Deforestation, Foreign Demand and Export Dynamics in Indonesia

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Abstract

This paper presents a dynamic, heterogeneous firm model of investment in environmental abatement and exporting. Specifically, we study firm-level investment in reducing deforestation in Indonesia's timber manufacturing industries. The model highlights the interaction between firms' environmental investment and export decisions on the evolution of productivity and export demand. The model is structurally estimated using Indonesian timber manufacturing data that captures firm-level variation in environmental investment and export behavior. The results suggest that environmental investment has little impact on productivity dynamics, but does encourage growth in export demand. Counterfactual experiments quantify the impact of policy change on trade and abatement decisions.

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"I want to appeal to the citizens of the whole world: look for the stamp of approval on legal wood products."

-Rashmat Witoelar, 2007

State Minister of Environment, Republic of Indonesia[1]

This paper develops a dynamic model of environmental abatement and exports with heterogeneous firms. Specifically, the paper addresses the impact of firm-level actions taken to reduce deforestation in Indonesia on domestic and export performance. The model emphasizes the role of firm-level environmental investment and export decisions on the evolution of the distribution of abatement and exports in Indonesian timber industries. The model is estimated using firm-level data from Indonesian timber manufacturers. Counterfactual policy experiments are used to assess the policy implications of trade and environmental regulation.

Today, consumers are often encouraged to "think globally and act locally" when purchasing a wide range of goods. What is less clear is whether such actions have discernable impacts on global environmental choices or outcomes. That is, can increasing demand for more environmentally conscious goods change the nature of production and products on a global level? This issue is particularly difficult since many goods of environmental concern are produced in developing countries which are often characterized by weak environmental regulation. Moreover, given the sparcity of data linking environmental actions in one country with outcomes in others it is nearly impossible to quantify or evaluate the potential role of evolving environmental preferences or regulation on production, abatement and export decisions across countries. We study one of the few cases (if not the only case) where there exists producer-specific information regarding both the actions taken by producers in a developing country and outcomes of these actions in export markets. We exploit the unique structure of trade and international timber product certification during the early 1990s along with unique data on environmental decisions from the same period to document and quantify the impact of actions taken to reduce deforestation on export market demand in the Indonesian wood furniture and saw mills industries.

This is not to suggest that there is little existing literature linking trade and environmental outcomes. Rather the opposite is true, particularly in developing countries. For example, Copeland and Taylor (1994, 1995) argue that international trade may be particularly likely to increase pollution in countries that have a comparative advantage in

[1]Environmental Investigation Agency (EIA), 2007.

pollution-intensive industries. Similarly, Ederington et al. (2005) and Levinson and Taylor (2008) argue that when we examine trade between developed and developing countries we often observe substantial reallocation of environmentally harmful production. In contrast, numerous authors cast doubt on the hypothesis that free trade will create pollution havens or reduce environmental quality.[2] We contribute to this literature by examining firm-level abatement and exporting activities and characterizing their behavior for a critical, resource-intensive industry in a developing country.

Recent research on export dynamics has emphasized the complementarity between investment and exporting activities. Costantini and Melitz (2008), Ederington and McCalman (2008), Atkeson and Burstein (2010), Lileeva and Trefler (2010) and Aw, Roberts and Xu (2011) highlight this link across firm-level decisions and emphasize the impact it may have on the evolution of firm-level outcomes over time. We follow this literature by examining the relationship between exporting and the investment in mitigating negative outcomes on the natural environment.

While the preceding literature has stressed the link between investment and exporting through the impact of investment on the evolution of firm-level productivity, our paper, in contrast, emphasizes the impact of environmental investment on the evolution of *export demand* at the firm-level. In this sense, our paper is also related to the literature on firm-level decisions, productivity and demand as in Foster et al (2008) or Eaton et al (2009). Using standard variation in domestic and export revenues we develop a methodology to estimate dynamic, stochastic, market-specific returns to firm-level investments even when those returns are only *partially* observed (since relatively few firms export in any given year). We examine a situation where firms may choose to make environmental investments which have differential future returns in both export and domestic markets. While exporting firms are able to directly capture the return from such actions in export markets, we also consider the possibility that non-exporting firms internalize the benefit that current environmental investments have on potential export sales in the future.

A large number of papers have studied whether environmental investment improves firm-level performance, with mixed results. Gollop and Roberts (1983), Smith and Sims (1983) and Brannlund (1995) all report large productivity declines, while Berman and Bui (2001) find significant improvements and Gray (1987) finds no significant change at all.[3] Porter and van der Linde (1995) argue that any measured productivity gain from

[2] See Grossman and Krueger (1995), Antweiler et al. (2001), or Frankel and Rose (2005) for examples.

[3] These papers study regulation in the US fossil-fueled electric power generator, Canadian brewing, Swedish pulp and paper, US oil refinery and US manufacturing industries, respectively. Further studies

environmental investment may actually reflect an increase in the demand for goods from "environmentally clean" sources. This interpretation is consistent with the evidence in Teisl et al. (2002) and Bjorner et al. (2004) which document that environmental labeling can have large impacts on consumer demand in US and European markets, respectively.

Although some of the above mentioned papers examine the impact of environmental investment on firm performance, none of them capture the impact of trade decisions on firm behavior. Kaiser and Schulze (2003) and Girma et al. (2008) explicitly examine the interaction of firm-level abatement with the decision to export abroad. While they confirm that exporting firms from Indonesia and the UK are more likely to abate, they do not study the impact of environmental expenditures or exporting on the evolution of productivity, export demand and export/abatement decisions over time. Similarly, Holladay (2010) demonstrates that exporting U.S. firms tend to emit 5.3 percent less than non-exporting firms on average. He is not, however, able to directly observe whether exporting firms have actively pursued environmental abatement. Pargal and Wheeler (1996) report that larger, more efficient firms tend to produce less local pollution on average in Indonesia. Our paper, in contrast, emphasizes the internal incentive firms may have to reduce local environmental degradation: an increase in profits. Moreover, conditional on the domestic market response to abatement behavior we are able to separately distinguish whether there are further gains in export markets. In fact, our results will suggest that exporting and environmental investment are closely linked within firms.

We build a dynamic structural model of exporting and abatement. As in the preceding exporting and abatement research we allow abatement and export decisions to influence the evolution of future productivity. However, our model adds another layer of firm-level heterogeneity, export demand, whose evolution is an endogenous function of firm decisions. The model links exporting and abatement through four mechanisms. First, the return to either activity is increasing in the firm's productivity, so that high-productivity firms self-select into both activities. Second, each activity potentially influences future productivity reinforcing the first effect. Third, we allow future export demand to depend directly on investment in abatement, encouraging future entry into export markets. Last, entry into either activity influences the return from undertaking the other activity. The decision to export directly influences the probability of abatement and vice-versa.

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of environmental management on firm performance include Jaffe and Palmer (1997), Konar and Cohen (2001) and Brunnermeier and Cohen (2003). Theoretical arguments for the impact of regulation on firm-level efficiency and environmental performance can be found in Xepapadeas and de Zeeuw (1999), Ambec and Barla (2002), Campbell (2003), Bajona et al. (2010) and references therein.

The data employed in this paper contain unique information detailing firm-level expenditures on environmental abatement, export decisions, and domestic and export revenues for all firms with more than 20 employees in the Indonesian manufacturing sector. While several papers have examined firm-level emissions we are not aware of any other data set that captures variation in *abatement behavior* across trade-oriented manufacturing firms. Fowlie (2010) examines firm-level abatement in the US electricity industry, but does not investigate the interaction of abatement with firm-level trade decisions given the domestic-orientation of this industry.

Our approach has a number of advantages. First, we are able to be specific regarding the environmental concern in the wood furniture and saw mills industries and tailor our model to suit these particular manufacturing industries. Second, deforestation is a leading environmental concern in Indonesia and has generated substantial interest both within Indonesia and abroad. Deforestation is a key environmental issue in Latin America, Eastern Europe, West and Central Africa and South East Asia. In almost every case deforestation and illegal timber practices are closely tied to international trade (WWF, 2008). Despite its importance, deforestation has received almost no attention in the economics literature. Third, the nature of the sustainable resource issue studied here is typical of the type of trade-off between resource depletion and development common in many developing countries. Sachs and Warner (1995) document that the economic development in Latin America has relied heavily on natural resources and the degree to which resource booms influence trade have important implications for economic growth.[4]

The model is estimated in two steps. First, the parameters governing the evolution of productivity are estimated using control function techniques as in Olley and Pakes (1996) and Doraszelski and Jaumandreu (2008). We find that abatement has little effect on firm productivity or on the evolution of domestic sales in the timber industry. The remaining dynamic parameters are estimated by Bayesian Markov Chain Monte Carlo (MCMC) methods. Our results suggest that deciding to abate has a significant positive effect on the evolution of export demand. We observe that firms which choose to start using wood in a sustainable, environmentally conscious manner observe export demand grow 1.4 to 6 percent faster than non-abating firms. Consistent with evidence from the US, we further find that industries whose main product is closer to a finished product tend to enjoy larger increases in demand from such activity (Arora and Cason, 1996).

We perform a number of counterfactual experiments in order to quantitatively as-

[4]Similarly, McNeely (1993) indicates that increased trade in Africa has lead to substantial resource depletion across many African countries.

sess the impact of policy on firms' decisions in a developing country. The experiments highlight that small changes in the regulatory environment can have large impacts on exporting and abatement over time. Moreover, similar to the evidence found in Ryan (2010), we demonstrate that the entry costs associated with these activities play a key role in determining aggregate outcomes over time.

The experiments suggest that trade liberalization and abatement subsidies encourage exporting and environmental investment. In the wood furniture industry increasing the size of the export market by 20 percent increases export participation rates by 22 percentage points over ten years while also increasing abatement rates by 33 percentage points. Reducing the cost of abatement by 20 percent similarly increases exports and abatement by 1 and 7 percent, respectively, in the same industry and time period. Last, we study the impact of shutting out firms which do not abate from export markets. We find that restricting export markets from environmentally non-compliant exporting firms encourages abatement, but causes export participation to fall. In the wood furniture industry the proportion of abating firms grows by 43 percentage points over ten years, but the proportion of exporting firms falls by 20 percentage points outlining a clear trade-off between these objectives. The experiments confirm that ignoring differential returns to the *same* activity on different markets can potentially lead to misleading policy conclusions.

