FIRMS' RESPONSE AND UNINTENDED HEALTH CONSEQUENCES OF INDUSTRIAL REGULATIONS[*]

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Abstract

Regulations that constrain firms' externalities in one dimension can distort incentives and worsen externalities in other dimensions. In Peru's industrial fishing sector, the world's largest, fishing boats catch anchovy that plants along the coast convert into fishmeal. Matching administrative daily data on plant production, ground-level air quality data, hospital admissions records, and survey data on individual health outcomes, we first show that fishmeal production worsens adult and child health through air pollution emitted by plants. We then analyze the industry's response to a 2009 reform that split the Total Allowable Catch (TAC) into boat-specific, transferable quotas (ITQs) to preserve fish stocks and reduce overcapacity. As predicted by a two-sector model with heterogeneous plants, on average across locations, fishmeal production was spread out in time, for two reasons: (i) boats' incentive to "race" for fish was removed, and (ii) inefficient plants decreased production and efficient plants expanded production (across time). The reform greatly exacerbated the industry's impact on health, causing e.g. 55,000 additional hospital admissions for respiratory diseases. We show that the reason is that longer periods of moderate air pollution are worse for health than shorter periods of higher intensity exposure. Our findings demonstrate the risks of piecemeal regulatory design, and that the common policy trade-off between duration and intensity of pollution exposure can be critical for industry's impact on health.

JEL codes: D2, L5, L7, O1, I1, Q5

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1 Introduction

Industries generate multiple types of externalities. This is especially so in developing countries, where market failures are commonplace (Laffont, 2005). Although regulations are typically designed with a particular externality in mind (e.g. overuse of a depletable natural resource), regulatory incentives also affect which firms survive and thrive and how firms organize production. If such industry responses in turn affect the extent of other sector externalities (e.g. pollution from the production process), regulations can have welfare consequences that differ from the planned partial equilibrium effects.[1]

In this paper we focus on the world's largest industrial fishing sector, located in Peru (Paredes and Gutierrez, 2008). The regulations in place are aimed at maintaining industry profitability while avoiding overfishing (see e.g. Hardin, 1968; Ostrom, 2008; Huang and Smith, 2014), but the plants that convert the raw fish into fishmeal also emit large amounts of air pollution.[2] We first document this additional externality by identifying the fishmeal industry's causal effect on the health of Peru's coastal population. We then show how the sector responded to the 2009 introduction of individual, transferable fishing quotas (ITQs) – the regulatory system most commonly prescribed to preserve fish stocks and maximize total sector profits.[3] Finally, we show that the reform dramatically worsened the industry's effects on health, and trace the increased impact to boats' and plants' reorganization of production in response to the 2009 ITQ reform.

To estimate the causal effect of fishmeal production on health, we exploit government-imposed, semi-annual fishing ban periods in a difference in differences approach. We link administrative hospital admissions data and repeated cross sections of household surveys to administrative data on all production of fishmeal at the day×plant level. The results show that exposure to fishmeal produc-

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[1] In the words of Greenstone and Jack (2015, p.10): "...different types of market failures may interact in complicated ways that can make an otherwise efficient correction (e.g., a Pigouvian tax) to one market failure suboptimal in the presence of others".

[2] The fishmeal plants are located at the ports. When a boat docks, its anchovy catch is transported into a plant through conveyor belts and immediately converted into fishmeal (the value of the resulting fishmeal rapidly decreases as the fish decays) by burning or steaming the fish. Locals argue that the industry is responsible for health problems stemming from air pollution emitted in the process of converting the fish into fishmeal. In a 2008 article, *The Ecologist* magazine reported that "When we visited one heavily afflicted community [in the fishmeal town of Chimbote], more than a dozen women and children gathered [...] to vent their anger at the fishmeal plants. They claim the plants that loom over their houses are responsible for asthma, bronchial and skin problems, particularly in children. 'We know the factories are responsible for these [problems], because when they operate the illnesses get worse', says one young woman [...] Another says when the plants are operating the pollution is so thick you cannot physically remain on the street. Footage [...] seen by *The Ecologist* illustrates typical conditions when fishmeal plants are operational: billowing black smoke drifts through the streets, obscuring vision and choking passers-by [...] Pupils at a Chimbote school [...] also complain of health problems. 'It causes fungal growths, breathlessness, we cannot breathe', says one boy." (The Ecologist, 2008). Such complaints are supported by case studies (Cerda and Aliaga, 1999; Sueiro, 2010; MINAM, 2010, 2011), and local doctors: "Dr Ramon de la Cruz, dean of Chimbote's Colegio Medico del Consejo Regional XIX, told *The Ecologist*: 'All these respiratory problems are caused by contamination from the fishing industry in Chimbote' [...] Cruz states that there is a direct correlation between the onset of fishmeal production and illness in children in Chimbote." (The Ecologist, 2008).

[3] See e.g. Boyce (2004, p.1): "In fishery management, an optimal instrument, individual transferable quotas (ITQs), exists". Costello, Gaines and Lynham (2008) find that the introduction of ITQs in general tends to slow declines in fish stocks, and Natividad (2014) finds efficiency gains in the Peruvian fishing sector after the 2009 ITQ reform.

tion in the last 30 or 90 days worsens health, increasing respiratory (and total) hospital admissions, increasing reported health issues and medical expenditures among adults, and increasing reported health issues and coughs among children ≤ 5 and children ≤ 1. The estimated health effects among adults are not concentrated among the five percent of our sample in fishmeal locations that report to work in the fishing industry, nor driven by seasonal migration or labor market responses. Estimates from regressions where we instrument for ground-level concentration of PM^{10}, $PM^{2.5}$, NO_2 and SO_2 with fishmeal production suggest that the industry's impact on health is explained in large part by air pollution emitted by plants.

We then investigate how the fishmeal industry responded to the 2009 ITQ reform, and how the response changed the industry's impact on health. Before the reform, the North/Central region operated under a market-wide "total allowable catch" (TAC) system and semi-annual fishing ban periods, while a small region in the South was largely unregulated (due to fears that Chilean fishing activity would offset any environmental or industrial benefits of regulation). The 2009 reform introduced boat-specific, transferable quotas (ITQs) country-wide and extended fishing ban periods to the South. While there was only a small decrease in total production of fishmeal, the reform benefited fish stocks and increased total sector profits.[4]

To illustrate how we expect firms' response to the introduction of individual property rights to affect the geographical and temporal distribution of fishmeal production, we present a simple two-sector model with heterogeneous plants. The model predicts that production will be spread out in time after the reform: the introduction of ITQs removes boats' incentive to rapidly capture as much as possible of the TAC, and without the glut of fish early in the season less efficient plants are predicted to decrease production or exit the industry, and more efficient plants to spread their production across time. These predictions find support in the data.[5] The industry consolidation and evening out of production due to the reform were applauded by environmentalists and the fishmeal sector (see e.g. International Sustainability Unit, 2011), but may have worsened the industry's impact on health if dispersed production increases the total amount of pollution emitted and/or the health impact of a given amount of emitted pollution.

When comparing fishmeal locations to non-fishmeal locations before and after the reform came into effect, we find that the introduction of ITQs on average dramatically worsened the impact of fishmeal production on adult and child health, leading to for example 55,000 additional respiratory hospital admissions. Cost/benefit calculations that are suggestive but conservative indicate that the monetized cost of the reform's impact on health surpassed the increase in sector profits and value of increased fish stocks.

Geographical heterogeneity in the estimated reform effects supports the hypothesis that in-

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[4] The increase in fish stocks was likely due to lower juvenile fish capture post-reform. The system used to determine the total allowable catch for a given season did not change in 2009. There were likely several reasons why profits increased after the reform; for example, a reduction in plant overcapacity.

[5] Boats in the North/Central region spread out fishing in time as the ITQ reform came into effect. (Boats in the previously unregulated southern region fished for fewer days of the year after the reform due to the introduction of ban periods.) Fishmeal production days increased in the North/Central region and in locations with efficient plants. Production days decreased in the South and in locations with inefficient plants.

troduction of ITQs affected health through changes in the time profile of production. For the North/Central region, where production was spread out in time as a result of the reform, the estimated reform effects are negative (adverse), large and significant. For the smaller southern region, where fishmeal production days decreased with the reform, the estimates are insignificant or significantly *positive*, for example we see a reduction in coughs among children. Similarly, the estimated reform effects are significantly more negative for locations with efficient plants, when compared to locations with inefficient plants.

Finally, we investigate *why* spreading plant production over time exacerbates the impact on health. The time profile of pollution shows a post-reform change that corresponds to the change in the time profile of production, with less temporal variation after the reform. In general, the concentration of air pollution appears to increase linearly in the level of plant production, and none of the measured air pollutants increase in concentration after the reform. It thus appears that the explanation why dispersing air polluting plant production across time leads to a deterioration in health lies in the shape of the health production function (rather than in more pollution being generated with dispersed production).[6]

We conclude (a) that the introduction of individual property rights aimed at preserving fish stocks and sector profits in Peru exacerbated the fishmeal industry's impact on health because changes in incentives and industry dynamics led production to be spread out in time in most locations; and (b) that the two are linked because longer periods of exposure to moderate levels of air pollution are worse for health than higher intensity, shorter periods of exposure. Overall our findings highlight the risks of piecemeal regulatory design.

This paper contributes both to the literature on how to design regulation of industrial externalities, with particular relevance for developing countries, and to the literature on health effects of air pollution. The primary focus in the former has been on comparing (i) the magnitude of decreases in the targeted type of externalities (e.g. pollution or overextraction of a resource – see Costello, Gaines and Lynham (2008) for the case of ITQs for fish) to (ii) the economic costs of compliance.[7] A handful of pioneering papers explore *unforeseen* effects of regulations on the targeted type of externalities (e.g. due to plant substitution between different pollutants)[8] or the economic costs of

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[6] We use the term "health production function" to mean either the three-dimensional relationship relating health at a given point in time to both the duration of exposure to air pollution and the intensity of exposure, or one of the two underlying two-dimensional relationships (the so-called "dose-response" and "duration-response" functions), depending on context.

[7] Gray and Shadbegian (1993) show that firm TFP drops after the introduction of environmental regulations. Greenstone (2002) finds that air pollution regulations reduce employment and the growth of capital stock. List et al. (2003) find that environmental regulations inhibit the formation of polluting plants. Greenstone, List and Syverson (2012) find that the introduction of environmental regulations in the U.S. led to a decline in TFP. However, regulations of some forms of air pollution have been found to increase plant TFP (Berman and Bui, 2001; Greenstone, List and Syverson, 2012).

[8] Sigman (1996); Greenstone (2003); Gibson (2015) explore plant substitution between regulated and unregulated pollutants. Becker and Henderson (2000) find that, in the U.S., environmental regulations favoring small firms led to a shift in industry structure towards single-plant firms, which in turns contributed to environmental degradation. Field, Glennerster and Hussam (2011) demonstrate that a large-scale effort in Bangladesh to convince households to abandon deep wells believed to be contaminated by arsenic in favor of surface wells increased child mortality from diarrheal diseases because the surface wells were contaminated with fecal bacteria. Knittel and Sandler (2011) show

compliance (e.g. due to effects on market power).[9] This paper is to our knowledge the first to focus instead on (iii) the impact on another type of externality that was ignored in the design of the regulation. We document that piecemeal regulatory design targeting a subset of externalities can dramatically worsen outcomes in the ignored dimensions, yielding ambiguous total welfare effects of otherwise laudable reforms.[10]

We also contribute to a nascent literature on how to regulate industrial pollution in developing countries (Laffont, 2005; Estache and Wren-Lewis, 2009; Burgess et al., 2012; Duflo et al., 2013; Greenstone and Jack, 2015; Duflo et al., 2014; Greenstone and Hanna, 2014; Jia, 2014). Greenstone and Hanna (2014) note that pollutant concentrations are extremely high in many developing countries,[11] imposing significant health costs and highlighting the need for effective regulation. Several innovative recent papers illustrate the need to take institutional capacity and the prevailing incentive structures into account when designing regulation (Burgess et al., 2012; Duflo et al., 2013, 2014; Jia, 2014). The evidence in this paper underscores the need for regulatory design that addresses all relevant externalities simultaneously. Comprehensive regulatory design is particularly important in developing countries where concurrent market failures are commonplace (see e.g. Field, Glennerster and Hussam, 2011).[12]

Air pollution has been shown to adversely affect the health of adults (see e.g. Brook RD et al., 2010; Moretti and Neidell, 2011; Schlenker and Walker, 2011; Chen et al., 2013; Currie et al., 2014), and children (see e.g. Chay and Greenstone, 2003; Case, Fertig and Paxson, 2005; Chay and Greenstone, 2005; World Health Organization, 2006; Jayachandran, 2006; Currie and Almond, 2011; Currie and Walker, 2011; Gutierrez, 2013; Roy et al., 2012; Currie et al., 2014, 2015), especially respiratory and pulmonary health outcomes. An existing literature analyzes how the impact depends on the intensity and duration of exposure, but the evidence is primarily correlational. Our analysis especially complements two of a handful of papers that provide convincing *causal* evidence on the dose-response and the duration-response functions. Chen et al. (2013) find much bigger effects on health and mortality of *sustained* exposure to high levels of air pollution than (the effects found elsewhere of) short-term exposure. Chay and Greenstone (2003) find non-linearity in the response of infant mortality to reductions in air pollution in the U.S. that are consistent

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that the benefits of carbon pricing are understated because such regulations reduce not only greenhouse gases but also local pollution. Davis, Fuchs and Gertler (2014) show that the expected benefits of buy-back programs are overstated because households may use newer appliances more.

[9] Ryan (2012) and Fowlie, Reguant and Ryan (2014) find that allocative inefficiencies due to changes in market power in the U.S. cement market counteract the social benefits of carbon abatement regulations.

[10] In fact our evidence suggests, consistent with theory (see e.g. Clark, 1980; Boyce, 2004; Weninger, 2008) and empirical evidence (see e.g. Natividad, 2014), that for the particular case of individual transferable quotas (ITQs) for open access resources, there is no trade-off between decreases in the targeted type of externalities and economic costs as the direct economic effects of ITQs are positive and thus to add to rather than substract from the environmental benefits.

[11] See also Hanna and Oliva (2014); Ebenstein (2012); Chen et al. (2013); Rau, Reyes and Urzua (2013); von der Goltz and Barnwal (2014).

[12] This paper can also be seen as contributing to the literature on the economics of property rights. See e.g. Goldstein and Udry (2008) and several papers by Erica Field, especially Field (2007), for examples of the benefits of securing property rights in developing countries, and Costello, Gaines and Lynham (2008) for benefits in the case of open access resources such as fish.

with concavity in the dose-response function (although the authors point out that there are other possible explanations of their findings). We add new evidence on the shape of the health production function by documenting that exposure to longer periods of moderate air pollution are worse for health than higher intensity, shorter periods of exposure. In their excellent survey of the literature on air pollution and health, Pope III et al. (2011) conclude that there is no existing evidence on the effect of simultaneous changes in duration and intensity of exposure – a trade-off commonly faced by policymakers.

The paper is organized as follows. In Section 2 we discuss background on the setting, why fishmeal production may affect health, and the 2009 ITQ reform. In Section 3 we present the data, and in Section 4 we go through our empirical strategy. Evidence on how and why fishmeal production affects health is presented in Section 5. Section 6 analyzes, theoretically and empirically, the industry's responses to the 2009 ITQ reform, and Section 7 how and why its impact on health changed as a consequence. Section 8 discusses the total costs and benefits of the reform and regulatory design, and Section 9 concludes.

2 Background

2.1 Peru's fishmeal sector

Peru's anchovy fishery accounts for around 10 percent of global fish capture (Paredes and Gutierrez, 2008). While "artisan" fishing boats are present in most towns along the coast, the industrial fishing sector is concentrated in around 22 towns with a suitable port. Only industrial boats can legally sell fish for "indirect consumption", primarily meaning for the production of fishmeal. The country's fishmeal plants, all located at ports, produce about a third of the global supply of fishmeal. In 2008, the sector consisted of 1,194 active industrial fishing boats and 110 fishmeal plants, and seven large companies accounted for around 70 percent of the country's fishmeal production.

The industrial fishing sector is very capital intensive. Paredes and Gutierrez (2008) estimate that there were only about 26,500 jobs in the sector in 2008. (The Peruvian Ministry of Production's Statistics Office gives similar numbers, estimating 19,853 workers in "extraction of the resource" for the industrial sector and 9,335 in processing in 2007). The figures in Christensen et al. (2014) suggest that the share of those jobs that were in fishmeal plants was about a quarter, indicating that the 110 plants operating in 2008 employed on average about 60 workers each. Five percent of our adult sample in fishmeal locations ($\leq$ five kilometers from a fishmeal port) reports to work in "fishing".[13]

Industrial fishing and fishmeal production only takes place certain periods of the year. In Table I, we present summary statistics from individual survey data (described below) comparing fishmeal and non-fishmeal locations in and out of the production season. The share of sampled adults that

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[13] Five percent of adults corresponds to eight percent of those who have a job. Some individuals that work outside of the industrial fishing sector may also report to work in fishing (e.g. artisan fishermen) so that the true proportion who works in the fishmeal sector is likely even lower.

were born in a different district than where they were surveyed is lower in fishmeal locations in season (37 percent) than out of season (40 percent). The numbers thus indicate that there is little seasonal work migration to the fishmeal locations. The reason is likely that jobs in the industrial fishing sector are quite stable.[14] Many fishmeal firms keep the (relatively high-skill) plant workers on payroll also outside of the production season.[15] In the APOYO (2008) survey of industrial fishing workers, 40 percent report not working at all outside of the production seasons; a large proportion of the remainder work as artisan fishermen outside of the industrial seasons.

The summary statistics in Table I show negligible changes in average incomes in fishmeal locations during the production season. While the industrial fishing sector does have linkages to the local economies, economic activity thus appears to vary less with the production cycle than one might expect. The summary statistics also show little change in mean household demographics, socioeconomic status and labor market outcomes during production seasons. Differences in household characteristics between fishmeal and non-fishmeal locations are also modest, although households in fishmeal locations appear to be of slightly higher socioeconomic status.

2.2 The fishmeal production process, pollution and health

Fishmeal is more valuable the fresher the fish when processed. Fishing boats therefore go out for at most one day at a time. Each fishmeal plant has its own docking station at the port. After docking at the station of the plant that has purchased the fish, the fish is offloaded and transported into the plant through a conveyor belt. Inside the plant the fish is weighed and cleaned. After cleaning, the fish is dried and converted into fishmeal by either exposure to direct heat or steaming. Fishmeal is storable for $6 - 12$ months (but fishmeal companies report that they rarely store for long).

Air pollution may occur in the form of chemical pollutants (such as carbon dioxide (CO_2) and nitrogen dioxide (NO_2)) from the plants' heavy use of fossil fuels, in the form of noxious gases (e.g. sulfur dioxide (SO_2) and hydrogen sulfide (H_2S)) released as fish decompose, and in the form of microscopic natural particles (PM^{10} or $PM^{2.5}$) released during the drying and burning processes. Case studies have found high levels of air pollution near fishmeal ports during production periods, as discussed in detail in the appendix. As also discussed at greater length in the appendix, air pollution in the form of particulate matter, chemical pollutants and gases associated with fishmeal production has been shown to cause a range of health problems in adults and children, especially respiratory disease episodes.

Peru's fishmeal plants are also alleged to pollute the ocean by releasing "stickwater" onto the beaches or into the ocean (see e.g. Rivas, Enriquez and Nolazco, 2008; Elliott et al., 2012). Stickwater can cause skin- and gastrointestinal diseases and conjunctivitis in humans (a) through direct exposure and (b) indirectly, by stimulating the growth of pathogens in the ocean, which

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[14] In a country-wide survey of workers in the sector conducted by the consulting firm APOYO in May 2007, 87 percent report having worked for the same company or fishing boat owner throughout their career, on average for about 14 years (APOYO, 2008). Many workers are unionized and 44 percent have permanent work contracts.

[15] Earnings from work on industrial fishing boats can be high during the industrial fishing season so that boat-workers' earnings may fluctuate more over the year (see e.g. Pereda, 2008).

can enter seafood and thus, ultimately, humans (Pruss, 1998; Fleming and Walsh, 2006; Garcia-Sifuentesa et al., 2009).

2.3 Regulations and the 2009 ITQ reform

The regulations imposed on the Peruvian fishmeal industry are aimed at preserving fish stocks while maintaining industry profitability. In the North/Central marine ecosystem (down to the $-16\,^{\circ}$S parallel), semi-annual fishing bans were in place for industrial boats during the periods when the anchovies reproduce throughout our data period (the exact start and end dates of the ban periods vary by year). In addition, before the 2009 reform, industrial boats in the North/Central region operated under a sector-wide "Total Allowable Catch" (TAC). The size of the aggregate quota varied by season and was set by the government agency in charge of publishing official estimates of fish stocks (IMARPE). In the much smaller southern marine ecosystem, fishing was allowed throughout the year and no aggregate quota was in place before the 2009 ITQ reform.

In 2008, officials estimated excess capacity in the industrial fishing sector (the industrial fleet and fishmeal plants) of 35–45 percent (Tveteras et al., 2011). Concerned about excess capacity and declining fish stocks, the goverment announced a new law introducing a system of individual, transferable quotas (ITQs) in the industrial fishing sector on June 30^{th}, 2008. The ITQ law came into effect in the North/Central region on April 20^{th}, 2009 and in the South on July 7^{th}, 2009. In the South, the new ITQ system also meant that an aggregate quota and fishing ban periods were introduced for the first time.

All industrial boats were included in the new ITQ system. Individual boat quotas were specified as a share of the regions's aggregate quota for the relevant season. The quota-share was based on historical catches and a boat's hull capacity. The quotas could be transferred between boats, subject to certain rules.[16] Quotas could not be transferred between the North/Central region and the South.

3 Data

We combine five different types of data: hospital admissions data, individual- and household-level survey data, administrative regulatory data, administrative production and transaction registries, and data on pollution.

Hospital admissions data. Information on hospital admissions was provided by the Peruvian Ministry of Health and consists of counts of all patients admitted to any public health facility (health posts, health centers, and hospitals) between 2007 and 2011. The data is at the facility×month level and gives information on the cause for admission (using the International Classification of Diseases system).

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[16] Firms or individuals that owned several boats/quotas were free to allocate their total quota to a subset of those boats. Quota-owners could also rent their quota out to others, for up to three years at a time.

Individual- and household-level survey data. The nationally representative Encuesta Nacional de Hogares (ENAHO) is the Peruvian version of the Living Standards Measurement Study (LSMS). Since 2004 surveying has taken place throughout the year, and the order in which sampling clusters are surveyed is randomly determined. A subset of clusters are re-surveyed every year. Information on the "centro poblado" where each respondent is interviewed is recorded.[17] In our analysis, we use the GPS coordinates of the centro poblado's centroid. Adult women and men are interviewed. The survey focuses on labor market participation, income and expenditures, self-reported health outcomes, etc., as in other LSMSs.

We also use the nationally representative Encuesta Demografica y de Salud Familiar (ENDES), which is the Peruvian version of a Demographic and Health Survey (DHS). The sampling framework is similar to ENAHO, with surveying taking place throughout the year since 2004. A subset of clusters are re-surveyed every year.[18] GPS coordinates for sample clusters are recorded. Women between 15 and 49 years old are interviewed, and information on their children (five years old and under) recorded. The survey is comparable to other DHS surveys, focusing on self-reported and measured health outcomes. For both surveys, we use the years 2007–2011.

