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The Impact of the Government's COVID-19 Restriction Policies on Human Mobility: Evidence from the United States

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Abstract:

Purpose – In responding to COVID-19, governments around the world have imposed various restrictions with different levels of success. One important aspect of pandemic control is the willingness of individuals to stay home when possible. The purpose of this paper is to study the impact of government restrictions on human mobility in the United States

Methodology/approach – Structural equation modelling is used to explore the issue. First, we use path regression analysis and factor analysis to identify the main factors that influence mobility. Second, we use total effect decomposition to investigate the deeper relationship between government restrictions and human mobility.

Finding – Two important findings are revealed First, the economic environment is the fundamental and direct factor affecting human mobility. There is a significant negative relationship between economic environment and human mobility, meaning that where economic conditions are bad mobility is greater. Second, government restrictions and the scale of the pandemic do not directly affect human mobility. Government restriction indirectly influences human mobility through economic environment as a mediating variable. Therefore, the economic environment has a significant mediating effect.

Originality/value – Existing literature lacks research on the mediating effect between government restrictions and human mobility. This paper provides new empirical evidence for the research topic by studying the mediating effect between government restrictions and human mobility. This provides policymakers with a more detailed picture of the processes through which policies operate.

Key words: Human mobility; COVID-19; Economic environment; Government restriction; mediating effect

1. Introduction

Governments around the world have attempted to limit the spread of COVID-19 in a variety of ways with varying levels of success. One important aim of pandemic policy has been to encourage people to stay home whenever possible. This goal can be pursued through a variety of means such as stay-at-home orders, social distancing rules which prevent mass gatherings, and travel limits. Past research has shown that COVID-19 policy impacts human mobility (Abouk and Heydari, 2020) and that human mobility impacts the spread of the virus (Nouvellet et al., 2021). Compliance with such policies will not be perfect, however, and it is worth considering the non-policy factors which influence human mobility during a pandemic. In this paper we analyze the impacts of government restrictions alongside the scale of the pandemic and the economic environment.

It is obvious enough how the severity of the pandemic and government restrictions might influence human mobility. Economic factors are also likely to play a role, as those in a precarious economic position may be forced out of the home for work even when the risk of infection is high or when restrictions are in place. Moreover, since economic conditions are influenced by government restrictions, we should expect to see a direct as well as an indirect impact of government policy on mobility. Restrictions may directly decrease mobility but indirectly increase it via their economic impacts.

In order to investigate the potentially complex relationships between government restrictions, the economic environment, and human mobility, we take a mediating variable approach. Mediating variables imply a mechanism that identifies and explains the observed relationship between independent and dependent variables. Through intermediating effect analysis, we can better understand the complex relationship between government restriction and mobility. Since government restrictions and the economic factors affecting mobility are each multifaceted, we use structural equation modelling to determine an appropriate empirical model.

This approach contributes to the prior literature linking government restrictions and human mobility in the context of the COVID-19 pandemic in two ways. First, by considering the direct and indirect effects of policy, this paper provides a deeper understanding of the mechanisms through which government policy operates. Secondly, the inclusion of economic factors provides a more reliable account of the impact of such policies.

2. Literature review

The existing literature on government restrictions during COVID-19 focuses on the impact of restrictions on the spread of COVID-19. Some studies directly examine the impact of government restrictive policies on the spread of COVID-19, while others indirectly illustrate the importance of government restrictive policies through the impact of human mobility on the spread of COVID-19.

McGrail et al. (2020) first demonstrated that the implementation of restrictive policies in U.S. states was negatively correlated with COVID-19 transmission rates, and that the decline in transmission rates was positively correlated with average changes in human mobility. They validated this observation on a global scale by analyzing COVID-19 transmission rates in 134 countries with different social distancing policies. They found that, globally, social distancing policies significantly reduced the rate of transmission of COVID-19. Tian et al. (2020) investigated the spread and control of COVID-19 in China using data sets including case reports, human activities, and public health interventions. They found that the Wuhan shutdown was linked to COVID-19 delays in other cities. Cities that introduced control measures earlier reported fewer cases in the first week of the outbreak, on average, than the cities that started control later. The suspension of public transport in cities, the closure of entertainment venues and the ban on public gatherings have had a significant impact on the reduction in cases. China's emergency response has limited the scale of the outbreak. Zhao et al. (2020) used instantaneous basic replication number to describe the change in transmission power of COVID-19 in 2019-2020 in China. They studied the change in transmission power of COVID-19 infection and its possible influencing factors. In addition, they selected Baidu Index (BDI) and Baidu Migration Scale (BMS) to measure the public's awareness and effect of the Wuhan lockdown strategy. They found that current restriction measures were effectively reducing the spread of the disease. However, instantaneous basic replication number is still greater than the threshold of 1. The Wuhan lockdown strategy adopted by the Chinese government has played an important role in rapidly controlling the potential infection in Wuhan, limiting the outflow of potentially infected people from the epidemic area, and preventing the spread of the virus throughout the country. At the same time, since 18 January 2020, people have been accessing information on COVID-19 via the Internet, which has helped to effectively implement the government's prevention and control strategy and reduce the transmission capacity of COVID-19. Therefore, continued travel restrictions and public health awareness remain critical to lay the foundation for containing the COVID-19 outbreak.