The next section describes the importance of the Indonesian timber industry, both at home and abroad. Sections 2 and 3 present the model and describe the estimation methodology. The fourth section describes the data while sections 5 and 6 present the empirical results and policy experiments. The last section concludes.

1 Deforestation, Abatement and Trade in Indonesia

1.1 Deforestation and Domestic Policy

Indonesia is home to a rich endowment of natural resources, including the worlds second largest expanse of tropical forest. The timber industry accounts for almost 20 percent of total output, 33 percent of total manufactured exports and played leading role in sustaining GDP growth rates near eight percent per annum before the 1997-1998 Asian crisis (FWI/GFW, 2002). The most common timber exports include plywood, profiled wood, wood furniture and other finished wood products (WWF, 2008). The success of *manufactured* Indonesian wood products on foreign markets is often tied to numerous policies which restrict the export of whole logs in order to encourage the development of the timber manufacturing industry in export markets (Resosudarmo and Yusuf, 2006).

In 1950 forests covered over 162 million hectares of the Indonesian archipelago. By 2000 forest coverage had fallen to 98 million hectares, a 40 percent loss. During the 1980s it is estimated that 1 million hectares of forest were cleared per year, with that rate accelerating to 1.7 million hectares per year by 1990 and 2 million hectares per year by 1996. By 2000, tropical forests had been nearly cleared from the region of Sulawesi and were shrinking rapidly in both the Sumatra and Kalimantan regions of Indonesia.[5] Due to the lack of domestic enforcement, Indonesian wood manufacturers routinely ignore harvest licenses and log trees illegally in order to export timber products abroad. It is estimated that of all of the wood products manufactured in Indonesia as much as three-quarters may be from illegally logged timber.[6]

We are most interested in the policy environment between 1994 to 1997 during which we have access to data describing firm-level abatement decisions. Indonesian manufacturers faced few domestic environmental regulations during our period of study. There were notable environmental programs in place by 1986 which encompassed a number of recommendations for air, water quality, hazardous waste control and deforestation (Afsah et al., 2000 and WWF, 2008), although compliance was extremely low since enforcement was essentially non-existent (Afsah and Vincent, 1997). Finally, in 1994 Indonesia was preparing to join the World Trade Organization (WTO). While trade barriers fell across timber manufacturing industries, tariffs in major export markets were already relatively low before trade liberalization.[7]

1.2 Saw Mills, Wood Furniture and Deforestation

Environmental impacts do vary somewhat across distinct timber industries. We focus on the two largest industries classified at the 4-digit ISIC code level, the saw mill and wood furniture industries.[8] In most timber industries, operations include the handling and transportation of logs, the drying of timber, sorting and classification, although these

[5]These figures are taken from the FWI/GFW report (2002).

[6]McCarthy (2002) reports that 60 percent of saw mills in the province of South Aceh were operating without necessary licenses during the mid-1990s. Similarly, Indonesia is reportedly the largest South-Asian exporter of illegally logged wood products to Europe and the second-largest European source of illegal wood products in the world (WWF, 2008).

[7]Although the EU added environmental clauses to its generalized scheme of tariff preferences (GSP) in 1998, Brack et al. (2002) report that no country has applied for these tariff reductions due to the low rate of duties already applied to timber products in importing countries.

[8]A joint report by the World Resources Institute and Forest Watch Indonesia provide exhaustive details of environmental impacts in the Indonesian timber industries: http://pdf.wri.org/indoforest_full.pdf.

activities plays a larger role in the saw mills industry (McCarthy, 2002). In contrast, several rare woods, some of which are particularly close to extinction, are used intensively in the production of wood furniture.[9]

Although deforestation is by-far the primary concern in these industries, it is not the exclusive environmental concern in this sector (Resosudarmo and Yusuf, 2006 and Synnott, 2005). Other saw mills activities include the transformation (sawing) of logs into dimension lumber, boards, and beams. Aside from design, typical operations in the wood furniture manufacturing industry include finishing, gluing, cleaning, and wash-off (EPA, 1995). Timber certification schemes, as we detail below, require firms to reduce the environmental impact on these dimensions as well so that consumers can be confident that they are purchasing a product that was produced in an environmentally conscious manner over its entire life-cycle.

Nonetheless, to check that abatement expenditures were primarily directed towards deforestation in these industries we investigated whether firm-level abatement activities have any impact on the rate at which firms use energy, intermediate materials or capital since these activities have been established as a good proxy for emissions (Cole and Elliott, 2003). Consistent with the results in Pargal and Wheeler (1996) we find no evidence that abatement has any effect on these firm-level attributes in the timber industry.[10]

1.3 Foreign Responses to Deforestation

In the mid 1980s and early 1990s, deforestation of tropical forests, began to receive greater international attention. During the 1980s international organizations such as the World Bank and Food and Agriculture Organization of the United Nations, in conjunction with numerous bilateral agencies, begin funding numerous projects to improve timber management, particularly in tropics (Synnott, 2005).[11]

The global institutional framework during the early 1990s played a key role in determining mechanism through which abatement operates in the timber products industry. In particular, Article 20 of the GATT (and later WTO agreements) obliges member countries

[9]For example, Merbau (or Kwila), a highly-prized tropical hardwood typically used to manufacture high-end luxury timber products, may be extinct world wide by 2042. By 2007, 83 percent of Indonesia's stock of Merbau had already been logged or was allocated for logging (Greenpeace, 2007).

[10]Details and full results can be found in the Supplemental Appendix at https://my.vanderbilt.edu/joelrodrigue. Although these processes generate environmental concerns due to air toxins contained in solvents and glue adhesives, a number of inexpensive, less toxic substitutes are widely available (Pollution Prevention Resource Exchange, 2011).

[11]For example, the Tropical Forest Action Plan or the International Tropical Timber Organization.

to treat imports and domestic goods equally, regardless of the nature of production. Despite international concern over tropical deforestation there were few government actions taken to distinguish sustainably produced products. The 1992 United Nations Conference on Environment and Development resolved to encourage sustainable harvesting practices across countries, but did not bind signatories (Tarasofsky, 1994). While Indonesia signed and ratified numerous similar agreements, essentially none of these agreements were binding. While it was initially expected that these agreements would eventually become binding, no such agreements were adopted during this period.[12]

1.4 Corporate Responses to Deforestation

In the late 1980s many timber retailers came under increased pressure to provide sustainably harvested alternatives, as numerous NGOs called for outright boycotts of tropical timber products (Synnott, 2005). By 1992 a number of the world's largest timber retailers had developed and instituted wood purchasing policies emphasizing environmental consciousness and tropical forest sustainability. Examples include the largest Do-It-Yourself (DIY) retailers in the US and UK, *HomeDepot* and *B&Q*, respectively, and the world's largest furniture retailer, *IKEA*.[13] These policies were influential in determining the nature of timber certification which followed shortly thereafter (Synnott, 2005).

Concurrently, across Europe and North America corporations in timber-related industries joined together to form buying groups committed to purchasing sustainably harvested wood. The first such group was formed in 1991 among 18 UK timber-purchasing firms from a variety of end-product industries. By 1996 similar groups had formed in Belgium, the Netherlands, France, Ireland, Switzerland, Austria, Germany, Spain, Sweden

[12] Austria and the Netherlands attempted to create national timber industry trade policies. In 1992, Austria introduced a special import duty of 70 per cent and a compulsory labeling system for tropical timber. The Netherlands sought to only allow imports of tropical timber only from regions where sustainable forestry management is practiced by 1995. The governments of Indonesia and Malaysia, primary suppliers to the Netherlands, brought these measures to the attention of the GATT. While these disagreements led to the cancelation of policies shortly after they were enacted it was expected these laws were broadly considered precursors to binding European agreements (Lee, 1997 and Patterson, 1997). However, the European Union reports that a Voluntary Partnership Agreement with Indonesia has only been signed very recently (European Union, 2011).

[13] In the Supplemental Appendix (https://my.vanderbilt.edu/joelrodrigue) we have compiled a list of more than 40 industry-leading, timber-purchasing corporations who made similar commitments during our period of study for our products of interest. Note that this list is not intended to be exhaustive. We only wish to illustrate the degree of corporate commitments to the issue of deforestation in tropical forests. Hundreds of other commitments in these industries can be readily found online with international organizations such as the Global Forest Trade Network (http://gftn.panda.org/), the TFT (formerly Tropical Forest Trust, www.tft-forests.org/) or the Rainforest Alliance (http://www.rainforest-alliance.org/).

and North America.[14] As an increasing number of firms became committed to purchasing sustainably harvested timber it became clear that there was a distinct need for an independent, global certification. In particular, purchasing firms needed a credible mechanism to evaluate a product's environmental impact over the entire course of production from harvesting to final use (Synnott, 2005). The lack of such a mechanism provided the necessary motivation for the creation of the initial forest certification bodies.

1.5 Smartwood, the FSC and LEI

In contrast to inter-governmental agreements, progress on voluntary timber certification came quickly. This provided a mechanism through which producers could voluntarily opt to distinguish their product *on the basis of how it was produced* in export markets. Moreover, because these certification schemes were operated by global, independent, non-governmental organizations, they did not run the risk of contravening GATT regulations since they were not administered by national governments (Okubo, 1998). Retailers in major export markets were quick to adopt these independent labels which allowed them to distinguish environmentally negligent and conscious suppliers on their store shelves. We document that this practice was common, particularly among the largest retailers in many of Indonesia's largest export markets for timber products.[15]

Consumer guides and timber certification began to appear as early as 1987 (Synnott, 2005). In 1989 the Rainforest Alliance had established its global "SmartWood" forest certification program and began certification in Indonesia in 1990. The "Smartwood" certification grew in Indonesia throughout 1991-1993 and has been shown to have had an important impact on producers: initial adopters of certification benefitted from a substantial rise demand traced to a export boom sustainably harvested Indonesian teak furniture (Muhtaman and Prasetyo, 2006).

By 1990 numerous international meetings were organized to explore the idea of an global, independent timber monitoring agency. In particular, in 1990 the Certification Working Group was born from meetings of numerous timber users, traders and environmental organizations in California. This group paved the way for the eventual establishment of Forest Stewardship Council (FSC) certification in 1993 (Perera and Vlosky, 2006).