Administrative regulatory data. We coded the dates of all fishing seasons from 2007 to 2011 and the size of each season's aggregate quota from the government gazette *El Peruano*.

Administrative production and transaction registries. The registry of all transactions between industrial fishing boats and fishmeal plants (including "within-firm" transactions) from 2007 to 2011 was provided by the Peruvian Ministry of Production. All offloads by industrial boats are included, i.e., all (legal) input into fishmeal production. Information on the date of the transaction, and the boat, plant and amount of fish involved (though not the price), is included.

We also have access to the ministry's records of fishmeal plants' production/output, recorded at the monthly level, from 2007 to 2011.

Pollution data. Air quality measurement stations are found only in the Lima area. Information on the daily concentration, from 2007 to 2010, of four air pollutants at each of five stations in Lima was provided by the environmental division (DIGESA) of the Ministry of Health. The measured air pollutants – PM^{10}, $PM^{2.5}$, NO_2 and SO_2 – have been shown to correlate with factory production in many contexts and are commonly used in the health literature.[19]

We also use weekly measurements of the concentration of coliforms at public beaches throughout the country. This information is recorded by DIGESA to inform beachgoers about beach/water safety, and is reported as a binary variable.

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[17] Centros poblados are villages in rural areas and neighborhoods in urban areas. After the sample restrictions we impose, 2096 sampling clusters with on average 77 households each are present in our sample. 710 centros poblados are present, with on average 228 households each.

[18] From 2004 to 2007, a fixed set of 1131 clusters was used, the survey order of which was randomized (as was the trimester of surveying). The definition of clusters changed somewhat in 2008 when Peru's statistical bureau updated the sampling frame with the 2007 national census. Furthermore, 2008 was unusual in that only 722 clusters were surveyed. From 2009 to 2011, 1132 clusters were used, including a panel of 566 clusters surveyed every year.

[19] We lack data on the concentration level of H_2S and CO_2, which may also respond to fishmeal production.

We construct seven primary outcome variables, with a particular focus on the health issues that are most likely to be affected by short-term variation in air pollution from plant production (see e.g. Chen et al., 2013) – respiratory issues. The outcome "Respiratory Admissions" is a count at the hospital level of all admissions due to diseases of the respiratory system (ICD codes J00-J99). As no explicit question on respiratory issues is asked in the ENAHO survey, for adults we construct an outcome labeled "Any Health Issue" as the complement to "No health issue in the last month". We also use expenditure data to construct an estimate of the individual's total medical expenditures. For children, we use ENDES survey data to construct a measure of "Any Health Issue". This variable is equal to one if the surveyed parent reported that the child had experienced any of the health issues the survey covers in the last two weeks.[20] We also separately report the outcome of experiencing a cough.

4 Empirical Strategy

To estimate the causal effect of fishmeal production on adult and child health, we exploit time and spatial variation in exposure to production. Our difference in differences approach compares individuals in locations close to fishmeal plants to individuals in locations further away from plants, during production periods and ban periods (the timing of which vary from year to year). The estimation equation for survey outcomes is as follows:

$$\begin{aligned} y_{ijtmy} = \alpha &+ \beta_1 Production_{jt} + \beta_2 FishmealLocation_j \times Production_{jt} + \beta_3 X_{ijt} \\ &+ \gamma_j + \delta_{my} + FishmealLocation_j \times \theta_m + \varepsilon_{ijtmy} \end{aligned} \tag{1}$$

where y_{ijtmy} is an outcome variable for individual i, who lives in location j, and was interviewed on date t, in calendar month m and year y. X_{ijt} are individual-level covariates – gender, age, mother tongue, years of education, and migration status for adults, and gender, age, mother's years of education, and the ENDES household asset index for children – that control for possible changes in the sample surveyed across time/space. γ_j is a centro poblado or district fixed effect,[21] δ_{my} is a year×month fixed effect, and $FishmealLocation_j \times \theta_m$ is a $FishmealLocation$ specific month fixed effect. The centro poblado/district and year×month fixed effects control for any time- or location-invariant shocks to the study population's health that may be correlated with fishmeal production, while $FishmealLocation_j \times \theta_m$ controls for possible differential seasonality in fishmeal locations. ε_{ijtmy} is an iid error clustered at the centro poblado or district level.

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[20] The covered health issues are cough, fever, and diarrhea. These have all been linked to air pollution in the existing epidemiological literature (see e.g. Peters et al., 1997; Kaplan et al., 2010), although the evidence linking air pollution and cough is more extensive.

[21] While we use centro poblado fixed effects in regressions using ENAHO data, the lowest geographical unit we can condition on when using ENDES data is districts. The reason is that the ENDES sampling framework changed in 2008/2009. While district information is included in all rounds of ENDES, the data key necessary to link specific sampling clusters/centros poblados before and after 2008/2009 was not stored. Note that Peruvian districts are small; there are 1838 districts in the country.

The estimation equation for hospital admissions outcomes is as follows:

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\begin{aligned}
y_{imy} = \alpha + \beta_1 Production_{imy} + \beta_2 FishmealLocation_i \times Production_{imy} \\
+ \gamma_i + \delta_{my} + FishmealLocation_i \times \theta_m + \varepsilon_{imy}
\end{aligned}
\tag{2}
$$

The primary difference between (2) and (1) is that monthly hospital level outcomes do not require use of a j or t subscript, nor individual level controls. In (2) γ_i is a hospital fixed effect.

$FishmealLocation_j$ ($FishmealLocation_i$) is a dummy variable that equals one if location j (hospital i) is within X kilometers of a fishmeal port.[22] For outcomes drawn from the ENAHO and ENDES surveys, for which we have a precise GPS point for the location to which the respondent belongs, we use five kilometers as the "treatment radius" within which any health effects of fishmeal production are hypothesized to be greatest,[23] based on the literature on air pollution (see e.g. Currie et al., 2015; Schlenker and Walker, 2011). For the hospital admissions outcomes, for which treatment status is instead defined by the location of the hospital, we use 20 kilometers as the treatment radius. The reason is that the geographical spread of health facilities is much greater than that of sampling clusters; to be able to pick up effects of exposure to fishmeal production, we need to include the facilities used by those living near the fishmeal plants in the "treatment group". For many ports the nearest hospital is more than 10 kilometers away. Note that our specification is conservative in that we compare locations inside the treatment radius to locations outside the radius, allowing the "control locations" to also be affected by production in the nearest port. We simply allow production to have a differential effect in locations close to the fishmeal plants. In Section 5 we investigate how our estimates vary with the treatment radius used.

$Production_{jt}$ ($Production_{imy}$) denotes either the number of days on which fishmeal production took place, or log total input into fishmeal production reported in 10,000s of metric tons, during X days in the port nearest to location j (hospital i). We use 30 days as our first lookback window to match the way the ENAHO survey questions are asked,[24] and also show estimates with a 90 day lookback window to capture health responses to more persistent exposure. For outcomes drawn from the ENAHO and ENDES surveys, for which an observation is associated with a specific date, we use the past X days to construct $Production$.[25] For hospital admissions outcomes, which are recorded at the monthly level, we use current month for 30 day regressions and current and past

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[22] In a slight abuse of notation, for ENDES outcomes we use j to denote both the location that determines a child's treatment status – (the centroid of) its sampling cluster – and also the geographical level for which we can include fixed effects in ENDES regressions – districts. For ENAHO survey outcomes, the centro poblado is used both to determine treatment status and in the geographical fixed effects.

[23] As we do not have GPS points for surveyed individuals' homes, nor shape files for the sampling clusters and centros poblados, we define the location of i as the centroid of j (the centro poblado (in ENAHO) or sampling cluster (in ENDES)) to which he/she belongs.

[24] A typical ENAHO question reads "Did you experience X in the past 30 days?".

[25] We thus use input rather than output to measure fishmeal production because we have data on input at the daily level and output only at the monthly level. As seen in Figure I, the output of fishmeal very closely tracks the input of fish.

two months for 90 day regressions. In Section 5 we investigate how our estimates vary with the lookback window used.

Figure II is a map of Peru illustrating our identification strategy by showing five kilometer radii around fishmeal ports and ENAHO and ENDES sampling clusters. We restrict our analysis to the coastal regions of Peru to increase comparability of the "treatment" and "control" locations. The map also shows the $-16\,^{\circ}$S parallel that separated the North/Central and South regulatory regimes before the 2009 ITQ reform.

The cross-sectional variation in fishmeal production is determined by geographical suitability – plants are located at ports in towns where the ocean is sufficiently deep close to shore to allow large vessels to offload fish, and where conditions at sea attract schools of anchovy. The time variation in fishmeal production is determined primarily by the regulatory framework, which allows industrial fishing only during official fishing seasons. The start and end dates of the seasons are decided by the authorities and vary by year/season. The identifying assumption is that, after controlling for time, location and seasonality fixed effects, trends in health across production and non-production periods would have been similar in fishmeal and non-fishmeal locations in the absence of fishmeal production. This assumption is supported by the semi-annual, on-and-off nature of fishmeal production in Peru, and the exogenously determined timing of the ban periods. Table I shows summary descriptive statistics for variables of interest. Average survey health outcomes in non-fishmeal locations closely resemble the fishmeal location averages measured outside of the production season. We show extensive evidence supporting the identifying assumption in Subsection 5.1.

In the second part of the empirical analysis, we estimate the causal effect of the 2009 ITQ reform on health outcomes in fishmeal locations. We compare fishmeal and non-fishmeal locations before and after the reform, using the following difference in differences specifications:

$$\begin{aligned} y_{ijtmy} = \alpha &+ \beta_1 FishmealLocation_j * Reform_{jt} + \beta_2 X_{ijt} \\ &+ \gamma_j + \delta_{my} + FishmealLocation_j \times \theta_m + \varepsilon_{ijtmy} \end{aligned} \tag{3}$$

$$\begin{aligned} y_{imy} = \alpha &+ \beta_1 FishmealLocation_i * Reform_{it} \\ &+ \gamma_i + \delta_{my} + FishmealLocation_i \times \theta_m + \varepsilon_{imy} \end{aligned} \tag{4}$$

where $Reform_{jt}$ ($Reform_{it}$) is a dummy variable equal to one after the reform took effect in the fishmeal port nearest to location j (hospital i). In some regressions we additionally include $FishmealLocation_j \times \tau_{my}$ (or $FishmealLocation_i \times \tau_{my}$), a $FishmealLocation$ specific time trend that is linear in months. Other variables are as defined for (1) and (2). The identifying assumption is that, after controlling for time, location and seasonality fixed effects, and linear time trends, trends in health across the date when the reform took effect would have been similar in fishmeal locations and non-fishmeal locations in the absence of the ITQ reform. The summary statistics in Table I show that fishmeal and non-fishmeal locations had similar mean household demographic characteristics, labor market outcomes, and health outcomes before the reform.[26] We show extensive evidence supporting the identifying assumption in Sub-section 7.1.

5 Fishmeal Production and Health

5.1 Effect of fishmeal production on health

In this section, we exploit exogenous variation in the timing of fishmeal production driven by government-imposed fishing ban periods to identify its effect on adult and child health outcomes. The summary statistics in Table I hint at our results: individuals exposed to fishmeal production have worse health outcomes. 58 percent of adults in fishmeal locations report having had a health issue during the past 30 days when interviewed outside of the production periods. This proportion is four percentage points higher during production periods. The time patterns are similar for medical expenditures, and for health issues and coughs for children. Overall, most health outcomes in fishmeal locations are worse during plant production than outside of production periods. The average health outcomes in non-fishmeal locations most closely resemble the fishmeal location averages measured outside of production periods.[27]

Table II shows the estimated effect of fishmeal production on adult and child health. We find that fishmeal production during the previous 30 or 90 days, whether measured as production days or total input into production, negatively affects adult and child health. A 50 percent increase in fishmeal production during the previous month leads to 1.98 (1.2 percent) more hospital admissions for respiratory diseases; a 0.95 percentage point (1.6 percent) higher incidence of "Any Health Issue" among adults; and a 4.6 percent increase in medical expenditures. For these outcomes the estimated effects are similar when using a 90 day window. We also find that a 50 percent increase in fishmeal production during the last 90 days leads to a 2.1 percentage point (4.6 percent) increase in the incidence of "Any Health Issue" and a 1.95 percentage point (5.3 percent) increase in the incidence of having a cough among children ≤ 5. The analogous estimates are 2.55 percentage points (5.2 percent) and 2.95 percentage points (7.8 percent) for children ≤ 1. We do not find significant effects for children of production in a 30 day window. The reason may be that our statistical power to detect effects on child health is lower than for adult health due to much smaller sample sizes.

The last two panels of Table II show the estimated effect of days of production on health. The patterns are similar to those found in the top panels; for example, 10 additional days of production during the last 30 days leads to 2.28 (or 1.4 percent) more hospital admissions for respiratory diseases, and 10 additional days of production during the last 90 days increases the incidence of "Any Health Issue" by 8.9 percent for children ≤ 5 and 6.1 percent for children ≤ 1. Overall, the

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[26] An exception is respiratory hospital admissions, which are considerably higher in fishmeal locations.

[27] Some health outcomes also appear to be worse in non-fishmeal locations during the times of the year when production takes places. This pattern is likely an artifact of the narrow "treatment radius" used, as can be seen e.g. in Figure III.

results in Table II indicate that exposure to fishmeal production leads to worse health outcomes for both adults and children.

In Appendix Table A.I, we expand the set of health outcomes to consider hospital admissions not only for respiratory issues (the type of disease episodes that we hypothesize to be most likely to respond to short-term variation in air pollution), but also for other health issues that the previous literature has found to correlate with air pollution. We find that fishmeal production increases total hospital admissions, admissions for digestive diseases (see also Kaplan et al., 2010), and for pregnancy complications. These results underline the seriousness of the fishmeal industry's impact on the health of Peru's coastal population.

5.2 Robustness

As the timing of fishmeal production is determined by government-mandated, semi-annual fishing ban periods (which "bind"), we consider the variation in production to be exogenous. However, we can alternatively explicitly instrument for production and production days during the last 30 or 90 days using the number of non-ban days during the same period. The resulting estimates are very similar to those in Table II when using survey-measured health outcomes, as seen in Appendix Table A.II.[28]

The treatment radius and lookback windows used in Table II were informed by the existing literature and the window used in the ENAHO survey questions, but nevertheless involved a degree of choice. In Figure III, we plot treatment effects estimated for all radii between 0 and 30 kilometers from fishmeal ports, for all outcomes.[29] For survey outcomes, the impact on health decays with distance from the nearest plant, although effects on "Any Health Issue" persist even at larger radii. For hospitals the effects become large and precisely estimated with radii that allow the inclusion of hospitals at most ports, as expected. In Figure IV, we plot treatment effects for production days estimated with a lookback window varying from 0 to 120 days. For production days within the lookback window, the point estimates are generally biggest in short windows for adults. For children, the effects are imprecisely estimated at short windows, but become precisely estimated and significant with larger windows. The estimates in Figures III and IV support the choice of 5/20 kilometer treatment radii and 30/90 lookback windows, and a causal interpretation of the estimates in Table II.

In Appendix Table A.III we show estimates from a falsification exercise using hospital admissions due to health issues that should not be affected by plant production as dependent variables:

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[28] The lack of cross-sectional variation in the instrument leads to very high standard errors when using respiratory hospital admissions as the outcome variable. The reason is that significant time variation in production (the instrumented variable) and the outcome is necessary to achieve precise estimates when using non-ban periods – the start and end dates of which do not vary by port – as an instrument. While survey-measured outcomes vary by day (and production and the instrument can therefore also be measured at the daily level), respiratory hospital admissions do not. Note also that "fishmeal production in the last X days" cannot be included in the respiratory hospital admissions IV regressions because the variation in non-ban days – the instrument – does not vary within months and is thus collinear with month×year fixed effects.

[29] Production here is defined as the number of production days in the last 90 days, as this is the time window in which we find significant effects of fishmeal production on the health also of chidren.

"Congenital Disorders", "External Factors such as injury and poisoning", and "Mental, Behavioral, and Neurodevelopmental disorders." We find no significant effects.

A possible concern with our estimation strategy is avoidance behavior. People can take costly actions to avoid exposure to fishmeal production. The obvious way to avoid harmful health effects of plant production is to temporarily or permanently migrate. As discussed in Sub-section 2.1, however, the summary statistics in Table I show no sign of temporary migration away from (or to) fishmeal locations during the the production seasons, and fishmeal locations are similar to non-fishmeal locations on household characteristics. We control for individual migration status in the regressions that use outcomes from surveys (from which migration information is available). Other forms of avoidance behavior – e.g. refraining from being outside during the production seasons – would lead us to underestimate the direct health effects of production. It is worth noting, though, that exposure to air pollution is generally difficult to avoid for those residing in fishmeal locations. $PM^{2.5}$ is, for example, likely to penetrate inside homes.

5.3 How fishmeal production affects health

Whether the estimated adverse health effects in the full sample are due to worse health during the production periods for those who work in the sector, or if instead whole communities are affected, is informative about the underlying mechanism. Recall that fishmeal production is a capital intensive industry. Only five percent of the adult sample in fishmeal locations report to work in "fishing", a broader category that includes the fishmeal sector. In Table III, we show results from estimating equation (1) separately for those who work in fishing. We see that fishing workers display health effects that are similar to those of other individuals.[30] One notable exception is a bigger increase in medical expenditures for fishing workers during production seasons, which may partly reflect an income effect. Overall, these results suggest that the estimated adverse health effect in the full sample are not driven by effects on the health of workers in the industry.

Another possible mechanism is that fishmeal production affects health through labor market responses. It may be that higher incomes in the industrial fishing sector during production periods stimulate the local economy. Such multiplier effects could enable or encourage e.g. local service sector employees to work harder, which may in turn worsen health (although mechanisms in the "wrong direction" – better labor market outcomes leading to improved health – are perhaps more plausible). In Table IV we investigate the impact of fishmeal production on labor market outcomes. As expected, we do see increases in the likelihood of having a job and in total income for workers in the industry during production seasons. However, fishmeal production does not affect average incomes and labor market outcomes in the full sample of adults. This suggests that the observed health effects are not due to changes in local labor markets during the production seasons.

A third possibility is that a part of the observed effect of fishmeal production on "Any Health Issue" operates through pollution of the ocean (effects on respiratory hospital admissions and coughs

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[30] The small number of fishing workers in our sample gives us limited power to detect differential effects but also suggests that fishing workers do not drive the aggregate effects we find.

are unlikely to be due to ocean pollution). If greasy "stickwater" is released onto the beaches or directly into the ocean, a process of eutrophication can lead organisms (e.g. algae) and bacteria to grow excessively. Toxins can in turn affect human health either through direct exposure or through the consumption of seafood (World Health Organization, 2002; Committee on Nutrient Relationships in Seafood, 2007). However, as seen in Table III, we do not observe bigger health effects for those who work in fishing, who presumably have greater direct exposure to the ocean. Moreover, in Appendix Table A.IV, we show that (a) the estimated health effects are not of greater magnitude for individuals who consume more fish, and (b) fishmeal production does not increase pollution at beaches near ports relative to those further away. We conclude that ocean pollution is unlikely to contribute noticeably to the estimated health effects of fishmeal production.

We now investigate if fishmeal production affects the health of the local population primarily through air pollution emitted in the production process, as we hypothesize. We first disaggregate respiratory hospital admissions into its ICD sub-categories. Doing so shows that the overall effect is driven primarily by a higher incidence of "Acute Upper Respiratory Infections" during production periods, consistent with air pollution as the underlying mechanism.[31]

To investigate more directly, we estimate (i) the effect of fishmeal production on air pollution, and (ii) the effect of air pollution on adult and child health in the Lima area. We make use of data on the daily, ground-level concentration of four air pollutants – PM^{10}, $PM^{2.5}$, NO_2 and SO_2 – from the five DIGESA measuring stations (all located in the Lima area).

The top panel of Table V documents the effect of fishmeal production on air quality. For each date we take the median of the measurements' from the five stations (to address missing values), and construct the average concentration of each of the measured air pollutants during the last 30 days. We then run a port-level regression with year×month fixed effects in which we regress the average pollutant level in Lima during the 30 days prior to the date in question on fishmeal production in the port that is closest to the five stations – Callao – during the same 30 days. (No other port is located near the five measurement stations). We find that fishmeal production is significantly positively correlated with all four air pollutants. A 50 percent increase in production in the last 30 days increases PM^{10} by 8.8 percent of a standard deviation, $PM^{2.5}$ by 7.7 percent of a standard deviation, NO_2 by 8.1 percent of a standard deviation, and SO_2 by 4.4 percent of a standard deviation.

In the bottom panel of Table V, we merge the air pollution data with outcome data for the respondents and hospitals that have Callao as their closest fishmeal port (27.34 percent of the total sample in ENAHO). To match the specification described in Section 4 and used in Table II, the measured pollutant levels are associated with all individuals and hospitals in the Callao sample, but allowed to co-vary differentially with production (and health) depending on whether the sampling cluster/hospital in question is located inside or outside of the treatment radius. We

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[31] Using specifications identical to those in Table II with admissions for different subcategories of respiratory admissions as dependent variables, we find a coefficient on "Fishmeal Production in Last 30 Days x Near Port" of 3.192 for "Acute Upper Respiratory Infections." The estimated effect is significant at the 5 percent level, and suggests that the subcategory explains about 80 percent of the total effect on respiratory admissions.

regress respiratory hospital admissions and adult health outcomes on the 30–day average level of an air pollutant, separately for each of the four pollutants, and instrument each by fishmeal production.[32] We present these IV regressions to illustrate the magnitude of the component of fishmeal production's impact on health that may arise through air pollution, acknowledging that the exclusion restriction is likely violated.[33] While distinguishing the relative contributions of different air pollutants is not the exercise in this paper, it is important to note that PM is regarded by many as a general indicator of air pollution, receiving contributions from fossil fuel burning, industrial processes, and other underlying sources (see e.g. Greenstone and Hanna, 2014). A (very) conservative interpretation of the results in the bottom panel of Table V would thus be to restrict attention to the PM results.

The results in Table V show that a one standard deviation (10 μg/m^3) increase in PM^{10}, as instrumented by fishmeal production, gives an increase in "Any Health Issue" of 2.5 percent (1.1 percent). A one standard deviation (10 μg/m^3) increase in PM$^{2.5}$ gives an increase in "Any Health Issue" of 2.6 percent (1.8 percent). A one standard deviation (10 μg/m^3) increase in NO$_2$ gives an increase in "Any Health Issue" of 2.5 percent (3.1 percent). Finally, a one standard deviation (10 μg/m^3) increase in SO$_2$ gives an increase in "Any Health Issue" of 5.0 percent (4.2 percent). PM$^{2.5}$, NO$_2$ and SO$_2$, as instrumented by fishmeal production, also significantly increase respiratory hospital admissions.

How do these estimated effect sizes compare to what has been found in other studies relating health outcomes to air pollution? Though the epidemiological literature on particulate matter and health outcomes is primarily correlational, it is also large and provides estimates that are broadly consistent with each other. In their review of the literature, Anderson, Thundiyil and Stolbach (2012) cite studies that for example associate a 10 $\mu g/m^3$ (14.8 $\mu g/m^3$) increase in PM^{10} with a 2.28 percent (3.37 percent) increase in respiratory hospital admissions, and a 10 $\mu g/m^3$ increase in PM$^{2.5}$ with a 2.07 percent increase in respiratory admissions. Our estimated effect sizes thus appear plausible in light of the epidemiological literature.

