Brighten life after sunset: the improvement on mental health from nighttime economy

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Abstract

Mental health problems impose substantial social and economic burdens worldwide and call for innovative public strategies beyond conventional individual medical interventions. The nighttime economy in China has developed over the ages into a multifaceted paradigm that systematically combines outdoor social entertainment and small family businesses, a phenomenon rare in the West. This paper aims to explore the relationship between the development of the nighttime economy and mental health. With a dataset from the China Family Panel Survey (CFPS), we find that the development of the nighttime economy significantly improves residents' mental health. This positive effect exhibits a distinct social-equality orientation: it effectively benefits both low- and high-income groups but through heterogeneous channels that align with their respective needs. Specifically, the nighttime economy enhances low-income residents' mental health via the income channel, while improving high-income residents' mental health via the consumption channel. Geographical patterns further show that the gains are concentrated where baseline amenities are relatively scarce. In northern provinces, where the nighttime economy lags behind that of southern counterparts, favorable summer temperatures expand opportunities for evening outdoor activities, so increases in nighttime economic activity translate into larger improvements

*Corresponding author: Hu (chun-chieh.hu@ucdenver.edu). The authors want to thank Daniela Iorio and Raul Santauaellia-Llopis at the 2026 Asia Meeting of Econometric Society - CSW at New York University Abu Dhabi for constructive comments and suggestions.

in mental health. Within provinces, the effects are stronger in rural than in urban areas, consistent with the idea that limited recreational alternatives leave greater scope for the nighttime economy to enhance well-being. These findings highlight the nighttime economy as an innovative socio-economic lever to promote population mental health, offering a complementary pathway to relieve healthcare burdens and foster inclusive growth.

Keywords:
Nighttime Economy, Nighttime Light, Mental Health, Mediation Analysis

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1. Introduction

Mental problems currently constitute a major global health challenge, accounting for roughly one-third of all years lived with disability and about 10 percents of total DALYs (Vigo et al., 2016). Depression alone affects an estimated 350 million people worldwide and is associated with elevated suicide risk (Guze and Robins, 1970). Additionally, existing literature has documented that the impact of mental health problems lies not only on public health, but also on economic development (Greenberg et al., 2015; Angelucci and Bennett, 2024). Global costs of mental health problems are projected to reach about $6 trillion by 2030 (Marquez and Saxena, 2016), of which a substantial share is attributable to productivity and income losses (Layard, 2017) rather than direct medical spending. These figures indicate that mental health issues are not only an urgent topic in medical care but also a severe challenge in social and economic development. Consequently, a growing body of scholars has sought to examine effective approaches to mitigate this burden (Bauer et al., 2016; Banerjee et al., 2011; Knapp and Wong, 2020). However, as can be seen from Knapp and Wong (2020)'s review, the existing literature has predominantly emphasized medical interventions, while comparatively little attention has been paid to the non-medical, socio-economic pathways that might alleviate psychological distress. Section text.

China provides a particularly salient context for exploring such alternative pathways. After decades of fast growth, the country now faces rising psychological distress and sizable economic costs (Xu et al., 2016; Wang and Granados, 2019). At the same time, China's collectivist social life has generated a distinct "nighttime economy" that is not confined to bars and clubs common in Western countries (Roberts, 2006), and people can get mental health benefits from it. It unfolds in open public spaces, such as night markets, street

performances, square dancing, riverside stalls etc., where commerce, urban culture, and everyday leisure blend (Lin et al., 2022). These venues draw diverse residents outdoors, lower the cost of casual contact, and create frequent, low-stakes opportunities to interact, join activities, and feel part of a community, which has the potential to alleviate people's mental health problems. Prior work shows that collective, place-based activities can lift mental health by strengthening social ties and shared experiences. For example, mega-events such as Olympic events raise life satisfaction and civic engagement (Dolan et al., 2019), while everyday neighborhood routines in China can deepen residents' sense of belonging within a collectivist social environment (Li et al., 2025; Yousuf et al., 2019). Building on this insight, the Chinese nighttime economy may operate as an underused socio-economic pathway to better mental health by nudging people outside, multiplying face-to-face encounters, and providing communal settings that help relieve stress. Hence, this paper investigates that pathway and evaluates whether, and through which mechanisms, China's outdoor-oriented nighttime economy improves mental well-being.

The unique characteristics of China's nighttime economy provide feasibility for exploring its impact on mental health. Measuring the activity level of the nighttime economy is particularly challenging in Western countries, where indoor activities predominate and are largely invisible to satellite-based measures. This lack of suitable data has limited large-scale empirical research on its mental health effects. In contrast, China's nighttime economy is strongly outdoor-oriented. The collectivist nature of Chinese social life encourages people to use public spaces at night for health, relaxation, and socializing (Cao and Kang, 2019), and much of the nighttime economy consists of lighting-dependent outdoor activities such as night markets, tourism, and cultural events (Lin et al., 2022). This makes satellite-detected nighttime light intensity a plausible proxy for the scale of nighttime economic activity. In addition, open-access data from the Defense Meteorological Satellite Program's Operational Linescan System (DMSP-OLS) and the Suomi National Polar-orbiting Partnership's Visible Infrared Imaging Radiometer Suite (SNPP-VIIRS) provide consistent annual measures of nighttime light across Chinese cities. Taken together, the population's preference for outdoor night activities and the availability of reliable nighttime light data substantially enhance the feasibility of this study and strengthen the accuracy and credibility of identifying the causal relationship between the nighttime economy and individuals' mental health.

Beyond documenting the structure of China's nighttime economy itself, examining its impact on mental health has substantial substantive and policy value. In many developing countries, clinical treatment for mental disorders remains costly and constrained by limited resources (Knapp and Wong, 2020), making it difficult to rely on medical interventions alone. China's nighttime economy offers a promising complementary avenue. The nighttime economy does not treat mental illness directly, but it can improve mental well-being indirectly by enriching daily experiences and expanding opportunities for leisure and social interaction. From a development perspective, this study allows us to ask whether a particular pattern of economic expansion generates positive externalities for population mental health, rather than merely trading off growth against well-being. This dual role of contributing to economic activity while potentially producing beneficial mental-health spillovers gives the nighttime economy distinctive policy relevance. It points to a feasible strategy for advancing mental health through broader social and economic development, reducing exclusive reliance on expensive medical inputs and leveraging routine economic activity to create positive mental-health externalities.

In our study, we use the China Family Panel Studies (CFPS) panel dataset, in which the unit of analysis is the individual. We utilize data from 2012, 2016, 2018, 2020, and 2022 waves, including CESD-8 used to measure respondents' mental health status, along with some demographic variables. This nearly decade-long longitudinal span not only allows us to capture the long-term dynamics of the relationship between the nighttime economy and mental health, but also ensures that our findings remain relevant and timely. To accurately measure nighttime economic activity, rather than using data from DMSP-OLS and VIIRS satellites, we use satellite-based nighttime light (NTL) data developed by Wu et al. (2021), which produces a continuous, consistent NTL series covering our study period. What distinguishes this approach from the original data is that it allows for more accurate and stable estimation of the nighttime economy. Moreover, to address potential endogeneity arising from the nighttime economy, we further apply an instrumental variable (IV) in the Two-Stage Least Squares (2SLS) model. As for mechanisms, we use mediation-effect models to examine the channels through which family income and consumption expenditures are related.

Based on our findings, a ten-percentage point increase in the intensity of nighttime economic development is associated with a 0.031 decrease in CESD-8 scores, indicating better mental health. This positive effect operates

through family income and consumption channels, especially for low-income people who tend to participate more in the nighttime economy for additional income, with a mediation effect accounting for 11.69%, while individuals with higher income mainly engage in consumption activities. Our results also reveal heterogeneity in the nighttime economy. In northern provinces, where nighttime activities are comparatively less developed, developing the nighttime economy could yield more pronounced mental health improvements during the summer season, which might be attributed to higher marginal benefits and favorable summer temperatures that create greater opportunities for residents to engage in evening life. In addition, due to the scarcity of recreational opportunities, rural areas leave ample space for the nighttime economy to foster meaningful enhancement in mental well-being, whereas the effect in urban settings is relatively modest. These findings highlight the nighttime economy as an innovative socio-economic lever to promote population mental health, offering a complementary pathway to relieve healthcare burdens and foster inclusive growth.

This paper contributes to mental health and development literature in two ways. First, our study fills a clear gap by expanding attention from medical-based interventions to socio-economic pathways, like China's nighttime economy. This study conceptualizes the nighttime economy as non-institutional leisure embedded in market activity that expands outdoor interaction (Farrer, 2018), which is an exposure channel underexplored in prior work. Second, we frame and examine the nighttime economy as a positive externality of economic development. This kind of development can unintentionally generate social environments that relieve stress and support mental health. By exploring this externality and its mechanism, our study emphasizes economic growth not merely as an end in itself, but also as a platform for improving population mental health, thereby complementing medical approaches with a more development-oriented approach.

We will discuss more related literature studying mental health and the nighttime economy in the next section. And in section 3, we will introduce our theoretical model and empirical design. After that, we present details about how we collect and process NTL data as well as the processing of the CFPS database. Section 4 contains our main regression results across different specifications, including an analysis of mechanisms. Section 5 discusses the heterogeneity of the impact of the nighttime economy within different groups, while the robust check will be presented in section 6. And lastly, in section 7, we will summarize and discuss our findings, providing relevant

insights into policy recommendations.

2. Literature Review

Globally, mental health issues have gradually evolved into a central concern that threatens public health and social development, thereby attracting extensive attention from interdisciplinary research. Within the field of economics, existing literature generally suggests a relatively robust positive association between economic development and mental health. A growing body of research highlights that economic recession affects people's mental health by leading to poverty, increased unemployment, decreased income, wealth inequality, and other factors (Occhipinti et al., 2024; Frasquilho et al., 2015; Burns, 2015). This impact is typically manifested by an increase in the frequency of mental illness and suicide rates, as well as an increase in the demand for mental disorder treatment. The majority of studies still primarily adopt pathological and medical perspectives. Arias et al. (2022) estimated that between 2010 and 2019, the economic loss caused by mental disorders increased from approximately $1.3 trillion to $1.6 trillion. The burden of mental illness is likely to generate substantial economic consequences, which in turn further undermine mental health, thereby creating a vicious cycle. Knapp and Wong (2020) highlighted the bidirectional and complex relationship between the economy and mental health: the economic costs of mental disorders directly constrain economic development, while economic disadvantage is also likely to induce mental illness. While previous literature has greatly clarified the burden and macroeconomic costs of mental disorders, systematic examinations of mental health from a broader socio-economic standpoint, focusing on social economic environments and non-medical channels, remain relatively scarce. This gap is particularly salient against the backdrop of the rapid expansion of nighttime economic activity in many countries.

Although the nighttime economy is an important issue in urban development, it has only recently garnered substantial scholarly attention. One of the main reasons behind this is the limitations in data collection. The concept of nighttime economy is initially famous in Western areas. In Western societies, the nighttime economy has focused on indoor areas such as bars, nightclubs, dance halls, etc. (Chew, 2009). A crucial characteristic of this model is the close association with alcohol consumption, making nightlife environments largely alcohol-oriented (Roberts, 2006). Roberts also emphasized that the primary driving force behind the expansion of the nighttime economy in the

UK comes from venues such as bars and nightclubs, which may bring potential safety risks to residents. In Japan, nighttime activities have traditionally focused on bars that also serve food, and it wasn't until 2016 that a law was passed allowing dance clubs and entertainment venues to operate beyond midnight (Santiago-Iglesias et al., 2024). The nighttime consumption data in Madrid, Spain shows that as the nighttime progresses, nighttime consumption gradually shifts from a diversified structure to a structure dominated by bars and restaurants. Through the analysis of the proportion of nighttime consumption categories such as bars and restaurants, fashion, food, etc., the number of bars and restaurants, as the core factor of research, is far ahead of other categories in terms of the proportion of nighttime consumption. This also demonstrates the local alcohol-oriented nighttime economy model (Sampériz et al., 2025).

In contrast to this predominantly alcohol-oriented and indoor pattern, China's nighttime economy has increasingly moved outdoors, opening up public space for work, consumption, and social interaction. Influenced by Chinese collectivism culture, people can often release pressure from social activities and gain happiness. In people's daily activities, neighborhood communication and family collective get along can improve people's sense of belonging, implying a positive impact on mental health (Li et al., 2025). The development of the nighttime economy in China has a relatively broader scope, covering more outdoor areas, which provides people with more opportunities for outdoor group activities and social space, such as night markets, beer plazas, square dancing and so on. As shown by Lin et al. (2022), who constructed a Nighttime Economy Vitality Index, in addition to growth in catering, shopping, recreation, and accommodation industries, outdoor activities such as fitness have also increased substantially. This demonstrates that the nighttime economy prolongs the duration of these activities, gives people more opportunities to socialize and spend money outdoors, and at the same time provides more employment opportunities, thus enhancing the happiness of life and improving the level of mental health. Chew (2009) also emphasized the remarkable social, economic, and political significance in his article.