[14]See the Supplemental Appendix (https://my.vanderbilt.edu/joelrodrigue)for further details and various citations.

[15]See the Supplemental Appendix (https://my.vanderbilt.edu/joelrodrigue) for a timeline of standards adoption for firms such as *B&Q*, *Carrefour*, *Homebase*, *HomeDepot*, *IKEA* and *Walmart* among others.

A key accomplishment of this group was the establishment of a criterion for evaluating sustainably produced timber products worldwide (Synnott, 2005).

There are three keys features of FSC certification that are important for our study. First, the FSC certification is required at *each stage of production*. That is, when consumers inquire about FSC certification they can assured that the product was produced in an environmentally conscious manner from harvesting to retailing. Second, although deforestation was the primary motivation for the creation of FSC certification, the FSC requires that timber producers take action to *broadly reduce their impact on the environment*. For instance, furniture producers are not just asked to use better sources of wood but also to adopt more environmentally conscious adhesives, finishes, etc. As such, any action taken by firms to reduce the environmental impact can contribute to FSC certification. Third, FSC was the most prominent global certification available to Indonesian producers during our sample period (Synnott, 2005).[16]

In 1993 the Indonesian government established the Lembaga Ekolabel Indonesia Working Group (LEI) to study the potential for a national certification scheme which would enable Indonesian producers to establish that their products were meeting international sustainability expectations. Based on the FSC guidelines, the LEI created a framework for timber certification tailored to the Indonesian context. In 1998 the group severed ties with the government and began certifying producers. While the LEI did not directly certify products between 1994 and 1997 they were working closely with Indonesian firms to help them meet international sustainability standards (Muhtaman and Prasetyo, 2006).

While certification was voluntary, numerous studies have found that voluntary certifications can have substantial impact on demand. Chen, Otsuki and Wilson (2008) find meeting foreign standards does have a significant impact on export performance among manufacturing firms in developing countries. Moreover, Arora and Cason (1996) demonstrate that these effects may be particularly important for firms which produce relatively finished products. Market studies suggest that over the 1992-1996 period tropical timber consumption fell by 36 percent in Germany, the UK and the Netherlands (Greenpeace, 1999) and that by 2000 certified wood products accounted for at least 5 percent of all timber sales in Western Europe (Brack et al., 2002).

Certification, however, can be quite costly. These expenditures often include changes in forest management, creating separate inventories of certified and non-certified products, tracking certified products through all previous stages of production and the costs

[16]Numerous alternatives appeared shortly after 1996-1997 such as the PEFC and ISO 14001.

directly associated with the actual certification process (Perera and Vlosky, 2006). Studies focussing on Indonesia emphasize costs associated with securing lands from illegal logging activities, redesigning the working area and allocating some land to protected area (Muhtaman and Prasetyo, 2006).[17] The actual certification process includes preparing the firm for a certification audit, paying the auditors' costs (travel, field visits, reports, annual follow-ups, certificates), and compliance costs associated with changes in management and employee training (Fischer et al, 2005). Some studies suggest that certification can increase costs by 5-25 percent (Gan (2005)), but others note these costs generally display large economies of scale (Fischer et al, 2005).

2 A Structural Model of Abatement and Exporting

We contribute to a rich literature that examines firm entry into exports markets such as Roberts and Tybout (1997), Clerides, Lach and Tybout (1998), Melitz (2003) and models of exporting and investment as in Costantini and Melitz (2008), Atkeson and Burstein (2010), Lileeva and Trefler (2010). Our structural model is closest to the structural models of firm entry into export markets presented in Das, Roberts and Tybout (2007) and Aw, Roberts and Xu (2011). While we will also allow abatement to influence the evolution of productivity, we do not need (or necessarily expect) that this is the primary mechanism through which abatement influences export decisions.

We prefer to emphasize the positive impact that abatement has on export demand. Our model allows us to separately identify *productivity* effects from *demand* effects in export markets, allowing us to test one version of the "Porter Hypothesis": that abatement may increase firm-specific demand (Porter and van der Linde, 1995).[18] To the extent that abatement may encourage growth in domestic demand (rather than improving firm productivity), our estimates in export markets identify the differential growth rate in demand across domestic and export markets.

[17] Examples reported by Indonesian timber producers include expenditures incurred to patrol their licensed timber holdings with military or police officers and the making of guard posts. The government does not fund these operations in Indonesia. Other timber producer have noted that they needed to restructure their production area to allocate some timber sources to conversation forests and recover higher percentage from the trees that were cut Muhtaman and Prasetyo, 2006).

[18] See Innes (2010) for other interpretations of the Porter hypothesis we do not consider here.

2.1 Static Decisions

We first consider the total costs for each firm. Firm i's short-run marginal cost function is modeled as:

$$\ln c_{it} = \ln c(k_{it}, \omega_{it}) = \beta_0 + \beta_k \ln k_{it} + \beta_w w_t - \omega_{it} \tag{1}$$

where k_{it} is the firm's stock of productive capital, w_t is the set of relevant variable input prices and ω_{it} is firm-level productivity. Data limitations require a number of assumptions. First, we assume that each firm is a separate organizational entity and that each firm produces a single output which can be sold at home or abroad.[19] Second, there are two sources of short-run cost heterogeneity: differences in firm-level capital stocks and productivity. Abatement can only affect short-run costs through its impact on productivity. Last, we assume that marginal costs do not vary with firm-level output. As such, demand shocks in one market do not affect the static output decision in the other market.

Both domestic and export markets are assumed to be monopolistically competitive in the Dixit and Stiglitz (1977) sense. However, we allow each firm to face a different demand curve and charge different markups in each market j where $j = D$ denotes the domestic market and $j = X$ denotes the export market. Specifically, firm i faces the following demand curve q_{it}^j in market j:

$$q_{it}^j = Q_t^j (p_{it}^j / P_t^j)^{\eta_j} e^{z_{it}^j(d_{it-1})} = \frac{I_t^j}{P_t^j} \left(\frac{p_{it}^j}{P_t^j} \right)^{\eta_j} e^{z_{it}^j(d_{it-1})} = \Phi_t^j (p_{it}^j)^{\eta_j} e^{z_{it}^j(d_{it-1})} \tag{2}$$

where Q_t^j and P_t^j are the industry aggregate output and price index, I_t^j is total market size and η_j is the elasticity of demand, which is constant. The individual firm's demand in each market depends on industry aggregates Φ_t^j, the elasticity of demand, its own price p_{it}^j and a firm-specific demand shifter $z_{it}^j(d_{it-1})$. The firm-specific demand shifter $z_{it}^j(d_{it-1})$ in turn depends on the firm's history of environmental abatement decisions d_{it-1}.

Both firm-specific productivity and the export demand shock capture various sources of heterogeneity, and as such, it is important to interpret their effect cautiously. Our data will not allow us to separately identify productivity from demand effects on the *domestic market*. As such, we follow Das, Roberts and Tybout (2007) and Aw, Roberts and Xu (2011) and assume $z_{it}^j = 0$ for all i and t if $j = D$. In this case, the term ω_{it} captures any source of firm-level heterogeneity that affects the firm's revenue in both markets; this

[19] The first part of this assumption is not too restrictive. Blalock, Gertler and Levine (2008) report that 95% of the firms in the Indonesian manufacturing census are separate organizational entities.

may be product quality, for example, but we will refer to it as productivity. If abatement affects domestic demand then it will show up as a productivity effect in domestic revenues. Moreover, if environmental investment affects both costs (productivity) and revenues (demand) our estimates will only reveal the net/total effect on the domestic market.

In this case z_{it}^{j} captures all sources of export revenue heterogeneity, arising from differences in either cost or demand, that are unique to the export market. We are particularly interested in identifying the component the export demand shifter that depends on environmental abatement. In the same sense as above if firm-level environmental investment improves product appeal or the efficiency with which the firm produces the "version" of the product for export, we cannot separately identify these effects. We will be more specific regarding the functional form of z_{it}^{j} in the following section.

Each period firm i decides whether or not to export, whether or not to abate and sets the price for its output in each market to maximize the discounted sum of profits. The firm's optimal price p_{it}^{j} implies that the log of revenue r_{it}^{j} in market j is:

$$\ln r_{it}^{j} = (\eta_j + 1) \ln \left(\frac{\eta_j}{\eta_j + 1} \right) + \ln \Phi_t^j + (\eta_j + 1)(\beta_0 + \beta_k \ln k_{it} + \beta_w \ln w_t - \omega_{it}) + z_{it}^{j}(d_{it-1}) \quad (3)$$

so that the firm's domestic revenue is a function of aggregate market conditions, the firm's capital stock, firm-specific productivity and demand. Export revenues will depend on abatement decisions through both firm-specific productivity and the export demand shock whereas abatement can only influence domestic revenues through productivity.

The structure of the model allows us to calculate operating profits in each market, $\pi_{it}^{j} = -\eta_j^{-1} r_{it}^{j}(\Phi_t^j, k_{it}, \omega_{it})$, and, as such, the short-run profits are observable with data on domestic and export revenues. These will be important for determining the export and environmental investment decisions over time developed in the dynamic model below.

2.2 Transition of the State Variables

We describe here the evolution of productivity, export demand shocks and the state variables Φ_t^D, Φ_t^X, and k_{it}. We assume that productivity evolves over time as a Markov process that depends on the firm's abatement decisions, its participation in the export market, and a random shock:

$$\begin{aligned} \omega_{it} &= g(\omega_{it-1}, d_{it-1}, e_{it-1}) + \xi_{it} \quad (4) \\ &= \alpha_0 + \alpha_1 \omega_{it-1} + \alpha_2 d_{it-1} + \alpha_3 e_{it-1} + \alpha_4 d_{it-1} e_{it-1} + \xi_{it} \end{aligned}$$

where d_{it-1} is the firm's abatement decision, and e_{it-1} is the firm's participation in export market in the previous period. We treat d_{it} (e_{it}) as a binary variable which takes a value of 1 if firm i abates (exports) in year t and zero otherwise. As described above, it is not unrealistic to assume that the costs associated with certification and abatement in this industry are fixed in nature. We assume that any effect abatement has on productivity occurs in the year subsequent to when the expense was incurred due to the time necessary to install new technology, for certification to be verified and processed and for upgraded product characteristics to be noticed in the market.