Zhang et al. (2020) investigated the interaction between age, contact patterns, social distancing, susceptibility to infection, and COVID-19 dynamics. They analyzed contact survey data from Wuhan and Shanghai before and during the outbreak, as well as contact tracing information from Hunan Province. They found a significant reduction in daily contact in China during COVID-19. Children and the elderly are more vulnerable to severe infections. The social distancing China implemented during the pandemic was enough to control COVID-19. Chen et al. (2020) studied the correlation between population migration scale index and the number of confirmed COVID-19 cases. They also described the effect of restricting population migration. They found that people who left Wuhan between January 9 and January 22 and Hubei province

between January 10 and January 24 were responsible for outbreaks in other parts of China. The lockdown of Wuhan and the initiation of a highest level response to this major public health emergency may have had a good effect in containing the COVID-19 outbreak. Djurovic et al. (2020) studied the response measures of the Serbian government in the early stage of the epidemic. He found that the maximum time for any restrictions to take effect was 15 days after they were implemented. As a result of the social behavior of citizens and the influx of diasporas returning to Serbia from severely affected areas, early government measures appear to have had only a modest impact in reducing the infectious growth, with the number of infected people maintaining an exponential increase. He believed that in the event of a similar outbreak, isolation and other social distancing measures should be introduced as soon as possible.

Salje et al. (2020) estimated the impact of French lockdown policy on population immunity. They found that across all age groups, men were more likely than women to be hospitalized, admitted to intensive care, and die. The lockdown has dramatically reduced the number of infections. They argue that if all control measures are released after the lockdown ends, the population's immunity does not appear to be sufficient to avoid a second wave. Tobias (2020) studied trends in event cases, deaths, and intensive care units (ICU) before and after lockdown in Spain and Italy. He found that after the first lockdown, morbidity trends dropped dramatically in both countries. However, the trend for future morbidity is still increasing. During the second wave lockdown, additional movement restrictions were implemented, and trends in daily event cases and ICU cases were changing in both countries. This improvement shows that the efforts that have been made (lockdown measures) are successfully flattening the epidemic curve. Zou et al. (2020) used a logistic growth model to review the growth and decline curves of epidemic viruses in China and summarize the outbreak dynamics. They found that the peak number of cases occurred, on average, 18 days after suppression began. China's containment of the disease has been successful, suggesting restriction policies are viable strategy to contain COVID-19. The results of Moosa's (2020) study suggest that social distancing is effective, although it is difficult to separate the effects of government measures from those of social distancing initiated by individuals. Sweden's empirical evidence shows that social distancing as an individual initiative is not enough to contain the virus. Brazil's empirical evidence shows that downplaying the virus can have serious consequences. Banerjee and Nayak (2020) analyzed the effectiveness of social distancing in the United States. They found that social distancing was effective in slowing the spread of COVID-19. Policy makers across the United States face difficult questions about the demand for and effectiveness of social distancing, and areas that have implemented these policies have actually increased social distancing and slowed the spread of COVID-19. These results may help policymakers inform the public about the risks and benefits of lockdowns. Alfano and Ercolano (2020) measured the effectiveness of lockdown measures over time from a longitudinal, cross-country perspective. They studied the impact of lockdown measures on the number of new infections by assessing them at the international level. Their results showed that the lockdown was effective in reducing the number of new cases compared to countries that did not impose it. This was particularly evident 10 days after the policy was implemented. Its effectiveness continued to grow within 20 days of implementation. The lockdown has been remarkably effective in reducing infection rates.

