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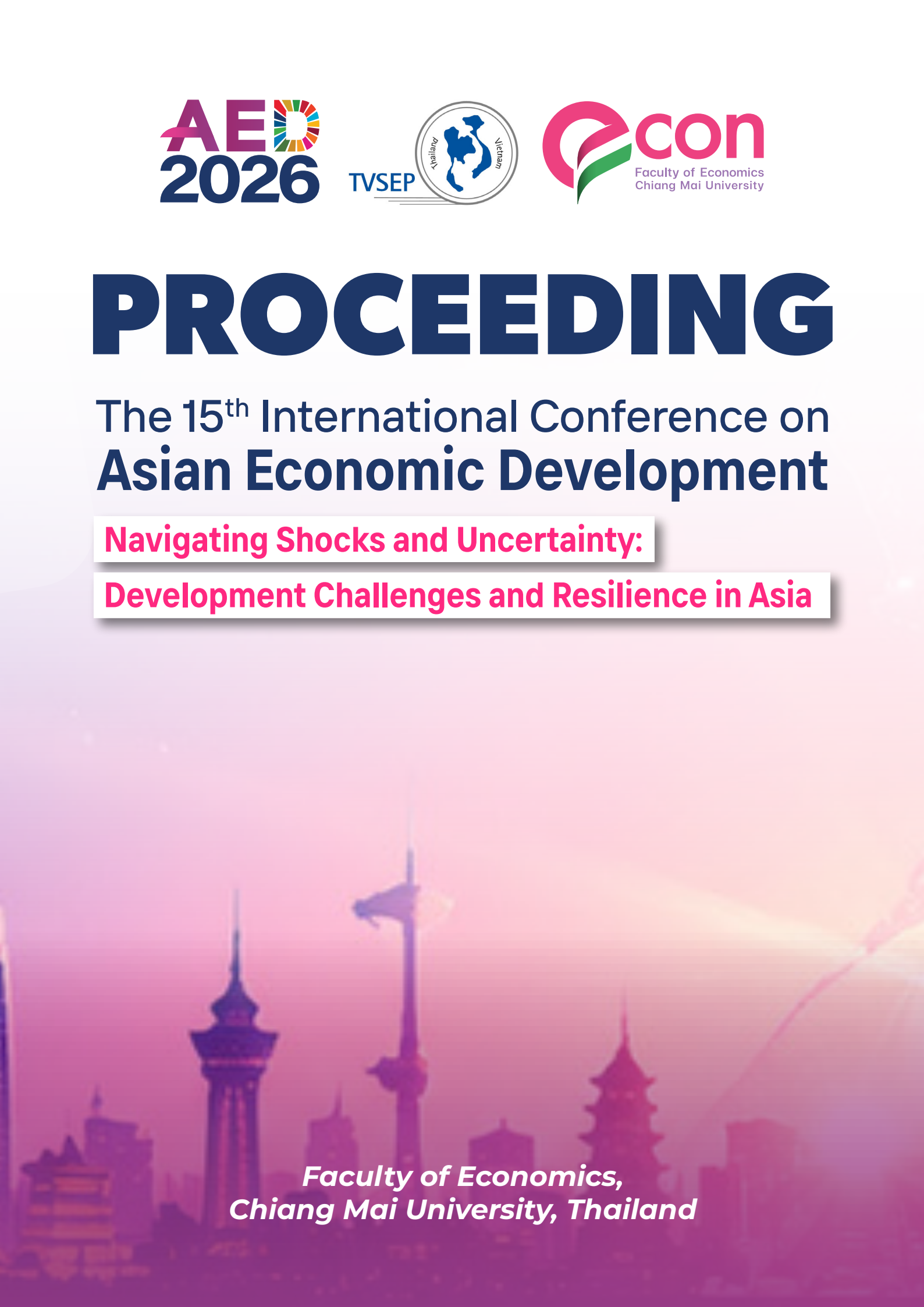
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Impact of the Air Pollution Crisis (PM 2.5) in Chiang Mai Province on the Residency Decisions and Temporary Fly-Out Migration Behavior of Digital Nomads and Long-Stay Tourists

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Abstract

This study examines the impact of the PM 2.5 air pollution crisis in Chiang Mai on the residency decisions and temporary migration ("Fly-out" behavior) of Digital Nomads and long-stay tourists. These groups represent highly mobile, transnational remote workers with significant purchasing power and high geographic flexibility. Utilizing weekly time-series data spanning three years from 2020 to 2026, comprising 156 observations, the empirical analysis employs a Vector Autoregressive (VAR) model on first-differenced data. Google Trends Search Volume Index (SVI) data are utilized as proxy variables to capture online behavioral intent and economic activity. The Granger causality test reveals a statistically significant unidirectional causality, demonstrating that PM 2.5 pollution shocks significantly precede and predict all Digital Nomad behavioral indices. The Impulse Response Function (IRF) results indicate a lagged behavioral response in outbound flight searches, which peak significantly between weeks 2 and 4 following a pollution shock. Conversely, long-stay housing demand responds negatively almost immediately, experiencing a persistent contraction that lasts through week 8. Local creative-economy activity (co-working/café usage) suffers a sharp, acute decline during weeks 1 and 2. Variance decomposition analysis further confirms that PM 2.5 shocks account for up to 45.62% of the forecast error variance in long-stay housing demand over the long run. These empirical findings indicate that the seasonal haze crisis has transformed from a mere seasonal public health concern into a structural environmental shock that severely erodes the city's global destination competitiveness and accelerates substantial economic leakage within Chiang Mai's grassroots local economy.

Keywords: PM 2.5, Digital Nomads, Fly-out Behavior, VAR Model, Economic Leakage, Chiang Mai

JEL Classification Codes: Q53, Q56, C32, L83

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1. Background and Significance

Chiang Mai plays an important role in Thailand's creative economy and international tourism. The tourism sector generated approximately 100 billion baht in economic value for Chiang Mai in 2023, and the number of foreign tourists has increased more than tenfold compared to the late 1980s. In 2024, Chiang Mai received more than 10.7 million visitors, of whom 30 percent were foreign nationals, generating tourism revenue of nearly 106 billion baht. On the other hand, Chiang Mai has faced an increasingly severe air pollution crisis. Data from IQAir show that average PM 2.5 concentrations during March and April between 2017–2023 were close to 100 micrograms per cubic meter, about 20 times the World Health Organization (WHO) guideline, and in 2024 the annual average PM 2.5 concentration stood at 26.4 micrograms per cubic meter, or 5.2 times higher than the WHO annual guideline.