The inclusion of e_{it-1} allows for the possibility of learning-by-exporting and, in this case, we expect that $\alpha_3 > 0$. The term d_{it-1} captures the impact of abatement on the evolution of productivity. If environmental technology is more costly to operate (e.g. maintenance costs, emission control costs, fewer resources allocated to production) we would expect that abatement would reduce firm productivity and $\alpha_2 < 0$. However, if environmental technology is more advanced such that firms which abate also experience productivity improvements, we would expect $\alpha_2 > 0$. We further argue that there may be important interactions between exporting and abatement. For instance, if foreign contacts allow firms to make better use of new technology we would expect that $\alpha_4 > 0$. The stochastic element of productivity evolution is captured by ξ_{it}. We assume that ξ_{it} is an *iid* draw from a distribution with zero mean and variance σ_ξ^2. Note that the stochastic element of productivity is carried forward into future periods.

We also assume that the export demand shock evolves according to the following first-order Markov-process:

$$\begin{aligned} z_{it} &= h(z_{it-1}, d_{it-1}, e_{it-1}) + \mu_{it} \\ &= \gamma_0 + \gamma_1 z_{it-1} + \gamma_2 d_{it-1} + \mu_{it} \end{aligned} \tag{5}$$

where $\mu_{it} \sim N(0, \sigma_\mu^2)$. Unlike previous studies our model allows firm-level export demand to endogenously evolve separately from firm-level productivity.[20] The persistence in z captures factors such as the nature of the firm's product or destination markets that lead to persistence in export demand over time. The coefficient γ_2 captures any effect that environmental investment has on export sales over and above any effect it had on productivity. If there is an export specific boost from abatement we expect that $\gamma_2 > 0$.[21]

[20] The Supplemental Appendix (https://my.vanderbilt.edu/joelrodrigue) provides methodological details on how to simulate the endogenous z process when it is only partially observed.

[21] We experimented with versions of (4) and (5) that included higher powers of ω_{it-1} or z_{it-1}, e.g. ω_{it-1}^2, ω_{it-1}^3, etc. In either case, the coefficients on those variables were always very close to zero and

As in Aw, Roberts and Xu (2011) we will assume that capital is fixed over time for each firm i. Due to the short time series in our data, there is little variation over time in firm-level capital stock (particularly relative to the cross-sectional variation). We will, however, allow for cross-sectional variation in capital stock across firms. Last, we treat the aggregate state variables $\ln \Phi_t^D$ and $\ln \Phi_t^X$ as exogenous first-order Markov processes.

2.3 Abatement and Export Decisions Over Time

We next consider the firm's dynamic decisions to abate and export. We assume that the firm first observes the fixed and sunk costs of exporting, γ_{it}^F and γ_{it}^S, and decides whether or not to export in the current year. After making its export decision, the firm observes the fixed and sunk costs of abatement, γ_{it}^A and γ_{it}^D, and makes the discrete decision to abate in the current year. All four costs are assumed to be *iid* draws from the joint distribution G^γ.[22]

Denote the value of firm i in year t before it observes fixed or sunk costs by V_{it}:

$$V_{it}(s_{it}) = \int (\pi_{it}^D + \max_{e_{it}}\{(\pi_{it}^X - e_{it-1}\gamma_{it}^F - (1-e_{it-1})\gamma_{it}^S) + V_{it}^E(s_{it}), V_{it}^D(s_{it})\}) dG^\gamma \tag{6}$$

where $s_{it} = (\omega_{it}, z_{it}, k_i, \Phi_t, e_{it-1}, d_{it-1})$ is a vector of state variables, V_{it}^E is the value of an exporting firm after it makes its optimal abatement decision and V_{it}^D is the value of a non-exporting firm after it makes its optimal abatement decision. The value of abating is determined by V_{it}^D and V_{it}^E:

$$\begin{aligned} V_{it}^E(s_{it}) &= \int \max_{d_{it}\in(0,1)} \{\delta E_t V_{it+1}(s_{it}|e_{it}=1, d_{it}=1) - d_{it-1}\gamma_{it}^A - (1-d_{it-1})\gamma_{it}^D, \\ &\quad \delta E_t V_{it+1}(s_{it}|e_{it}=1, d_{it}=0) dG^\gamma \end{aligned} \tag{7}$$

$$\begin{aligned} V_{it}^D(s_{it}) &= \int \max_{d_{it}\in(0,1)} \{\delta E_t V_{it+1}(s_{it}|e_{it}=0, d_{it}=1) - d_{it-1}\gamma_{it}^A - (1-d_{it-1})\gamma_{it}^D, \\ &\quad \delta E_t V_{it+1}(s_{it}|e_{it}=0, d_{it}=0) dG^\gamma \end{aligned} \tag{8}$$

The net benefit (or loss) to abating and exporting, conditional on previous decisions, is embedded in the value functions. The tradeoffs facing the firms are captured in the

statistically insignificant.

[22] An alternative assumption is that the export and environmental abatement decisions are made simultaneously. While this leads to a similar model, the computational difficulty associated with calculating the probability of each decision is substantially greater.

expected future value of any possible choice:

$$E_tV_{it+1}(s_{it}|e_{it},d_{it}) = \int_{\Phi'}\int_{z'}\int_{\omega'} V_{it+1}(s')dF(\omega'|\omega_{it},e_{it},d_{it})dF(z'|z)dG(\Phi'|\Phi) \tag{9}$$

Notably, we allow for the possibility abatement may reduce productivity and increase the cost of production. We do expect, however, that the return to exporting and abatement are both increasing with respect to export demand. In industries where this second effect is dominant we expect a typical selection effect: only highly productive firms that expect large export sales will choose to export and abate.

The model explicitly recognizes that current choices affect the evolution of export demand and productivity, and potentially influence future export and abatement decisions. It is important to emphasize that the structure of the model further implies that the return to either decision may depend very much on the other. For example, the return to abatement depends on export decisions both through the evolution of productivity and the sunk cost associated with export behavior. Similarly, the return to exporting intuitively depends on the past abatement decisions which influence the path of export demand and the productivity directly through equations (4) and (5), but also influences the export decision through the sunk cost of abatement. The marginal benefit of abating from equations (7) and (8) can then be defined as the difference in expected future returns between investing or not investing in abatement for any vector of state variables, s_{it}:

$$MBA_{it}(s_{it}|e_{it}) = E_tV_{it+1}(s_{it+1}|e_{it},d_{it}=1) - E_tV_{it+1}(s_{it+1}|e_{it},d_{it}=0) \tag{10}$$

As alluded to earlier, the marginal benefit of abatement will not only depend on the effect that abatement has on future productivity but also on the decision to export. The difference in the marginal benefit of abatement between both groups can be defined as:

$$\Delta MBA_{it}(s_{it}) = MBA_{it}(s_{it}|e_{it}=1) - MBA_{it}(s_{it}|e_{it}=0). \tag{11}$$

This difference will be positive if abatement is more worthwhile to exporters relative to non-exporters in which case we might expect that α_4 in equation (4) and/or γ_2 in equation (5) are positive, suggesting complementarity between the decision to export and abate. Likewise, for any given state vector, the marginal benefit of exporting can be defined as:

$$MBE_{it}(s_{it}|d_{it-1}) = \pi_{it}^X(s_{it}) + V_{it}^E(s_{it}|d_{it-1}) - V_{it}^D(s_{it}|d_{it-1}) \tag{12}$$

This reflects current export profits plus the expected gain in future export profit from being an exporter as opposed to serving only the domestic market. Analogous to the marginal benefit of abatement discussion, in general the marginal benefit of exporting will depend on past abatement decisions when there is a sunk cost to abating where $\Delta MBE_{it}(s_{it}) = MBE_{it}(s_{it}|d_{it} = 1) - MBE_{it}(s_{it}|d_{it} = 0)$ indicates the marginal effect of abating on the return to exporting. In the next section we examine how we can empirically estimate the interdependence between these decisions.

3 Estimation

Next we develop the empirical counterpart to the model presented in the previous section and describe the estimation procedure. We estimate the model in two steps; in the first step we employ control function techniques similar to Olley and Pakes (1996), Levinsohn and Petrin (2003) and Doraszelski and Jaumandrau (2008) to recover the parameters of the revenue function and the evolution of productivity. In the second stage, we describe a Bayesian MCMC method to estimate the dynamic parameters and capture the impact of abatement on export decisions over time.[23]

3.1 Mark-ups and Productivity

As a first step, we recover an estimate of the mark-ups at home and abroad. We exploit the fact that each firm's marginal cost, c_{it} is constant with respect to total output and equal across domestic and export output. Setting marginal revenue equal to marginal cost in each market we can write total variable cost, tvc_{it}, as a combination of domestic and export revenue weighted by their respective elasticities:

$$\begin{aligned} tvc_{it} &= q_{it}^D c_{it} + q_{it}^X c_{it} \\ &= r_{it}^D \left(1 + \frac{1}{\eta_D}\right) + r_{it}^X \left(1 + \frac{1}{\eta_X}\right) + \varepsilon_{it} \end{aligned} \tag{13}$$

[23]Our method is similar to Das, Roberts and Tybout (2007). We extend their method to allow us to estimate an endogenous, dynamic process which is only partially observed in the data. Given the generalized type II Tobit likelihood function in our model, classical estimation techniques such as Maximum Likelihood Estimation often do not perform well. Hence we choose to use Bayesian MCMC methods to estimate the dynamic parameters of the model. Methodological details can be found in the Supplemental Appendix at https://my.vanderbilt.edu/joelrodrigue.

where the error term ε_{it} captures measurement error in total variable cost. Estimating equation (13) by OLS we retrieve the estimates of η_D, and η_X and turn next to estimating the parameters of the productivity process.

