search of environmental spillovers, *The World Economy*, 32(1), 136–163.

Antweiler, W., Copeland, B. R., Taylor, M. S., 2001, Is free trade good for the environment? *The American Economic Review*, 91(4), 877–908.

Arnold, M. J., Javorcik, B. S., 2009, Gifted kids or pushy parents? Foreign direct investment and plant productivity in Indonesia, *Journal of International Economics*, 79(1), 42-53.

Barrett, S., 1994, Strategic environmental policy and international trade, *Journal of Public Economics*, 54(3), 325–338.

Batrakova, S., Davies, R. B., 2012, Is there an environmental benefit to being an exporter? Evidence from firm-level data, *Review of World Economics*, *148*(3), 449-474.

Bernard, A. B., Redding, S. J., Schott, P. K., 2007, Comparative advantage and heterogeneous firms, *The Review of Economic Studies*, 74(1), 31–66.

Blundell, R., Dias, M. C., 2000, Evaluation methods for non-experimental data, *Fiscal Studies*, 21(4), 427–468.

Castellani, D., 2002, Export behaviour and productivity growth: Evidence from Italian manufacturing firms, *Weltwirtschaftliches Archiv*, 138, 605–628.

Castellani, D., Serti, F., Tommasi, C., 2010, Firms in International Trade: Importers and Exporters Heterogeneity in the Italian Manufacturing Industry, *The World Economy*, 33(3), 424-457.

Cole, M. A., Elliott, R. J. R., Strobl, E., 2008, The environmental performance of firms: The role of foreign ownership, training, and experience, *Ecological Economics*, 65(3), 538–546.

Copeland, B. R., Taylor, M. S., 1994, North-south trade and the environment, *The Quarterly Journal of Economics*, 109(3), 755–787.

Copeland, B. R., Taylor, M. S., 1997, A simple model of trade, capital mobility, and the environment, NBER Working Paper No. 5898, Cambridge, MA: National Bureau of Economic Research.

Damijan, J., Polanec, S., Prasnikar, J., 2007, Outward FDI and productivity: Micro evidence for Slovenia, *The World Economy*, 30, 135–155.

Dean, J. M., Lovely, M. E., 2010, Trade growth, production fragmentation, and China's environment. In: R. Feenstra, & S.-J. Wei (Eds.), China's growing role in world trade, (Chapter 11 pp. 429–474). Chicago: University of Chicago Press.

Eskeland, G. S., Harrison, A. E., 2003, Moving to greener pastures? Multinationals and the pollution haven hypothesis, *Journal of Development Economics*, 70(1), 1–23.

Ethier, W. J., 1982, National and international returns to scale in the modern theory of international trade, *American Economic Review*, 72 (3), 389–405.

Galdeano-Gomez, E., 2010, Exporting and environmental performance: A firm-level productivity analysis, *The World Economy*, 33(1), 60–88.

Gibson, Mark J., Graciano, T.A., 2011, The Decision to Import, *American Journal of Agricultural Economics*, 93(2), 444-449.

Girma, S., Hanley, A., Tintelnot, F., 2008, Exporting and the environment: A new look with microdata (Kiel Working Paper No. 1423). Kiel: Kiel Institute for the World Economy.

Goldberg, P. K., Khandelwal A. K., Pavcnik N., Topalova P., 2010, Imported Intermediate Inputs and Domestic Product Growth: Evidence from India, *The Quarterly Journal of Economics*, 125(4), 1727-1767.

Greenaway, D., Kneller, R., 2008, Exporting, productivity and agglomeration, *European Economic Review*, 52, 919-939.

Grossman, G.M., Helpman, E., 1991, Innovation and Growth in the Global Economy, MIT Press, Cambridge, MA.

Heckman, J. J., Ichimura, H., Todd, P. E., 1997, Matching as an econometric evaluation estimator: Evidence from evaluating a job training programme, *The Review of Economic Studies*, 64(4), 605-654.

Imbruno, M., 2014, Trade Liberalization, Intermediate Inputs and Firm Efficiency: Direct versus Indirect Modes of Import, Discussion Papers 2014-02, University of Nottingham, GEP.

Kaiser, K., Schulze, G.G., 2003, International competition and environmental expenditures: Empirical evidence from Indonesian manufacturing plants, HWWA Discussion Paper 222, Hamburg: Hamburg Institute of International Economics.

Kasahara, H., Rodrigue, J., 2008, Does the use of imported intermediates increase productivity? Plant-level evidence, *Journal of Development Economics*, 87(1), 106-118.

Khandelwal, A., Topalova, P., 2011, Trade Liberalization and Firm Productivity: The Case of India, *The Review of Economics and Statistics*, 93(3), 995-1009.