Yang et al. (2020) tracked and analyzed the development of COVID-19 in 100 cities in China. They found a significant positive and linear relationship between the proportion of people traveling from Wuhan to each city and the cumulative number of confirmed COVID-19 cases in each city after January 24. The average intensity of urban travel in the 100 cities dropped significantly compared to data collected on Feb 18, after the Chinese government implemented restriction policies. During the epidemic period, the average urban travel intensity of each city was positively correlated with the growth rate of confirmed cases and showed a significant linear relationship. Higher levels of human mobility are associated with higher incidence of COVID-19 during a pandemic. Restricting the movement of people can effectively contain the development of the epidemic. Wang et al. (2020) studied the relationship between human mobility and government restriction policies at the initial stage of the outbreak by using the data of confirmed COVID-19 cases in Australia and Google mobility data. They found that social restrictions implemented early in the epidemic were effective in controlling its spread; Movement restrictions have a time lag in the growth of COVID-19, with the correlation between movement and transmission increasing within 7 days after implementation and decreasing thereafter. The association between human mobility and the spread of COVID-19 varies over time and space and is influenced by the type of mobility. Beck and Hensher (2020) analyzed a series of longitudinal travel and activity surveys using Australian data. They found that during this period, tourism began to slowly return, with increased use of private cars, shopping, and social entertainment. They argue that working from home remains an important strategy for reducing travel and restricted transport networks today and in the future as the pandemic continues. Bonaccorsi et al. (2020) conducted a large-scale analysis using near-real-time mobile data from Italy provided by Facebook to investigate how lockdown strategies affect the economic situation of individuals and local governments. They found that the better the economic environment, the stronger the impact of government lockdowns. The shrinkage of human mobility was greater in cities with higher inequality and lower per capita income.

The studies above consider the direct impact of government restrictions on human mobility and COVID-19 transmission using a variety of empirical methods. These findings are important, but there is reason to think that government policy also has indirect effects. Mobility and COVID-19 spread depend not only on government policy but also on other social and economic variables. This paper investigates such indirect effects using mediating variables and structural equation modelling.

3. Methodology

There are four broad factors of interest which impact human mobility in a pandemic: economic environment, mental health status, the government restriction and epidemic scale. We will use a structural equation model (SEM) to study these four main variables. The structural equation model incorporates the regression model. Path model and confirmatory factor model are developed on the basis of their respective advantages (Schumacker & Lomax, 2016).

Our Data comes from the U.S. Household Pulse Survey Data (The experimental Household Pulse Survey is designed to quickly and efficiently deploy data collected on how people's lives have been impacted by the coronavirus pandemic). (Source: <https://www.census.gov/programs-surveys/household-pulse-survey/data.html>), U.S. CDC (Source: <https://data.cdc.gov/Case-Surveillance/United-States-COVID-19-Cases-and-Deaths-by-State-o/9mfq-cb36>) and the Oxford University of COVID-19 government response tracker (Source: <https://www.bsg.ox.ac.uk/research/research-projects/covid-19-government-response-tracker>). We use 51 states panel data to analysis. This is a database that is counted every two weeks. We used data from August 19, 2020, to July 5, 2021. Weekly data is converted into monthly data by frequency conversion method (In data processing, we found that monthly data could better pass the stationarity test than weekly data, although monthly data might reduce the sample size). Appendix Table 1 shows all data names and data sources.

3.1 Dependent Variables: Human mobility

We measure human mobility as our dependent variable. The four observed indicators, total number of people who are going trip (y_{tt_t}), number of people who are teleworking (y_{tele_t}), who are taking shopping trip as usual (y_{shop_t}) and who are not taking fewer trips by bus, rail, or ride-sharing services than normal (y_{ft_t}), are the three main features that have been used to measure human mobility. There is no reason not to suspect that more features of the human mobility may go uncounted or undiscovered. Therefore, we took the human mobility as a latent variable, denoted as PCA_{y_t} (We list the symbols for all variables in Appendix Table 2), and entered it into our model for analysis.

3.2 Control variable:

COVID-19 scale in this paper, denoting as $PCA_{COVID19_t}$. The scale or severity of the COVID-19 pandemic in an area can be defined in terms of two indicators: the number of new confirmed cases (CC_t) and the number of deaths (CD_t) as reported by the CDC. Since it is unclear to what extent mobility will respond to each of these indicators, we treat the scale of the pandemic as a latent variable. Using the method of principal component dimension reduction, it can be changed to an observed variable. When COVID-19 scale is large, rational governments should adopt strict restriction policies to avoid further spread of the virus. Therefore, $PCA_{COVID19_t}$ affect the dependent variable PCA_{y_t} in two ways: 1. Direct way: If COVID-19 grows (reduces) in scale, People are more willing to staying (leaving) home, because the health risk of going out increases (decrease). 2. Indirect: If COVID-19 grows (reduces) in scale, the government will implement (relax) lockdown policies of varying degrees to control the outbreak of COVID-19. People's willingness to leave home will decrease (increase) as the government tightens (relax) its policies.