Existing literature demonstrates that participation in outdoor social and recreational activities can improve mental health. According to Brajša-Žganec et al. (2011), participating in various kinds of social activities can significantly increase citizens' subjective well-being by providing them with more chances to establish social relationships, grasp more skills as well as

improve the quality of life. George K and Fonceca (2024) revealed in their study that the level of participation in nighttime activities is directly proportional to the mental health status, especially in women and the elderly. Study of Jiang et al. (2025) focused on that college students engaging in sports activities in a green environment at night can effectively reduce anxiety levels and improve well-being. Moreover, especially for the unemployed, people's mental health can be improved due to the effective use of leisure time (Goodman et al., 2016). Similarly, in the context of COVID-19, Bone et al. (2023) suggested that engaging in creative leisure activities such as handicrafts and gardening during closed periods can reduce symptoms of depression and anxiety. Such studies have confirmed that people improve their well-being and mental health by engaging in social activities such as exercise and entertainment during their free time, while the nighttime economy has created many more opportunities and provided broader venues for such leisure and entertainment activities. Given the unique model of the nighttime economy in China, examining its impact on mental health within the Chinese context appears particularly justified.

As for Nighttime Light (NTL), a novel and effective indicator in the field of economics, it has been increasingly used in the field of economics in recent years to analyze issues related to economic and social development. Several scholars have proven that NTL has been widely used in urban application areas such as urbanization, urban development, expansion, and land identification (Zheng et al., 2023; Sono et al., 2022; Tong et al., 2018). Talebian and Riza (2020) elaborated in detail in their research on how to use urban nighttime lights to analyze the utilization of urban public spaces. Meanwhile, NTL is often used in research to measure or assist in measuring the level of economic development. When Michalopoulos and Papaioannou (2013) tried to analyze the impact of pre-colonial ethnic institutions in African countries, they used satellite images of light density at night to measure the local economic performance. Mamo et al. (2019) also used NTL as the major measure of development in studying the economic effects of mining in Sub-Saharan Africa, as they could use NTL to estimate the possible improvements in local GDP brought by mining. NTL could also be used as a proxy variable for the measurement of the nighttime economy (Yan et al., 2024; Liu et al., 2020), especially in contexts where direct measures are unavailable or limited. It's meaningful to use NTL to monitor and evaluate the nighttime economy. Because these artificial lights, captured by satellite sensors, are closely related to human activities, which are great indicators for promoting consumption,

economic growth and even industrial structure. Henderson et al. (2012), similarly, put forward that using satellite data of NTL to assist in predicting economic indicators. However, most existing studies still use NTL primarily to proxy aggregate economic development or urban growth, rather than to capture the structure and externalities of the nighttime economy. Even when NTL is interpreted as an indicator of nighttime economic activity, the focus typically remains on macroeconomic outcomes such as city-level output, land use, or commercial vitality, with little attention to the micro-level consequences for individuals' well-being. In particular, there is a lack of evidence on whether, and through which channels, nighttime economic activity generates social externalities in the form of improved mental health. By combining satellite-based NTL data with panel information on individuals' mental health, this paper instead uses NTL as a measure of the intensity of outdoor nighttime economic activity and examines its causal impact on mental well-being.

In conclusion, our study contributes to the existing literature by addressing a critical gap in the understanding of how economic development, particularly the nighttime economy, affects mental health. While previous research has focused on the positive link between economic growth and mental health, China's nighttime economy offers a distinct and broader model. Unlike the predominantly indoor and alcohol-focused activities in the West, China's nighttime economy integrates both indoor and a variety of outdoor leisure activities, which play a crucial role in enhancing well-being. This broader model provides a promising non-medical approach to tackling the global mental health crisis, especially in developing countries with limited access to mental healthcare. Furthermore, we present a novel framework that outlines the potential mechanisms through which nighttime economic activity may influence mental health. By emphasizing the importance of family income and consumption within the context of the nighttime economy, we highlight pathways through which nighttime economic activities can enhance psychological well-being. Our study, therefore, offers an innovative approach to addressing mental health challenges, demonstrating how non-medical, socio-economic interventions can complement healthcare strategies and contribute to global mental health improvement.

3. Data and Methodology

3.1. Methodology

3.1.1. Model

To provide foundation for our later empirical design, we introduce a theoretical model to illustrate our core concepts. Building on the household production framework developed by Becker (1965), we adopt a health-capital style model (Grossman, 1972) tailored to mental health and to the setting of the nighttime economy. The key distinction is between the stock of mental health capital and the flow of mental-health services generated from that stock.

In our framework, mental health can also be viewed as a durable capital stock. Let MHC_{it} denote individual i's mental health capital stock at time t. Following the service-flow interpretation, experienced mental health is a service flow generated from the stock:

$$h_{m_{it}} = \phi_{m_i} MHC_{it} \tag{1}$$

where ϕ_{m_i} is the service flow per unit of mental health capital, and $h_{m_{it}}$ is the total consumption of mental-health services. Individuals also consume a composite of other goods Z_{it}. Hence lifetime utility can be written as:

$$U_i = U(h_{m_{i0}}, h_{m_{i1}}, ..., h_{m_{it}}, Z_{i0}, Z_{i1}, ..., Z_{it}) \tag{2}$$

This formulation emphasizes that improvements in mental well-being can arise either because individuals increase investment in mental health capital, or because the effective service flow per unit of stock changes through ϕ.

Since mental health is also a form of health capital, we assume it follows standard law of motion. Therefore, MHC evolves according to:

$$MHC_{i,t+1} = I_{it} + (1 - \delta_t) MHC_{it} \tag{3}$$

where I_{it} is gross investment in mental health and δ_t is the depreciation rate. Specifically, depreciation summarizes forces such as stress accumulation, adverse shocks, and natural deterioration in resilience. Equation 3 makes clear that external factor can affect mental health outcomes by changing the net accumulation of mental health capital, either by increasing gross investment I_{it} or by altering depreciation δ_t. In the context of the nighttime economy, the most plausible and policy-relevant pathway is through investment. NTE

development reshapes individuals' opportunities and incentives to engage in nighttime activities, which are precisely the inputs that translate into purposeful investments in mental health. Therefore, we focus on how NTE enters the model through the investment technology, which provides the key theoretical bridge to our later empirical mechanisms.

As for I_{it}, in Grossman (1972), investment in physical health is produced using medical care M_i and time TH_i, with resource constraints E_i. In our context, the mechanism of interest is not medical treatment, but the way a more vibrant nighttime economy reshapes individuals' nighttime participation, leisure-related consumption, and economic resources. Therefore, we try to map the canonical investment technology into a nighttime-economy-specific form to show how NTE influences people's mental health status.

Starting from the generic Grossman-style production function for health investment, we translate the model in a way that can fit in our story. In the nighttime economy setting, we assume that NTE mainly affects people's behaviors in three major ways. It can change the time allocated to nighttime leisure and social participation. With more time devoted to night activities, people tend to consume more for leisure-related gain, as well as relaxing resource constraints by generating additional income opportunities. Based on these insights, since actually we keep the same health-production logic and mental health can also be regarded as a form of capital, we transform inputs as follows:

$$\underbrace{I_i = I_i(M_i, TH_i; E_i)}_{Grossman(1972)} \Rightarrow \underbrace{I_i = I_i(C_{L_i}, T_i; E_i)}_{NighttimeEconomyContext} \tag{4}$$

where the relevant time input becomes time spent on nighttime activities, denoted by T_i, and C_{L_i} represents those inputs that are leisure-related consumption enabled by nighttime economic activity, like spending on recreation, dining, and traveling. Similarly, E_i captures people's constraints and resources that can shape their ability to invest in mental health capital, like income.

With this new investment function under the NTE setting, we can further make use of Grossman (1972)'s optimality condition to help explain the mechanism that nighttime economy influences mental health status, which also provides foundations for later analysis. Grossman's framework implies that individuals invest in mental health capital up to the point where the marginal benefit of one more unit of mental health capital equals its marginal

cost. In our notation, the equilibrium condition can be expressed as:

$$\gamma_{m_i} = \underbrace{G_i\left[\frac{W_{m_i}\phi_{m_i} + \frac{U_{h_{m_i}}}{\lambda}(1+r)^i}{\pi_{m_i}}\right]}_{\text{Marginal Benefit}} = \underbrace{r + \delta_i - \tilde{\pi}_{m_i}}_{\text{Marginal Cost}} \tag{5}$$

where:

G_i = marginal product of mental health capital (how effectively a higher stock translates into welfare gains);
W_{m_i} = shadow productive value of an additional unit of mental-health service flow;
$U_{h_{m_i}}$ = marginal utility of mental-health service flow;
λ = marginal utility of wealth;
π_{m_i} = shadow marginal cost of producing one unit of mental health capital;
r = opportunity cost of investing;
δ_i = depreciation rate of mental health capital.

In our framework, we do not adopt the canonical Grossman model as a fully calibrated steady-state structural model. Instead, we use its equilibrium logic and assign each term a context-specific meaning under the nighttime economy. This re-mapping allows us to articulate, in a transparent manner, how nighttime economic development can shift the marginal utility derived from mental-health service flows, the tightness of individuals' resource constraints, and the effective costs of producing mental health capital. Consequently, the model delivers an intuitive decision rule, how much to invest in mental health, while serving as a theoretical foundation for the empirical specifications and mediation channels examined later.

This equilibrium condition yields clear empirical implications for how the nighttime economy can affect mental health. First, a more vibrant nighttime economy expands the variety and accessibility of nighttime activities, lowering the effective cost of participating in night life and thereby reducing the shadow marginal cost of producing mental health capital, π_{m_i}. This encourages individuals to reallocate time toward nighttime participation. Second, as our statements before, increased participation is typically accompanied by higher leisure-related consumption, which enhances the utility derived from mental-health service flows and mainly operates by raising $U_{h_{m_i}}$. Third, NTE can generate additional income opportunities that relax resource constraints,

primarily reflected in a lower marginal utility of wealth, which amplifies the utility-relevant benefit term $\frac{U_{hm_i}}{\lambda}$. Taken together, driven by direct increase in time allocation in night activities, the model predicts a positive relationship between nighttime economy intensity and mental health, and it also motivates indirect mechanism tests focusing on consumption and income channels in our empirical analysis.

3.1.2. Empirical Design

To empirically test the previous model, we first adopted Ordinary Linear Squares (OLS) to examine the relationship between nighttime economy and mental health, and its function is written as follows:

$$MH_{it} = \alpha + \beta_1 NTE_{pt} + \mathbf{X}'_{it}\gamma + \varepsilon_{it} \tag{6}$$

where i indexes individuals, p denotes provinces, and t refers to survey years. MH_{it} is the dependent variable measuring mental health. NTE_{pt} measures nighttime economy at the provincial level. $\mathbf{X}_{it}$ is a vector of control variables, and ε_{it} is the error term.

To further examine the relationship under the fixed effect model, we also include province and year fixed effects into the model:

$$MH_{it} = \alpha + \beta_1 NTE_{pt} + \mathbf{X}'_{it}\gamma + \mu_p + \lambda_t + \varepsilon_{it} \tag{7}$$

where μ_p and λ_t denote province and year fixed effects, respectively, which control for time-invariant provincial characteristics and common shocks that vary over time.

To address the potential endogeneity issues arising from the possible correlation between nighttime economy and unobserved factors influencing mental health, we then employ a Two-Stage Least Squares (2SLS) estimation approach, using electricity usage as an instrument. In the first stage, the specification could be expressed as follows:

$$NTE_{pt} = \alpha_1 + \delta_1 \, Elec_{pt} + \mathbf{X}'_{it}\gamma + \mu_p + \lambda_t + \varepsilon_{it} \tag{8}$$

where Elc_{pt} refers to the annual percentage change in the average annual electricity usage of provinces geographically adjacent to province p in year t.

In the second stage, we use predicted values of NTE_{pt} from the first stage regression results as the main independent variable to estimate the causal effect of nighttime economic activity on individuals' mental health. The second stage specification is as follows:

$$MH_{it} = \alpha_2 + \delta_2 \widehat{NTE}_{pt} + \mathbf{X}'_{it}\gamma + \mu_p + \lambda_t + \varepsilon_{it} \tag{9}$$

where $\widehat{NTE}_{pt}$ is the predicted value of nighttime economy obtained from the first stage regression, and the rest of the terms in equation 9 is the same as 7.