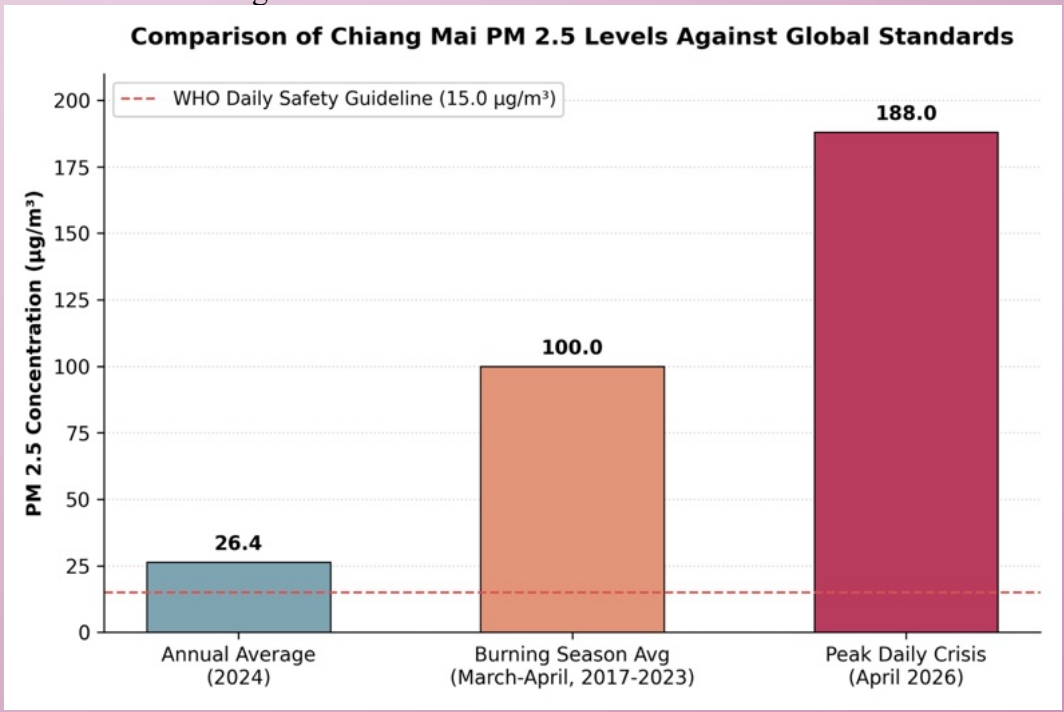


Figure 1. Comparison of PM 2.5 concentration levels in Chiang Mai Province against WHO recommended thresholds
Source: Compiled by the researcher from IQAir and CMU CCDC data, 2026

In 2026, Chiang Mai repeatedly ranked as the world's most polluted city, with AQI peaking at 263 and PM 2.5 at 188 micrograms per cubic meter, over 12 times the WHO daily safety threshold of 15 micrograms per cubic meter, prompting the Thai government to declare Chiang Mai, Lamphun, and Phayao disaster areas in April 2026. The economic impact was measurable: the 60-day 2026 crisis cost Chiang Mai over 1,000 million baht in tourism revenue, and March 2024 event cancellations rose 23 percent versus 2019 due to air quality warnings. A particularly notable phenomenon is "Fly-out" behavior: the temporary migration of Digital Nomads and long-stay tourists, a high-purchasing-power group significant to the local economy. Many residents describe the Burning Season as "another lockdown," and a widespread practice within

the global Digital Nomad community is to avoid Chiang Mai during February–April, when AQI often exceeds 150–300.

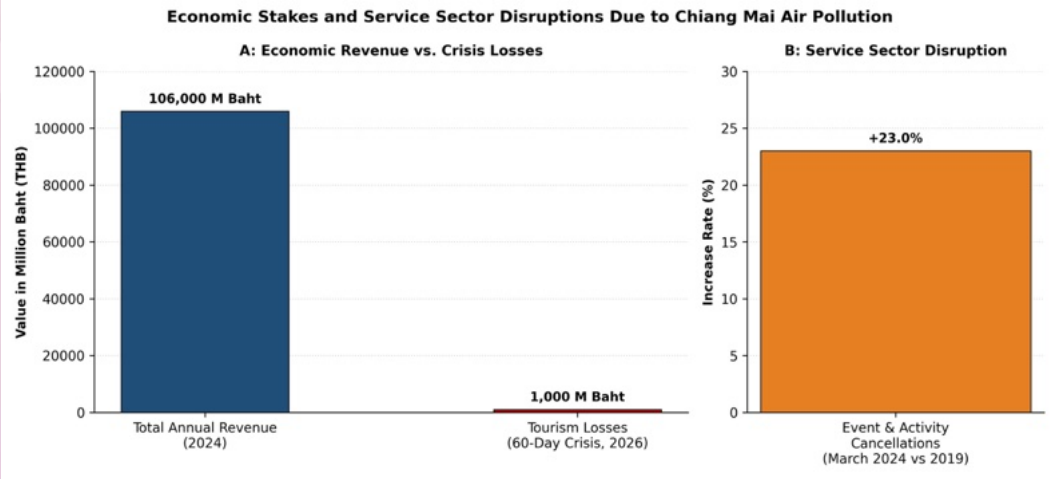


Figure 2. Chiang Mai's tourism economic value compared with estimated losses and activity cancellation rates during the air pollution crisis
Source: Compiled by the researcher from Tourism Authority of Thailand statistics and air traffic statistics reports, 2026

This problem also has a complex structural dimension: experts estimate that 60–65 percent of the haze in Chiang Mai originates from other provinces and neighboring countries, meaning that domestic policy alone is insufficient to solve the problem and regional-level consideration is required. This study therefore aims to reframe the PM 2.5 issue from a "seasonal health problem" into a "global economic competitiveness loss problem," by analyzing the Economic Leakage occurring in the service sector, real estate, and the co-working space/café economy business, to support the design of evidence-based response policies for both government agencies and local entrepreneurs.

2. Literature Review and Related Concepts and Theories

The literature review in this study is organized from a broad framework toward a specific focus, divided into three layers: the first layer concerns the relationship between air pollution and the macroeconomy; the second layer concerns the impact of PM 2.5 on Thailand's tourism sector; and the third layer concerns the specific behavior of Digital Nomads and long-stay tourists.