Krugman, P.. 1980. Scale Economies, Product Differentiation, and the Pattern of Trade, *American Economic Review,* 70 (5), 950-59.

Larch, M., and Wanner J., 2014. Carbon Tariffs: An Analysis of the Trade, Welfare and Emission Effects, CESifo Working Paper Series 4598, CESifo Group Munich.

Levinsohn, James, Petrin, Amil, 2003. Estimating production functions using inputs to control for unobservables, *Review of Economic Studies*, 70, 317-341.

Levinson, A., 2009, Technology, international trade, and pollution from US manufacturing, *American Economic Review*, 99(5), 2177-2192.

Markusen, J. R., 1989, Trade in Producer Services and in Other Specialized Intermediate Inputs, *American Economic Review*, 79(1), 85.95.

Markusen, J. R., Morey, E. R., Olewiler, N., 1995, Competition in regional environmental policies when plant locations are endogenous, *Journal of Public Economics,* 56(1), 55–77.

Martin, L., 2011, Energy efficiency gains from trade: greenhouse gas emissions and India's manufacturing sector, Melbourne University Working Paper.

McGuire, M. C., 1982, Regulation, factor rewards, and international trade, *Journal of Public Economics*, 17(3), 335–354.

Melitz, M.J., 2003, The impact of trade on intra-industry reallocations and aggregate industry productivity, *Econometrica*, 71(6), 1695-1725.

Melitz, M.J., Ottaviano, G.I.P., 2008, Market Size, Trade, and Productivity, *Review of Economic Studies*, 75(1), 295-316.

Olley, S., Pakes, A., 1996. The dynamics of productivity in the telecommunications equipment industry, *Econometrica*, 65(1), 292-332.

Pethig, R., 1976, Pollution, welfare, and environmental policy in the theory of comparative advantage. *Journal of Environmental Economics and Management*, 2(3), 160-169.

Popp,D., 2011, International Technology transfer, climate change, and the clean development mechanism, *Review of Environmental Economics and Policy*, 5, 131-152.

Rodríguez-Pose, A., Tselios, V., Winkler, D., Farole, T., 2013, Geography and the Determinants of Firm Exports in Indonesia, *World Development*, 44: 225-240

Romer, P., 1990. Endogenous technological change, *Journal of Political Economy*, 98 (5), 71-102.

Rosenbaum, P. R., Rubin, D. B., 1983, The central role of the propensity score in observational studies for causal effects, *Biometrika*, 70(1), 41-55.

Schor, A., 2004, Heterogeneous productivity response to tariff reduction. Evidence from Brazilian manufacturing firms, *Journal of Development Economics*, 75(2), 373-396.

Stern, N., 2007, The Economics of Climate Change: The Stern Review, Cambridge: Cambridge University Press.

Solow, R., M., 1957, Technical change and the aggregate production function, *Review of Economics and Statistics*, 39(3), 312–320.

Vogel, A., Wagner J., 2010, Higher Productivity in Importing German Manufacturing Firms: Self-selection, Learning from Importing or Both? *The World Economy*, 145(4), 641-665.

ANNEX

Annex Table 1: Summary statistics, manufacturing.

Variable	Variable	Obs	Mean	Std. Dev.	Min	Max
ln(Energy intensity)	$\ln(\varepsilon)$	186385	1.063161	1.361077	-9.948113	14.10848
ln(Productivity)	$\ln(\varphi)$	184911	5.738964	1.165371	-2.624947	13.22763
ln(Output)	$\ln(q_y)$	188598	20.13823	1.996547	6.239851	29.28566
ln(Employment)	$\ln(L)$	188598	4.189506	1.141718	2.397895	11.66179
ln(Wages)	$\ln(w)$	125424	11.93598	1.578521	3.727293	21.36423
ln(Share of production workers)	$\ln(L^L/L^H)$	187155	4.424071	0.2488497	-0.1061602	4.60517
ln(Energy consumption)	$\ln(X_e)$	186385	10.36579	2.243911	0	21.06554
ln(Intermediate inputs)	$\ln(X_m)$	188,598	13.11404	2.294891	2.302585	23.77262
ln(Capital)	$\ln(K)$	188576	11.88695	2.275252	-1.685408	24.08672
Import dummy	IMP	188598	0.2812437	0.4496073	0	1
Import share	$IMPsh$	188598	0.0497212	0.1800893	0	1
Export dummy	EXP	188598	0.3529624	0.4778924	0	1
Export share	$EXPsh$	137,714	0.104974	0.282588	0	1
FDI dummy	FDI	188598	0.0422698	0.2012046	0	1
Foreign ownership	$FORsh$	188598	3.114685	15.67663	0	100
Domestic Private ownership	$DOMPRIVsh$	188598	81.78259	37.87354	0	100
Domestic Public ownership	$DOMPUBsh$	188598	15.1027	35.53457	0	100

