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Balancing Environment and Growth: Dams, Air Pollution, and Trade Effects in Southeast Asia

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# Balancing Environment and Growth: Dams, Air Pollution, and Trade Effects in Southeast Asia

A dissertation submitted in partial satisfaction of the

requirements for the degree

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in

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by

Ha Vu

Committee in charge:

Professor Joshua Graff Zivin, Chair
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The dissertation of Ha Vu is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

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# EPIGRAPH

*If you really want to do something you'll find a way.*

*If you don't, you'll find an excuse.*

— Jim Rohn

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ABSTRACT OF THE DISSERTATION

# Balancing Environment and Growth: Dams, Air Pollution, and Trade Effects in Southeast Asia

by

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The first chapter examines how upstream dam construction impacts freshwater levels downstream, affecting salinity intrusion and agricultural productivity in the delta. The study combines historical records of dam construction on the Mekong River, water level observations, and agricultural productivity statistics, with satellite data as proxies for salinity index and vegetation coverage. The findings show that increased reservoir capacity significantly reduces downstream freshwater discharge, decreases rice yield, and intensifies saltwater intrusion, while annual electricity output partially mitigates these effects. These impacts are most severe during dry seasons and closer to the shore. Two mechanisms are identified: the disruptive but temporary ”filling effect” in the first year post-dam completion, and the persistent, smaller ”operational effect” over time.

The second chapter explores the relationship between air pollution and individuals' risk preferences and decision-making behaviors, utilizing remote sensing data on global air pollution and data from the Indonesia Family Life Survey. By matching individual characteristics with pollution levels (Mass Concentration and Aerosol Optical Thickness) on their interview day, preliminary results show that higher dust and PM2.5 levels increase risk aversion. Additionally, increased exposure to SO4 over the previous 30 days also heightens risk aversion.

The third chapter analyzes labor market changes in response to export shocks, incorporating supply chain spillovers. Using trade data from UN COMTRADE, input-output tables from GTAP, and Vietnam's Labor Force Survey (2010-2019), we calculated each worker's total exposure to export changes. This includes direct exposure (changes in their own industry's exports) and indirect exposure (changes in other industries using outputs from their industry as inputs). We find that both direct and indirect export exposures significantly increase wages, boost employment rates, and reduce inactivity. The college premium decreases and the gender wage gap narrows, indicating improved equality. Wage gains are most significant for the lowest income workers, and employment gains are concentrated among unskilled workers, while the employment rate falls for skilled workers.

# Chapter 1

# IMPACT OF DAMS ON SALINITY INTRUSION AND AGRICULTURAL PRODUCTIVITY: EVIDENCE FROM MEKONG RIVER

## 1.1 Introduction

Dams are essential to humans and the economy, offering benefits such as reliable irrigation water for agriculture, hydroelectric power generation and flood control. Their multifaceted role in water management and energy generation is indispensable for economic growth and overall well-being ([2], [45], [24]). Nevertheless, these economic benefits often come hand in hand with different environmental costs to ecology and human livelihood. The environmental impact of dams ranges from disruption to water flow, changes in water temperature and speed, aquatic biodiversity loss to sediment deterioration to river bank erosion and coastal salinity intrusion ([51], [5], [18]).

Understanding the construction and operation of hydrological dams might give the impression that, aside from the temporary disruption during the construction phase and the filling process, dams do not significantly impact overall average water conditions. However, a closer examination reveals that dams can indeed modify the seasonality of water flow downstream, exacerbating the variability of water's effects on agriculture. In regions where the dry season exhibits lower electricity demand, dams may be operated to retain more water during the dry season and release it during the rainy season. This operational strategy can extend the duration of dry periods and delay flood season. As a result, when freshwater supply to the downstream is low and during high-tide days, when ocean water rises and penetrates, saltwater intrusion spikes. This in turn could cause immediate and vast consequences on agriculture as crops usually can only withstands up to a certain threshold of soil ([25]). These consequences are particularly serious in international river basins where upstream authorities lack incentives to prioritize downstream impacts ([39]).

This paper investigates into the impacts of dam construction in upstream areas on water level, salinity intrusion, and agricultural productivity within the expansive delta region of a river. Our primary focus is on the Mekong River, a prominent watercourse in Southeast Asia, for two main reasons. First, unlike in the United States, where the big dam era (1930s-1960s) [30] has largely concluded, this region remains actively engaged in this transformative process, marked by a number of dams currently under construction or planned for future development in the near term. Furthermore, the Mekong River Delta stands as the world's third-largest delta [31], providing a vital support to a substantial community of nearly 20 million people [10] whose living relies deeply on agriculture. The potential for significant river disruption, in absence of effective mitigation policies, poses an existential threat to these age-old, culturally ingrained ways of life that have endured for centuries. Third, the Mekong River Delta is situated in Southeast Asia, a region currently experiencing the most rapid relative sea-level rise globally with Ho Chi Minh city ranks second among all coastal cities in terms of peak sinking velocity (-43mm per year) [46]. This phenomenon, when coupled with the reduced freshwater inflow resulting from dam construction and operation, exacerbates the issue of salinity intrusion, thereby adversely impacting agricultural outcomes.

The paper undertakes an empirical approach to examine the effects of dams on coastal salinity levels and agricultural productivity. To achieve this, we combine data from different sources on dams to form a complete historical record on dam construction on the Mekong River. This data set includes details on the dams' geospatial location, their year of commission, their attributes such as maximum reservoir capacity, power generating capacity, average annual electricity output, etc. The geo-location of the dams allow for further computation of distances and mapping to local river basins and merge it with satellite data. The dams are matched with that approximates outcomes of interest, vegetation coverage and salinity intrusion, observed in the impacted region of the Vietnam Mekong Delta based on the timing of the dams' commision. In particular, we use observations on Normalized Difference Vegetation Index and Vegetation Soil Salinity Index, which respectively provides approximation for outcomes of interest including salinity level and agriculture productivity. An Ordinary Linear Regression is then adopted to study the impact of the dams' properties on the outcomes.

To compare the short-term and long-term impact after the dams' construction, we aggregate and include in the regression the total of newly added reservoir capacity and annual electricity output of all the dams that go online between one year and zero year prior to the observation of outcomes, two years and one year prior to the observation of outcomes, three years and two years prior to the observation of outcomes, etc. The more years are included from the past, the longer the horizon of effect we can study.

To disentangle the effect of dams on agriculture through salinity intrusion and the effect through water supply, we interact the outcomes with distance to cost, a variable that measure the shortest distance from the centroid of the district polygon at which the outcome is observed, to the coastline. The further away from the shore a district is, the less likely its crop will be impacted by saltwater intrusion, thus an interactive term between the dams' characteristics and the coast will capture this effect.

In addition, this paper also addresses the heterogeneity in season since seasonality is an inherent property of water flow. We stratify the data to separate and compare the results for the dry season versus the rain season.

The analysis uncovers evidence indicating that upstream dams exert a substantial and time-evolving influence on the reduction of water flow into the delta river over the years. This impact is most pronounced in the immediate aftermath of dam construction, attributed in part to the reservoir filling effect, and subsequently diminishes over the years as the dams continue to operate. Furthermore, the findings also underscore the role of dams in reducing the Normalized Difference Vegetation Index while elevating the Salinity Index within downstream areas. Most interestingly, a closer look into the seasonal heterogeneity suggests a hidden pattern in how dams exaggerate the volatility of water flow and floods. Even though the overall effect throughout the year is insignificant due to the dominant insignificant effect in the rain season, the impacts on all both vegetation and salinity outcomes exhibit greater magnitude and significance during the dry season. The heterogeneity analysis on spatial location shows that the effect on agriculture in dry season increases in intensity as the proximity to the coast increases, suggesting that salinity intrusion partly channels the damage.

Our results expand our understanding in the literature on the impact of dams. Dams have transformative effects on rivers and the surrounding ecosystems. Their influence on river systems is manifold.

Among many environmental impacts, alteration of natural river flow regimes is one of the most primary concerns. Around the world, dams alter water flow dynamics by reducing downstream water availability through evaporation and diversion, consequently reshaping the timing, speed and sediment component of water flows, and worse, smoothing out the flood patterns between seasons. For example, changes in flood patterns caused by reservoirs in the United States, reveal pronounced alterations in regions west of the Mississippi River, particularly in the southern Great Plains, arid Southwest, and northern California. Over half of large rivers in the U.S. have experienced a reduction of more than 25% in their median annual flood, with corresponding figures of 25% for medium-sized rivers and 10% for small rivers (FitzHugh and Vogel (2011) [19]). In Quebec, a comparison on monthly flow characteristics between natural rivers and reservoir-regulated rivers, found that dams impact all monthly flow characteristics, with different responses and magnitudes depending on watershed size and season ([29]). Similarly, in the Huai River Basin, dams and floodgates have been shown to reduce annual average flow by 2%, with more pronounced effects during non-flood seasons and dry years. The impact on water quality varies, with positive effects in upper reaches and negative effects in middle and lower reaches ([53]). In addition to reducing the amount of water discharge to the downstream and changing the patterns of runoff, dams can also reduce the variation in water temperature, seasonally and daily, [32] weaken the natural air–water temperature synchrony [26] and decrease the dissolved oxygen concentration of water downstream [7] that are necessary to aquatic life, particularly fish populations.

As a consequence of alterations to the aquatic environment, dams dam construction poses a real threat to biodiversity. Dams can impact various aquatic life, including microorganisms, benthic organisms, plankton, fish, botany, and even bird populations. The impact often stems from the fragmentation of rivers, which can isolate wildlife populations and disrupt migration patterns ([51]). There has also been evidence on significant homogenization of species in heavily dammed rivers in the United States ([42]). Despite the complex and varied responses of rivers and their ecosystems to dams, the general principle to protect biodiversity in dam-impacted rivers relies on preserving natural flow variations, such as alternating low and high flow periods, periodic bed scour, and floodplain inundation—crucial for regulating the life cycles of river organisms and supporting their dependent food webs ([43]).

On coastal areas, one of the most widely recognized impacts of dams is the disruption of natural sediment transport. Dams can trap sediments in their reservoirs, preventing them from flowing downstream to the coast. In delta regions, sediments are crucial for maintaining land elevation and countering sea-level rise. The reduction of sediment delivery to the coastal zone can lead to land subsidence, increased vulnerability to storm surges, and coastal erosion. Evidences regarding decreasing sediment loads due to reservoir deposition has been found, particularly for African and Asian rivers like the Pearl River in Southern China ([12]), Yangtze River in China ([28]), which hosts the gigantic Three Gorgeous Dam or Mekong River ([6]) which is forecasted to further decline by up to 50% in the next twenty years.

Salinity intrusion in the estuaries is another major dam-induced issues that has been a subject of increasing concern and research. Dam's regulation of river flow can reduce the freshwater discharge, leading to an increase in saltwater intrusion and altering the estuarine ecosystem. Studies on the impact of the impoundment phases of the Three Gorges Dam on both water and soil salinity in the estuary of the Yangtze River, particularly during the extreme drought of the 2006 dry season, reveal the significant influence of dam construction on salinity intrusion ([13], [52]).

Our study is not only closely related to the literature on the environmental effects of dams, but also provides novel insights into the dams' impact on the economic and agricultural activities. On one hand, dams provide flood protection and irrigation management to areas in local downstream areas. Duflo and Pande (2005) [17] found that downstream districts experience increased agricultural production and reduced vulnerability to rainfall shocks as a result of new dam construction while the district in which the dam is situated exhibits a negligible rise in agricultural production but sees greater production volatility. However, this common perception agriculture production in the downstream areas are usually better off from irrigation schemes provided by dams and other ancillary facilities has also been challenged by a case study in Ghana's Kpong Dam ([40]). On the other hand, the impoundment of water behind a dam creates reservoirs that can submerge vast areas of land, resulting in habitat loss and the inundation of forests, wetlands, and agricultural fields. These changes can displace communities affecting agriculture practice and livelihood of locals. Galipeau, Ingman and Tilt (2013) [20] shows that resettlement from dam construction on the Mekong River basin in Yunnan Province, China, surprisingly, is associated with higher household incomes, while differences in landholdings were mixed.

Furthermore, these findings are also highly relevant for informed decision-making and the development of sustainable policies and practices that consider the interconnectedness of river ecosystems and the well-being of vulnerable communities in a regional context. Frequently, rivers traverse various legal jurisdictions, spanning across different nations or states within a single country. This inherent multi-jurisdictional nature of rivers incentivizes upstream government to freeride in exploiting water resources [39] and becomes a catalyst for potential political conflicts concerning dam building and their management. International institutions, including multinational financing mechanisms and international water management treaties, have the potential to mitigate this freeriding tendency [39]. The negotiation process, however, hinges on a comprehensive understanding of the magnitude and scope of these externalities.

The paper proceeds as follows. Section 1.3 discusses data and provides descriptive facts about dam construction in the Mekong River Basin as well as historical statistics on Water Level, Vegetation Coverage, Salinity Intrusion and Agriculture Productivity in the impacted region. Section 1.4 describes the empirical strategy and Section 1.5 presents the empirical results. Section 1.6 concludes.

## 1.2 Vietnam Mekong Delta

The Mekong River, spanning six Southeast Asian nations, constitutes one of the world's most intricate river systems, ranking 12th among world's longest river and the third largest in Asia [11]. Originating from the Tibetan Plateau in China, it courses through Myanmar, Lao People's Democratic Republic (Lao PDR), Thailand, and Cambodia, draining a vast watershed of approximately 795,000 square kilometers before reaching the Mekong Delta in Vietnam [10]. It stands as the second richest river in terms of aquatic biodiversity and freshwater capture fishery, following only the Amazon [50].

Vietnam Mekong Delta (VMD) is the most downstream part of the entire Mekong River Basin, belongs to the lower part of the Lower Mekong River Basin. It consists of 13 provinces, covers an area of 95,000 km2 and is home to 21.49 million people (2019) according to the Vietnamese Population and Houses Census [37]. Unlike Cambodia which also belongs to the floodplain within the Lower Mekong River, Within the Vietnamese section of the delta, there is an elaborate network of canals that were developed by local farmers for transportation and agricultural practice purpose over the last century [11]. Thanks to the favorable tropical weather, nutrient-rich river water, and the intricate irrigation network, VMD is a highly productive supplier of agriculture, especially rice paddy. In 2014, the Mekong Delta and Central Highlands (MD/CH) region constituted 56% of Vietnam's entire rice output and contributed approximately 90% of Vietnam's total rice exports [11].

In the VMD, rice is the most widely planted crop, followed by soybean and other cereal crops [38]. Rice production in the VDM depends on seasonal climatic conditions and fresh water resources which are provided by the Mekong River and the monsoon rains that occur generally from May to September or early October.[11] Often, rice paddy cultivation revolves around three primary crop seasons. The winter-spring crop, typically sown at the end of November or the beginning of December and harvested around April, coincides entirely with the dry season, lasting from November through April. The rainy season spans the remaining months of the year, from May to the end of October and early November. The other two crop seasons are both planted during the rainy season but vary in duration until harvesting. The summer-fall crop season commences in April and concludes in August, with August being the harvest month. Meanwhile, the fall-winter crop season, which extends two months longer than the summer-fall crop, starts in May and ends in November.

Like other river estuaries in modern time, VMD is also the victim of various mindless human intervention including dam construction in the upper Mekong. 66% of the entire delta shoreline and 400 different locations along the riverbank is currently under erosion [36]. 50% to 60% decreae in annual sediment load to the delta, lower flood discharges, more frequent low flow events, earlier and more severe salinity intrusion, unblocked ocean surge, etc. are different consequences of how hydrological infrastructures has shifted the natural seasonal regime of water here [36].

Soi salinity, in turn, is considered one of the most serious problems threatening food security. Both rice and soybean, the two most common crops in VMD, have low salinity tolerance [25], making them particularly susceptible to salinity intrusion. Findings from Dam et. al. (2019) [14], a case study taken place in the north-central coastal region of Vietnam during the dry season, show that soil salinity, consistently lower the the yield of rice paddy. Moreover, farmers with smaller and scattered plots may be disproportionately affected by salinity, making it more challenging for them to manage saline soils. A contingent valuation study taken place in VMD [27] reveals that ”more than half of households are willing to pay for reduced salinity intrusion risk” and that ”willingness to pay increases with proximity to, and severity of, the problem”. In regions facing current salinity impacts, households are willing to contribute US$2.58/month. The willingness is US$1.99/month in areas anticipating salinity effects by 203. Remarkably, areas without expected intrusion for the next 15 years, the contribution willingness is still positive at US$1.32/month.

## 1.3 Data and Summary Statistics

### 1.3.1 Dams

To construct a comprehensive dataset for dam construction analysis, data from various sources was amalgamated. Initially, data on Basin-wide Dams and Connectivity was sourced from the Mekong Infrastructure Tracker Dashboard, a data tool offered by the Mekong Dam Monitor project. This project, funded by the Stimson Center with support from USAID Mekong Safeguards and implemented by The Asia Foundation, compiled comprehensive records of dam construction in the Greater Mekong River Basin. The dataset comprises information on the year of dam commission, geolocation, operational status, and power-generating capacity, encompassing a total of 477 observations on hydropower projects. These projects fall into four known operational status categories: Operational, Under Construction, Planned and Cancelled. The dataset not only provides dam locations, including the country, province or state, and district, but also the river tributary to which the dams belong, along with precise latitude and longitude coordinates for seamless integration with other geospatial datasets. Additionally, the dataset offers valuable information on the power-generating capacity, measured in Megawatts, and the average annual electricity output, measured in Megawatt hours.

Second, the Mekong Dam Monitor's Basin-wide dams and connectivity data was subsequently merged with the Geo-referenced Global Dams and Reservoirs Dataset (GeoDAR) [48], utilizing their geographical coordinates. This merger enriches the dataset by incorporating information regarding the reservoirs' capacity, measured in million cubic meters, associated with these dams.

Finally, for dams with missing data on their opening dates and other characteristics such as annual average output and reservoir capacity, I conducted manual data collection from internet sources. While labor-intensive, this effort culminated in the compilation of a dataset comprising a total of 464 dams, among which 132 are currently in operation, and 36 are under construction. In the Appendix, Table A.1 presents summary statistics of the dams' hydropower capacity categorized by operational status. Table A.1 also provides summary statistics based on the country of origin for the dams' power-generating capacity. This distribution is further illustrated in Figure 3.1, which reveals the different strategies employed by different countries in the realm of hydropower. Notably, China houses a relatively small number of dams (19 in total); however, the majority are large or mega-sized, collectively dominating the dams' power-generating capacity and reservoir capacity among all nations. In contrast, Laos hosts more than 330 dams, predominantly of small and mid-size, amassing a combined capacity of approximately 25,000 MW—making it the second-largest hydropower producer, following China's massive total of nearly 30,000 MW from all its dams. Additionally, Figure A.1 provides a visual representation of dam distribution on a regional map. In this visualization, the size of the circles corresponds to the power-generating capacity of the dams, while the green lines represent the river systems as per the HydroSHEDS database [4], categorized at level 3. The shaded green area represents the study's impacted region, totaling 13 provinces within the Mekong Delta area of Vietnam. Furthermore, Figure A.3 delves into the distribution of dam construction over the years. Figures A.3a and A.3b illustrate the distribution of dams over time in terms of power-generating capacity and reservoir capacity, respectively. These figures highlight the onset of the dam construction era in the early 21st century, with a significant surge approximately a decade later. The presence of ongoing construction projects and future plans emphasizes the relevance and urgency of this study, which aims to estimate the impact of dam construction on the environment and agricultural outcomes and predict the future marginal effects of these dams.

Reservoir capacity, power-generating capacity, and average annual electricity output constitute the primary attributes derived from the dataset. These attributes offer insights into the potential disruptive impact of dams, with some level of correlation among them. Figure A.4 illustrates the complex relationship between dams' attributes by plotting them on the reservoir capacity and power-generating capacity plane. Unlike reservoir capacity which only carries information on the size of the dams, average annual output, besides the size, provides valuable information about how the dams are likely to operate. When being controlled on having the same reservoir capacity, dams with higher average annual output typically allow more water to pass through in order to generate more electricity. Therefore, this attribute may have an offsetting effect on the outcomes in relative to the reservoir capacity attribute. It is important to note that these variables remain time-invariant and specific to each dam. Average annual output estimates the annual electricity production capacity of the dam but does not reflect the actual energy generated across different years. As a result, during years when dams are unlikely to operate, particularly in the first year following completion when reservoirs need to be filled, this variable may not accurately capture the information it is intended to convey. Further discussion on this issue and its implications for the identification will be presented in Section **??**.

### 1.3.2 Water Level

The data for water levels is sourced from our partner at the Institute for Water and Environmental Research in Vietnam and is not publicly accessible. This time series data provides daily measurements spanning a 20-year period, from 2000 to 2019. It includes observations of daily average water levels obtained from two distinct water stations: Tan Chau and Chau Doc, both located in An Giang province, Vietnam. Each of these two stations is located on one of the two branches of the Mekong River, right after they cross the Cambodia-Vietnam border and enter the Delta area. The daily average water level measured at these two stations exhibit very high correlation, with Tan Chau consistently having slightly higher yearly maximum water level (Figure A.5). Thus, for the sake of simplicity, the average of the measurements from these two stations is calculated and employed as a unified indicator of the water discharged into the impacted region.

The impact of dam construction and operation on water levels is a multifaceted process, generally categorized into two distinct channels: the initial ”filling effect,” where reservoirs need to be filled in the year following completion, and the ”operational effects” in subsequent years, resulting from dam management and operation. The latter encompasses a combination of various mechanisms, including water diversion for urban use and upstream agricultural irrigation, evaporation due to water storage impeding the river's flow, and more. Hypothetically, among these two effects, the reservoir-filling process exerts a substantial but temporary impact on water levels while the ongoing effects might be of smaller magnitude but persist for a long time.

To study the lasting operational effects of dams, we take a look at the long-term trend of water level. In Figure A.6, the time series of daily water levels (averaged across two stations) spanning the past two decades is depicted, along with fitted lines tracking the yearly maximum, yearly mean, and yearly minimum levels. The graph unmistakably illustrates a significant decrease in the yearly maximum water levels over time from around 500 cm in 2000 to only marginally above 350 cm in 2010, and a slight downward trend in the yearly average water levels with a drop of about 50 cm after 20 years. Conversely, there is no apparent alteration in the minimum water levels across the years. However, the graph reveals a visible elongation of the dry season, suggesting that seasonality of water runoff has become progressively more volatile over time.

Given that water discharge to the downstream region is intricately linked with the water supply to the river, it is crucial to scrutinize the total precipitation in the upstream river basin to rule out the possibility of any objective change in water discharge due to endogenous factors such as climate change. This entails examining the overall precipitation in the entire river basin while subtracting the precipitation within the impacted region. In Figure A.7, we offer a comparative view of the stability of total precipitation in the upstream river basin alongside the changes in water discharge to the downstream delta area over time. Remarkably, a substantial disparity is evident between the volume of water entering and leaving the river system, prompting questions regarding the destination of this deficit water. Is it attributed to processes such as water evaporation and diversion facilitated by the dams? This contrast invites further investigation into the complex dynamics of water management in the region.

To provide a glimpse of the filling effects, in Figure A.8, we illustrate the water time series in relation to the opening dates of the six largest dams, as measured by power-generating capacity. The graph reveals a notable sharp drop in the yearly maximum water level in the year following the opening of all six dams. The plot brings attention to two of these dams, Nuozhadu and Huangdeng, ranked as the largest and third-largest in terms of capacity, respectively, and were completed in 2015 and 2019. Interestingly, or perhaps not coincidentally, the years that followed these dam completions, namely 2016 and 2020, experienced two of the most severe droughts and salinity intrusions in the Mekong River Delta, resulting in record-breaking losses in agricultural output in the region. Detailed information on these agricultural losses will be presented in Section 1.3.3 when discussing data pertaining to agricultural productivity.

### 1.3.3 Agricultural Productivity

The General Statistics Office of Vietnam has been publishing annual statistical data on agriculture since the year 2000. These yearly statistics are aggregated at province level, covering various variables related to rice production, such as for rice output, planted area, yield, and the number of farms. Similar variables are also available for cereal crops, which are the second most commonly cultivated crops in the region after rice.

Figure A.11 presents a graphical representation of rice yield, measured in kilograms per hectare, for different crop seasons, as well as the yearly average rice yield across different crop seasons. The overarching trend reveals a gradual increase in yield for all crop seasons. The winter-spring crop boasts the highest yield, followed by the fall-winter crop, while the summer-fall crop ranks the lowest in terms of yield. Notably, two sharp drops in rice yield are evident in the years 2016 and 2020. These downturns align with the two most severe drought and saltwater intrusion events in history, suggesting a potentially causal relationship worth investigating. The data hints that the response in rice yield to these shocks is particularly pronounced during the dry season when salinity intrusion is expected to be most intense, while the response during the rainy season is almost negligible.

Furthermore, apart from seasonal variations, the response of rice production to drought and salinity shocks can differ between different geographical locations. Figure A.12 compares and contrasts changes in rice yield over time between Ben Tre, a typical coastal province, and Dong Thap, a typical inland province. While rice yield in the dry season in Dong Thap experienced a slight decline in 2016, it remained far from matching the level of response observed in Ben Tre. In the latter province, rice yield for the winter-spring season dropped to zero in both 2016 and 2020. The fall-winter crop, which partly overlaps with the beginning of the dry season, also exhibited a decrease in yield. Similarly, Figure A.14b and Figure A.13 shows the same patterns for rice output by crop-season and by location.

### 1.3.4 Remote Sensing Data

While the government's provided statistics offer reliability, they are only accessible at the provincial level, which somewhat diminishes the power and robustness of empirical analyses reliant upon them. To address this limitation, remote sensing data has been leveraged to estimate measurements of vegetation coverage and soil salinity outcomes. All remote sensing data employed in this paper is derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) collection. Two indexes are directly extracted, and one index is computed using various bands from the Terra Surface Reflectance 8-Day L3 Global 500m SIN dataset according to algorithms proposed in recent literature. In this data collect, satellite images are captured every eight days at a 500-meter pixel scale for the Sinusoidal Tile Grid. Subsequently, all remote sensing indexes are rasterized and utilized to compute zonal statistics for each district. Detailed descriptions of each index are provided below.

### Normalized Difference Vegetation Index (NDVI)

To estimate vegetation coverage and crop yield, we employs the Normalized Difference Vegetation Index (NDVI), which is ”referred to as the continuity index to the existing National Oceanic and Atmospheric Administration-Advanced Very High Resolution Radiometer (NOAA-AVHRR) derived NDVI.” [1]. The NDVI is widely accepted among both earth scientists and applied researchers as a standard measure for approximating vegetation coverage using remote sensing data.

To ensure that the vegetation coverage provides the most accurate estimation of rice yield, the primary crop in the Mekong Delta area, the average NDVI is computed for each crop season only during its peak greenness period. For rice, this period typically falls between two months and one month before the harvest season. Figure A.10 displays the distribution of aggregated NDVI across different districts throughout the year 2016. The map validates the fact that inland areas tend to exhibit greater greenness and higher vegetation coverage, while regions closer to the shoreline are often less suitable for cultivation.

### Vegetation Soil Salinity Index (VSSI)

In contrast to NDVI, the soil salinity index is a relatively recent algorithm for estimating soil salinity using remote sensing imagery, and as such, it remains a subject of debate

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[1] MODIS Data (MOD09GA) Description from data documentation.
https://lpdaac.usgs.gov/products/mod13q1v061/

among researchers. Various indexes have been proposed to approximate soil salinity, with the Vegetation Soil Salinity Index (VSSI) introduced in one of the most recent studies and receiving significant acceptance.

In addition to VSSI, this paper also use the Near Infra-red (NIR) band as an alternative measure of soil salinity, based on the findings in a case study conducted in Tra Vinh, one of the provinces in the Mekong Delta Area [35]. The comparison between satellite data and in situ data in this study concludes that NIR and VSSI exhibit the highest consistency among all the analyzed indexes, with R2 = 0.89 and RMSE = 0.96 dS/m for the NIR band and R2 = 0.77 and RMSE = 1.27 dS/m for VSSI. Regression results using these two different indexes also exhibit relatively close agreement.

Crops, particularly rice, typically have a certain threshold of soil salinity that they can tolerate. Above this threshold, crops become significantly vulnerable and can be affected within a few days on a large scale. Taking that into account, maximum soil salinity is considered more crucial than average salinity index for the purpose of this study. Consequently, in producing the data for zonal statistics, the salinity index is aggregated within each district based on its maximum level throughout the crop season.

Figure A.10a displays the distribution of aggregated VSSI throughout the year 2016, which was marked by an extreme salinity intrusion event, across different districts, with coastal districts unsurprisingly exhibiting the highest levels of soil salinity. Furthermore, in Figure A.9, a time series of the salinity index is plotted against the water time series, illustrating how water and salinity move in opposite phases. Understandably, soil salinity peaks during the dry season when freshwater availability is at its lowest.

## 1.4 Identification Strategy

To estimate the impact of dam construction on various outcomes of interest (water level, soil salinity and vegetation coverage), an Ordinary Linear Regressio (OLS) approach was adopted. Since the dams are constructed and operated in sites that are far-removed from the impacted regions, by foreign authorities who do not have interest in concerning with the welfare of communities in the Delta Area, the dam construction can be plausibly considered as exogenous treatment. In that case, an OLS is enough to identify the causal effects. The main identification strategy is presented in the following regression equation.

$$Y_{i,t} = \beta_0 + \sum_{z=0}^{t} \beta_{1,z} \times RV_{t-z-1,t-z} + \sum_{z=0}^{t} \beta_{2,z} \times RV_{t-z-1,t-z} \times DIST_i + \tag{1.1}$$

$$\sum_{z=0}^{t} \beta_{3,z} \times GWH_{t-z-1,t-z} + \sum_{z=0}^{t} \beta_{4,z} \times GWH_{t-z-1,t-z} \times DIST_i + \tag{1.2}$$

$$\beta_5 \times DIST_i + \beta_6 \times X_{i,t} + \varepsilon_{i,t} \tag{1.3}$$

where $Y_{i,t}$ denotes the outcome in district $i$ at time $t$ ($t$ is identified at the yar-crop seaon level), may it be water level, VSSI for soil salinity index or NDVI for vegetation coverage. On the right handside, the term $RV_{t-z-1,t-z}$ measures the total of the reservoir capacity of all new dams that were open within 1 year, $z$ years prior to the time $t$ at which the outcome is observed. By letting $z$ increases from 0, we include can include more lags of newly added reservoir capacity and thus, capture the on-going effects of older dams that were constructed further in the past on the current outcomes. The second term in the regression is the interaction between these lags of reservoir added $RV_{t-z-1,t-z}$ and the distance to the shore $DIST_i$ of district $i$, measure as the shortest distance from the centroid of the district polygon to the shoreline. Symmetrically, $GWH_{t-z-1,t-z}$ measures the total average annual electricity output of all new dams that were open within 1 year, $z$ years prior to time $t$ of observing the outcome and $GWH_{t-z-1,t-z} \times DIST_i$ is the interactive term between added electricity output and distance to the shore. Lastly, $X_{i,t}$ is a vector of control variables for district $i$ at time $t$, includes total length of all river stems within the district, distance from the district centroid to the water measuring station, the distance from the district to the main river (irrigation cannals are excluded), precipitation within each district, precipitation in the entire upstream river basin (excluding precipitation in the delta), average daily mean temperature in the district, average daily maximum temperature in the district, monthly fixed effect and province fixed effect.