Moreover, our framework implies that the effect of the nighttime economy on mental health may operate both directly and indirectly, with household income and household consumption serving as two key mediating channels. In Figure 1, the direct effect of nighttime economics is represented by line c. As for an indirect effect, nighttime economy could affect mental health via channels of income and consumption. Particularly to say, the nighttime economy would affect income and consumption first (line a) and then, in turn, they would further affect people's mental health (line b). To examine the mediation effect of income and consumption, we adopt the method developed by Baron and Kenny (1986), in which the approach to examining mediation effect can be separated into three steps. The first step examines the direct effect of the nighttime economy on individuals' mental health, which is identical to equation 7. Therefore, in our study, we proceed with the subsequent steps with two-way fixed effects:

$$Mediator_{ft} = \alpha + \beta_2 NTE_{pt} + \mathbf{X}'_{it}\gamma + \mu_p + \lambda_t + \varepsilon_{it} \tag{10}$$

$$MH_{it} = \alpha + \beta_3 NTE_{pt} + \sigma\, Mediator_{ft} + \mathbf{X}'_{it}\gamma + \mu_p + \lambda_t + \varepsilon_{it} \tag{11}$$

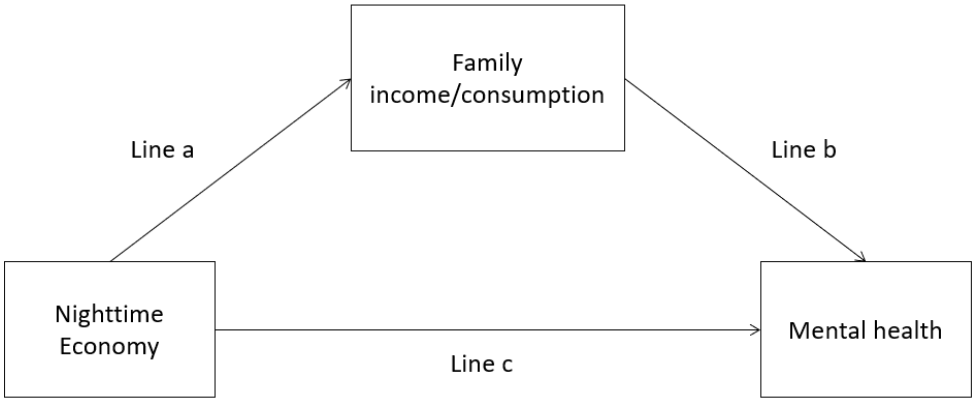
where $Mediator_{ft}$ denotes the income and consumption percentage change of family f that individual i lives in during year t, respectively. To assess the statistical significance of the mediation effect, we also applied the Sobel Test as a robustness check. Based on the mediation analysis, the total effect of nighttime economy on mental health satisfies the decomposition:

$$\beta_1 = \beta_3 + \sigma\beta_2 \tag{12}$$

where β_3 captures the direct effect of $\ln NTL_{pt}$ on mental health, while the indirect effect operating through the mediator is given by $\sigma\beta_2$.

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Figure 1: Mediation Model Linking Nighttime Economy to Mental Health



3.2. Data

3.2.1. China Family Survey

Our analysis is based on the China Family Panel Studies (CFPS), a nationally representative dataset collected by Peking University to track the social, mental and economic conditions of Chinese citizens and families. So, CFPS includes respondents' detailed health information, such as their self-reported mental health status, demographic background, and their family-level economic status, including family income and family income per capita. Up to the current study, the CFPS has released seven waves of the survey in 2010, 2012, 2014, 2016, 2018, 2020, and 2022.

In this research, the key dependent variable is mental health, measured by the Center for Epidemiological Studies Depression Scale-8 (CESD-8), which consists of eight self-reported items. Since the 2010 and 2014 waves of the CFPS did not include the items of CESD-8, we decided to restrict our analysis to data from 2012, 2016, 2018, 2020 and 2022 waves. Specifically, as for CESD-8, it requires respondents to provide self-assessments on the following eight items: "I felt depressed;" "I felt it hard to do everything;" "My sleep was restless;" "I enjoyed life;" "I felt lonely;" "I was happy;" "I felt sad;" and "I could not get going." Then, each question offers four response options, from which respondents are asked to choose the one that best reflects their mental state based on their experience in the past week: never (0 points), sometimes (1 point), often (2 points), or most of the time (3 points). We

add their points for each question up to a composite score, which is typically called CESD-8. Therefore, each respondent's CESD-8 score ranges from 0 to 24, with higher scores indicating much severe mental distress.

Now, CESD has been widely used in various medical and public health fields as a reliable tool for assessing psychological well-being. Actually, CESD originally has 20 items, so it's also called CESD-20. However, although CFPS contains both CESD-20 and CESD-8, there are many missing values for CESD-20. Therefore, to obtain more reliable and accurate results, like many previous studies have done, we choose to use CESD-8 as the measure of mental health. Although CESD-8 is a shortened version of CESD-20, some studies have shown that it won't affect respondents' motivation to participate and it's a reliable and valid tool to detect depressive symptoms (O'halloran et al., 2014).

3.2.2. Nighttime Light

Nighttime Light (NTL), captured by satellites, is mainly used to reflect the degree of light during the night in a certain area. NTL data originally comes from Defense Meteorological Satellite Program Operational Linescan System (DMSP-OLS), and the SNPP-VIIRS, which was launched in 2011 by NASA and the National Oceanic and Atmospheric Administration (NOAA). Actually, these two sources of NTL are different in some ways. For DMSP-OLS, its initial purpose was detecting moon-lit clouds with an operational period between the 1970s and 2013. While SNPP-VIIRS is mainly used for earth observation for scientific research and has worked since October 2011. Additionally, DMSP-OLS and SNPP-VIIRS are also different in many other respects, such as the time of nightly overpass, swath, quantization, minimum detectable signal and etc., which make it difficult to simply merge these two sources. Within the economic area, more studies chose to use DMSP-OLS instead of SNPP-VIIRS when they discussed nighttime light, although the data from SNPP-VIIRS has some improvement over DMSP-OLS. But the truth is that both of these two sources are not perfect for some potential backwards.

Since our study's time interval ranges between 2012 and 2022, it's impossible to just utilize one NTL data source due to the transition from DMSP-OLS to SNPP-VIIRS. Therefore, we choose to adopt the time-series DMSP-OLS-like dataset developed by Wu et al. (2021), in which they integrated DMSP-OLS and SNPP-VIIRS. In their study, the authors calibrated the DMSP-OLS data (1992-2013) using a "pseudo-invariant pixel" method, which

helps minimize discontinuities caused by sensor differences and inter-annual inconsistencies. They further applied an exponential smoothing model to patch missing monthly SNPP-VIIRS data (2013-2019) and used a sigmoid model to simulate DMSP-OLS-like values for the post-2013 period. Outliers and noise were also removed to improve data quality. Through these steps, the researchers constructed a temporally consistent and spatially comparable time-series NTL dataset covering 1992 to 2019, which has been demonstrated to exhibit strong correlation with the official SNPP-VIIRS records and thus provides a reliable proxy for analyzing long-term socio-economic changes. Another important thing is that the authors annually update new data after 2021, so this allows us to cover our research period from 2012 to 2022. Figure 2 visualizes the raw nighttime light (NTL) in 2022, where brighter pixels indicate higher light intensity and thus more concentrated nighttime economic activity across China.

The original data is in Tag Image File Format (TIFF), and to get data that we could use in STATA, we processed the raw data in ArcGIS. By combining the Shapefile (SHP) of China provinces in ArcGIS, we could then convert the raw data of TIFF into a dataset including the mean, sum, standard deviation, minimum, and maximum of NTL at the province level. In CFPS, it includes the province code of each respondent, which helps us to merge the dataset of CFPS and that of NTL together in every year of our research period. Among all indicators of NTL, we chose to use the sum of NTL as our independent variable. Because it has been shown that within the scope of economic development, the sum of NTL has a relatively more apparent positive relation with GDP in many industries (Chen et al., 2024), like construction, retail, transportation, lodging and catering. So, the sum of NTL can be an effective proxy for us to use as a measurement for nighttime economy, since many activities of different industries, especially the tertiary industry, are representatives of urbanization (Zhang et al., 2019).

3.2.3. Instrumental Variable

To address the endogeneity caused by nighttime economy, we introduce electricity usage as an instrumental variable into our regression model. Specifically, electricity consumption is tightly related to the nighttime economy, which greatly relies on the local electricity supply. However, province-level electricity usage usually does not directly affect individual-level mental health status, unless it goes through some economic activities to people's lives. Therefore, electricity usage has a proper potential working as an instrumen-

Figure 2: Spatial Distribution of Nighttime Lights in China, 2022



Source: Harvard Dataverse. https://doi.org/10.7910/DVN/GIYGJU..

tal variable in our analysis. Additionally, to further ensure our instrument would not cause more endogeneity, which may be due to changing individuals' living conditions, we treat electricity usage with space lag method by calculating the percentage change of the average annual electricity consumption in provinces around the specific province, which is donated as *elec_usage*. Specifically, the definition of *elec_usage* is as follows:

$$\overline{Elec}_{p,t} = \frac{1}{|N_p|} \sum_{q \in N_p} Elec_{q,t}, \; elec_usage_{p,t} = \ln\left(\overline{Elec}_{p,t}\right). \tag{13}$$

where N_p denotes the set of provinces geographically adjacent to province p and $|N_p|$ is the number of such adjacent provinces. $\overline{Elec}_{p,t}$ is the average electricity consumption in year t across provinces adjacent to p, and $elec_usage_{p,t}$ is the natural logarithm of this spatially lagged electricity mea-

sure used as the instrument. In addition, based on the result of the first stage of the 2SLS model, our instrument does not suffer from weak-instrument concerns ($F = 410.16$).

3.2.4. Mediation Variable

We further explore the mechanisms through which nighttime economy activity influences individual mental health. Conceptually, the nighttime economy is regarded as one interpretation of a city's expansive service sector dynamism, because satellite-measured nighttime light rises where retail, leisure and other after-dark services cluster (Geiger, 2007; Roberts and Eldridge, 2012; Schwanen et al., 2012) and has long been shown to track local economic output and socio-economic conditions (Leng et al., 2019). That is to say, when such kind of activity intensifies, two economic channels can become especially notable, which are income and consumption.

Extending business hours and expanding service jobs create additional and multiple, often flexible, employment opportunities. Previous studies show that people can pursue multiple jobs or secondary jobs for increased income, work-life-family balance, and also psychological fulfilment (Dickey et al., 2011; Doucette and Bradford, 2019; Campion et al., 2020). Additionally, with the development of the tertiary industry, including the service industry, not only has the related skilled labor demand increased, but also people can take advantage of more abundant resources to actively run their businesses, which leads to more diversified increased income sources during a period of increasing relative wages (Buera and Kaboski, 2012). Since greater income eases financial stress and improves access to health-promoting resources, it is commonly linked to lower depression risk and higher life satisfaction (Ettner, 1996; Shields-Zeeman and Smit, 2022). Therefore, in our analysis, we choose to use the percentage change of family income as our first mediator, which is denoted as $lfincome$.

As for consumption, a richer nighttime economy creates a livelier atmosphere and environment for people to relax and entertain, lowering the time cost of spending and encouraging more frequent discretionary purchases. So, they have more incentives to consume goods (Sampériz et al., 2025) to meet their needs of releasing their inner pressure. Evidence from some studies indicates that leisure-oriented and socially motivated expenditures, which can be defined as experimental consumption, are positively correlated with subjective well-being (Gilovich et al., 2015; Li and Zeng, 2025). By extending opportunities for relaxation and social interaction under greater nighttime

economics, higher consumption can therefore bolster people's mental health outcomes. Based on this idea, the percentage change of family consumption expenditure, *lpce*, could be used as the second mediator to explore the mechanism of consumption.

3.2.5. Control Variable

Based on existing literature that analyzes factors affecting individuals' mental health, we include a set of control variables to account for individual demographic and socio-economic characteristics, as well as healthcare accessibility. Specifically, we controlled for respondents' age, gender, and education level, employment status, and marital status. Since family background would also play an important role in affecting mental health, we also add family size to explain the influence of family structure. As for the province level, we include hospital density to assess the provincial accessibility of healthcare services, which helps us isolate the effect of nighttime economic activity on mental health from the confounding influence of regional healthcare supply.

Table 1 shows the definitions of variables used in our study. $life_satisfy$ and *covidnumber* are an alternative dependent variable and a new control variable respectively that would be considered in our robust check section.