In addition to reflecting the characteristics of the economic environment, the indicators used to measure the economic environment can also affect the dependent variables as control variables. human mobility depends directly on key economic indicators such as employment status, security, and household spending. These three dimensions will be discussed in the section 3.4.

We also include mental health status as a control variable, including anxiety (ANX_t), stress ($PRES_t$). These two indicators reflect the number of people feeling anxious and stressed during COVID-19. Anxiety and stress during a pandemic can be caused by a variety of factors (Moosa, 2020; Oum and Kun, 2020; Cullen, et al., 2020; Galea et al., 2020; Holmes, et al., 2020; Gollwitzer et al., 2021; Jackson et al. 2020; Schweizer et al., 2021). The most important one is the change of economic

environment such as rising debt, unemployment, not having enough food and so on. As we noted in our review of the literature, mental health factors can make people more eager to go outside. Using the principal component dimension reduction method, we changed the latent variable into an observed variable, denoting as PC_{mh_t} .

3.3 Independent Variable

The Oxford COVID-19 Government Response Tracker has tracked different policy responses in more than 180 countries since January 1, 2020, and compiled them into 23 indicators, such as school closures, travel restrictions, vaccination policies, etc. These policies are recorded on a scale to reflect the extent of government action and the scores are aggregated into a set of policy indexes. As a result, these indexes can accurately reflect the government restriction (Source: <https://www.bsg.ox.ac.uk/research/research-projects/covid-19-government-response-tracker>). Using the Stringency index from Oxford University, we obtain a set of observed indicators of government restriction: Stringency Index (SI_t), Stringency Legacy Index (SLI_t), Government Response Index (GRI_t) and Containment Health Index (CHI_t).

It is not hard to see that the government restriction is not observable, denoted PCA_{gov_t} . Using principal component factor dimension reduction method, A can be transformed into an observed variable. The government's response affects the economic environment. If the government adopts strict lockdown policies, including social distancing, working from home, closing entertainment venues, etc., there will be an economic downturn. For independent variables, we use the following equation to express their relationship:

$$\ln(PCA_{gov_t}) = \gamma_1 \ln(PCA_{eco_t}) + \gamma_2 \ln(PCA_{COVID19_t}) + \epsilon_t \quad (1)$$

Where PCA_{eco_t} represents economic environment (we will introduce the details in section 3.4). ϵ represents the white noise vector with 0 mean value and σ_ϵ variance.

3.4 Intermediating variable

Based on the previous statement, we assume the economic environment as a mediating variable to analyze the more complex relationship between government restriction policies and human mobility. If the indirect effect of the economic environment is significant, there is evidence that government restriction policies indirectly affect human mobility through the economic environment. The economic environment can be reflected by many indicators. The economic environment can't be measured; therefore, we also assume that the economic environment is a latent variable, denoted as PCA_{eco_t} , which can be reflected by multiple observed indicators. Using the same method, we transform it from a latent variable to an observed variable.

We made the following statements and assumptions for our measurement indicators. We use 13 indicators to illustrate the economic environment characteristics of the five dimensions: employment status (PC_{es_t}), food sufficiency (PC_{fs_t}), security (PC_{ss_t}), household mortgage (PC_{hm_t}) and household spending (PC_{s_t}).

Employment status (PC_{es_t}) mainly includes:

1. Individual's expected losing income in the next four weeks, denoted as EXP_{inc_t} ;
2. Individual was employed in the last 7 days, denoted as EMP_t ;
3. Individual has received Unemployment Insurance benefits, denoting as $UNEMP_{ins_t}$.

We counted whether food was sufficient (PC_{fs_t}), including:

1. The number of people who had had enough food at times in the past 7 days, denoting as $SUFF_{F_t^S}$
2. The number of people had not had enough food at all times in the past 7 days, denoting as $SUFF_{F_t^A}$.

Security (PC_{ss_t}) can be divided into health insurance (H_{ins_t}) and social insurance (SOC_{ins_t}). Social security refers to the number of people who apply for social benefit.