## 1.5 Results

In this section, we present the results of the regression analysis conducted in Section **??**, with variations in the specifications. The study focuses on three primary outcomes: water level, the Normalized Difference Vegetation Index (NDVI), and the Vegetation Soil Salinity Index (VSSI). The analysis on water level is conducted at daily level - the granularity at which water outcome is observed. As for NDVI and VSSI, although more frequent data is available, it is pertinent to investigate these outcomes at the district-crop season level, stratified into two distinct sub-sample groups: rain season crops and dry season crops.

### 1.5.1 Impact of dams on water level

First, we examine the impact of dams' reservoir capacity (Table A.2) and dams' average annual electricity output (Table **??**) on water levels in two separate regression models. Both variables exhibit a significantly negative effect, most pronounced in the first year and gradually diminishing over time. Specifically, one billion cubic meters of reservoir capacity added to the river system in the first year results in a 2.56 centimeter drop in water level, while one additional thousand GWHs of average annual output in the first year leads to a 2.74-centimeter decrease. . Allowing for more lags reveals minor positive effects in the fourth year and beyond, possibly indicating a recovery from the initial disruptive impact of dam construction. However, these later-year effects do not fully offset the damages incurred in the initial years, highlighting the lasting consequences of the dams' construction.

As mentioned earlier, reservoir capacity and average annual output tend to offset each other. While both indicators reflect the disruptive nature of dams, controlling for reservoir capacity reveals that average annual output also signifies turbine operation frequency and, consequently, the amount of water released. Annual average output, being a time-invariant estimate rather than an actual observation, can overstate the positive effect of dams' operation in the first year when they are likely non-operational. Table A.4 presents regression results including both reservoir capacity and average annual output for the first five years, excluding the first year's average annual output. The coefficients on reservoir capacity are consistently negative and those on average annual outputs are consistently positive throughout the year, showing significant impact on water level and confirming the offsetting effects between the two attributes.

In Table A.4, the overall effects also decrease in magnitude over time. However, the coefficient for the first year is an exception; it is relatively smaller than in other years and does not capture the expected filling effects observed in the graphs. This discrepancy arises because, when excluding the first year's electricity output, we not only impute zero for the actual output produced in the first year but also eliminate the information on the size of the dams embedded in this variable. Therefore, while effects on reservoir capacity from year two and beyond are offset by the annual electricity output, reservoir capacity in year one is not. To facilitate a more comparable and interpretable analysis, we also provide a table in which both reservoir capacity and annual output for the first year are excluded in the regression. Table A.5 reveals consistent results for the ongoing effects of dams on water levels discharged into the Delta starting from year two. One billion cubic meter of reservoir capacity added to the river system would cause the water level to decrease by 9.7 cm after two years, 3.27 cm after three years, 1.53 cm after four years, and 2.69 cm after five years. On the other hand, a thousand GWHs of newly added average annual output would offset the water level by 8.07 cm in the second year, 2.99 cm in the third year, 2.03 cm in the fourth year, and 1.41 cm in the fifth year.

### 1.5.2 Impact of dams on vegetation

We encounter similar issues regarding the overestimation of first-year average annual output in the other regressions for both NDVI and VSSI. Therefore, we present two sets of tables for these results: one with first-year annual output excluded (Table **??**) and the other with both reservoir capacity and annual output omitted (Table A.10). In addition to coefficients on reservoir capacity and average annual output, the tables also report the coefficient on the interaction of these variables with the distance to the shore from the district center.

As expected, significant findings are consistently observed in the dry season for both the attributes and their interaction with the distance to the shore. However, this is not the case for outcomes in the rainy season. For most years, except the fifth year, we still observe a significantly negative effect of reservoir capacity and a significantly positive effect of average annual output on NDVI one month prior to the harvest season of the crop. In the dry season, the interactive term between reservoir and distance has a positive sign, suggesting that when controlling for the same amount of newly added reservoir, the impact of reservoir capacity becomes more positive as the distance increases, and vice versa for average annual output—its impact on NDVI decreases for more inland districts. This emphasizes once again how salinity intrusion could be the primary driver channeling these detrimental consequences to vegetation and crop productivity.

### 1.5.3 Impact of dams on salinity intrusion

Table **??** and Table A.11 present the results for the maximum soil salinity index throughout the crop season, following a similar structure to the tables for NDVI, with and without the effect of first-year reservoir capacity. In these two tables, the signs are mostly flipped compared to the same coefficients found in the results for NDVI, indicating that salinity and vegetation are moving in opposite directions. Again, the results are only significant in the dry season but not the rainy season, supporting the hypothesis that salinity intrusion is an important factor through which dams are damaging the crops.

### 1.5.4 Predictive margins

Due to the offsetting effect between reservoir capacity and electricity output, interpreting the total effects on the outcomes of adding a dam to the river from the regression tables can be challenging, despite the high significance of the coefficients. Therefore, we present a table (Table A.12) that estimates the total marginal effects of different operational dams and a separate table (Table A.13) that predicts the total marginal effects of various future dams, whether under construction or planned. This approach offers a more straightforward interpretation of the results and allows for comparisons across different dam characteristics. The tables only zoom into the effect in the dry season as it is suggest to be significant by the regression tables.

To achieve this, we select various dams from the data based on their reservoir capacity and electricity output, aiming to represent different types of dams. These may include dams with a small reservoir but significant hydro-power capacity (typically with tall walls and large turbines) or dams with a large reservoir but shallower characteristics and older turbines, for example. Table A.12 presents the predicted total marginal effects of seven different operational dams, arranged in descending order based on the reservoir capacity to electricity output ratio from left to right. Se San 4 (2009) in Vietnam stands out as the least productive dam conditional on reservoir capacity and Don Sahong (2009) in Laos is the most productive one. Nuozhadu (2015) in China holds the distinction of being the largest dam in the dataset in terms of both reservoir capacity and electricity output, with its reservoir being one and a half times larger than that of Xiaowan (2010), the second-largest dam in the dataset. Huangdeng and Xayaburi are the two sizable dams that both became operational in 2019, coinciding with the subsequent year being the record-breaking extreme event of drought and salinity season in the Delta provinces. Table A.13 provides predictions for the total effects of two dams currently under construction, Luang Prabang (Laos) and Tuoba (China), as well as two planned dams in China, Ganlanba and Guxue, offering insights into their potential impact.

The coefficients utilized for calculating the predictive margins are derived from the main specification, which includes the first five year newly added reservoir capacity and electricity output while excluding the first year electricity output. In additional to the actual reservoir capacity and electricity output of the dams selected, we use the average distance from all coastal districts to the shore to predict the marginal effect on the coastal regions, and the average distance from all inland districts to the shore to estimate the impact on the inland areas.

There are several interesting ways to compare the margins in this table to explore the heterogeneity of the effects. First, the effect on water level in the first year is consistently negative regardless of the dams' attributes, indicating a strong negative impact of the filling effect. From the second year and beyond, depending on the characteristics of the dams, the effect could be either negative or positive. The offsetting effect of electricity output for reservoir capacity appears to be very strong on water level outcomes. For example, compared to Huangdeng, whose reservoir is about nine times larger than Xiaowan's and produces twice as much electricity annually, Xiaowan exhibits a slightly positive marginal effect on the water level in the second year, whereas Huangdeng still shows an extremely negative effect on the river. Meanwhile, dams like Don Sahong and Miaowei, due to their relatively small ratios of reservoir to output, exert considerably positive impacts on the downstream compared to Se San 4, which is of similar size but has the least electricity productivity. Overall, the magnitude of the effects decreases over time from the second year and beyond.

Secondly, the predictive margins on NDVI are often negative for dams with a relatively larger reservoir capacity and relatively smaller electricity capacity. In contrast, for VSSI, which measures the effect on soil salinity, dams with larger reservoirs and smaller annual output lead to the highest saltwater intrusion, while dams with smaller reservoirs but sizable annual output can cause the reverse result. For both NDVI and VSSI, the absolute value of the change in outcomes is consistently slightly smaller for inland districts than for coastal districts. Once again, the offsetting dynamic between reservoir capacity and electricity output can still be observed for NDVI and VSSI outcomes across different dams, similarly to the water level outcomes interpreted above.

## 1.6 Conclusion

The development of hydrological dams on the Mekong River at a fast pace over the last two decades has raised a serious concern on its environmental impacts. Dams wield the power to significantly modify water flow dynamics, leading to shifts in the timing, speed, and components of downstream water flows. As a consequence, salinity intrusion in the estuary becomes more severe and unpredictable under lower level of water discharge with higher seasonal volatility. This, in turn, triggers drastic impacts on agriculture, particularly within the expansive river delta. This paper examines and quantifies the linkage between dam construction and salinity intrusion and agriculture productivity.

Our empirical approach to this investigation uses data on historical dam construction on the Mekong River, complemented by remote sensing data approximating outcome variables such as salinity levels and agricultural productivity. The two main attributes, maximum reservoir capacity and average annual electricity output, of newly open dams are matched to the outcomes observed in the Vietnam Mekong Delta by aggregating them within an annual period for different time horizons prior to the observation of outcomes. We employ an ordinary least square model that regressing these different lags of newly added reservoir capacity and electricity output on salinity index and vegetation index. This approach allows for a dynamic analysis of how the effects evolve over time. Furthermore, the model includes an interaction term between these lags and the distance to the shore of the districts in the delta, providing insights into spatial heterogeneity effects. Lastly, separate regressions are ran on stratified data for the dry and rain seasons, to provide insights on the dams' volatile effect through changes in floods and droughts.

The findings unveiled the profound influence of upstream dams on the reduction of water flow into the delta over time, with the most pronounced effects emerging in the immediate aftermath of dam construction.

Our study underscores the vital role of international institutions and water management treaties in mediating potential conflicts arising from the development of dams, particularly in the context of transboundary rivers. Informed decision-making and the formulation of sustainable policies necessitate a comprehensive understanding of the magnitude and scope of these externalities. The interconnectedness of river ecosystems and the well-being of downstream communities demand careful consideration to navigate the complex landscape of dam development while safeguarding the vitality of both ecosystems and human livelihoods. In conclusion, this research provides essential insights into the far-reaching impact of dams on agriculture and highlights the urgency of addressing the regional implications of dam construction in a rapidly changing world.

# Chapter 2

# IMPACT OF AIR POLLUTION ON RISK AVERSION AND DECISION MAKING: EVIDENCE FROM INDONESIA

## 2.1 Introduction

Air pollution is a pervasive environmental issue that significantly contributes to various health problems, ranging from respiratory and cardiovascular diseases to more subtle but equally serious cognitive impairments. Cognitive impairment is one of the significant consequences of air pollution exposure. Research has increasingly shown that pollutants such as fine particulate matter (PM2.5) can cross the blood-brain barrier, leading to inflammation and oxidative stress that affect brain function. These cognitive impairments can manifest in various ways, including diminished memory, attention, and decision-making abilities. Among these, changes in risk preference — a key indicator of cognitive function — are particularly important to understand. Risk preference shapes how individuals approach decisions that involve uncertainty, which is central to many aspects of life.

An individual's risk preference can have a direct influence on numerous facets of their lives, including economic outcomes. For example, individuals with higher risk aversion might avoid investments or entrepreneurial ventures, opting for safer but potentially less profitable opportunities. This can impact personal wealth accumulation, career advancement, and overall economic mobility. Conversely, individuals who become more risk-seeking due to cognitive changes induced by environmental factors might engage in behaviors that expose them to higher financial risks, such as speculative investments or gambling. These shifts in behavior not only affect individual economic outcomes but can also have broader implications for economic stability and growth.

Understanding the link between air pollution, cognitive impairment, and risk preference is crucial for several reasons. First, it highlights the hidden costs of air pollution that extend beyond physical health issues to include significant economic and societal impacts. Second, by identifying how air pollution influences decision-making processes, policymakers can design more effective interventions to mitigate these effects. For instance, improving air quality could be seen not just as a health measure, but also as an economic strategy to enhance cognitive function and decision-making capabilities across the population.

The paper is set within the specific context of Indonesia for several important reasons. First, Indonesia features a diverse landscape in both natural geography and economic activities, providing substantial variation in the spatial distribution of air pollution. This variation includes pollution from volcanic and wildfire activities as well as from industrial production.

Such diversity allows for a comprehensive analysis of different pollution sources and their impacts on human behavior.

Second, while many national-level household surveys with substantial sampling and coverage primarily focus on economic and lifestyle outcomes, the Indonesia Family Life Survey (IFLS) includes key sections that examine individuals' risk preference, time preference, and trust. This unique feature makes the IFLS particularly suitable for studying the relationship between air pollution and decision-making behaviors. Moreover, the longitudinal nature of the IFLS allows for the tracking of changes in individual behavior over time in response to varying levels of air pollution. This temporal aspect is crucial for understanding the dynamic relationship between pollution exposure and decision-making processes.

Additionally, Indonesia's status as a developing country with rapidly growing industrial sectors and frequent environmental challenges such as deforestation and haze from wildfires makes it an ideal setting for this research. The findings from this study could have significant implications for policy interventions aimed at mitigating the adverse effects of pollution on human behavior and economic decisions.

This paper undertakes an empirical approach to examine the subtle link between air pollution and risk preference as well as risky decision behaviors. To achieve this, we utilize data from the MERRA-2 collection—NASA's remote sensing data that provides approximations of air pollution exposure with fine spatial granularity and daily frequency. These pollution indexes are then mapped to household and individual risk preferences, as revealed by the Indonesia Family Life Survey (IFLS), along with their decision-making behaviors. These behaviors include financial decisions, choices of employment sector, and significant life-changing decisions such as migration and business startups.

The matching process is based on the physical locations of the respondents and the dates of their interviews. This precise matching ensures that the pollution exposure data accurately reflects the environmental conditions experienced by the respondents at the time their risk preferences and decision behaviors were recorded. The random and representative nature of the survey sampling allows for plausible exogeneity, minimizing potential biases that could arise from non-random sampling or endogeneity issues.

Given the robustness of the survey design and the precision of the matching process, an Ordinary Linear Regression (OLR) is employed to analyze the impact of air pollution on the various outcomes. This methodological approach helps isolate the effect of air pollution on risk preferences and decision-making behaviors, controlling for a wide range of individual and household characteristics. By doing so, we aim to uncover how different levels of pollution exposure influence individuals' willingness to take risks and make critical life decisions.

Intuitively, there are two distinct mechanisms that can facilitate the impact of environmental factors and behavioral decision making. The first channel is the entering of environmental quality into the decision making process as an input information. This channel only works for pollution exposure that is visible or communicable. For example, [8] have found that one standard deviation increase in air pollution leads to an increase of 7.2% in the number of same-day contracts to purchase health insurance, which reflects the projection bias and is consistent with the salience theory.

The second channel in which air pollution is suspected to have influence on decision making is through its damage to human brain and mood alteration. In theory, this mechanism is salient to both visible and invisible exposure. The rationale for such speculation relies on an important link of the reaction chain - human brain. The detrimental effects of air pollution on human cognition is well-established in the environmental economic literature. Meanwhile, the role of the subjects' neural capacity and instantaneous sentiment in the measure of their risk preference and the decision making process is also gradually brought to light by neuroscientists and behavioralists in recent studies. Although there has been few direct biological evidences documented for this channel, some of the first empirical studies have looked at the relationship between air pollution and decision making outcomes in general. One of the earliest results of this kind can be found in [23], where bad air quality in Manhattan area is found to be significantly associated with a lower same-day return in the S&P 500. Similarly, [16] provides proof of a negative correlation between air pollution during corporate site visits by investment analysts and subsequent earnings forecasts in the immediate following week, suggesting a mood-driven mechanism. Another recent paper by [34] that assesses data on stock market anomalies and severe pollution episodes, also exhibits strong evidence of the impact of haze and financial market performance.

In addition to these empirical studies, there has been some effort to examine the effect of air pollution on various decision making biases using an experimental approach. So far, [9] appears to be the only publication from this approach. By conducting a natural laboratory experiment involving more than 600 students, the authors are able to identify a causal effect of PM 2.5 (particular matters with diameter less than 2.5 micro-meters) on various behavioral decisions. In particular, they find that with higher concentration of PM 2.5 in the air, subjects become more risk averse over losses and ambiguity aversion over gains. In terms of social preferences, they observe smaller contributions in public good game, less giving in dictator game as well as less reciprocation in sequential prisoner's dilemma, all of which point to a less pro-social response associated with more polluted environment.

In general, existing papers in this literature are at their pioneering stage, hence, are unavoidably subject to some drawbacks. Most applied studies in this topic are using an intuitive outcome for risk preference and decision making instead of a standard measure such as risk aversion or implied discount rate, etc. This disadvantage causes all the findings to be highly context-dependent and thus, lack of generalizability. Therefore, being the first study to establish the linkage between air pollution and risk aversion, this paper does not only provide further empirical evidence of how haze can influence human's risk preference and risky decision making but also offers an explanation to the drive of this relationship - risk aversion.

The paper proceeds as follows. Section 2.2 discusses data and provides descriptive facts about Air Pollution in Indonesia as well as Individual's Risk Aversion measured from the survey. Section 2.3 describes the empirical strategy and Section 2.4 presents the empirical results. Section 2.5 concludes.

## 2.2 Data

There are three main sets of data that are required to achieve the listed goals: first, the Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) for estimated pollution concentration; second, the Indonesia Family Life Survey (IFLS) for the risk aversion measure and other individual and household outcomes that are related to risky decision making; and third, the Moderate Resolution Imaging Spectroradiometer (MODIS) for Thermal Anomalies & Fire intensity.

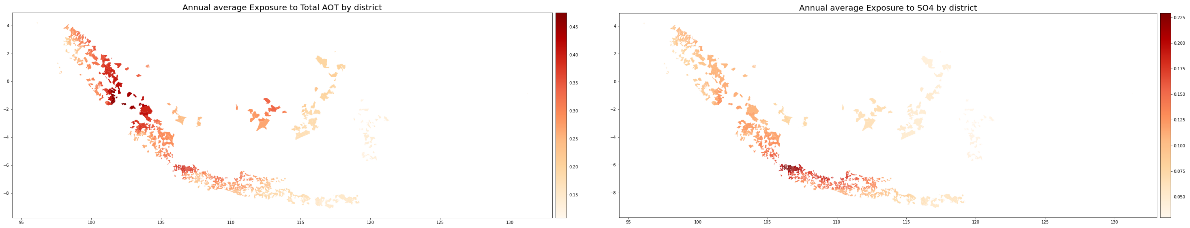
### 2.2.1 Air Pollution Data

Traditionally, economists and scientists have relied on data from ground stations to measure surface aerosol concentrations. While ground-station data is highly accurate, it suffers from limited coverage due to the sparse distribution of these stations, particularly in the developing world where they are often scarce or nonexistent. This limitation has hindered comprehensive analysis and understanding of air pollution's global impact. Fortunately, recent advancements in satellite technology and machine learning algorithms have provided a new source of air pollution data through satellite imagery of the Earth's surface. By processing these images with remote sensing algorithms, researchers have developed an alternative estimate to approximate aerosol concentrations, known as aerosol optical depth (AOD).

AOD leverages the optical properties of sunlight as it travels through aerosols in the Earth's atmosphere. Specifically, this technique measures the extent to which sunlight is absorbed or scattered back into space by aerosols. By calculating the amount of sunlight that reaches the ground, scientists can estimate the columnar concentration of aerosols in the atmosphere. This method provides a reliable proxy for surface-level pollution levels. The use of AOD data has several advantages. It offers extensive spatial coverage, including remote and under-monitored regions, thereby filling the gaps left by ground-station networks. Additionally, satellite data can be updated frequently, providing timely and consistent information on air quality across the globe. Moreover, integrating AOD data with ground-station measurements can enhance the accuracy and reliability of pollution estimates. This hybrid approach allows for cross-validation and calibration, improving the robustness of air quality assessments. The combination of satellite-derived data and traditional ground measurements thus represents a significant advancement in environmental monitoring and research.

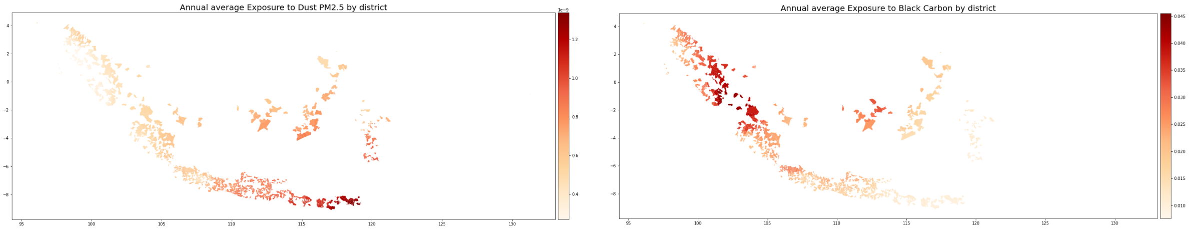
In recent years, there has been a surge in the development of various data products to meet the growing demand of applied sciences. In general, these products can be divided into three categories: model-based, satellite-based, and reanalysis data. *Model-based data* uses meteorology-chemistry forecasting models to estimate AOD for different times and locations. This approach offers the advantage of spatial and temporal continuity; however, it fails to capture rapid changes in aerosol levels in real time. On the other hand, *satellite-based* *datasets*, such as the MODIS Aqua/Terra data set, process satellite images using remote sensing algorithms like the deep blue and dark target algorithms. These data sets are capable of producing reliable near-real-time estimates for AOD. However, this comes at the cost of spatial and temporal continuity due to cloud coverage and limited satellite orbits. To harmonize this trade-off between accuracy and coverage, *reanalysis data products* combine both satellite-based and model-based information. A popular product of this type, which is also adopted for this project, is the MERRA-2 dataset released in 2017 by NASA's Global Modeling and Assimilation Office.

MERRA-2 offers continuous spatial and temporal coverage with high resolution. Specifically, MERRA-2 observations are taken every hour over a grid box of 0.5° in latitude by 0.65° in longitude. Importantly, MERRA-2 provides a full profile of different PM2.5 species, including dust, black carbon, organic carbon, sea salt, and $SO_4$, which vary significantly in nature and indicate different ground activities. For example, $SO_4$ is primarily an industrial discharge and is usually found in industrialized areas. Figure 1a depicts the monthly average concentration of $SO_4$ over Indonesia for the study period from September 2014 to December 2015, showing the highest concentration in Jakarta, the capital and most industrialized area of Indonesia. Meanwhile, Figures 1b and 1d respectively capture the monthly average surface mass concentration of black carbon and organic carbon PM2.5 over the same period. The most intense clusters in these graphs align with areas that experienced the most severe wildfires during that year, reflecting the nature of black carbon and organic carbon as products of biomass burning. Lastly, Figure 1c portrays the profile of desert dust aerosols, which mainly originate from deserts and are transported across continents by air currents, showing little connection with natural and artificial activities on the ground.



(a) Annual average Exposure to Total AOT

(b) Annual average Exposure to SO4



(c) Annual average Exposure to Dust PM2.5

(d) Annual average Exposure to Black Carbon

**Figure 2.1**: Annual Average Exposure to different air pollution particles

### 2.2.2 Risk Preference and Decision Making Data

In addition to air pollution, the key variables required for this study are risk preference and decision-making outcomes, which I extract from the Indonesia Family Life Survey (IFLS). The IFLS is a longitudinal survey that follows about 16,204 households and 50,148 individuals (statistics from the most recent wave) through at least five waves of data collection to date. The surveys were conducted across the majority of provinces in Indonesia, covering the country's most populated islands. The modules on Risk Preference, Time Preference, and Trust were introduced in the $4^{\text{th}}$ wave in 2007 and continued through the $5^{\text{th}}$ wave in 2014/2015, making these two waves particularly relevant for this project.

The survey data is highly granular in terms of geographic identification and includes the exact date and time of each survey occurrence, allowing for precise matching with air pollution data on both spatial and temporal dimensions. Each individual's physical address is identified at three levels: province, which is equivalent to a US state; regency or city, which corresponds to a US county; and district, the subdivision of regency/city level, akin to a US neighborhood. The average area of a district is refined enough to capture heterogeneity within a grid cell of pollution data. This granularity is crucial for linking individual behavior and preferences to specific air pollution exposure levels. By leveraging the detailed geographic and temporal data from the IFLS, it is possible to analyze how variations in air pollution at different times and locations influence risk preferences and decision-making processes. The IFLS's comprehensive coverage and depth make it an ideal dataset for studying the intricate relationships between environmental factors and economic behaviors in Indonesia.

### Risk Aversion Measure

For each individual, their risk aversion can be estimated using two sets of questions in the Risk Preference Module: one set focuses on high-stake gambles and the other on low-stake gambles. These yield two measures: high-stake risk aversion and low-stake risk aversion. Each set contains five questions formatted as choices between a certain payoff and a gamble with a 50 percent chance of winning a higher payoff and a 50 percent chance of receiving a lower payoff compared to the certain amount. If the subject chooses the certain payoff, they exit the survey; otherwise, they proceed to the next question, which involves a riskier gamble with a potentially higher payoff for winning but a lower payoff for losing. This process is illustrated in Figure 2 in the Appendix. Based on where the subject exits the survey, a risk aversion score between 1 and 5 is assigned. Figure 2.2 provides a roadmap for how the risk aversion score is assigned based on respondents' answers.

A complication arises from a non-standard question in the survey, which asks respondents to choose between a certain amount and a gamble with a 50% chance of receiving a

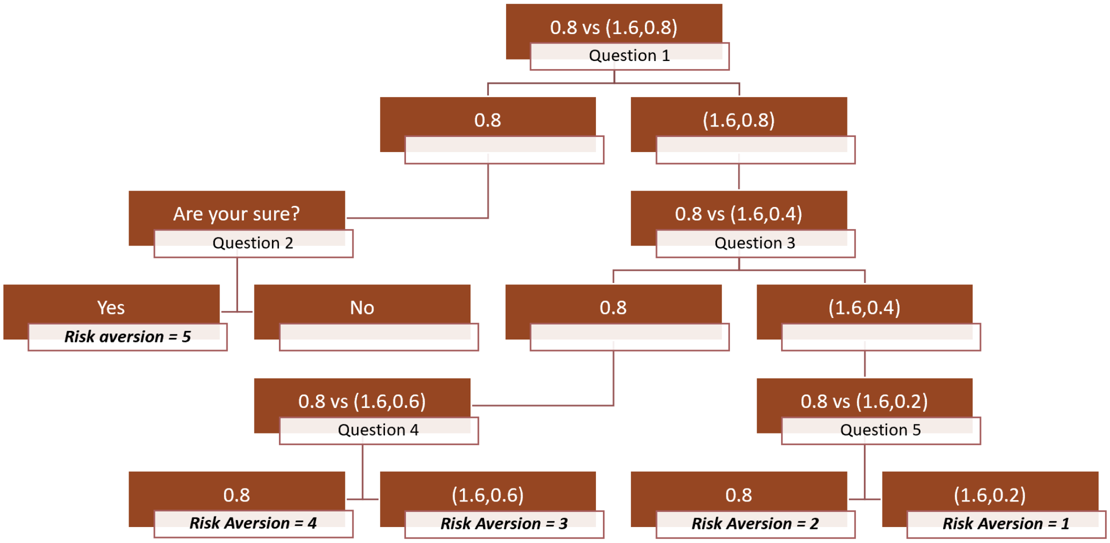


**Figure 2.2**: Risk Aversion Questionnaires

higher payoff and a 50% chance of getting the same amount as the certain payoff. According to expected utility theory, a perfectly rational person would always prefer the gamble over the certain amount. For these subjects, if they choose the certainty option, indicating extreme risk aversion, I assign a risk aversion score of 5. However, it is important to note that the risk aversion score is not linear in nature.

A comparison between the distributions of high-stake and low-stake risk aversion within the sample is presented in the histograms in Figure 3. As shown in Figure 3b, there is a significant proportion, approximately 30%, of interviewees who refused to enter the low-stake riskless gamble (RA = 5). In contrast, this proportion is only slightly over 10% in the high-stake set. This phenomenon contradicts what prospect theory predicts. Therefore, for a robustness check, I will conduct a version of regressions excluding this group of gamble-averse individuals.

### Decision Making Outcome Variables

The Indonesia Family Life Survey (IFLS) is a well-designed survey encompassing a wide range of modules on individual and household behaviors. Using these modules, I construct three primary sets of outcome variables relevant for assessing risk preference and decision-making biases.

First, for household financial decisions, I select Borrowing, Loan, Saving, and Net Saving, which is calculated by subtracting the Borrowing amount from the Total Saving. Second, at the individual level, I examine the personal choice of employment sector, which is likely correlated with one's tolerance for risk. Indicators for different employment sectors, such as Private, Public, Self-employed, and Unpaid family worker, are examined separately. The third set of outcome variables focuses on individual lifetime risky decisions, such as Quitting a job, Starting a business, Owning a business, and Migrating.

In addition to the wide selection of outcome variables, the survey also offers a rich set of control variables for both households and individuals. The household control variables include Household (HH) Size, HH Income, HH Assets, and Urban. Individual control variables include Female, Age, Married, Income, Dummies for Highest Level of Educational Achievement, Ethnicity, and Religion. Additionally, there are two levels of geographic fixed effects (FE): province FE and regency/city FE.

Both the outcome and control variables are summarized in Table B.1.

## 2.3 Empirical Strategy

The empirical strategy of this study is structured into two parts. In the first part, individuals and households are matched with air pollution data based on their location and the date of their interview. Then, I regress risk aversion on their exposure to air pollution to uncover the direct relationship between air pollution exposure and variations in individuals' risk aversion. In the second part, to ensure that risk aversion is a meaningful measure of risky decision-making, I conduct an empirical exercise to evaluate the correlation between risk preference and decision-making behaviors.

### 2.3.1 Air Pollution and Risk Preference

To examine the correlation between air pollution and risk preference, I first match the observations for these two variables spatially and temporally.

**Spatial Matching:** For spatial matching, I assign each individual's risk aversion score to the PM 2.5 value in the pollution data grid-box that completely contains their district. If an individual's district spans multiple grid-boxes, I construct the air pollution exposure for that individual by calculating the average PM 2.5 value across these grid-boxes, weighted by the overlapping area of each grid-box with the district. This approach ensures that the pollution exposure accurately reflects the geographic distribution of air quality within the district.

**Temporal Matching:** For temporal matching, I assign the daily average PM 2.5 value from the date the individual took the survey to their pollution exposure. If an individual participated in the survey multiple times, I use the value from the last recorded occurrence. This is because the Risk Preference module is the second-to-last module in the survey, and the survey protocol involves asking questions sequentially. Thus, the last occurrence provides the most relevant pollution exposure data corresponding to when the risk preference was assessed.

A straightforward regression can be used to analyze the relationship between air pollution and risk preference, incorporating meteorology controls such as temperature and precipitation as well as regency-year FE.

$$RA_{i,t,d,r} = \sum_{p} \beta_{1,p} \times AOT_{p,t,d,r} + \beta_2 \times X_{i,t,d,r} + \beta_3 \times YEAR_t + \beta_4 \times REGENCY_r + \varepsilon_{i,t,r} \qquad (2.1)$$

where $RA_{i,t,d,r}$ is the Risk Aversion index of individual $i$ living in district $d$, regency $r$ and interviewed at time $t$. $YEAR_t$, $REGENCY_r$ and $X_{i,t,d,r}$ are Year Fixed effects, Regency Fixed effects and the vector of control variables for the same individual as defined in 2.2

### 2.3.2 Risk Preference and Risky Behavior Decision-Making

To study the relationship between Risk Preference and Risky Behavior Decision-Making, I regress risk aversion score on the three sets of outcome variables described in section 3.2.2.