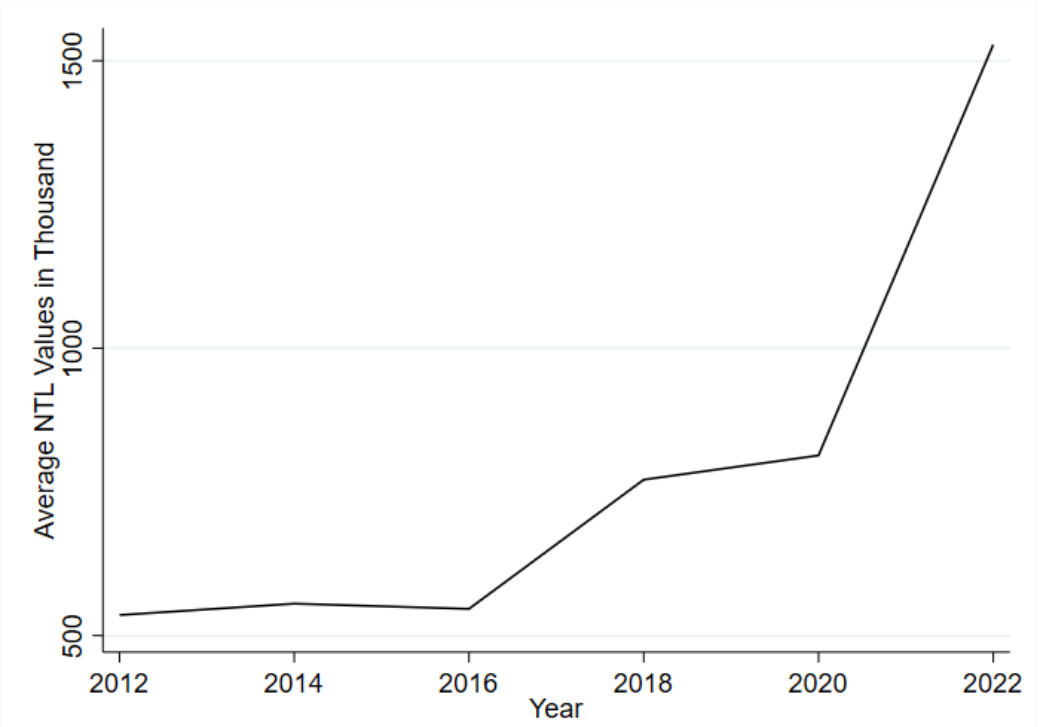
4. Results

4.1. Descriptive Statistics

In Table 2, it shows that there is a total of 136,504 respondents who have a valid CESD-8 score. Its average is 5.42, the median is 5 and the standard deviation is 4.02, which shows a great fluctuation. When we use 8 as a cutoff score for CESD-8 (Bi et al., 2023) to identify respondents who may have significant depression, 26.83% of samples showed a mental illness, and there are 65 respondents whose CESD-8 score is 24, so most of our samples in the survey have a relatively positive mental status.

Table 2 also reports 151 valid NTL values, corresponding to all provincial-level regions represented in our CFPS sample across the survey years 2012, 2016, 2018, 2020, and 2022. The NTL unit is Digital Number (DN), representing the total nighttime light (NTL) intensity for a specific province in a given year. The mean of the total NTL is 933,363 with a standard deviation of 750,217. From Figure 3, there is a general upward trend in NTL values over time, suggesting an expansion of nighttime economic activity during the study period. Additionally, since the distribution of nighttime light (NTL)

Figure 3: Trend in Average Annual Nighttime Light (NTL) Values of Mainland China Provinces, 2012-2022



Note: The annual NTL value is computed as the average across all provinces in mainland China, excluding Hong Kong, Macao, and Taiwan. NTL is measured in DN units (in 10^2).

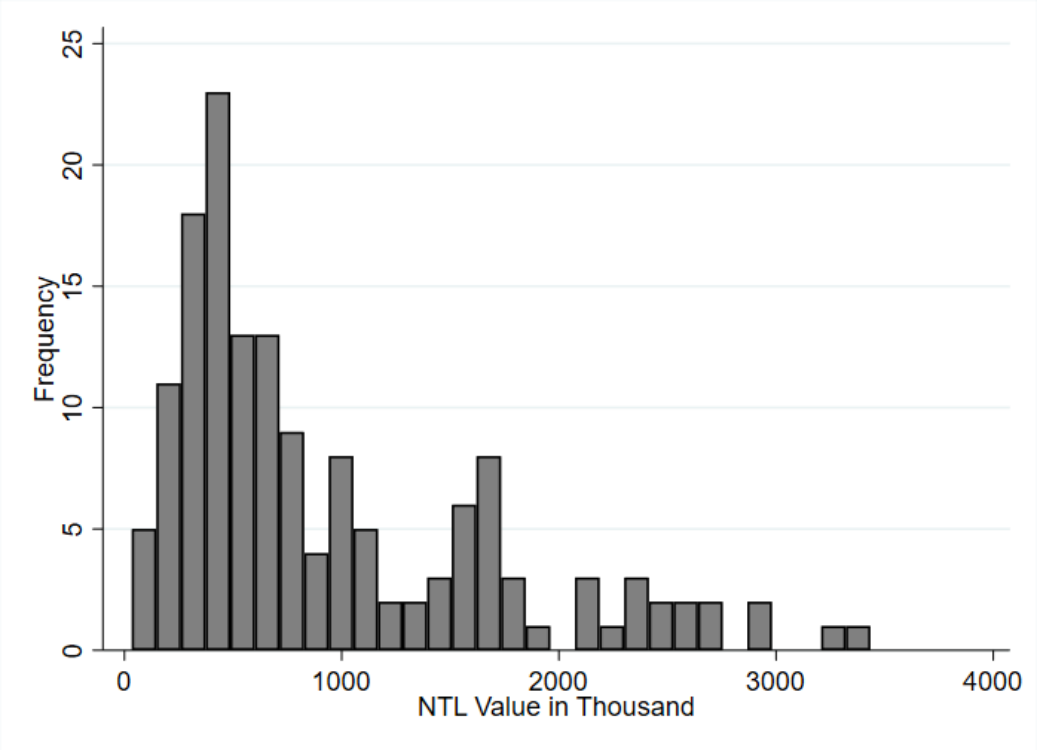
is highly right skewed (Figure 4), we applied a natural logarithmic transformation to compress the scale and mitigate the influence of outliers. This transformation also allows for a more linear relationship with the dependent variable and facilitates the interpretation of coefficients in terms of percentage changes in NTL.

4.2. Results Analysis

4.2.1. Baseline Regression

As shown in Table 3, it reports baseline regression results to examine the relationship between nighttime economic activity, which is measured by the logarithm of nighttime light, and individuals' mental health. It includes results from various specifications, including both OLS, fixed effects, and the 2SLS model.

Figure 4: Distribution of Province Level NTL Values



Note: NTL is measured in DN units (in 10^2).

In both columns (1), (2), (3), and (4), the coefficients of $\ln NTL$ are significantly negative at 1% level, indicating that greater nighttime economic activity is associated with lower levels of psychological distress. This result is robust across different OLS and fixed effects specifications, suggesting that the nighttime economy may play a role in improving individuals' mental well-being.

After considering the instrumental variable (columns 5 and 6), the results are still robust. Our 2SLS model using electricity usage as an instrument passes the tests of under identification (Chi-sq = 410.30) and weak identification (F statistic = 410.16) of individual endogenous variables, confirming the validity of our instrument. In column (6), when using predicted values of $\ln NTL$, the interested coefficient is still significantly negative ($p < 0.01$). The first stage of 2SLS model, presented in column (5), demonstrates a significant positive relationship ($\widehat{\delta_1} = 0.305$, $p < 0.01$) between the percent-

age change of the average annual electricity usage in neighboring provinces and local nighttime economy. This suggests that electricity consumption in neighboring provinces can actually spill over to the local nighttime economy, driving the local demand for business and services, providing a more suitable social community, which further releases daytime stress and improves mental well-being.

One potential explanation for this funding is that the nighttime economy can be regarded as an informal social space that extends beyond working hours, providing individuals with more opportunities for what they really need. These include opportunities for social interaction, leisure, emotional relief, and even informal economic engagement, which are de-institutionalized production activities (Godfrey, 2011), especially for urban residents with limited daytime availability. And some studies have shown that these activities are particularly important for mental health (Eisenberg et al., 2013; Nyberg et al., 2025), as they help individuals decompress, foster social bonds, and improve overall psychological well-being.

4.2.2. Mechanism Analysis

In Table 4, it illustrates the regression results of exploring the mediation effect of family income and expenditure in the relationship between nighttime economy and people's mental health.

Column 1 shows the total effect, path c, of nighttime economy on people's mental health, which is also one of our precious baseline regressions. Column 2 represents the impact of the nighttime economy on family income percentage change, path a, with a coefficient positive and statistically significant at 1% level, suggesting that a stronger nighttime economy could lead to an increase in family income, and this is consistent with our previous discussion. Then, column 3 represents the regression that after adding the mediator, family income percentage change, to the column 1's regression. The result reports that the effect of nighttime economy gets smaller, and both the coefficients of $\ln NTL$ and $lfincome$ are negative and significant at 1% level, which demonstrates that both of them could significantly improve people's mental health status. Therefore, combining these three columns, family income change indeed has an important role in this mechanism. Firstly, a stronger nighttime economy could provide more informal work opportunities and thus increase a whole family's income. Secondly, with higher family income, people's financial burden would decrease, and their living standard might increase as well, resulting in a lighter living burden and a more positive

mental state. Additionally, based on Table 5, it could be calculated that the total effect is -0.305, and the direct effect of nighttime economy on mental health is -0.275, so the indirect effect through family income is -0.030, which means that the proportion of total effect that is mediated is about 9.78%. By using Sobel test to examine this mediation effect, p-value is 0.000, so it reports that the mediation effect of family income is valid and significant.

Since family consumption is also a critical part of a province's economy, this part talks about the results of the mediation effect of family consumption expenditure in the relationship between nighttime economics and people's mental health. Column 5 reports the result of the influence of nighttime economy on family consumption expenditure, indicating a significantly positive effect. With the development of the nighttime economy, the rise of a consumption-driven economy can shift toward a more accessible, experience-oriented form. Rather than only relying on formal daytime commercial services, the nighttime economy creates a more inclusive consumption environment that is closely tied to people's entertainment and leisure time. And this finding is consistent with existing studies and our previous discussion, with the higher participation in spare time and living in a more relaxed, immersive, and socially engaging atmosphere, people would be more willing to spend on discretionary goods and services that provide emotional or experiential value (Gilovich et al., 2015). So, the nighttime economy not only increases opportunities for economic transactions but also reframes consumption as a form of leisure and well-being, making individuals more inclined to engage with it.

And column 6 shows the regression result of using both family consumption expenditure and NTL percent change. Although coefficients of these two independent variables are significantly negative ($p = 0.000$) at the same time, the effect of NTL decreases, suggesting that part of nighttime economy's impact actually works through consumption expenditure. By consuming goods for entertainment and leisure, the emotional value people derive could help them lower their pressure and gradually improve their mental health. These forms of consumption, such as experiential purchases, which refers to spending money with the primary intention of acquiring a life experience, rather than material ones, are highly linked to increasing life satisfaction and also lower risk of depression, as they provide people with a method to decompress and enhance perceived well-being (Gilovich et al., 2015).

Therefore, the results of columns 4, 5, and 6 prove to us the existence of the mediation effect of family consumption percentage change. This me-

diating pathway implies that the nighttime economy development improves people's mental health status not only through direct channels, but also indirectly by promoting family consumption expenditures that potentially contribute to mental health. According to Table 5, the total effect is -0.341, while the direct effect is -0.323, resulting in the indirect effect -0.019. Thus, considering the mediation effect of family consumption, the proportion of total effect that is mediated is about 5.55%. Furthermore, the Sobel test confirms the validity and statistical significance of this mediation effect, with a p-value of 0.000.

These two mediation pathways highlight that by elaborating through increased family income and higher consumption levels, the nighttime economy can contribute to improved mental well-being, due to enhanced financial security and emotional satisfaction. This supports the view that economic development, when accompanied by enriched lifestyle options, can generate broader public mental health returns.

5. Heterogeneity Analysis

5.1. Income Effect

To further explore the economic mediation effect between nighttime economy and mental health in different demographic contexts, we first focus on disposable income per capita, which reflects individual's economic conditions. Based on Lettau and Ludvigson (2004), people with different income levels tend to display different attitudes towards consumption. Individuals with higher disposable income would like to spend more money on enhancing their well-being and lived experience, while those who have relatively low income usually hold a conservative attitude. However, as a relatively novel yet more accessible form of economic and social activity, nighttime economy offers a broad range of experiences that are not limited to high-income people, such as second-hand markets, street vending, food stalls etc. Low-income people can also become multiple jobs holders to improve financial conditions. Therefore, we propose that people respond to nighttime economy based on their own economic conditions, thereby deriving various extents of emotional value.