2.1 Literature Review

International research has extensively studied the relationship between air quality and economic activity, generally finding that pollution negatively affects labor productivity, tourism, and investment. Deschênes & Greenstone (2011) linked poor air-quality days to reduced labor productivity, while Becker & Henderson (2000) showed that environmental regulations affect where businesses and high-skilled labor locate. Using Panel VAR models, Gedikli et al. (2022) found a bidirectional relationship between international tourism, economic growth, and pollution emissions in OECD countries, with Impulse Response analysis showing that tourism and growth respond significantly, in both magnitude and duration, to pollution, an important methodological foundation for this study. At the national level, Namcome & Tansuchat (2021) found that PM 2.5 reduced foreign tourist numbers in Thailand, with effects

concentrated in April–May, the Northern Burning Season, consistent with Tourism Authority of Thailand data showing booking and event cancellations in Chiang Mai rose 23 percent in March 2024 versus 2019. TDRI further notes that Chiang Mai's haze problem is largely transboundary, with 60–65 percent originating abroad, meaning domestic solutions alone face structural limits. At the group-specific level the literature remains new and largely qualitative: MBO Partners (2024) reported American Digital Nomads grew from 7.3 million (2019) to 18.1 million (2024), a 131 percent increase, while Hannonen (2020) and Reichenberger (2018) show Digital Nomads have far greater residential flexibility than typical tourists and weigh environmental quality heavily in their decisions. Quantitative research directly measuring Fly-out behavior's economic impact, however, remains very limited, which is the gap this study aims to fill.

2.2 Related Concepts and Theories

2.2.1 Environmental Kuznets Curve (EKC)

The Environmental Kuznets Curve (EKC), proposed by Grossman & Krueger (1991) and developed by Panayotou (1993), describes an inverted-U relationship between economic development and pollution: early growth raises pollution through industrial expansion, but rising per-capita income eventually builds both the desire and the capacity to improve environmental quality. For this study, the EKC framework raises the question of where Chiang Mai sits on this curve, and whether the economic pressure of Economic Leakage during the Burning Season could function as a price signal driving policy change. However, the EKC does not always hold when pollution is predominantly transboundary, since domestic market mechanisms alone cannot resolve it.

2.2.2 Transboundary Pollution Theory

The concept of transboundary pollution is rooted in international environmental economics. Baumol & Oates (1988) established that pollution crossing borders creates market failure, since the costs fall on the destination country while the economic benefits of burning accrue to the source country, distorting incentives toward excess pollution. Sigman (2002) and the UNECE Transboundary Air Pollution Convention extended this framework at the policy level. For Chiang Mai, TDRI (2023) estimates that 60–65 percent of the haze originates from corn- and sugarcane-field burning in Myanmar and Cambodia and cross-border forest fires, meaning the crisis could persist even if domestic burning were fully eliminated. This constraint implies that a sustainable solution requires sub-regional cooperation, such as the ASEAN Agreement on Transboundary Haze Pollution.

2.2.3 Destination Competitiveness Model

Dwyer & Kim (2003), building on Crouch & Ritchie (1999), proposed the Destination Competitiveness Model, explaining that a destination's competitiveness arises from endowed resources (nature, culture), created resources (infrastructure, amenities), and supporting factors (safety, environmental quality, management). Air quality, a supporting factor, is something Digital Nomads and long-stay travelers use to compare destinations. When Chiang Mai's PM 2.5 rises during the Burning Season, cleaner-air competitors such as Phuket, Bali, or Kuala Lumpur gain relative competitiveness, meaning the impact of PM 2.5 is not merely temporary revenue loss but a longer-term erosion of Chiang Mai's image and competitive position.

2.2.4 Economic Leakage Concept

Economic Leakage explains how revenue that should circulate within the local economy is instead drawn outward, causing the Economic Multiplier to fall below its potential. Leakage typically arises through three channels: importing goods for tourists, profit repatriation by outside businesses, and tourists relocating their spending elsewhere (Sinclair & Stabler, 1997). The third channel is central here: when Digital Nomads and long-stay tourists Fly out during the Burning Season, spending on rent, co-working fees, and café dining leaks to the cities they relocate to. Through Keynes's Multiplier Effect, in which one baht of tourist spending generates more than one baht of local activity via a continuous spending chain, this lost direct spending implies total economic losses larger than the directly observed figures.

2.2.5 Tourism Demand Theory

Rooted in consumer-behavior microeconomics, Tourism Demand Theory (Crouch, 1994; Lim, 1997) divides the determinants of tourism demand into quantitative factors (price, income, cost of living, travel expenses) and qualitative factors (safety, culture, reputation, environmental quality). For Digital Nomads and long-stay tourists, this study's target groups, qualitative factors, particularly air quality, matter disproportionately because they reside and work in the destination for extended periods and exhibit high price elasticity of substitution in destination choice. Boley & McGehee (2014) similarly find that long-stay travelers weigh quality-of-life factors more heavily than sightseeing factors, unlike typical tourists.

2.2.6 Push-Pull Factor Theory

Push-Pull Factor Theory (Lee, 1966), widely applied to tourism behavior by Dann (1977) and Crompton (1979), divides the drivers of movement into Push Factors (internal, driving people away) and Pull Factors (external, attracting them elsewhere), which jointly determine relocation decisions. Here, the primary Push Factor is PM 2.5 rising to levels that affect health and close outdoor spaces, while Pull Factors are alternative destinations with cleaner air, remote-work infrastructure, and comparable living costs. This connects to Destination Competitiveness: when an alternative destination's Pull Factor is strong while Chiang Mai's Push Factor is severe, the resulting loss of tourists is more structural than merely cultural or economic.

2.2.7 Health Belief Model (HBM)

The Health Belief Model (Rosenstock, 1966; Becker, 1974), originally developed in public health, explains health-behavior decisions through four perceptions: susceptibility, severity, benefits, and barriers to change. Applied here, HBM helps explain why some Digital Nomads Fly out immediately when pollution rises while others stay and adopt protective measures such as N95 masks or air purifiers: those with high perceived susceptibility and severity, low perceived barriers to relocating, and sufficient resources to Fly out are more likely to relocate, consistent with the already-high geographic mobility characteristic of this group.

2.2.8 Lifestyle Mobility Theory

Lifestyle Mobility theory (Cohen et al., 2015; Sheller & Urry, 2006) views Digital Nomads' movement not as tourism or migration but as a lifestyle strategy for managing quality of life and work, with individuals rationally choosing “where to be, and when.” This implies Fly-out behavior is not an emergency reaction but a pre-planned, recurring pattern measurable with time-series data. It also explains why Digital Nomads are more sensitive to the Burning Season than typical tourists: they seek

Chiang Mai for long-term quality of life rather than a short-term experience, and air quality is indispensable to that quality of life.