#### Individual Outcomes

For individual outcome, the identification is specified in the following equation

$$Y_{i,t} = \beta_1 \times RA_{i,t} + \beta_2 \times X_{i,t} + \beta_3 \times YEAR_t + \beta_4 \times REGENCY_{i,t} + \varepsilon_{i,t} \qquad (2.2)$$

where $Y_{i,t}$ is the outcome variable for individual $i$ at time $t$ ($t \in \{2007, 2014\}$ is the year when the wave of survey takes place). $RA_{i,t}$ is the Risk Aversion Score assigned to individual $i$ who answers the survey at time $t$ as described in section 3.2.1. Regressions are ran separately for high-stake RA and low-stake RA. $X_{i,t}$ is the vector of individual control variables including Age, Female, Urban, Married, Dummies of Ethnicity, Religion and Education level. $YEAR_t$ is the Year FE for year $t$, and $REGENCY_{i,t}$ is the Regency/City FE for each individual at a certain year.

The key estimate of interest, parameter $\beta_1$, measures the average changes in the outcome as the individual moved one step up the scale of risk aversion.

**Household Outcomes**

Since the Risk Aversion measure is observed at the individual level, matching it to household outcomes requires an additional intermediate step. This involves identifying a Decision Maker (DM) for each household based on the Decision Making module. This module asks respondents to identify the person or persons responsible for making major decisions regarding large financial expenditures and savings. A household can have a single or multiple decision makers.

If there is a single DM, the Risk Aversion score and other individual control variables for this DM are matched to the household outcomes. If there are multiple DMs, the Risk Aversion scores and other numerical controls (such as age and income) are averaged across all DMs. Since average values are meaningless for categorical variables, I match the values of the DM who earns the most to the household outcomes. To ensure the robustness of the results, I conduct an additional test where I match the male and female DMs separately to the household outcomes. This approach allows for a comprehensive understanding of how individual risk preferences influence household decision-making, accounting for potential variations in decision-making dynamics within households.

The formal regression equation is as followed:

$$Y_{h,t} = \beta_1 \times DMRA_{h,t} + \beta_2 \times DMX_{h,t} + \beta_3 \times YEAR_t + \beta_4 \times REGENCY_{h,t} + \varepsilon_{h,t} \tag{2.3}$$

where $Y_{h,t}$ is the outcome variable for household $h$ at time $t$. $DMRA_{h,t}$ is the Risk Aversion Score assigned to Decision Maker of HH $h$ at time $t$. $DMX_{h,t}$ is the vector of control variables for the HH DM, including Age, Female, Urban, Married, Income, HH Income, HH Size, HH Asset, Dummies for Religion, Ethnicity and Education Level. Other notations and interpretation of the coefficient are the same as in equation (2.2).

## 2.4 Results

### 2.4.1 Air Pollution and Risk Aversion

Table B.8 presents the results of regressing Low-stake Risk Aversion on the Air Pollution Index measured on the day of the interview, considering different types of pollution profiles. While most pollution types do not significantly impact an individual's risk aversion on the interview day, dust shows a positive and significant effect at a 95 percent confidence level. In contrast, Table B.9 demonstrates a minor effect of accumulated exposure to SO4 within the 30 days prior to the interview on the Risk Aversion score. However, other pollutants, such as black carbon, organic carbon, dust, and sea salt, do not exhibit a similar impact.

Given the differing nature of these pollutants—SO4, a major industrial discharge known for its toxicity to human health, and dust, primarily referring to desert dust that is highly visible to the human eye, one might speculate that the immediate effect of dust on risk aversion during the interview reflects the psychological impact of pollution. Meanwhile, the accumulated effect of SO4 could indicate the physical impact of pollution on the human brain and cognitive capacity.

### 2.4.2 Risk Aversion and Household Decision Making

To examine the relevance of Risk Aversion score measured from the survey with the Households and the Individuals' risky decisions, I study the correlation between their Risk Aversion Score with some major outcomes from the survey mainly in three aspects of life that reflects their risk preference: Household Financial Decision, Individual Choice of Employment Sector, Individual Life-time Decision and Individual Choice of Health Insurance.

Tables B.4 through B.7 present the regression results for Low-stake Risk Aversion and Tables B.10 through B.13 present that of High-stake Risk Aversion. In general, Low-stake Risk Aversion show significantly correlation with most household and individual outcomes while High-stake Risk Aversion exhibits a more modest significance. The figures suggest that Low-Stake Risk Aversion is a strong indicators of individual and household risk preference and risky decision making behaviors while High-Stake Risk Aversion has minimal predictive power.

In particular, in terms of household financial decision-making, Table B.4 shows that Low Stake Risk Aversion is slightly associated with less Saving while being strongly associated with more Saving, and thus significantly associated with positive Net Saving overall. Additionally, the connection between low-stake risk aversion and employment sector choice is also highly intuitive, as illustrated in Table B.5. Individuals with higher risk aversion are significantly more likely to work in the public sector, which offers greater job security and lower income volatility. Conversely, they are less likely to be self-employed or unpaid family workers, roles that inherently involve higher financial risk and uncertainty. Interestingly, no significant relationship is observed for private sector workers, likely due to the heterogeneous nature of this group, which includes both employers and employees with varying levels of risk tolerance. Similar patterns emerge in the context of individual health insurance choices

(Table B.7). More risk-averse individuals tend to prefer public insurance, which typically offers more comprehensive coverage and lower out-of-pocket costs, over private or labor insurance options, which may involve higher financial risks and uncertainties. When examining life-changing decisions, the result from Table **??** indicates that higher levels of low-stake risk aversion correlate with a lower likelihood of engaging in uncertain activities, such as quitting a job, starting a business, owning a business, or relocating. This tendency underscores the broader impact of risk aversion on major life choices, reinforcing its role as a critical measure of risk preference.

Although this analysis is not causal in nature, it provides compelling evidence that risk aversion significantly influences various aspects of individual and household decision-making. The strong correlation between risk aversion and financial and employment decisions highlights its importance in shaping economic outcomes and the overall economic status of households and individuals. Understanding these dynamics is crucial for developing policies and interventions that support better financial and employment decisions.

## 2.5 Conclusion

In addition to many well-known health effects of air pollution on human beings, bad air quality also impairs cognitive abilities, influencing economic behaviors and overall societal well-being. Understanding the impact of air pollution on cognitive function and decision-making is crucial because it highlights the broader, often overlooked consequences of environmental issues. This paper investigates the link between air pollution and risk preferences, focusing on how exposure to pollutants affects individuals' decision-making behaviors. It examines how increased exposure to pollution may impact individual risk aversion, which leads to changes in decision-making processes.

Our empirical approach to this investigation utilizes data from NASA's MERRA-2 remote sensing collection, which provides approximate measurements of air pollution with fine spatial granularity and daily frequency. This pollution data is matched with household and individual risk preferences and decision-making behaviors from the Indonesia Family Life Survey (IFLS) based on the physical location of the respondents and the accurate time at which interview was taken.

The findings reveal that higher exposure to air pollution is significantly associated with increased risk aversion. This change in risk preference influences various domains: more risk-averse individuals are more likely to work in the public sector and less likely to be self-employed or unpaid family workers. There is a preference for safer investment options and public health insurance. Additionally, higher risk aversion correlates with a lower likelihood of engaging in uncertain activities, such as starting a business or relocating.

This study makes a significant contribution by establishing a direct link between air pollution and risk aversion, providing empirical evidence of how environmental factors influence economic behaviors. By focusing on Indonesia, a developing country with diverse pollution sources, the research offers valuable insights applicable to other regions facing similar challenges. The findings advocate for comprehensive air quality management, not only as a health measure but also as an economic strategy to enhance cognitive function and decision-making capabilities across populations.

# Chapter 3

# EXPORT AND LABOR MARKET OUTCOMES: A SUPPLY CHAIN PERSPECTIVE - EVIDENCE FROM VIETNAM

## 3.1 Introduction

In the past two decades, the notable uptick of integration of developing nations into global trade and value chains (GVCs) has sparked heightened interest among policymakers and researchers regarding the implications for labor markets. Consequently, a substantial body of literature has emerged seeking to unravel the intricate relationship between trade dynamics and localized labor market outcomes.

Standard theory about the benefits of trade assumes perfect mobility of factors across geographical regions and industries within a country. However, recent empirical evidence has shed light on the limitations of these conventional theoretical models. Findings from Topalova (2010) [47] uses data from India to indicate that regions more exposed to trade liberalization have experienced slower poverty reduction and muted consumption growth, diverging from the predictions of traditional trade frameworks. Assuming segmented labor markets, and exploiting cross-market variation in import exposure, a key study by Autor, Dorn, and Hanson (2013) [3] confirms that the ”China Shock” led to significant decline in employment and wages in more exposed U.S. regions. This sparked more studies on the repercussions of tariff changes or import competition on local labor markets (Pierre and Schott 2016 [41]; Acemoglu et al. 2016 [1]; Dix-Carneiro and Kovak 2013 [15]).

It is crucial to note that trade affects not only tradable but also non-tradable sectors within the same local labor markets; while increased import competition or market access directly impact specific tradable sectors, there are also indirect effects non-tradable sectors such as retail, healthcare, or hospitality in the same region. With few exceptions, current literature largely ignores estimating these indirect effects propagated through domestic production linkages within a country [49]. While a few studies have examined the indirect effects of import shocks on local labor markets, there’s been limited exploration of indirect effects of exports. A central motivation for this empirical inquiry stems from the well-documented fact that as economies undergo structural transformation—that is, as they move from less agriculture to more services and manufacturing—the proportion of domestic services or inputs in total outputs tend to rise (McCaig 2013 [33]; Ghosh 2021). At first glance, this might suggest that a larger proportion of employment remains unaffected by trade, given the larger non-tradable component of the services sector. However, more trade can even indirectly influence non-tradable industries that serve as inputs to tradeable sectors.

This paper focuses on estimating the total effect on labor market outcomes in response to an export shock at the provincial level in Vietnam from 2009 to 2019. In order to fully capture the overall impact of trade, we need to consider crucial supply chain linkages previous research has overlooked. Our analysis goes beyond solely focusing on directly exporting industries and takes into account industries indirectly affected by the rising demand for exports.

To accomplish this, we adopt a multi-stage approach. Initially, we employ an instrumental variable (IV) methodology to isolate an exogenous component of trade driven solely by foreign demand. The chosen IV is the proportion of a given trading partner country's share in a specific commodity relative to Vietnam's total export value in that commodity, adjusted by the observed GDP growth of the partner country. This IV demonstrates a strong predictive capacity for Vietnam's export values while maintaining plausible independence from any supply-side determinants of exports.

Subsequently, leveraging the predicted export exposure obtained in the first stage, we construct a matrix delineating the direct and indirect exposure of each industry in each province. This is accomplished by utilizing input-output tables that document the flow of intermediate goods among different sectors in the economy. The predicted export exposure calculated earlier is then distributed proportionally to the labor share of each industry within each province.

Finally, we estimate the direct and indirect effects of exports by conducting a regression analysis of these computed exposures against various labor market outcomes of interest at the provincial level: wage levels, income disparities, the premium on college education wages, gender wage differentials, employment rates, rates of inactivity, informality in employment, and female employment rates. Additionally, we conduct a detailed examination of how these labor effects differ across gender, income levels, educational attainment, and employment sectors to elucidate which demographic groups benefit and which are adversely affected by this process.

This study looks at the specific context of Vietnam for a few important reasons. First, Vietnam exemplifies the success of East Asia's export-driven growth model, making it a prime candidate for study due to the wealth of empirical evidence available. Over the past two decades, Vietnam has witnessed substantial increases in real income, a reduction in poverty (excluding the Covid-19 pandemic in 2020), and an alignment of import-export activities with GDP, reflecting its integration into global value chains. Improvements in the labor market have accompanied this economic progress, including lower unemployment rates and increased female workforce participation. Figure 3.1 visually encapsulates Vietnam's economic advancement driven by its export focus.

Second, the prominence of domestic services within Vietnam's non-tradable sectors is notable, representing an average of 10 percent of total output. The connection between non-service and service sectors is vital for amplifying the impact of exports on labor markets. In Vietnam, domestic non-service industries heavily rely on domestic services as inputs. Figure A.2 illustrates that around 50 percent of Vietnamese non-service sectors use local services, making up more than 15 percent of their end output. Neglecting these indirect export effects on domestic services and input supply sectors overlooks a crucial link tying local labor markets to foreign demand changes. Recognizing and understanding these connections is crucial for grasping the wider effects of export-oriented economic activities in Vietnam. A significant proportion of non-service sector-country clusters exhibit a substantial reliance on local services, with approximately 50 percent showcasing a local services usage share exceeding 8 percent, and a minority displaying shares as high as 20 percent. Against this background, this study aims to examine the direct and indirect effects of exports, which are supported by

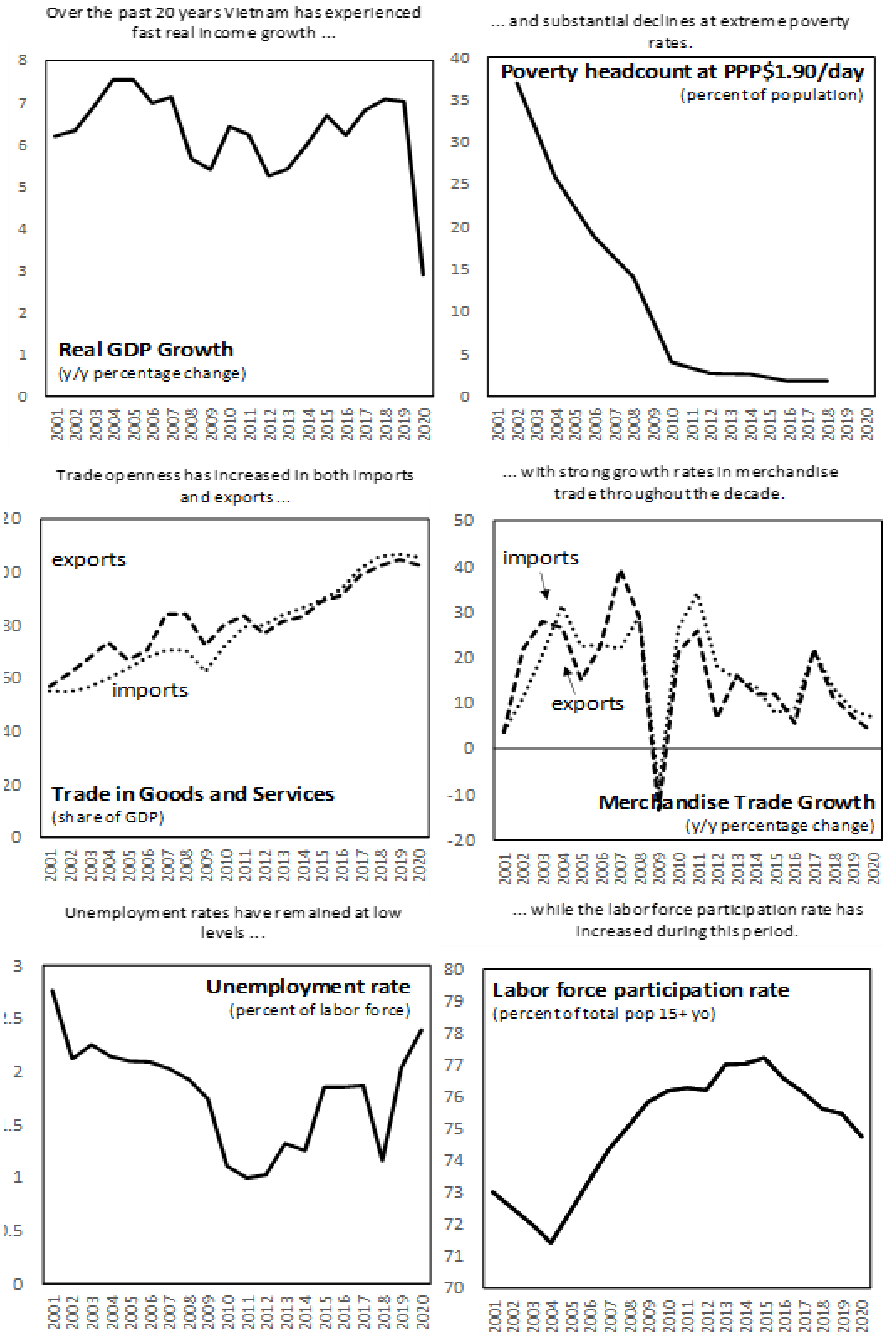


**Figure 3.1**: Trends in Trade, Labor, and Socioeconomic Indicators in Vietnam (2001-2020)

Source: World Bank staff calculations and World Development Indicators.

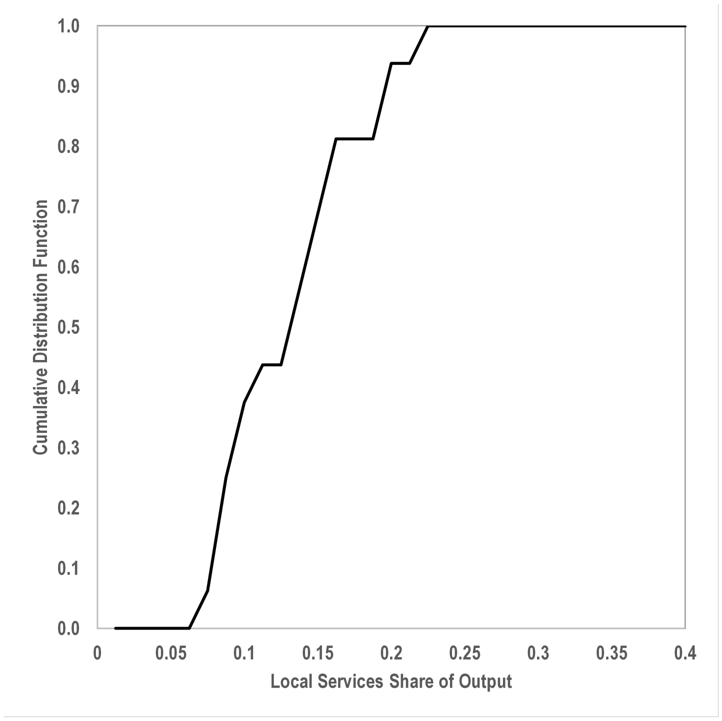


**Figure 3.2**: Domestic Service Sector Share in Total Output of Domestic Non-Service Sector in Vietnam (2020)

Source: World Bank staff calculation with Asian Development Bank data.

supply chain connections, on the labor market.

Third, Vietnam heavily relies on the advantageous demographic structure of its labor force to propel economic advancement, characterized by a great proportion of the population in the labor age as well as a sigificant spatial variation across sectoral specialization. Therefore, this investigation aims to leverage these variances to scrutinize potential how effects vary across diverse demographic strata within the labor force: urban, rural, youthful, highly-skilled, and female cohorts, among others.

We find that both direct and indirect exposure to exports has a significant impact on labor market outcomes, especially for those with no to little education and in the lowest income bracket. The wage premium for attending college decreases, and the gender wage gap narrows. With respect to employment variables, direct exposure to exports increases employment and reduces inactivity, with findings remaining consistent when accounting for supply chain linkages. The gains in employment concentrate among workers with no schooling, while employment rate falls for more skilled workers.

In this paper, we estimate total impact of changes in exports driven by foreign demand shocks, rather than tariff changes or import competition, on labor market outcomes including income and employment variables. This direct and indirect export-induced demand has been studied in Goutam et al. (2017) [22], however, as only employment variables are in focus, many other questions regarding wages and heterogeneity have been left unanswered.

The paper proceeds as follows. Section 3.2 present a conceptual framework that allows us to examine the local labor market repercussions of exports, incorporating a supply chain perspective. Section 3.3 discusses data used and how we constructed export exposure analysis using Input-Output linkages. Section 3.4 describes the empirical strategy and Section 3.5 presents the empirical results. Section 3.6 concludes.

## 3.2 Conceptual Framework

We apply a standard shift-share approach that assesses the effects of trade shocks on labor markets. Relevant works in the literature include Autor, Dorn and Hanson (2013) and Dix-Carneiro and Kovak (2015) [15][3]. More directly related to exploring the effects of exports on local labor markets are studies by Robertson et. al. (2021) and Góes, Lopez-Acevedo, and Robertson (2023) [44] [21].

Unlike the papers above, however, our index in this paper is not one of exports exposure, but one of total exports receipts exposure. By exploiting the input-output structure of production, we account for both direct and indirect payments to factors of production, and use trade data to move closer to regional production, which is what we would ideally like to observe.

Let $s,d$ be industry index ($s$ stands for source sector and $d$ stands for destination sector), and let $\gamma_{s,d}$ denote the intermediate use shares of a good of industry $s$ in the production process of a good of industry $d$. Under the assumptions of perfect competitive or monopolistic competitive product markets, a constant fraction of total sales will be paid to the factors of production. If domestic factor markets are competitive, there are no mark-ups or mark-downs on factor prices. Under those assumptions, then, up to a first-order approximation, the value of export sales can be distributed through the production network in the following fashion:

$$\underset{\text{Value of Export of sector d}}{P_d Q_d} \propto \underset{\text{Value of intermediate use of sector d}}{\sum_s \gamma_{s,d} P_s Q_s} + \underset{\text{Value added of sector d}}{VA_d}$$

Therefore, we can account for total payments to each source sector $s$ by summing over payments to sector $s$ from every sector $d$ in addition to the value added of sector $s$:

$$\Delta X_{s,t+h} \propto \left( \sum_d \gamma_{s,d} P_{s,t+h} Q_{s,t+h} - \sum_d \gamma_{s,d} P_{s,t} Q_{s,t} \right) + \Delta VA_{s,t+h}$$

or in words,

$$\text{Total Export Exposure} \propto \text{Indirect Export Exposure} + \text{Direct Export Exposure}$$

So far, we have defined these relationships in terms of input-output linkages. To turn to the empirical effects over labor markets, we now define local labor markets exposure to total export receipts. Let $r$ denote different regions in the country, exposure to total export receipts growth at regional level is defined as:

$$\Delta X_{r,s,t+h} \equiv \sum_{s} \frac{L_{r,s,t}}{L_{s,t}} \equiv \sum_{s} \frac{L_{r,s,t}}{\sum_{r} L_{r,s,t}} \cdot \Delta X_{s,t+h}$$

where $X_{r,s,t}$ denotes total export exposure of industry $s$ to region $r$ at period $t$ , as defined above; $L_{r,s,t}$ denotes total employment of industry $s$ in region $r$ at time $t$. The term $\frac{L_{r,s,t}}{L_{s,t}}$ measures the share of region $r$ in the national employment of industry $s$.

## 3.3 Data

The goal of the paper is to assess the direct and indirect effects of export expansion on local labor market outcomes in Vietnam while accounting for supply chain linkages. To do this, we exploit variation in export expansion across provinces and industries between 2010 and 2019 and combine export data from the United Nations Commodity Trade Statistics (UNCOMTRADE) data, input-output coefficient matrix from Global Trade Analysis Project (GTAP) data, and information on local labor market outcomes from Vietnam's Labor Force Survey (LFS) data. Details on each dataset and cleaning techniques are described below.

### 3.3.1 Labour Force Data

Our main source of labor market data is the LFS provided by General Statistics office of Vietnam (GSO) between 2010 and 2019, a period during which it was implemented every year. The LFS observations collect information in a host of areas including key labor market, household, and individual demographic characteristics.

Our analysis looks at two main sets of outcome variables: wage outcomes and employment outcomes. The wage outcome data sets include real annual wages, real annual income, college degree wage premium and gender wage premium. The employment outcome sets include employment rate, inactive rate, informality status, and female labor force participation. All of the outcomes are constructed from survey questionnaires, of which the wage outcomes are calculated at the province x sector level, while the employment outcomes are aggregated at the province level because we do not have sector information for those who are not employed. Over the period 2010 to 2019, several changes were introduced in the Vietnamese LFS, together with updates in concepts and definitions. These have been standardized to make key labor market outcomes, administrative geographies, as well as industry classifications, comparable over time.

### 3.3.2 Construction of Export Exposure using Input-Output Linkages

Any changes in the foreign export demand for products of a particular sector will have dual effects. First, it will lead to a direct increase in demand for output in that sector. Secondly, it indirectly affects the upstream sectors that supply inputs to the directly impacted sector. Not accounting for these linkages will underestimate the export exposure at the province level, as some provinces may not have concentration of industries directly exporting but still be supplying to exporting sectors. To account for these value chain linkages, the literature represents uses Leontief inverse of an input-output production matrix for an economy. The method clearly tracks the use of intermediate inputs by each sector (Goutam et al. 2017; Acemoglu et al. 2016; Acemoglu et al. 2012).

To explore potential effects of exports through domestic inputs, we employ the 2011 Vietnam Input-Output table to calculate the input shares of each industry. These shares are determined by dividing the input usage by the gross output (which includes the value added in the own sector with own-sector inputs). We then multiply the resulting shares by the exports of the final sector aggregated over the input industry to obtain the total value of exports for each input sector (representing the cumulative effect of servicing multiple exporting sectors). In this sense, non-traded sectors that are assigned a value "zero" for exports will also have an implied value and will be used to estimate the total export exposure index at the province level using the following index.

The total export exposure (accounting for supply chain linkages) is measured as the growth in exports in industry *i* between time periods, $t$ and $t+1$, captured by the term $\Delta W_{i,t+h} = W_{i,t} - W_{i,t+h}$. This change is allocated to each province *r* in Vietnam using the share of provinces in total national employment in each industry *i*.

$$\Delta X_{r,t+h} = \sum_i \frac{L_{i,r,t}}{L_{i,t}} \Delta W_{i,t+h} = \sum_i \frac{L_{i,r,t}}{\sum_r L_{i,r,t}} \Delta W_{i,t+h}$$

To construct the total exposure index at the province level in Vietnam, we utilize several databases. Initially, we gather data on export value from the UNCOMTRADE database. To account for demand generated in other sectors as a result of exports, and thus calculate the overall exposure index, we incorporate the 2011 input-output (I-O) GTAP tables.

We begin by computing the input-output coefficients from the GTAP I-O tables, which capture the interdependencies between sectors in an economy. We match these coefficients with trade data the UNCOMTRADE data to compute the total export value for each sector, accounting for indirect changes in export demand through input-output linkages. Annex B.2 of the study provides a detailed explanation of how these coefficients are computed and merged with UNCOMTRADE data.

The next step is to link these total export data with the LFSs. We utilize concordance tables available from UNSD that translate International Standard classification (ISIC) rev 3.1. codes into HS codes. By leveraging this concordance, we merge the micro-data on labor force variables at the industry and area level in Vietnam with total export data. Once the integrated labor and trade data is prepared, we are able to calculate the total trade exposure index based on provinces, as previously explained. The starting point for the analysis is the idea that the impact of a trade shock differs across regions, depending on each province-industry composition.

A fundamental principle for this approach is the existence of segmented labor markets. Existing labor mobility barriers or rigidities (such as commuting costs or lack of transport infrastructure) allow us to observe variations in local labor market outcomes and, as a result, to estimate the effects of differentiated exposure to trade. One heuristic method for assessing labor-market integration involves examining the standard deviation of wages across regions and over time. This heuristic measure is used because various factors can prevent wage equalization across regions. To investigate the level of labor-market integration in Vietnam, we calculate province and industry- province premiums, the existence of which can indicate segmented labor markets. Table **??** in the Annex clearly show that wages are not equal across provinces and industry-provinces in Vietnam, providing strong support for the existence of segmented labor markets during our study period.

## 3.4 Identification

The goal of our empirical strategy is to understand how rising export expansion affects real wages, informality, and female labor force participation, exploiting data on cross-regional exposure to total exports in Vietnam between 2010 and 2019. To this effect, we consider the following simple linear regression model:

$$\Delta Y_{r,t+h} = \beta_0 + \beta_1 \Delta X_{r,t+h} + \beta_2 K_{r,t} + \varepsilon_{r,t}$$

where $\Delta Y_{r,t+h}$ is the change in outcomes of interest, may it be employment rate, informality rate, female participation rate, average annual income average annual wage, college premium or gender wage gap, among others, identified at province $r$ over the period from time $t$ to $t+h$. $\Delta X_{r,t+h}$ is our main independent variable, which stands for the change at regional level of total export exposure, as defined in the previous section. The key coefficient of interest is $\beta_1$, which measures the effects of total trade exposure on the outcome after accounting for the I-O structure, $K_{r,t}$ is the vector of ex-ante control variables including individual demographic background taken from the LFS such as urban dummy, gender, marital status, age group, education level, social security ownership, among others.

A relevant issue needed to be addressed is potential endogeneity in the export exposure covariate. Since we observe changes in labor outcomes and exports simultaneously, we cannot identify which one is driving the other. To ensure truly exogeneity of our export exposure, we need a variable that predicts exports from Vietnam based solely on its trading partners internal demand growth, rather than supply-side determinants. Hence, we construct our instrument using time-series regressions of Vietnam exports to its trading partners on the trading partner's GDP by industry at the four-digit level as follows:

$$\Delta Z_{r,t+h} \equiv \sum_i \frac{L_{i,r,t}}{L_{i,t}} \cdot \sum_j \left( \frac{Q_{j,i,t}}{Q_{i,t}} \cdot \Delta Y_{j,t+h} \right)$$

where, $\frac{Q_{j,i,t}}{Q_{i,t}} = \frac{Q_{j,i,t}}{\sum_j Q_{j,i,t}}$ denotes country $j$'s share of industry $i$' export; $\Delta Y_{j,t+h}$ is the change in real GDP in destination country $j$.

Predicted values or exports from these regressions serve as a proxy for Vietnam's exports to its trading partners explained exclusively by the export market's domestic aggregate demand. These predicted exports combine with I-O coefficients to generate total exports accounting for supply chain linkages. Subsequently, we use these total exports to generate provincial export exposure in Vietnam.

Then, estimation will take the form of two-stage least squares, with the first stage being:

$$\Delta X_{r,t+h} = \tilde{\alpha} + \tilde{\beta}\Delta Z_{r,t+h} + \tilde{\delta}K_{r,t} + \tilde{\varepsilon}_{r,t}$$

and the second stage:

$$\Delta Y_{r,t+h} = \beta_0 + \beta_1 \Delta \hat{X}_{r,t+h} + \beta_2 K_{r,t} + \varepsilon_{r,t}$$

where $\Delta \hat{X}_{r,t+h}$ is the predicted value obtained from the first stage regression:

$$\Delta \hat{X}_{r,t+h} = \hat{\alpha} + \hat{\beta}\Delta Z_{r,t+h} + \hat{\delta}K_{r,t}$$

## 3.5 Results

### 3.5.1 Impact of exports on wage

Table C.3 presents the outcomes of the two-stage least squares regression, detailing the relationship between changes in income-related variables—wages, income, gender wage differentials, and the college wage premium—and shifts in exposure to exports, instrumented by alterations in exposure to foreign demand. All models incorporate standard errors clustered at the province level and control for various socio-demographic factors such as age, gender, education level, urban-rural status, economic sector, and hours of work.

Overall, all measures of exposure—Total Exposure, Direct Exposure, and Indirect Exposure—exhibit statistically significant effects on income-related variables. It is important to note that the Income variable often reflects a more positive improvement compared to the Wage variable for individuals, as it encompasses additional sources of non-wage income such as bonuses, dividends, and personal gifts. Direct Exposure demonstrates the most substantial improvement, with a US$32.5 increase in annual wages and a US$36.31 increase in annual income for every US$1,000 rise in annual Direct Exposure per worker. While Indirect Exposure yields a similar effect on wages (an increase of US$31.14 per unit of exposure), its influence on income is relatively lower (an increase of US$23.22 per unit of exposure) compared to Direct Exposure.