To classify respondents in our dataset based on their income level, we refer to the annual provincial disposable income per capita released by the National Bureau of Statistics of China. Specifically, individuals whose reported

disposable income per capita is greater than or equal to the provincial benchmark are categorized into the high-income group ($high_inc = 1$), while those below the benchmark are classified into the low-income group ($high_inc = 0$). Table 6 presents the regression results of the mediation analysis incorporating both family income and consumption expenditure, conducted separately for high- and low-income groups to examine income-based heterogeneity.

For high-income people, column 1 tells that nighttime economy indeed improves their mental status. But column 2 shows that nighttime economy doesn't significantly influence high-income people's family income, while family income still has a significant and negative correlation with CESD-8 in column 3, which demonstrates that nighttime economy does not appear to improve high-income people's mental health through the channel of increased family income. However, combining results from columns $4-6$, we find that the development of nighttime economy still significantly increases consumption among high-income individuals, which in turn improves their mental health status. This provides evidence that, for this group, the mediation effect of family consumption is significantly valid and plays a meaningful role in linking nighttime economics activity to better psychological outcomes.

As for low-income people, panel B of Table 6 presents that both family income and family consumption serve as significant mediating channels. Nighttime economy appears to stimulate increases in their income and consumption levels, which further contributes to improvements in mental health. These findings suggest that for economically disadvantaged groups, nighttime economic activity enhances psychological well-being through two pathways: by alleviating financial burden and enabling greater access to consumption-based emotional and social experiences. Compared with the high-income group, Table 7 shows that the proportions of total effect of development of nighttime economy that is mediated by family income and consumption expenditure are much larger, which are 11.73% and 6.46% respectively. Therefore, the larger mediation effects observed among low-income people can be explained by the fact that current nighttime economy activities in China are still largely consist of low-end, accessible, and informal forms of commerce, where many high-income people don't mainly rely on. Many of these commercial activities are operated by individuals as a means of supplementing their income outside of formal sectors. Günther and Launov (2012) have found that poor people in developing countries tend to participate in the informal economy, which is characterized by low and volatile earnings. This movement from formal into informal sectors can be ascribed to desirable non-

wage features of the informal sector where individuals maximize their utility rather than their earnings (Maloney, 2004). In addition, regardless of income background, people are willing to participate in nighttime consumption to enjoy unique hedonic experiences. Through this process, their sense of life satisfaction and emotional fulfillment could increase, ultimately contributing to better mental health outcomes.

5.2. Regional and Seasonal Effect

In the northern provinces, where nighttime activities are comparatively less developed than in the south, people usually tend to stay at home rather than going outside for social activities. This regional disparity is largely driven by both economic and climatic factors. From the perspective of economic growth, northern provinces generally lag behind the south in terms of industrial structure and urbanization (Liang et al., 2021) leading to weaker commercial vitality and fewer consumption activities at night. More developed provinces usually have a more diversified population structure and denser clusters of service industries, both of which can contribute to stronger nighttime economic activities. Additionally, another important reason lies in climatic differences between these two areas. Temperature is a key factor affecting economic activities (Dell et al., 2012). Unlike the south, where nighttime temperatures are warm for much of the year, the north experiences pronounced seasonal variation in nighttime temperatures. In summer, as typically cold conditions become warmer, the frequency of outdoor leisure activities increases (Graff Zivin and Neidell, 2014), which provides a potential opportunity to develop the nighttime economy. However, in other seasons, temperature becomes considerably lower, which discourages people's willingness for outdoor leisure and social interactions (Tucker and Gilliland, 2007). Therefore, in the north, this divergence in temperature places the nighttime economy in distinct developmental contexts, and its implications for mental health may likewise vary in magnitude.

First of all, based on China's official administrative-geographic division, we select all northern province in our database. Secondly, to capture potential heterogeneity between the summer and other seasons in the north, we construct a seasonal dummy variable based on the month in which each respondent was interviewed. Specifically, individuals interviewed in June, July, and August are classified as $summer = 1$, indicating they fall within the summer season. All others are coded as $summer = 0$, representing all three other seasons. Accordingly, we restrict our empirical analysis to northern provinces

and contrast summer with non-summer months to identify seasonal heterogeneity in the nighttime economy's impact on mental health, because various temperature conditions in northern provinces could provide proper context.

Columns 1 and 2 of Table 8 show the regression results for summer and other seasons in the north respectively, and according to these estimates, increasing nighttime economy could significantly bring higher effect on improving people's mental health, while its impact is much milder and insignificant during other seasons. By applying the Chow test (LR chi2(8) = 170,09), there is a significant difference between coefficients of $\ln NTL$ in columns 1 and 2. This comparison implies that in the northern provinces, during summer nights, favorable climatic conditions facilitate the mental health benefits of the nighttime economy. Warmer temperatures increase individuals' propensity to go out (Chen and Ng, 2012), thereby raising their exposure to and utilization of nighttime economic activities. By contrast, in other seasons, lower nighttime temperatures suppress this mechanism. Reduced willingness to engage in outdoor leisure diminishes demand and in turn dampens the supply of nighttime activities, ultimately weakening the nighttime economy's capacity to improve mental health.

5.3. Rural-Urban Divide

In China, there exists a huge disparity in economic development (Chen et al., 2018), like consumption and income patterns, as well as the access to mental health resources across urban and rural areas (Nie et al., 2023; Sun and Lyu, 2020). Meanwhile, the economic activities measured by nighttime light (NTL) also vary significantly between these two regions (Chen et al., 2023). In general, urban areas exhibit more vibrant nighttime economic activity compared to rural regions. Therefore, given these unequal distributions, we expect the impact of nighttime economy on mental health will display different trends.

As shown in columns 3 and 4 of Table 8, the coefficients of $\ln NTL$ are significantly negative for both individuals living in urban (column 3) and rural (column 4), suggesting that the nighttime economy has a universally positive association with people's mental health. However, there is an apparent difference between these two columns, for the magnitude of the rural areas' effect (-0.460, $p < 0.01$) is substantially larger than urban areas (-0.199, $p < 0.05$). Additionally, result from Chow test (LR chi2(8) = 1472.05) also helps to confirm the difference. The concept of marginal effect benefits may serve as a key explanatory factor. Rural areas are generally equipped with

fewer leisure facilities and less public infrastructure. Therefore, as nighttime economies begin to emerge and grow, those resources provide residents with noticeable economic gains, which in turn enrich their life experiences and contribute to better mental health outcomes. In contrast, many urban areas have already established more comprehensive nighttime activities through various channels. As a result, the marginal positive impact of advanced development in the nighttime economy may be weaker for urban residents, even though they could still significantly benefit from it.

6. Robust Check

6.1. Difference-in-Difference Estimation Based on COVID-19 Shock

At the end of 2019, the COVID-19 outbreak began in China and rapidly spread across the country. In response, many cities started to implement lockdown to prevent further infection. Because of fear and concerns, many people reduced their outdoor activities and chose to stay at home instead. So, as the pandemic intensified, people's anxiety levels rose, contributing to a general deterioration in mental health (Wang and Fattore, 2020; Moeti et al., 2022; Björkegren et al., 2024).

As an indicator of economic development, the nighttime economy could have lost its positive effect on mental health during this special period. As we have discussed before, the nighttime economy improves people's mental health by promoting economic activities such as consumption, but the outbreak of the pandemic brought severe shock to those nighttime-economy-intensified areas (Sampériz et al., 2025; Santiago-Iglesias et al., 2024), like close down and isolation. Hence, in areas with highly active night activities, which are typically more economically developed and densely populated, the pandemic might have brought additional mental burdens to residents. The fear of infection due to dense population, higher cost of living, business closures, and the suspension of public activity all could contribute to limited opportunities for emotional relief. Therefore, incorporating the dynamic impact of the COVID-19 shock into our analysis can help us validate the robustness of our findings: the nighttime economy improves people's mental well-being under normal conditions, but its effect may be diminished under public health crises like COVID-19.

To better reflect COVID-19's impact on mental health, it's necessary to add one control variable related to the pandemic. By manually collecting data released by the Health Commission of each province in China, we sorted the

annual cumulative number of confirmed COVID-19 cases for each province after 2019. After removing those missing values, the data was merged with our CFPS dataset, and the variable was defined as *covidnumber*. Then, based on our equation 7, we apply difference-in-differences (DID) combined with event study methods to our CFPS dataset. And to conduct the pre-trend test, our event-study model can be written as follows:

$$\begin{aligned} MH_{it} = \alpha + \sum_{k=-7,\, k\neq -1}^{3} \beta_k \Big(highNTL_p \times \mathbf{1}[t - 2019 = k] \Big) \\ + \theta\, covidnumber_{pt} + \mathbf{X_{it}'}\gamma + \mu_p + \lambda_t + \varepsilon_{it}. \end{aligned} \tag{14}$$

where the event time k ranges from -7 to 3, and we omit $k = -1$ (year 2018) as the reference period to avoid collinearity. $highNTL_p$ is a time-invariant indicator equal to 1 if province p's NTL level in 2018 is above the national median, and 0 otherwise. This classification is based on the year prior to the COVID-19 outbreak and is used to distinguish provinces with relatively active nighttime economic activity before the pandemic. $\mathbf{1}[t - 2019 = k]$ is an event-time dummy that equals 1 if year t is k years relative to 2019, and 0 otherwise. $covidnumber_{pt}$ represents the cumulative number of COVID-19 cases for a certain province p that individual i resides in since 2019. It is set to 0 for all pre-pandemic year.

We also employ a standard DID model to estimate the average treatment effect of nighttime economy on mental health between control group and the treatment group before and after the COVID-19 outbreak. The model is as follows:

$$MH_{it} = \alpha + \beta \big(highNTL_p \times post_t \big) + \theta\, covidnumber_{it} + \mathbf{X_{it}'}\gamma + \mu_p + \lambda_t + \varepsilon_{it}. \tag{15}$$

where $post_t$ equals 1 for the post-pandemic period and 0 for the pre-pandemic period. Other terms are the same as in equation 14.

As Figure 5 shows, the estimated coefficients before the COVID-19 outbreak are statistically insignificant, suggesting that the treatment and control groups followed a pre-trend in mental health before the pandemic, which confirms the appropriateness of the DID strategy. In addition, based on results in Table 9, the coefficients of $highNTL \times post$ are all significantly positive with CESD-8 across four specifications. This illustrates that individuals living in high-NTL provinces experienced worsened mental health outcomes (higher CESD-8 scores) after the outbreak of COVID-19. While the baseline re-

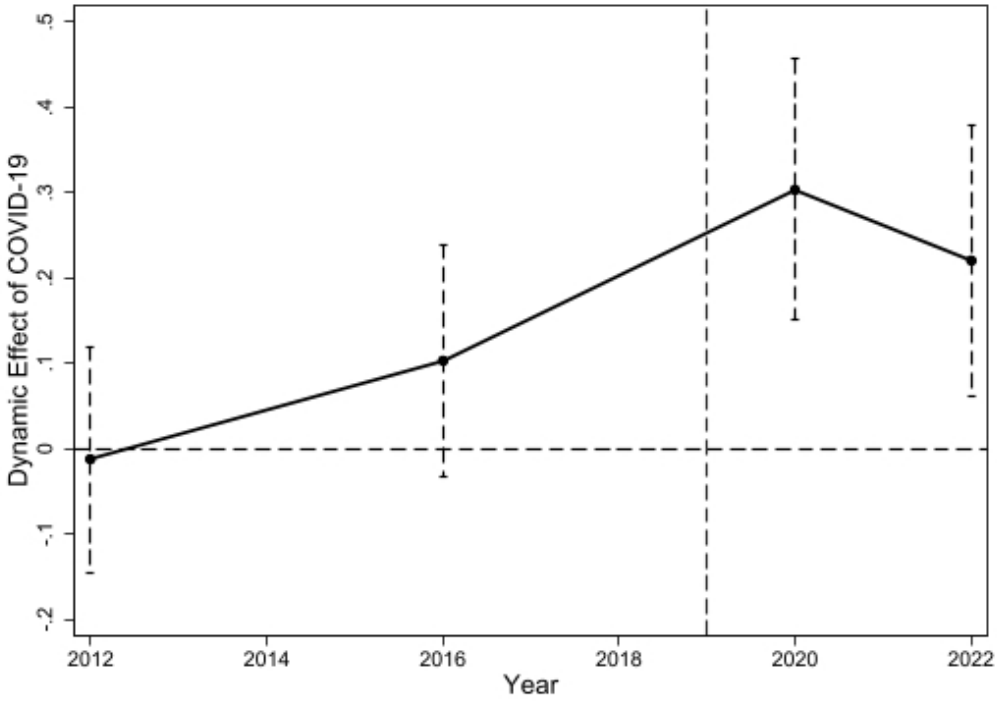
gressions indicate a significant and negative association between ln NTL and CESD-8, and DID analysis reveals a positive effect of the $highNTL \times post$, which is not contradictory. Rather, it proves that the results of baseline models are not affected by other unobserved provincial heterogeneity, and the pandemic did disrupt the beneficial mechanisms of nighttime economy because the social restrictions and economic burdens in highly developed areas diminished nighttime economy's mental health advantages. According to Santiago-Iglesias et al. (2024)'s study, people living in nighttime-economy-intensified areas apparently reduced outdoor activities in the evening during the pandemic, and population outflow also occurred during the initial phases of the pandemic due to the fear caused by dense population. These phenomena would hinder the nighttime economy from playing its role. Therefore, this strategy supports our findings that the nighttime economy plays a protective role in improving people's mental health.