Recall that the domestic revenue function is

$$\ln r_{it}^D = (\eta_D + 1) \ln \left(\frac{\eta_D}{\eta_D + 1} \right) + \ln \Phi_t^D + (\eta_D + 1)(\beta_0 + \beta_k \ln k_{it} + \beta_w \ln w_t - \omega_{it}) + u_{it} \quad (14)$$

where we have added an *iid* error term to equation (3). The composite error includes both an *iid* component and firm-specific, time varying productivity: $-(\eta_D + 1)\omega_{it} + u_{it}$. As in Olley and Pakes (1996) we rewrite unobserved productivity as a non-parametric function of observables that are correlated with it. Note that the relative demand for m_{it} and n_{it} are not a function of output (or z_{it}), given our assumption of constant marginal costs. If technology differences are not Hick's neutral then productivity differences cause input demand to vary across firms and time.[24] As such, input demand will contain information on firm productivity levels, $\omega_{it} = \omega(k_{it}, m_{it}, n_{it}, d_{it-1})$, and we can write the domestic revenue function in (14) as

$$\begin{aligned} \ln r_{it}^D &= \varrho_0 + \sum_{t=1}^{T} \varrho_t D_t + (\eta_D + 1)(\beta_k \ln k_{it} - \omega_{it}) + u_{it} \\ &= \varrho_0 + \sum_{t=1}^{T} \varrho_t D_t + f(k_{it}, m_{it}, n_{it}, d_{it-1}) + v_{it} \end{aligned} \quad (15)$$

where ϱ_0 is a constant, D_t is a set of year dummies and we approximate $f(\cdot)$ by a fourth order polynomial of its arguments. The essence of the above method is that the function $f(\cdot)$ captures the combined effects of exporting, abatement, capital and productivity on domestic revenue. We denote the fitted value of the $f(\cdot)$ function as $\hat{\varphi}_{it}$. According to our model the estimate of $\hat{\varphi_{it}}$ captures $(\eta_D + 1)(\beta_k \ln k_{it} - \omega_{it})$ which is a function of capital and productivity. We first estimate (15) by OLS, recover an estimate of the composite term, $\hat{\varphi}_{it}$ and construct a productivity series for each firm. Specifically, inserting φ_{it} into (4) we write the estimating equation

$$\hat{\varphi}_{it} = \beta_k^* \ln k_{it} - \alpha_0^* + \alpha_1(\hat{\varphi}_{it-1} - \beta_k^* \ln k_{it-1}) - \alpha_2^* d_{it-1} - \alpha_3^* e_{it-1} - \alpha_4^* d_{it-1} e_{it-1} + \xi_{it}^* \quad (16)$$

where the asterisk indicates that the coefficients are scaled by $(\eta_D + 1)$. Equation (16) is

[24]Numerous studies find that technical change is not Hick's neutral. See Jorgenson, Gollop, and Fraumeni (1987) for an example.

estimated by non-linear least squares and the parameters are retrieved given η_D.[25]

3.2 Dynamic Parameters

The remaining parameters of the model can be estimated using the discrete decisions for exporting and abatement. Given the first-stage parameter estimates we construct a firm-level productivity series, $\omega_i \equiv (\omega_{i1}, ..., \omega_{iT})$ and in combination with the observed firm-level series of exporting $e_i \equiv (e_{i1}, ..., e_{iT})$, export revenues $r_i^X \equiv (r_{i1}^X, ..., r_{iT}^X)$, and firm-level abatement $d_i \equiv (d_{i1}, ..., d_{iT})$ we can write the i^{th} firm's contribution to the likelihood function as

$$P(e_i, d_i, r_i^X | \omega_i, k_i, \Phi) = P(e_i, d_i | \omega_i, k_i, \Phi, z_i^+) h(z_i^+ | d_i^-) \tag{17}$$

where z_i^+ is the time series of export market shocks for firm i in years in which it exports and $d_i^- \equiv (d_{i0}, ..., d_{iT-1})$ is the sequence of lagged abatement decisions. Equation (17) expresses the joint probability of discrete export and abatement decisions, conditional on export market shocks and the marginal distribution of z. Note that in this case the marginal distribution of z varies across firms with different abatement histories. Given the estimated parameters of the export shock process we can simulate exports shocks, construct the density $h(z_i^+ | d_i^-)$, and evaluate the likelihood function.[26]

The model allows us to express the probabilities of exporting or abatement as functions of the value functions and sunk and fixed cost parameters. Specifically, assuming that the sunk and fixed costs are *iid* draws from a known distribution, the joint probabilities of exporting and abatement can be written as the product of the choice probabilities for d_{it} and e_{it} in each year, conditional on s_{it}. The probability of exporting can be written as:

$$P(e_{it} = 1 | s_{it}) = P(e_{it-1}\gamma_{it}^F + (1 - e_{it-1})\gamma_{it}^S \leq \pi_{it}^X + V_{it}^E - V_{it}^D) \tag{18}$$

Intuitively, the sunk and fixed costs are identified from differential entry and exit behavior across similar firms with different export histories.

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[25] Standard errors are computed by bootstrapping over equations (13),(15), and (16).

[26] The Supplemental Appendix (https://my.vanderbilt.edu/joelrodrigue) describes how we simulate the density of endogenous export shocks conditional on a firm's observable abatement history.

Similarly, the probability of abatement can be calculated as:

$$\begin{aligned} P(d_{it} = 1|s_{it}) &= P(d_{it-1}\gamma_{it}^{A} + (1 - d_{it-1})\gamma_{it}^{S} \leq \\ &\quad \delta E_t V_{it+1}(s_{it}|e_{it}, d_{it} = 1) - \delta E_t V_{it+1}(s_{it}|e_{it}, d_{it} = 0)) \end{aligned} \tag{19}$$

The probability of abatement depends on the *current* export decision due to the model's timing assumption requiring export decisions to be made ahead of abatement decisions.[27]

The probabilities depend on sunk and fixed cost parameters, export and abatement histories, and the expected value functions, $E_t V_{it+1}$, V_{it}^{D} and V_{it}^{E}. For a given set of parameters we employ a Bayesian Monte Carlo Markov Chain (MCMC) estimator to characterize the posterior distribution of the sunk and fixed cost parameters. We assume that all fixed and sunk costs are drawn from separate, independent exponential distributions. The estimated sunk and fixed costs we estimate should then be interpreted as the the means of those distributions.[28]

4 Data

We estimate the model using firm-level data from Indonesia between 1994-1997, collected annually by the Central Bureau of Statistics, *Budan Pusat Statistik* (BPS). The survey covers the population of manufacturing firms in Indonesia with at least 20 employees. The data capture the formal manufacturing sector and record detailed firm-level information on domestic and export revenues, capital, intermediate inputs, energy and expenditures on environmental abatement. Data on revenues, investment and inputs are combined with detailed wholesale price indices to deflate price changes over time.[29] We abstract from the firm's initial (domestic) entry decision and focus on the set of continuing firms. Initially, we study the period between 1994-1996 due to the potential concern that the 1997-1998 Asian crisis may affect the results. However, as documented in the Supplemental Appendix, including this year leads to similar estimates in both industries.

Table 1 describes size differences across firms measured by average sales in the saw

[27] In the first year of the data we do not observe d_{it-1}. To deal with this initial conditions problem we model the initial decisions using probit equations in the first year (Heckman, 1981).

[28] Due to the small estimated change in Φ_X over time we also constrain it to be constant below.

[29] Price deflators are constructed as closely as possible to Blalock and Gertler (2004) and include separate deflators (1) output and domestic intermediates, (2) capital, (3) energy, (4) imported intermediates and (5) export sales. Further details can be found in the Supplemental Appendix at https://my.vanderbilt.edu/joelrodrigue.

Table 1: Average Sales

	Saw Mills				Wood Furniture		
	Non-Exporters	Exporters			Non-Exporters	Exporters	
	Average Domestic Sales	Average Domestic Sales	Average Export Sales		Average Domestic Sales	Average Domestic Sales	Average Export Sales
1994	19,267	23,913	140,742	1994	3,702	6,352	13,147
1995	18,159	28,657	115,485	1995	3,616	7,304	11,717
1996	12,207	27,884	142,923	1996	3,933	6,616	14,588

Table 2: Average Sales Across Abatement Status 1994-1996

	Non-Exporters		Exporters	
	Non-Abate	Abate	Non-Abate	Abate
Saw Mills	16,113	9,629	91,028	127,401
Wood Furniture	3,369	4,029	13,305	16,352

Notes: Abatement expenditures are measured in thousands of 1983 Indonesian rupiahs.

mill (ISIC 3311) and wood furniture (ISIC 3321) industries.[30] Overall, we follow 583 saw mill producers and 460 wood furniture producers who operate continuously between 1994 and 1996.[31] In both industries, exporters report larger average sales than non-exporters which is indicative of the superior productivity enjoyed by firms who self-select into export markets. It is worth noting, however, that the distribution of sales is highly skewed in each industry; the average level of domestic sales among domestic non-exporters is approximately 7.6 and 4.7 times the size of the median level of domestic sales in the saw mill and wood furniture industries, respectively. The distributions of domestic and export sales among exporters are similarly skewed. Table 1 also documents important size differences across industries. The average saw mill producer earns 3-5 times more domestic revenue than the average furniture producer, while the average saw mill exporter earns 10-11 times more export revenue than the average furniture exporter.

While it is well known that exporting is relatively uncommon among manufacturing firms there are few estimates of abatement rates in developing nations. Define an abating firm as one that invests a positive amount in environmental abatement in the current year.[32] Overall, 20 and 11 percent of producers in the saw mill and wood furniture

[30]Throughout our paper we focus exclusively on domestically-owned firms where less than 10 percent of equity is held by foreign investors. Using this definition, 94 percent of firms in the Indonesian manufacturing industry are domestically-owned during this period.

[31]Summary statistics for the comparable 1994-1997 sample are reported in the Supplemental Appendix at https://my.vanderbilt.edu/joelrodrigue.

[32]Given the short time dimension of the panel data and the small number of firms which choose to abate estimating a model with a continuous abatement choice variable is practically very difficult

Table 3: Abatement and Export Behaviour

	Saw Mills			Wood Furniture		
	Abt. Rate	Abt. Expend.	Obs.	Abt. Rate	Abt. Expend.	Obs.
Exporter	22.74	119.04	1148	15.52	56.36	1218
Non-Exporter	15.62	26.38	1934	9.58	6.47	1827
	Exp. Rate	Exp. Rev.	Obs.	Exp. Rate	Exp. Rev.	Obs.
Abater	46.36	106,263.10	563	51.92	14,712.77	364
Non-Abater	35.21	77,196.40	2519	38.38	10,972.06	2681

Notes: Abatement expenditures are measured in thousands of 1983 Indonesian rupiahs.

industry reported positive abatement expenditures during this period.