Household spending (PC_{s_t}) mainly include the number of people who are struggling to pay their household spending during COVID-19. Household spending can be further classified as $HOUS_{S_t^V}$ and $HOUS_{S_t^S}$: very difficult to pay and somewhat difficult to pay. We also consider the reason changing household spending because of concerned about going to public or

crowded places or having contact with high-risk people, $HOUS_{R_t^r}$. $HOUS_{R_t^E}$ for those who changed their household spending for economic reasons.

Household mortgage (PC_{hm_t}) is represented as the number of people who are confident that they will be able to repay their household mortgage in the next four weeks, which can be classified as $HOUS_{M_t^N}$ and $HOUS_{M_t^S}$. These main indicators of living can be reflected in the economic environment. However, the worse the economic environment, the more willing people are to go outside and trip. For example, when food is scarce, people will go out to buy food; When unemployment goes up and incomes go down, people go out and look for work; When the economic environment becomes better (worse), people will reduce (increase) their mental stress and anxiety. Defaulting on household mortgage also makes people decide to go out in search of income.

The relationship between the above dimensions and the economic environment can be expressed as the following equation:

$$\ln(PCA_{eco_t}) = \beta_1 \ln(PC_{es_t}) + \beta_2 \ln(PC_{fs_t}) + \beta_3 \ln(PC_{ss_t}) + \beta_4 \ln(PC_{hm_t}) + \beta_5 \ln(PC_{s_t}) + \beta_6 \ln(PC_{mh_t}) + \epsilon_t \quad (2)$$

Where β_i is the coefficient with i th dimension. ϵ is the white noise vector with 0 mean value and σ_ϵ variance.

Finally, in combination with our introduction of dependent variables, independent variables and intermediating variables, the relationship between dependent variables, independent variables and intermediating variables can be expressed as the following equation. We assume that the Cobb-Douglas function expresses the relationship between people attitude to taking trip LH_t and each variable $PCA_{COVID19_t}$, PCA_{gov_t} , PCA_{eco_t} , PC_{mh_t} , PC_{es_t} , PC_{ss_t} and PC_{s_t} .

$$PCA_{y_t} = PCA_{COVID19_t}^{\alpha_1} PCA_{eco_t}^{\alpha_2} PCA_{gov_t}^{\alpha_3} PC_{mh_t}^{\alpha_4} PC_{es_t}^{\alpha_5} PC_{ss_t}^{\alpha_6} PC_{s_t}^{\alpha_7} \theta_t \quad (3)$$

Where $\{\alpha_i\}_{i \in 1,2,3,4}$ is the contribution rate of each variable to LH_t . θ_t is the white noise with mean value 0 and variance σ_θ . After logarithmic processing of the equation (1), we get the following equation:

$$\ln(PCA_{y_t}) = \alpha_1 \ln(PCA_{COVID19_t}) + \alpha_2 \ln(PCA_{eco_t}) + \alpha_3 \ln(PCA_{gov_t}) + \alpha_4 \ln(PC_{MH_t}) + \alpha_5 \ln(PC_{es_t}) + \alpha_6 \ln(PC_{SS_t}) + \alpha_7 \ln(PC_{s_t}) + \theta_t \quad (4)$$

As for conclusion, our structural equations are as follows:

$$\begin{aligned} \ln(PCA_{y_t}) &= \alpha_1 \ln(PCA_{COVID19_t}) + \alpha_2 \ln(PCA_{eco_t}) + \alpha_3 \ln(PCA_{gov_t}) + \alpha_4 \ln(PC_{MH_t}) + \alpha_5 \ln(PC_{es_t}) + \alpha_6 \ln(PC_{SS_t}) + \alpha_7 \ln(PC_{s_t}) + \theta_t \\ \ln(PCA_{eco_t}) &= \beta_1 \ln(PC_{es_t}) + \beta_2 \ln(PC_{fs_t}) + \beta_3 \ln(PC_{ss_t}) + \beta_4 \ln(PC_{hm_t}) + \beta_5 \ln(PC_{s_t}) + \beta_6 \ln(PC_{mh_t}) + \epsilon_t \\ \ln(PCA_{gov_t}) &= \gamma_1 \ln(PCA_{eco_t}) + \gamma_2 \ln(PCA_{COVID19_t}) + \epsilon_t \end{aligned} \quad (5)$$

We thus posit four hypotheses as follows:

1. H_0 : There is a significant positive correlation between economic environment and human mobility.
2. H_0 : There is a significant negative correlation between government restriction and human mobility.
3. H_0 : There is a significant negative correlation between mental health and human mobility.
4. H_0 : There is a significant negative correlation between COVID-19 and human mobility.
5. H_0 : There is significant positive correlation among employment status, security, household spending and human mobility.