6.2. Alternative Dependent Variable

Another way to check the robustness of our results is replacing our mental health measurement from CESD-8 to self-reported life satisfaction, which examines the solidity of the relationship between nighttime economy and mental health. In earlier research, life satisfaction has been commonly adopted as a metric for well-being, representing individuals' holistic evaluation of their lives. It has been proven that significant associations are found between life satisfaction and psychiatric (Fergusson et al., 2015), like depressive symptoms. People with worse mental health also have lower mean life satisfaction, which could be recognized as a meaningful proxy for mental health outcomes. In the survey, there is a question that requires respondents to evaluate their own life satisfaction from 1 to 5, which we define as $life_satisfy$, with higher numbers meaning higher satisfaction.

As the results shown in Table 10, after using life satisfaction as our dependent variable, the coefficients of nighttime economy are significantly positive with people's life satisfaction across all specific models, indicating that people living in a better nighttime economy environment tend to have great life satisfaction, which is positively related to mental well-being (Fergusson et al., 2015; Chen et al., 2025). Therefore, these results are consistent with baseline findings using CESD-8 as the outcome variable. In addition, this suggests that the positive consequences of the development of nighttime economy are not just confined to depression but also extend to broader life well-being. Hence, our findings are robust and significant as well.

Figure 5: Parallel Trend Test for the Impact of COVID-19 Shock

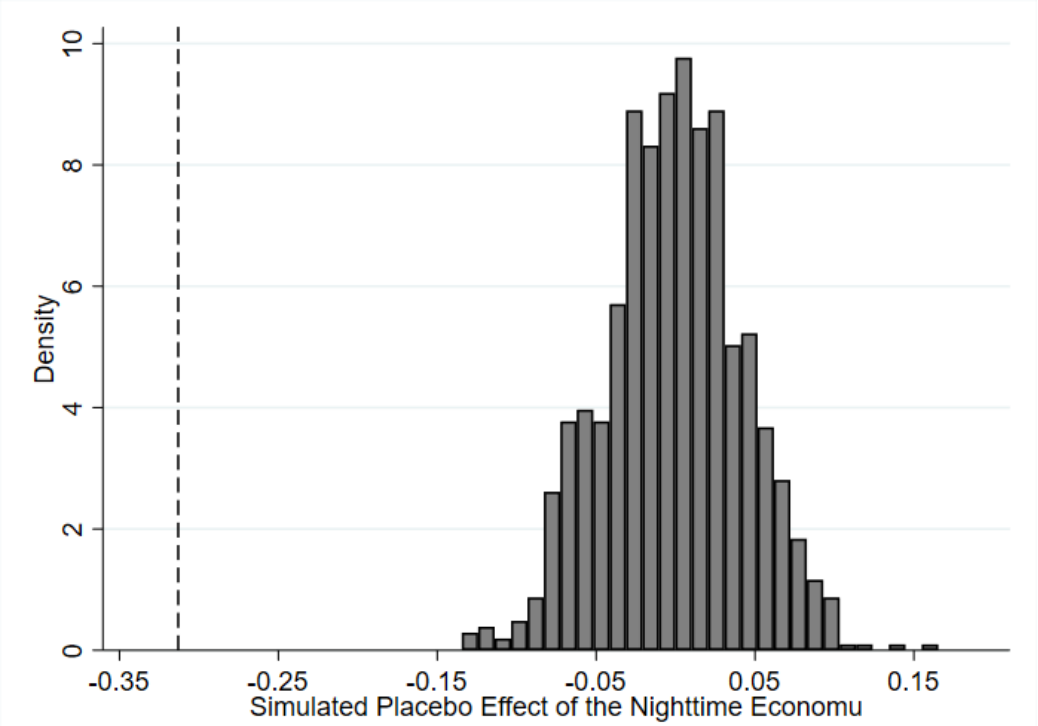


Note: Year 2019 is defined as the shock year marking the outbreak of COVID-19. The year 2018 is used as the baseline (reference) period in the event study design.

6.3. Placebo Test

Considering some concerns that unobserved trends in the nighttime economy are also influencing mental health status, based on the approach of Burns and Dague (2017), we have decided to perform a placebo test to check our design results. There is a total of 1000 placebo simulations, and for each simulation, we randomly reassign to each province the nighttime economy value of another province within the same year, which makes sure that the cross-sectional distribution of nighttime economy remains unchanged while its province-level allocation is fully shuffled and then estimate the main regression on these samples by using changed NTL values. Figure 6 shows the results of 1000 placebo simulations of the estimated coefficients of the nighttime economy combined with a vertical line indicating the true estimated effect from Table 3, column 4 (-0.313***). The histogram also indicates that the average estimated coefficient is -0.001 with an average standard devia-

Figure 6: Histogram of Simulated Placebo Effects



Note: The Figure shows a histogram of 1000 placebo simulations of the estimated effect of the nighttime economy. The vertical line represents the real coefficient from Table 3, -0.313. Each simulation assigns to each province the nighttime economy value of another province within the same year and then estimates the main regression on these samples by using changed NTL values. The average resulting coefficient is -0.001 with an average standard deviation of 0.043.

tion of 0.043. Notably, the distribution of these simulated estimates is tightly clustered around zero and remains substantially distant from the true coefficient, thereby reinforcing the factor that the nighttime economy is the factor driving the improvement in people's mental health.

7. Conclusion

In the worldwide, mental health has recently been an increasingly prominent concern in modern societies, affecting both individuals' well-being, productivity, and even social stability. Among the various determinants of mental health, life experiences and personal fulfillment play a particularly cru-

cial role in shaping people's emotional well-being. In recent years, China's rapidly expanding nighttime economy has created new opportunities for social interactions and informal economic activity. While previous studies have extensively examined the role of nighttime activity as an indicator of national development, its potential psychological benefits have received less attention. However, exploring this relationship is also essential for understanding why economic development could improve people's lives and further how economic transformation can translate into increased well-being.

Therefore, in this study, we examine the relationship between nighttime economy and individual mental health using panel data from the China Family Panel Studies (CFPS) combined with satellite-based nighttime light data (NTL) and provincial data from the National Bureau of Statistics. We find that, as expected, a higher percentage change in the nighttime economy would decrease an individual's reported CESD-8 score, which is 0.031 lower with a ten percent increase in the nighttime economy in the two-way fixed effect model. Since CESD-8 measures depressive symptoms with higher values meaning more severe mental problems, this proves that there is a significantly positive association between the nighttime economy and mental health status. Areas with greater night activity generally provide a variety of economic activities and public amenities, making it easier for individuals to access resources that support mental well-being – such as engaging in social interactions or simply enjoying recreational experiences alone. These informal, after-work, and accessible spaces play an important role in relieving stress and fostering emotional resilience.

In addition, exploring the mechanism from nighttime economy to mental health is crucial as well, as it gives us insight into designing more effective guidance and policies to fully harness the potential of nighttime economy. Therefore, we use family income and consumption expenditure as our mediators in our study. Nighttime economy creates additional, often flexible, employment and business opportunities, enhancing income and also reducing financial burden, which is an important contributor to mental health. Meanwhile, night activity cultivates a more engaging consumption environment. Individuals have more incentives to allocate more spending toward leisure and entertainment. And our results of mediation effect give support. Both development of family income and consumption expenditure play significant mediating roles, which are positively influenced by the development of nighttime economy. The mediation analysis reveals that the development of family income and consumption expenditure mediates 9.84% and 5.54% of the to-

tal effect respectively. Furthermore, the mechanisms differ notably across income groups. Among high-income individuals, the nighttime economy enhances mental health primarily through a modest increase in family consumption expenditure, with the mediation effect accounting for only 1.36% of the total effect. In contrast, as for low-income groups, the mediating roles of family income and consumption are much more pronounced, respectively explaining 11.69% and 6.47%. This suggests that low-income individuals are more likely to be driven to operate night activities and social interactions for additional income generation, and they are also key participants in these kinds of activities as consumers. For them, nighttime consumption offers an affordable and accessible avenue for leisure and emotional relief, which significantly promotes their mental health.

When incorporating geographic and seasonal dimensions into our analysis, we observe that for northern provinces, where temperature fluctuates more than in the south, the mental health benefits of nighttime economic activity are most evident during summer, suggesting that better climatic conditions promote the mental health benefits of the nighttime economy. Moreover, rural areas are present to benefit more from nighttime economic development. With fewer existing leisure and mental health resources, the expansion of accessible and inclusive nighttime economic activities in rural regions offers a promising strategy to mitigate mental problems more effectively.

In conclusion, our findings fill the literature gap by highlighting the importance of incorporating nighttime economics development into broader public health and also urban planning strategies. Unlike traditional approaches that focus on directly providing mental health services, the nighttime economy, which is an emerging lifestyle, offers indirect yet meaningful psychological benefits, not just its economic contributions. So, this makes it a promising policy tool, particularly in resource-limited regions such as rural areas, where expanding more formal mental health infrastructure may be difficult. And given that current China nighttime economic activities are largely low-end and cater primarily to low-income groups, policy efforts can focus on supporting these populations to achieve more significant benefits. At the same time, to broaden the scope of these benefits, policy may also consider developing some premium nighttime economic opportunities that encourage greater participation from high-income individuals to promote their consumption and also generate more income resources for them.

Further studies can build on our study by further exploring which specific

types of nighttime activities are most effective in improving psychological well-being. And as more local governments launch policies aimed at boosting the nighttime economy, evaluating their outcomes will also offer valuable insights for improving people's mental health.

8. Acknowledgement

The authors received no external financial support for this research. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Angelucci, M., Bennett, D., 2024. The economic impact of depression treatment in india: Evidence from community-based provision of pharmacotherapy. American Economic Review 114, 169–198.

Arias, D., Saxena, S., Verguet, S., 2022. Quantifying the global burden of mental disorders and their economic value. EClinicalMedicine 54.

Banerjee, S., Hellier, J., Dewey, M., Romeo, R., Ballard, C., Baldwin, R., Bentham, P., Fox, C., Holmes, C., Katona, C., et al., 2011. Sertraline or mirtazapine for depression in dementia (hta-sadd): a randomised, multicentre, double-blind, placebo-controlled trial. The Lancet 378, 403–411.

Baron, R.M., Kenny, D.A., 1986. The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology 51, 1173.

Bauer, A., Knapp, M., Adelaja, B., 2016. Best practice for perinatal mental health care: the economic case. London: Personal Social Services Research Unit (PSSRU) .

Becker, G.S., 1965. A theory of the allocation of time. The Economic Journal 75, 493–517.

Bi, K., Chen, P., Chen, M.S., 2023. Validating the 8-item center for epidemiological studies depression scale-chinese (cesd-chinese): Data from the china family panel studies (cfps) .

Björkegren, E., Svaleryd, H., Vlachos, J., 2024. Remote instruction and student mental health: Swedish evidence from the pandemic. American Economic Journal: Economic Policy 16, 491–517.

Bone, J.K., Fancourt, D., Sonke, J.K., Fluharty, M.E., Cohen, R., Lee, J.B., Kolenic, A.J., Radunovich, H., Bu, F., 2023. Creative leisure activities, mental health and well-being during 5 months of the covid-19 pandemic: a fixed effects analysis of data from 3725 us adults. J Epidemiol Community Health 77, 293–297.

Brajša-Žganec, A., Merkaš, M., Šverko, I., 2011. Quality of life and leisure activities: How do leisure activities contribute to subjective well-being? Social Indicators Research 102, 81–91.

Buera, F.J., Kaboski, J.P., 2012. The rise of the service economy. American Economic Review 102, 2540–2569.

Burns, J.K., 2015. Poverty, inequality and a political economy of mental health. Epidemiology and Psychiatric Sciences 24, 107–113.

Burns, M., Dague, L., 2017. The effect of expanding medicaid eligibility on supplemental security income program participation. Journal of Public Economics 149, 20–34.

Campion, E.D., Caza, B.B., Moss, S.E., 2020. Multiple jobholding: An integrative systematic review and future research agenda. Journal of Management 46, 165–191.

Cao, J., Kang, J., 2019. Social relationships and patterns of use in urban public spaces in china and the united kingdom. Cities 93, 188–196.