Table 2 presents the average sales across export and abatement status. Notably, among non-exporting firms that abate in the saw mills industry, average sales at home are 40 percent *smaller* on average than firms which do not abate. This pattern is reversed among exporting firms; among exporters total sales are 40 percent *higher* among abating firms. The difference across abating and non-abating firm is indicative of the impact abatement may have on export sales in particular. In the wood furniture industry this pattern is not nearly as stark. Abating firms tend to generate sales which are 20 percent higher than non-abaters among non-exporting firms and 23 percent higher among exporting firms.

The top panel of Table 3 documents differences in abatement behavior across exporting and non-exporting firms in Indonesia. Columns 1 and 4 present the percentage of exporting and non-exporting firms which incur abatement expenditures in the saw mills and wood furniture industries. We observe that exporting firms are always more likely to engage in abatement than their non-exporting counterparts by 6 to 7 percent. Similarly, columns 2 and 5 present the average annual abatement expenditures across exporting and non-exporting firms, conditional on the firms having incurred some positive abatement expense. On average exporters spent 350 to 770 percent more on abatement than non-exporters over the same period. Across industries, abatement expenditures tend to be higher in the saw mills industry than in the wood furniture industry, capturing the size difference across industries. The average abatement expenditure (among those who abate) in the saw mill and wood furniture industries were respectively, 69 and 32 thousand 1983 Indonesian rupiahs, and these represent approximately 2 percent of the median firm's

in this context. The small number of observations severely restricts our ability to identify the firm's abatement policy rule. We do, however, test this restriction and find that using a continuous measure of abatement has little impact on the estimated demand parameters. See the Supplemental Appendix at https://my.vanderbilt.edu/joelrodrigue.

Table 4: Annual Transition Rates for Continuing Plants

Saw Mills

	Status in $t+1$			
Status in t	Neither	only Exp.	only Abt.	Both
All Firms	0.566	0.231	0.105	0.098
Neither	0.857	0.069	0.063	0.012
only Exp.	0.112	0.729	0.000	0.155
only Abt.	0.344	0.156	0.547	0.094
Both	0.059	0.314	0.098	0.529

Wood Furniture

	Status in $t+1$			
Status in t	Neither	only Exp.	only Abt.	Both
All Firms	0.682	0.209	0.065	0.045
Neither	0.901	0.054	0.041	0.005
only Exp.	0.167	0.790	0.016	0.027
only Abt.	0.375	0.063	0.469	0.094
Both	0.000	0.200	0.029	0.771

total revenue in each industry. Even though abatement is captured by a binary variable in our model it is worth noting that we do allow for abatement cost heterogeneity by drawing fixed and sunk costs from exponential distributions. The bottom panel of Table 3 documents the export rate and the average size of export revenues across abatement status. Similarly, we find that firms who choose to abate are more likely to export and, among those who export, they tend to have much higher export sales.

Finally, Table 4 reports the transitions in and out of exporting and abatement across all four possible combinations these variables could have taken in the preceding year. Only 10 percent of firms abate and export in the saw mills industry, while only 5 percent of firms are simultaneously engaged in both activities in the wood furniture industry. Export status is very persistent in the saw mill and wood furniture industries where exporters respectively receive 81 and 85 percent of revenues from export sales on average. Firms engaged in either activity are much more likely to begin the other activity than are firms that are not engaged in either activity. Moreover, the persistence in each state is suggestive of potential sunk costs associated with each behavior.

The above tables suggest the potential interdependence of the export and abatement decisions. However, if both exporting and abatement are costly we might expect that only the most productive firms are able to engage in either activity. Any correlation across activities may be spurious and offer no real indication of an important interaction at the firm-level. Moreover, if there is a causal relationship between abatement and exporting, the simple correlations offer little indication on the mechanism through which exporting affects the decision to abate or vice-versa. For example, if exporting encourages firms to improve firm-level productivity, then we might expect that exporting encourages the adoption of costly abatement technology. Similarly, abatement may introduce new highly productive technology to the firm and improve productivity to the point where firms are willing to enter export markets. Most importantly, if abatement influences export growth separately from changes in productivity the above correlations provide little evidence of

Table 5: First Stage Parameter Estimates

	Saw Mills		Wood Furniture	
$1+1/\eta_D$	0.817	(0.025)	0.864	(0.170)
$1+1/\eta_X$	0.598	(0.032)	0.600	(0.043)
β_k	-0.028	(0.011)	-0.005	(0.013)
α_0	0.245	(0.067)	0.053	(0.099)
α_1	0.863	(0.028)	0.901	(0.033)
α_2	-0.029	(0.018)	0.011	(0.031)
α_3	0.040	(0.018)	0.024	(0.048)
α_4	0.036	(0.025)	-0.023	(0.047)
Obs.	1329		1731	

Notes: Bootstrap standard errors are in parentheses.

the differential return to abatement in different markets. We quantify and disentangle these various effects below.[33]

5 Empirical Results

5.1 Elasticity of Demand, Cost and Productivity Evolution

The first-stage parameter estimates are reported in Table 5.[34] The point estimate of the domestic market elasticity in the saw mill and wood furniture industries are -5.5 and -7.4, respectively, which implies mark-ups of 32 and 16 percent. Export market demand is estimated to be less elastic in both industries with an estimated elasticity parameter of -2.5 in either case and an implied mark-up of 67 percent.

The coefficient on the log of capital stock is negative in each industry (though only significantly in the saw mills industry) and implies that firms with larger capital stocks have lower marginal costs. The parameter α_1 captures the effect of lagged productivity on current productivity and implies a strong linear relationship between the two variables. The coefficients α_2 and α_3 measure the impact of past abatement and export experience on future productivity. In both industries α_2 is estimated to be insignificantly different from zero, implying that firms which abate witness almost identical productivity evolution to those that do not. In contrast, there appear to be small, but positive and significant learning-by-exporting effects in the saw mill industry. The estimated parameter implies that manufacturing firms in the saw mill industry can expect productivity to improve by

[33]The Supplemental Appendix (https://my.vanderbilt.edu/joelrodrigue) provides further reduced form evidence. It is omitted here for brevity.

[34]Estimates based on the 1994-1997 sample are presented in the Supplemental Appendix.

an extra 4.0 percent, in years subsequent to exporting. The parameter α_4 captures the interaction between export experience and abatement and is also insignificantly different from zero in both industries. Overall, our first stage results present little evidence for any impact of abatement on productivity. However, they may also indicate that any increases in domestic demand from abatement are offset by increases in marginal cost.

5.2 Dynamic Estimates

Table 6 reports the means and standard deviations of the posterior distributions for all parameters in both industries. The first set of estimates apply to the dynamic process on export demand and indicate that abatement has a positive impact on future export demand growth in both the saw mill and wood furniture industries. In the saw mills industry, the parameter γ_2 implies that firms which abate expect export demand to grow 1.4 percent faster than similar firms who do not while in the wood furniture industry abating firms anticipate that export demand will grow 6 percent faster.

The difference in magnitude across wood products is striking and can be interpreted in a number of ways. First, our estimates may reflect the fact that wood furniture is closer to a finished product than the plywood and other basic lumber products produced by saw mills. As argued by Arora and Cason (1996) firms which are closer to final consumers tend to be much more sensitive to their environmental performance. Second, our estimates may simply reflect the fact that most products from the saw mills industry are more common, easier to smuggle, and more difficult to credibly tie to unsustainable harvesting practices. This evidence stands in contrast to the finding that abatement had little effect on productivity and domestic revenues. Moreover, it suggests that the interaction between trade and abatement may leave substantial room for policy intervention.

The parameter γ_0 captures the growth in export demand over time. It is estimated to be positive in the wood furniture industry, but close to zero in the saw mills industry. This is consistent with evidence at the aggregate level which suggests that the volume of Indonesian plywood exports peaked in 1993, while the exports of other timber products have demonstrated consistent increases over the period (Brann, 2002). Finally, the parameter γ_1 is the autocorrelation parameter in the export demand process and indicates that export demand tends to be a highly persistent process across industries and that decisions to abate may have a long-lived impact on export sales.

The reported values of the fixed and sunk cost parameters, γ^A, γ^D, γ^F and γ^S, capture the mean of the exponential distributions for abatement fixed costs, abatement sunk costs,

Table 6: Dynamic Parameter Estimates

	Saw Mills		Wood Furniture	
γ_0(Export Shock Intercept)	0.004	(0.002)	0.202	(0.049)
γ_1(Export Shock AR process)	0.975	(0.002)	0.795	(0.022)
γ_2(Abatement effect on Export)	0.014	(0.002)	0.060	(0.010)
γ^A(Abatement FC)	19.598	(0.953)	0.027	(0.006)
γ^D(Abatement SC)	113.485	(1.946)	2.194	(0.719)
γ^F(Export FC)	24.301	(0.490)	0.069	(0.006)
γ^S(Export SC)	164.770	(4.954)	20.578	(0.405)
Φ_X (Export Rev Intercept)	7.851	(0.093)	8.615	(0.071)
σ_μ(Export Shock Std Dev)	0.973	(0.037)	1.304	(0.060)
Obs.	1154		886	

Notes: Standard deviations are in parentheses.

export fixed costs and export sunk costs, respectively.[35] The sunk costs parameters are estimated to be much larger than the fixed cost parameters, though the difference is greatest for exporting. This implies that for each activity the sunk cost distribution will have more mass concentrated in the high cost values. Thus, for the same marginal benefit, a firm will be more likely to continue exporting or abating than to begin exporting or abating.[36] The reported parameters are the mean values of the distribution of fixed and sunk cost draws. Below we show that the incurred costs by most firms are much smaller.