In sum, the evidence presented in this sub-section is strongly supportive of air pollution emitted by plants being the primary mechanism through which fishmeal production affects adult and child health.[34] In the next section we explore how the industry responded to the 2009 introduction of individual, transferable quotas, and how the impact on health changed as a consequence.

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[32] Child health outcomes are not included because the ENDES data does not have sufficient treatment observations in the vicinity of Callao to estimate standard errors.

[33] PM^{10}, PM$^{2.5}$, NO$_2$ and SO$_2$ have all been linked with adverse health outcomes in the existing literature. The exclusion restriction is violated in each of these regressions in the sense that fishmeal production likely affects health also through (at least) three other air pollutants. For a similar approach, see e.g. Malamud and Pop-Eleches (2011).

[34] We additionally attempted to compare individuals and hospitals located downwind from the fishmeal plants to those located upwind. The estimated coefficient on "Fishmeal production × Near Plant × North of Plant" is positive in almost all specifications (indicating a more adverse health impact of fishmeal production north of the plants) and for some health outcomes also significant. While winds are reported to blow north most of the time along the coast of Peru, we do not have wind maps that would allow us to precisely define downwind/upwind locations and exploit time variation in wind directions.

6 Industrial Response to the 2009 ITQ Reform

6.1 Industrial response to the ITQ reform: theoretical framework

This paper investigates how changes in firms' incentives due to new regulation of other externalities can lead to industrial responses that affect firms' impact on health. In this section, we present a simple two-sector model with homogeneous suppliers (boats) and heterogeneous final good producers (plants) that predicts how the introduction of individual property rights over intermediate goods (fish) affects the spatial and temporal distribution of final good (fishmeal) production. With an added hypothesis on how the distribution of fishmeal production matters for the industry's impact on health, the model delivers a prediction on how the 2009 ITQ reform affected the health of Peru's coastal population. More importantly, the model's predictions will help us test hypotheses on why the fishmeal industry's impact on health may have changed as a result of the reform.

The intuition of the model is as follows. An industry wide quota regime encourages boats to "race" for fish early in the season. A high per-period fish capture early in the season in turn decreases the price of fish and thereby allows less efficient fishmeal plants to survive. When boats' incentive to race for fish is removed with the introduction of individual quotas, fishing is spread out in time, the price of fish increases and less efficient plants are forced to reduce their production or exit the industry.

The model consists of two sectors: homogeneous fishing boats, who capture and sell fish, and heterogeneous fishmeal plants, who buy fish to use as an intermediate good and sell fishmeal on the international market. We assume that the price of fishmeal is fixed, and that the price of fish is determined in equilibrium based on the contemporaneous demand for and supply of fish.

Fishing boats. Our specification of the boat sector follows Clark (1980) and subsequent research. There are N identical boats, who capture fish (q_i) as a function of (costly) effort e_i and the stock of fish x, according to $q_i = \gamma x e_i$, where γ is a constant. Boats face an increasing and convex cost of effort $c(e_i)$, and a decreasing inverse market demand $p(q)$. Within each season, the fish stock declines according to the amount captured, that is $x(t) = x_0 - \int_0^t \gamma x(t') \sum_i^N e_i(t') dt'$.

Let the maximum length of the season under any regulatory regime be T. We first consider the case of an industry wide total allowable catch (TAC) quota, with magnitude H.[35] We take boats to be small relative to the industry, and assume they take the path of prices $p(t)$ and the fish stock $x(t)$ as given. Each boat chooses $e_i(t)$ for all t to maximize:

$$\pi_i = \int_0^{t^*} [p(t)\gamma x(t) e_i(t) - c(e_i(t))] dt \tag{5}$$

which gives optimal effort $e_i^*(t)$ defined by the first order condition $c_i'(e_i^*(t)) = p(t)\gamma x(t)$. Under the TAC regime, boats simply choose effort to equate marginal revenue and marginal costs, without internalizing their impact on the fish stock.

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[35] We focus on situations where the quota binds. The season ends when the total quantity of fish captured is equal to the industry quota H.

We next turn to the individual quota regime (ITQ). We assume that each boat is assigned a quota of H/N. There is no fixed t^*; instead each boat implicitly chooses a path of effort that determines when their quota is exhausted (time $\tilde{t}$) – an optimal control problem for each boat's cumulative catch, $y_i(t)$. Each boat solves:

$$\max \int_0^{\tilde{t}} [p(t)\gamma x(t)e_i(t) - c(e_i(t))]dt \tag{6}$$

subject to $\frac{dy_i}{dt} = \gamma x(t)e_i(t)$ for $0 \leq t \leq \tilde{t}$, $y_i(0) = 0$, $y_i(\tilde{t}) = H/N$, and $\tilde{t} \leq T$. This gives $c'(e_i(t)) = (p(t) - \lambda_i)\gamma x(t)$ and $\frac{d\gamma_i}{dt} = -\frac{\partial \mathcal{H}}{\partial y_i} = 0 \Rightarrow \lambda_i$ constant.[36] If the quota binds, $\lambda_i > 0$.

λ_i represents each boat's internalization of the reduction in season length generated by an additional unit of effort. We can write the inverse demand in equilibrium in terms of the individual effort decision and stock of fish. We can then rewrite the first order conditions (with e^* representing the optimal effort level of a boat under the TAC regime, and $\tilde{e}$ representing the optimal effort level under the ITQ regime) as $c'(e_i^*(t)) = p(\gamma x(t)e_i^*(t))\gamma x(t)$ for $t \leq t^*$ and $c'(\tilde{e}_i(t)) = [p(\gamma x(t)\tilde{e}_i(t)) - \lambda_i]\gamma x(t)$ for $t \leq \tilde{t}$.

With λ_i in hand the effort decision at any t is determined by $x(t)$ at all points. It is thus helpful to consider each boat as simply solving a static problem (at any t) that differs under the two regimes as follows:

$$c'(e_i^*) = p(\gamma x e_i^*)\gamma x \tag{7}$$

$$c'(\tilde{e}_i) = [p(\gamma x \tilde{e}_i) - \lambda_i]\gamma x \tag{8}$$

These two equations imply that (a) facing an equal stock of fish x, effort at any t must be weakly higher in the TAC regime, and (b) fish capture is decreasing in the stock of fish under both regimes.[37] Together (a) and (b) imply that the highest fish capture, and lowest price, occur under the TAC regime (when the stock of fish is at its initial x_0). Finally, (c) the fish stock must always be weakly higher under the ITQ regime than under the TAC regime. Hence, the season must be longer under the ITQ regime.[38]

Fishmeal plants. We now turn to the plant sector. There is a mass M of fishmeal plants with heterogenous marginal costs that require one unit of intermediate good q to produce each unit of the homogeneous final good q^f. The price of the final good is normalized to one. The price of the intermediate good at time t is $p(t)$. Let plant j's marginal cost be given by:

$$MC_j(q^f, p(t)) = MC(q^f) + \alpha_j + p(t) \tag{9}$$

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[36] The Hamiltonian is: $\mathcal{H} = p(t)\gamma x(t)e_i(t) - c(e_i(t)) + \lambda_i \gamma x(t)e_i(t)$.

[37] Suppose, for the TAC regime, that $x > x'$, but $\gamma x' e_i' \geq \gamma x e_i$. Then $e_i' > e_i$, so $c'(e_i) < c'(e_i') = p(\gamma x' e_i')\gamma x' < p(\gamma x e_i)\gamma x = c'(e_i)$. An identical argument holds for the ITQ regime.

[38] Note that a necessary condition for $x^*(t) > \tilde{x}(t)$, for some t, is that there be some x such that the equilibrium effort at fish stock x is higher under the ITQ regime than under the TAC regime.

where α_j is a plant-specific constant. If firms share common technology outside of the α_j, the minimum average cost for each firm can be described as $r + \alpha_j + p(t)$, where r is the minimum average cost for a firm with $\alpha_j = 0$ and facing 0 cost of the intermediate good. Firm j produces some positive amount so long as $r + \alpha_j + p(t) < 1$. This means that as firms face higher input prices $p(t)$, the less efficient firms – those with high α_j – decrease production and eventually drop out of the market. Each firm has a threshold price

$$p_j^* = 1 - r - \alpha_j \tag{10}$$

above which it will not produce. Let p_j^* be distributed among firms in the industry on [0,1] according to $F(\cdot)$. For firm j, denote demand by $\tilde{q}(p(t), p_j^*)$ (where demand is 0 for $p(t) < p_j^*$). We can then describe the market demand $q(p(t))$ by:

$$q(p(t)) = M \int_{p(t)}^{1} \tilde{q}(p(t), p_j^*) dF(p_j^*) \tag{11}$$

Under standard assumptions, this gives decreasing market demand. As discussed above, the highest per-period production, and lowest price, occur under the TAC regime. For fishmeal plants, this implies that (d) a greater mass of plants have non-zero production (at some point in the season) in the TAC regime than in the ITQ regime, and (e) the plants that produce in the TAC regime but not in the ITQ regime are those with the lowest p_j^*, that is, those with the highest marginal cost. We test the model's predictions in the next section.

6.2 Industrial response to the ITQ reform: empirical evidence

The 2009 ITQ reform is widely seen as a success. The fishmeal industry reported an increase in profits *and* improvements in the fish stock.[39] Any positive effects on the sustainability of the fish stock likely came primarily through changes in the *intensity* of fishing – capture of juvenile fish fell (Paredes and Gutierrez, 2008) – as the reform did not target total capture. Most ports saw minor decreases in production after the reform came into effect, while two ports expanded considerably, as seen in Figure V. On average production fell. These changes reflect a combination of factors.[40]

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[39] Adriana Giudice, CEO of Austral Group (one of Peru's "big seven" fishmeal companies), in a 2011 interview with the International Sustainability Unit (an NGO) explained: "Since the 1990s, we have had a stable system of setting total catches based on stock assessments [...] However, this system brought a major increase in the fleet [...] some days 150,000 tons of fish were fished, putting the biomass under pressure [...] in this race for the resource. In 2009, the government introduced an individual quota system, supported by most of the companies [...] The fishing season has been extended [...] and average catches per day reduced to 30,000 tons [...] Austral now owns seven percent of the quota for the northern stock, and four percent of the southern stock [...] it costs us less to catch the same amount of fish [...] The fish we catch arrives fresher as there is no need to catch fish intensively and boats do not need to queue to come into port for unloading" (International Sustainability Unit, 2011).

[40] The total allowable catch continued to be set by the regulatory authorities after the reform, likely reflecting economic and political considerations in addition to estimates of fish stocks. Production was unusually low in 2010 due to El Niño. Consolidation in the industry, and how the boats and plants that exited or expanded production were selected, may also have affected total production.

Natividad (2014) documents that the price of anchovy rose after the reform, as predicted by our theoretical framework. To test if firms responded to the new regulations as predicted by our model, we now make use of administrative production registries.

The most noteworthy change in the industry after the reform was in the time profile of production. Consistent with our framework's predictions, the introduction of ITQs led to longer production seasons, as seen in Figure VI. Fish capture and therefore production of fishmeal was spread out in time as boats' incentive to rapidly capture as much as possible of the TAC early in the season was removed. Production early in the season was considerably greater before the reform, but the decline in output over time was less steep after the reform.[41]

As seen in the top panel of Figure VII, the reform also led to considerable consolidation in the industry. The number of active plants began a steady decline in 2009. It thus appears that the increase in the price of fish after the ITQ reform came into effect led some plants to exit the market, as predicted by the framework above.

The bottom panel of Figure VII shows the intensive margin corresponding to the extensive margin in the top panel. For any date during the first season after the reform (2009) and the corresponding season in 2008, the figure plots the number of plants in the top and bottom quartiles (of 2009 production days) that were producing. Before the reform, the longest– and shortest–producing plants produced for about the same period of time. After the reform, bottom-quartile plants (that did not exit the market) began to decrease or stop production mid-season, while top-quartile plants continued to produce. This time pattern is consistent with the framework above, which predicts that, after the reform, plants will gradually exit production as the season progresses and the price of fish increases.

Figure VIII shows that the plants that produce for comparatively longer periods after the reform tend to be the efficient plants. In the top panels we plot production and production days after the reform against plants' pre-reform output (of fishmeal) / input (of fish) ratio (a proxy for cost discussed in Sub-section 7.3). While the pattern is noisy,[42] a clear upward slope emerges. Similarly, the bottom panels show the average number of production days before and after the reform for efficient versus inefficient *ports*, noting that a plant's costs are partly determined by its location. It is clear from the figure that plants in efficient ports expand production across time after the reform, while plants in inefficient ports do not. The plants and ports that expand production do so in the time dimension, consistent with the model and as expected.

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[41] Note that the pause in fishing mid-season in the pre-reform regime was due to a regulatory rule that was removed with the ITQ reform. Before the reform, the seasonal TAC had two components; a total amount that could be fished before a specified "pause date" (this sub-quota was reached long before the pause date due to the race for fish), and a second amount that could be fished only after a specified "recommence" date. The removal of the pause rule contributed to production being spread out in time after the reform, along with the forces highlighted in our theoretical framework.

[42] An important third factor not accounted for here is the largely unpredictable movement of the anchovies.

6.3 How should we expect the industrial response to the ITQ reform to affect the industry's impact on health?

On the basis of the evidence in Sub-section 6.2, we conclude that, from a health perspective, the fishmeal industry's response to the 2009 ITQ reform first and foremost led exposure to fishmeal production to be spread out in time. This happened both because boats evened out their fishing activity, leading to a dispersion of plant production everywhere, and also because market share moved from some plants (and ports) to others, with those plants and ports that expanded doing so in the time dimension.

How should we expect such a change in the "distribution" of fishmeal production to affect the industry's impact on health? This will depend both on (a) the "pollution production function" – how the amount and profile of air pollution generated depends on the profile of plant production, and on (b) the health production function – how health depends on the level and duration of air pollution exposure. We are aware of no existing evidence on (a), but find it most plausible to generally expect the amount of pollution emitted at a given point in time to be either concave (if, for example, there is a fixed pollution cost to turning on the machines and (pollution) returns to scale are limited) or linear in the level of factory production.

When it comes to the health production function, the existing literature analyzes the underlying dose-response and duration-response relationships separately. Chen et al. (2013) presents convincing evidence of much bigger effects on health and mortality of *sustained* exposure to high levels of air pollution than (the effects found elsewhere of) short-term exposure. Chay and Greenstone (2003) find evidence consistent with concavity in the function relating infant mortality to the intensity of air pollution. Pope III et al. (2011) summarize the primarily correlational epidemiological evidence on dose-response and duration-response for cardiovascular mortality risk.[43] The authors conclude that "the evidence suggests that...longer duration exposure has larger, more persistent cumulative effects than short-term exposure, but the highest marginal effects occur with relatively short-term exposures most proximal in time. With regards to intensity of exposure, very steep, near-linear, exposure-response relationships are observed for low to moderate exposures and there is a flattening out or leveling off of the exposure-response function at very high exposures" (Pope III et al., 2011, p. 1). While no existing research convincingly compares the health effects of a *given* amount of pollution when concentrated versus spread out in time,[44] the existing evidence is thus arguably consistent with a health production function shape in which dispersing air pollution over time can exacerbate the impact on health.

In Table VI we show results from running (1) and (2), with the change that we include *both* production days and total production interacted with the "Near Plant" indicator. While the results are noisier due to the high correlation between the two variables, it appears that days of production are more important than the total amount produced for the impact on health, especially in the 90

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[43] The authors point out that cardiovascular and pulmonary diseases have "substantial common co-morbidity" and can therefore be grouped together and evaluated as cardiopulmonary diseases.

[44] Pope III et al. (2011) point out that "there are likely important risk trade-offs between duration and intensity of exposure" (Pope III et al., 2011, p. 13).

day window and for adults. We thus hypothesize that the move from "short, sharp" to "long, low" production after the ITQ reform worsened the impact of the fishmeal industry on health.

7 The 2009 ITQ reform, Fishmeal Production, and Health

7.1 Effect of the 2009 ITQ reform on health

In this section we investigate how the 2009 ITQ reform affected the fishmeal industry's impact on health. The summary statistics in Table I hint at our results. Most health outcomes worsen in fishmeal locations after the reform. While there is also a deterioration in health in non-fishmeal locations (a pattern that is likely an artifact of the narrow "treatment radius" used, as discussed above) the decline is considerably greater in fishmeal locations.

As described in Section 4, we employ a difference in differences approach comparing fishmeal and non-fishmeal locations before and after the reform took effect. Table VII presents the results. In the top panel, in which we limit the sample to the last year before and first year after the reform, we see respiratory hospital admissions increase by 7.3 percent in fishmeal locations, relative to non-fishmeal locations, after the reform. For adults, we see large and significant effects on health, with the likelihood of reporting a health issue increasing by over 10 percent, and medical expenditures by 23.9 percent, after the reform. We see even bigger effects for children, with the incidence of "Any Health Issue" increasing by 40 percent for children ≤ 5 and 79.2 percent for children ≤ 1, and coughs increasing by 58.7 percent for children ≤ 1.

We interpret these effects of the 2009 ITQ reform as being due to a post-reform change in the fishmeal industry's impact on the health of the local population. Is such an interpretation consistent with the direct effects of fishmeal production on health estimated in Section 5.1? Suppose that what matters most for the industry's impact on health is the number of days of production in the recent past, as e.g. the findings in Table VI suggest. Table VII suggests that each hospital admits an additional 12.24 patients for respiratory diseases per month after the reform. The findings in Section 5.1 imply that an additional day of production during the last 90 days generates 0.22 additional admissions for respiratory diseases per hospital, which in turn suggests that approximately 56 additional days of production would be necessary to generate the reform effect estimated here.[45] Chimbote and Callao, the largest fishmeal port in terms of production and population respectively, saw an additional 71 and 45 days of production in 2009 relative to 2008, for example. While this back-of-the-envelope calculation is presented for illustrative purposes,[46] it highlights that the findings in Section 5.1 suggest that the mid-2009 deterioration in health estimated here was plausibly a direct result of a change in the fishmeal industry's impact on health.

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[45] Similarly, our estimates imply that an additional day of production gives a 0.1 percentage point increase in the probability of "Any Health Issue" for adults. The restimated reform effect is 5.9 percentage points, which then translates into 59 additional days of production.

[46] For example, the identification strategy used in Section 5.1 can only pick up health effects of fishmeal production that occur within 90 days after production ends. The estimates discussed in this section capture the (change in) the total health effects of persistent exposure to polluting plant production after the reform.

7.2 Robustness

The middle panel of Table VII presents results from a regression that is identical to the one in the top panel, except that we additionally control for $FishmealLocation$ specific time trends. Their inclusion has little effect on the reform effect estimated using survey outcomes, but the estimated reform effect on respiratory hospital admissions increases somewhat.

In the bottom panel of Table VII, we re-estimate the reform effects including data from the last two years before and first two years after the reform. Again the significance and magnitude of the coefficients is similar to the estimates in the top panel, with some changes for specific outcomes (for example, the reform effect on cough becomes significant for children 5 and under, but loses significance for children 1 and under). The estimated reform effects are also robust to varying the "treatment radius" around ports used to define fishmeal locations.

Finally, Figure IX shows trends in health outcomes in fishmeal and non-fishmeal locations before and after the reform took effect. We see similar trends in the two groups before the reform, suggesting that the identifying assumption of parallel trends holds. We also see differential jumps in all seven healths outcomes in fishmeal locations when the reform takes effect. We conclude that the estimated worsening of the fishmeal industry's impact on health after the 2009 ITQ reform is robust and likely reflects a causal relationship.

7.3 Understanding the effect of the 2009 ITQ reform on health

Why did the ITQ reform worsen the fishmeal industry's impact on health? Recall first that total production decreased after the reform and thus is unlikely to explain an exacerbated health impact. The estimated reform effects are robust to excluding the two ports that saw an increase in total, yearly production after the reform.

A first possibility is that the impact on health was due to changes in labor markets after the reform. As seen in Table VIII, the reform increased the probability of having a job for fishing workers, but had no significant effects in the sample as a whole. Labor market responses are unlikely to explain the aggregate health effect.

In Appendix Table A.V, we investigate how the ITQ reform affected health outcomes for fishing workers. We find no significantly different effect on fishing workers' health when compared to the rest of the population, suggesting that the adverse health impact of the reform estimated in the full sample is not driven by impacts on fishing workers' health.

We now investigate if the fishmeal industry's exacerbated impact on health after the reform was due to the change in the time profile of production, as we hypothesize. As seen in Subsection 6.2, the reform led to significant changes in the organization of production and industry dynamics, which in turn led production, on average across ports, to be spread out in time with the introduction of ITQs. The average change in the time profile of production seen in Figure VI masks considerable heterogeneity across locations, however. The North/Central region covers the large majority of the country (as seen in the map in Figure II). For this reason the theoretical framework above was built to match the regulatory system in place in the North/Central region before (and after) the reform, and we expect the full-sample industrial response to the reform discussed in Section 6.2 to largely reflect what occurred there. Indeed, ports in the North/Central region saw a striking increase in the average number of days produced per year, as predicted by the model and illustrated in Figure X. Typical examples include the port of Chimbote, which experienced 51 days of production in 2008 and 122 days in 2009, and the port of Huarmey, which experienced 52 days of production in 2008 and 83 in 2009.[47] Conversely, in the smaller southern region, fishing and fishmeal production instead became more concentrated in time with the introduction of fishing ban periods in conjunction with the ITQ reform, as seen in Figure X. For example, the port of Ocoña experienced 74 days of fishmeal production in 2008, and 42 in 2009.

We first compare reform effects in the North/Central region and the South. The top panel of Table IX shows results from a difference in differences in differences specification in which we interact the double difference term in (3) with an indicator for the household residing in the North/Central region. For respiratory hospital admissions and medical expenditures, the estimated coefficient on "Post-reform×Near Plant" is negative (beneficial) and significant for the South, and positive (adverse) and significant for the North/Central region. We similarly see a differential increase in "Any Health Issue" in North/Central (although the coefficient on "Post-reform×Near Plant" is positive also for the South).[48] Overall, the results in Table IX, with a deterioration in health in the North/Central region after the reform and signs of improvement in the South, supports the hypothesis that the fishmeal industry's exacerbated impact on health after the introduction of ITQs operates through changes in the time profile of production.

In a second and complementary test of the time-profile-of-production hypothesis, we exploit another key prediction of our model, namely that inefficient plants should exit or reduce production after the reform and efficient plants should expand. To relate changes in plants' production to health effects of the reform estimated at the port level, we need a proxy for plants' costs at the port level. We take advantage of the fact that we observe both input of fish and output of fishmeal and construct pre-reform, plant-level output/input ratios in 2008. With the objective of testing the hypothesis that days of production is the primary driver of the fishmeal industry's impact on health in a given location in mind, the proxy most closely tied to our model is the maximum "efficiency" (output/input ratio) observed among plants in the port before the reform.[49] As shown in Figure VIII, days of production increased considerably in more efficient ports and increased only slightly in less efficient ports when the ITQ reform took effect.