Chen, C., LeGates, R., Zhao, M., Fang, C., 2018. The changing rural-urban divide in china's megacities. Cities 81, 81–90.

Chen, G., Zhao, C., Li, C., 2025. Mental health and well-being in tourism: A horizon 2050 paper. Tourism Review 80, 139–150.

Chen, L., Ng, E., 2012. Outdoor thermal comfort and outdoor activities: A review of research in the past decade. Cities 29, 118–125.

Chen, Z., You, X., Wang, C., Wu, W., Wei, Y., Shi, K., Yu, B., 2024. An increasing mutual promotion of economic growth between china and the world observed from nighttime light remote sensing. International Journal of Digital Earth 17, 2426521.

Chen, Z., Yu, S., You, X., Yang, C., Wang, C., Lin, J., Wu, W., Yu, B., 2023. New nighttime light landscape metrics for analyzing urban-rural differentiation in economic development at township: A case study of fujian province, china. Applied Geography 150, 102841.

Chew, M.M., 2009. Research on chinese nightlife cultures and night-time economies: guest editor's introduction. Chinese Sociology & Anthropology 42, 3–21.

Dell, M., Jones, B.F., Olken, B.A., 2012. Temperature shocks and economic growth: Evidence from the last half century. American Economic Journal: Macroeconomics 4, 66–95.

Dickey, H., Watson, V., Zangelidis, A., 2011. Is it all about money? an examination of the motives behind moonlighting. Applied Economics 43, 3767–3774.

Dolan, P., Kavetsos, G., Krekel, C., Mavridis, D., Metcalfe, R., Senik, C., Szymanski, S., Ziebarth, N.R., 2019. Quantifying the intangible impact of the olympics using subjective well-being data. Journal of Public Economics 177, 104043.

Doucette, M.H., Bradford, W.D., 2019. Dual job holding and the gig economy: Allocation of effort across primary and gig jobs. Southern Economic Journal 85, 1217–1242.

Eisenberg, D., Golberstein, E., Whitlock, J.L., Downs, M.F., 2013. Social contagion of mental health: evidence from college roommates. Health Economics 22, 965–986.

Ettner, S.L., 1996. New evidence on the relationship between income and health. Journal of Health Economics 15, 67–85.

Farrer, J., 2018. Nightlife and night-time economy in urban china. The SAGE Handbook of Contemporary China , 1112–1130.

Fergusson, D.M., McLeod, G., Horwood, L.J., Swain, N.R., Chapple, S., Poulton, R., 2015. Life satisfaction and mental health problems (18 to 35 years). Psychological Medicine 45, 2427–2436.

Frasquilho, D., Matos, M.G., Salonna, F., Guerreiro, D., Storti, C.C., Gaspar, T., Caldas-de Almeida, J.M., 2015. Mental health outcomes in times of economic recession: a systematic literature review. BMC Public Health 16, 115.

Geiger, S., 2007. Exploring night-time grocery shopping behaviour. Journal of Retailing and Consumer Services 14, 24–34.

George K, N., Fonceca, C.M., 2024. After dark: How nightlife and digital worlds shape youth wellbeing. Clayton Michael, After Dark: How Nightlife and Digital Worlds Shape Youth Wellbeing (September 27, 2024) .

Gilovich, T., Kumar, A., Jampol, L., 2015. A wonderful life: Experiential consumption and the pursuit of happiness. Journal of Consumer Psychology 25, 152–165.

Godfrey, P.C., 2011. Toward a theory of the informal economy. Academy of Management Annals 5, 231–277.

Goodman, W.K., Geiger, A.M., Wolf, J.M., 2016. Differential links between leisure activities and depressive symptoms in unemployed individuals. Journal of Clinical Psychology 72, 70–78.

Graff Zivin, J., Neidell, M., 2014. Temperature and the allocation of time: Implications for climate change. Journal of Labor Economics 32, 1–26.

Greenberg, P.E., Fournier, A.A., Sisitsky, T., Pike, C.T., Kessler, R.C., 2015. The economic burden of adults with major depressive disorder in the united states (2005 and 2010). J Clin Psychiatry 76, 155–162.

Grossman, M., 1972. On the concept of health capital and the demand for health. Journal of Political economy 80, 223–255.

Günther, I., Launov, A., 2012. Informal employment in developing countries: Opportunity or last resort? Journal of Development Economics 97, 88–98.

Guze, S.B., Robins, E., 1970. Suicide and primary affective disorders. The British Journal of Psychiatry 117, 437–438.

Henderson, J.V., Storeygard, A., Weil, D.N., 2012. Measuring economic growth from outer space. American Economic Review 102, 994–1028.

Jiang, Y., Fu, Y., Dong, X., 2025. Effects of physical exercise on college students' academic self-efficacy: the chain mediating role of future orientation and mental toughness. Frontiers in Psychology 16, 1604725.

Knapp, M., Wong, G., 2020. Economics and mental health: the current scenario. World Psychiatry 19, 3–14.

Layard, R., 2017. The economics of mental health. IZA World of Labor .

Leng, W., He, G., Jiang, W., 2019. Investigating the spatiotemporal variability and driving factors of artificial lighting in the beijing-tianjin-hebei region using remote sensing imagery and socioeconomic data. International Journal of Environmental Research and Public Health 16, 1950.

Lettau, M., Ludvigson, S.C., 2004. Understanding trend and cycle in asset values: Reevaluating the wealth effect on consumption. American Economic Review 94, 276–299.

Li, H., Zeng, W., 2025. Consumption, relative deprivation and mental health: evidence from hedonic consumption. Frontiers in Public Health 13, 1511547.

Li, Y., Dijst, M., Van Acker, V., Chai, Y., 2025. Understanding effects of daily activity on neighborhood belongingness: A chinese perspective. Cities 158, 105680.

Liang, L., Chen, M., Luo, X., Xian, Y., 2021. Changes pattern in the population and economic gravity centers since the reform and opening up in china: The widening gaps between the south and north. Journal of Cleaner Production 310, 127379.

Lin, V.S., Qin, Y., Ying, T., Shen, S., Lyu, G., 2022. Night-time economy vitality index: Framework and evidence. Tourism Economics 28, 665–691.

Liu, Q., Sha, D., Liu, W., Houser, P., Zhang, L., Hou, R., Lan, H., Flynn, C., Lu, M., Hu, T., et al., 2020. Spatiotemporal patterns of covid-19 impact on human activities and environment in mainland china using nighttime light and air quality data. Remote Sensing 12, 1576.

Maloney, W.F., 2004. Informality revisited. World Development 32, 1159–1178.

Mamo, N., Bhattacharyya, S., Moradi, A., 2019. Intensive and extensive margins of mining and development: Evidence from sub-saharan africa. Journal of Development Economics 139, 28–49.

Marquez, P.V., Saxena, S., 2016. Making mental health a global priority. volume 2016.

Michalopoulos, S., Papaioannou, E., 2013. Pre-colonial ethnic institutions and contemporary african development. Econometrica 81, 113–152.

Moeti, M., Gao, G.F., Herrman, H., 2022. Global pandemic perspectives: public health, mental health, and lessons for the future. The Lancet 400, e3–e7.

Nie, W., Hu, M., Ye, X., 2023. Internet use and rural-urban mental health inequalities: evidence from china. Frontiers in Public Health 11, 1107146.

Nyberg, S.T., Frank, P., Pentti, J., Alfredsson, L., Ervasti, J., Goldberg, M., Knutsson, A., Koskinen, A., Lallukka, T., Nordin, M., et al., 2025. Health benefits of leisure-time physical activity by socioeconomic status, lifestyle risk, and mental health: a multicohort study. The Lancet Public Health 10, e124–e135.

Occhipinti, J.A., Skinner, A., Doraiswamy, P.M., Saxena, S., Eyre, H.A., Hynes, W., Geli, P., Jeste, D.V., Graham, C., Song, C., et al., 2024. The influence of economic policies on social environments and mental health. Bulletin of the World Health Organization 102, 323.

O'halloran, A., Kenny, R., King-Kallimanis, B., 2014. The latent factors of depression from the short forms of the ces-d are consistent, reliable and valid in community-living older adults. European Geriatric Medicine 5, 97–102.

Roberts, M., 2006. From 'creative city'to 'no-go areas'–the expansion of the night-time economy in british town and city centres. Cities 23, 331–338.

Roberts, M., Eldridge, A., 2012. Planning the night-time city. Routledge.

Sampériz, J.d.l.O.L., García-Palomares, J.C., Ramiro-Farinas, D., Martín-Caro, M.S.H., Gutiérrez, J., 2025. Consumption after dark exploring spatio-temporal patterns of spending in the night-time economy. Cities 159, 105726.

Santiago-Iglesias, E., Romanillos, G., Sun, W., Schmöcker, J.D., Moya-Gómez, B., García-Palomares, J.C., 2024. Light in the darkness: Urban nightlife, analyzing the impact and recovery of covid-19 using mobile phone data. Cities 153, 105276.

Schwanen, T., Van Aalst, I., Brands, J., Timan, T., 2012. Rhythms of the night: Spatiotemporal inequalities in the nighttime economy. Environment and Planning A 44, 2064–2085.

Shields-Zeeman, L., Smit, F., 2022. The impact of income on mental health. The Lancet Public Health 7, e486–e487.

Sono, D., Wei, Y., Chen, Z., Jin, Y., 2022. Spatiotemporal evolution of west africa's urban landscape characteristics applying harmonized dmsp-ols and npp-viirs nighttime light (ntl) data. Chinese Geographical Science 32, 933–945.

Sun, J., Lyu, S., 2020. Social participation and urban-rural disparity in mental health among older adults in china. Journal of Affective Disorders 274, 399–404.

Talebian, K., Riza, M., 2020. Mashhad, city of light. Cities 101, 102674.

Tong, L., Hu, S., Frazier, A.E., 2018. Mixed accuracy of nighttime lights (ntl)-based urban land identification using thresholds: Evidence from a hierarchical analysis in wuhan metropolis, china. Applied Geography 98, 201–214.

Tucker, P., Gilliland, J., 2007. The effect of season and weather on physical activity: a systematic review. Public Health 121, 909–922.

Vigo, D., Thornicroft, G., Atun, R., 2016. Estimating the true global burden of mental illness. The Lancet Psychiatry 3, 171–178.

Wang, Q., Granados, J.A.T., 2019. Economic growth and mental health in 21st century china. Social Science & Medicine 220, 387–395.

Wang, Y., Fattore, G., 2020. The impact of the great economic crisis on mental health care in italy: Y. wang, g. fattore. The European Journal of Health Economics 21, 1259–1272.

Wu, Y., Shi, K., Chen, Z., Liu, S., Chang, Z., 2021. Developing improved time-series dmsp-ols-like data (1992–2019) in china by integrating dmsp-ols and snpp-viirs. IEEE Transactions on Geoscience and Remote Sensing 60, 1–14.

Xu, J., Wang, J., Wimo, A., Qiu, C., 2016. The economic burden of mental disorders in china, 2005–2013: implications for health policy. BMC Psychiatry 16, 137.

Yan, G., Zou, L., Liu, Y., 2024. The spatial pattern and influencing factors of china's nighttime economy utilizing poi and remote sensing data. Applied Sciences 14, 400.

Yousuf, H., Narula, J., Zwetsloot, P.P., Hofstra, M., de Levita, A., Scherder, E., van Rossum, B., Hofstra, L., 2019. Using entertainment to improve lifestyles and health. The Lancet 394, 119–120.

Zhang, J., Zhang, D., Huang, L., Wen, H., Zhao, G., Zhan, D., 2019. Spatial distribution and influential factors of industrial land productivity in china's rapid urbanization. Journal of Cleaner Production 234, 1287–1295.

Zheng, Q., Seto, K.C., Zhou, Y., You, S., Weng, Q., 2023. Nighttime light remote sensing for urban applications: Progress, challenges, and prospects. ISPRS Journal of Photogrammetry and Remote Sensing 202, 125–141.

Table 1: Variable Definition

Variable	**Definition**
cesd8	An 8-item depression scale ranging from 0 to 24, with higher scores indicating more severe depressive symptoms.
life_satisfy	A scale ranging from 1 to 5, with higher scores indicating greater life satisfaction.
elec_usage	The mean annual percentage change of the average annual electricity consumption in provinces geographically adjacent to the respondent's province, excluding the respondent's own province.
NTL	Satellite-based light intensity used to proxy nighttime economic activity.
lnNTL	Logarithm of NTL.
covidnumber	The total number of confirmed COVID-19 cases in each province in a given year, expressed in thousands.
age	The age of the respondent.
female	Whether the respondent's gender of birth is female.
hs	Whether the respondent has attained a high school degree or above.
familysize	Total number of family members living in the same household.
work	Whether the respondent is currently employed.
married	Whether the respondent is currently married.
hosp_den	Hospital density, defined as the number of hospitals in a province divided by the provincial population.
lfincome	Logarithm of the individual's family disposable income.
lpce	Logarithm of the individual's family consumption expenditure.
region	Whether the respondent resides in an urban or rural area.
north	Whether the respondent's province is classified as north or south, based on the Qinling Mountains–Huaihe River Line.
summer	A time-based variable used to categorize the interview period, coded as 1 if the interview is conducted in the second quarter, otherwise 0.