Second, we make the following hypothesis about the economic environment and government restriction :

H_0 : There is a two-way negative correlation between economic environment and government restriction .

Third, naturally, we make the following hypothesis about COVID-19 fatality rates versus the government restriction :

H_0 : There is a significant positive relationship between the COVID-19 scale and the government restriction .

Those hypotheses can answer our first research question: *What are the important factors that influence human mobility during COVID-19?*

We will answer our second research question by using the variance decomposition contributions and existence of intermediating effects. Firstly, we will analyze the contribution rate of each variable by factor score and variance decomposition. Secondly, we use direct effect, indirect effect, and total effect to analyze whether economic environment and government restriction directly affect human mobility. If there is a mediating effect in economic environment, we have clear evidence and a greater understanding of how the level of government restriction affects human mobility. Therefore, we propose the hypothesis of research question 2 as follows:

H_0 : There is a mediating effect between government restriction and human mobility.

4. Empirical results and their implications

4.1 Data description and processing

We make a statistical description of all observable indicators (Appendix Table 3). By calculating the mean and variance of these indicators, we make a preliminary analysis of these indicators. The overall variance of the data is small, and the fluctuation is relatively stable. The sample is stable over time and over region. The standard deviation of Y_1 is 0.09, which is smaller than that of other variables. It suggests that the frequency of trip is relatively stable, and it seems unaffected by COVID-19 and government restriction policies.

Because our data structure is panel data. Therefore, it is necessary to apply the unit root test into our sample to prevent the instability of time series. Appendix Table 4 shows the results of the unit root test. It is not difficult to find that at level, our data passed the unit root test in the 5% confidence interval. It means that we can use strong panel data to do modeling analysis over time, and we guarantee that there will be no spurious regression results in the regression analysis.

Further, for a more detailed description of the variables and indicators. We present the correlation test results among each group of variables. Bartlett test P value is 0.00, which significantly rejects the hypothesis of no correlation between indicators, indicating that each indicator is significantly correlated. The KMO test value is 0.949, which is a very good test value (Kaiser,1974). This shows that the indicators we choose have high commonality and can be used to measure common factors. The Cronhach's α reliability test coefficient is 0.968, which exceeds the critical value 0.7 (Kline, 2000). These three test results show that we can use these indicators for principal component factor analysis. Multivariate normal test significantly rejects the null hypothesis, which indicates that these variables do not satisfy the joint normal distribution hypothesis. Table 2 shows the correlation test results.

Table 1. Correlation test results

Type of test	Results
Bartlett test	$\chi^2 = 43913.752; p = 0.0000$
KMO test	0.949
Cronbach's α test	0.968
Multivariate normality test	$Mardia\ mSkewness = 86.79255$ $\chi^2(2925) = 8118.455; (P > \chi^2) = 0.0000$ $Mardia\ mKurtosis = 766.8425$ $\chi^2(1) = 871.621; (P > \chi^2) = 0.0000$ $Henze - Zirkler = 1.005533$ $\chi^2(1) = 4146.268; (P > \chi^2) = 0.0000$

4.2 Structure Equation model results

We use principal component factor analysis to further analyze each indicator to judge the objective classification of all indicators. Table 3 and Table 4 reflect the results of principal component analysis and factor analysis.

Table 2. Factor Analysis results

Indicator Type	Indicators	Factor F1 loading	Factor F2 loading	Factor F3 loading
Human mobility	y_{tt_t}	-0.067	0.004	-0.062
	y_{tele_t}	0.971	0.042	-0.024
	y_{shop_t}	0.927	-0.086	0.071
	y_{ft_t}	0.930	0.082	-0.071
Government restriction/restriction	SI_t	0.034	0.961	-0.099
	SLI_t	0.045	0.949	-0.110
	GRI_t	-0.013	0.947	0.057
	CHI_t	-0.005	0.977	0.026
COVID-19	CC_t	-0.021	-0.106	0.962
	CD_t	-0.017	0.004	0.966
Economic environment	EXP_{inc_t}	0.980	-0.035	0.034
	EMP_t	0.988	-0.014	0.009
	$UNEMP_{ins_t}$	0.940	0.079	-0.064
	$SUFF_{F_t^S}$	0.983	-0.011	0.003
	$SUFF_{F_t^A}$	0.947	-0.008	-0.005
	ANX_t	0.996	0.023	-0.018
	$PRES_t$	0.995	0.010	0.004
	H_{ins_t}	0.992	-0.011	0.009
	$HOUS_{M_t^N}$	0.949	0.012	-0.023
	$HOUS_{M_t^S}$	0.974	0.016	-0.004
	SOC_{ins_t}	0.988	-0.017	0.018
	$HOUS_{S_t^V}$	0.996	0.005	0.006
	$HOUS_{S_t^S}$	0.987	0.008	-0.011
	$HOUS_{R_t^T}$	0.967	0.088	-0.071
$HOUS_{R_t^E}$	0.987	0.042	-0.059	
Eigenvalues		17.05354	3.802367	1.968409
Proportion		0.6821	0.1521	0.0787
Cumulative Proportion		0.6821	0.8342	0.913