Additionally, variables reflecting labor market inequality—namely, the college wage premium and gender wage gap—decrease in response to export exposure, with the college premium exhibiting a higher degree of significance. Specifically, a US$1,000 increase in annual direct exposure per worker results in about a US$28 reduction in return on attending college. The effect of indirect exposure on this premium is a reduction of about US$30.87.

### 3.5.2 Impact of exports on employment

Regarding employment outcomes, Table C.4 illustrates that both Total Exposure and Indirect Exposure exert statistically significant effects on the employment rate at the provincial level. Specifically, for every US$1000 increase in Total Exposure per worker, the likelihood of employment rises by 0.2 percent point, while Indirect Exposure increases the employment rate by 0.52 percent point. Interestingly, Direct Exposure exhibits either non- or minimally significant effects on the employment rate and other employment metrics such as the rate of informal employment and female employment rate. Conversely, both Total Exposure and Indirect Exposure significantly reduce informality rates and augment female participation in the labor force. All of these trends imply that exports have caused healthy benefits to the labor market and created a more efficient and balanced working environment for workers.

### 3.5.3 Heterogeneity by Education

Tables C.7 and C.8 provide insights into how wage and employment outcomes vary across different segments of the population based on their level of education. Our findings suggest that workers across all educational strata benefit from trade. Notably, individuals with a college education premium derive the greatest benefit, with a US$42.38 increase in wages for every US$1000 rise in Total Exposure, compared to a US$14.84 gain for workers with no formal education. This disparity becomes more pronounced when examining the impact of Direct Exposure and Indirect Exposure on workers with a college degree, yielding increases of US$67.11 and US$72.13, respectively, for each type of exposure. Generally, the discrepancy between changes in wages resulting from Direct and Indirect exposure is minimal across all educational levels.

On the contrary, changes in employment outcomes exhibit divergent patterns across different educational groups. While the employment rate among workers with little to no formal education (primary school level) tends to increase, that of college graduates decreases in response to higher export exposure, whether direct or indirect. For instance, a US$1000 increase in annual Total Expo- sure per worker can elevate the employment rate of workers with no formal education by 0.15 percent point while concurrently reducing the likelihood of employment for college graduates by 0.19 percent point. This outcome, coupled with the discussed variance of education on wages, suggests a nuanced interpretation. Specifically, it implies a more competitive environment for highly-skilled workers, juxtaposed with an expansion in economic opportunities for low-skilled workers following an export-driven boost.

### 3.5.4 Heterogeneity by Economic Sector

Tables C.9 and C.10 provide provide a detailed examination of wage and employment outcomes across various economic sectors, namely Household Farm, Household Business, Private Sector, State Agency, and Foreign Sector. While employment demonstrates significant improvement across all sectors, Household Farm experiences the most substantial gains, with approximately a 3.54 percent point increase for every US$1000 rise in total exposure. However, notable wage increases are only evident for workers in Household Farm and Household Business, regardless of the type of exposure. Notably, Household Business witnesses a sharper rise in wages, amounting to approximately US$40.19 per worker for every unit increase in Total Exposure, compared to a US$19.4 increase in wage observed in the Household Farm sector.

The prominence of wage enhancements primarily within the Household Farm and Household Business sectors can be attributed to their inherent liquidity and adaptability. These sectors tend to be more responsive compared to others sectors, which are often characterized by rigidity and subject to stringent labor regulations. Moreover, workers in Private, Government, and Foreign sectors typically possess less bargaining power in their respective working environments.

### 3.5.5 Heterogeneity by Income Level

To gain a comprehensive understanding of how trade influences income inequality within the labor market, we extend our analysis to examine various income quantiles among workers. Tables C.11 and C.12 present the outcomes of these regressions. Our findings indicate that the most significant wage improvements occur among workers in the lowest income quantile, which aligns with the observation that the sectors most affected by trade tend to predominantly employ labor from this demographic segment.

Conversely, we observe enhanced employment opportunities across all income quantiles, albeit with diminishing effects as income levels rise. Specifically, the likelihood of employment increases the most among workers in the lowest income quantile, with an about 1.77 percent point rise for every US$1000 increase in Total Exposure. This effect gradually diminishes across the second and third lowest quantiles, reaching as low as a 0.14 percent point increase in employment probability in the highest worker income bracket.

### 3.5.6 Heterogeneity by Tradability

In our final analysis, we speculate about the spillover of direct trade exposure into indirect exposure, a phenomenon closely intertwined with the tradability nature of sectors. In this section, we explore the divergent effects of direct and indirect exposure on labor outcomes between tradable and non-tradable sectors. We classify industries into "non-tradable" sectors if their export exposure is "zero", as indicated by the summary statistics in Table C.1. These sectors include Mining Extraction, Chemicals, Pharmaceuticals & Medical Products, Rubber and Plastics, Electrical Equipment, Electricity, Gas Manufacturing and Distribution, Water Supply, Construction, Wholesale and Retail Trade, Accommodation and Food Service, Land Pipelines and Transportation, Water Transportation, Air Transportation, Warehousing, Other

Financial Inter-mediation, Insurance, Real Estate Activities, Other Government Services, Education, and Human Health & Social Work. Broadly, these sectors are characterized by their focus on supplementary goods and domestic services. Conversely, we designate sectors with “non-zero” export exposure as “tradable”.

Having established this differentiation based on tradability, we conduct regression analysis on samples restricted to these two categories. This approach enables us to derive insightful interpretations regarding how direct and indirect exposure to exports affect labor outcomes. As anticipated, Table C.14 indicates that direct exposure exerts a notably pronounced and robust impact on both wage and employment outcomes within tradable sectors, whereas indirect exposure demonstrates a more modest effect on wages while still fostering employment growth and reducing informality. This observation aligns logically with the understanding that tradable sectors, in addition to producing goods for direct export, may also provide inputs for other traded sectors, thereby benefiting from indirect exposure.

Table C.13 initially presents a perplexing observation, revealing an unexpected trend wherein both direct and indirect exposure reduces employment and wages within non-tradable sectors, with indirect exposure exhibiting a stronger negative effect. However, upon closer examination, this finding unveils contrasting patterns regarding how trade influences these two distinct sectors. On one hand, trade has the potential to expand the overall economic “pie”, thereby reshaping wage and employment dynamics in both tradable and non-tradable sectors. Conversely, an intriguing offsetting effect, wherein trade acts as a driving force, can pull labor directly from non-tradable to tradable sectors within the confines of fixed labor supply. This second nuance might have a greater significance given the ample evidence of relatively full employment in Vietnam and the limited benefits or unemployment insurance available, rendering staying in non-tradable sectors a far less attractive option compared to seeking opportunities in rapidly expanding tradable sectors.

## 3.6 Conclusion

The intrinsic connection between direct exporting sectors and the indirect supplying sectors (that furnish production inputs to exporters), is crucial for transmitting the benefits of foreign demand-driven exports not only to tradable sectors, such as agriculture and manufacturing, but also to non-tradable sectors, such as services, where such effects are less anticipated. Leveraging this relationship within the supply chain, we have devised a theoretical framework and an empirical approach to re-examine the ramifications of trade on the labor market, incorporating considerations of both direct and indirect export exposure.

Our analysis provides comprehensive insights into the impact of trade on various aspects of the labor market, shedding light on nuanced patterns across different demographic and economic segments. Results indicate significant labor benefits of exposure to exports on income-related variables such as wages, income, and labor market inequality, with directly exposed sectors and provinces enjoying the greatest benefit. Moreover, both exposure types contribute to a decrease in labor market inequality measures such as the college wage premium and the gender wage gap. Employment out- comes also vary, with both total and indirect exposure positively affecting employment, informality, and female employment rates, while direct and total exposure reduce informality rates and increase female labor force participation.

Across educational levels, workers benefit from an increase in trade, with college-educated individuals deriving the greatest wage benefits. Changes in employment outcomes vary, with employment increasing for workers with lower education but decreasing for college graduates in response to higher export exposure. Employment improves across all economic sectors, with Household Farm experiencing the most substantial gains, while notable wage increases are observed only in Household Farm and Household Business sectors, suggesting differential impacts across economic sectors. Wage improvements are most significant among workers in the lowest income quantile, while enhanced employment opportunities are observed across all income levels, albeit with diminishing effects as income rises. Direct exposure causes a pronounced increase on both wage and employment outcomes within tradable sectors, while indirect exposure exhibits a more modest increase on wages but still fosters employment growth. In contrast, both direct and indirect exposure reduce employment and wages within non-tradable sectors, highlighting the intricate interplay between trade dynamics and labor markets.

Considering both direct and indirect export exposure leads to a more nuanced understanding of how trade shapes employment, wage dynamics, and labor market inequality across various sectors and demographic groups. These insights are crucial for policymakers and stakeholders seeking to navigate the complexities of globalization and ensure inclusive economic growth.

# Appendix A

**Table A.1**: Summary Statistics - Power Capacity

| | Hydro-power Capacity (MW) | | | | | |
|---|---|---|---|---|---|---|
| | Sum | Mean | SD | Min | Max | N |
| ***By Current Status*** | | | | | | |
| Cancelled | 1410.0 | 470.0 | 498.7 | 10.0 | 1000.0 | 3 |
| Operational | 34649.6 | 262.5 | 700.8 | 0.4 | 5850.0 | 132 |
| Planned | 22608.7 | 78.5 | 256.7 | 1.0 | 2600.0 | 288 |
| Postponed | 5672.0 | 1418.0 | 1037.7 | 220.0 | 2600.0 | 4 |
| Under Construction | 5006.1 | 139.1 | 344.3 | 1.3 | 1460.0 | 36 |
| Unknown | 60.0 | 60.0 | . | 60.0 | 60.0 | 1 |
| ***By Country*** | | | | | | |
| Cambodia | 6331.4 | 119.5 | 383.8 | 0.4 | 2600.0 | 53 |
| China | 30636.0 | 1458.9 | 1414.0 | 10.0 | 5850.0 | 21 |
| Laos | 25100.5 | 76.1 | 183.9 | 1.0 | 1460.0 | 330 |
| Myanmar | 775.0 | 110.7 | 74.5 | 36.0 | 240.0 | 7 |
| Thailand | 3529.5 | 271.5 | 518.7 | 1.1 | 1872.0 | 13 |
| Vietnam | 3034.0 | 75.8 | 137.6 | 1.0 | 720.0 | 40 |

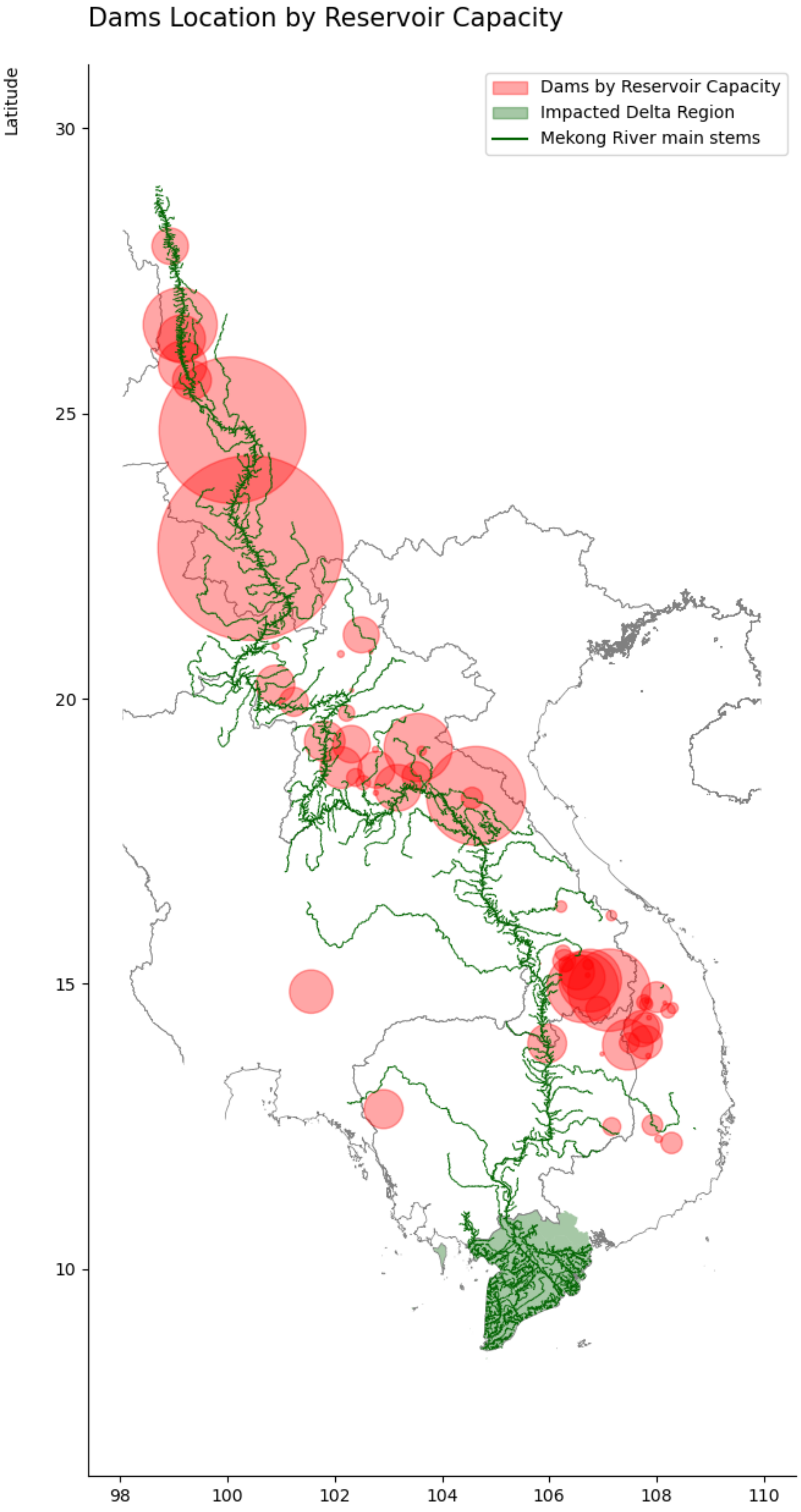
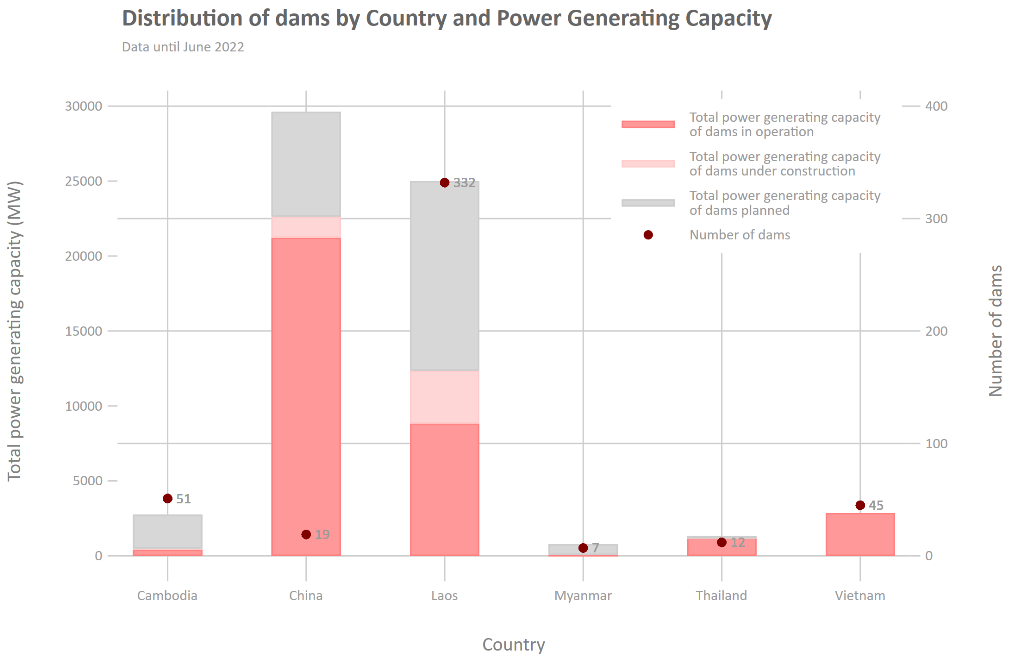
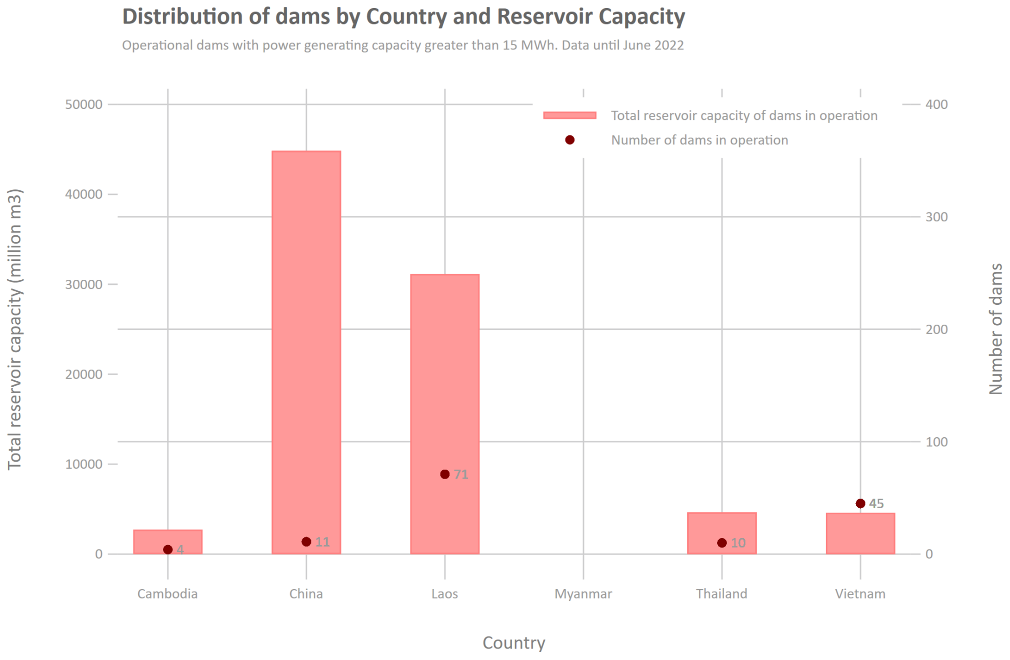