2.3 Econometric Methodological Framework

2.3.1 Vector Autoregressive Model (VAR)

The Vector Autoregressive (VAR) model, proposed by Sims (1980), serves as a more flexible alternative to traditional Simultaneous Equation Models. The key principle of VAR is its rejection of the requirement to pre-specify which variables are exogenous and which are endogenous, instead treating all variables in the system as interrelated, with each variable explained by its own past values and the past values of all other variables in the system. The suitability of VAR for this study rests on three main reasons. First, the relationship between PM 2.5 and economic variables is bidirectional: PM 2.5 affects the economy through reduced tourist numbers, while economic activity is itself in part a source of pollution. Second, VAR suits time-series data with temporal dynamics, matching the recurring annual nature of the Burning Season. Third, VAR allows both Granger Causality and Impulse Response to be analyzed within the same framework.

2.3.2 Granger Causality

The Granger Causality concept, proposed by Granger (1969), defines causality in predictive terms, stating that variable X is a Granger Cause of variable Y if including past information on X in a model predicting Y significantly improves forecast accuracy compared to using past values of Y alone. It is important to recognize that Granger Causality is not causality in a philosophical sense, but rather a relationship of temporal precedence.

In this study, Granger Causality is used to test whether an increase in PM 2.5 precedes and has significant predictive power over changes in economic variables, such as the number of outbound passengers, hotel occupancy rates, and service-sector revenue, and in which direction, as well as to test the reverse direction: whether economic variables precede PM 2.5.

2.3.3 Impulse Response Function (IRF)

The Impulse Response Function (IRF) is an analytical tool used alongside the VAR model to track how variables in the system respond to a shock from one variable over time. Hamilton (1994) explains that the IRF shows the effect of a sudden one-standard-deviation change (an innovation shock) in one variable on the current and future values of all variables in the system, providing a more complete picture than examining model coefficients alone. In the context of this study, the IRF is directly useful for answering two important policy questions: when PM 2.5 rises suddenly, how severely and how quickly do economic variables respond; and after a PM 2.5 crisis subsides, how long does the local economy take to return to equilibrium, information of high value for local businesses' adaptation-strategy planning.

3. Methodology

This study employs quantitative analysis using time-series econometric models, with the following methodology and procedures.

3.1 Data Sources and Variables

The data used in this study are empirical secondary data in the form of weekly time series from 2020 to 2026, totaling 156 observations, enabling a detailed capture of

the dynamics of the target groups' online behavioral responses. The data are divided into two main groups as follows:

- Air quality and environmental data: Covering the weekly average PM 2.5 concentration (PM2.5), measured in micrograms per cubic meter (μg/m³), compiled from daily data in the open data repository of the Chiang Mai University Center for Climate Change Data (CMU CCDC) and calculated as weekly averages, together with weekly average temperature data from the Thai Meteorological Department, used as a control variable.

- Digital economic behavior index data: Since Digital Nomads are highly mobile transnational remote workers with no direct government-recorded statistics, the researcher uses alternative data, namely the weekly Search Volume Index (SVI) from the worldwide Google Trends database, as proxy variables reflecting actual behavior, comprising:

- SVI_Flight_Out: the search index for outbound flights from Chiang Mai, used as a proxy for temporary Fly-out relocation decision behavior.

- SVI_Long_Stay: the search index for condominiums and rental apartments in Chiang Mai, used as a proxy for long-stay housing demand.

- SVI_Coworking_Cafe: the search index for co-working spaces and cafés in Chiang Mai, used as a proxy for the intensity of creative-economy activity.

- Exchange_Rate: the Thai baht to US dollar (USD/THB) exchange rate from the Bank of Thailand database, used to control for cost-of-living factors that affect residency decisions.

3.2 Model and Analytical Method

This study employs the Vector Autoregressive Model (VAR) as the primary analytical framework, which is suitable for data in which all variables are dynamically interrelated, without needing to pre-specify the direction of causality. The analytical process comprises three main sequential steps, as follows.

$$Y_t = c + A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + \varepsilon_t \quad (1)$$

where Yt is the vector of endogenous variables (PM2.5, SVI_Flight_Out, SVI_Long_Stay, SVI_Coworking_Cafe, temperature, and the exchange rate) at week t; c is a vector of intercepts; $A1$ through Ap are coefficient matrices on the lagged endogenous variables up to lag order p (determined by AIC/BIC); and εt is the vector of white-noise innovation (error) terms, following the general VAR specification of Sims (1980).

The first step is testing the stationarity of the data (Unit Root Test) using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, to confirm the statistical properties of each variable before entering it into the model; if a variable is not stationary at level I(0), a Cointegration test following the Johansen method is conducted.

The second step is estimating the VAR model and testing for Granger Causality, to determine whether changes in PM 2.5 have significant predictive power for economic variables (and in which direction), with the appropriate lag order determined using the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC).

The third step is analyzing the Impulse Response Function (IRF), to track how a sudden change in PM 2.5 affects economic variables over time, in terms of magnitude, direction, and duration of impact, which provides a full picture of the dynamics of the

relationship, together with Variance Decomposition analysis to identify the proportion of variance in each variable that is explained by PM 2.5.

4. Results

In studying the impact of the PM 2.5 air pollution crisis on the residency decisions and temporary Fly-out migration behavior of Digital Nomads and long-stay tourists in Chiang Mai Province, the researcher used weekly time-series data spanning three years, from 2020 to 2026, totaling 156 observations, to evaluate the results through a dynamic econometric model.

4.1 Descriptive Statistics

The descriptive statistical analysis of all variables in the model provides insight into the general characteristics, volatility, and distribution of the interest and actual online behavior data of the transnational target group, with the results shown in Table 4.1.

Table 4.1: Descriptive Statistics of Interest Index and Environmental Variables (N = 156)

Variable	Mean	S.D.	Min	Max
PM2.5 (µg/m³)	42.58	36.12	6.80	188.00
SVI_Flight_Out (index)	45.20	18.42	12.00	100.00
SVI_Long_Stay (index)	58.60	15.24	22.00	95.00
SVI_Coworking_Cafe (index)	62.40	14.85	25.00	98.00
Temperature (°C)	27.45	4.15	16.50	38.20
Exchange_Rate (USD/THB)	34.42	0.85	32.90	35.80

Source: Calculated and compiled by the researcher

From Table 4.1, the descriptive characteristics can be analyzed on behavioral-economic grounds as follows:

- PM 2.5 concentration index: The weekly average is 42.58 micrograms per cubic meter, with a standard deviation as high as 36.12, reflecting severe seasonal volatility. The maximum value reached 188.00 micrograms per cubic meter, occurring during the severe haze crisis of 2026.