Based on the sample reliability and correlation matrix, factor analysis (Table 1) was adopted to solve the problem. According to the criterion that the eigenvalues should be greater than 1, the number of factors $m = 4$ was selected and the factor analysis results were obtained. It can be seen from Table 3 that the cumulative contribution of the four common factors to the original variable is 91.6%, indicating that dimension reduction is achieved through factor analysis. It is not difficult to find from Table 3 that the indicators representing the economic environment has a high loading on the common factor F1, which can be called the economic environment factor. The indicators representing government restriction has a high loading on F2, which can be called government restriction factor. Indicators representing the scale of COVID-19 have higher loading

on F3, which can be called COVID-19 factors. By observing the factor load after rotation, it can be found that the actual meaning of each factor is clearer.

More importantly, we can further analyze the attitude to taking trip indicator in the rotated factor loading. It is not hard to find that the maximum loadings of the four indicators in attitude to taking trip are 0.004, 0.971, 0.927 and 0.930 respectively. These indicate that the factors representing the economic environment and government restriction have the strongest explanatory power for the change of human mobility, that is, whether people are willing to leave home in the sample range is greatly affected by the economic environment and whether the government implements strict restriction policies, among which the economic environment plays a dominant role.

Through principal component factor analysis results, we further clarify the correlation between the indicators. In order to quantify these relationships, we use structural equation model to carry out path and regression analysis for each dimension and variable. Figure 1 shows the SEM model structure.