The bottom panel of Table IX shows results from a difference in differences in differences specification in which we interact the double difference term in (3) with a variable equal to the maximum efficiency observed among plants in a given port in 2008. The adverse health effects of the

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[47] The increase in days produced in the North/Central region occurred despite the fact that only two ports saw a non-negligible increase in total, yearly production – in Chimbote, for example, total production decreased.

[48] Child outcomes are not included in Table IX because we have insufficient observations in ENDES to estimate standard errors in difference in differences in differences specifications.

[49] The maximum output/input ratio observed among plants in a port is a proxy for the limits on efficiency imposed by the geography of that port, and hence provides a measure of the port specific component of costs. We have also tried alternative efficiency proxies; these give qualitatively similar results.

reform for adults are concentrated in locations with efficient plants; negative, though insignificant, health effects are seen for adults in locations with inefficient plants. Similarly, we see a large (but imprecisely estimated) increase in respiratory hospital admissions in ports with more efficient plants, but not in ports with less efficient plants.

The majority of ports with efficient plants are located in the North/Central region. Note, however, that plant costs predict both the response in days produced and in the health consequences of the reform also *within* the North/Central region. In Appendix Table A.VI we see adverse health effects that are bigger and more significant in efficient ports than inefficient ports in the North/Central region. Further, the strikingly different effects of the reform on health outcomes in the North/Central region and the South, and in locations with efficient versus inefficient plants are not driven by differential effects on incomes or labor market outcomes, nor on fishing workers' health.[50] We conclude that the concentration of adverse health effects in fishmeal locations where production days increased, due both to changes in regulatory incentives (the North) and industry dynamics (efficient ports) after the introduction of individual property rights, supports the hypothesis that the industry's exacerbated impact on health post-reform was due to changes in the time profile of production.

In Figure XI we plot the time profile of adult health issues and medical expenditures across time alongside the time profile of production, for the first season after the reform and the corresponding season the year before. We see clear spikes in health issues and medical expenditures associated with the two spikes in production before the reform. After the reform, when production decreases much more slowly as the season progresses, the incidence of health issues is steady at a high level throughout the five months depicted, and similarly for medical expenditures. The change in the time profile of health issues after the reform thus corresponds to the change in the time profile of production. The time patterns in Figure XI also suggest that more sustained exposure to fishmeal production can lead to health issues that continue after production has ended.[51] In sum, the geographical heterogeneity in the health effects of the reform, and the change in the time profile of health issues after the reform, strongly support the hypothesis that the introduction of ITQs affected health through changes in the time profile of production.

The across-port movements in market share after the reform intensify port level changes in the time profile of production and thus help us test our hypothesized explanation for the deterioration in health post-reform. However, the port-level average change in the time profile of production after the reform is affected by boats spreading out fishing in time to a much greater extent than by the movements in market share.[52] As seen in Figure V, only two ports saw a non-negligible

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[50] Appendix Table A.V shows that there is no significant differential effect across regions or high versus low cost ports on either health or labor market outcomes for those who work in the fishing industry.

[51] It appears that the longer production period in 2009 may have exacerbated and extended a post-production season spike in health issues. Such a spike occured in 2008 also, but to a lesser extent.

[52] Because post-reform movements in (the *level* of) production across ports were limited, market share moving towards more populous areas (see e.g. Fowlie, 2010), or those in which the impact on health of a given level of production (with a given time profile) is worse, is also unlikely to explain the negative average effect of the reform on health. For example, the overall reform effect is not explained by more efficient plants (that gain market-share post-reform) being more polluting / having a greater impact on health in general – we see adverse reform effects also

increase in the level of production after the reform, six saw a considerable decrease, while almost all ports (in the North/Central region) saw a significant increase in days produced after the reform. In most ports the ITQ reform can thus be thought of as spreading out fishmeal production over time without changing the total amount of production. Our findings indicate that such a dispersion worsens the impact of polluting plant production on health.[53]

In the next sub-section we investigate *why* plant production spreading out over time exacerbates the industry's impact on health.

7.4 Investigating why a dispersion in polluting plant production exacerbates health impacts

There are two obvious possible reasons why spreading out plant production over time could worsen health: that the total amount of air pollution generated in the "long, low" production scenario is greater than that in the "short, sharp" scenario, and/or that prolonged exposure to low levels of air pollution is worse for health than short-term exposure to higher pollution levels.[54] Importantly, these two possibilities are not mutually exclusive.

In Figure XII we plot the time profile of each of the four air pollutants in Lima alongside the time profile of production in Callao (the nearest port), for the first season after the reform and the corresponding season in 2008. In 2008, before the reform, there are clear spikes in the level of the four pollutants corresponding to the two spikes in production. For some of the pollutants, especially NO_2, there is also a moderate build-up in concentration after the second spike in production. After the reform, when production spreads out over time, the same happens to each of the four pollutants. The highest observed level of each pollutant is lower after the reform, but moderately high levels are sustained for longer periods, also after production ends. These patterns further reinforce the view that air pollution is the link between the time profile of production and the time profile of health in Figure XI.

Figure XIII plots air pollution against fishmeal production in the Lima area. The figure depicts how pollution concentration levels on a given day depend on the level of fishmeal production on the day in question. Although fishmeal production explains a modest proportion of the total variance in air pollution, the relationship between the two time series is increasing (consistent with the evidence in Table V), and appears linear. Linearity is consistent with the observed, overall changes in air pollution levels, which saw a marginal decrease post-reform (for all four air pollutants). Overall, Figure XIII suggests that the primary explanation why spreading out polluting plant production

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in inefficient ports in the North.

[53] We estimate very similar reform effects if we limit the sample to those 15 ports that saw a negligible change in the level of production after the reform, but lose significance because 2/3 of the sample live near the ports that saw bigger changes in levels of production.

[54] Note that the estimated reform effect is not explained by production expanding into periods of the year in which the impact of air pollution on health is worse. To check for this possibility we construct a "New Period" variable equal to one for those periods of the year in which non-negligible production took place after the reform but not before. We then estimate (1) and (2), additionally interacting "Fishmeal production × Near Plant" with "New Period" and using only post-reform data. We do not find worse health effects post-reform of fishmeal production during the "new" production periods relative to the periods on which production took place also before the reform.

over time exacerbates health impacts is not a corresponding increase in average pollution levels due to concavity in the pollution production function. The evidence indicates that a dispersion in air pollution over time lowers average levels of health due to non-linearity in the health production function.

8 Cost/benefit Analysis and Policy

In this section we discuss what our estimates imply about regulatory design and the 2009 ITQ reform's total costs and benefits. We have seen that the reform exacerbated the industry's impact on the health of the local population, but that the fishmeal companies reported an increase in profits and fish stocks post-reform. The increase in fish stocks was likely due to lower juvenile fish capture after the reform, when boats no longer "raced" for fish early in the season. There were likely several reasons for the increase in profits.[55]

In our cost/benefit calculations we include the increase in sector profits after the reform, as well as the (monetized) value of the deterioration in health.[56] We consider only the increase in disease episodes associated with a respiratory hospital admission and medical expenditures in the total health costs of the reform. We do not count the health issues measured in the ENAHO and ENDES surveys because it is difficult to estimate the monetary cost of "Any Health Issue", and because the extent to which the health issues reported in the surveys also led to hospital admissions and hence would be double counted if included is unclear.

We first need to estimate the increase in total sector profits. We obtained data on the profits of the fishmeal companies that are publicly listed from publicly available financial statements. To scale these up to a yearly, sector-wide estimate, we extrapolate based on the share of production the publicly listed firms account for in each year. The resulting estimate of the increase in sector-wide profit in the first post-reform year, relative to the last pre-reform year, is USD 219 million. (The details of the cost/benefit calculations are in Table X).

To calculate the total health costs of the reform, we start with the 55,516 additional respiratory hospital admissions caused each year (inferred from the post reform increase of 12.24 admissions per hospital/month estimated in Table VII). We convert the respiratory disease episodes caused to an equivalent number of "years lived with disability (YLDs)" using standard weights from the Global Burden of Disease Study 2010 (Murray, 2012; U.S. Environmental Protection Agency, 2010). Assuming conservatively that the estimated additional disease episodes did not result in increased mortality, our results imply that 5,681 disability-adjusted life year equivalents were lost due to the reform's impact on respiratory diseases. Finally, we use a conventional "value of statistical life (VSL)" method to monetize the DALYs lost (see e.g. Ashenfelter and Greenstone, 2004; Ashenfelter, 2006; Hall and Jones, 2007; Greenstone, Ryan and Yankovich, 2012; Leon and Miguel, 2015). As there are no existing convincing estimates of the value of a statistical life year in Peru, we use the

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[55] These include, for example, a decrease in overcapacity. See also Natividad (2014).

[56] Local incomes are not considered in our cost/benefit calculations as we find no significant effect of the reform on average incomes.

value estimated for Africans in Leon and Miguel (2015) – the only existing paper to estimate VSL in a developing country setting with revealed preference methods. We scale the estimate up based on GNI per capita in Sub-Saharan Africa and Peru with the commonly used elasticity estimated by Hall and Jones (2007). This gives a value of USD 52,358 per statistical life year in Peru. The per-year costs of the 2009 ITQ reform due to its impact on respiratory disease episodes estimated using this methodology is USD 297 million. To this we add the additional medical expenditures caused to arrive at a total, yearly health cost of the reform of USD 343 million.[57]

It thus appears that the costs of the 2009 ITQ reform in Peru, due to its impact on health, surpassed its benefits. While the methodology used to monetize the health costs rests on strong assumptions and the resulting numbers should be interpreted with caution, we note that our calculation probably underestimates the total health costs.[58]

To consider also the reform's impact on fish stocks, we can potentially use IMARPE data on stocks to inform how far into the future we should "project" the additional, yearly profits and health costs due to the ITQ reform. Figure XIV provides suggestive evidence that the reform succeeded at slowing the decline in the fish stock. While the cumulative gap between the additional health costs and profit due to the reform will obviously exceed the per-year gap, we prefer to count only the per-year gap.[59]

The most important take-away from this paper is that regulations should be designed to address all concurrent externalities simultaneously. Certainly our findings do not contradict the principle that externalities should be regulated directly rather than indirectly. Rather, the method and "level" of regulation used to restrict each externality should be optimally chosen *in equilibrium*, taking into account that e.g. a tax on one externality may affect the extent of another externality. In the specific case of air polluting plant production, our findings indicate that the expected influence of potential regulations on the time profile of production should be considered at the design stage. Our findings do not speak to the relative merits of the many regulatory methods that can be used to restrict or influence the time profile of production.[60]

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[57] If we alternatively use the VSL estimated for the U.S. by the EPA (Murray, 2012; U.S. Environmental Protection Agency, 2010) and equivalent scaling, we get a value of USD 22,548 per statistical life year in Peru, and a total, yearly health cost of the reform of USD 174 million. We prefer the estimate based on scaling up Leon and Miguel (2015)'s VSL for Africans to Peru's GNI per capita over the one based on scaling down the EPA's VSL for the U.S. because Peru's GNI per capita (in 2009 USD PPP) – USD 8,760 – is much closer to Sub-Saharan Africa's – USD 2,108 – than that of the U.S. – USD 47,420.

[58] We do not count health problems that do not lead to hospitalization, non-respiratory disease episodes, or effects on mortality.

[59] (i) We only have access to fish stock numbers at the regional (North/Central versus South) level, and, as seen in Figure XIV, the numbers can vary considerably from year to year (and also depend on e.g. the size of the total quota allowed). (ii) To what extent the increase in profits due to the reform will persist is unclear. (Comparing 2011 to 2006, Paredes and Gutierrez (2008) estimate that sector-wide profits increased by USD 144 million). (iii) Reasonable discount factors will in any case mean that later years will receive little weight in the cumulate cost calculation.

[60] Of course, regulations that seek to reduce the level of emissions per unit of production, such as filters or scrubbers, can also be used. (In Peru the government has struggled to convince/force the fishmeal industry to install such technologies (De La Puente et al., 2011)). Our findings suggest that the time profile of production affects health above and beyond the level of emissions.

9 Conclusion

This paper considers the interplay of industrial externalities and how regulation affect industry structure and firms' organization of production in a setting where externalities are multidimensional. We analyze the impact of Peru's industrial fishing sector, the world's largest, on the health of the country's coastal population.

Using both hospital admissions records and survey data on individual health outcomes, and exploiting government-imposed semi-annual production ban periods in a difference in differences approach, we find that the plants that convert the day's catch into fishmeal harm adult and child health through air pollution emitted in the process. We then analyze how and why the impact on health changed with a 2009 reform that introduced individual, transferable quotas (ITQs) for fishing boats so as to sustain fish stocks and maintain sector-wide profits (health was ignored in the regulatory design). We find that, on average across fishmeal locations, the adverse impact on health increased after the reform, leading to 55,000 additional respiratory hospital admissions and a deterioration in self-reported adult and child health.

While total fishmeal production fell slightly, the quotas removed boats' incentive to "race" for fish early in the season and led inefficient plants to decrease production or exit the market and efficient plants to expand production across time, as predicted by a two-sector model with heterogeneous plants. As a result, fishmeal production was spread out in time on average across locations. We show that the fishmeal plants' exacerbated impact on health after the reform is due to the shape of the health production function: at least in the Peruvian context, longer periods of exposure to moderate air pollution levels are worse for health than shorter periods of higher intensity exposure. The estimated benefits of the 2009 ITQ reform in Peru (increased profits and fish stocks) are surpassed by the costs of the negative impact on the population's health.

These results highlight that the common policy trade-off between duration and intensity of exposure to air pollution can be of first order importance. In the particular case of industries that rely on extraction of a common pool resource processed into a final product by polluting factories, policymakers face an additional trade-off. On the one hand, the objective of preventing depletion of the resource suggests "internalizing the externality" by giving market participants individual property rights. Quotas will tend to spread out production in time as the incentive to "race" for the resource is removed. On the other hand, the evidence in this paper suggests that the impact of pollution on health may be minimized by concentrating production in time. More generally, our findings highlight the risks of piecemeal regulatory design.

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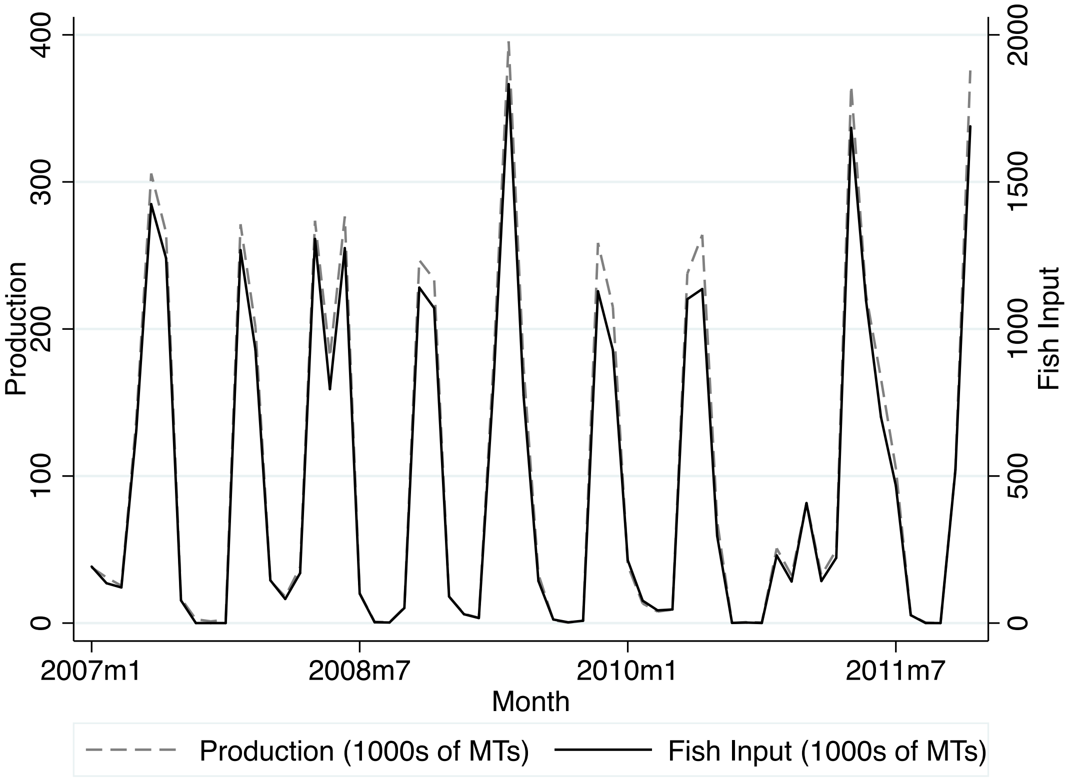
Tables and Figures

Figure I
Relationship Between Fishmeal Production and Input of Fish



Monthly port level fishmeal production (dashed line) and fish input (solid line), measured in 1000s of metric tons. Input based on daily boat level fish capture as weighed at fishmeal plants. Production based on monthly plant level reports.

Figure II
Location of Fishmeal Ports and Sampling Clusters

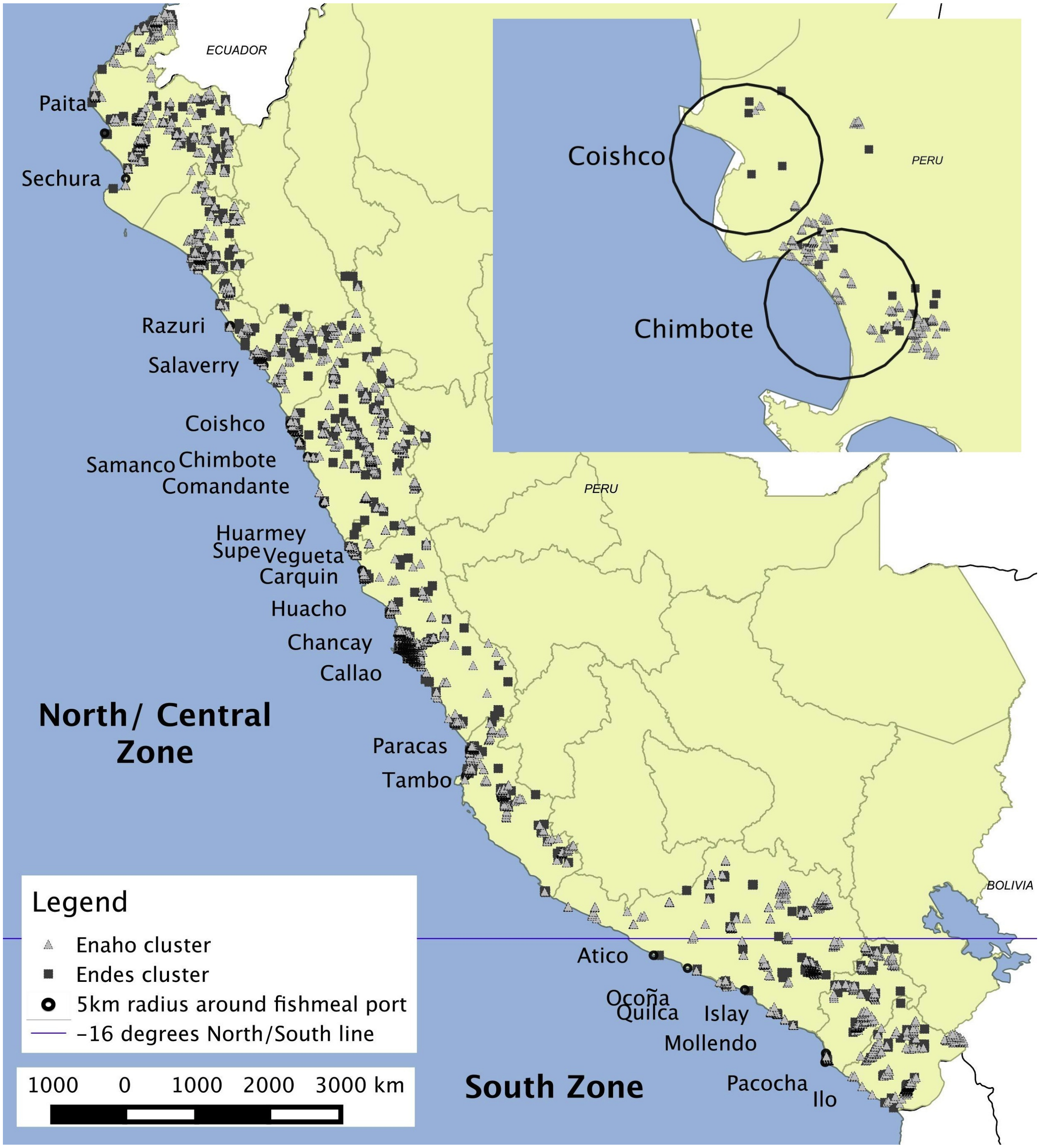
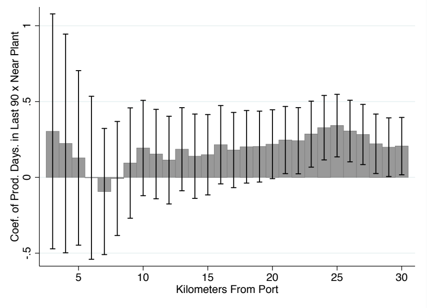
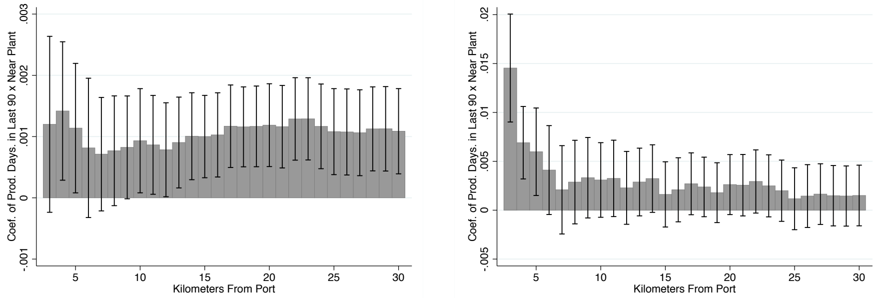


Figure III
Impact of Fishmeal Production on Health: Varying Treatment Radius

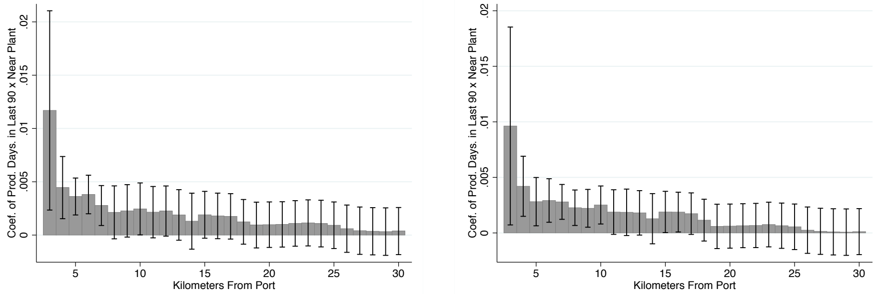
(a) Respiratory Admissions



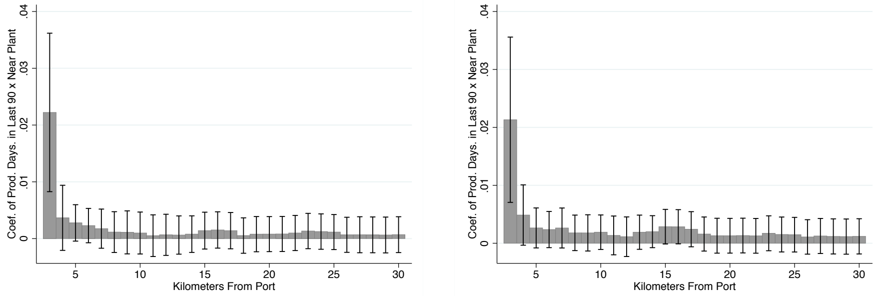
Adults


(a) Any Health Issue
(b) Log Medical Expenditure

Children (≤ 5)


(a) Any Health Issue
(b) Cough

Children (≤ 1)

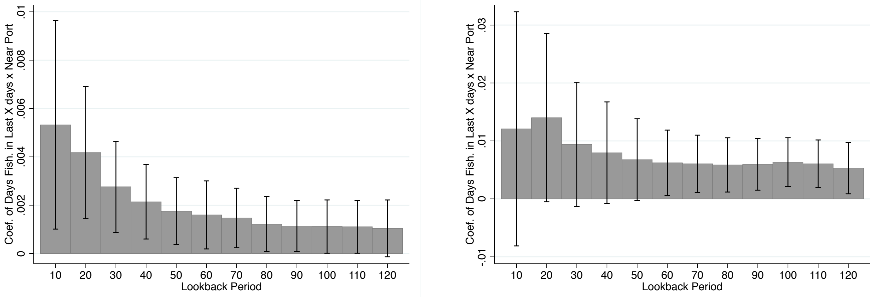

(a) Any Health Issue
(b) Cough

We plot the coefficient of "Production Days in the Last 90 Days × Near Plant", based on regressions similar to those in Table II. We allow the treatment radius that defines "Near Plant" to vary up to 30 kilometers and correspondingly vary the control group, defined as those living outside the treatment radius. 95% confidence intervals based on standard errors clustered as in Table II are shown.