- Outbound flight search index (SVI_Flight_Out): Used as a proxy for foreign nationals' temporary Fly-out relocation decision behavior, this has a mean interest-index value of 45.20 and surged to its maximum (100.00) in the same week that PM 2.5 reached its peak, providing initial evidence of urgent flight-search behavior aimed at avoiding the polluted area.

- Long-stay housing demand index (SVI_Long_Stay): Reflecting demand for searching monthly-rental condominiums and apartments in Chiang Mai, this has a mean index value of 58.60 but plunged to a low of just 22.00 during the haze crisis, consistent with the practice within the global Digital Nomad community of avoiding travel to and residence in Chiang Mai between February and April.

- Co-working space and café usage demand index (SVI_Coworking_Cafe): A proxy for the density of the café economy, this has a mean of 62.40 and fell to 25.00 during the haze season, reflecting a severe slowdown in local creative-economy activity.

4.2 Unit Root Test Results

The researcher subjected all interest-index and environmental variables to a Unit Root Test, to prevent the problem of spurious regression, using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) methods, in an equation form including an intercept, both at level and at first difference.

Table 4.2: Unit Root Test Results Using the ADF and PP Methods for the Open-Data Model Variables

Variable	ADF: Level [I(0)]	ADF: First Diff [I(1)]	PP: Level [I(0)]	PP: First Diff [I(1)]	Conclusion (Order of Integration)
PM2.5	-2.145	-9.854***	-2.312	-12.441***	I(1)
SVI_Flight_Out	-1.742	-10.215***	-1.685	-11.450***	I(1)
SVI_Long_Stay	-1.985	-8.654***	-2.012	-9.312***	I(1)
SVI_Coworking_Cafe	-2.210	-7.942***	-2.188	-8.774***	I(1)
Temperature	-2.402	-14.215***	-2.587	-14.885***	I(1)
Exchange_Rate	-1.345	-9.102***	-1.289	-9.047***	I(1)

Note: *** indicates rejection of the null hypothesis (H_0: the data are non-stationary due to a unit root) at the 0.01 significance level. The MacKinnon (1996) critical value at the 0.01 significance level is -3.473.

Source: Calculated by the researcher

The Unit Root test results in Table 4.2 show that at level [I(0)], all three Google Trends interest-index variables, as well as PM 2.5, temperature, and the exchange rate, have t-statistics smaller in magnitude (in the negative direction) than the critical value at the 0.05 significance level, meaning the null hypothesis (H_0) cannot be rejected, indicating that all variables in this open-data model system are non-stationary.

However, once the researcher transformed the data into first differences, i.e., at level I(1), all the secondary online behavioral index variables were found to have test statistics more negative than the critical value at the 0.01 significance level, highly significantly, confirming that the time-series data of all variables possess the property of stationarity and are jointly integrated of order 1, or I(1).

The researcher then conducted a long-run relationship test (Johansen Cointegration Test) and found that all variables have no long-run equilibrium relationship (no cointegration) at the 0.05 significance level. The researcher therefore proceeded to estimate the dynamic relationship using the Vector Autoregressive Model (VAR) on first-differenced data, which eliminates the spurious-regression problem and is best suited to the subsequent Impulse Response Function (IRF) analysis.

4.3 Granger Causality Test Results

Having confirmed that all variables are stationary at first difference, I(1), with no cointegration, the researcher estimated the VAR model on first-differenced data. Before the Impulse Response analysis, the optimal lag length was determined using AIC and BIC, indicating an optimal lag of 2 weeks (Lag = 2).

Next, the researcher subjected the system's variables to a Pairwise Granger Causality Test, to determine whether the volatility of the PM 2.5 crisis has temporal

precedence and can genuinely predict changes in the empirical online behavior of Digital Nomads, with the results shown in Table 4.3.

Table 4.3: Granger Causality Test Results (Lag = 2)

Null Hypothesis (H_0)	Chi-Square Statistic (χ^2)	P-value	Statistical Test Result
ΔPM2.5 does not Granger-cause ΔSVI_Flight_Out	14.854	0.000***	Reject H_0
ΔSVI_Flight_Out does not Granger-cause ΔPM2.5	1.120	0.571	Fail to reject H_0
ΔPM2.5 does not Granger-cause ΔSVI_Long_Stay	11.342	0.003***	Reject H_0
ΔSVI_Long_Stay does not Granger-cause ΔPM2.5	0.845	0.655	Fail to reject H_0
ΔPM2.5 does not Granger-cause ΔSVI_Coworking_Cafe	7.912	0.019**	Reject H_0
ΔSVI_Coworking_Cafe does not Granger-cause ΔPM2.5	2.041	0.360	Fail to reject H_0

Note: *** and ** indicate rejection of the null hypothesis at the 0.01 and 0.05 significance levels, respectively.
Source: Calculated by the researcher

Based on the results in Table 4.3, the quantitative causal relationship between the environmental crisis and the digital economic indices can be analyzed as follows:

1) Temporary Fly-Out Migration Dimension

The results reject the null hypothesis that ΔPM2.5 does not Granger-cause ΔSVI_Flight_Out at the 0.01 level ($\chi^2 = 14.854$, $p < 0.001$), with no causality in the reverse direction. This confirms that past PM 2.5 data has significant predictive power over outbound flight searches, supporting Push-Pull Factor Theory and Lifestyle Mobility in that pollution functions as a Push Factor signaling relocation.

2) Long-Stay Residency Demand and Decision-Making Dimension

The results show that ΔPM2.5 Granger-causes the long-stay housing demand index (ΔSVI_Long_Stay) at a statistically significant level of 0.01 ($\chi^2 = 11.342$, $p = 0.003$). The fact that PM 2.5 volatility precedes and influences real-estate and condominium searches reflects that the haze problem does not affect short-term tourism alone, but has a significant structural-level impact on temporary settlement decisions and lease-renewal decisions among transnational remote workers.