**Figure A.1**: Dams Location by Reservoir Capacity

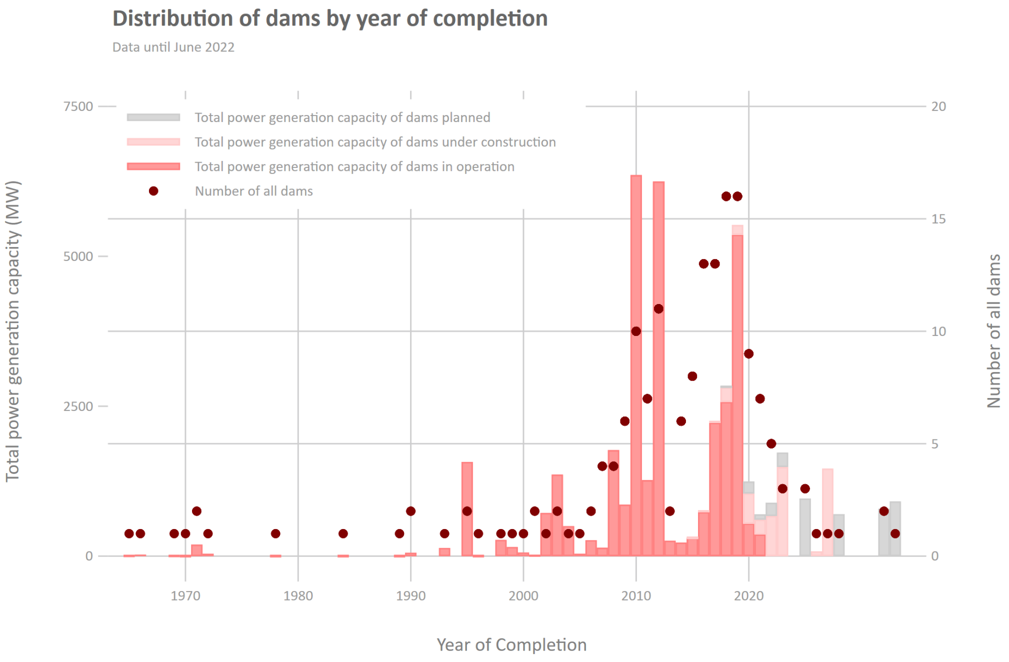


(a) Over Power Generating Capacity

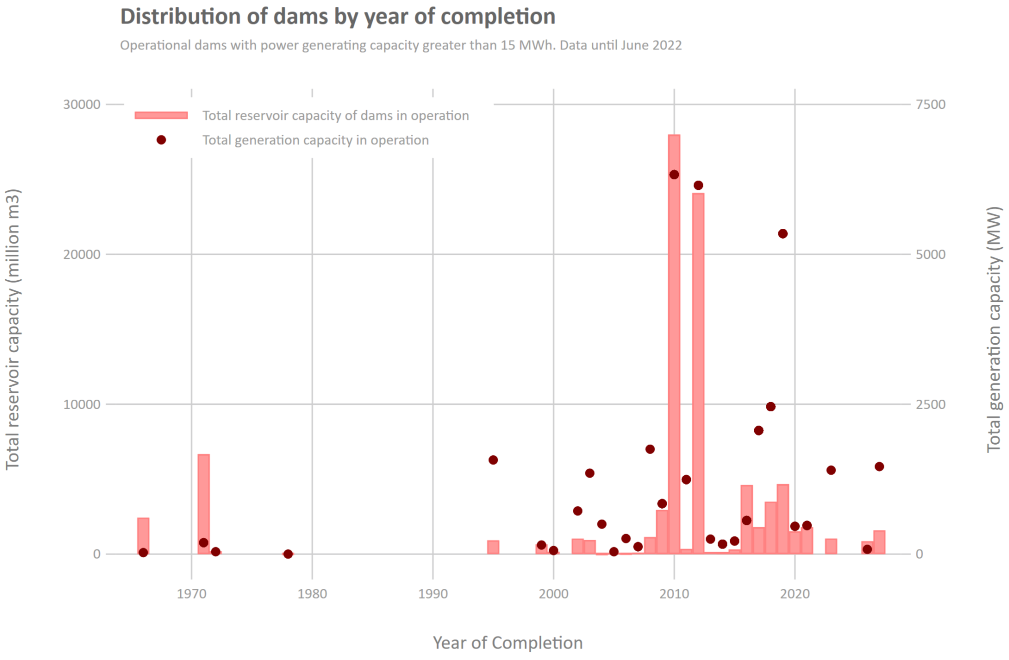


(b) Over Reservoir Capacity

**Figure A.2**: Distribution of Dams by Country



(a) Over Power Generating Capacity



(b) Over Reservoir Capacity

**Figure A.3**: Distribution of Dams by Year of Completion

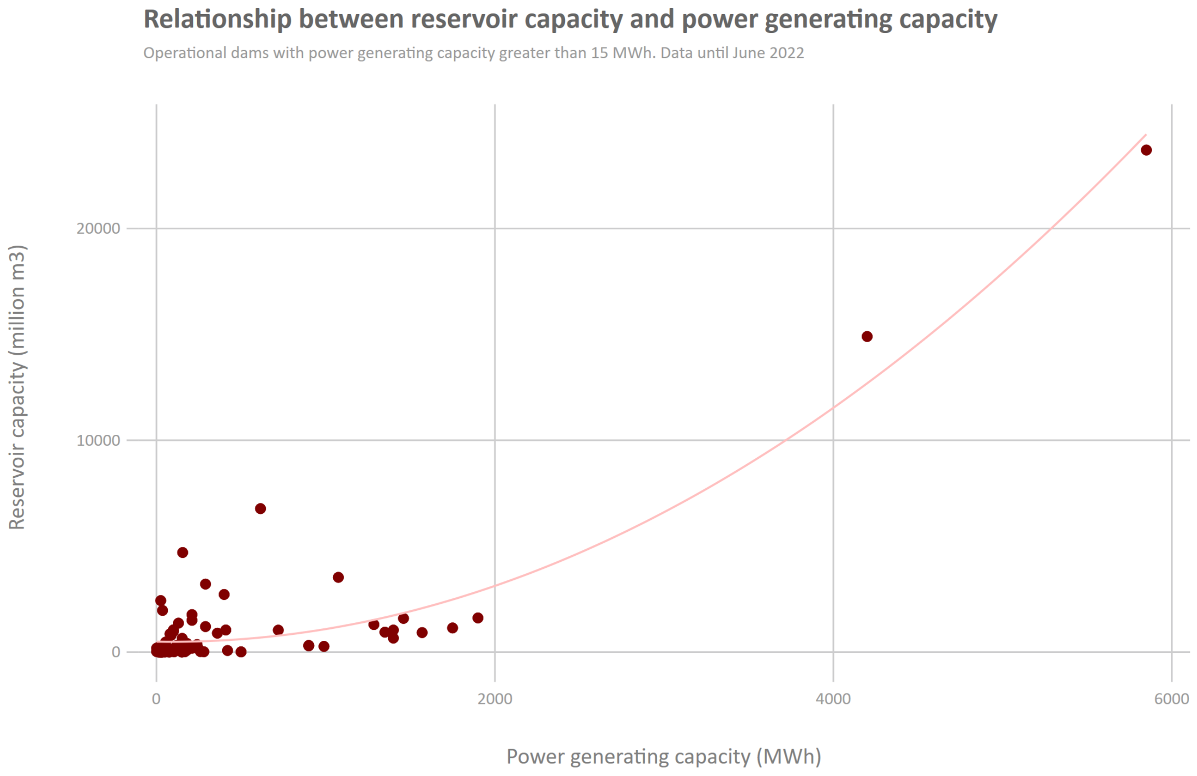


**Figure A.4**: Reservoir Capacity and Power Generating Capacity

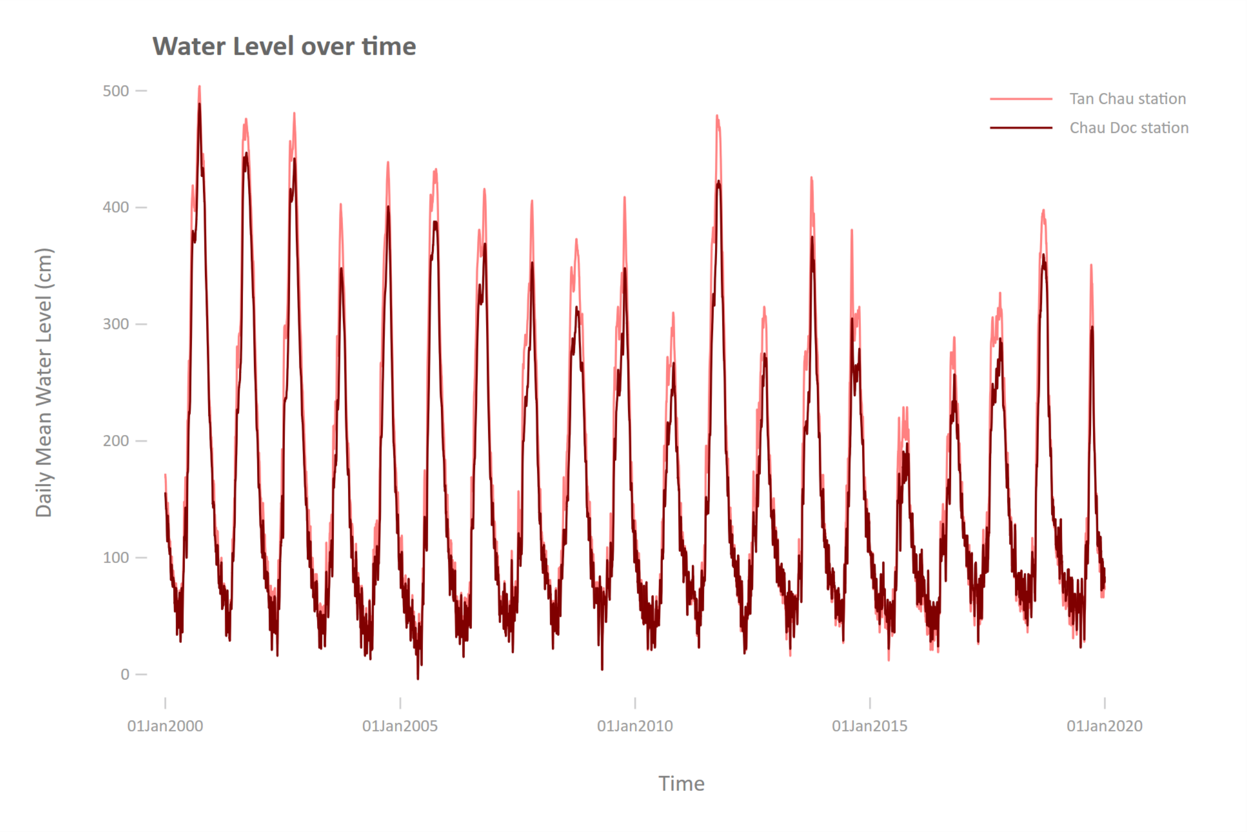


**Figure A.5**: Water Level across two measuring stations

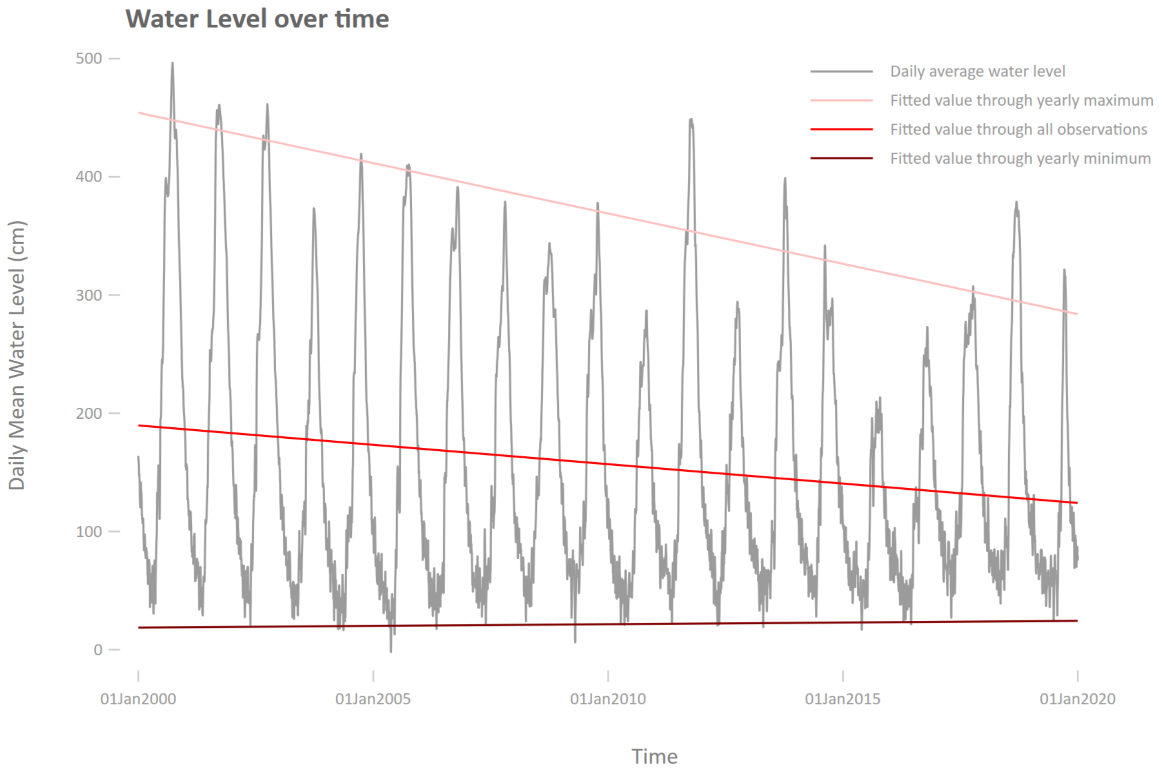


**Figure A.6**: Water Level with Long-run Trend

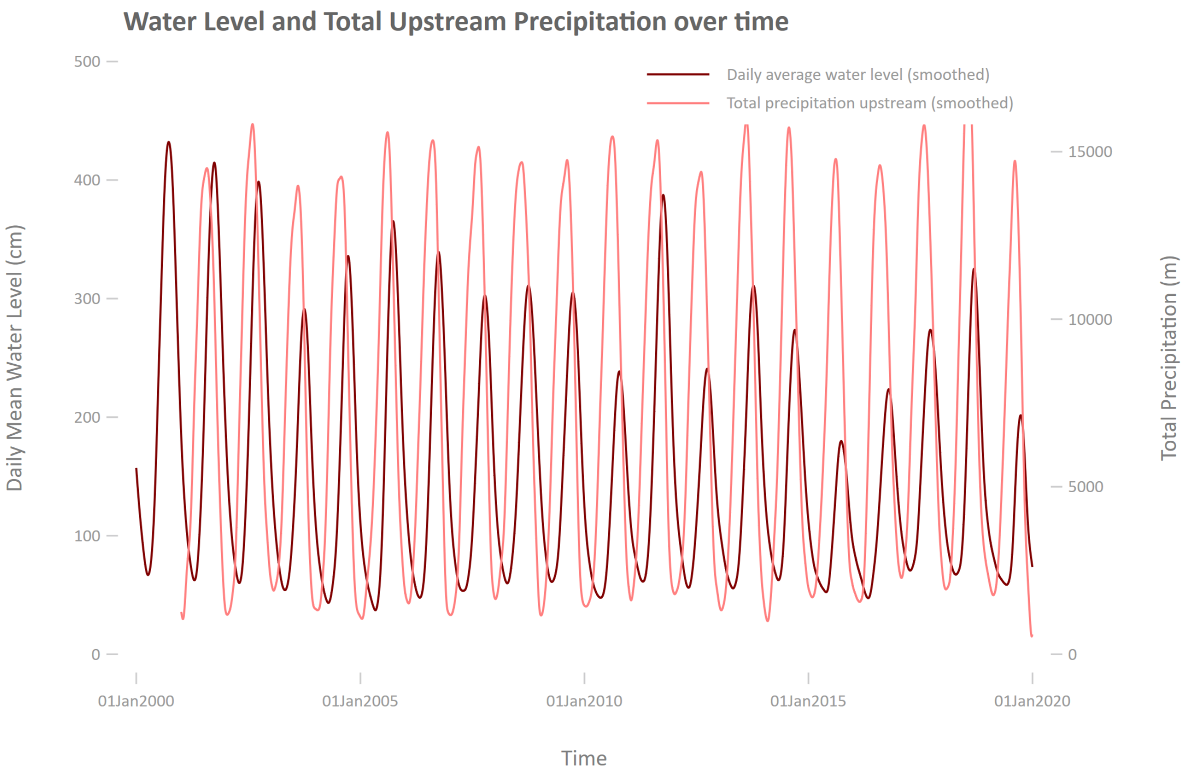


**Figure A.7**: Water Level and Total Precipitation in the Upstream river basin

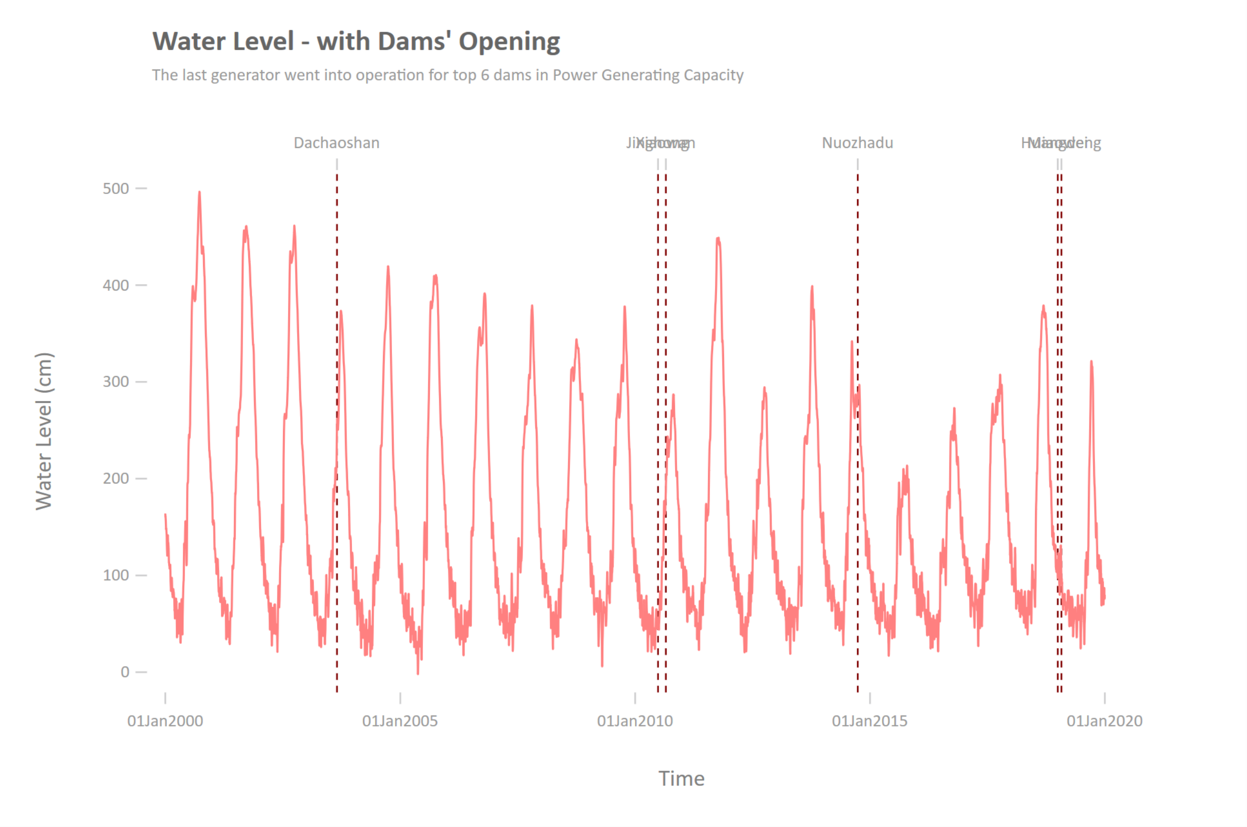


**Figure A.8**: Water Level with Dams' opening

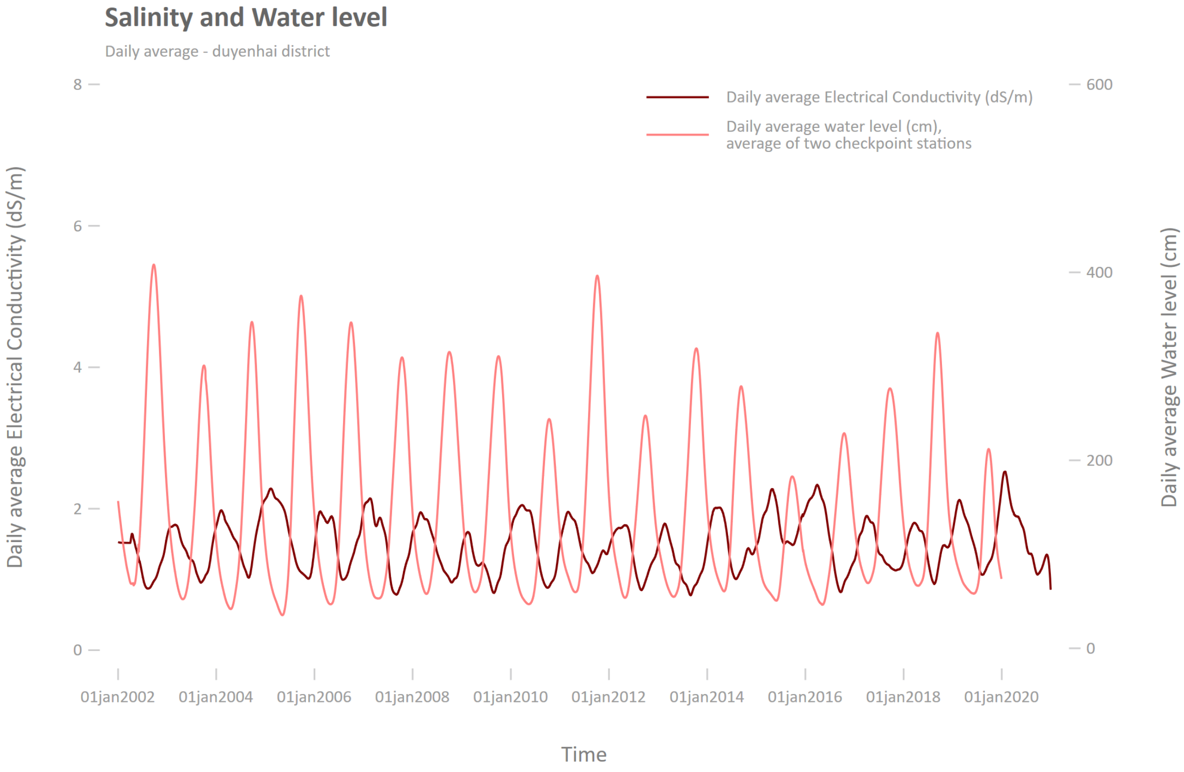
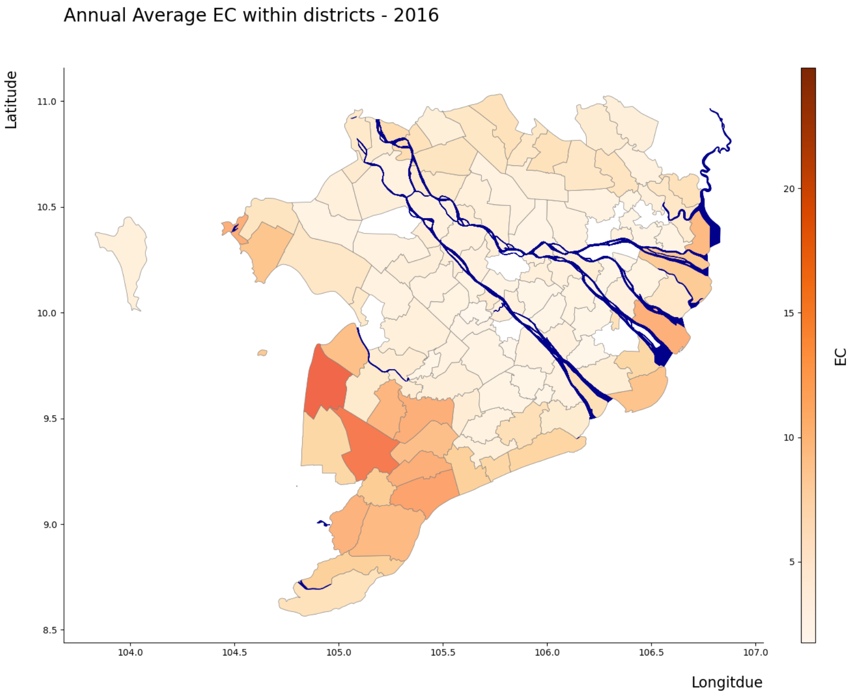


**Figure A.9**: Salinity and Water Level over time

(a) Salinity by district - 2016



(b) Vegetation by district - 2016

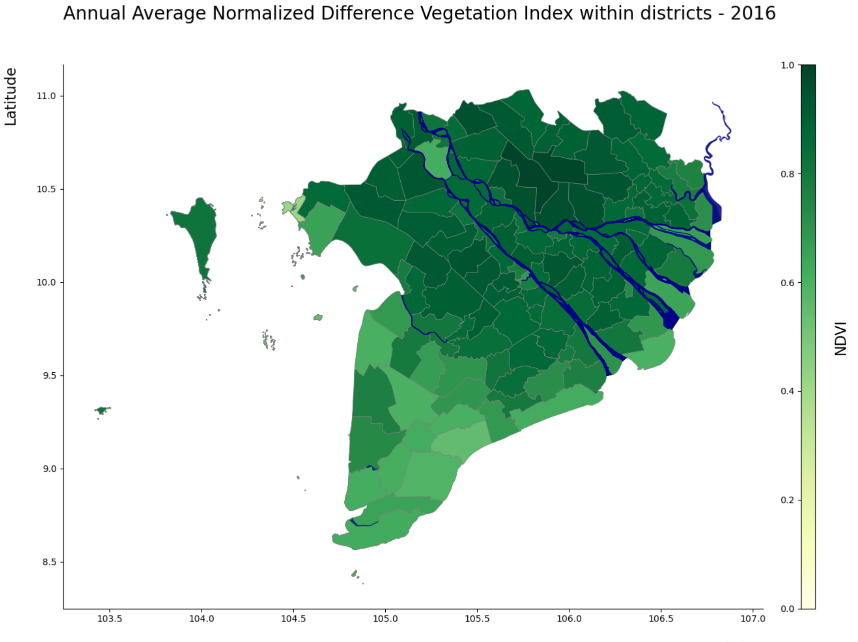


**Figure A.10**: Salinity and Vegetation by district

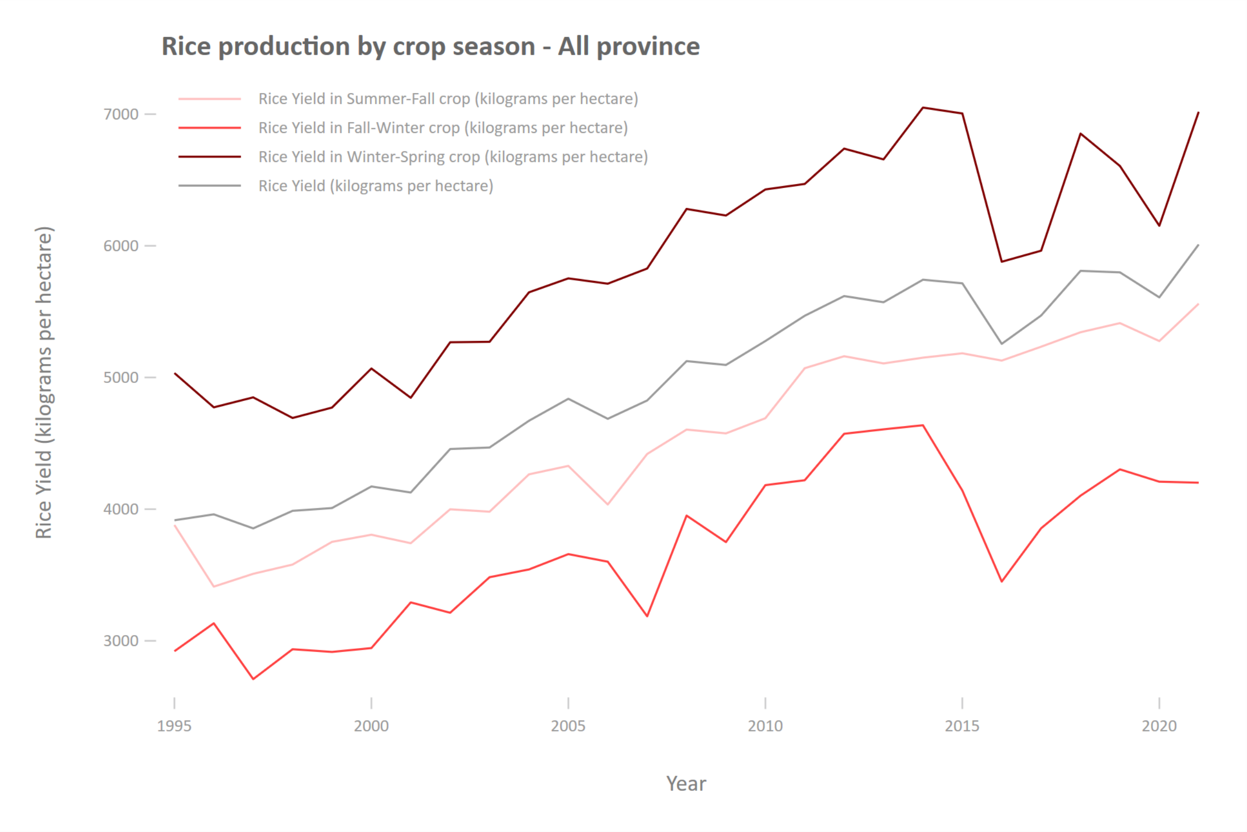
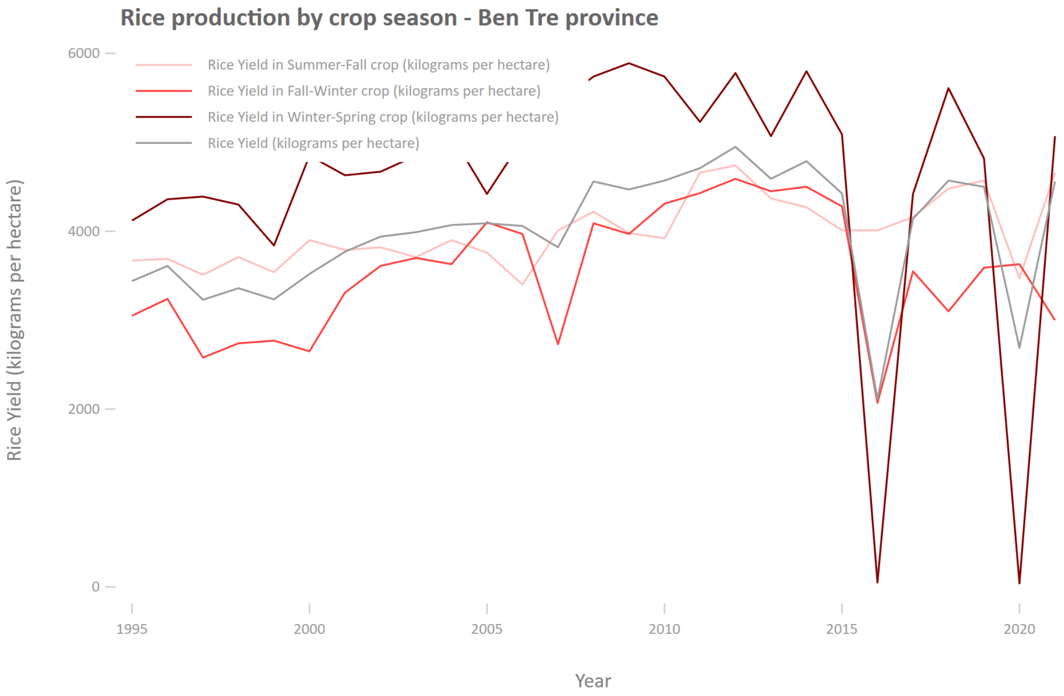
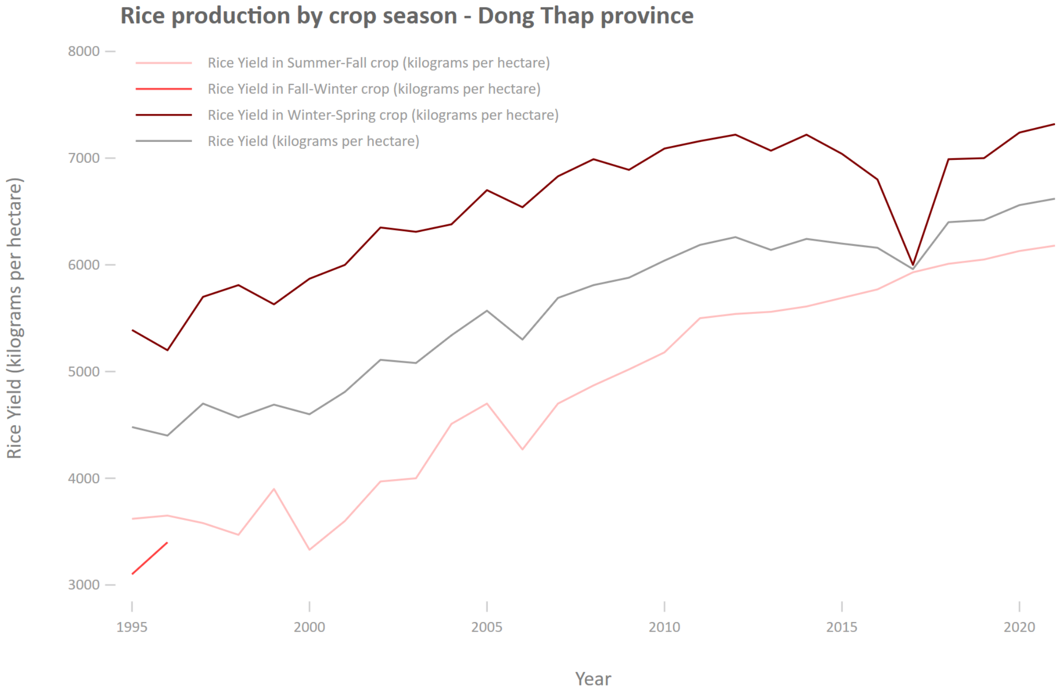


**Figure A.11**: Agriculture yield - paddy



(a) Coastal province



(b) In-land province

**Figure A.12**: Agriculture yield - paddy

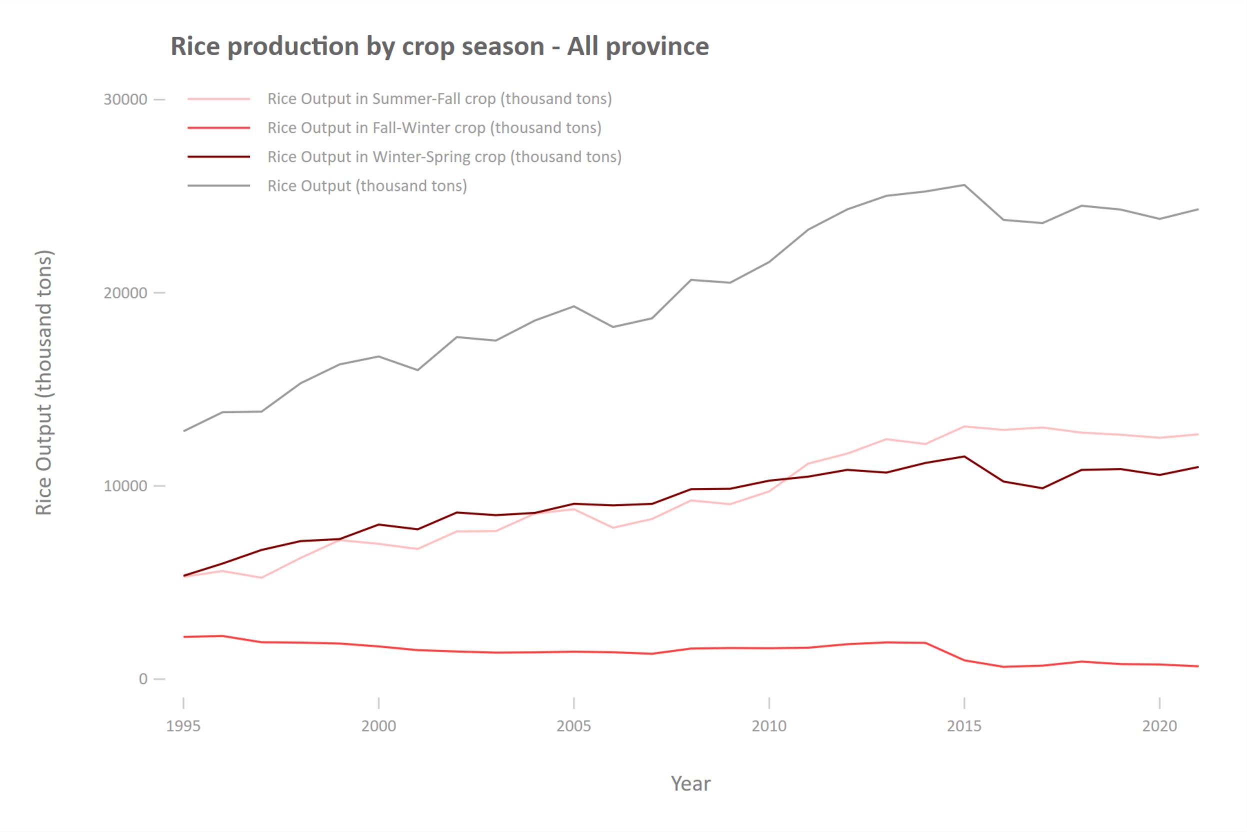
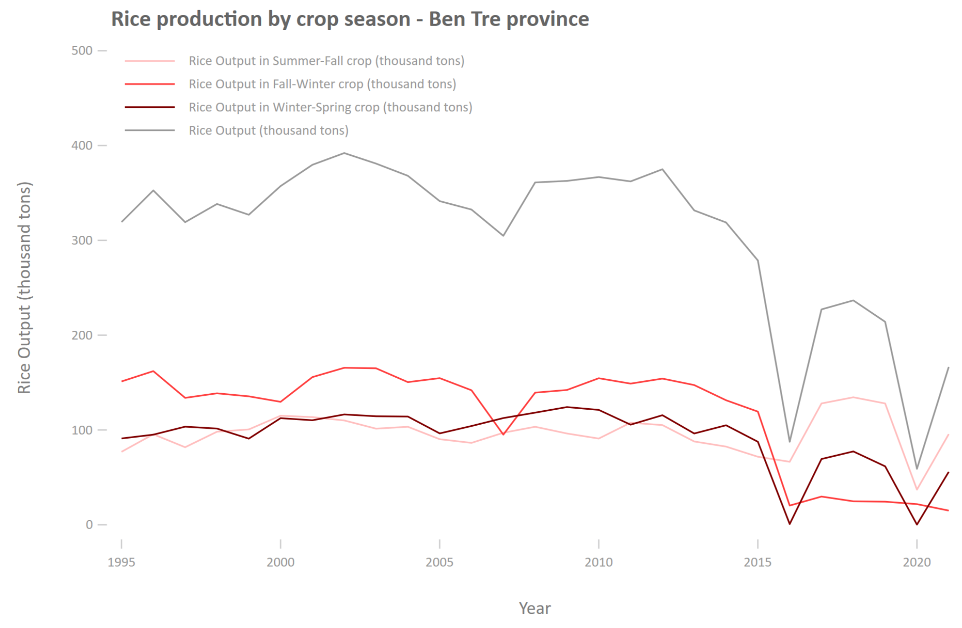
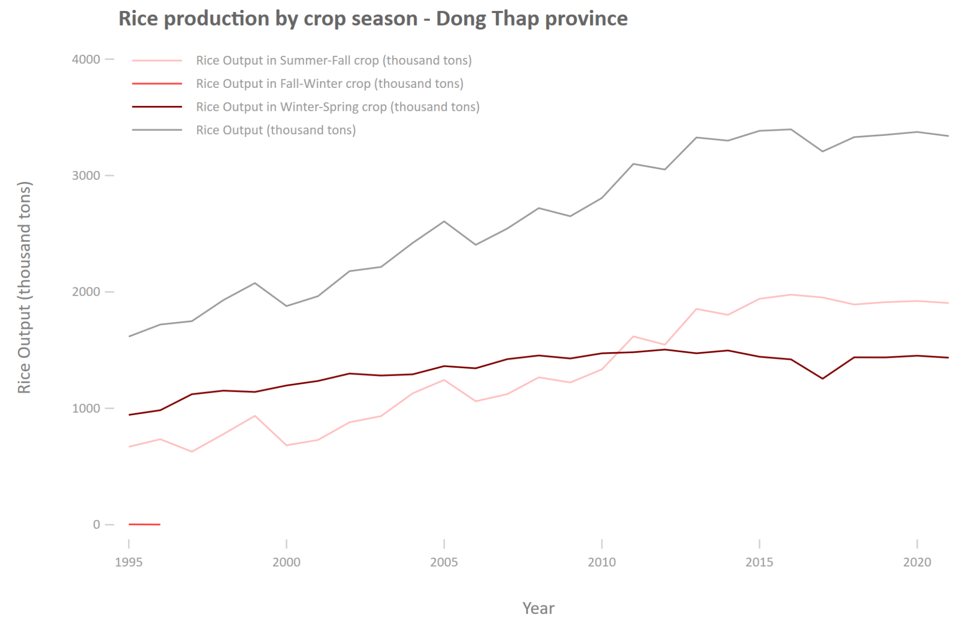


**Figure A.13**: Agriculture output by crop season - paddy



(a) Coastal province



(b) In-land province

**Figure A.14**: Agriculture output by crop season - paddy

**Table A.2**: Impact of Dams Reservoir on Water Level

| | Water Level (cm) | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| RESERVOIR CAPACITY ($10^9 m^3$) 1 yrs | -0.80*** | -0.33*** | -0.50*** | -1.16*** | -2.56*** |
| | (0.07) | (0.07) | (0.07) | (0.11) | (0.22) |
| RESERVOIR CAPACITY ($10^9 m^3$) 2 yrs | | 0.03 | -0.12 | -0.27** | -1.11*** |
| | | (0.08) | (0.08) | (0.10) | (0.18) |
| RESERVOIR CAPACITY ($10^9 m^3$) 3 yrs | | | 0.13* | 0.26*** | -0.14 |
| | | | (0.06) | (0.07) | (0.12) |
| RESERVOIR CAPACITY ($10^9 m^3$) 4 yrs | | | | 1.05*** | 0.88*** |
| | | | | (0.07) | (0.10) |
| RESERVOIR CAPACITY ($10^9 m^3$) 5 yrs | | | | | 0.30** |
| | | | | | (0.11) |
| Observations | 6940 | 6575 | 6210 | 5845 | 5480 |
| Adjusted R2 | 0.827 | 0.860 | 0.867 | 0.874 | 0.873 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Additional controls include Daily Total Precipitation in the entire river basin and Monthly FE.

**Table A.3**: Impact of Dams' Average Annual Electricity Output on Water Level

| | Water Level (cm) | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| AVERAGE ANNUAL OUTPUT ($10^3$ GWh) 1 yrs | -1.06*** | -0.56*** | -0.84*** | -1.45*** | -2.74*** |
| | (0.06) | (0.06) | (0.07) | (0.11) | (0.21) |
| AVERAGE ANNUAL OUTPUT ($10^3$ GWh) 2 yrs | | 0.18* | -0.06 | -0.39*** | -1.21*** |
| | | (0.07) | (0.07) | (0.09) | (0.17) |
| AVERAGE ANNUAL OUTPUT ($10^3$ GWh) 3 yrs | | | -0.06 | -0.15* | -0.68*** |
| | | | (0.05) | (0.06) | (0.12) |
| AVERAGE ANNUAL OUTPUT ($10^3$ GWh) 4 yrs | | | | 0.69*** | 0.35*** |
| | | | | (0.06) | (0.09) |
| AVERAGE ANNUAL OUTPUT ($10^3$ GWh) 5 yrs | | | | | 0.22* |
| | | | | | (0.09) |
| Observations | 6940 | 6575 | 6210 | 5845 | 5480 |
| Adjusted R2 | 0.830 | 0.861 | 0.869 | 0.875 | 0.874 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Additional controls include Daily Total Precipitation in the entire river basin and Monthly FE.