Annex Table 2: Definition of firm-level variables

Variable	Variable	Description
Energy intensity	ε	Total electricity and fuel purchased standardised by total output (i.e. Energy-Output ratio).
Productivity	φ	Total Factor Productivity (TFP) as defined by Levinsohn and Petrin (2003).
Output	q_y	Total value of all goods produced in any given year.
Employment	L	Total number of workers (paid and unpaid)
Wages	w	Real total compensation of production and non-production workers
Share of production workers	L^L/L^H	Employment share of production to non-production workers.
Energy consumption	X_e	Total electricity and fuel purchased as reported by Indonesian firms to BPS.
Intermediate inputs consumption	X_{int}	Total consumption in intermediate inputs, (including both Materials (Xm) and energy consumption (Xe).
Capital	K	Capital stocks calculated on the basis of the perpetual inventory method using depreciation rates of 20%, 10%, and 3.3% for transport equipment, machinery and equipment, and for buildings, respectively. Land is not depreciated.
Import dummy	IMP	Indicator variable taking the value one if a particular firm imported at some point over the considered time horizon; and zero otherwise.
Import share	$IMPsh$	Inputs imported (as % of total intermediate consumption)
Export dummy	EXP	Indicator variable taking the value one if a particular firm exported at some point over the considered time horizon; and zero otherwise.
Export share	$EXPsh$	Export sales (as % of total output)
FDI dummy	FDI	Indicator variable taking the value one, if a firm is foreign owned (i.e. if a foreign company owns at least 10% of the firm's equity).
Foreign ownership	$FORsh$	Percentage of firm assets owned by a foreign investor.
Domestic Private ownership	$DOMPRIVsh$	Percentage of firm assets owned by a domestic private investor.
Domestic Public ownership	$DOMPUBsh$	Percentage of firm assets owned by the government.
Import-starter dummy (Treated group)	IM	Indicator variable taking the value one if a firm switched from being a non-importer to being an importer. When we use matching techniques input-importers are identified as firms that switch to and stay input-importer: i.e. firms that do not import intermediates two years prior to switching to importing, and then import for at least 2 years.
Never-importer dummy (Untreated group)	NIM	Indicator variable taking the value one if a firm never imports along the entire sample period.

Annex Table 3: Selection into importing

Dependent variable	Import Entry
	IM
$\ln(\text{Energy intensity}_{t-1})$	-0.004
	(0.010)
$\ln(\text{Productivity}_{t-1})$	0.116***
	(0.026)
$\ln(\text{Capital}_{t-1})$	0.098***
	(0.014)
$\ln(\text{Wages}_{t-1})$	0.149***
	(0.014)
$\ln(\text{Output}_{t-1})$	0.005
	(0.016)
$\ln(\text{Share of production workers}_{t-1})$	0.031
	(0.041)
Foreign ownership$_{t-1}$	1.467***
	(0.564)
Observations	128161
Chi2	1634.920
Prob>Chi2	0.0000
Pseudo R2	0.0984

Notes: Standard errors are in parentheses below all coefficients. *, **, *** respectively denote the 10%, 5%, 1% significance levels.

Annex Table 4: Quality of propensity score matching: T-tests comparing sample means of the treated and control groups

	ln(Energy intensity)				ln(Productivity)				ln(Output)			
	Treated	Control	T-test (stat.)	T-test (p-value)	Treated	Control	T-test (stat.)	T-test (p-value)	Treated	Control	T-test (stat.)	T-test (p-value)
ln(Energy intensity$_{t-1}$)	-3.658	-3.680	0.410	0.682	-3.678	-3.717	0.710	0.480	-3.667	-3.702	0.650	0.518
ln(Productivity$_{t-1}$)	-5.234	-5.313	1.540	0.124	-5.223	-5.294	1.370	0.169	-5.233	-5.304	1.390	0.166
ln(Capital$_{t-1}$)	0.460	0.397	0.930	0.350	0.425	0.357	1.010	0.312	0.451	0.392	0.880	0.380
ln(Wages$_{t-1}$)	13.124	13.017	1.570	0.116	13.131	12.987	2.020	0.110	13.122	13.018	1.530	0.126
ln(Output$_{t-1}$)	14.729	14.626	1.190	0.236	14.731	14.596	1.500	0.135	14.725	14.635	1.040	0.300
ln(Share non-production workers$_{t-1}$)	-7.136	-7.129	-0.600	0.549	-7.134	-7.128	-0.460	0.645	-7.135	-7.125	-0.870	0.386
Foreign ownership$_{t-1}$	0.006	0.006	-0.880	0.380	0.006	0.006	-0.910	0.362	0.006	0.007	-1.200	0.231

Notes: Standard errors are in parentheses below all coefficients. *, **, *** respectively denote the 10%, 5%, 1% significance levels. All model specifications include ISIC 4-digit industry and time effects. P-values are reported for the respective t-tests.