5.3 Model Performance

We simulate the model in order to assess its predictive ability relative to observed empirical patterns. We compute patterns of abatement and export choice, transition patterns between choices and productivity trajectories to compare the simulated patterns with those observed in the data. Specifically, we take the initial year status $(\omega_{i1}, z_{i1}, d_{i1}, e_{i1}, k_i)$

Table 7: Predicted Abatement, Exporting and Productivity in 1996

	Abatement Rate		Export Rate		Productivity	
	Saw Mills	Wood Furn	Saw Mill	Wood Furn	Saw Mill	Wood Furn
Actual Data	0.204	0.111	0.329	0.263	3.175	0.876
Predicted	0.198	0.079	0.312	0.244	3.153	0.851

of all firms in our data as given and simulate the next 3 year's export demand shocks

[35]They are measured in millions of 1983 Indonesian rupiahs.

[36]Note as argued in Eaton et al. (2009) export sunk costs may be capturing longer-run entry dynamics associated with building a customer base abroad.

Table 8: Actual and Predicted Transition Rates

Saw Mills

Data	Status in $t+1$			
Status in t	Neither	only Exp.	only Abt.	Both
Neither	0.857	0.069	0.063	0.012
only Exp.	0.112	0.729	0.000	0.155
only Abt.	0.344	0.156	0.547	0.094
Both	0.059	0.314	0.098	0.529
Model	Status in $t+1$			
Status in t	Neither	only Exp.	only Abt.	Both
Neither	0.841	0.070	0.070	0.020
only Exp.	0.306	0.514	0.026	0.096
only Abt.	0.437	0.025	0.442	0.154
Both	0.091	0.145	0.084	0.680

Wood Furniture

Data	Status in $t+1$			
Status in t	Neither	only Exp.	only Abt.	Both
Neither	0.901	0.054	0.041	0.005
only Exp.	0.167	0.790	0.016	0.027
only Abt.	0.375	0.063	0.469	0.094
Both	0.000	0.200	0.029	0.771
Model	Status in $t+1$			
Status in t	Neither	only Exp.	only Abt.	Both
Neither	0.949	0.034	0.013	0.003
only Exp.	0.039	0.914	0.000	0.047
only Abt.	0.311	0.001	0.612	0.077
Both	0.012	0.071	0.002	0.915

z_{it}, abatement costs γ^A, γ^I and export costs γ^F, γ^S. Solving the firm's dynamic problem we compute the optimal export and abatement decisions year-by-year. For each firm, we repeat the simulation exercise 100 times and report the average of these simulations.

Table 7 reports the mean abatement rate, export market participation rate and productivity level in both the data and in the model. The model matches the empirical predictions very closely in both industries, though it slightly underpredicts abatement in the wood furniture industry. Table 8 reports the actual and predicted transition rates for the saw mill and wood furniture industries. In both industries the model is successful in matching the broad patterns in the empirical transition matrix, though it does slightly underpredict (overpredict) the persistence in export status and abatement status in the saw mills (wood furniture) industry.

5.4 Determinants of Abatement and Exporting

In this section we isolate the roles that export and abatement history play across the distribution of firms on the subsequent export or abatement decisions. The left panel of Table 9 reports the marginal benefit to abatement across export status (columns) and productivity levels (rows). The right panel of Table 9 provides a similar decomposition for exporting across productivity and abatement. We observe that in both industries the marginal benefit to exporting always large and strongly increasing in productivity.

The left panel of Table 9 indicates that the marginal benefit to abatement is positive, large and increasing in productivity for exporting firms in both industries. In contrast, the marginal benefit to abatement is decreasing and negative among non-exporting firms in the saw mills industry. This difference occurs because non-exporting firms do not reap any immediate benefit from abatement, but are required to incur start-up costs associated with this activity. Moreover, our first-stage point estimates implied that abatement had small, but negative effects on productivity growth. Among saw mill producers who are likely to export in the future, Table 9 suggests that it is often optimal to wait until entering the export market before starting to abate. To this extent, the estimated model suggests that barriers to trade may also hinder abatement.

Table 9: Marginal Benefit of Abatement and Exporting (Millions of Rupiahs)

Marginal Benefit of Abatement						Marginal Benefit of Exporting					
Saw Mills			Wood Furniture			Saw Mills			Wood Furniture		
ω_t	$e_t = 1$	$e_t = 0$	ω_t	$e_t = 1$	$e_t = 0$	ω_t	$d_{t-1} = 1$	$d_{t-1} = 0$	ω_t	$d_{t-1} = 1$	$d_{t-1} = 0$
2.78	333.0	-134.4	0.38	0.19	0.11	2.78	6502.9	6494.0	0.38	2.52	2.45
3.55	733.2	-1033.1	0.69	0.20	0.11	3.55	20789.7	20771.1	0.69	3.15	3.08
4.31	628.9	-894.9	1.00	0.21	0.12	4.31	56888.7	56850.5	1.00	4.12	4.06
5.08	1426.2	-2502.7	1.31	0.22	0.14	5.08	176184.0	176119.5	1.31	5.62	5.56
5.84	7704.0	-16614.6	1.62	0.24	0.15	5.84	574346.2	574265.5	1.62	7.93	7.87

In the wood furniture industry we observe the opposite pattern: the marginal value of abatement is always positive and increasing in productivity, though we note that the marginal benefit is relatively small. The explanation for this result is two-fold. First, this result is picking up the fact that the average producer in the wood furniture industry is much smaller than the average producer in the saw mills industry. Second, we estimated that non-exporting, abating firms tend to experience somewhat faster productivity growth than those that do not abate in the wood furniture industry. As such, abatement has value even to firms that are unlikely to begin exporting. Furthermore, there is a much larger immediate impact from abatement on export growth for wood furniture producers relative to their counterparts in the saw mills industry.[37].

Table 10: Incurred Fixed and Sunk Abatement/Export Costs

Saw Mills					Wood Furniture				
	$d_{t-1} = 1$	$d_{t-1} = 0$	$d_{t-1} = 1$	$d_{t-1} = 0$		$d_{t-1} = 1$	$d_{t-1} = 0$	$d_{t-1} = 1$	$d_{t-1} = 0$
ω_t	$e_{t-1} = 1$	$e_{t-1} = 1$	$e_{t-1} = 0$	$e_{t-1} = 0$	ω_t	$e_{t-1} = 1$	$e_{t-1} = 1$	$e_{t-1} = 0$	$e_{t-1} = 0$
2.78	9.9/14.8	38.3/12.7	13.1/ 71.1	62.3/ 56.5	0.38	0.02/0.06	0.09/0.06	0.01/1.17	0.05/1.14
3.55	10.6/17.6	41.5/17.3	17.5/ 66.0	81.4/ 65.0	0.69	0.02/0.06	0.09/0.06	0.01/1.43	0.05/1.39
4.31	13.5/23.9	47.3/23.8	17.7/ 99.3	95.7/ 96.7	1.00	0.02/0.06	0.10/0.06	0.01/1.78	0.06/1.75
5.08	18.9/24.3	68.5/24.3	19.6/158.2	113.4/157.1	1.31	0.02/0.06	0.10/0.06	0.01/2.25	0.06/2.23
5.84	19.2/24.3	90.2/24.3	19.6/163.8	113.4/163.7	1.62	0.02/0.06	0.11/0.06	0.01/2.82	0.07/2.80

Table 10 reports the average abatement and exporting fixed and sunk costs for each combination of export and abatement history across productivity levels. These values correspond to predicted costs *incurred* by firms with different export and abatement histories.

[37]Setting the estimated first stage coefficients governing the productivity effects of abatement and export experience to zero, $\alpha_2 = \alpha_3 = \alpha_4 = 0$, reveals a pattern which suggests that the marginal benefit to abatement is positive but also always increasing in productivity for both non-exporters and exporters in both industries

For instance, given a productivity level of say 4.31 in the saw mills industry, the average fixed cost of abatement and exporting incurred by firms that have previous exporting and abatement experience is 13.5 and 23.9 million Indonesian Rupiahs, respectively. Similarly, for the same productivity level and no past experience in either activity, the sunk cost of abatement and exporting is 95.7 and 96.7 million, respectively. Fixed and sunk costs of both activities increase with productivity but more so for exporting than abating.

In the wood furniture industry we observe relatively little difference in the fixed costs abatement across the distribution of productivity. Together with the observation that sunk abatement costs are proportionally much larger than fixed abatement costs, these results suggest that abatement behavior in the wood furniture industry is largely driven by the sunk abatement costs. This is arguably reasonable for two reasons. First, saw mills tend to be much bigger operations, which require greater year-to-year abatement expenditures. Saw mills are more heavily involved in timber harvesting (cutting), forest-licensing and replanting and, as such, incur larger costs each year to meet certification requirements. In contrast, wood furniture producers are more likely to specialize in production of particular types of wood and do not always harvest timber themselves. In this case certification would require that they purchase materials from a certified source (Synnott, 2005). Auditing and administrative costs are likely to account for a larger percentage of abatement costs in the wood furniture industry.

6 Policy Experiments

In this section we consider three distinct policy experiments. The first two experiments consider the impact of trade liberalization and abatement subsidies, respectively, on future exporting and abatement. The last experiment considers the implications of tighter environmental export restrictions imposed by countries which import Indonesian products. The experiments actual capture policies which have been considered in the Indonesian context. In each case we simulate the model for 10 years after changing a policy-influenced parameter. We assume throughout that Indonesia is a small country relative to the rest of the world and that any general equilibrium effects from changes in policy are small.

6.1 Trade Liberalization

In the first experiment we increase in the size of the foreign market by 20 percent which, in this context, may be interpreted as a reduction in variable trade costs.[38] The top panel of Table 11 presents the change in the proportion of firms which choose to abate relative to the baseline model after 1, 2, 5 and 10 years in the first 4 columns. The increase in the size of the export market has a positive impact on abatement. Across industries the proportion of firms who endogenously choose to abate rate increases by 7.5-8.6 percent in the first year and is 15.0 to 33.2 percentage points higher after 10 years.