**Table A.4**: Impact of Dams on Water Level

| | Water Level (cm) | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| RESERVOIR CAPACITY | -1.25*** | -1.03*** | -0.95*** | -0.54*** | -0.77*** |
| ($10^9 m^3$) 1 yrs | (0.07) | (0.06) | (0.06) | (0.07) | (0.09) |
| RESERVOIR CAPACITY | | -5.92*** | -6.76*** | -7.53*** | -6.75*** |
| ($10^9 m^3$) 2 yrs | | (0.27) | (0.32) | (0.33) | (0.39) |
| RESERVOIR CAPACITY | | | -2.53*** | -4.55*** | -4.32*** |
| ($10^9 m^3$) 3 yrs | | | (0.27) | (0.30) | (0.30) |
| RESERVOIR CAPACITY | | | | -2.32*** | -3.22*** |
| ($10^9 m^3$) 4 yrs | | | | (0.26) | (0.31) |
| RESERVOIR CAPACITY | | | | | -2.77*** |
| ($10^9 m^3$) 5 yrs | | | | | (0.26) |
| AVERAGE ANNUAL | | 4.81*** | 5.43*** | 6.20*** | 5.60*** |
| OUTPUT ($10^3$ GWh) 2 yrs | | (0.22) | (0.26) | (0.27) | (0.31) |
| AVERAGE ANNUAL | | | 2.17*** | 3.98*** | 3.65*** |
| OUTPUT ($10^3$ GWh) 3 yrs | | | (0.23) | (0.26) | (0.26) |
| AVERAGE ANNUAL | | | | 2.45*** | 3.08*** |
| OUTPUT ($10^3$ GWh) 4 yrs | | | | (0.22) | (0.27) |
| AVERAGE ANNUAL | | | | | 2.25*** |
| OUTPUT ($10^3$ GWh) 5 yrs | | | | | (0.23) |
| Observations | 6940 | 6575 | 6210 | 5845 | 5480 |
| Adjusted R2 | 0.798 | 0.855 | 0.866 | 0.867 | 0.866 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Additional controls include Daily Total Precipitation in the entire river basin and Monthly FE

**Table A.5**: Impact of Dams on Water Level

| | **Water Level (cm)** | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| RESERVOIR CAPACITY | -6.62*** | -7.72*** | -9.13*** | -9.70*** |
| ($10^9 m^3$) 2 yrs | (0.27) | (0.33) | (0.34) | (0.38) |
| RESERVOIR CAPACITY | | -1.01*** | -3.27*** | -3.27*** |
| ($10^9 m^3$) 3 yrs | | (0.27) | (0.29) | (0.30) |
| RESERVOIR CAPACITY | | | -2.19*** | -1.53*** |
| ($10^9 m^3$) 4 yrs | | | (0.26) | (0.32) |
| RESERVOIR CAPACITY | | | | -2.69*** |
| ($10^9 m^3$) 5 yrs | | | | (0.30) |
| AVERAGE ANNUAL | 5.26*** | 6.28*** | 7.66*** | 8.07*** |
| OUTPUT ($10^3$ GWh) 2 yrs | (0.23) | (0.28) | (0.29) | (0.33) |
| AVERAGE ANNUAL | | 1.20*** | 3.11*** | 2.99*** |
| OUTPUT ($10^3$ GWh) 3 yrs | | (0.23) | (0.25) | (0.26) |
| AVERAGE ANNUAL | | | 2.85*** | 2.03*** |
| OUTPUT ($10^3$ GWh) 4 yrs | | | (0.22) | (0.27) |
| AVERAGE ANNUAL | | | | 1.41*** |
| OUTPUT ($10^3$ GWh) 5 yrs | | | | (0.26) |
| Observations | 6575 | 6210 | 5845 | 5480 |
| Adjusted R2 | 0.822 | 0.833 | 0.840 | 0.844 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Additional controls include Daily Total Precipitation in the entire river basin and Monthly FE

**Table A.6**: Impact of Dams on Vegetation

| | Average NDVI 1 month prior to harvest season | |
|---|---|---|
| | RAIN SEASON | DRY SEASON |
| RESERVOIR CAPACITY | 0.04*** | -0.05*** |
| 1yr | (0.01) | (0.01) |
| RESERVOIR CAPACITY | 0.03*** | -0.01 |
| 2yrs | (0.01) | (0.01) |
| RESERVOIR CAPACITY | -0.01*** | -0.05*** |
| 3yrs | (0.00) | (0.01) |
| RESERVOIR CAPACITY | 0.01* | -0.00 |
| 4yrs | (0.00) | (0.01) |
| RESERVOIR CAPACITY | 0.01*** | -0.07*** |
| 5yrs | (0.00) | (0.00) |
| DISTANCE TO SHORE | 0.00 | -0.01 |
| × RESERVOIR CAPACITY 1yr | (0.00) | (0.01) |
| DISTANCE TO SHORE | -0.01 | 0.01 |
| × RESERVOIR CAPACITY 2yrs | (0.00) | (0.01) |
| DISTANCE TO SHORE | 0.01** | -0.02 |
| × RESERVOIR CAPACITY 3yrs | (0.00) | (0.02) |
| DISTANCE TO SHORE | -0.01 | 0.01 |
| × RESERVOIR CAPACITY 4yrs | (0.01) | (0.01) |
| DISTANCE TO SHORE | 0.00 | -0.01 |
| × RESERVOIR CAPACITY 5yrs | (0.00) | (0.01) |
| DISTANCE TO SHORE | 19.25 | 21.15* |
| | (11.75) | (7.44) |
| Observations | 2483 | 1396 |
| Adjusted R2 | 0.694 | 0.673 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Standard errors clustered at year-season level
Additional controls include Total Daily Precipitation and Maximum Daily Temperature within districts through the crop-season, Province FE, Year-season FE.

**Table A.7**: Impact of Dams on Vegetation

| | **Average NDVI 1 month prior to harvest season** | |
|---|---|---|
| | RAIN SEASON | DRY SEASON |
| AVERAGE ANNUAL | 0.05*** | 0.02*** |
| OUTPUT 2yrs | (0.01) | (0.00) |
| AVERAGE ANNUAL | -0.01* | -0.00 |
| OUTPUT 3yrs | (0.00) | (0.00) |
| AVERAGE ANNUAL | 0.01*** | 0.02*** |
| OUTPUT 4yrs | (0.00) | (0.00) |
| AVERAGE ANNUAL | 0.01*** | -0.04*** |
| OUTPUT 5yrs | (0.00) | (0.00) |
| DISTANCE TO SHORE | -0.00 | 0.01 |
| × AVERAGE ANNUAL OUTPUT 2yrs | (0.00) | (0.01) |
| DISTANCE TO SHORE | 0.01* | -0.00 |
| × AVERAGE ANNUAL OUTPUT 3yrs | (0.00) | (0.01) |
| DISTANCE TO SHORE | -0.01 | -0.00 |
| × AVERAGE ANNUAL OUTPUT 4yrs | (0.00) | (0.01) |
| DISTANCE TO SHORE | 0.00 | 0.00 |
| × AVERAGE ANNUAL OUTPUT 5yrs | (0.00) | (0.01) |
| DISTANCE TO SHORE | 23.93 | 23.46* |
| | (13.46) | (8.23) |
| Observations | 2483 | 1396 |
| Adjusted R2 | 0.694 | 0.674 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Standard errors clustered at year-season level
Additional controls include Total Daily Precipitation and Maximum Daily Temperature within districts through the crop-season, Province FE, Year-season FE.
.

**Table A.8**: Impact of Dams on Salinity

| | **Maximum Salinity throughout crop-season** | |
|---|---|---|
| | RAIN SEASON | DRY SEASON |
| RESERVOIR CAPACITY 1yr | 0.05 | -0.10*** |
| | (0.05) | (0.02) |
| RESERVOIR CAPACITY 2yrs | 0.03 | 0.26*** |
| | (0.03) | (0.03) |
| RESERVOIR CAPACITY 3yrs | -0.04*** | -0.09*** |
| | (0.00) | (0.02) |
| RESERVOIR CAPACITY 4yrs | 0.00 | 0.24*** |
| | (0.02) | (0.03) |
| RESERVOIR CAPACITY 5yrs | 0.00 | 0.04*** |
| | (0.01) | (0.01) |
| DISTANCE TO SHORE × RESERVOIR CAPACITY 1yr | -0.00 | 0.01 |
| | (0.02) | (0.02) |
| DISTANCE TO SHORE × RESERVOIR CAPACITY 2yrs | -0.01 | 0.00 |
| | (0.01) | (0.03) |
| DISTANCE TO SHORE × RESERVOIR CAPACITY 3yrs | -0.00 | -0.02 |
| | (0.01) | (0.04) |
| DISTANCE TO SHORE × RESERVOIR CAPACITY 4yrs | 0.02 | 0.02 |
| | (0.01) | (0.03) |
| DISTANCE TO SHORE × RESERVOIR CAPACITY 5yrs | -0.00 | -0.05 |
| | (0.02) | (0.04) |
| DISTANCE TO SHORE | -194.20*** | -282.16*** |
| | (31.64) | (29.12) |
| Observations | 2483 | 1396 |
| Adjusted R2 | 0.630 | 0.730 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Standard errors clustered at year-season level
Additional controls include Total Daily Precipitation and Maximum Daily Temperature within districts through the crop-season, Province FE, Year-season FE.

**Table A.9**: Impact of Dams on Salinity

| | **Maximum Salinity throughout crop-season** | |
|---|---|---|
| | RAIN SEASON | DRY SEASON |
| AVERAGE ANNUAL | 0.02 | 0.04*** |
| OUTPUT 2yrs | (0.03) | (0.00) |
| AVERAGE ANNUAL | -0.01 | -0.04*** |
| OUTPUT 3yrs | (0.02) | (0.01) |
| AVERAGE ANNUAL | -0.01 | 0.04*** |
| OUTPUT 4yrs | (0.02) | (0.01) |
| AVERAGE ANNUAL | -0.00 | 0.10*** |
| OUTPUT 5yrs | (0.01) | (0.01) |
| DISTANCE TO SHORE | 0.00 | 0.01 |
| × AVERAGE ANNUAL OUTPUT 2yrs | (0.01) | (0.02) |
| DISTANCE TO SHORE | -0.01 | -0.02 |
| × AVERAGE ANNUAL OUTPUT 3yrs | (0.01) | (0.02) |
| DISTANCE TO SHORE | 0.02* | 0.03 |
| × AVERAGE ANNUAL OUTPUT 4yrs | (0.01) | (0.02) |
| DISTANCE TO SHORE | -0.01 | -0.04 |
| × AVERAGE ANNUAL OUTPUT 5yrs | (0.01) | (0.02) |
| DISTANCE TO SHORE | -189.02*** | -273.28*** |
| | (36.57) | (33.85) |
| Observations | 2483 | 1396 |
| Adjusted R2 | 0.630 | 0.730 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Standard errors clustered at year-season level
Additional controls include Total Daily Precipitation and Maximum Daily Temperature within districts through the crop-season, Province FE, Year-season FE.

**Table A.10**: Impact of Dams on Vegetation

| | **Average NDVI 1 month prior to harvest season** | |
|---|---|---|
| | RAIN SEASON | DRY SEASON |
| RESERVOIR CAPACITY 2yrs | 0.39*** | -0.15*** |
| | (0.08) | (0.01) |
| RESERVOIR CAPACITY 3yrs | 0.09 | -1.00*** |
| | (0.07) | (0.06) |
| RESERVOIR CAPACITY 4yrs | 0.07* | -0.43*** |
| | (0.03) | (0.03) |
| RESERVOIR CAPACITY 5yrs | 0.36** | 0.83*** |
| | (0.10) | (0.05) |
| AVERAGE ANNUAL OUTPUT 2yrs | -0.38*** | -0.11*** |
| | (0.08) | (0.01) |
| AVERAGE ANNUAL OUTPUT 3yrs | -0.10 | 0.75*** |
| | (0.06) | (0.05) |
| AVERAGE ANNUAL OUTPUT 4yrs | -0.05* | 0.31*** |
| | (0.02) | (0.02) |
| AVERAGE ANNUAL OUTPUT 5yrs | -0.35** | -0.58*** |
| | (0.10) | (0.04) |
| DISTANCE TO SHORE × RESERVOIR CAPACITY 2yrs | 0.02 | -0.16*** |
| | (0.02) | (0.03) |
| DISTANCE TO SHORE × RESERVOIR CAPACITY 3yrs | 0.04* | 0.33** |
| | (0.02) | (0.09) |
| DISTANCE TO SHORE × RESERVOIR CAPACITY 4yrs | -0.01 | 0.19** |
| | (0.02) | (0.05) |
| DISTANCE TO SHORE × RESERVOIR CAPACITY 5yrs | -0.03 | 0.21** |
| | (0.02) | (0.06) |
| DISTANCE TO SHORE × AVG ANNUAL OUTPUT 2yrs | -0.02 | 0.16*** |
| | (0.01) | (0.03) |
| DISTANCE TO SHORE × AVG ANNUAL OUTPUT 3yrs | -0.02 | -0.18** |
| | (0.01) | (0.05) |
| DISTANCE TO SHORE × AVG ANNUAL OUTPUT 4yrs | -0.00 | -0.15** |
| | (0.01) | (0.04) |
| DISTANCE TO SHORE × AVG ANNUAL OUTPUT 5yrs | 0.03 | -0.06** |
| | (0.02) | (0.02) |
| DISTANCE TO SHORE | -4.62 | -50.65 |
| | (30.34) | (31.03) |
| Observations | 2483 | 1396 |
| Adjusted R2 | 0.695 | 0.675 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Standard errors clustered at year-season level

Additional controls include Average Daily Mean Temperature, Average Daily Maximum Temperature, Average Daily Total Precipitation within districts through the crop-season, Total Precipitation in the upper river basin, Province FE, Year-season FE, Distance from district centroid to Water Station, Distance from district centroid to Water Station, River length within districts.

**Table A.11**: Impact of Dams on Salinity

| | Maximum Salinity throughout crop-season | |
|---|---|---|
| | RAIN SEASON | DRY SEASON |
| RESERVOIR CAPACITY | 0.61 | 0.37*** |
| 2yrs | (0.45) | (0.03) |
| RESERVOIR CAPACITY | 0.44 | 2.95*** |
| 3yrs | (0.35) | (0.22) |
| RESERVOIR CAPACITY | 0.09 | 1.10*** |
| 4yrs | (0.15) | (0.10) |
| RESERVOIR CAPACITY | 0.73 | -2.56*** |
| 5yrs | (0.55) | (0.19) |
| AVERAGE ANNUAL | -0.61 | 0.40*** |
| OUTPUT 2yrs | (0.45) | (0.03) |
| AVERAGE ANNUAL | -0.47 | -2.29*** |
| OUTPUT 3yrs | (0.35) | (0.17) |
| AVERAGE ANNUAL | -0.06 | -0.77*** |
| OUTPUT 4yrs | (0.11) | (0.07) |
| AVERAGE ANNUAL | -0.74 | 1.80*** |
| OUTPUT 5yrs | (0.55) | (0.13) |
| DISTANCE TO SHORE | -0.22*** | 0.32* |
| × RESERVOIR CAPACITY 2yrs | (0.03) | (0.15) |
| DISTANCE TO SHORE | 0.02 | -1.00* |
| × RESERVOIR CAPACITY 3yrs | (0.04) | (0.41) |
| DISTANCE TO SHORE | -0.02 | -0.54* |
| × RESERVOIR CAPACITY 4yrs | (0.05) | (0.25) |
| DISTANCE TO SHORE | 0.13** | -0.67* |
| × RESERVOIR CAPACITY 5yrs | (0.04) | (0.27) |
| DISTANCE TO SHORE | 0.18*** | -0.34* |
| × AVG ANNUAL OUTPUT 2yrs | (0.03) | (0.15) |
| DISTANCE TO SHORE | -0.02 | 0.57* |
| × AVERAGE ANNUAL OUTPUT 3yrs | (0.03) | (0.24) |
| DISTANCE TO SHORE | 0.04 | 0.41* |
| × AVG ANNUAL OUTPUT 4yrs | (0.04) | (0.18) |
| DISTANCE TO SHORE | -0.11*** | 0.19 |
| × AVG ANNUAL OUTPUT 5yrs | (0.03) | (0.09) |
| DISTANCE TO SHORE | -113.03* | 7.12 |
| | (51.68) | (180.30) |
| Observations | 2483 | 1396 |
| Adjusted R2 | 0.630 | 0.730 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Standard errors clustered at year-season level

Additional controls include Average Daily Mean Temperature, Average Daily Maximum Temperature, Average Daily Total Precipitation within districts through the crop-season, Total Precipitation in the upper river basin, Province FE, Year-season FE, Distance from district centroid to Water Station, Distance from district centroid to Water Station, River length within districts.

**Table A.12**: Predictive margins for operational dams

| | | Operational dams | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Se San 4 | Nuozhadu | Xiaowan | Xayaburi | Huangdeng | Miaowei | Don Sahong |
| Daily | Water_1yr | -0.600 | -15.916 | -10.101 | -4.052 | -5.760 | -0.443 | -0.017 |
| | Water_2yr | -6.327 | -43.577 | 3.712 | -50.472 | -73.695 | 42.645 | 16.194 |
| | Water_3yr | -1.696 | -9.263 | 3.141 | -13.681 | -20.009 | 12.353 | 4.660 |
| | Water_4yr | -1.824 | -22.875 | -8.078 | -13.908 | -20.170 | 8.367 | 3.310 |
| Coast | NDVI_1yr | -0.153 | -4.057 | -2.575 | -1.033 | -1.468 | -0.113 | -0.004 |
| | NDVI_2yr | -0.164 | -6.017 | -4.240 | -1.003 | -1.400 | -0.757 | -0.224 |
| | NDVI_3yr | -0.275 | -2.748 | -0.594 | -2.143 | -3.117 | 1.531 | 0.592 |
| | NDVI_4yr | 0.540 | 5.705 | 1.442 | 4.188 | 6.088 | -2.888 | -1.122 |
| Inland | NDVI_1yr | -0.154 | -4.078 | -2.588 | -1.038 | -1.476 | -0.114 | -0.004 |
| | NDVI_2yr | -0.185 | -6.025 | -4.108 | -1.178 | -1.656 | -0.565 | -0.153 |
| | NDVI_3yr | -0.586 | -5.036 | -0.542 | -4.615 | -6.725 | 3.571 | 1.369 |
| | NDVI_4yr | -0.248 | -2.529 | -0.583 | -1.927 | -2.803 | 1.359 | 0.527 |
| Coast | VSSI_1yr | 0.580 | 15.395 | 9.770 | 3.920 | 5.571 | 0.429 | 0.016 |
| | VSSI_2yr | 0.391 | 13.951 | 9.753 | 2.423 | 3.388 | 1.646 | 0.480 |
| | VSSI_3yr | 1.157 | 8.074 | -0.587 | 9.225 | 13.468 | -7.760 | -2.948 |
| | VSSI_4yr | 0.534 | 6.602 | 2.278 | 4.081 | 5.920 | -2.489 | -0.983 |
| Inland | VSSI_1yr | 0.580 | 15.392 | 9.768 | 3.919 | 5.570 | 0.429 | 0.016 |
| | VSSI_2yr | 0.425 | 13.591 | 9.210 | 2.726 | 3.838 | 1.196 | 0.317 |
| | VSSI_3yr | 0.977 | 5.688 | -1.499 | 7.862 | 11.494 | -6.985 | -2.639 |
| | VSSI_4yr | 0.443 | 5.728 | 2.117 | 3.364 | 4.877 | -1.963 | -0.780 |

All margins are predicted for dry season only. First year average annual output is not included in the regression

**Table A.13**: Predictive margins for future dams

| | | Under construction | | Planned | |
|---|---|---|---|---|---|
| | | Luang Prabang | Tuoba | Ganlanba | Guxue |
| Daily level | Water_1yr | -1.068 | -0.698 | -0.389 | -5.205 |
| | Water_2yr | 37.340 | 40.940 | 3.801 | -14.287 |
| | Water_3yr | 10.956 | 11.916 | 1.173 | -3.040 |
| | Water_4yr | 6.732 | 7.794 | 0.440 | -7.488 |
| Dry - Coast | NDVI_1yr | -0.272 | -0.178 | -0.099 | -1.327 |
| | NDVI_2yr | -0.944 | -0.839 | -0.213 | -1.967 |
| | NDVI_3yr | 1.291 | 1.450 | 0.111 | -0.900 |
| | NDVI_4yr | -2.414 | -2.726 | -0.199 | 1.868 |
| Dry - Inland | NDVI_1yr | -0.274 | -0.179 | -0.100 | -1.334 |
| | NDVI_2yr | -0.768 | -0.652 | -0.191 | -1.970 |
| | NDVI_3yr | 3.070 | 3.406 | 0.289 | -1.650 |
| | NDVI_4yr | 1.143 | 1.286 | 0.097 | -0.828 |
| Dry - Coast | VSSI_1yr | 1.033 | 0.675 | 0.377 | 5.035 |
| | VSSI_2yr | 2.090 | 1.841 | 0.481 | 4.561 |
| | VSSI_3yr | -6.789 | -7.447 | -0.689 | 2.647 |
| | VSSI_4yr | -2.011 | -2.322 | -0.135 | 2.161 |
| Dry - Inland | VSSI_1yr | 1.032 | 0.675 | 0.377 | 5.034 |
| | VSSI_2yr | 1.663 | 1.395 | 0.423 | 4.444 |
| | VSSI_3yr | -6.177 | -6.730 | -0.654 | 1.866 |
| | VSSI_4yr | -1.565 | -1.823 | -0.095 | 1.875 |

All margins are predicted for dry season only. First year average annual output is not included in the regression

# Appendix B

**Table B.1**: Variable Description

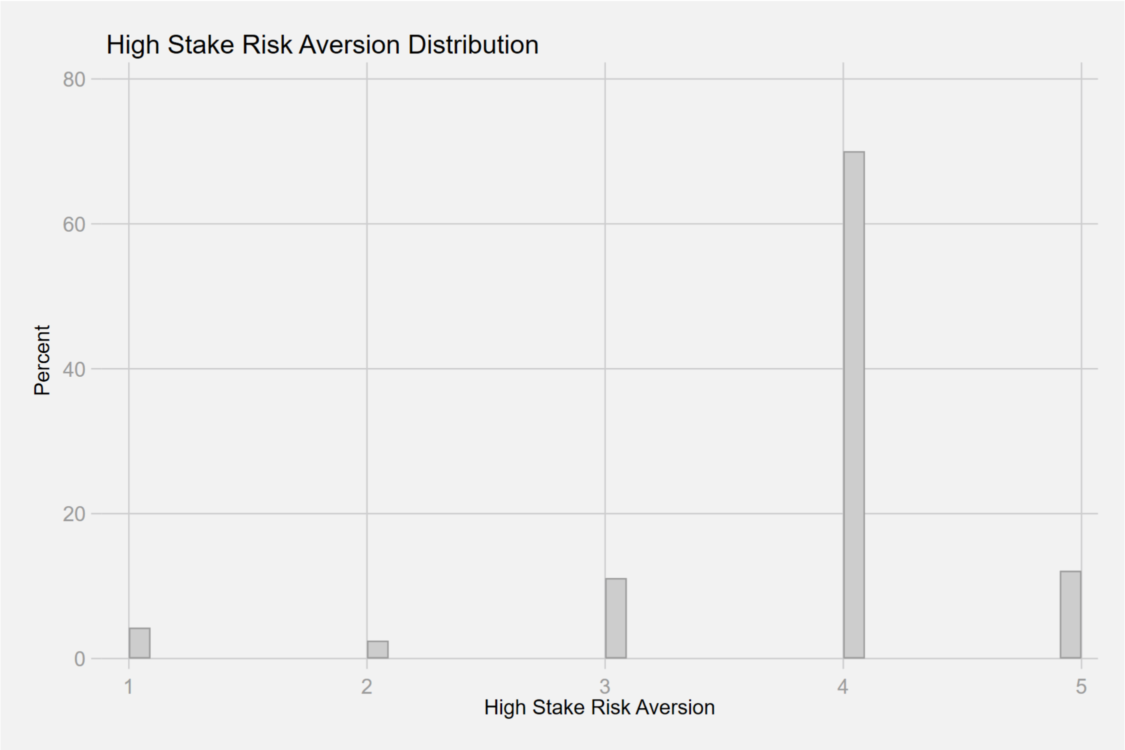
| Variable name | Construction | Unit |
|---|---|---|
| HIGH STAKE RISK | High-stake Risk Aversion | No unit |
| LOW STAKE RISK | Low-stake Risk Aversion | No unit |
| AGE | Individual Age | Years |
| FEMALE | Indicator for being female | No unit |
| URBAN | Indicator for living in urban area | No unit |
| MARRIED | Indicator for being currently married | No unit |
| INCOME | Income the year before survey | Rupiah |
| HH SIZE | Household size | No unit |
| HH INCOME | Household income the year before survey | Rupiah |
| HH ASSET | Household total asset | Rupiah |
| BORROWING | Borrowing the year before survey | Rupiah |
| LOAN | Current outstanding loan | Rupiah |
| SAVING | Saving the year before survey | Rupiah |
| PRIVATE | Indicator for working in Private sector | No unit |
| PUBLIC | Indicator for working in Public sector | No unit |
| SELF-EMPLOYED | Indicator for being Self-employed | No unit |
| UNPAID FAMILY WORKER | Indicator for being an Unpaid family worker | No unit |
| AGRI WORKER | Indicator for working as an agriculture worker | No unit |
| NON-AGRI WORKER | Indicator for working as a non-agriculture worker | No unit |
| QUIT JOB | Indicator for having quitted job in the last 5 years | No unit |
| STARTUP | Indicator for having tried to start up in the last year | No unit |
| OWN BUSINESS | Indicator for currently owning a business | No unit |
| MIGRATE | Indicator for having migrated since 12 years old | No unit |

**Table B.2**: Summary Statistics

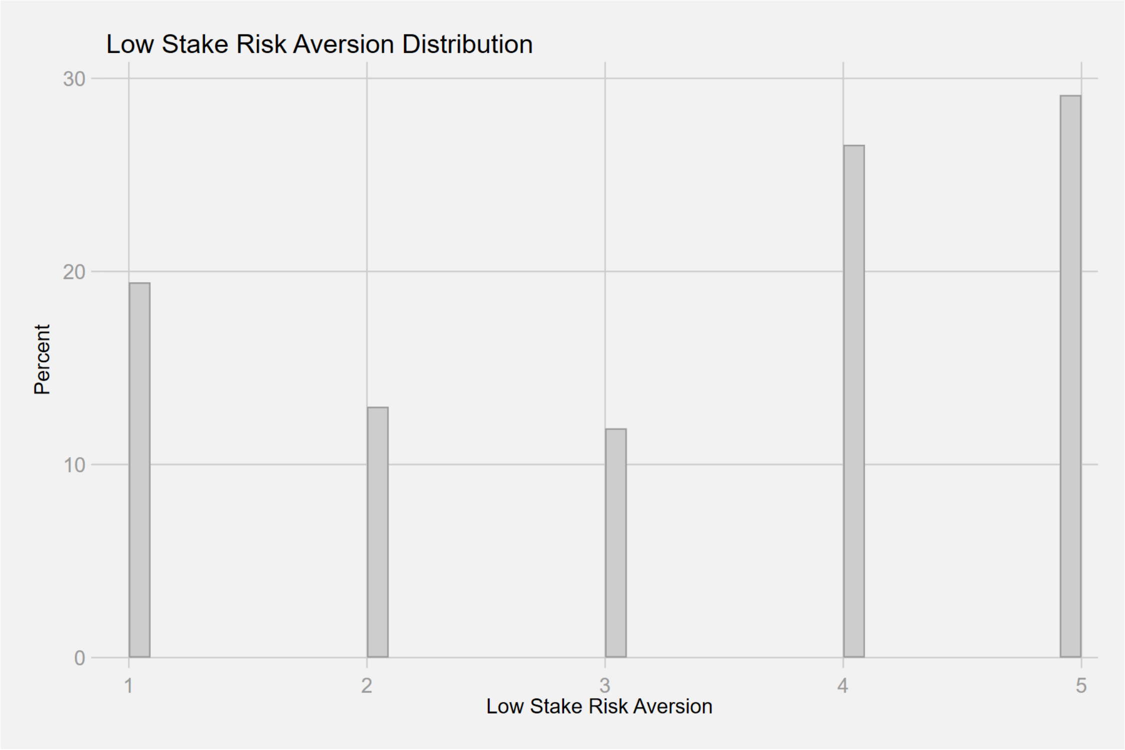
| | Count | Mean | St.dev |
|---|---|---|---|
| HIGH STAKE RISK AVERSION | 25703 | 3.84 | 0.83 |
| LOW STAKE RISK AVERSION | 25709 | 3.34 | 1.50 |
| AGE | 50706 | 30.13 | 31.34 |
| FEMALE | 50706 | 0.51 | 0.50 |
| URBAN | 43703 | 0.58 | 0.49 |
| MARRIED | 50706 | 0.83 | 1.22 |
| INCOME | 23374 | 1.74e+07 | 42554077.30 |
| HH SIZE | 50706 | 6.77 | 3.28 |
| HH INCOME LAST YEAR | 47586 | 4.62e+07 | 90199112.56 |
| HH ASSET | 36308 | 2.39e+08 | 4.86e+08 |
| BORROW LAST YEAR | 48202 | 5.86e+06 | 32682968.19 |
| LOAN | 47610 | 1.24e+07 | 58941753.15 |
| SAVING LAST YEAR | 50085 | -5.33e+06 | 2.01e+08 |
| PRIVATE SECTOR | 20222 | 0.34 | 0.47 |
| PUBLIC SECTOR | 20222 | 0.10 | 0.29 |
| SELF-EMPLOYED | 20222 | 0.25 | 0.43 |
| ORDINARY AGRICULTURE WORKER | 20222 | 0.05 | 0.22 |
| ORDINARY NON-AGRICULTURE WORKER | 20222 | 0.10 | 0.30 |
| QUIT JOB IN THE LAST 5 YEARS | 24217 | 0.07 | 0.25 |
| STARTUP IN THE LAST YEAR | 28316 | 0.07 | 0.26 |
| OWNING BUSINESS | 28316 | 0.04 | 0.19 |
| DIVORCE EVER | 28316 | 0.04 | 0.19 |
| MIGRATE SINCE 12 YEARS OLD | 27892 | 0.12 | 0.33 |
| Observations | 50706 | | |

**Table B.3**: Summary Statistics - Pollution

| | Count | Mean | St.dev | Min | Max |
|---|---|---|---|---|---|
| SO4 2014-2015 Average AOT | 34280 | 0.12 | 0.05 | 0.03 | 0.23 |
| Black Carbon 2014-2015 Average AOT | 34280 | 0.02 | 0.01 | 0.01 | 0.05 |
| Organic Carbon 2014-2015 Average AOT | 34280 | 0.08 | 0.04 | 0.04 | 0.26 |
| Dust 2014-2015 AOT | 34280 | 0.00 | 0.00 | 0.00 | 0.01 |
| Dust PM2.5 2014-2015 Average AOT | 34280 | 0.00 | 0.00 | 0.00 | 0.01 |
| Daily 2014-2015 Total AOT | 34280 | 0.26 | 0.07 | 0.11 | 0.48 |
| Temperature 2014-2015 Average | 34280 | 24.37 | 1.69 | 19.50 | 27.34 |
| Approximate District Area (sqkm) | 34280 | 106.33 | 182.34 | 0.65 | 4880.58 |
| Observations | 34280 | | | | |



(a) High Stake Risk Aversion Distribution



(b) Low Stake Risk Aversion Distribution

**Figure B.1**: Risk Aversion Distribution

**Table B.4**: Household Financial Decision and Low Stake Risk Aversion

| | Borrow | Loan | Saving | Net Saving |
|---|---|---|---|---|
| DM Low stake Risk Aversion | -0.92* | -0.43 | 2.90*** | 3.77*** |
| | (0.39) | (0.64) | (0.67) | (0.81) |
| DM Age | 0.06 | 0.09 | -0.15 | -0.21* |
| | (0.05) | (0.06) | (0.08) | (0.10) |
| DM Female | 0.05 | 1.18 | -3.53 | -3.76 |
| | (1.65) | (2.43) | (2.24) | (2.80) |
| DM Married | 0.41 | 0.36 | 0.34 | -0.02 |
| | (0.79) | (1.48) | (1.42) | (1.77) |
| DM Income | 0.02 | 0.13 | 0.02 | 0.00 |
| | (0.06) | (0.08) | (0.13) | (0.17) |
| Urban | 0.16 | 0.09 | -2.58 | -2.70 |
| | (1.28) | (3.05) | (2.68) | (3.10) |
| HH Size | -0.09 | -0.21 | -0.60 | -0.54 |
| | (0.15) | (0.25) | (0.32) | (0.37) |
| HH Income | 0.09* | 0.11** | 0.79*** | 0.70*** |
| | (0.04) | (0.04) | (0.05) | (0.06) |
| HH Asset | 0.01* | 0.01** | -0.03*** | -0.04*** |
| | (0.00) | (0.00) | (0.01) | (0.01) |
| Observations | 5685 | 5632 | 5694 | 5685 |
| Adjusted R2 | 0.104 | 0.138 | 0.477 | 0.342 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Additional Controls include Dummies for Highest education level, Ethnicity, Religion, Regency FE.
Outcome variables are in million Indonesian currency Rupiah
DM means Decision Maker.

