Burning Fields, Shifting Roles: Forest Fire Exposure and Gendered Labor Supply in Indonesia

Extended Abstract

Indonesia is a major global hotspot for forest fire and land fires, shows the high tension between high economic growth and at the same time protecting of one of the world's largest tropical forest areas (Global Forest Watch, 2025). The intended forest fire has been done traditionally by crude palm oil farmer to open the farm and increase their technical efficiency. Even after the forest moratorium policy has been published in 2014, the deforestation rate and forest fire remains high (Chen et al., 2019). In addition to intentional burning, unplanned fires are exacerbated by low rainfall and dry monsoon conditions, which are becoming more frequent and intense with climate change.

Recent work has begun to document the labor market consequences of fire and related environmental shocks, including gender-differentiated effects. Garg et al. (2021, 2024) show that the incidence of crop fires can make structural changes that draw labor out of agriculture can substantially increase, highlighting a feedback loop between labor markets and fire risk in rural economies. Hickson & Marshan (2022) find that bushfires in Australia reduce women's employment probabilities by about 1.6 percentage points and shift labor away from more female-intensive industries, underscoring women's greater vulnerability to disaster-related shocks in regional labor markets. However, this literature typically measures exposure using spatially and temporally aggregated indices of fire or haze, which may obscure short-run dynamics in labor supply and time use at the individual level. The present study contributes to this literature by constructing high-frequency, respondent-specific measures of fire exposure using the interview date. For each individual, the analysis defines cumulative forest fire exposure over multiple windows, one and two weeks, one month, and one year, preceding the survey interview. This design allows the estimation of gender-specific labor responses at different time horizons, capturing both immediate disruptions and short-run recovery dynamics in employment, hours worked, and unpaid domestic care.

This study investigates the causal impact of forest fires on gender-differentiated labor market outcomes in Indonesia by combining longitudinal survey data from IFLS (Indonesia Family Live Survey) with high-resolution satellite information. We conducted two stage analysis to answer the research questions. First, we utilized Instrumental Variables with high dimensional fixed effect approach to examine the impact of forest fire on gender-differentiated labor market outcomes. The second stage utilized the Mediation Analysis for Causal Inference to understand the mechanism of how that can be happened by using sickness day and chronic air pollution related diseases as mediation variables following Chetty & Imai (2025). The analysis uses individual-level data from waves 4 and 5 of the Indonesian Family Life Survey (IFLS), linked to remotely sensed fire and meteorological variables derived from NASA and aggregated at the sub-district level.

The longitudinal dataset consists of 8,649 men and 11,525 women aged 17–65 who are actively participating in the labor market and reside in 34 provinces. Labor outcomes include weekly hours worked, monthly labor income, transitions into unpaid domestic work, and a measure of labor productivity. Last week working hours are based on self-reported hours worked in the week prior to the interview date, while income is also self-reported by each individual in monthly basis. We measured the transitions into unpaid domestic work using dummy if individual participated doing unpaid domestic work such as taking care of children and elderly, helping children studying, cooking, cleaning, and other domestic related work. Furthermore, we measured the simple labor productivity by doing ratio between monthly income by the monthly working

hours for each individual, assuming that all individual has the same working hours every week and full-time job. Outliers in all key variables are removed to limit the influence of extreme observations and measurement error.

Forest fire exposure is measured using fire radiative energy (FRE), a satellite-based indicator of the time-integrated fire radiative power that captures both the intensity of flaming combustion and the duration of burning over a day or season. For each individual, exposure is defined as the average FRE in the person's sub-district over the one week, two week, one months and 1-year windows before the interview date. Because fire incidence is likely endogenous to local economic conditions and human activity, the analysis adopts an instrumental-variables strategy. The endogenous FRE measures are instrumented using sub-district-level averages of four meteorological variables namely rainfall, wind speed, wet wind, and dry wind. These instruments are motivated by the physical link between weather conditions and fire risk, while plausibly affecting labor outcomes only via their impact on fire activity.

The current study used several controls for household and individual characteristics, including the number of children, marital status, indicators of household assets and infrastructure (cooking fuel, access to television, sanitation, clean water, livestock ownership, and electricity), the number of working members in the household, years of education, household size, household assistance, and an urban–rural indicator. Province and survey-wave fixed effects are included to absorb time-invariant regional heterogeneity and common macroeconomic shocks, and standard errors are clustered at the individual level. Instrumental Variables with High-dimensional fixed-effects techniques are employed to ensure robust inference in the presence of multiple layers of unobserved heterogeneity. The econometric framework consists of a first-stage equation relating FRE to the weather instruments and controls, and a second-stage equation relating each labor outcome to the predicted FRE measure, conditional on the same set of controls and fixed effects.