Table 11: Trade Liberalization

Export Demand	Endogenous, $\gamma_2 > 0$				Exogenous, $\gamma_2 = 0$			
Years after 1996	1	2	5	10	1	2	5	10
	Change in the Proportion of Abating Firms							
Saw Mills	8.6	12.9	15.2	15.0	1.1	1.1	1.4	1.2
Wood Furniture	7.5	12.3	22.3	33.2	0	0	0	0
	Change in the Proportion of Exporting Firms							
Saw Mills	1.6	2.3	3.3	3.8	0.3	0.7	0.6	0.8
Wood Furniture	5.2	8.8	15.5	22.2	5.6	9.3	16.2	22.3

This experiment highlights the importance of the complementarity between exporting and abatement *on the export market*. In other words, the above results are not driven by productivity dynamics but rather the complementarity of export demand and abatement. To demonstrate this point we resimulate the model under the baseline specification and after trade liberalization with the additional restriction that $\gamma_2 = 0$ before and after the change in policy. This amounts to assuming that the only impact of abatement on the transition of the state variables occur through productivity. We observe that in either case trade liberalization has a very small impact on abatement rates. After 10 years the change in policy has increased the proportion of abating firms by 1.2 percentage points in the saw mills industry and has had no effect in the wood furniture industry.

The bottom panel of Table 11 presents the same information for the response of exporting to trade liberalization. In either industry we observe moderate increases in export participation over time. In the saw mills industry, the proportion of exporters rises by 1.6 percentage points in the first year and is 3.8 percentage points higher than the baseline level after 10 years. Similarly, the proportion of wood furniture exporters

[38] We assume that tariffs are embedded in the effective size of the foreign market. Alternatively, we may interpret this experiment as capturing the impact of growing demand for wood products from emerging markets. It is expected that demand for wood products from emerging market countries such as China will grow substantially in the coming decades (FWI/GFW, 2002).

rises by 5.2 percentage points in the first year and is over 22 percentage points higher 10 years after the change in policy.

Note, however, a similar pattern is found when we consider an exogenous export demand process where $\gamma_2 = 0$. This is not surprising since increasing the size of the export market should induce firms to export regardless of any complementarity with abatement decisions. What is more surprising is that we observe a slightly stronger rise in exporting in the wood furniture industry after the change in policy with exogenous rather endogenous export demand. There are two reasons for the effect. The primary reason for this result is the effect (not shown Table 13) that the exogenous export demand has on baseline export rates. In particular, baseline export rates are 1 percent lower in the first year under exogenous demand and 3 percent lower after 10 years (relative to baseline endogenous demand model). In the the wood furniture industry the change in policy is large enough to draw in almost the same set of firms into exporting regardless of the export abatement complementarity. A secondary reason for the difference in dynamics is due to the complementarity between exporting and abatement. Exporting firms which have previously abated tend to have slower productivity growth (given our first stage estimates) in the endogenous export demand model than firms which export alone. By discouraging abatement the exogenous export demand model has the effect of encouraging greater exporting through slightly stronger productivity growth.

6.2 Abatement Subsidies

The second policy experiment we consider is lowering the fixed abatement costs by 20 percent in each industry.[39] We interpret this experiment as broadly capturing the impact of firm-level subsidies to practice sustainable production. Currently, the Indonesian government along with numerous foreign governments and non-governmental agencies are actively engaged in subsidizing sustainable timber management in Indonesia.[40]

The top panel of Table 12 documents the difference in abatement participation due to the change in policy. A 20 percent reduction in the fixed cost of abatement has a

[39] In the saw mills industry this amounts to a reduction in the fixed abatement costs of 3.9 million 1983 Indonesian Rupiahs. In the wood furniture industry the fixed abatement parameter is reduced by 5.4 thousand 1983 Indonesian Rupiahs. The reduction in the cost parameter in the wood furniture industry is smaller since the estimated fixed cost parameter is smaller.

[40] Examples include (funding source in brackets): Tree Seed Source Development Project (Nordic Development Fund (NDF) / Nordic Development Bank (NDB)), Indonesian Forest Seed Project (Danida Forest Seed Centre), Overseas Economic Cooperation Fund Project (Japan), and the Japan International Forestry Promotion and Cooperation Center Project (JIFPRO).

moderate, positive impact on abatement rates. In the saw mills industry abatement rates increase by 3.4 percentage points in the first year and are 5.4 percentage points higher than the baseline model after 10 years. The impact of abatement subsidies is similar in the wood furniture industry even though the immediate return to abatement is larger. We observe that the model predicts that over the 10 year period abatement increases by 6.8 percentage points relative to the baseline model.

Table 12: Abatement Subsidies

Export Demand	Endogenous, $\gamma_2 > 0$				Exogenous, $\gamma_2 = 0$			
Years after 1996	1	2	5	10	1	2	5	10
	Change in the Proportion of Abating Firms							
Saw Mills	3.4	4.5	5.4	5.4	1.0	1.3	1.0	0.5
Wood Furniture	2.6	3.5	4.7	6.8	0.1	0	0	0
	Change in the Proportion of Exporting Firms							
Saw Mills	0.5	0.5	0.5	1.1	0.8	1.0	1.0	1.0
Wood Furniture	0.5	0.5	0.8	1.3	0.1	0.1	0.4	0.5

The bottom panel of Table 12 presents the impact of abatement subsidies on export participation in both industries. We observe that in either industry the subsidies have a small initial impact on exporting and, even after 10 years, the export rates are still only 1 percent higher than the baseline model. These results, in conjunction with the result in the top panel, are driven by the fact that new uptake in abatement is largely coming from existing exporters in this case. Given the large sunk and fixed costs associated with exporting, the abatement subsidies are not sufficient enough to get non-exporting firms to start abatement until they have entered export markets.

The last four columns of Table 12 report the results for the model with exogenous export demand. They indicate that the observed changes in abatement are again driven by the complementarity of exporting and abatement on the export market. We note that ignoring the differential returns across markets we would not otherwise be able to distinguish the group of firms most affected by the policy change (exporters).

6.3 Import Restrictions

In the last policy experiment, we constrain export markets in such a fashion that firms which did not abate in the previous year are completely cut off from export markets. The idea we are trying to capture is one where importing nations strictly reject uncertified products for import. Importantly, the cost of abatement to producers does not change throughout this experiment. Although this policy is extreme we note that this type of policy has been proposed as a potential mechanism to combat unsustainably harvested wood in developing countries (Brack et al., 2002). Further this experiment allows us quantify the full impact of export participation on abatement rates over time.

Table 13: Import Restrictions

Export Demand	Endogenous, $\gamma_2 > 0$				Exogenous, $\gamma_2 = 0$			
Years after 1996	1	2	5	10	1	2	5	10
	Change in the Proportion of Abating Firms							
Saw Mills	14.7	18.8	19.7	17.3	10.9	12.4	12.8	12.7
Wood Furniture	10.6	17.9	31.6	43.2	11.5	13.6	20.9	29.1
	Change in the Proportion of Exporting Firms							
Saw Mills	-23.2	-18.1	-8.9	-5.2	-26.8	-25.7	-22.4	19.1
Wood Furniture	-20.0	-20.5	-22.2	-20.3	-20.6	-21.4	-24.8	-28.4

The first column of Table 13 demonstrates that abatement increases substantially relative to the baseline model in the first year. By the tenth year proportion of firms abating has risen by 17 percentage points in the saw mills industry and by 43 percentage points in the wood furniture industry, relative to baseline. This also suggests that using the export markets as a means to encourage abatement may be an effective policy tool, though we caution that the export market is very large in both industries studied here.

The last four columns of Table 13 present the same estimates for the exogenous export demand model. In both industries we note that the increase in abatement relative to baseline is only slightly smaller than that in the endogenous demand model in the first year. This suggests that closing export markets to environmentally damaging goods may be an effective abatement policy tool *even if there is no differential effect of abatement on export demand growth*. Beyond the initial impact the two models differ more substantially. By the tenth year abatement gains in the exogenous demand model are 4.6 and 14.1 percentage points smaller than the model with endogenous export demand.[41]

The bottom panel of Table 13 presents the impact of import restrictions on export participation. In contrast to the previous policy experiments where encouraging trade (abatement) increased the incentive to abate (export) over time, in this case encouraging abatement through import restrictions harms exporting. In both industries export participation rate is reduced by at least 20 percentage points in the first year. This is not surprising since only a small fraction of exporting firms initially abate and so most incumbent exporters are forced to exit export markets. In the saw mills industry we observe a

[41]Due to the difference in baseline rates we can interpret the estimated differences between the two models as capturing the lower bound of the complementarity between exporting and abatement.

strong return to exporting in the subsequent years. Ten years after the policy change the export participation rate is only 5 percentage points lower than the baseline rate. In the wood furniture industry export participation grows much more slowly.

The last four columns of the bottom panel present the results for the exogenous export demand model in both industries. In the saw mills industry we observe an even larger fall in initial export participation and a slower increase afterwards. In the wood furniture industry the results are even more stark; exporting falls sharply after the implementation of the policy and *continues to fall* in each subsequent year. This result presents a very different picture of the impact of this policy relative to the endogenous export demand model. Exporting falls because fixed and sunk export costs are now effectively the sum of the respective export and abatement costs. As such, many exporters incur higher annual expenditures to stay in export markets and over time many firms no longer find exporting profitable. Once exporters have left the market re-entry is also deterred by higher effective sunk export costs. In the endogenous export demand model higher sunk and fixed costs are offset by a larger export market.

7 Conclusions

This paper presents and estimates a dynamic model of heterogenous firm which endogenously choose to make environmental investments and export. The model is estimated using a panel of Indonesian timber producers. Counterfactual policy experiments are employed to assess the impact of changing environmental or trade policy on firm-level export and abatement decisions.

The model is able to broadly match environmental investment and exporting behavior among Indonesian timber producers. The model captures the differential export behavior across firms which abate and those that do not. It emphasizes that accounting for the interaction between firm-level abatement and export decisions is essential to recovering accurate estimates of the impact of changes in trade or environmental policy on either outcome over time. The empirical estimates of the model's parameters suggest firm-level environmental investment may increase export demand growth by 1.4 to 6 percent across timber industries.

The counterfactual experiments imply that import restrictions in destination markets can have a large impact on exporting and environmental investment. Over ten years we estimate that closing export markets to non-abating firms would increase abatement rates by 18 and 43 percentage points in the saw mills and wood furniture industries, but cause export participation rates to fall by 5 and 20 percentage points, respectively. In this sense our model confirms that environmental restrictions in destination markets can act as trade barriers and suggests that these barriers may be an effective tool in encouraging firm-level abatement. The experiments confirm that ignoring the differential returns to the same activity on different markets can potentially lead to misleading policy conclusions.

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