**Table B.5**: Employment Sector and Low Stake Risk Aversion

| | Private | Self Employed | Public | Unpaid Family Worker |
|---|---|---|---|---|
| Low stake Risk Aversion | 0.30 | -0.74*** | 0.44*** | -0.98*** |
| | (0.21) | (0.21) | (0.13) | (0.22) |
| Age | -0.78*** | 0.40*** | 0.15*** | 0.51*** |
| | (0.03) | (0.03) | (0.02) | (0.03) |
| Female | -7.34*** | -4.41*** | -2.18*** | 10.49*** |
| | (0.66) | (0.64) | (0.40) | (0.67) |
| Married | 0.46 | 2.95*** | 0.00 | -4.30*** |
| | (0.31) | (0.36) | (0.18) | (0.34) |
| Urban | 8.57*** | 0.94 | 0.06 | -10.27*** |
| | (1.15) | (1.08) | (0.74) | (1.14) |
| HH Size | -0.31** | -0.23* | -0.06 | 0.35*** |
| | (0.11) | (0.10) | (0.07) | (0.10) |
| Observations | 18722 | 18722 | 18722 | 18722 |
| Adjusted R2 | 0.161 | 0.057 | 0.188 | 0.188 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Additional Controls include Dummies for Highest education level, Ethnicity, Religion, Regency FE.
Private, Self Employed, Public and Unpaid Family Worker are measured in percentage point

**Table B.6**: Individual Life Time Decision and Low Stake Risk Aversion

| | Quit Job | Start-up | Own Business | Migrate |
|---|---|---|---|---|
| Low stake Risk Aversion | -0.29* | -0.59*** | -0.65*** | -1.45** |
| | (0.12) | (0.14) | (0.12) | (0.48) |
| Age | -0.31*** | -0.10*** | 0.15*** | 1.04*** |
| | (0.02) | (0.02) | (0.02) | (0.09) |
| Female | -1.90*** | -3.10*** | 1.38*** | -3.74* |
| | (0.37) | (0.43) | (0.36) | (1.47) |
| Married | 0.58*** | 0.21 | -0.26 | 11.78*** |
| | (0.15) | (0.19) | (0.19) | (1.49) |
| Urban | 1.38* | 0.41 | 0.47 | 1.78 |
| | (0.60) | (0.74) | (0.59) | (2.32) |
| HH Size | -0.03 | 0.29*** | -0.08 | -0.40 |
| | (0.06) | (0.07) | (0.05) | (0.21) |
| Observations | 18721 | 18722 | 18722 | 4648 |
| Adjusted R2 | 0.043 | 0.046 | 0.033 | 0.172 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Additional Controls include Dummies for Highest education level, Ethnicity, Religion, Regency FE. Quit Job, Start-up, Own Business, Migrate are measured in percentage point.

**Table B.7**: Individual Health Insurance Choice and Low Stake Risk Aversion

| | Private Ins | Saving Ins | Labor Ins | Public Ins | Uninsured |
|---|---|---|---|---|---|
| Low Stake Risk Aversion | -0.17** | -0.08 | -0.31** | 0.47*** | -0.21 |
| | (0.07) | (0.04) | (0.11) | (0.12) | (0.24) |
| Age | -0.00 | -0.00 | -0.09*** | 0.35*** | -0.05 |
| | (0.01) | (0.01) | (0.01) | (0.02) | (0.03) |
| Female | -0.20 | -0.12 | -1.30*** | 0.97* | -0.60 |
| | (0.21) | (0.13) | (0.35) | (0.39) | (0.73) |
| Married | -0.02 | 0.04 | -0.04 | -0.42* | 0.13 |
| | (0.09) | (0.05) | (0.13) | (0.19) | (0.38) |
| Urban | -0.10 | -0.36* | 2.31*** | 1.26 | -2.73* |
| | (0.30) | (0.18) | (0.63) | (0.66) | (1.22) |
| HH Size | -0.02 | 0.05 | -0.13* | 0.06 | 0.05 |
| | (0.04) | (0.03) | (0.06) | (0.06) | (0.12) |
| Observations | 18626 | 18626 | 18626 | 18626 | 18626 |
| Adjusted R2 | 0.069 | 0.036 | 0.088 | 0.181 | 0.113 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Additional Controls include Dummies for Highest education level, Ethnicity, Religion, General Health Condition, Chronic Diseases, Regency FE. Private Ins, Saving In, Labor Ins, Public Ins and Uninsured are measured in percentage point.

**Table B.8**: Low Stake Risk Aversion and Interview day Exposure to Pollution

| | SO4 | BC | OC | Dust | Salt | All |
|---|---|---|---|---|---|---|
| SO4 Ivwday AOT | 0.08 | | | | | 0.06 |
| | (0.12) | | | | | (0.14) |
| Black Carbon Ivwday AOT | | 0.34 | | | | 1.40 |
| | | (0.90) | | | | (2.22) |
| Organic Carbon Ivwday AOT | | | 0.02 | | | -0.29 |
| | | | (0.12) | | | (0.30) |
| Dust Ivwday AOT | | | | 9.70** | | 9.49** |
| | | | | (3.20) | | (3.26) |
| Sea salt Ivwday AOT | | | | | 0.58 | 0.27 |
| | | | | | (0.52) | (0.59) |
| Observations | 24493 | 24493 | 24493 | 24493 | 24493 | 24493 |
| Adjusted R2 | 0.034 | 0.034 | 0.034 | 0.034 | 0.034 | 0.034 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Additional Controls include Dummies for Highest education level, Ethnicity, Religion, Regency FE, Season FE.

**Table B.9**: Low Stake Risk Aversion and 30-day Accumulated Exposure to Pollution

| | SO4 | BC | OC | Dust | Salt | All |
|---|---|---|---|---|---|---|
| SO4 30dayAcc AOT | 0.03 | | | | | 0.03* |
| | (0.01) | | | | | (0.02) |
| Black Carbon 30dayAcc AOT | | 0.04 | | | | -0.22 |
| | | (0.07) | | | | (0.25) |
| Organic Carbon 30dayAcc AOT | | | 0.01 | | | 0.02 |
| | | | (0.01) | | | (0.04) |
| Dust 30dayAcc AOT | | | | 0.13 | | 0.12 |
| | | | | (0.27) | | (0.34) |
| Sea salt 30dayAcc AOT | | | | | 0.05 | 0.05 |
| | | | | | (0.05) | (0.07) |
| Observations | 22752 | 22752 | 22752 | 22752 | 22752 | 22752 |
| Adjusted R2 | 0.035 | 0.034 | 0.034 | 0.034 | 0.034 | 0.034 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Additional Controls include Dummies for Highest education level, Ethnicity, Religion, Regency FE, Season FE.

**Table B.10**: Household Financial Decision and High Stake Risk Aversion

| | Borrow | Loan | Saving | Net Saving |
|---|---|---|---|---|
| DM High Stake Risk Aversion | -1.22 | -3.51* | 3.35* | 4.54** |
| | (1.16) | (1.37) | (1.31) | (1.76) |
| DM Age | 0.06 | 0.09 | -0.15 | -0.21* |
| | (0.05) | (0.06) | (0.08) | (0.10) |
| DM Female | -0.03 | 1.35 | -3.16 | -3.32 |
| | (1.65) | (2.41) | (2.22) | (2.77) |
| DM Married | 0.38 | 0.24 | 0.33 | 0.00 |
| | (0.81) | (1.50) | (1.41) | (1.77) |
| DM Income | 0.02 | 0.12 | 0.02 | -0.00 |
| | (0.06) | (0.07) | (0.13) | (0.18) |
| Urban | 0.24 | 0.19 | -2.90 | -3.09 |
| | (1.28) | (3.04) | (2.68) | (3.10) |
| HH Size | -0.10 | -0.24 | -0.58 | -0.51 |
| | (0.15) | (0.25) | (0.32) | (0.37) |
| HH Income | 0.09* | 0.10** | 0.78*** | 0.69*** |
| | (0.04) | (0.03) | (0.05) | (0.06) |
| HH Asset | 0.01* | 0.01** | -0.03*** | -0.04*** |
| | (0.00) | (0.00) | (0.01) | (0.01) |
| Observations | 5686 | 5633 | 5695 | 5686 |
| Adjusted R2 | 0.104 | 0.138 | 0.472 | 0.335 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Additional Controls include Dummies for Highest education level, Ethnicity, Religion, Regency FE.
Outcome variables are in million Indonesian currency Rupiah
DM means Decision Maker.

**Table B.11**: Employment Sector and High Stake Risk Aversion

| | Private | Self Employed | Public | Unpaid Family Worker |
|---|---|---|---|---|
| High Stake Risk Aversion | 0.37 | -0.74 | 0.50* | -1.07** |
| | (0.38) | (0.38) | (0.23) | (0.38) |
| Age | -0.78*** | 0.40*** | 0.15*** | 0.51*** |
| | (0.03) | (0.03) | (0.02) | (0.03) |
| Female | -7.29*** | -4.54*** | -2.09*** | 10.35*** |
| | (0.66) | (0.64) | (0.40) | (0.67) |
| Married | 0.46 | 2.95*** | 0.00 | -4.25*** |
| | (0.31) | (0.36) | (0.18) | (0.34) |
| Urban | 8.53*** | 0.99 | 0.01 | -10.14*** |
| | (1.15) | (1.08) | (0.75) | (1.14) |
| HH Size | -0.32** | -0.22* | -0.06 | 0.33** |
| | (0.11) | (0.10) | (0.07) | (0.10) |
| Observations | 18711 | 18711 | 18711 | 18711 |
| Adjusted R2 | 0.161 | 0.056 | 0.188 | 0.187 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Additional Controls include Dummies for Highest education level, Ethnicity, Religion, Regency FE. Private, Self Employed, Public and Unpaid Family Worker are measured in percentage point

**Table B.12**: Individual Life Time Decision and High Stake Risk Aversion

| | Quit Job | Start-up | Own Business | Migrate |
|---|---|---|---|---|
| High Stake Risk Aversion | -0.00 | -0.87** | -0.17 | 0.26 |
| | (0.22) | (0.27) | (0.21) | (0.81) |
| Age | -0.31*** | -0.10*** | 0.15*** | 1.04*** |
| | (0.02) | (0.02) | (0.02) | (0.09) |
| Female | -1.97*** | -3.17*** | 1.23*** | -3.99** |
| | (0.37) | (0.43) | (0.36) | (1.47) |
| Married | 0.59*** | 0.21 | -0.25 | 12.00*** |
| | (0.15) | (0.19) | (0.19) | (1.49) |
| Urban | 1.41* | 0.48 | 0.61 | 2.06 |
| | (0.60) | (0.74) | (0.59) | (2.33) |
| HH Size | -0.03 | 0.29*** | -0.08 | -0.43* |
| | (0.06) | (0.07) | (0.05) | (0.21) |
| Observations | 18710 | 18711 | 18711 | 4650 |
| Adjusted R2 | 0.043 | 0.046 | 0.031 | 0.172 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Additional Controls include Dummies for Highest education level, Ethnicity, Religion, Regency FE. Quit Job, Start-up, Own Business, Migrate are measured in percentage point.

**Table B.13**: Individual Health Insurance Choice and High Stake Risk Aversion

| | Private Ins | Saving Ins | Labor Ins | Public Ins | Uninsured |
|---|---|---|---|---|---|
| High Stake Risk Aversion | -0.08 | -0.06 | 0.14 | 0.47* | 0.13 |
| | (0.14) | (0.08) | (0.20) | (0.22) | (0.42) |
| Age | -0.00 | -0.00 | -0.09*** | 0.35*** | -0.05 |
| | (0.01) | (0.01) | (0.01) | (0.02) | (0.03) |
| Female | -0.23 | -0.13 | -1.40*** | 1.06** | -0.71 |
| | (0.21) | (0.13) | (0.35) | (0.39) | (0.73) |
| Married | -0.02 | 0.04 | -0.03 | -0.40* | 0.09 |
| | (0.09) | (0.05) | (0.13) | (0.19) | (0.38) |
| Urban | -0.09 | -0.36* | 2.34*** | 1.19 | -2.75* |
| | (0.29) | (0.18) | (0.63) | (0.67) | (1.22) |
| HH Size | -0.02 | 0.05 | -0.14* | 0.07 | 0.06 |
| | (0.04) | (0.03) | (0.06) | (0.06) | (0.12) |
| Observations | 18614 | 18614 | 18614 | 18614 | 18614 |
| Adjusted R2 | 0.069 | 0.036 | 0.088 | 0.180 | 0.112 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Additional Controls include Dummies for Highest education level, Ethnicity, Religion, General Health Condition, Chronic Diseases, Regency FE. Private Ins, Saving In, Labor Ins, Public Ins and Uninsured are measured in percentage point.

**Table B.14**: High Stake Risk Aversion and Interview day Exposure to Pollution

| | SO4 | BC | OC | Dust | Salt | All |
|---|---|---|---|---|---|---|
| SO4 Ivwday AOT | 0.06 | | | | | 0.02 |
| | (0.06) | | | | | (0.07) |
| Black Carbon Ivwday AOT | | 0.88 | | | | 0.01 |
| | | (0.48) | | | | (1.35) |
| Organic Carbon Ivwday AOT | | | 0.15* | | | 0.12 |
| | | | (0.07) | | | (0.20) |
| Dust Ivwday AOT | | | | 1.25 | | 0.56 |
| | | | | (1.96) | | (2.08) |
| Sea salt Ivwday AOT | | | | | 0.32 | 0.15 |
| | | | | | (0.25) | (0.30) |
| Observations | 24501 | 24501 | 24501 | 24501 | 24501 | 24501 |
| Adjusted R2 | 0.018 | 0.019 | 0.019 | 0.018 | 0.018 | 0.018 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Additional Controls include Dummies for Highest education level, Ethnicity, Religion, Regency FE, Season FE.

**Table B.15**: High Stake Risk Aversion and 30-day Accumulated Exposure to Pollution

| | SO4 | BC | OC | Dust | Salt | All |
|---|---|---|---|---|---|---|
| SO4 30dayAcc AOT | 0.02** | | | | | 0.02 |
| | (0.01) | | | | | (0.01) |
| Black Carbon 30dayAcc AOT | | 0.06 | | | | -0.10 |
| | | (0.03) | | | | (0.16) |
| Organic Carbon 30dayAcc AOT | | | 0.01 | | | 0.02 |
| | | | (0.01) | | | (0.03) |
| Dust 30dayAcc AOT | | | | 0.03 | | -0.04 |
| | | | | (0.14) | | (0.21) |
| Sea salt 30dayAcc AOT | | | | | 0.03 | 0.01 |
| | | | | | (0.02) | (0.03) |
| Observations | 22759 | 22759 | 22759 | 22759 | 22759 | 22759 |
| Adjusted R2 | 0.019 | 0.019 | 0.019 | 0.019 | 0.019 | 0.019 |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Additional Controls include Dummies for Highest education level, Ethnicity, Religion, Regency FE, Season FE.

# Appendix C

**Table C.1**: Summary Statistics - Export Exposure by Industry

| | **Annual Change Export Exposure (million USD)** | | | |
|---|---|---|---|---|
| | Export Exposure | Total Exposure | Direct Exposure | Indirect Exposure |
| Veg & Fruit | 43.98 | 225.58 | 40.99 | 184.58 |
| Cattle | 4.45 | 9.12 | 3.56 | 5.56 |
| Other Animal Products | 4.95 | 5.89 | 3.39 | 2.50 |
| Forestry | 2.53 | 35.16 | 2.31 | 32.85 |
| Fishing | -17.99 | 447.85 | 11.69 | 436.16 |
| Coal | -0.09 | 21.68 | -0.08 | 21.76 |
| Oil | 0.01 | 0.18 | 0.01 | 0.17 |
| Gas | 0.00 | 0.00 | 0.00 | 0.00 |
| Other Mining Extraction | 0.00 | 0.00 | 0.00 | 0.00 |
| Vegetable Oils | -2.13 | -1.78 | -1.78 | 0.01 |
| Milk | 4.45 | 3.04 | 2.99 | 0.05 |
| Sugar and molasses | -2.56 | -1.25 | -1.42 | 0.17 |
| Other Food | 30.65 | 196.60 | 192.92 | 3.68 |

continued . . .

**Table C.1** Summary Statistics - Export Exposure by Industry (Continued)

| | **Annual Change Export Exposure (million USD)** | | | |
|---|---|---|---|---|
| | Export Exposure | Total Exposure | Direct Exposure | Indirect Exposure |
| Beverages and Tobacco | 0.03 | 0.56 | 0.29 | 0.27 |
| Textiles | 5.56 | 28.06 | 4.35 | 23.72 |
| Wearing apparel | 53.35 | 46.36 | 39.28 | 7.08 |
| Leather | 36.49 | 1584.48 | 1580.67 | 3.81 |
| Lumber | 11.35 | 7.38 | 5.49 | 1.89 |
| Paper | 73.12 | 190.41 | 170.32 | 20.09 |
| Petroleum & Coke | -0.02 | 0.27 | -0.01 | 0.28 |
| Chemicals | 0.00 | 0.00 | 0.00 | 0.00 |
| Pharmaceuticals & medicinal | 0.00 | 0.00 | 0.00 | 0.00 |
| Rubber and plastics | 0.00 | 0.00 | 0.00 | 0.00 |
| Other non-metallic mineral | 2.09 | 10.26 | 1.51 | 8.75 |
| Iron & Steel | 2.44 | 0.54 | 0.49 | 0.05 |
| Non-Ferrous Metals | 0.92 | 1.12 | 0.57 | 0.55 |
| Fabricated metal | 12.81 | 11.13 | 10.81 | 0.32 |
| Computer and electronic | -147.13 | -97.61 | -122.86 | 25.24 |
| Electrical equipment | 0.00 | 0.00 | 0.00 | 0.00 |
| Machinery and equipment | 12.50 | 10.19 | 9.94 | 0.25 |
| Motor vehicles | 0.08 | 2.37 | 0.07 | 2.30 |
| Other transport equipment | 1.31 | 6.25 | 1.14 | 5.10 |
| Other Manufacturing | 69.10 | 1432.10 | 1318.29 | 113.81 |
| Electricity | 0.00 | 40.24 | 0.00 | 40.24 |

continued . . .

**Table C.1** Summary Statistics - Export Exposure by Industry (Continued)

| | **Annual Change Export Exposure (million USD)** | | | |
|---|---|---|---|---|
| | Export Exposure | Total Exposure | Direct Exposure | Indirect Exposure |
| Gas manufacture, distribution | 0.00 | 0.04 | 0.00 | 0.04 |
| Water supply | 0.00 | 0.59 | 0.00 | 0.59 |
| Construction | 0.00 | 0.05 | 0.00 | 0.05 |
| Wholesale and retail trade | 0.00 | 546.83 | 0.00 | 546.83 |
| Accommodation and Food Service | 0.00 | 0.00 | 0.00 | 0.00 |
| Land pipelines and transport | 0.00 | 15.44 | 0.00 | 15.44 |
| Water transport | 0.00 | 0.39 | 0.00 | 0.39 |
| Air transport | 0.00 | 0.64 | 0.00 | 0.64 |
| Warehousing | 0.00 | 0.00 | 0.00 | 0.00 |
| Information and communication | 0.06 | 25.26 | 12.51 | 12.76 |
| Other Financial Intermediation | 0.00 | 3.46 | 0.00 | 3.46 |
| Insurance | 0.00 | 0.00 | 0.00 | 0.00 |
| Real estate activities | 0.00 | 0.00 | 0.00 | 0.00 |
| Other Business Services | -0.00 | 29.06 | 0.12 | 28.93 |
| Recreation, Other Services | -19.66 | 178.78 | 178.47 | 0.32 |
| Other Services (Government) | 0.00 | 10.34 | 0.00 | 10.34 |
| Education | 0.00 | 0.00 | 0.00 | 0.00 |
| Human health and social work | 0.00 | 0.00 | 0.00 | 0.00 |

continued . . .

**Table C.2**: Summary Statistics - Export Exposure by Province

| | Annual Change Export Exposure (million USD) | | | |
|---|---|---|---|---|
| | Export Exposure | Total Exposure | Direct Exposure | Indirect Exposure |
| An Giang | 500.99 | 89.24 | 49.19 | 31.10 |
| Bac Giang | 405.61 | 55.67 | 37.59 | 13.42 |
| Bac Kan | 337.79 | 30.52 | 16.22 | 11.27 |
| Bac Lieu | 584.02 | 98.62 | 22.75 | 58.19 |
| Bac Ninh | 442.86 | 139.10 | 106.50 | 24.30 |
| Ba Ria - Vung Tau | 377.51 | 85.98 | 50.16 | 28.11 |
| Ben Tre | 437.36 | 72.32 | 39.86 | 23.79 |
| Binh Dinh | 407.73 | 99.50 | 67.57 | 23.60 |
| Binh Duong | 460.68 | 310.43 | 273.29 | 27.52 |
| Binh Phuoc | 464.60 | 101.85 | 67.20 | 25.95 |
| Binh Thuan | 442.99 | 80.47 | 43.35 | 27.99 |
| Can Tho | 417.10 | 80.51 | 45.17 | 25.71 |
| Cao Bang | 323.90 | 18.86 | 7.71 | 8.70 |
| Ca Mau | 629.74 | 110.99 | 24.15 | 68.26 |
| Dak Nong | 357.52 | 26.06 | 13.59 | 9.73 |
| DakLak | 318.88 | 35.54 | 18.67 | 13.05 |
| Da Nang City | 378.28 | 103.32 | 65.53 | 27.94 |
| Dien Bien | 371.92 | 20.92 | 9.84 | 8.66 |
| Dong Nai | 389.74 | 185.41 | 158.48 | 20.42 |
| Dong Thap | 435.84 | 85.31 | 51.65 | 24.13 |
| Gia Lai | 342.27 | 30.51 | 16.43 | 10.80 |

continued . . .

**Table C.2** Summary Statistics - Export Exposure by Industry (Continued)

| | **Annual Change Export Exposure (million USD)** | | | |
|---|---|---|---|---|
| | Export Exposure | Total Exposure | Direct Exposure | Indirect Exposure |
| Ha Giang | 368.58 | 18.39 | 9.91 | 6.79 |
| Hai Duong | 431.11 | 95.74 | 70.50 | 18.25 |
| Hai Phong | 427.47 | 131.39 | 100.84 | 22.97 |
| Hanoi | 354.86 | 90.02 | 59.74 | 23.24 |
| Hau Giang | 471.94 | 65.50 | 40.07 | 19.53 |
| Ha Nam | 503.85 | 111.70 | 82.51 | 21.32 |
| Ha Tinh | 390.94 | 59.86 | 32.64 | 20.42 |
| Ho Chi Minh City | 385.15 | 110.53 | 77.05 | 25.94 |
| Hoa Binh | 346.89 | 28.73 | 15.52 | 9.76 |
| Hung Yen | 450.38 | 84.07 | 58.92 | 18.82 |
| Khanh Hoa | 449.72 | 75.53 | 38.64 | 27.67 |
| Kien Giang | 508.43 | 81.99 | 31.10 | 39.33 |
| Kon Tum | 368.79 | 39.54 | 19.90 | 15.38 |
| Lai Chau | 430.70 | 23.26 | 12.57 | 8.35 |
| Lam Dong | 363.86 | 47.76 | 27.40 | 15.10 |
| Lang Son | 389.87 | 32.58 | 18.15 | 10.60 |
| Lao Cai | 433.41 | 28.21 | 12.54 | 11.74 |
| Long An | 415.50 | 127.11 | 101.93 | 18.95 |
| Nam Dinh | 444.56 | 104.69 | 73.39 | 22.37 |
| Nghe An | 344.61 | 40.90 | 22.76 | 14.10 |
| Ninh Binh | 437.69 | 69.68 | 46.19 | 17.53 |

continued . . .

**Table C.2** Summary Statistics - Export Exposure by Industry (Continued)

| | Annual Change Export Exposure (million USD) | | | |
|---|---|---|---|---|
| | Export Exposure | Total Exposure | Direct Exposure | Indirect Exposure |
| Ninh Thuan | 530.56 | 72.38 | 35.61 | 27.90 |
| Phu Tho | 435.20 | 55.56 | 34.30 | 15.87 |
| Phu Yen | 401.89 | 75.45 | 43.02 | 24.75 |
| Quang Binh | 435.60 | 52.76 | 24.18 | 21.66 |
| Quang Nam | 385.30 | 71.23 | 46.67 | 18.49 |
| Quang Ngai | 383.37 | 53.07 | 28.41 | 19.69 |
| Quang Ninh | 381.45 | 63.06 | 20.97 | 31.31 |
| Quang Tri | 457.58 | 66.60 | 34.64 | 24.22 |
| San La | 375.94 | 20.82 | 9.62 | 8.86 |
| Soc Trang | 503.88 | 72.29 | 30.68 | 32.48 |
| Tay Ninh | 452.32 | 140.53 | 108.46 | 23.71 |
| Thai Binh | 431.36 | 67.48 | 44.45 | 17.25 |
| Thai Nguyen | 380.89 | 48.62 | 27.82 | 16.42 |
| Thanh Hoa | 376.16 | 62.34 | 43.88 | 14.16 |
| Thua Thien Hue | 409.91 | 86.51 | 49.81 | 27.18 |
| Tien Giang | 429.61 | 110.81 | 83.40 | 20.15 |
| Tra Vinh | 440.07 | 103.72 | 71.46 | 23.06 |
| Tuyen Quang | 394.78 | 44.28 | 26.95 | 13.47 |
| Vinh Long | 488.18 | 98.44 | 68.94 | 21.59 |
| Vinh Phuc | 444.16 | 85.49 | 59.36 | 19.33 |
| Yen Bai | 443.67 | 40.89 | 22.68 | 13.71 |

**Table C.3**: Impact of trade exposure on Wages, 2010 - 2019

|  | Change in labor outcomes | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | WAGE | | | INCOME | | | COLLEGE PREMIUM | | | GENDER WAGE GAP | | |
|  | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| TOTAL | 19.86*** | | | 19.93*** | | | -17.90*** | | | -5.79* | | |
| EXPOSURE | (5.29) | | | (5.10) | | | (4.76) | | | (2.37) | | |
| DIRECT | | 32.50** | | | 36.31** | | | -28.01** | | | -10.65* | |
| EXPOSURE | | (11.65) | | | (10.56) | | | (10.21) | | | (5.29) | |
| INDIRECT | | | 31.14** | | | 23.22* | | | -30.87*** | | | -6.55 |
| EXPOSURE | | | (9.32) | | | (10.34) | | | (8.32) | | | (3.61) |
| Observations | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 |
| Adjusted R2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |

*** p<.001, ** p<.05, * p<.01.

Standard errors clustered at Province level.

Total Exposure = Direct Exposure + Indirect Exposure.

Additional controls include Age, Gender, Education level, Urban-Rurual dummy, Economic Sector and Hours of work.

Wage and wage premium measured in US dollars per year, Export Exposure measured in thousand US dollar per worker.

Unemployed, Inactive, Informal and Female Employed measured in percentage point.

**Table C.4**: Impact of trade exposure on Employment, 2010 - 2019

| | Change in labor outcomes | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EMPLOYED | | | INACTIVE | | | INFORMAL | | | FEMALE EMPLOYED | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| TOTAL | 0.20** | | | -0.72*** | | | -0.43** | | | 0.14*** | | |
| EXPOSURE | (0.06) | | | (0.09) | | | (0.16) | | | (0.04) | | |
| DIRECT | | 0.23 | | | -0.91*** | | | -0.04 | | | 0.15* | |
| EXPOSURE | | (0.11) | | | (0.18) | | | (0.22) | | | (0.07) | |
| INDIRECT | | | 0.52*** | | | -1.71*** | | | -2.08*** | | | 0.36*** |
| EXPOSURE | | | (0.10) | | | (0.17) | | | (0.27) | | | (0.06) |
| Observations | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 |
| Adjusted R2 | 0.2 | 0.1 | 0.2 | 0.4 | 0.3 | 0.4 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |

*** p<.001, ** p<.05, * p<.01.

Standard errors clustered at Province level.

Total Exposure = Direct Exposure + Indirect Exposure.

Additional controls include Age, Gender, Education level, Urban-Rurual dummy, Economic Sector and Hours of work.

Wage and wage premium measured in US dollars per year, Export Exposure measured in thousand US dollar per worker.

Unemployed, Inactive, Informal and Female Employed measured in percentage point.