Figure IV
Impact of Fishmeal Production on Health: Varying Lookback Window

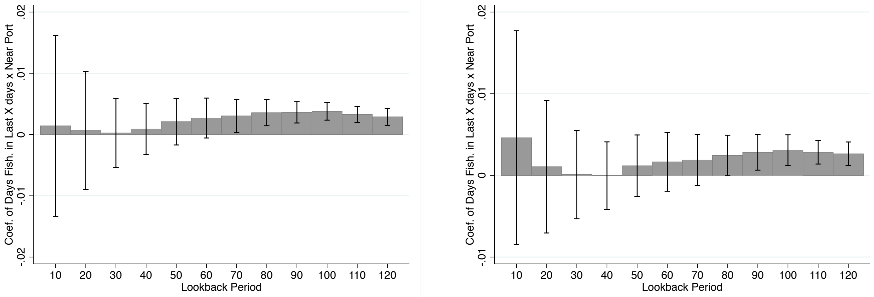
Adults

(a) Any Health Issue (b) Medical Expenditure



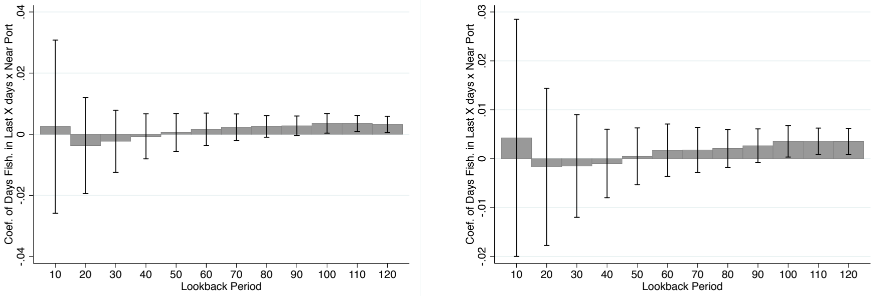
Children (≤ 5)

(a) Any Health Issue (b) Cough



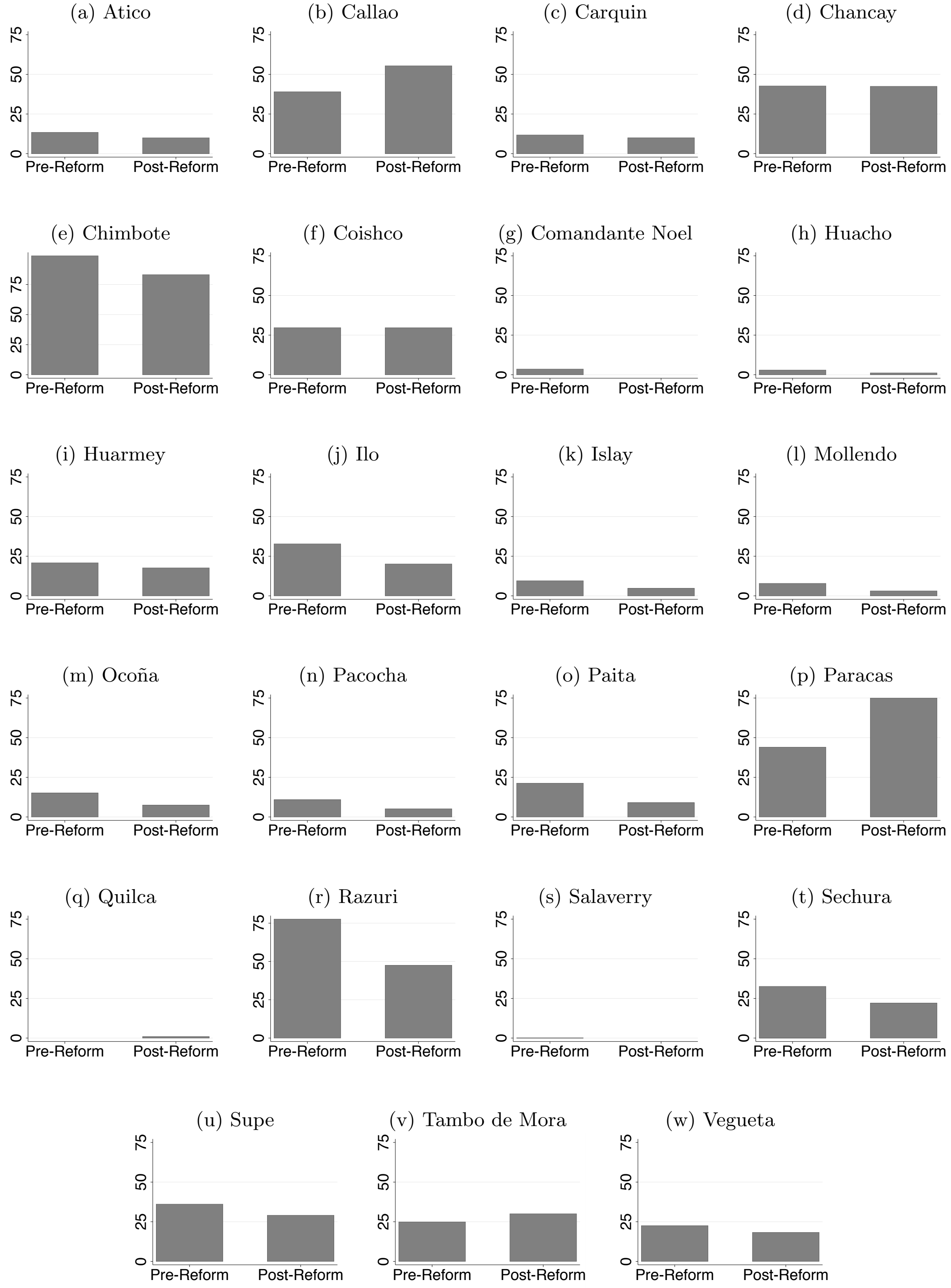
Children (≤ 1)

(a) Any Health Issue (b) Cough



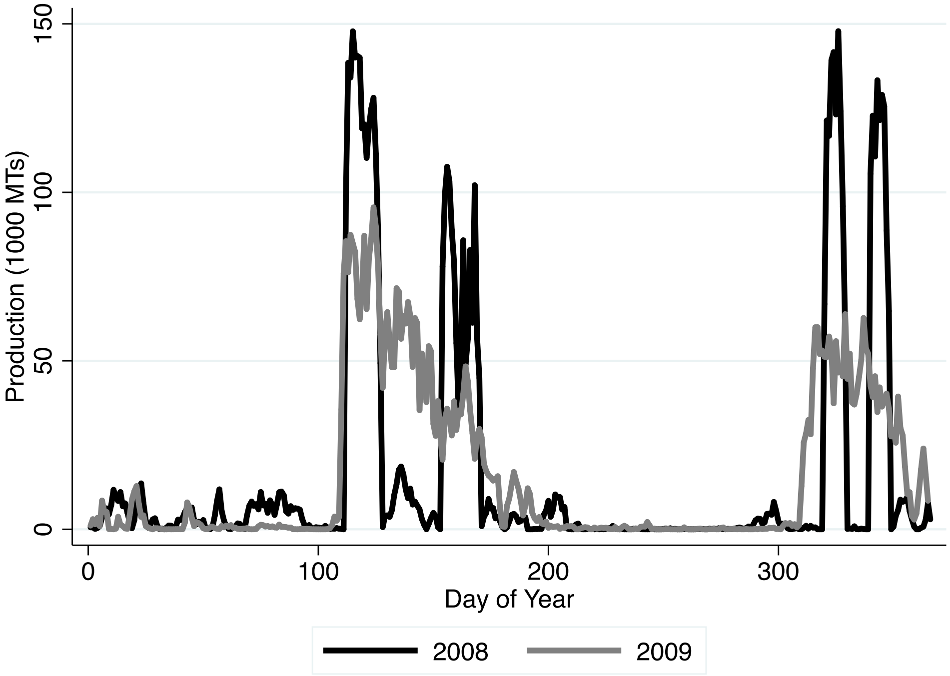
We plot the coefficient of "Production Days in the Last x Days × Near Plant", based on regressions similar to those in Table II. We allow the length of the lookback window "x" to vary up to 120 days. 95% confidence intervals based on standard errors clustered as in Table II are shown. Figures for hospital admissions are not shown as the data only allows for monthly variation in the lookback window.

Figure V
Port-Level Fishmeal Production Pre- and Post-Reform



Average yearly production levels by port in 1000s of metric tons, pre-and post-reform. There was no production in Quilca pre-reform.

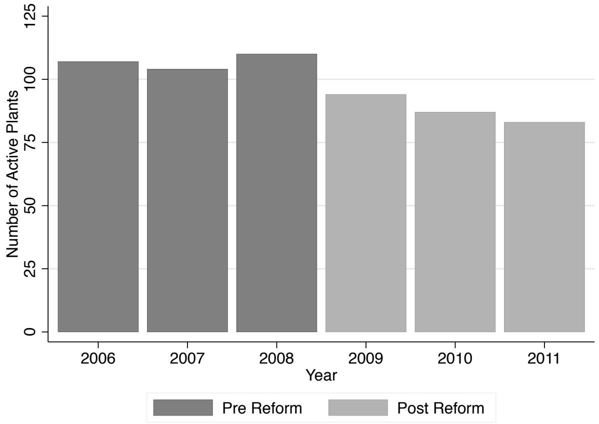
Figure VI
Time Profile of Fishmeal Production



Comparisons of production (measured as fish inputs) in 1000s of metric tons in 2008 and 2009. Before the reform, the seasonal regulation (TAC) had two components; a total amount that could be fished before a specified "pause date" (note that this sub-quota was reached long before the pause date due to the race for fish) and a second amount that could be fished only after a specified "recommence" date. The removal of the pause rule contributed to production being spread out in time after the reform, along with the forces highlighted in our theoretical framework.

Figure VII
Plant Activity Pre- and Post-Reform

Number of Active Plants Across Years

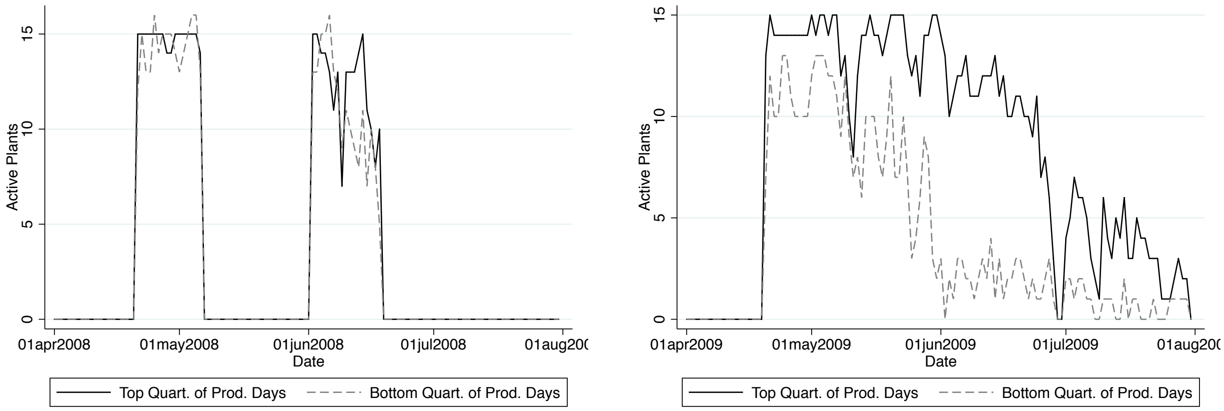


Number of Active Plants During the Season: Top vs. Bottom Quartiles of 2009 Production Days

Active Plants

(a) 2008

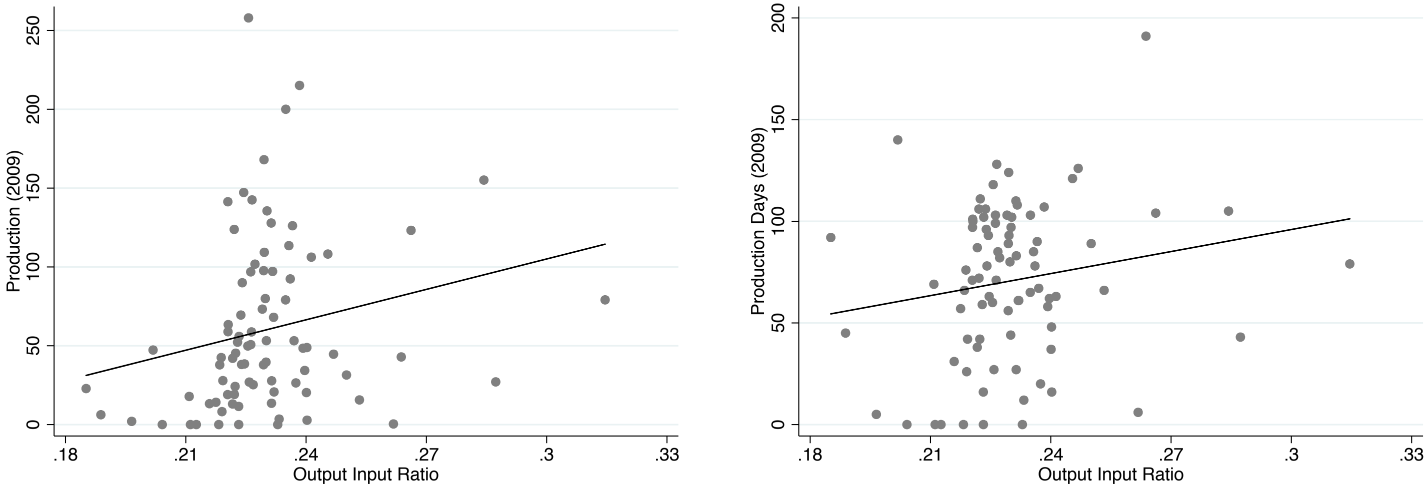
(b) 2009



Top figure plots total number of active plants by year, where a plant is considered active if it purchases fish input any day of the year. The lower figures plot the number of active plants during the first production seasons in 2008 and 2009. The solid line in each shows plants in the top quartile of production days in 2009, while the dashed line shows plants in the bottom quartile of production days in 2009.

Figure VIII
Production by Port and Plant Level Efficiency

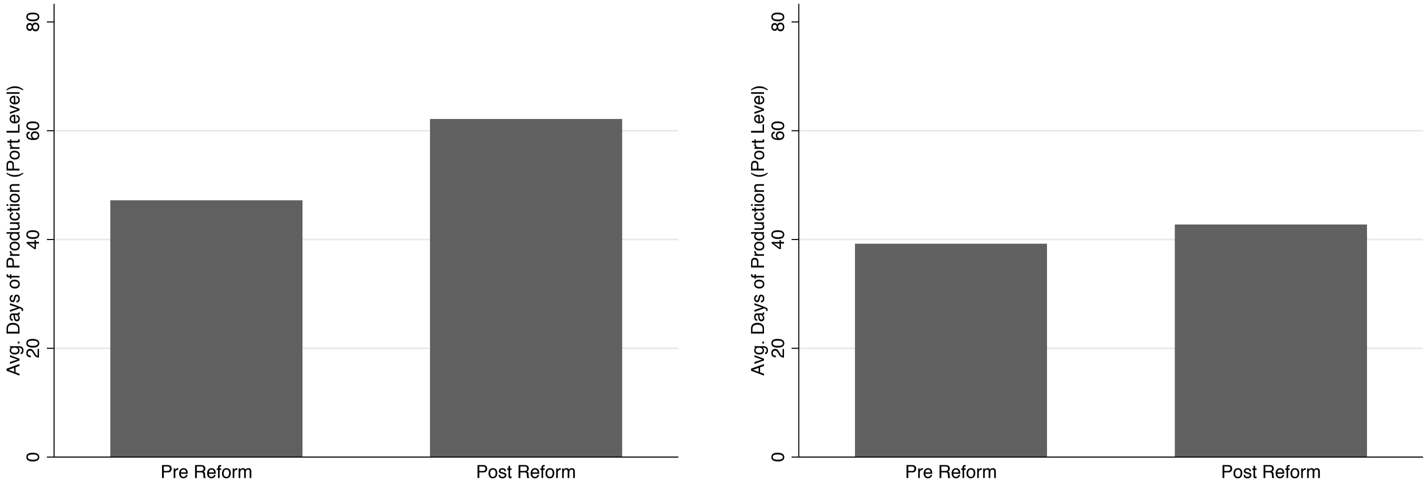
Fishmeal Production and Plant Level Efficiency



(a) Production

(b) Production Days

Average Port Level Days of Production by Efficiency: Pre-Reform vs. Post-Reform



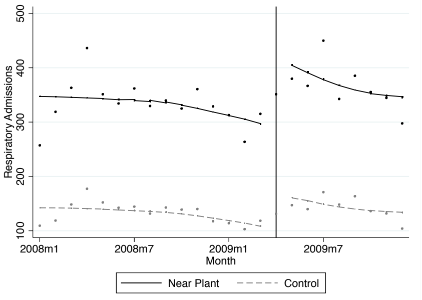
(a) Ports Above Median Efficiency

(b) Ports Below Median Efficiency

Top figures show the relationships between efficiency and 2009 production or production days. Bottom figures show average yearly days of production at the port level pre-and post- reform, split by port level efficiency. A production day is defined by > 1000 MTs of input at the port level. Efficiency is measured as output/input ratio (Fishmeal/Fish Input) for plants and the maximum port level output/input ratio for ports. In the top figures, we omit plants in the top and bottom 5% of efficiency

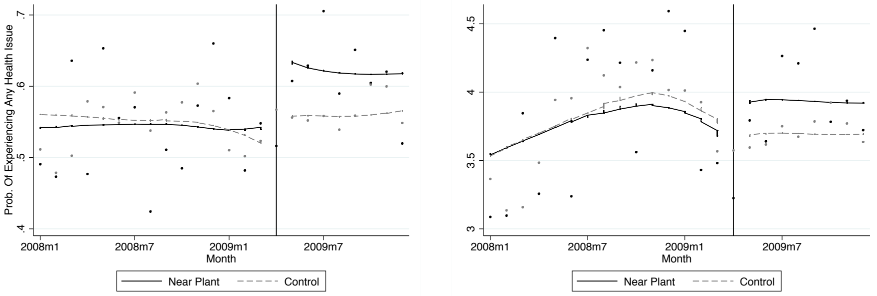
Figure IX
Plotting Health Outcomes Across Time Pre- and Post-Reform

(a) Respiratory Admissions



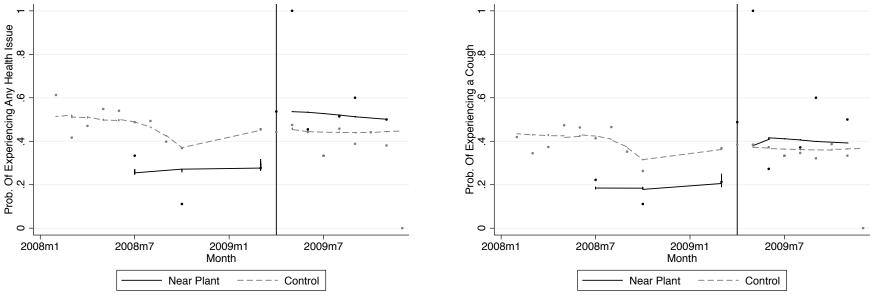
Adults

(b) Any Health Issue (c) Log Medical Exp.



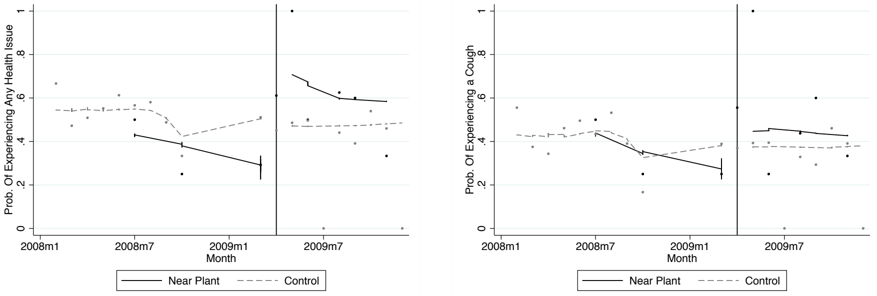
Children ≤ 5

(d) Any Health Issue (e) Cough



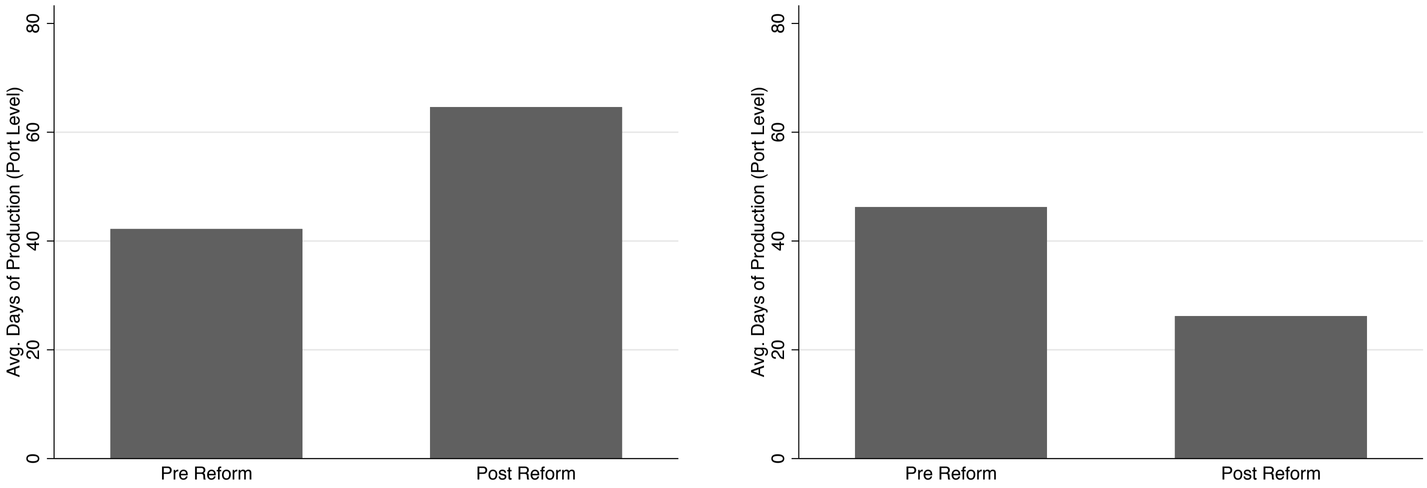
Children ≤ 1

(f) Any Health Issue (g) Cough.