Annex Table 4: continued.

	ln(Employment)				ln(Wages)			
	Treated	Control	T-test (stat.)	T-test (p-value)	Treated	Control	T-test (stat.)	T-test (p-value)
ln(Energy intensity$_{t-1}$)	-3.662	-3.702	0.730	0.464	-3.537	-3.535	-0.020	0.984
ln(Productivity$_{t-1}$)	-5.231	-5.300	1.350	0.176	-5.151	-5.237	1.200	0.232
ln(Capital$_{t-1}$)	0.451	0.392	0.890	0.372	0.454	0.434	0.210	0.833
ln(Wages$_{t-1}$)	13.130	13.028	1.490	0.136	13.270	13.121	1.480	0.139
ln(Output$_{t-1}$)	14.733	14.647	0.990	0.320	15.003	14.782	1.810	0.071
ln(Share non-production workers$_{t-1}$)	-7.133	-7.125	-0.710	0.477	-7.134	-7.133	-0.070	0.947
Foreign ownership$_{t-1}$	0.006	0.007	-1.150	0.249	0.005	0.006	-0.570	0.571

Notes: see above.

Annex Table 5: Post entry energy intensity effects: Difference in difference analysis of new input importers and non-importers for the matched sample of firms
(Cross-section by cross-section matching)

	(1)	(2)	(3)	(4)	(5)
Dependent variable (growth)	Energy intensity	Productivity	Output	Employment	Wages
	$\ln(\varepsilon)$	$\ln(\varphi)$	$\ln(q_y)$	$\ln(L)$	$\ln(w)$
Entry effect	-0.136***	0.245***	0.391***	0.114***	0.264***
	(0.044)	(0.047)	(0.039)	(0.018)	(0.034)
1st year of importing	-0.116**	0.284***	0.402***	0.160***	0.314***
	(0.050)	(0.052)	(0.045)	(0.025)	(0.038)
2nd year of importing	-0.137***	0.302***	0.426***	0.159***	0.346***
	(0.051)	(0.055)	(0.050)	(0.025)	(0.043)
3rd year of importing	-0.102*	0.284***	0.385***	0.151***	0.341***
	(0.053)	(0.058)	(0.052)	(0.026)	(0.046)

Notes: Standard errors are in parentheses below all coefficients. *, **, *** respectively denote the 10%, 5%, 1% significance levels.

Annex Table 6: Post entry effects: Input market participation , Exporting, FDI
(Cross-section by cross-section matching)

	Foreign input market participation (25%)		Non-exporting input importers		Non-FDI non-exporting importers	
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable (growth)	Energy intensity	Productivity	Energy intensity	Productivity	Energy intensity	Productivity
	$\ln(\varepsilon)$	$\ln(\varphi)$	$\ln(\varepsilon)$	$\ln(\varphi)$	$\ln(\varepsilon)$	$\ln(\varphi)$
Entry effect	-0.112**	0.282***	-0.164***	0.354***	-0.175***	0.310***
	(0.056)	(0.059)	(0.065)	(0.072)	(0.066)	(0.079)
1st year of importing	-0.106*	0.253***	-0.196***	0.361***	-0.189**	0.294***
	(0.063)	(0.063)	(0.066)	(0.083)	(0.019)	(0.085)
2nd year of importing	-0.094	0.283***	-0.109	0.380***	-0.141*	0.351***
	(0.065)	(0.071)	(0.074)	(0.088)	(0.075)	(0.087)
3rd year of importing	-0.046	0.293***	-0.124	0.295***	-0.171**	0.289***
	(0.068)	(0.073)	(0.078	(0.093)	(0.081)	(0.095)

Notes: Standard errors are in parentheses below all coefficients. *, **, *** respectively denote the 10%, 5%, 1% significance levels.

Annex Table 7: Post entry effects: Industry Fixed Effects (Cross-section by cross-section matching)

	Industry Fixed Effects (ISIC 3-digit)	
	(1)	(2)
Dependent variable (growth)	Energy intensity	Productivity
	$\ln(\varepsilon)$	$\ln(\varphi)$
Entry effect	-0.128***	0.256***
	(0.044)	(0.047)
1st year of importing	-0.114**	0.286***
	(0.050)	(0.056)
2nd year of importing	-0.138***	0.305***
	(0.051)	(0.056)
3rd year of importing	-0.104*	0.283***
	(0.053)	(0.058)

Notes: Standard errors are in parentheses below all coefficients. *, **, *** respectively denote the 10%, 5%, 1% significance levels.