The first research questions are following this econometric modelling:

First Stage

$$Fre_ratio_{it-1week} = \beta_0 + \beta_1 rainfall_{i\,t} + \beta_x X_{it} + \gamma_i + \delta_i + \varepsilon_{it} \quad (1)$$

Where fre_ratio is forest fire exposure for each individual depends on the interview data measured by Megajoules at sub-district level. $rainfall$ are the instrumental variables to solve the endogeneity problems. This research has three types of instrumental variables namely rainfall (mm/sub-district), wind speed (m/s), wet wind(m/s), and dry wind(m/s). The X_{it} represent the control variables for the current research.

Second Stage

$$working_hours_{it} = \beta_0 + \beta_1 fre_ratio_{\,it-1\,week} + \beta_x X_{it} + \gamma_i + \delta_i + \varepsilon_{it} \quad (2)$$

Where the $working_hours_{it}$ is the number of last week's working hour reported subjectively by each individual before the interviewed date. Except previous working hour, we also conducted the other labor outcomes such as weekly hours worked, monthly labor income, transitions into unpaid domestic work, and a measure of labor productivity. While the fre_ratio is the forest fire exposure.

Next, we conducted the mechanism analysis to explain the linkage between forest fire exposure to the gender-differentiated labor outcomes, by using the sickness day and the number of chronic diseases related to the air pollution for each individual.

The result can be explained in three main results. The first main result will explain in short term (one and two weeks after the interviewed date), the second result will focus on the long term (one month and one year after the interviewed date) and the last is about mechanism analysis by using health related issues for each individual. The short-term result shows very interesting

findings, one week after a forest fire, average weekly working hours decline by 3.4 hours for women and 3.3 hours for men. The one-week short-term effect indicates a temporary shock in labor activity, which might be because of health risk, mobility constraints, or workplace disruptions after the exposure. There is no significant impact that women shift into unpaid domestic care, while for men shows a 24.4 percent of higher probability of engaging in unpaid domestic care. This shows that there is temporarily reallocate time toward household responsibilities when formal employment constrained for men. Among agriculture workers, Women shows the decrease of last week working hours approximately 3.7 hours with no change observed for men. There is disproportionate impact in agriculture women shows the limited access to adaptive coping mechanism in the rural labor market.

The result shows reverse impact after two-week forest fire. Women working hours increased by 1.6 hours and men by 2.1 hours. This rebound effect shows a short-lived recovery phases, as individual resume their activities or fire-related cleanup activity after the exposure. The tendency for women to remain unaffected in unpaid domestic care persists, while man probability of providing support on this unpaid work only increases 10 percent, which are lower compared to the first week after the exposure. This lower probability of engage in the unpaid domestic work for men, might be because man is putting more time and effort in their main job. For agricultural women, weekly working hours rise by 1.3 hours after two weeks of fire exposure, whereas male agricultural workers remain unaffected. This pattern implies that women's agricultural engagement intensifies once immediate disruptions pass, possibly as part of compensatory labor efforts to offset initial productivity losses.

Second, after one month of exposure, the result is almost similar with two-week short-term result. The result reported to have the increase of forest fire exposure can statistically increase last week working hours by about 2.1 hours for women and men's by about 3.1 hours, indicating a clear intensive-margin labor supply response to fire shocks in both groups. Within agriculture sector, however, only women adjust their hours in response to fires. Women employed in agriculture increase farm work by roughly 2.1 hours per week, while men in agriculture show no statistically detectable change, suggesting that adjustment to agricultural income losses is borne disproportionately by female labor. In contrast, monthly labor income declines significantly for both genders following higher fire exposure. This pattern is consistent with fires reducing effective wages or pushing workers into lower-productivity or lower-quality jobs, so that households cope partly by supplying more hours at worse pay. The analysis detects no significant change in women's probability of shifting into unpaid domestic work, whereas men experience a statistically significant decline in unpaid domestic work. This implies a gendered reallocation of time: men substitute out of unpaid tasks into market work after fires, while women maintain their unpaid workload and absorb adjustment mainly by expanding total hours. Effects on labor productivity are larger in magnitude for men than for women. This may reflect a sharper deterioration in male productivity, through health, task reallocation, or job downgrading or a stronger selection of men into low-productivity employment after forest fire exposure. Respondent who are interviewed during the wet season have increasing the last week working hours approximately by 1.2 hours, while no effect found on respondent for the dry season. Comparing one-week until one-year exposure windows shows that short-run fire shocks have stronger effects on labor outcomes than longer-run average exposure. The results therefore highlight that acute fire episodes, rather than persistent background risk, drive the main adjustments in hours, income, and productivity.

Finally, sickness days and chronic diseases associated with forest fire have negative and statistically significant total, direct, and indirect effects on women's working hours, while we

found no effect on men. This suggests that health-mediated channels of fire exposure disproportionately depress female labor supply, compounding the unequal adjustment burden documented above.

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