Scatter plots and lowess smoothing of health outcomes across months. Black lines and dots are based on data for those living near plants, gray lines and dots are based on data for all others. Dots are monthly mean levels for each group. Adult data includes those over 13 years of age living in costal regions sampled in ENAHO (2008-2009), child data includes those under 6 years old living in coastal regions sampled in ENDES (2008-2009). Note that no clusters in ENDES sampled in the early part of 2008 were near a plant. Noisier graphs for child outcomes are in general due to smaller sample sizes for children. Smoothed separately before and after the start of the reform in the north region (April 2009). The small South region is omitted due to a later reform starting date and different regulatory change.

Figure X
Average Port Level Days of Production by Region: Pre-Reform vs. Post-Reform


(a) North/Central Region

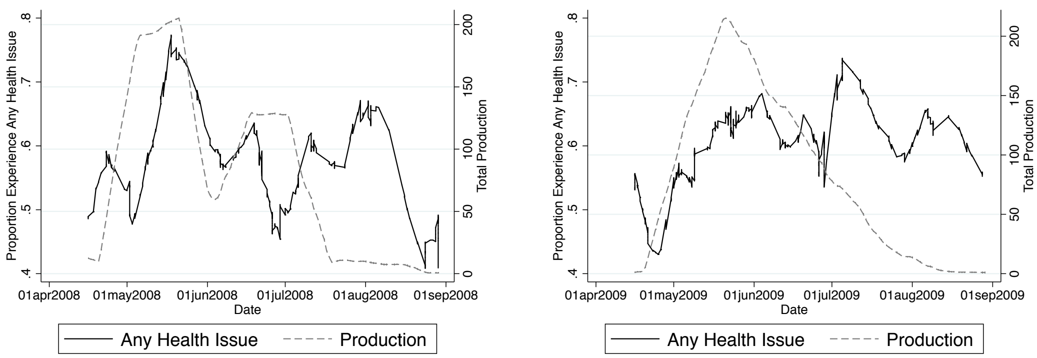
(b) South Region

Average yearly days of production at the port level. pre-and post- reform in the North/Central and South regions. A production day is defined by > 1000 MTs of input at the port level.

Figure XI
Time Profile of Health Outcomes and Production

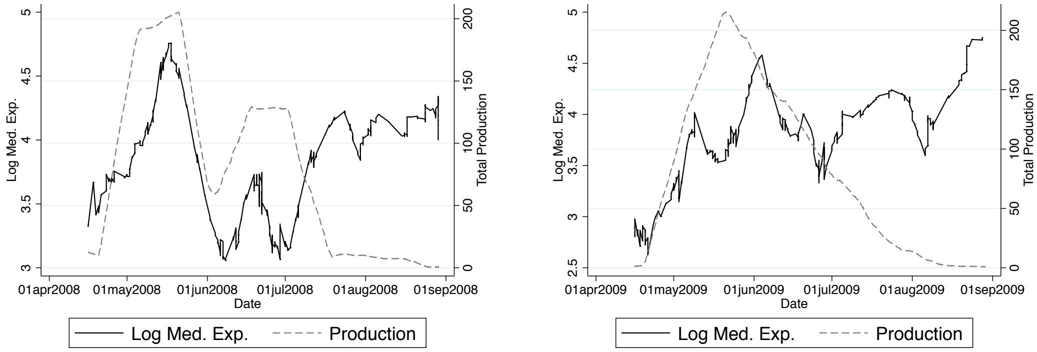
Adults: Any Health Issue

(a) 2008 (b) 2009



Adults: Medical Expenditure

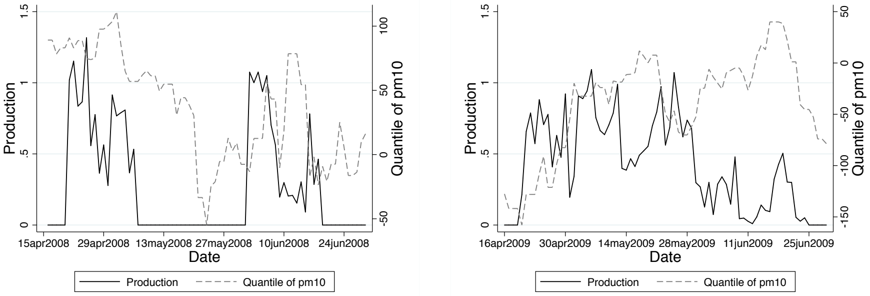
(a) 2008 (b) 2009



Average total production in last month across ports and average levels of health outcomes for adults plotted over time for the first seasons of 2008 and 2009. Survey data smoothed using a lowess smoother with bandwidth 0.01.

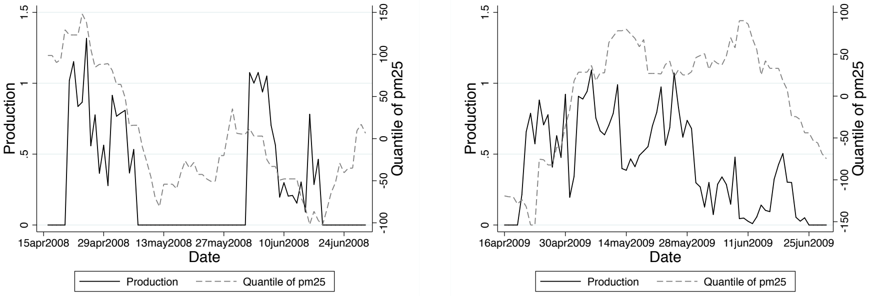
Figure XII
Time Profile of Production and Air Pollution in Lima

PM^{10}



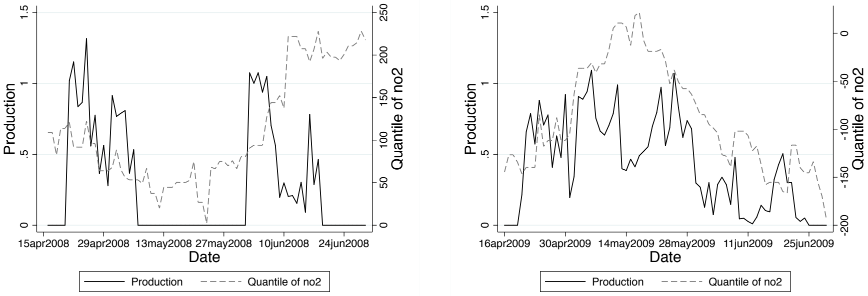
(a) 2008 (b) 2009

PM$^{2.5}$



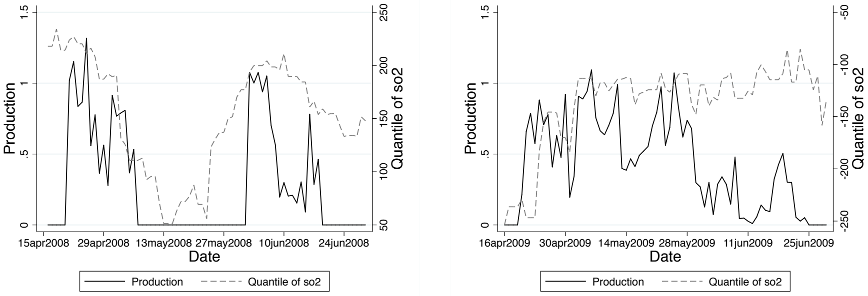
(a) 2008 (b) 2009

NO$_2$



(a) 2008 (b) 2009

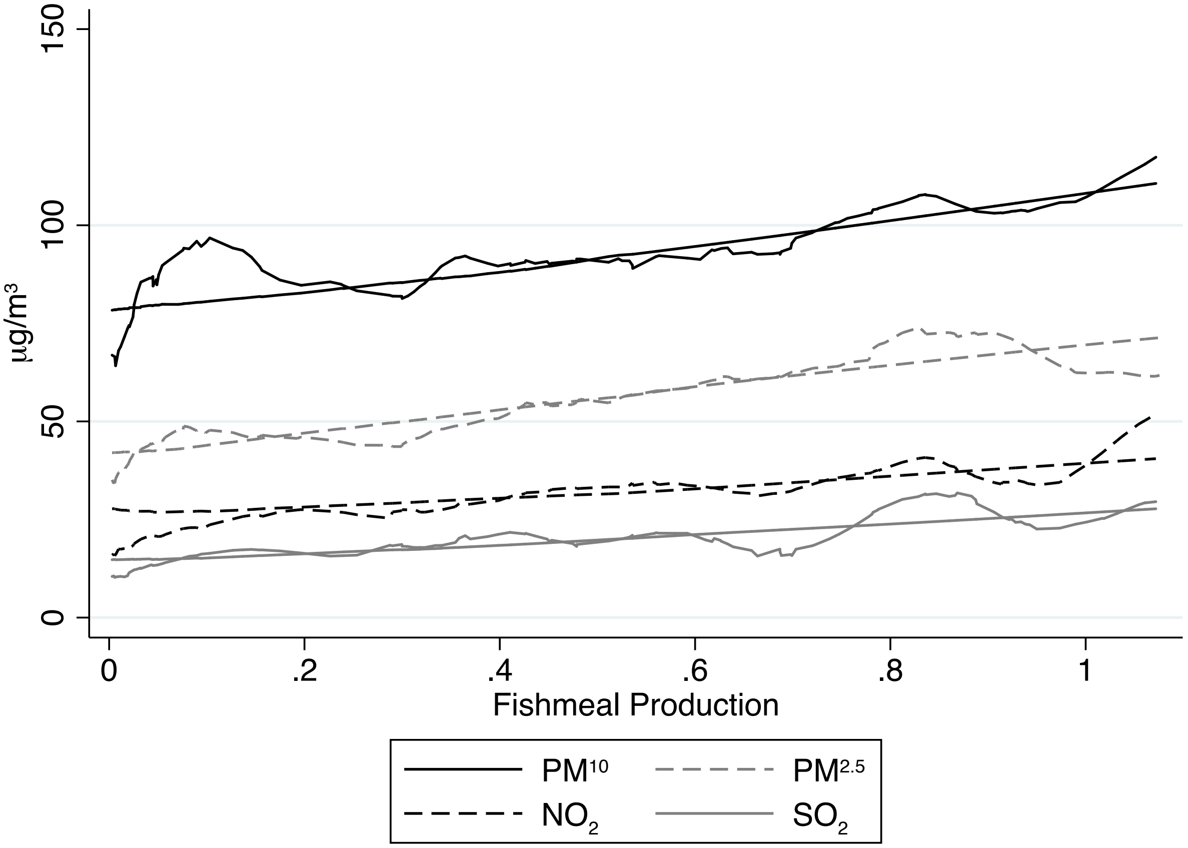
SO$_2$



(a) 2008 (b) 2009

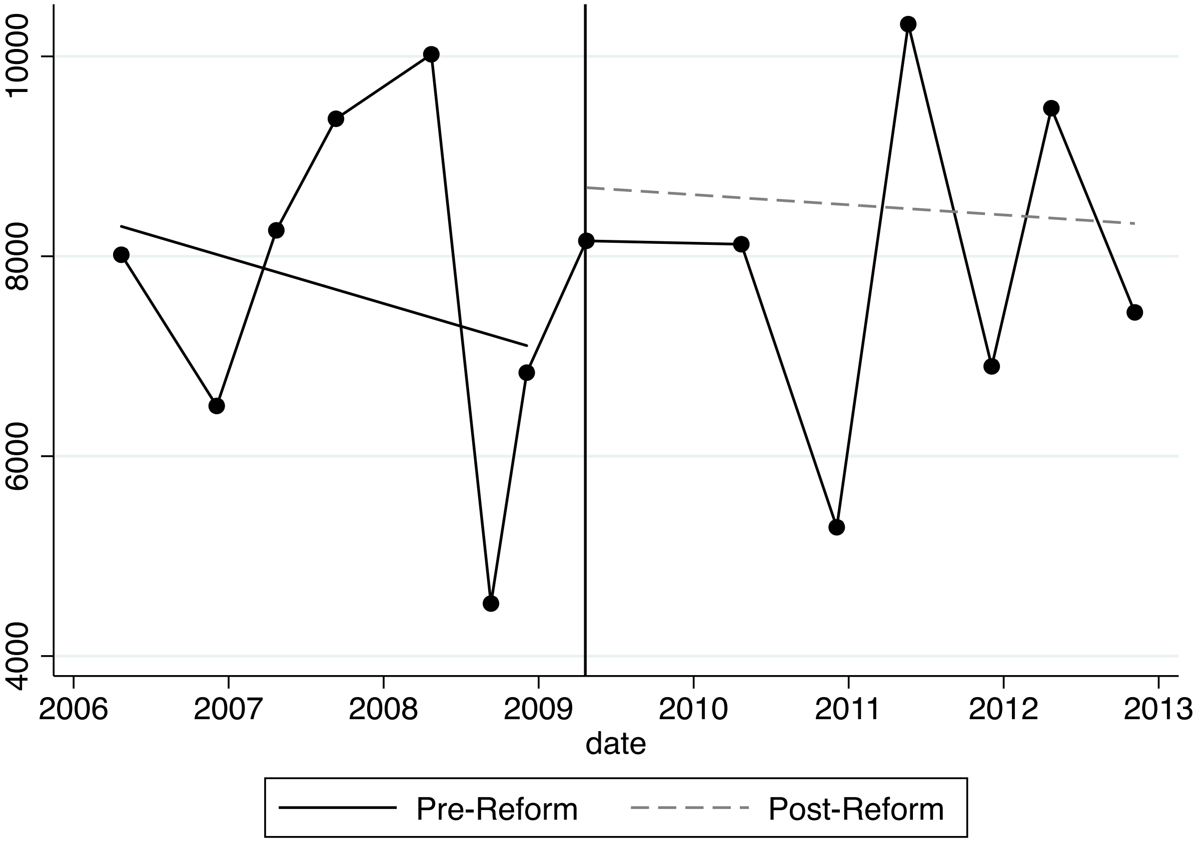
We plot production and pollution levels for the first season of 2008 and 2009 in the port of Callao and city of Lima. We present 10 day lead and lag moving averages of the time series of pollution plotted against total port level production. The pollution series was created by converting pollution levels to quantiles at each of five measurement stations, taking the mediant across stations, and demeaning at the monthly level.

Figure XIII
Daily Fishmeal Production and Air Pollution in Lima



Lowess smoothing of median pollutant levels across 5 air quality measurement stations in Lima (in $\mu g/m^3$) against daily fishmeal production in Callao (measured as inputs in 10,000s of MTs). We present each data series with two different levels of smoothing (bandwidths of 0.05 and 0.8, respectively). We omit observations in the top and bottom 1% of production.

Figure XIV
Anchoveta Stock Pre- and Post-Reform



Total biomass of anchoveta between 2006-2012 from IMARPE, with linear trends pre- and post-reform. We omit 2010 from the trend line estimation due to the occurrence of El Niño. Vertical line represents beginning of reform in North/Central region (April 20th, 2009).

Table I
Summary Statistics: Health Outcomes

	Health Outcomes															
	Near Plant				Control				Near Plant				Control			
	No Prod.		Prod. Season		No Prod.		Prod. Season		Pre-Ref.		Post-Ref.		Pre-Ref.		Post-Ref.	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Respiratory Admissions	316.2	328.4	331.0	343.7	124.6	169.6	127.9	181.4	322.4	338.9	322.3	327.2	125.6	175.7	124.7	169.4
Any Health Issue (Adults)	0.58	0.49	0.62	0.49	0.59	0.49	0.59	0.49	0.55	0.50	0.64	0.48	0.57	0.50	0.60	0.49
Log Medical Expend.	3.88	2.88	3.88	2.86	3.71	2.86	3.68	2.88	3.66	2.89	4.06	2.84	3.59	2.86	3.79	2.88
Any Health Issue (Children)	0.40	0.49	0.46	0.50	0.44	0.50	0.47	0.50	0.41	0.49	0.43	0.50	0.45	0.50	0.45	0.50
Cough	0.33	0.47	0.39	0.49	0.36	0.48	0.39	0.49	0.34	0.47	0.35	0.48	0.37	0.48	0.37	0.48
	Adult Labor Outcomes and Covariates															
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Has Any Job	0.58	0.49	0.57	0.49	0.64	0.48	0.64	0.48	0.56	0.50	0.59	0.49	0.63	0.48	0.65	0.48
Has 2nd Job	0.090	0.29	0.088	0.28	0.12	0.32	0.11	0.31	0.070	0.25	0.10	0.31	0.10	0.30	0.12	0.33
Total Labor Hours	28.5	28.5	28.5	28.7	30.4	27.4	30.6	27.6	29.2	29.3	27.9	28.0	30.6	27.8	30.3	27.2
Total Labor Income	3.52	3.17	3.41	3.19	3.42	3.14	3.51	3.15	3.36	3.13	3.56	3.21	3.40	3.09	3.50	3.18
Fishing Worker	0.084	0.28	0.068	0.25	0.025	0.16	0.027	0.16	0.082	0.27	0.072	0.26	0.027	0.16	0.025	0.16
Manual Laborer	0.26	0.44	0.26	0.44	0.37	0.48	0.34	0.47	0.27	0.44	0.25	0.44	0.35	0.48	0.36	0.48
Current. Lives in Birth Prov.	0.43	0.49	0.47	0.50	0.39	0.49	0.40	0.49	0.45	0.50	0.45	0.50	0.40	0.49	0.38	0.49
Current. Lives in Birth Dist.	0.60	0.49	0.63	0.48	0.59	0.49	0.63	0.48	0.62	0.49	0.61	0.49	0.62	0.49	0.59	0.49
Age	35.4	21.5	36.6	20.4	35.3	20.8	35.7	20.5	36.7	20.6	35.4	21.3	35.1	20.4	35.7	21.0
Male	0.43	0.49	0.45	0.50	0.44	0.50	0.44	0.50	0.45	0.50	0.43	0.49	0.44	0.50	0.44	0.50
Years of Education	9.87	4.21	9.69	4.29	9.21	4.60	9.47	4.48	9.64	4.27	9.90	4.22	9.32	4.54	9.30	4.57
Indigenous Language	0.078	0.27	0.11	0.31	0.13	0.34	0.13	0.34	0.099	0.30	0.088	0.28	0.13	0.34	0.13	0.34
	Child Covariates															
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age	2.43	1.42	2.53	1.40	2.49	1.43	2.49	1.43	2.41	1.38	2.50	1.43	2.49	1.44	2.49	1.43
Male	0.061	0.24	0.041	0.20	0.052	0.22	0.045	0.21	0.040	0.19	0.061	0.24	0.047	0.21	0.051	0.22
Mothers Years of Educ.	10.8	3.48	11.5	3.09	9.53	4.16	9.72	4.04	10.9	3.32	11.1	3.38	9.58	4.21	9.60	4.05
HH Asset Index	0.85	0.66	0.95	0.64	0.30	0.94	0.44	0.91	1.04	0.64	0.80	0.64	0.54	0.91	0.21	0.91

Adult data from ENAHO (2007-2011), child data from ENDES (2007-2011) and hospital admissions from administrative data. Adults older than 13 and children under 6 living in coastal regions are included. All health outcomes excluding “Log Medical Expenditure” and counts of hospital admissions are binary. Income and medical expenditure are measured in Peruvian Soles. The share of sampled adults that report to work in “fishing” is actually slightly higher outside of the production season. The reason may be that many (boat and plant) industrial fishing workers work as artisan fishermen outside of the industrial season.