**Table C.5**: Impact of trade exposure on Wages, 2010 - 2019

| | Change in labor outcomes | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WAGE | | | INCOME | | | COLLEGE PREMIUM | | | GENDER WAGE GAP | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| TOTAL EXPOSURE | 26.99*** | | | 25.74*** | | | -24.15*** | | | -8.09** | | |
| | (5.85) | | | (6.65) | | | (5.15) | | | (2.52) | | |
| HANOI x TOTAL | -26.65** | | | -22.91* | | | 22.15* | | | 10.39* | | |
| | (9.81) | | | (10.44) | | | (8.74) | | | (3.99) | | |
| HCM x TOTAL | 5.37 | | | -0.87 | | | -2.99 | | | -4.96 | | |
| | (16.82) | | | (12.19) | | | (15.36) | | | (7.81) | | |
| DIRECT EXPOSURE | | 49.45*** | | | 54.43** | | | -42.22*** | | | -16.78** | |
| | | (13.70) | | | (16.68) | | | (11.47) | | | (6.17) | |
| HANOI x DIRECT | | -43.99* | | | -44.78* | | | 35.86* | | | 18.07* | |
| | | (17.76) | | | (19.61) | | | (15.30) | | | (7.56) | |
| HCM x DIRECT | | 6.85 | | | -10.81 | | | -4.75 | | | -6.92 | |
| | | (27.40) | | | (22.85) | | | (24.59) | | | (11.90) | |
| INDIRECT EXPOSURE | | | 41.26*** | | | 31.42** | | | -39.29*** | | | -10.04* |
| | | | (10.72) | | | (10.97) | | | (9.76) | | | (4.12) |
| HANOI x INDIRECT | | | -73.28* | | | -62.77 | | | 58.12* | | | 27.75** |
| | | | (28.82) | | | (31.69) | | | (24.82) | | | (10.18) |
| HCM x INDIRECT | | | -9.07 | | | -7.23 | | | 11.88 | | | 0.14 |
| | | | (20.15) | | | (17.54) | | | (18.02) | | | (13.42) |
| Observations | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 |
| Adjusted R2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |

*** p<.001, ** p<.05, * p<.01. Standard errors clustered at Province level. Total Exposure = Direct Exposure + Indirect Exposure. Additional controls include Age, Gender, Education level, Urban-Rurual dummy, Economic Sector, Hours of work, Dummies for Hanoi Economic Area and HCMC Economic Area. Wage and wage premium measured in US dollars per year, Export Exposure measured in thousand US dollar per worker. Unemployed, Inactive, Informal and Female Employed measured in percentage point.

**Table C.6**: Impact of trade exposure on Employment, 2010 - 2019

| | Change in labor outcomes | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EMPLOYED | | | INACTIVE | | | INFORMAL | | | FEMALE EMPLOYED | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| TOTAL EXPOSURE | 0.31*** | | | -0.87*** | | | -0.78*** | | | 0.20*** | | |
| | (0.06) | | | (0.08) | | | (0.15) | | | (0.03) | | |
| HANOI x TOTAL | -0.19 | | | 0.29 | | | 0.97*** | | | -0.10 | | |
| | (0.12) | | | (0.18) | | | (0.26) | | | (0.07) | | |
| HCM x TOTAL | -0.44*** | | | 0.47** | | | 0.14 | | | -0.29*** | | |
| | (0.11) | | | (0.15) | | | (0.37) | | | (0.07) | | |
| DIRECT EXPOSURE | | 0.51*** | | | -1.40*** | | | -0.72* | | | 0.32*** | |
| | | (0.11) | | | (0.18) | | | (0.29) | | | (0.07) | |
| HANOI x DIRECT | | -0.41* | | | 0.74** | | | 1.28** | | | -0.23* | |
| | | (0.17) | | | (0.27) | | | (0.41) | | | (0.11) | |
| HCM x DIRECT | | -0.74*** | | | 1.01*** | | | 0.39 | | | -0.48*** | |
| | | (0.17) | | | (0.24) | | | (0.65) | | | (0.10) | |
| INDIRECT EXPOSURE | | | 0.55*** | | | -1.61*** | | | -2.06*** | | | 0.37*** |
| | | | (0.12) | | | (0.19) | | | (0.31) | | | (0.07) |
| HANOI x INDIRECT | | | 0.15 | | | -0.76* | | | 0.57 | | | 0.13 |
| | | | (0.25) | | | (0.38) | | | (0.72) | | | (0.18) |
| HCM x INDIRECT | | | -0.79** | | | 0.14 | | | -1.31 | | | -0.48* |
| | | | (0.27) | | | (0.27) | | | (0.72) | | | (0.22) |
| Observations | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 |
| Adjusted R2 | 0.2 | 0.2 | 0.2 | 0.4 | 0.3 | 0.4 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |

*** p<.001, ** p<.05, * p<.01. Standard errors clustered at Province level. Total Exposure = Direct Exposure + Indirect Exposure. Additional controls include Age, Gender, Education level, Urban-Rurual dummy, Economic Sector, Hours of work, Dummies for Hanoi Economic Area and HCMC Economic Area. Wage and wage premium measured in US dollars per year, Export Exposure measured in thousand US dollar per worker. Unemployed, Inactive, Informal and Female Employed measured in percentage point.

**Table C.7**: Impact of trade exposure on Wages by Education, 2010 - 2019

| | Change in labor outcomes | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NO EDUCATION | | | PRIMARY SCHOOL | | | SECONDARY SCHOOL | | | HIGH SCHOOL | | | COLLEGE | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
| TOTAL | 14.84** | | | 17.00** | | | 19.77** | | | 16.42** | | | 42.38*** | | |
| EXPOSURE | (4.73) | | | (5.70) | | | (6.59) | | | (4.94) | | | (10.37) | | |
| DIRECT | | 22.47* | | | 28.03* | | | 32.42* | | | 31.91** | | | 67.11*** | |
| EXPOSURE | | (8.85) | | | (11.05) | | | (12.43) | | | (9.93) | | | (14.25) | |
| INDIRECT | | | 27.30** | | | 26.38* | | | 31.07* | | | 15.13 | | | 72.13* |
| EXPOSURE | | | (9.76) | | | (10.48) | | | (14.51) | | | (9.98) | | | (27.29) |
| Observations | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 502 | 502 | 502 |
| Adjusted R2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |

*** p<.001, ** p<.05, * p<.01.

Standard errors clustered at Province level.

Total Exposure = Direct Exposure + Indirect Exposure.

Additional controls include Age, Gender, Education level, Urban-Rurual dummy, Economic Sector and Hours of work.

Wage and wage premium measured in US dollars per year, Export Exposure measured in thousand US dollar per worker.

Unemployed, Inactive, Informal and Female Employed measured in percentage point.

**Table C.8**: Impact of trade exposure on Employment by Education, 2010 - 2019

| | Change in labor outcomes | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NO EDUCATION | | | PRIMARY SCHOOL | | | SECONDARY SCHOOL | | | HIGH SCHOOL | | | COLLEGE | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
| TOTAL | 0.15** | | | 0.12* | | | 0.06 | | | 0.03 | | | -0.19*** | | |
| EXPOSURE | (0.05) | | | (0.05) | | | (0.06) | | | (0.05) | | | (0.02) | | |
| DIRECT | | 0.19** | | | 0.16* | | | 0.11 | | | 0.01 | | | -0.29*** | |
| EXPOSURE | | (0.07) | | | (0.08) | | | (0.09) | | | (0.09) | | | (0.04) | |
| INDIRECT | | | 0.37** | | | 0.24* | | | 0.05 | | | 0.12 | | | -0.36*** |
| EXPOSURE | | | (0.12) | | | (0.10) | | | (0.13) | | | (0.08) | | | (0.06) |
| Observations | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 |
| Adjusted R2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.2 |

*** p<.001, ** p<.05, * p<.01.

Standard errors clustered at Province level.

Total Exposure = Direct Exposure + Indirect Exposure.

Additional controls include Age, Gender, Education level, Urban-Rurual dummy, Economic Sector and Hours of work.

Wage and wage premium measured in US dollars per year, Export Exposure measured in thousand US dollar per worker.

Unemployed, Inactive, Informal and Female Employed measured in percentage point.

**Table C.9**: Impact of trade exposure on Wages by Economic Sector, 2010 - 2019

| | Change in labor outcomes | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HH Farm | | | HH Business | | | Private | | | State | | | Foreign | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
| TOTAL | 19.40** | | | 40.19*** | | | 6.75 | | | 19.30 | | | -12.18 | | |
| EXPOSURE | (6.28) | | | (8.10) | | | (5.54) | | | (12.14) | | | (16.13) | | |
| DIRECT | | 27.89* | | | 66.37*** | | | 14.01 | | | 33.49 | | | -1.57 | |
| EXPOSURE | | (11.75) | | | (12.76) | | | (9.10) | | | (21.66) | | | (18.68) | |
| INDIRECT | | | 38.76** | | | 62.26*** | | | 4.09 | | | 26.43 | | | -62.33 |
| EXPOSURE | | | (11.84) | | | (17.85) | | | (13.08) | | | (23.89) | | | (47.36) |
| Observations | 504 | 504 | 504 | 480 | 480 | 480 | 418 | 418 | 418 | 430 | 430 | 430 | 328 | 328 | 328 |
| Adjusted R2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 |

*** p<.001, ** p<.05, * p<.01.

Standard errors clustered at Province level.

Total Exposure = Direct Exposure + Indirect Exposure.

Additional controls include Age, Gender, Education level, Urban-Rurual dummy, Economic Sector and Hours of work.

Wage and wage premium measured in US dollars per year, Export Exposure measured in thousand US dollar per worker.

Unemployed, Inactive, Informal and Female Employed measured in percentage point.

**Table C.10**: Impact of trade exposure on Employment by economic sector, 2010 - 2019

| | Change in labor outcomes | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HH Farm | | | HH Business | | | Private | | | State | | | Foreign | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
| TOTAL | 3.54*** | | | 2.68*** | | | 2.63*** | | | 2.36*** | | | 2.28*** | | |
| EXPOSURE | (0.42) | | | (0.43) | | | (0.45) | | | (0.42) | | | (0.48) | | |
| DIRECT | | 5.83*** | | | 4.54*** | | | 4.52*** | | | 4.15*** | | | 3.95*** | |
| EXPOSURE | | (0.95) | | | (0.97) | | | (1.00) | | | (0.92) | | | (0.99) | |
| INDIRECT | | | 5.48*** | | | 3.88*** | | | 3.65*** | | | 3.07*** | | | 3.15** |
| EXPOSURE | | | (0.85) | | | (0.79) | | | (0.79) | | | (0.80) | | | (0.95) |
| Observations | 504 | 504 | 504 | 504 | 504 | 504 | 498 | 498 | 498 | 504 | 504 | 504 | 357 | 357 | 357 |
| Adjusted R2 | 0.4 | 0.4 | 0.3 | 0.3 | 0.4 | 0.3 | 0.4 | 0.4 | 0.3 | 0.4 | 0.4 | 0.3 | 0.4 | 0.4 | 0.4 |

*** p<.001, ** p<.05, * p<.01.

Standard errors clustered at Province level.

Total Exposure = Direct Exposure + Indirect Exposure.

Additional controls include Age, Gender, Education level, Urban-Rurual dummy, Economic Sector and Hours of work.

Wage and wage premium measured in US dollars per year, Export Exposure measured in thousand US dollar per worker.

Unemployed, Inactive, Informal and Female Employed measured in percentage point.

**Table C.11**: Impact of trade exposure on Wages by Income level, 2010 - 2019

| | Change in labor outcomes | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Income quantile 1 | | | Income quantile 2 | | | Income quantile 3 | | | Income quantile 4 | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| TOTAL | 14.54** | | | -12.00 | | | -4.18 | | | -2.78 | | |
| EXPOSURE | (5.31) | | | (6.82) | | | (3.85) | | | (3.62) | | |
| DIRECT | | 20.40 | | | -12.88 | | | -1.38 | | | 0.61 | |
| EXPOSURE | | (11.09) | | | (7.32) | | | (6.65) | | | (5.54) | |
| INDIRECT | | | 30.12*** | | | -33.73 | | | -18.49* | | | -15.53 |
| EXPOSURE | | | (7.28) | | | (21.41) | | | (8.70) | | | (8.86) |
| Observations | 504 | 504 | 504 | 452 | 452 | 452 | 478 | 478 | 478 | 504 | 504 | 504 |
| Adjusted R2 | 0.3 | 0.3 | 0.3 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 |

*** p<.001, ** p<.05, * p<.01.

Standard errors clustered at Province level.

Total Exposure = Direct Exposure + Indirect Exposure.

Additional controls include Age, Gender, Education level, Urban-Rurual dummy, Economic Sector and Hours of work.

Wage and wage premium measured in US dollars per year, Export Exposure measured in thousand US dollar per worker.

Unemployed, Inactive, Informal and Female Employed measured in percentage point.

**Table C.12**: Impact of trade exposure on Employment by Income level, 2010 - 2019

| | Change in labor outcomes | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Income quantile 1 | | | Income quantile 2 | | | Income quantile 3 | | | Income quantile 4 | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| TOTAL | 1.77*** | | | 0.32*** | | | 0.23*** | | | 0.14** | | |
| EXPOSURE | (0.25) | | | (0.07) | | | (0.05) | | | (0.05) | | |
| DIRECT | | 2.91*** | | | 0.44*** | | | 0.29** | | | 0.15* | |
| EXPOSURE | | (0.58) | | | (0.12) | | | (0.09) | | | (0.07) | |
| INDIRECT | | | 2.73*** | | | 0.69*** | | | 0.55*** | | | 0.39*** |
| EXPOSURE | | | (0.43) | | | (0.16) | | | (0.11) | | | (0.10) |
| Observations | 504 | 504 | 504 | 452 | 452 | 452 | 478 | 478 | 478 | 504 | 504 | 504 |
| Adjusted R2 | 0.3 | 0.3 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 |

*** p<.001, ** p<.05, * p<.01.

Standard errors clustered at Province level.

Total Exposure = Direct Exposure + Indirect Exposure.

Additional controls include Age, Gender, Education level, Urban-Rurual dummy, Economic Sector and Hours of work.

Wage and wage premium measured in US dollars per year, Export Exposure measured in thousand US dollar per worker.

Unemployed, Inactive, Informal and Female Employed measured in percentage point.

**Table C.13**: Impact of trade exposure on Labor market in Nontradable sectors, 2010 - 2019

| | Change in labor outcomes | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WAGE | | | INCOME | | | EMPLOYED | | | INFORMAL | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| TOTAL | -11.30* | | | -6.83 | | | -0.05*** | | | -1.17*** | | |
| EXPOSURE | (4.27) | | | (5.33) | | | (0.01) | | | (0.23) | | |
| DIRECT | | -16.26** | | | -7.58 | | | -0.06** | | | -1.16** | |
| EXPOSURE | | (5.69) | | | (7.66) | | | (0.02) | | | (0.37) | |
| INDIRECT | | | -22.80* | | | -18.61 | | | -0.11*** | | | -3.46*** |
| EXPOSURE | | | (11.33) | | | (13.41) | | | (0.03) | | | (0.41) |
| Observations | 441 | 441 | 441 | 441 | 441 | 441 | 441 | 441 | 441 | 441 | 441 | 441 |
| Adjusted R2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |

*** p<.001, ** p<.05, * p<.01.

Standard errors clustered at Province level.

Total Exposure = Direct Exposure + Indirect Exposure.

Additional controls include Age, Gender, Education level, Urban-Rurual dummy, Economic Sector and Hours of work.

Wage and wage premium measured in US dollars per year, Export Exposure measured in thousand US dollar per worker.

Unemployed, Inactive, Informal and Female Employed measured in percentage point.

**Table C.14**: Impact of trade exposure on Labor market in Tradable sectors, 2010 - 2019

| | Change in labor outcomes | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WAGE | | | INCOME | | | EMPLOYED | | | INFORMAL | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| TOTAL | 11.40** | | | 21.26*** | | | 0.55*** | | | -0.78* | | |
| EXPOSURE | (4.09) | | | (5.11) | | | (0.09) | | | (0.32) | | |
| DIRECT | | 19.00** | | | 37.91*** | | | 0.66*** | | | -0.18 | |
| EXPOSURE | | (7.05) | | | (9.32) | | | (0.16) | | | (0.47) | |
| INDIRECT | | | 17.13 | | | 26.54* | | | 1.37*** | | | -3.61*** |
| EXPOSURE | | | (9.72) | | | (11.65) | | | (0.19) | | | (0.49) |
| Observations | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 | 504 |
| Adjusted R2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 |

*** p<.001, ** p<.05, * p<.01.

Standard errors clustered at Province level.

Total Exposure = Direct Exposure + Indirect Exposure.

Additional controls include Age, Gender, Education level, Urban-Rurual dummy, Economic Sector and Hours of work.

Wage and wage premium measured in US dollars per year, Export Exposure measured in thousand US dollar per worker.

Unemployed, Inactive, Informal and Female Employed measured in percentage point.

# Bibliography

[1] Daron Acemoglu et al. "Import Competition and the Great US Employment Sag of the 2000s". In: *The University of Chicago Press Journal* (2016). URL: `https://www.journals.uchicago.edu/doi/full/10.1086/682384`.

[2] Mostafa Aleseyed, Terance Rephann, and Andrew Isserman. "The local effects of large dam reservoirs: U.S. experience, 1975–1995". In: *Review of urban and regional development studies* (1999).

[3] David H. Autor, David Dorn, and Gordon H. Hanson. "The China Syndrome: Local Labor Market Effects of Import Competition in the United States". In: *American Economic Review* (2013). URL: `https://www.aeaweb.org/articles?id=10.1257/aer.103.6.2121`.

[4] Lehner B and Grill G. In: *Hydrological Processes* (2013). ISSN: 27(15). URL: `https://doi.org/10.1002/hyp.9740`.

[5] M.D. Bejarano et al. "Tradeoff between economic and environmental costs and benefits of hydropower production at run-of-river-diversion schemes under different environmental flows scenarios". In: *Journal of Hydrology* 572 (2019), pp. 790–804. ISSN: 0022-1694. DOI: `https://doi.org/10.1016/j.jhydrol.2019.03.048`. URL: `https://www.sciencedirect.com/science/article/pii/S002216941930229X`.

[6] Gianbattista Bussi et al. "Impact of dams and climate change on suspended sediment flux to the Mekong delta". In: *Science of The Total Environment* 755 (2021), p. 142468. ISSN:

0048-9697. DOI: https://doi.org/10.1016/j.scitotenv.2020.142468. URL: https://www.sciencedirect.com/science/article/pii/S0048969720359970.

[7] Meghan K. Carr et al. "Impacts of Varying Dam Outflow Elevations on Water Temperature, Dissolved Oxygen, and Nutrient Distributions in a Large Prairie Reservoir". In: *Environmental Engineering Science* 37.1 (2020), pp. 78–97. DOI: 10.1089/ees.2019.0146. URL: https://doi.org/10.1089/ees.2019.0146.

[8] Tom Y Chang, Wei Huang, and Yongxiang Wang. "Something in the Air: Pollution and the Demand for Health Insurance". In: *The Review of Economic Studies* 85.3 (Mar. 2018), pp. 1609–1634. ISSN: 0034-6527. DOI: 10.1093/restud/rdy016. eprint: https://academic.oup.com/restud/article-pdf/85/3/1609/25078096/rdy016.pdf. URL: https://doi.org/10.1093/restud/rdy016.

[9] Soo Hong Chew, Wei Huang, and Xun Li. "Does haze cloud decision making? A natural laboratory experiment". In: *Journal of Economic Behavior & Organization* 182 (2021), pp. 132–161. ISSN: 0167-2681. URL: https://www.sciencedirect.com/science/article/pii/S0167268120304662.

[10] Mekong River Commision. *State of the Basin Report 2010. Vientiane, Lao PDR*. 2010. URL: https://www.mrcmekong.org/assets/Publications/basin-reports/MRC-SOB-report-2010full-report.pdf.

[11] Tuyet L. Cosslett and Patrick D. Cosslett. "The Lower Mekong Basin: Rice Production, Climate Change, ENSO, and Mekong Dams". In: *Sustainable Development of Rice and Water Resources in Mainland Southeast Asia and Mekong River Basin*. Springer Singapore, 2018, pp. 85–114. ISBN: 978-981-10-5613-0. URL: https://doi.org/10.1007/978-981-10-5613-0_5.

[12] S.B. Dai, S.L. Yang, and A.M. Cai. "Impacts of dams on the sediment flux of the Pearl River, southern China". In: *CATENA* 76.1 (2008), pp. 36–43. ISSN: 0341-8162. DOI: https:

//doi.org/10.1016/j.catena.2008.08.004. URL: https://www.sciencedirect.com/science/article/pii/S034181620800132X.

[13] Zhijun Dai et al. "Unusual Salinity Conditions in the Yangtze Estuary in 2006: Impacts of an Extreme Drought or of the Three Gorges Dam?" In: *AMBIO* (2011). URL: https://doi.org/10.1007/s13280-011-0148-2.

[14] T.H.T. Dam et al. "The impact of salinity on paddy production and possible varietal portfolio transition: a Vietnamese case study". In: *Paddy Water Environment* (2019). URL: https://doi.org/10.1007/s10333-019-00756-9.

[15] Rafael Dix-Carneiro and Brian K. Kovak. "Trade Liberalization and the Skill Premium: A Local Labor Markets Approach". In: *American Economic Review* (2015). URL: https://www.aeaweb.org/articles?id=10.1257/aer.p20151052.

[16] Rui Dong et al. "Air pollution, affect, and forecasting bias: Evidence from Chinese financial analysts". In: *Journal of Financial Economics* 139.3 (2021), pp. 971–984. ISSN: 0304-405X. DOI: https://doi.org/10.1016/j.jfineco.2019.12.004. URL: https://www.sciencedirect.com/science/article/pii/S0304405X19302910.

[17] Esther Duflo and Rohini Pande. "Dams*". In: *The Quarterly Journal of Economics* 122.2 (May 2007), pp. 601–646. ISSN: 0033-5533. DOI: 10.1162/qjec.122.2.601. eprint: https://academic.oup.com/qje/article-pdf/122/2/601/5470136/122-2-601.pdf. URL: https://doi.org/10.1162/qjec.122.2.601.

[18] Peilei Fan et al. "Recently constructed hydropower dams were associated with reduced economic production, population, and greenness in nearby areas". In: *Proceedings of the National Academy of Sciences* 119.8 (2022), e2108038119. DOI: 10.1073/pnas.2108038119. eprint: https://www.pnas.org/doi/pdf/10.1073/pnas.2108038119. URL: https://www.pnas.org/doi/abs/10.1073/pnas.2108038119.

[19] Thomas W. FitzHugh and Richard M. Vogel. "The impact of dams on flood flows in the United States". In: *River Research and Application* (2011).

[20] B.A. Galipeau, M. Ingman, and B. Tilt. “Dam-Induced Displacement and Agricultural Livelihoods in China’s Mekong Basin”. In: *Human Ecology* (2013). URL: `https://doi.org/10.1007/s10745-013-9575-y`.

[21] Carlos Góes, Gladys Lopez-Acevedo, and Raymond Robertson. “Gender-Segmented Labor Markets and Trade Shocks”. In: *IZA Discussion Papers 15892, Institute of Labor Economics (IZA)* (2023). URL: `https://ideas.repec.org/p/iza/izadps/dp15892.html`.

[22] Prodyumna Goutam et al. “Does Informal Employment Respond to Growth Opportunities? Trade-Based Evidence from Bangladesh”. In: *RAND Corporation*. Working Paper (2017). URL: `https://www.rand.org/content/dam/rand/pubs/working_papers/WR1100/WR1198/RAND_WR1198.pdf`.

[23] Anthony Heyes, Matthew Neidell, and Soodeh Saberian. “he Effect of Air Pollution on Investor Behavior: Evidence from the S&P 500””. In: *National Bureau of Economic Research* 22753 (Oct. 2016). DOI: `10.3386/w22753`. URL: `http://www.nber.org/papers/w22753`.

[24] Marc Jeuland. “The economics of dams”. In: *Oxford Review of Economic Policy* 36.1 (Jan. 2020), pp. 45–68. ISSN: 0266-903X. DOI: `10.1093/oxrep/grz028`. eprint: `https://academic.oup.com/oxrep/article-pdf/36/1/45/31709532/grz028.pdf`. URL: `https://doi.org/10.1093/oxrep/grz028`.

[25] Brooke Kaveney et al. “Inland dry season saline intrusion in the Vietnamese Mekong River Delta is driving the identification and implementation of alternative crops to rice”. In: *Agricultural Systems* 207 (2023), p. 103632. ISSN: 0308-521X. DOI: `https://doi.org/10.1016/j.agsy.2023.103632`. URL: `https://www.sciencedirect.com/science/article/pii/S0308521X23000379`.

[26] Mariola Kedra and Łukasz Wiejaczka. “Climatic and dam-induced impacts on river water temperature: Assessment and management implications”. In: *Science of The Total Environment* 626 (2018), pp. 1474–1483. ISSN: 0048-9697. DOI: `https://doi.org/10.1016/`

j.scitotenv.2017.10.044. URL: `https://www.sciencedirect.com/science/article/pii/S004896971732747X`.

[27] Tien Dung Khong et al. “Mekong River Delta farm-household willingness to pay for salinity intrusion risk reduction”. In: *Agricultural Water Management* 200 (2018), pp. 80–89. ISSN: 0378-3774. DOI: `https://doi.org/10.1016/j.agwat.2017.12.010`. URL: `https://www.sciencedirect.com/science/article/pii/S0378377417304018`.

[28] Yang S. L. et al. “Impact of dams on Yangtze River sediment supply to the sea and delta intertidal wetland response”. In: *Journal of Geophysical Research: Earth Surface* 110.F3 (2005). DOI: `https://doi.org/10.1029/2004JF000271`. URL: `https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2004JF000271`.

[29] Francis Lajoie et al. “Impacts of dams on monthly flow characteristics. The influence of watershed size and seasons”. In: *Journal of Hydrology* 334.3 (2007), pp. 423–439. ISSN: 0022-1694. DOI: `https://doi.org/10.1016/j.jhydrol.2006.10.019`. URL: `https://www.sciencedirect.com/science/article/pii/S0022169406005555`.

[30] Gabriel Lee. “Overview: The Big Dam Era”. In: *Energy History Online. Yale University* (2023). URL: `https://energyhistory.yale.edu/the-big-dam-era/`.

[31] Coleman M. and Huh O. K. *Major Deltas of the World: A Perspective from Space*. URL: `https://cires1.colorado.edu/science/groups/wessman/projects/wdn/papers/colemanManuscript.pdf` (visited on 10/04/2023).

[32] Audrey Maheu et al. “A regional analysis of the impact of dams on water temperature in medium-size rivers in eastern Canada”. In: *Canadian Journal of Fisheries and Aquatic Sciences* (2016).

[33] Brian McCaig and Nina Pavcnik. “Export Markets and Labor Allocation in a LowIncome Country”. In: *American Economic Reviewn.* 108 (7): 1899–941 (2018). URL: `https://www.aeaweb.org/articles?id=10.1257/aer.20141096`.

[34] Hung T. Nguyen and Mia Hang Pham. "Air pollution and behavioral biases: Evidence from stock market anomalies". In: *Journal of Behavioral and Experimental Finance* 29 (2021), p. 100441. ISSN: 2214-6350. DOI: `https://doi.org/10.1016/j.jbef.2020.100441`. URL: `https://www.sciencedirect.com/science/article/pii/S2214635020303701`.

[35] Kim-Anh Nguyen et al. "Soil salinity assessment by using near-infrared channel and Vegetation Soil Salinity Index derived from Landsat 8 OLI data: a case study in the Tra Vinh Province, Mekong Delta, Vietnam". In: *Prog Earth Planet Science* (2020). URL: `https://doi.org/10.1186/s40645-019-0311-0`.

[36] Nguyen Huu Nhan and Nguyen Ba Cao. "Chapter 19 - Damming the Mekong: Impacts in Vietnam and Solutions". In: *Coasts and Estuaries*. Elsevier, 2019. DOI: `https://doi.org/10.1016/B978-0-12-814003-1.00019-8`.

[37] Vietnamese General Statistics Office. *Poplation and Houses Census*. 2019. URL: `https://www.gso.gov.vn/en/population-and-houses-census/`.

[38] Vietnamese General Statistics Office. *Rural, agricultural and fishery census*. 2011. URL: `https://www.gso.gov.vn/en/rural-agricultural-and-fishery-census/`.

[39] Sheila M. Olmstead and Hilary Sigman. "Damming the Commons: An Empirical Analysis of International Cooperation and Conflict in Dam Location". In: *Journal of the Association of Environmental and Resource Economists* (2015). URL: `https://energyhistory.yale.edu/the-big-dam-era/`.

[40] Kwadwo Owusu, Peter Bilson Obour, and Maame Asiwah Nkansah. "Downstream effects of dams on livelihoods of river-dependent communities: the case of Ghana's Kpong Dam". In: *Geografisk Tidsskrift-Danish Journal of Geography* 117.1 (2017), pp. 1–10. DOI: `10.1080/00167223.2016.1258318`. URL: `https://doi.org/10.1080/00167223.2016.1258318`.

[41] Justin R. Pierce and Peter K. Schott. “The Surprisingly Swift Decline of US Manufacturing Employment”. In: *American Economic Review* (2016). URL: `https://www.aeaweb.org/articles?id=10.1257/aer.20131578`.

[42] N. LeRoy Poff et al. “Homogenization of regional river dynamics by dams and global biodiversity implications”. In: *Proceedings of the National Academy of Sciences* 104.14 (2007), pp. 5732–5737. DOI: `10.1073/pnas.0609812104`. URL: `https://www.pnas.org/doi/abs/10.1073/pnas.0609812104`.

[43] Mary E. Power, William E. Dietrich, and Jacques C. Finlay. “Dams and downstream aquatic biodiversity: Potential food web consequences of hydrologic and geomorphic change”. In: *Environmental Management* (1996).

[44] Raymond Robertson et al. “International Trade and Labor Markets: Evidence from the Arab Republic of Egypt”. In: *IZA Discussion Paper No. 14413, Institute of Labor Economics (IZA)* (2021). URL: `https://ssrn.com/abstract=3860594`.

[45] Haiyun Shi et al. “The Role of Large Dams in Promoting Economic Development under the Pressure of Population Growth”. In: *Sustainability* 11.10 (2019). ISSN: 2071-1050. DOI: `10.3390/su11102965`. URL: `https://www.mdpi.com/2071-1050/11/10/2965`.

[46] Cheryl Tay et al. “Sea-level rise from land subsidence in major coastal cities”. In: *Nature Sustainability* (2022). URL: `https://doi.org/10.1038/s41893-022-00947-z`.

[47] Petia Topalova. “Factor Immobility and Regional Impacts of Trade Liberalization: Evidence on Poverty from India”. In: *American Economic Journal: Applied Economics 2* (2010). URL: `https://www.aeaweb.org/articles?id=10.1257/app.2.4.1`.

[48] Jida Wang et al. “GeoDAR: Georeferenced Global Dams and Reservoirs Dataset for bridging attributes and geolocations”. In: *Earth System Science Data* (2022). URL: `10.5194/essd-14-1869-2022.`.

[49] Zhi Wang et al. "Reexamining the Effects of Trading with China on Local Labor Markets: A Supply Chain Perspective." In: *National Bureau of Economic Research*. Working Paper 24886 (2018). URL: `https://www.nber.org/papers/w24886`.

[50] K. O. Winemiller et al. "Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong". In: *Science* 351.6269 (2016), pp. 128–129. DOI: `10.1126/science.aac7082`. URL: `https://www.science.org/doi/abs/10.1126/science.aac7082`.

[51] Haipeng Wu et al. "Effects of dam construction on biodiversity: A review". In: *Journal of Cleaner Production* 221 (2019), pp. 480–489. ISSN: 0959-6526. DOI: `https://doi.org/10.1016/j.jclepro.2019.03.001`. URL: `https://www.sciencedirect.com/science/article/pii/S0959652619306845`.

[52] W. P. Xie et al. "Impact Study of Impoundment of the Three Gorges Reservoir on Salt-Water Dynamics and Soil Salinity in the Yangtze River Estuary". In: *Journal of Environmental Informatics* (2020). ISSN: 1726-2135. URL: `10.3808/jei.202000432`.

[53] Yongyong Zhang et al. "Impact of Water Projects on River Flow Regimes and Water Quality in Huai River Basin". In: *Water Resources Management* (2009).