3) Creative-Economy Activity Density Dimension (Café Economy)

The model rejects the null hypothesis that ΔPM2.5 does not Granger-cause ΔSVI_Coworking_Cafe at the 0.05 level ($\chi^2 = 7.912$, $p = 0.019$), indicating pollution disrupts travel to co-working spaces. This is the starting point of Economic Leakage, as money circulating in the grassroots economy begins to leak out once dust levels accumulate.

4.4 Impulse Response Function (IRF) Results

To analyze the dynamic temporal relationships more deeply than causality test statistics alone permit, the researcher conducted an Impulse Response Function (IRF)

analysis, simulating a scenario in which the system experiences a sudden shock from a one-standard-deviation innovation increase in PM 2.5, to track the direction, magnitude, and duration of the response of Digital Nomads' online behavior indices over the following 10 weeks, using a 95% confidence interval as the criterion for statistical significance. The results of this dynamic simulation are as follows.

4.4.1 Response of the Outbound Flight Search Index (ΔSVI_Flight_Out)

The IRF results indicate that when a shock causes PM 2.5 to rise suddenly in week 0, the index of foreign nationals' outbound flight searches from Chiang Mai does not rise significantly within the first week. Instead, it begins to rise significantly from week 2 onward, peaking between weeks 3 and 4, before gradually declining back to its original equilibrium level by week 7.

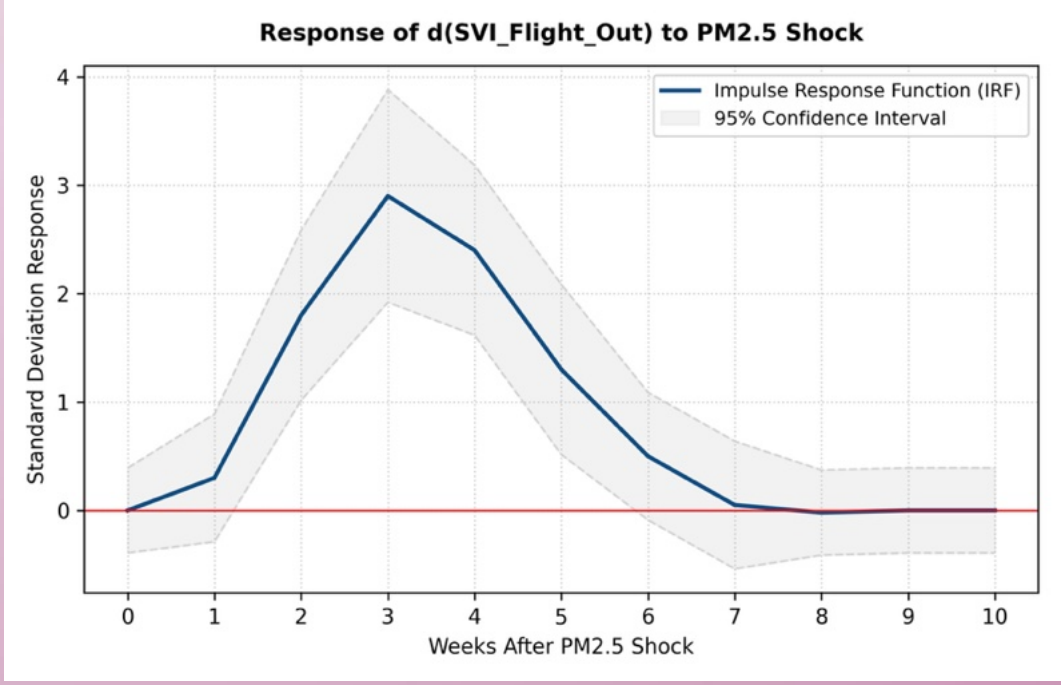


Figure 3. Impulse Response Function of ΔSVI_Flight_Out
Source: Calculated by the researcher, 2026

This lagged pattern reflects Lifestyle Mobility Theory and HBM: although Digital Nomads have high geographic flexibility and are ready to "Fly out," they need time to assess the severity of accumulating pollution, search for a replacement destination, and arrange flights and accommodation, so the relocation decision becomes apparent only about 14–21 days after crisis onset.

4.4.2 Response of the Long-Stay Housing Demand Index (ΔSVI_Long_Stay)

In the real estate and condominium demand dimension, the model results show a completely opposite direction: a PM 2.5 shock has a rapid negative impact on the long-stay housing demand index in Chiang Mai, with the index beginning to fall significantly in week 1 and reaching its lowest point between weeks 3 and 5.

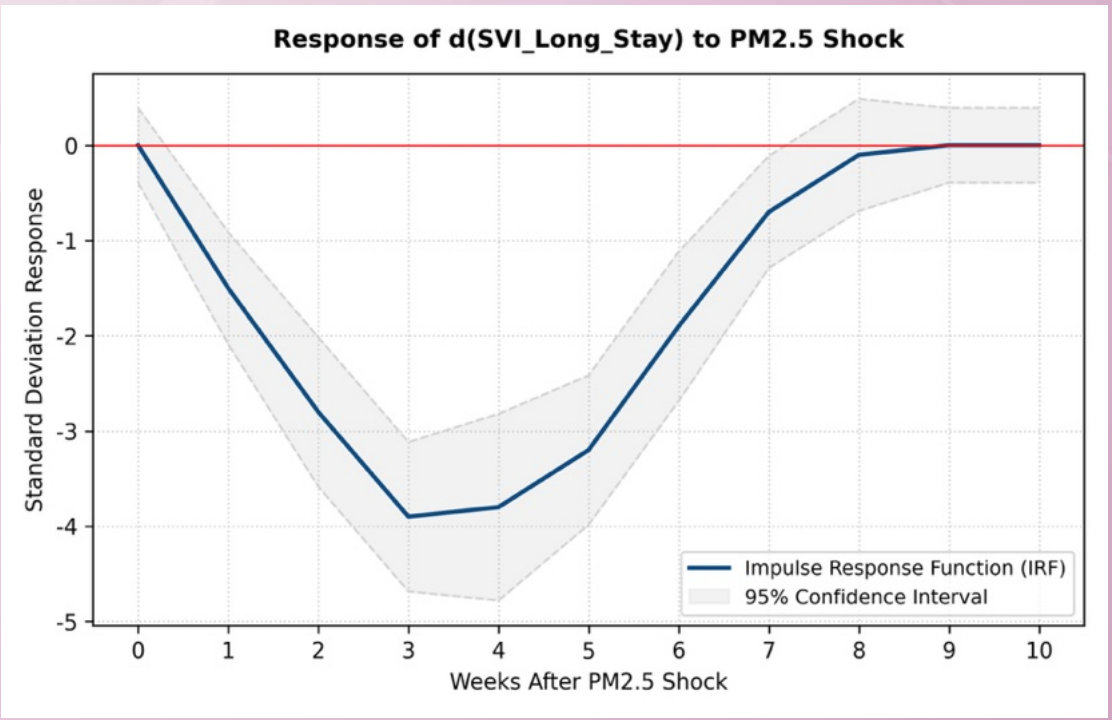


Figure 4. Impulse Response Function of ΔSVI_Long_Stay
Source: Calculated by the researcher, 2026