Note: For dummy variables, value 1 represents Yes and 0 represents No.

Table 2: Descriptive Statistics

Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
cesd8	136,504	5.42	4.02	0	24
life_satisfy	136,381	3.79	1.02	1	5
elec_usage	151	7.74	0.46	6.29	8.79
NTL	151	933,363	750,217	33,805	3,434,294
lnNTL	151	13.42	0.858	10.43	15.05
covidnumber	142	0.33	1.17	0	6.89
age	136,499	45.75	16.75	16	99
female	136,204	0.50	0.50	0	1
hs	134,935	0.28	0.45	0	1
familysize	136,504	4.24	2.00	1	21
work	128,619	0.709	0.454	0	1
married	136,497	0.78	0.415	0	1
hosp_den	136,504	0.225	0.078	0.10	0.50
Mediators					
lfincome	133,704	10.82	1.20	0	16.59
lpce	126,505	10.64	0.91	0	15.34
Region	134,628	-	-	-	-
urban	66,732	-	-	-	-
rural	67,896	-	-	-	-
North	78,501	-	-	-	-
summer	56,837	-	-	-	-
others	21,664	-	-	-	-

Note: The number of observations for NTL and lnNTL is 151, and for covidnumber is 142 because they are measured at the province-year level. Each value corresponds to the total nighttime light intensity of the respondent's province in a given CFPS survey year. Female, hs, work, and married are binary variables.

Table 3: Regression Results for Baseline

	(1) OLS cesd8	(2) OLS+CV cesd8	(3) FE cesd8	(4) FE+CV cesd8	(5) FIRST lnNTL	(6) IV cesd8
lnNTL	-0.166***	-0.161***	-0.374***	-0.313***		-5.578***
	(0.015)	(0.016)	(0.072)	(0.077)		(1.200)
elec_usage					0.305***	
					(0.015)	
age		0.013***		0.014***	0.000*	0.015***
		(0.001)		(0.001)	(0.000)	(0.001)
female		0.857***		0.864***	0.000	0.866***
		(0.023)		(0.023)	(0.001)	(0.023)
hs		-0.862***		-0.782***	0.000	-0.780***
		(0.025)		(0.025)	(0.001)	(0.026)
familysize		0.006		-0.057***	0.000	-0.057***
		(0.006)		(0.006)	(0.000)	(0.006)
work		0.061**		-0.096***	0.003**	-0.081***
		(0.027)		(0.028)	(0.001)	(0.029)
married		-1.200***		-1.114***	-0.000	-1.115***
		(0.033)		(0.033)	(0.001)	(0.033)
hosp_den		2.584***		-1.326**	2.069***	9.916***
		(0.148)		(0.635)	(0.025)	(2.640)
Constant	7.696***	7.211***	10.532***	10.395***		
	(0.210)	(0.221)	(0.980)	(1.017)		
Observations	136,504	126,759	136,504	126,759	126,759	126,759
R-squared	0.001	0.037	0.027	0.065		
Year FE	NO	NO	YES	YES	YES	YES
Province FE	NO	NO	YES	YES	YES	YES
SW F					410.16	
SW Chi-sq					410.30	

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The Sanderson-Windmeijer first-stage chi-squared (SW Chi-sq) and F statistics (SW F) represent tests of underidentification and weak identification, respectively, of individual endogenous regressors. The value of 410.30 of SW Chi-sq helps reject the null that the particular endogenous regressor is unidentified. The value of 410.16 of SW F can reject that the excluded instrument is correlated with the endogenous regressors weakly.

Table 4: Results of Mediation Effect Regressions

	Family Income			**Family Consumption**		
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	cesd8	lfincome	cesd8	cesd8	lpce	cesd8
lnNTL	-0.305***	0.077***	-0.275***	-0.341***	0.079***	-0.322***
	(0.077)	(0.020)	(0.077)	(0.079)	(0.015)	(0.079)
lfincome			-0.385***			
			(0.012)			
lpce						-0.240***
						(0.015)
Sobel Test	*Mediator:* lfincome P = 0.000***			*Mediator:* lpce P = 0.000***		
Observations	124,144	124,144	124,144	117,316	117,316	117,316
R-squared	0.064	0.289	0.074	0.065	0.264	0.067

Note: All regressions include control variables, year fixed effects, and province fixed effects. *lfincome* and *lpce* exhibit different patterns of missingness. To identify the mediation effect of each mediator, columns 1–3 and 4–6 are estimated on different subsamples, using all observations with non-missing values for the corresponding mediator. The Sobel test evaluates the significance of the indirect effect. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5: Effect Table of Mediation Effect Regressions

Effect	**Effect Value**	**Std. Err.**	**P Value**	**Effect Proportion**
Total effect				
lfincome	-0.3047	0.0772	0.0001	–
lpce	-0.3414	0.0790	0.0000	–
Direct effect				
lfincome	-0.2749	0.0769	0.0004	90.22%
lpce	-0.3225	0.0789	0.0000	94.45%
Indirect effect				
lfincome	-0.0298	0.0079	0.0002	9.78%
lpce	-0.0190	0.0039	0.0000	5.55%

Note: Total effect is the overall effect of nighttime light on mental health from the regression without mediators (columns 1 and 4 of Table 4). Direct effect is the coefficient on *lnNTL* when the mediator is included in the regression (columns 3 and 6 of Table 4), capturing the part of the effect that does not operate through the mediator. Indirect effect is the difference between the total and direct effects and represents the portion of the *lnNTL* effect transmitted through the mediator.

Table 6: Results of Mediation Effects by Income Groups

	Family Income			**Family Consumption**		
VARIABLES	(1) cesd8	(2) lfincome	(3) cesd8	(4) cesd8	(5) lpce	(6) cesd8
Panel A: high income						
lnNTL	-0.324**	0.018	-0.321**	-0.433***	0.067**	-0.427***
	(0.131)	(0.021)	(0.131)	(0.132)	(0.026)	(0.132)
lfincome			-0.176***			
			(0.040)			
lpce						-0.088***
						(0.028)
Sobel Test		*Mediator:* lfincome P = 0.400			*Mediator:* lpce P = 0.048**	
Observations	34,037	34,037	34,037	33,760	33,760	33,760
R-squared	0.050	0.504	0.051	0.051	0.297	0.051
Panel B: low income						
lnNTL	-0.274***	0.090***	-0.242***	-0.287***	0.099***	-0.268***
	(0.095)	(0.022)	(0.094)	(0.098)	(0.018)	(0.098)
lfincome			-0.357***			
			(0.016)			
lpce						-0.186***
						(0.019)
Sobel Test		*Mediator:* lfincome P = 0.000***			*Mediator:* lpce P = 0.000**	
Observations	90,107	90,107	90,107	83,556	83,556	83,556
R-squared	0.071	0.361	0.078	0.072	0.278	0.073

Note: Panel A reports results for the high-income subsample, while Panel B reports results for the low-income subsample. All regressions include control variables, year fixed effect, and province fixed effect. Within each income group, *lfincome* and *lpce* exhibit different patterns of missingness. To identify the mediation effect of each mediator, columns 1–3 and 4–6 are estimated on different subsamples, using all observations with non-missing values for the corresponding mediator. The Sobel test evaluates the significance of the indirect effect. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7: Effect Table of Mediation Effect Regressions by Income Groups

Effect	**Effect Value**	**Std. Err.**	**P Value**	**Effect Proportion**
Panel A: high income				
Total effect				
lfincome	-0.324	0.131	0.014	–
lpce	-0.433	0.132	0.001	–
Direct effect				
lfincome	-0.321	0.131	0.014	99.03%
lpce	-0.427	0.132	0.001	98.63%
Indirect effect				
lfincome	-0.003	0.004	0.400	0.97%
lpce	-0.006	0.003	0.048	1.37%
Panel B: low income				
Total effect				
lfincome	-0.274	0.095	0.004	–
lpce	-0.287	0.098	0.003	–
Direct effect				
lfincome	-0.242	0.094	0.010	88.27%
lpce	-0.268	0.098	0.006	93.54%
Indirect effect				
lfincome	-0.032	0.016	0.000	11.73%
lpce	-0.019	0.004	0.000	6.46%

Note: For both high- and low-income individuals, total effect is the overall effect of nighttime light on mental health from the regression without mediators (columns 1 and 4 of Table 6). Direct effect is the coefficient on *lnNTL* when the mediator is included in the regression (columns 3 and 6 of Table 6), capturing the part of the effect that does not operate through the mediator. Indirect effect is the difference between the total and direct effects and represents the portion of the *lnNTL* effect transmitted through the mediator.

Table 8: Heterogeneous Effects of Nighttime Economy on Mental Health: North Season and Urban–Rural Subsamples

	Season in the North		**Region**	
VARIABLES	summer	other	urban	rural
lnNTL	-0.483***	-0.107	-0.199**	-0.460***
	(0.159)	(0.236)	(0.100)	(0.123)
age	0.017***	0.021***	-0.001	0.028***
	(0.001)	(0.002)	(0.001)	(0.001)
female	0.909***	0.682***	0.763***	0.964***
	(0.036)	(0.056)	(0.031)	(0.033)
hs	-0.805***	-0.726***	-0.649***	-0.788***
	(0.040)	(0.061)	(0.033)	(0.043)
familysize	-0.073***	-0.039***	-0.047***	-0.081***
	(0.010)	(0.015)	(0.009)	(0.008)
work	-0.116***	-0.303***	-0.066*	-0.414***
	(0.044)	(0.068)	(0.039)	(0.042)
married	-1.190***	-0.931***	-1.006***	-1.158***
	(0.055)	(0.076)	(0.045)	(0.048)
hosp_den	-2.235*	-6.998***	-0.551	-1.600*
	(1.152)	(1.929)	(0.883)	(0.946)
Constant	13.050***	8.673***	8.889***	12.454***
	(2.145)	(3.198)	(1.329)	(1.634)
Observations	52,969	20,303	61,978	63,083
R-squared	0.066	0.074	0.048	0.080
Chow Test LR chi2	170.09***		1472.05***	

Note: Columns 1–2 report subsample estimates for northern provinces in summer and other seasons, respectively. Columns 3–4 report subsample estimates for urban and rural areas. All regressions include year fixed effects and province fixed effects. Robust standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 9: Difference-in-Differences Estimates on the Mental Impact of Nighttime Economy

VARIABLES	(1) cesd8	(2) cesd8	(3) cesd8	(4) cesd8
highNTL×post	0.261***	0.251***	0.245***	0.235***
	(0.050)	(0.052)	(0.051)	(0.052)
age		0.015***		0.015***
		(0.001)		(0.001)
female		0.870***		0.871***
		(0.023)		(0.023)
hs		-0.780***		-0.781***
		(0.026)		(0.026)
familysize		-0.058***		-0.058***
		(0.006)		(0.006)
work		-0.099***		-0.098***
		(0.028)		(0.028)
married		-1.112***		-1.112***
		(0.033)		(0.033)
hosp_den			-1.199*	-1.306**
			(0.630)	(0.643)
covidnumber			0.021	0.022
			(0.014)	(0.014)
Constant	5.374***	5.762***	5.643***	6.051***
	(0.015)	(0.063)	(0.144)	(0.159)
Observations	132,693	123,201	132,693	123,201
R-squared	0.028	0.065	0.028	0.066

Note: All regressions include province and year fixed effects. Column 1 does not include individual-level or province-level control variables. Columns 2 and 3 include only individual-level and province-level controls, respectively. Column 4 includes both individual-level and province-level control variables. Robust standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 10: Estimated Results Using Life Satisfaction as the Dependent Variable

VARIABLES	(1) life satisfaction	(2) life satisfaction	(3) life satisfaction	(4) life satisfaction
lnNTL	0.078***	0.033***	0.085***	0.138***
	(0.019)	(0.009)	(0.025)	(0.042)
Constant	1.967***	-0.162	-1.925***	-3.125***
	(0.244)	(0.119)	(0.308)	(0.506)
Observations	126,639	126,639	126,639	126,639
R-squared	0.086	0.072		

Note: All four specifications include control variables and province and year fixed effects. Column 1 reports OLS estimates using the original ordinal life-satisfaction measure. Columns 2–4 estimate a binary specification of life satisfaction (coded as 1 for respondents with original scores of 4 or 5, and 0 for scores of 1–3) using a linear probability model (LPM), a logistic model, and a probit model, respectively. Robust standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.