Table II
Impact of Fishmeal Production on Health

	Hospitals	Adults		Children: ≤ 5		Children: ≤ 1	
	Respiratory Admissions	Any Health Issue	Log Medical Expenditure	Any Health Issue	Cough	Any Health Issue	Cough
			Log Fishmeal Production in Last 30 Days				
Log Fishmeal Prod. in Last 30 Days	-2.340^{***} (0.555)	0.010^{***} (0.003)	0.006 (0.014)	0.002 (0.009)	0.000 (0.010)	-0.013 (0.014)	-0.018 (0.013)
Log Fishmeal Prod. in Last 30 Days x Near Plant	3.952^{**} (1.591)	0.019^{***} (0.006)	0.092^{**} (0.043)	0.014 (0.028)	0.014 (0.029)	-0.017 (0.049)	-0.006 (0.055)
			Log Fishmeal Production in Last 90 Days				
Log Fishmeal Prod. in Last 90 Days	-1.800^{***} (0.483)	0.006^{**} (0.003)	0.017 (0.014)	-0.001 (0.007)	-0.005 (0.007)	-0.015 (0.010)	-0.023^{**} (0.011)
Log Fishmeal Prod. in Last 90 Days x Near Plant	4.374^{**} (2.047)	0.010^{*} (0.006)	0.073^{**} (0.033)	0.041^{***} (0.015)	0.039^{**} (0.019)	0.051^{**} (0.023)	0.059^{**} (0.030)
			Production Days in Last 30 Days				
Production Days in Last 30 Days	-0.268^{***} (0.066)	0.001^{***} (0.000)	0.001 (0.002)	0.000 (0.001)	0.000 (0.001)	-0.002 (0.002)	-0.003^{*} (0.002)
Production Days in Last 30 Days x Near Plant	0.228 (0.174)	0.003^{***} (0.001)	0.010^{**} (0.005)	0.000 (0.003)	0.000 (0.003)	-0.002 (0.005)	-0.001 (0.005)
			Production Days in Last 90 Days				
Production Days in Last 90 Days	-0.172^{***} (0.038)	0.000^{**} (0.000)	0.000 (0.001)	-0.000 (0.000)	-0.001^{**} (0.000)	-0.001^{*} (0.001)	-0.002^{***} (0.001)
Production Days in Last 90 Days x Near Plant	0.219^{*} (0.116)	0.001^{**} (0.001)	0.006^{***} (0.002)	0.004^{***} (0.001)	0.003^{**} (0.001)	0.003^{*} (0.002)	0.003 (0.002)
Mean of Dep. Var.	160.7	0.59	3.71	0.45	0.37	0.49	0.38
N	141981	161773	161806	14684	14678	5748	5747
Hospital/Centro Poblado/District FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Near Plant FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HH Controls	No	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Hospital admissions measure total monthly admissions at the hospital level. Adult data includes those over 13 years of age living in costal regions sampled in ENAHO (2007-2011), child data includes those under 6 years old living in coastal regions sampled in ENDES (2007-2011). Last 30 or 90 days is calculated as last 1 or 3 months for hospital data. "Near Plant" is defined as 5 kilometers for survey data and 20 kilometers for hospital data. All specifications include a dummy variable for living near a plant. Adult regressions include controls for age, gender, native language and level of education. Child regressions include controls for age gender, household assets and mother's level of education. Hospital, adult and child specifications include hospital, Centro Poblado and district fixed effects respectively, with standard errors clustered at the same level. A "Production Day" is defined by $>$ 1000 MTs of input at the port level. Fishmeal production is based on daily inputs of fish, measured in 10,000s of MTs. "Respiratory Admissions" is a count, medical expenditure is measured in Peruvian Soles and all other dependent variables are binary. Mean of dep. var. gives unconditional mean for sample included in the corresponding regression. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table III
Impact of Fishmeal Production on Adult Health – By Job Category

	Non-Fishing Workers		Fishing Workers		Non-Fishing Workers		Fishing Workers	
	Any Health Issue	Log. Medical Expenditure	Any Health Issue	Log. Medical Expenditure	Any Health Issue	Log. Medical Expenditure	Any Health Issue	Log. Medical Expenditure
	Production Days in Last 30 Days				Production Days in Last 90 Days			
Production Days in Last 30 Days	0.001***	0.001	−0.002	0.000	0.000**	0.000	−0.001	−0.004
	(0.000)	(0.002)	(0.002)	(0.012)	(0.000)	(0.001)	(0.001)	(0.006)
Production Days in Last 30 Days x Near Plant	0.003***	0.009	0.003	0.040**	0.001**	0.006***	−0.000	0.010
	(0.001)	(0.006)	(0.003)	(0.017)	(0.001)	(0.002)	(0.002)	(0.009)
	Log Fishmeal Production in Last 30 Days				Log Fishmeal Production in Last 90 Days			
Log Fishmeal Prod. in Last 30 Days	0.011***	0.005	−0.019	−0.005	0.006**	0.016	−0.011	−0.014
	(0.003)	(0.014)	(0.018)	(0.102)	(0.003)	(0.014)	(0.017)	(0.097)
Log Fishmeal Prod. in Last 30 Days x Near Plant	0.020***	0.083*	0.017	0.341***	0.013**	0.074**	−0.037	0.052
	(0.006)	(0.047)	(0.031)	(0.128)	(0.005)	(0.033)	(0.038)	(0.156)
Mean of Dep. Var.	0.59	3.72	0.54	3.13	0.59	3.72	0.54	3.13
N	158456	158489	3317	3317	158456	158489	3317	3317
Centro Poblado FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Near Plant FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HH Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Data from ENAHO (2007-2011). Adults older than 13 living in coastal regions are included. "Near Plant" is defined as within 5 kilometers. All specifications include a dummy variable for living within 5 kilometers of a port and controls for age, gender, native language and level of education. Standard errors, clustered at the Centro Poblado level, are included in parentheses. A "Production Day" is defined by $>$ 1000 MTs of input at the port level. Fishmeal production is based on daily inputs of fish, measured in 10,000s of MTs. Medical expenditure is measured in Peruvian Soles, all other dependent variables are binary. Mean of dep. var. gives unconditional mean for sample included in the corresponding regression. Labor categories are based on 3 digit job codes. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table IV
Impact of Fishmeal Production on Labor Market Outcomes

	Has Any Job	Has 2nd Job	Total Labor Hours	Log. Total Income	Has Any Job	Has 2nd Job	Total Labor Hours	Log. Total Income
Panel A: All Adults								
	Log Fishmeal Production in Last 30 Days				Log Fishmeal Production in Last 90 Days			
Production Days in Last 30(90) Days	0.001*	−0.000	0.000	0.027	−0.000	−0.000**	−0.001	0.004
	(0.000)	(0.000)	(0.002)	(0.018)	(0.000)	(0.000)	(0.001)	(0.008)
Production Days in Last 30(90) Days x Near Plant	−0.000	0.000	−0.002	−0.018	0.000	0.000	−0.000	−0.021
	(0.001)	(0.001)	(0.006)	(0.037)	(0.000)	(0.000)	(0.002)	(0.015)
	Log Fishmeal Production in Last 30 Days				Log Fishmeal Production in Last 90 Days			
Log Fishmeal Prod. in Last 30(90) Days	0.006**	0.001	0.011	0.260	0.002	−0.001	0.003	0.163
	(0.002)	(0.002)	(0.016)	(0.160)	(0.002)	(0.001)	(0.013)	(0.124)
Log Fishmeal Prod. in Last 30(90) Days x Near Plant	−0.007	0.002	−0.028	−0.243	−0.002	0.005	−0.019	0.140
	(0.009)	(0.005)	(0.053)	(0.405)	(0.006)	(0.003)	(0.031)	(0.346)
Mean of Dep. Var.	0.64	0.11	3.46	30.3	0.64	0.11	3.46	30.3
N	161612	161612	161612	161612	161612	161612	161612	161612
Panel B: Non-Fishing Workers								
	Production Days in Last 30 Days				Production Days in Last 90 Days			
Production Days in Last 30(90) Days	0.001*	−0.000	0.000	0.028	0.000	−0.000**	−0.001	0.005
	(0.000)	(0.000)	(0.002)	(0.018)	(0.000)	(0.000)	(0.001)	(0.008)
Production Days in Last 30(90) Days x Near Plant	−0.000	0.000	−0.004	−0.027	−0.000	0.000	−0.002	−0.029*
	(0.001)	(0.001)	(0.005)	(0.041)	(0.000)	(0.000)	(0.002)	(0.017)
	Log Fishmeal Production in Last 30 Days				Log Fishmeal Production in Last 90 Days			
Log Fishmeal Prod. in Last 30(90) Days	0.006**	0.001	0.011	0.261	0.003	−0.001	0.003	0.158
	(0.003)	(0.002)	(0.016)	(0.163)	(0.002)	(0.001)	(0.013)	(0.127)
Log Fishmeal Prod. in Last 30(90) Days x Near Plant	−0.008	0.002	−0.046	−0.327	−0.001	0.005	−0.024	0.099
	(0.009)	(0.005)	(0.052)	(0.465)	(0.006)	(0.003)	(0.035)	(0.393)
Mean of Dep. Var.	0.63	0.11	3.41	30.1	0.63	0.11	3.41	30.1
N	158295	158295	158295	158295	158295	158295	158295	158295
Panel C: Fishing Workers								
	Log Fishmeal Production in Last 30 Days				Log Fishmeal Production in Last 90 Days			
Production Days in Last 30(90) Days	−0.002*	−0.001	0.000	−0.066	0.000	0.000	0.004	0.020
	(0.001)	(0.001)	(0.008)	(0.089)	(0.001)	(0.001)	(0.004)	(0.057)
Production Days in Last 30(90) Days x Near Plant	0.003**	0.004**	0.031***	0.142	−0.000	0.002	0.010*	−0.011
	(0.001)	(0.002)	(0.010)	(0.176)	(0.001)	(0.001)	(0.006)	(0.086)
	Log Fishmeal Production in Last 30 Days				Log Fishmeal Production in Last 90 Days			
Log Fishmeal Prod. in Last 30(90) Days	−0.011	−0.001	−0.003	−0.153	0.005	−0.001	0.085*	1.288*
	(0.007)	(0.011)	(0.063)	(0.784)	(0.007)	(0.011)	(0.051)	(0.757)
Log Fishmeal Prod. in Last 30(90) Days x Near Plant	0.012	0.016	0.290***	1.065	−0.011	0.012	0.077	−0.136
	(0.009)	(0.020)	(0.090)	(1.334)	(0.010)	(0.017)	(0.113)	(1.276)
Mean of Dep. Var.	0.93	0.13	5.64	43.0	0.93	0.13	5.64	43.0
N	3317	3317	3317	3317	3317	3317	3317	3317
Centro Poblado FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Near Plant FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HH Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Data from ENAHO (2007-2011). Adults older than 13 living in coastal regions are included. All specifications include a dummy variable for living within 5 kilometers of a port and controls for age, gender, native language and level of education. Standard errors, clustered at the Centro Poblado level, are included in parentheses. A "Production Day" is defined by $>$ 1000 MTs of input at the port level. Fishmeal production is based on daily inputs of fish, measured in 10,000s of MTs. Total income is measured in Peruvian Soles. Mean of dep. var. gives unconditional mean for sample included in the corresponding regression. Labor categories are based on 3 digit job codes. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table V
Impact of Fishmeal Production on Health Through Air Pollution in Lima

	Port Level Correlation Between Fishmeal Production and Air Pollution			
	PM^{10}	PM$^{2.5}$	NO$_2$	SO$_2$
Log Fishmeal Prod. in Last 30 Days	4.108^{***} (0.385)	2.222^{***} (0.309)	1.284^{***} (0.220)	1.056^{***} (0.214)
Mean of Dep. Var.	89.5	53.2	31.4	22.7
N	1231	1414	1416	1416
Month x Year FEs	Yes	Yes	Yes	Yes
	Impact of Air Pollution Instrumented by Fishmeal Production on Health			
	Hospitals	Adults		
	Respiratory Admissions	Any Health Issue	Log Medical Expenditure	
		PM10		
Average PM^{10} level in Last 30 Days x Near Plant	0.172 (0.348)	0.001^{***} (0.000)	-0.001 (0.000)	
		PM2.5		
Average PM$^{2.5}$ level in Last 30 Days x Near Plant	0.707^{**} (0.345)	0.001^{***} (0.000)	-0.000 (0.001)	
		NO$_2$		
Average NO$_2$ level in Last 30 Days x Near Plant	2.223^{**} (1.086)	0.002^{***} (0.000)	0.000 (0.001)	
		SO$_2$		
Average SO$_2$ level in Last 30 Days x Near Plant	3.053^{**} (1.492)	0.002^{***} (0.000)	-0.000 (0.001)	
Mean of Dep. Var.	327.0	0.54	4.04	
N	19976	33570	33583	
Hospital/Centro Poblado FEs	Yes	Yes	Yes	
Month x Year FEs	Yes	Yes	Yes	
HH Controls	No	Yes	Yes	

Hospital admissions measure total monthly admissions at the hospital level for hospitals whose closest port is Callao. Adult data includes those over 13 years of age whose closest port is Callao sampled in ENAHO (2007-2011). Pollution data based upon median levels across 5 air quality measurement in Lima, Peru averaged over the past 30 days (or 1 month for hospital data). The top panel presents pollutant levels regressed on "Log Fishmeal Production" and month fixed effects. The bottom panel presents IV regressions of health outcomes on average pollutant levels in the last 30 days and average pollutant level in the last 30 days interacted with an indicator for "Near Plant" instrumented by "Log Fish Capture in Last 30 Days" and "Log Fish Capture in Last 30 Days × Near Plant." All pollutants are measured in $\mu g/m^3$. Outcomes for children are excluded due to a lack of observations near the port of Callao. Last 30 days refers to the calendar month for hospital data and to the 30 days preceding the survey date for survey data. "Near Plant" is defined as 5 kilometers for survey data and 20 kilometers for hospital data. All specifications include a dummy variable for living near a plant. Adult regressions include controls for age, gender, native language and level of education. Hospital and adult specifications include hospital and Centro Poblado fixed effects respectively, with standard errors clustered at the same level. A "Production Day" is defined by $>$ 1000 MTs of input at the port level. Fishmeal production is based on daily inputs of fish, measured in 10,000s of MTs. Medical expenditure is measured in Peruvian Soles, all other dependent variables are binary. Mean of dep. var. gives unconditional mean for sample included in the corresponding regression. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table VI
Impact of Level and Dispersion of Fishmeal Production on Health

	Hospitals	Adults		Children: ≤ 5		Children: ≤ 1	
	Respiratory Admissions	Any Health Issue	Log Medical Expenditure	Any Health Issue	Cough	Any Health Issue	Cough
				Last 30 Days			
Log Fishmeal Prod. in Last 30 Days	−1.579 (1.089)	0.010 (0.006)	−0.016 (0.033)	−0.004 (0.020)	−0.001 (0.023)	0.003 (0.028)	0.016 (0.030)
Production Days in Last 30 Days	−0.101 (0.127)	0.000 (0.001)	0.003 (0.004)	0.001 (0.002)	0.000 (0.003)	−0.002 (0.003)	−0.005 (0.004)
Log Fishmeal Prod. in Last 30 Days x Near Plant	7.785^{*} (4.123)	−0.013 (0.015)	0.054 (0.094)	0.100^{*} (0.056)	0.119^{**} (0.053)	0.031 (0.074)	0.078 (0.084)
Production Days in Last 30 Days x Near Plant	−0.470 (0.443)	0.004^{**} (0.002)	0.005 (0.011)	−0.010 (0.006)	-0.013^{**} (0.005)	−0.006 (0.007)	−0.010 (0.006)
				Last 90 Days			
Log Fishmeal Prod. in Last 90 Days	0.690 (0.745)	0.002 (0.004)	0.031 (0.022)	0.011 (0.013)	0.016 (0.013)	−0.005 (0.021)	0.005 (0.021)
Production Days in Last 90 Days	-0.211^{***} (0.059)	0.000 (0.000)	−0.001 (0.001)	−0.001 (0.001)	-0.002^{**} (0.001)	−0.001 (0.001)	−0.002 (0.001)
Log Fishmeal Prod. in Last 90 Days x Near Plant	3.644 (3.171)	−0.008 (0.008)	−0.001 (0.043)	−0.030 (0.022)	0.008 (0.025)	0.050 (0.037)	0.095^{***} (0.030)
Production Days in Last 90 Days x Near Plant	0.076 (0.182)	0.001^{**} (0.001)	0.007^{**} (0.003)	0.005^{***} (0.001)	0.002^{**} (0.001)	0.000 (0.003)	−0.002 (0.002)
Hospital/Centro Poblado/District FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Near Plant FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HH Controls	No	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Hospital admissions measure total monthly admissions at the hospital level. Adult data includes those over 13 years of age living in costal regions sampled in ENAHO (2007-2011), child data includes those under 6 years old living in coastal regions sampled in ENDES (2007-2011). Last 30 or 90 days is calculated as last 1 or 3 months for hospital data. "Near Plant" is defined as 5 kilometers for survey data and 20 kilometers for hospital data. All specifications include a dummy variable for living near a plant. Adult regressions include controls for age, gender, native language and level of education. Child regressions include controls for age gender, household assets and mother's level of education. Hospital, adult and child specifications include hospital, Centro Poblado and district fixed effects respectively, with standard errors clustered at the same level. A "Production Day" is defined by $>$ 1000 MTs of input at the port level. Fishmeal production is based on daily inputs of fish, measured in 10,000s of MTs. "Respiratory Admissions" is a count, medical expenditure is measured in Peruvian Soles and all other dependent variables are binary. Mean of dep. var. gives unconditional mean for sample included in the corresponding regression. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table VII
Impact of Fishmeal Industry on Health Before and After 2009 ITQ Reform

	Hospitals	Adults		Children: ≤ 5		Children: ≤ 1	
	Respiratory Admissions	Any Health Issue	Log Medical Expenditure	Any Health Issue	Cough	Any Health Issue	Cough
				Sample Limited to 2008-2009			
Post-Reform x Near Plant	12.239**	0.059**	0.239*	0.184**	0.146	0.388**	0.223*
	(5.245)	(0.027)	(0.140)	(0.092)	(0.090)	(0.160)	(0.129)
Mean of Dep. Var.	170.5	0.57	3.70	0.45	0.37	0.48	0.37
N	57554	62158	62167	6602	6599	2665	2665
				Sample Limited to 2008-2009 – With Time Trends			
Post-Reform x Near Plant	19.483***	0.061*	0.198	0.241**	0.206*	0.278*	0.241
	(6.364)	(0.033)	(0.174)	(0.116)	(0.121)	(0.169)	(0.183)
Mean of Dep. Var.	170.5	0.58	3.68	0.45	0.37	0.48	0.37
N	57554	62158	62167	6602	6599	2665	2665
				Sample Limited to 2007-2010			
Post-Reform x Near Plant	9.681*	0.056***	0.181**	0.099***	0.083**	0.167*	0.104
	(5.408)	(0.018)	(0.084)	(0.036)	(0.038)	(0.086)	(0.080)
Mean of Dep. Var.	167.2	0.58	3.68	0.46	0.37	0.49	0.38
N	114755	125084	125106	11112	11107	4397	4396
Hospital/Centro Poblado/District FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Near Plant FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HH Controls	No	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Hospital admissions measure total monthly admissions at the hospital level. Adult data includes those over 13 years of age living in costal regions sampled in ENAHO (2007-2010), child data includes those under 6 years old living in coastal regions sampled in ENDES (2007-2010). The reform began on April 20th, 2009 in the North/Central region and July 7th, 2009 in the South. All specifications include a dummy variable for living near a plant. Time trends refers to the inclusion of a treatment specific monthly linear trend. Adult regressions include controls for age, gender, native language and level of education. Child regressions include controls for age gender, household assets and mother's level of education. Hospital, adult and child specifications include hospital, Centro Poblado and district fixed effects respectively, with standard errors clustered at the same level. "Respiratory Admissions" is a count, medical expenditure is measured in Peruvian Soles, all other dependent variables are binary. Mean of dep. var. gives unconditional mean for sample included in the corresponding regression. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table VIII
Impact of Fishmeal Industry on Labor Market Outcomes Before and After 2009 ITQ Reform – By Job Category

	Panel A: All Adults			
	Has Any Job	Has 2nd Job	Total Labor Hours	Log. Total Income
Post-Reform x Near Plant	0.023	-0.001	-0.111	-0.675
	(0.020)	(0.015)	(0.110)	(0.973)
Mean of Dep. Var.	0.63	0.10	3.44	30.3
N	62104	62104	62104	62104
	Panel B: Non-Fishing Workers			
	Has Any Job	Has 2nd Job	Total Labor Hours	Log. Total Income
Post-Reform x Near Plant	0.022	-0.002	-0.110	-0.148
	(0.022)	(0.014)	(0.127)	(1.067)
Mean of Dep. Var.	0.62	0.10	3.40	30.0
N	60832	60832	60832	60832
	Panel C: Fishing Workers			
	Has Any Job	Has 2nd Job	Total Labor Hours	Log. Total Income
Post-Reform x Near Plant	0.097^{***}	0.085	0.453	-3.334
	(0.036)	(0.090)	(0.330)	(6.480)
Mean of Dep. Var.	0.93	0.12	5.67	43.8
N	1272	1272	1272	1272
Hospital/Centro Poblado FEs	Yes	Yes	Yes	Yes
Month x Year FEs	Yes	Yes	Yes	Yes
Month x Near Plant FEs	Yes	Yes	Yes	Yes
HH Controls	Yes	Yes	Yes	Yes

OLS regressions. Data from ENAHO (2007-2011). Adults older than 13 living in coastal regions are included. All specifications include a dummy variable for living within 5 kilometers of a port and controls for age, gender, native language and level of education. Standard errors, clustered at the Centro Poblado level, are included in parentheses. A "Production Day" is defined by > 1000 MTs of input at the port level. Fishmeal production is based on daily inputs of fish, measured in 10,000s of MTs. Total income is measured in Peruvian Soles. Mean of dep. var. gives unconditional mean for sample included in the corresponding regression. Labor categories are based on 3 digit job codes. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table IX
Impact of Fishmeal Industry on Health Before and After 2009 ITQ Reform – North vs. South and Efficient vs. Inefficient Ports

	Hospitals	Adults	
	Respiratory Admissions	Any Health Issue	Log Medical Expenditure
	North vs. South		
Post-Reform x Near Plant	-15.472	-0.080	-0.315^{*}
	(11.603)	(0.054)	(0.178)
North/Central Region x Post-Reform	-20.047^{***}	0.040^{**}	-0.263^{*}
	(3.399)	(0.019)	(0.146)
North/Central Region x Post-Reform x Near Plant	31.151^{**}	0.134^{**}	0.547^{**}
	(12.976)	(0.055)	(0.221)
	Efficient vs. Inefficient Ports		
Post-Reform x Near Plant	-2.135	-0.072	-0.330
	(22.528)	(0.055)	(0.350)
Pre-Reform Max. Efficiency x Post-Reform	-49.622^{***}	-0.016	-1.333^{***}
	(12.454)	(0.068)	(0.479)
Pre-Reform Max. Efficiency x Post-Reform x Near Plant	56.634	0.356^{***}	1.802^{**}
	(85.399)	(0.129)	(0.813)
Mean of Dep. Var.	169.8	0.56	3.73
N	54323	57250	57259
Hospital/Centro Poblado FEs	Yes	Yes	Yes
Month x Year FEs	Yes	Yes	Yes
Month x Near Plant FEs	Yes	Yes	Yes
HH Controls	No	Yes	Yes

OLS regressions. Hospital admissions measure total monthly admissions at the hospital level, limited to 2008/2009. Adult data includes those over 13 years of age living in costal regions sampled in ENAHO (2008-2009). The reform began on April 20th, 2009 in the North/Central region and July 7th, 2009 in the South. All specifications include a dummy variable for living near a plant. Adult regressions include controls for age, gender, native language and level of education. Children are excluded due to a lack of observations in Southern ports. Hospital and adult specifications include hospital and Centro Poblado fixed effects respectively, with standard errors clustered at the same level. "Respiratory Admissions" is a count, medical expenditure is measured in Peruvian Soles, all other dependent variables are binary. The port of Ilo is excluded from both specifications due to production outside of designated seasons. Efficiency is determined by the maximum 2008 output/input ratio for any plant within the port. Efficiency is included as a continuous variable interacted with both living near a plant and post-reform. Mean of dep. var. gives unconditional mean for sample included in the corresponding regression. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table X
Cost Benefit Analysis of 2009 ITQ Reform

Panel A: Increase in Sector Profits		
Increase in net income for listed companies (USD)	$58,526,966	
Estimated sector wide increase in net income (USD)	$219,237,448	
Panel B: Health Costs		
Medical Expenditures:		
Estimated increase per person/year	$38	
Estimated total increase (USD)	$45,523,379	
Respiratory Hospital Admissions:		
Estimated increase in total hospital admissions	55,516	
Estimated increase in years lived with disability (YLDs)	5,681	
Estimated cost of years lived with disability (YLDs)	$297,455,874	
Panel C: Total Costs and Benefits		
Estimated benefit to sector (USD)		$219,237,448
Estimated total cost (medical exp. + cost of YLDs)		$342,929,254

Net income from public available firm financials, calendarized for April-April fiscal years. Sector wide estimates based on 2008 proportion of fishmeal production represented by publicly listed firms. Population estimates are based on total 2009 population living in locations with fishmeal plants from the Peru Institute of National Statistics and Information. Medical expenditure is annualized and extrapolated to the population based on estimates in Table VII. Disability weights translate health conditions over a given duration into an equivalent number of years lived with disability (YLDs). We estimate YLDs using the average disability weight for respiratory diseases (from the Global Burden of Disease Study 2010), and assume a total duration per disease episode of one year. VSL (value of statistical life) estimates for Peru are estimated as $5.42 million, based on an African VSL of $577,000 (from Leon and Miguel (2015)), scaled to Peru GNI using the elasticity in Hall and Jones (2007). We calculate the value of a statistical life year by dividing our VSL estimates by the average life expectancy in the relevant population (40.88, based on remaining life expectancy in Peru for the average individual experiencing a respiratory disease). We alternatively conduct our calculation using a United States VSL estimate of $7.87 million, per US EPA recommendations, again scaled by GNI. US estimates give an estimated total cost of $173,620,448. All numbers reported are in 2009 USD, calculated using the USA BLS inflation calculator. Scalings use World Bank estimates of GNI per capita (PPP).