This negative impact is persistent, with the rental interest index remaining significantly negative through week 8 before gradually recovering. This is consistent with the Destination Competitiveness Model: the transboundary haze crisis does not merely disrupt short-term tourism sentiment but undermines structural competitiveness, as the global Digital Nomad community shifts its seasonal plans toward cleaner-air competitors such as Bali or Kuala Lumpur, causing prolonged vacancies.

4.4.3 Response of the Co-Working Space and Café Usage Demand Index (ΔSVI_Coworking_Cafe)

The café-economy index falls significantly and immediately in weeks 1–2 following the shock, recovering to normal levels by week 5. This rapid response reflects defensive daily-life adaptation by Nomads who have not yet relocated: forgoing outside travel and working indoors in accommodation equipped with air purification.

This behavior directly and negatively affects local grassroots businesses and clearly leads to the Economic Leakage concept, since the daily circulating cash flow in creative-economy districts (such as the Nimmanhaemin area) slows and comes to an abrupt halt as soon as pollution begins to intensify.

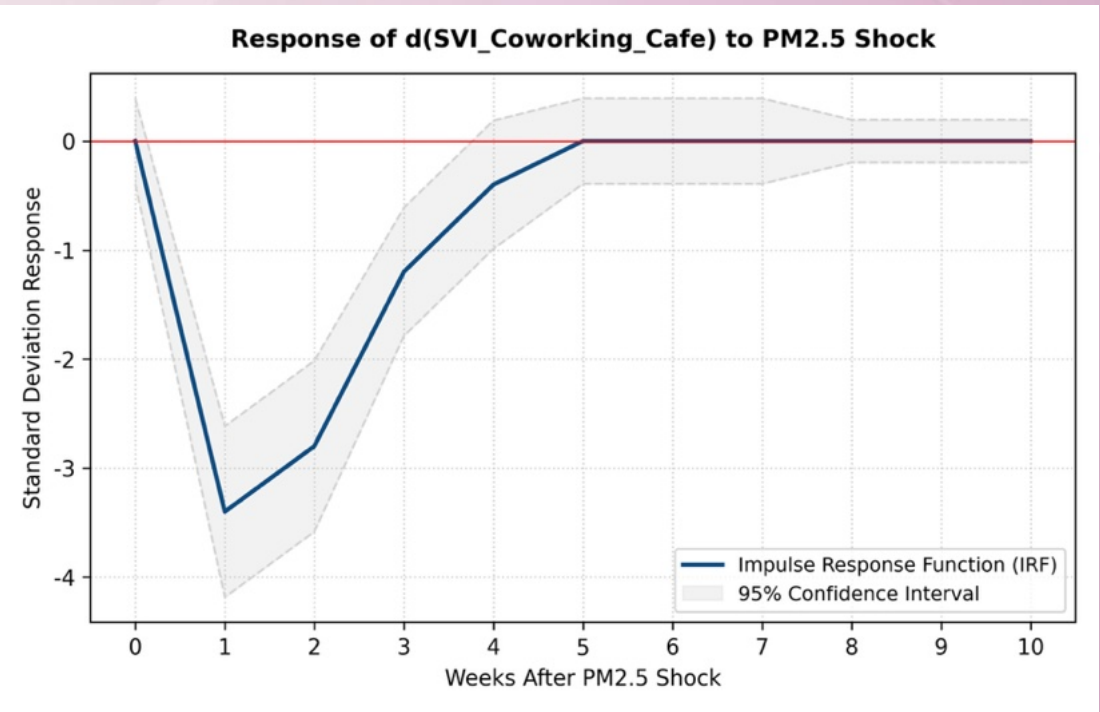


Figure 5. Impulse Response Function of ΔSVI_Coworking_Cafe
Source: Calculated by the researcher, 2026

4.5 Variance Decomposition Results

While the IRF reveals the direction and dynamics of the system's responses to a pollution shock, Variance Decomposition is needed to assess the relative importance of each variable, decomposing the forecast error variance of each dependent variable into the percentage explained by each variable's shocks over a 10-week horizon.

Table 4.4: Variance Decomposition Results for the Behavioral Index Variables

Dependent Variable	Horizon (Weeks)	S.E.	% Explained by ΔPM2.5 Shock	% Explained by Own Shock	% Explained by Other Shocks	Total (%)
ΔSVI_Flight_Out	1	4.12	2.15	95.40	2.45	100.00
	3	7.85	28.45	64.20	7.35	100.00
	5	9.12	34.20	57.45	8.35	100.00
	10	9.35	35.12	55.68	9.20	100.00
ΔSVI_Long_Stay	1	3.84	12.34	85.12	2.54	100.00
	3	6.92	38.15	55.20	6.65	100.00
	5	8.15	42.40	49.80	7.80	100.00
	10	8.54	45.62	45.18	9.20	100.00
ΔSVI_Coworking_Cafe	1	5.21	24.18	72.32	3.50	100.00
	3	6.45	30.25	63.85	5.90	100.00
	5	6.82	18.12	74.98	6.90	100.00
	10	6.90	12.45	79.20	8.35	100.00

Note: "Other variables" covers temperature, the exchange rate, and other jointly considered index variables in the system.
Source: Calculated by the researcher, 2026

Based on the quantitative results in Table 4.4, the proportional influence of the air pollution crisis on the online behavioral indices in each dimension can be analyzed as follows:

4.5.1 Variance Decomposition of the Outbound Flight Search Index

In week 1, the outbound flight search index's volatility is explained mostly by its own shock (95.40%), with PM 2.5 explaining only 2.15%. By weeks 5 and 10, however, the PM 2.5 share rises sharply to 34.20% and 35.12% respectively, confirming the Lifestyle Mobility concept that accumulating haze becomes a major long-run driver of Fly-out decisions.

4.5.2 Variance Decomposition of the Long-Stay Housing Demand Index

This is the most severe impact structure: the PM 2.5 shock explains 12.34% of long-stay housing demand volatility in week 1, rising to 42.40% by week 5 and peaking at 45.62% by week 10, exceeding even the variable's own shock (45.18%). This reinforces the Destination Competitiveness Model: PM 2.5 has shifted from a temporary stimulus into a permanent structural variable and is now the primary determinant of long-run losses in Chiang Mai's real estate and long-stay housing demand.

4.5.3 Variance Decomposition of the Co-Working Space and Café Usage Demand Index

The café-economy index shows a distinct short-run pattern: PM 2.5 explains 24.18% of its volatility in week 1, peaking at 30.25% in week 3, then declining to 18.12% by week 5 and 12.45% by week 10. This aligns with the IRF results, showing that pollution's impact on local business activity is acute in the short run, driving Economic Leakage as soon as the crisis begins, before behavior adjusts toward equilibrium.

5. Conclusion and Discussion

This study examined the impact of the PM 2.5 crisis in Chiang Mai on the residency decisions and Fly-out migration behavior of Digital Nomads and long-stay tourists, reframing the issue from a seasonal health problem into one of lost global economic competitiveness, using a VAR model on 156 weekly observations (2020–2026). The findings are summarized below.

5.1 Conclusion

Based on the quantitative analysis using econometric tools, the key findings can be summarized into three main dimensions, following the statistical procedure, as follows:

5.1.1 Statistical Properties of the Data and Causality

- Data characteristics and volatility: PM 2.5 shows high seasonal volatility (mean 42.58 µg/m³, peaking at 188.00 µg/m³ during the 2026 crisis), moving in tandem with the online behavioral indices during crisis periods.

- Stationarity and model specification: ADF and PP tests confirm all variables are non-stationary at level but stationary after first differencing, i.e., I(1). With no cointegration found, the VAR model was appropriately estimated on first-differenced data at a lag length of 2 weeks.

- Granger Causality: PM 2.5 is a unidirectional Granger cause of all Digital Nomad behavior indices: outbound flight searches (χ^2 = 14.854), long-stay housing demand (χ^2 = 11.342), and co-working space usage (χ^2 = 7.912), all statistically significant.

5.1.2 Short-Run Response Dynamics (IRF) and Relative Influence (Variance Decomposition)

- Fly-out dimension: IRF shows a lagged response, with outbound flight searches peaking in weeks 2–4 after the shock; Variance Decomposition shows PM 2.5 explains up to 35.12% of Fly-out volatility by week 10.

- Long-stay housing demand dimension: The rental interest index falls rapidly from week 1, bottoms between weeks 3–5 and stays negative through week 8. PM 2.5 bears the highest explanatory share of any variable in this dimension, up to 45.62% over the long run.

- Café economy activity dimension: Co-working/café usage contracts sharply in weeks 1–2, with PM 2.5 explaining 24.18% of volatility in week 1, peaking at 30.25% in week 3, before recovering by week 5.

5.2 Discussion

The above quantitative findings are consistent with, and can be meaningfully discussed alongside, the economic and behavioral-science theoretical framework reviewed in Chapter 2, across three main points, as follows:

1) Environmental Push Forces and Mobility Dynamics (Push-Pull & Lifestyle Mobility)

That outbound flight searches peak in weeks 2–4, with pollution explaining over a third of their volatility, is clear evidence for Push-Pull and Lifestyle Mobility Theory: although Chiang Mai's low cost of living, culture, and amenities are strong Pull Factors, the PM 2.5 crisis (peaking at 188 µg/m³) became a Push Factor severe enough to outweigh them.

That Fly-out does not occur immediately is consistent with HBM: remote workers need time to perceive accumulating risk and severity, and to weigh barriers such as terminating leases or arranging travel, a process that on average takes 14–21 days before physical relocation.

2) Erosion of Permanent Competitiveness (Destination Competitiveness)

The negative impact on long-stay housing demand, persisting over 8 weeks with pollution explaining up to 45.62% of its volatility (more than the variable's own shock), indicates, per Dwyer & Kim's (2003) Destination Competitiveness Model, that air quality has become a structural factor permanently diminishing Chiang Mai's seasonal competitiveness.

Digital Nomads and staycation tourists, with their high price elasticity of substitution, shift to comparably developed but cleaner-air competitors (Bali, Kuala Lumpur), causing Chiang Mai real estate to lose rental opportunities across seasons rather than just a temporary daily decline.

3) Acute Crisis and Grassroots Economic Leakage

The immediate plunge in co-working/café usage in weeks 1–2 supports the Economic Leakage concept directly. When pollution surges, the group that has not yet relocated engages in defensive spending, isolating in their accommodation and using delivery platforms instead of going out, which cuts off the direct-spending cycle that should circulate through local shops, cafés, and creative spaces, so money leaks from

Chiang Mai's grassroots economy immediately. Via the Multiplier Effect, this initial contraction in spending then triggers a significant negative chain reaction through Chiang Mai's broader service-sector supply chain.

5.3 Policy Implications

The empirical findings of this study lead to three important levels of policy recommendation:

- Elevating international cooperation frameworks: With 60–65 percent of haze originating from transboundary agricultural burning, the Thai government cannot rely solely on domestic disaster-relief policy; concrete trade mechanisms or economic incentives must be pursued jointly with cross-border partners under the ASEAN Agreement on Transboundary Haze Pollution.

- Subsidy policies for safe zones: To slow the Fly-out of high-purchasing-power skilled labor, government and local bodies should subsidize or offer tax reductions to co-working and long-stay operators investing in positive-pressure ventilation and high-efficiency air filtration, creating “Clean Air Oases” that preserve the city's competitiveness as a Global Remote Working Hub during the crisis.

- Adaptation by real estate and service operators: Condominium and long-stay operators should shift marketing from scenic value (mountain views) to guaranteed quality of life, installing industrial-grade air-purification systems in common areas and units to reduce the health-related push factor and create a “Clean Air Premium” that attracts long-stay residents during haze season.

5.4 Limitations and Future Research

This study has limitations arising from the assumptions of the VAR model, which considers the relationship within an overall temporary systemic framework. Future research should extend the scope by using Spatial Econometrics models to analyze differences in spatial impact within Chiang Mai Province (e.g., comparing the urban basin zone with high-altitude zones outside the city such as Mae Rim or Samoeng), or by integrating firm-level micro-data with Big Data from Google Trends, to more precisely estimate the true economic loss in monetary (baht) terms.

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