Appendix

Case studies have found high levels of air pollution near fishmeal ports during the production seasons. Sueiro (2010) investigated the environmental situation in 2008 in the city surrounding the port of Chimbote, the largest in the country with 27 fishmeal plants operating at the time. The Swedish Meteorological and Hydrological Institute (SMHI) monitored the air quality in the same port area between April 2005 and April 2006. These studies found very high levels of air pollution. (SMHI found that the annual levels of SO_2 were around 110 μg/m^3 – exceeding the international standard of 80 μg/m^3. Monthly concentrations of hydrogen sulfide (H_2S) fluctuated between 20 and 40 μg/m^3 during the fishing seasons, and the hourly concentrations reached 80 to 90 μg/m^3, again exceeding the WHO standard of seven μg/m^3). In their reports, focusing especially on Ferrol Bay, the Ministry of the Environment (MINAM) cite investigations that found levels of sulfur dioxide near twice the level of international standards, hydrogen sulfide levels beyond international standards, and PM^{10} levels that vary dramatically over time and can at times reach more than twice the international standard. PM^{10} levels were higher near fishmeal plants (MINAM, 2010, 2011). A study by Consejo Nacional del Medio Ambiente (2010) of air pollution levels in Chimbote from April to August 2006 found a high correlation between PM^{10} and fishmeal production. The concentration of PM^{10} exceeded international standards throughout the study period.

Air pollution in the form of particulate matter has been shown to cause respiratory diseases, cardiovascular diseases and affect mortality in adults (see e.g. Brook RD et al., 2010; Moretti and Neidell, 2011; Schlenker and Walker, 2011; Chen et al., 2013; Currie et al., 2014). Some PM components are also associated with heartbeat irregularities, arterial narrowing, issues with lung function and increased emergency room visits (Stanek et al., 2011). PM has also been shown to cause respiratory diseases, skin diseases, eye diseases, and affect lung growth and mortality in children (see e.g. Currie et al., 2014; Currie and Walker, 2011; Gutierrez, 2013; Roy et al., 2012; Jayachandran, 2006; Chay and Greenstone, 2005; World Health Organization, 2006). Chemical pollutants and gases associated with fishmeal production have been linked to respiratory complications, heart disease, low blood cells counts and increased mortality (see e.g. Mustafa and Tierney, 1978; World Health Organization, 2006; Reiffenstein and Roth, 1992; Clarke et al., 2000). (Nitrogen oxide exposure is linked to respiratory effects, airway irritation and lung injury (Mustafa and Tierney, 1978). Short-term sulfur dioxide exposure is associated with higher hospital admissions due to heart disease and pulmonary complications and greater mortality (World Health Organization, 2006). Most organ systems are susceptible to hydrogen sulfide, including the nervous and respiratory systems (Reiffenstein and Roth, 1992). Clarke et al. (2000) found that dogs had reduced blood cell counts when exposed to sulfur).

We are aware of one study of the health effects of air pollution generated by fishmeal plants in Peru. The Regional Health Offices found that, among children 3 to 14 years of age, those in schools located near fishmeal plants had a 10 percent incidence of respiratory diseases in 2003; much higher than in comparable populations (see Sueiro, 2010).

Table A.I
Impact of Fishmeal Production on Hospital Admissions – Non-Respiratory Issues

	Total Admissions	Blood Disorders	Nervous System	Circulatory System	Digestive System	Pregnancy Complications	Perinatal Issues
				Log Fishmeal Production in Last 30 Days			
Log Fishmeal Prod. in Last 30 Days	0.570	−0.004	0.075^{**}	−0.049	1.161^{***}	0.262^{***}	0.017
	(1.180)	(0.013)	(0.036)	(0.046)	(0.375)	(0.085)	(0.017)
Log Fishmeal Prod. in Last 30 Days x Near Plant	2.277	−0.052	−0.133	−0.142	−1.069	0.934^{***}	0.152
	(5.000)	(0.076)	(0.237)	(0.214)	(1.278)	(0.330)	(0.139)
				Log Fishmeal Production in Last 90 Days			
Log Fishmeal Prod. in Last 90 Days	4.268^{***}	0.000	0.124^{***}	−0.047	1.480^{***}	0.486^{***}	0.030
	(1.362)	(0.018)	(0.047)	(0.058)	(0.358)	(0.100)	(0.021)
Log Fishmeal Prod. in Last 90 Days x Near Plant	11.509^{*}	−0.005	−0.071	0.322	2.379^{*}	0.888^{**}	0.071
	(6.075)	(0.084)	(0.211)	(0.230)	(1.295)	(0.391)	(0.100)
				Production Days in Last 30 Days			
Production Days in Last 30 Days	0.238	−0.000	0.005	−0.002	0.159^{***}	0.021^{*}	0.000
	(0.150)	(0.002)	(0.004)	(0.005)	(0.049)	(0.011)	(0.003)
Production Days in Last 30 Days x Near Plant	1.438^{**}	0.002	−0.010	0.014	0.334^{**}	0.186^{***}	0.017
	(0.569)	(0.013)	(0.044)	(0.025)	(0.166)	(0.050)	(0.017)
				Production Days in Last 90 Days			
Production Days in Last 90 Days	0.182^{*}	−0.001	0.006^{*}	−0.004	0.084^{***}	0.015^{*}	0.000
	(0.108)	(0.001)	(0.003)	(0.004)	(0.027)	(0.008)	(0.002)
Production Days in Last 90 Days x Near Plant	1.157^{***}	−0.001	−0.014	0.011	0.339^{***}	0.128^{***}	0.001
	(0.407)	(0.009)	(0.028)	(0.020)	(0.107)	(0.036)	(0.010)
Mean of Dep. Var.	516.0	1.47	6.00	8.60	71.3	16.5	1.73
N	141981	141981	141981	141981	141981	141981	141981
Hospital FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Near Plant FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Hospital admissions measure total monthly admissions at the hospital level. Last 30 or 90 days is calculated as last 1 or 3 months for hospital data. Near plant is defined as 20 kilometers for hospital data. Hospital fixed effects are included and standard errors are clustered at the hospital level. A “Production Day” is defined by $>$ 1000 MTs of input at the port level. Fishmeal production is based on daily inputs of fish, measured in 10,000s of MTs. Mean of dep. var. gives unconditional mean for sample included in the corresponding regression. Categorizations based upon International Classification of Disease Codes (ICD). We found at least one paper associating each of the categories used: (see Medeiros et al., 1983; Dusseldorp et al., 1995; Xu, Ding and Wang, 1995; Gordian et al., 1996; Landgren, 1996; Ponka and Virtanen, 1996; Wang et al., 1997; Dejmek et al., 1999; Pope et al., 1999; Seaton et al., 1999; Van der Zee et al., 1999; Brook et al., 2002; Bruce, Perez-Padilla and Albalak, 2002; Hoek et al., 2002; Pope et al., 2004; Riediker et al., 2004; Baccarelli et al., 2007; Kaplan et al., 2010; Moulton and Yang, 2012). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.II
Impact of Fishmeal Production Instrumented by Fishing Seasons on Health

	Hospitals	Adults		Children: ≤ 5		Children: ≤ 1	
	Respiratory Admissions	Any Health Issue	Log Medical Expenditure	Any Health Issue	Cough	Any Health Issue	Cough
			Log Fishmeal Production in Last 30 Days				
Log Fishmeal Prod. in Last 30 Days		0.002	−0.015	0.034	0.013	0.023	−0.014
		(0.009)	(0.042)	(0.032)	(0.033)	(0.047)	(0.050)
Log Fishmeal Prod. in Last 30 Days x Near Plant	−6.316	0.068***	0.243**	0.010	0.033	−0.016	−0.049
	(6.870)	(0.021)	(0.095)	(0.048)	(0.055)	(0.104)	(0.104)
			Log Fishmeal Production in Last 90 Days				
Log Fishmeal Prod. in Last 90 Days		−0.002	−0.031	−0.002	−0.032	−0.045	−0.070
		(0.012)	(0.053)	(0.024)	(0.026)	(0.045)	(0.044)
Log Fishmeal Prod. in Last 90 Days x Near Plant	−3.531	0.147*	0.516*	0.045	0.103**	0.106*	0.136**
	(14.704)	(0.089)	(0.304)	(0.056)	(0.049)	(0.055)	(0.063)
			Production Days in Last 30 Days				
Production Days in Last 30 Days		0.001	−0.003	0.004	0.002	0.003	−0.002
		(0.001)	(0.007)	(0.004)	(0.004)	(0.006)	(0.007)
Production Days in Last 30 Days x Near Plant	−0.566	0.008**	0.024*	0.001	0.004	−0.002	−0.006
	(0.615)	(0.003)	(0.013)	(0.006)	(0.007)	(0.012)	(0.012)
			Production Days in Last 90 Days				
Production Days in Last 90 Days		−0.001	−0.001	−0.000	−0.003	−0.004	−0.006
		(0.001)	(0.004)	(0.002)	(0.002)	(0.004)	(0.004)
Production Days in Last 90 Days x Near Plant	−0.087	0.005***	0.018**	0.004	0.009**	0.009*	0.012**
	(0.362)	(0.002)	(0.007)	(0.005)	(0.004)	(0.005)	(0.005)
Mean of Dep. Var.	163.6	0.58	3.78	0.47	0.40	0.51	0.41
N	119007	161773	161806	10164	10162	3965	3965
Hospital/Centro Poblado/District FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Near Plant FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HH Controls	No	Yes	Yes	Yes	Yes	Yes	Yes

IV regressions of health outcomes regressed on measures of production ("Log Fishmeal Production" and "Production Days") and those measures of production interacted with a dummy for living near a plant. We instrument for production and the interaction with the number of days the fishing season was open in last 30 or 90 days and number of days the fishing season was open × "Near Plant." Hospital admissions measure total monthly admissions at the hospital level. Adult data includes those over 13 years of age living in costal regions sampled in ENAHO (2007-2011), child data includes those under 6 years old living in coastal regions sampled in ENDES (2007-2011). Last 30 or 90 days is calculated as last 1 or 3 months for hospital data. "Near Plant" is defined as 5 kilometers for survey data and 20 kilometers for hospital data. All specifications include a dummy variable for living near a plant. Production not interacted with near plant excluded from hospital regressions due to collinearity with Month × Year fixed effects. Adult regressions include controls for age, gender, native language and level of education. Child regressions include controls for age gender, household assets and mother's level of education. Hospital, adult and child specifications include hospital, Centro Poblado and district fixed effects, respectively, with standard errors clustered at the same level. A "Production Day" is defined by > 1000 MTs of input at the port level. Fishmeal production is based on daily inputs of fish, measured in 10,000s of MTs. "Respiratory Admissions" is a count, medical expenditure is measured in Peruvian Soles and all other dependent variables are binary. Mean of dep. var. gives unconditional mean for sample included in the corresponding regression. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.III
Impact of Fishmeal Prod. on Hosp. Admis. – Placebo Outcomes

	Congenital Disorders	Ext. Factors: Injury/Poisoning	Mental Health
	Log Fishmeal Production in Last 30 Days		
Log Fishmeal Prod. in Last 30 Days	0.016 (0.018)	−0.032 (0.052)	0.063 (0.070)
Log Fishmeal Prod. in Last 30 Days x Near Plant	0.051 (0.100)	0.060 (0.145)	0.254 (0.358)
Mean of Dep. Var.	1.30	3.37	9.45
N	141981	141981	141981
	Log Fishmeal Production in Last 90 Days		
Log Fishmeal Prod. in Last 90 Days	0.035^{*} (0.020)	−0.039 (0.059)	0.071 (0.073)
Log Fishmeal Prod. in Last 90 Days x Near Plant	0.095 (0.085)	−0.102 (0.167)	0.409 (0.385)
Mean of Dep. Var.	1.30	3.37	9.45
N	141981	141981	141981
	Production Days in Last 30 Days		
Production Days in Last 30 Days	0.003 (0.002)	−0.003 (0.007)	0.006 (0.009)
Production Days in Last 30 Days x Near Plant	0.016 (0.011)	0.017 (0.024)	0.097 (0.063)
Mean of Dep. Var.	1.30	3.37	9.45
N	141981	141981	141981
	Production Days in Last 90 Days		
Production Days in Last 90 Days	0.002 (0.002)	−0.006 (0.006)	−0.001 (0.006)
Production Days in Last 90 Days x Near Plant	0.009 (0.006)	0.006 (0.017)	0.070 (0.043)
Mean of Dep. Var.	1.30	3.37	9.45
N	141981	141981	141981
Hospital FEs	Yes	Yes	Yes
Month x Year FEs	Yes	Yes	Yes
Month x Near Plant FEs	Yes	Yes	Yes

OLS regressions. Hospital admissions measure total monthly admissions at the hospital level. Last 30 or 90 days is calculated as last 1 or 3 months for hospital data. Near plant is defined as 20 kilometers for hospital data. Hospital fixed effects are included and standard errors are clustered at the hospital level. A "Production Day" is defined by $>$ 1000 MTs of input at the port level. Fishmeal production is based on daily inputs of fish, measured in 10,000s of MTs. Mean of dep. var. gives unconditional mean for sample included in the corresponding regression. Categorizations based upon International Classification of Disease Codes (ICD). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.IV

Impact of Fishmeal Production on Seawater Quality and on Adult Health by Fish Consumption

	Panel A: Impact of Fishmeal Production on Adult Health by Fish Consumption							
	Production Days				Log Fishmeal Production			
	30 Days		90 Days		30 Days		90 Days	
	Any Health Issue	Log. Medical Expenditure	Any Health Issue	Log. Medical Expenditure	Any Health Issue	Log. Medical Expenditure	Any Health Issue	Log. Medical Expenditure
Consumed Fresh Fish	0.002	0.118^{***}	0.002	0.122^{***}	0.000	0.108^{***}	0.000	0.110^{***}
	(0.004)	(0.023)	(0.004)	(0.030)	(0.004)	(0.021)	(0.004)	(0.024)
Consumed Fresh Fish x Near Plant	0.004	0.008	0.016	0.105	0.003	0.022	0.005	0.080
	(0.019)	(0.127)	(0.024)	(0.141)	(0.019)	(0.114)	(0.020)	(0.119)
Log Fishmeal Prod. in Last 30 (90) Days	0.013^{***}	0.035^{**}	0.007^{**}	0.029^{*}				
	(0.004)	(0.017)	(0.003)	(0.018)				
Log Fishmeal Prod. in Last 30 (90) Days x Near Plant	0.019^{*}	0.120^{*}	0.016	0.139^{***}				
	(0.010)	(0.066)	(0.010)	(0.051)				
Log Fishmeal Prod. in Last 30 (90) Days x Consumed Fresh Fish	−0.002	-0.035^{**}	−0.001	−0.019				
	(0.003)	(0.017)	(0.003)	(0.016)				
Log Fishmeal Prod. in Last 30 (90) Days x Consumed Fresh Fish x Near Plant	−0.002	−0.042	−0.009	-0.089^{*}				
	(0.010)	(0.077)	(0.011)	(0.053)				
Production Days in Last 30 (90) Days					0.001^{***}	0.004^{*}	0.000^{*}	0.001
					(0.000)	(0.002)	(0.000)	(0.001)
Production Days in Last 30 (90) Days x Near Plant					0.003^{*}	0.015^{*}	0.001	0.011^{***}
					(0.001)	(0.008)	(0.001)	(0.003)
Production Days in Last 30 (90) Days x Consumed Fresh Fish					−0.000	−0.003	0.000	−0.001
					(0.000)	(0.002)	(0.000)	(0.001)
Production Days in Last 30 (90) Days x Consumed Fresh Fish x Near Plant					−0.000	−0.008	−0.000	-0.007^{*}
					(0.001)	(0.008)	(0.001)	(0.004)
Mean of Dep. Var.	0.59	3.74	0.59	3.74	0.59	3.74	0.59	3.74
N	161773	161806	161773	161806	161773	161806	161773	161806
Centro Poblado FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Near Plant FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HH Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	Panel B: Impact of Fishmeal Production on Seawater Quality							
	Log Fishmeal Production				Production Days			
	Near Port = Within 5 kilometers		Near Port = Within 20kilometers		Near Port = Within 5 kilometers		Near Port = Within 20kilometers	
	30 Days	90 Days	30 Days	90 Days	30 Days	90 Days	30 Days	90 Days
Log Fishmeal Prod. in Last 30 (90) Days	-0.045^{***}	-0.016^{***}	-0.041^{***}	−0.009				
	(0.006)	(0.006)	(0.006)	(0.005)				
Log Fishmeal Prod. in Last 30 (90) Days x Near Plant	0.028	0.024	−0.002	−0.013				
	(0.033)	(0.023)	(0.015)	(0.013)				
Production Days in Last 30 (90) Days					-0.006^{***}	-0.002^{***}	-0.005^{***}	-0.001^{**}
					(0.001)	(0.001)	(0.001)	(0.001)
Production Days in Last 30 (90) Days x Near Plant					0.003	0.003	−0.001	−0.001
					(0.004)	(0.002)	(0.002)	(0.001)
Mean of Dep. Var.	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
N	14547	14547	14547	14547	14547	14547	14547	14547
Beach FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel A: OLS regressions. Adult data includes those over 13 years of age living in costal regions sampled in ENAHO (2007-2011). "Near Plant" is defined as 5 kilometers for survey data. All specifications include a dummy variable for living near a plant. Adult regressions include controls for age, gender, native language and level of education. Standard errors are clustered at the Centro Poblado level. A "Production Day" is defined by > 1000 MTs of input at the port level. Fishmeal production is based on daily inputs of fish, measured in 10,000s of MTs. Medical expenditure is measured in Peruvian Soles. We define consumption of fresh fish as the purchase of fresh fish at the household level. Mean of dep. var. gives unconditional mean for sample included in the corresponding regression. Panel B: OLS regressions. Data collected approximately weekly at the beach level from January 2007-April 2009. Quality is a binary variable equal to 1 for low levels of coliforms ($\leq$1000 NMP/100ml) and 0 for high levels. Note that fishmeal production is correlated with the prevalence of coliforms at public beaches, but the correlation is not greater inside versus outside a five, 20 or 50 kilometer treatment radius around fishmeal ports. Standard errors, clustered at the beach level, are included in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.V
Impact of Fishmeal Industry on Health Before and After 2009 ITQ Reform – By Job Category

	Reform Effect				Efficient vs. Inefficient Ports				North/Central vs. South			
	Non-Fishing Workers		Fishing Workers		Non-Fishing Workers		Fishing Workers		Non-Fishing Workers		Fishing Workers	
	Any Health Issue	Log Medical Expenditure	Any Health Issue	Log Medical Expenditure	Any Health Issue	Log Medical Expenditure	Any Health Issue	Log Medical Expenditure	Any Health Issue	Log Medical Expenditure	Any Health Issue	Log Medical Expenditure
					North Vs. South							
Post-Reform x Near Plant	0.053**	0.225	0.143	0.679	−0.091	−0.325*	−0.154	0.636	−0.086	−0.359	−0.127	0.118
	(0.027)	(0.145)	(0.124)	(0.531)	(0.057)	(0.180)	(0.315)	(0.971)	(0.053)	(0.342)	(0.282)	(1.376)
North/Central Region x Post-Reform					0.041**	−0.272*	−0.018	−0.177				
					(0.019)	(0.149)	(0.198)	(0.784)				
North/Central Region x Post-Reform x Near Plant					0.142**	0.545**	0.276	0.346				
					(0.056)	(0.220)	(0.281)	(1.058)				
Pre-Reform Max. Efficiency x Post-Reform									−0.021	−1.415***	0.388	4.944
									(0.068)	(0.481)	(0.490)	(3.236)
Pre-Reform Max. Efficiency x Post-Reform x Near Plant									0.388***	1.872**	0.585	1.871
									(0.119)	(0.806)	(0.846)	(3.726)
Mean of Dep. Var.	0.57	3.71	0.52	3.16	0.59	3.75	0.54	3.16	0.59	3.75	0.54	3.16
N	60886	60895	1272	1272	56979	56988	1164	1164	56097	56106	1153	1153
Centro Poblado	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Near Plant FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HH Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Data from ENAHO (2007-2011). Adults older than 13 living in coastal regions are included. Near plant is defined as within 5 kilometers. All specifications include a dummy variable for living within 5 kilometers of a port and controls for age, gender, native language and level of education. Standard errors, clustered at the Centro Poblado level, are included in parentheses. The reform began on April 20th, 2009 in the North/Central region and July 7th, 2009 in the South. The port of Ilo is excluded from North vs. South specification due to production outside of designated seasons. Efficiency determined by the maximum 2008 output/input ratio for any plant within the port. Efficiency is included as a continuous variable interacted with both living near a plant and post-reform. Mean of dep. var. gives unconditional mean for sample included in the corresponding regression. Labor categories are based on 3 digit job codes. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.VI
Impact of Fishmeal Industry on Health Before and After 2009 ITQ Reform – Efficient vs. Inefficient Ports – North Only

	Hospitals	Adults		Children: ≤ 5		Children: ≤ 1	
	Respiratory Admissions	Any Health Issue	Log Medical Expenditure	Any Health Issue	Cough	Any Health Issue	Cough
				High Vs. Low Cost Ports			
Post-Reform x Near Plant	2.021	-0.059	0.167	-1.490^{***}	-0.831^{***}	-1.099^{***}	-0.619^{**}
	(26.470)	(0.065)	(0.407)	(0.176)	(0.250)	(0.260)	(0.243)
Pre-Reform Max. Efficiency x Post-Reform	-36.093^{**}	-0.054	0.427	0.115	0.467	-1.346^{*}	-0.671
	(17.590)	(0.115)	(0.614)	(0.500)	(0.455)	(0.750)	(0.742)
Pre-Reform Max. Efficiency x Post-Reform x Near Plant	38.986	0.328^{**}	0.058	4.170^{***}	2.956^{***}	4.339^{***}	3.262^{***}
	(98.722)	(0.162)	(0.887)	(0.504)	(0.592)	(0.741)	(0.739)
Mean of Dep. Var.	173.4	0.56	3.80	0.46	0.38	0.50	0.40
N	47815	49902	49910	4445	4443	1780	1780
Hospital/Centro Poblado/District FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month x Near Plant FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HH Controls	No	Yes	Yes	Yes	Yes	Yes	Yes

OLS regressions. Hospital admissions measure total monthly admissions at the hospital level, limited to 2008/2009. Adult data includes those over 13 years of age living in costal regions sampled in ENAHO (2008-2009). The reform began on April 20th, 2009 in the North/Central region and July 7th, 2009 in the South. All specifications include a dummy variable for living near a plant. Adult regressions include controls for age, gender, native language and level of education. Hospital, adult and child specifications include hospital, Centro Poblado and district fixed effects respectively, with standard errors clustered at the same level. "Respiratory Admissions" is a count, medical expenditure is measured in Peruvian Soles, all other dependent variables are binary. Efficiency is determined by the maximum 2008 output/input ratio for any plant within the port. Efficiency is included as a continuous variable interacted with both living near a plant and post-reform. Mean of dep. var. gives unconditional mean for sample included in the corresponding regression. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.