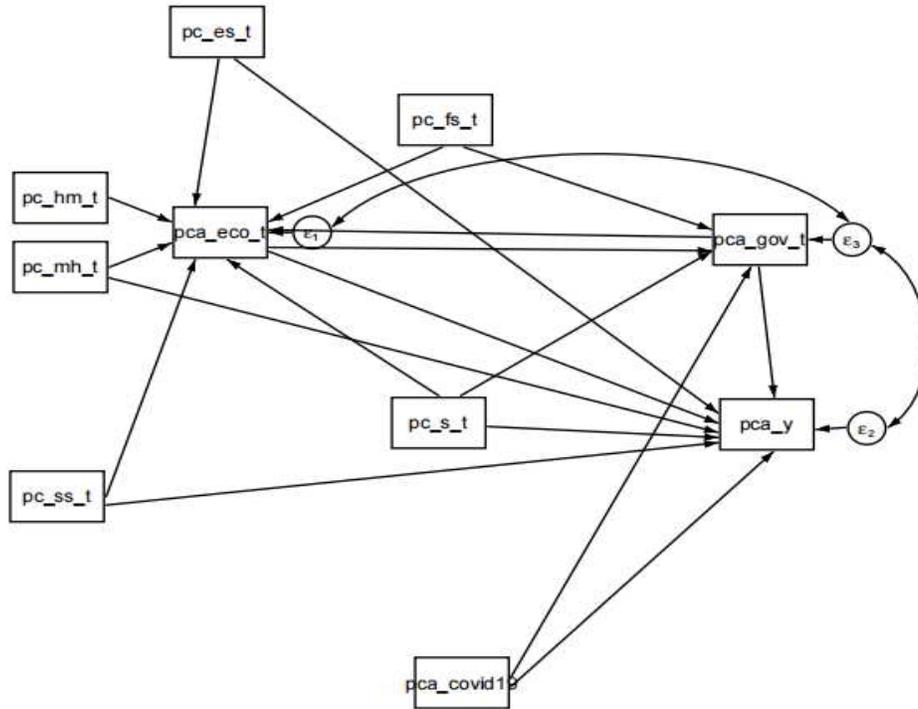


Figure 1. SEM model path structure

By using the maximum likelihood estimation, we obtain the total goodness of fit, the goodness of fit for each endogenous variable and the path regression coefficient estimation results in table 3. In the total goodness of fit, the absolute index $\chi^2(4)$, *SRMR* and *RMSEA* were 4.524, 0.015 and 0.001, respectively. relative fitting index *TLI* and *CFI* are 1. Key fitting index, *p* value of $\chi^2(4)$ and *RMSEA*, indicating that there is little difference between the theoretical model and the actual model. Therefore, the results of our model can be accepted and close to the actual model. In the goodness of fit for each endogenous variable, the R^2 for human mobility (PCA_{y_t}) and economic environment (PCA_{eco_t}) are 0.991 and 0.999 respectively, meaning that 99.1% and 99.9% of the variance for PCA_{y_t} and PCA_{eco_t} have been explained. For those two variables, our interpretation of them is comprehensive enough. However, for the government restriction (PCA_{gov_t}), its R^2 is only 0.286, meaning that 71.4% of its variance has not been explained, which may be due to random or systematic errors, or the existence of other variables that have not been included in the model.

Table 3. SEM model coefficient results and goodness of fitting

Structure	Variables and indicators	Coefficient
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<i>PCA_{eco_t}</i>	<i>PCA_{gov_t}</i>	-0.009*** (-2.91)
	<i>PC_{es_t}</i>	0.437*** (236.48)
	<i>PC_{fs_t}</i>	0.351*** (87.28)
	<i>PC_{hm_t}</i>	0.357*** (242.57)
	<i>PC_{mh_t}</i>	0.367*** (231.14)
	<i>PC_{s_t}</i>	0.538*** (78.51)
	<i>PC_{ss_t}</i>	0.366*** (232.61)
	<i>Constant</i>	-0.000 (-0.05)
<i>PCA_{y_t}</i>	<i>PCA_{eco_t}</i>	-0.317*** (-5.39)
	<i>PCA_{gov_t}</i>	0.000 (0.07)
	<i>PC_{es_t}</i>	1.081*** (15.53)
	<i>PC_{mh_t}</i>	0.108 (1.33)
	<i>PC_{s_t}</i>	0.272*** (3.58)
	<i>PC_{ss_t}</i>	0.237*** (3.00)
	<i>PCA_{covid19_t}</i>	0.001 (0.09)
	<i>Constant</i>	-0.000 (-0.04)
<i>PCA_{gov_t}</i>	<i>PCA_{eco_t}</i>	-1.142*** (-4.45)
	<i>PC_{fs_t}</i>	-0.712** (-2.38)
	<i>PC_{s_t}</i>	2.717*** (6.31)
	<i>PCA_{covid19_t}</i>	-0.020** (-2.18)
	<i>Constant</i>	-0.004 (-0.04)

Variance	$var(PCA_{eco_t})$	0.0002455
	$var(pca_{y_t})$	0.0511536
	$var(PCA_{gov_t})$	3.423597
Covariance	$cov(PCA_{eco_t}, PCA_{gov_t})$	0.029*** (2.83)
	$cov(pca_{y_t}, PCA_{gov_t})$	0.007** (2.32)
The goodness of fit for each endogenous variable		R²
PCA_{eco_t}		0.999
PCA_{y_t}		0.991
PCA_{gov_t}		0.286
Total		0.999

Total goodness of fit	Values
Likelihood ratio	
$\chi^2(4)$	4.524
$p > \chi^2$	0.34
Population error	
$RMSEA$	0.015
Baseline comparison	
CFI	1
TLI	1
Size of residuals	
$SRMR$	0.001
CD	1

Notes: *** denotes significance level at 1%, ** denotes significance level at 5%.

According to the coefficient estimation results in Table 3, there are four variables that have a significant impact on human mobility, namely economic environment, employment status, household spending and social security. Their coefficients are -0.317, 0.108, 0.272 and 0.237, respectively. The z-values of these coefficients all pass the test at the 5% significance level. Economic environment is negatively correlated with human mobility, that is, the worse (better) economic environment is, the more people want to leave (stay) home. However, we further found that in the PCA_{y_t} structure in Table 3, the government restriction had no significant impact on human mobility, and its z-value is 0.07, which do not pass the test at the significance level of 5%. At the same time, the impact of COVID-19 on people's travel was not significant, with a z-value of 0.09, which did not pass the test under the significance level of 5%. Table 4 conclusively answers the hypothesis of section 3.

Table 4. Hypothesis Judgment

H_0	True / False
There is a significant positive correlation between economic environment and human mobility.	TRUE
There is a significant negative correlation between government restriction and human mobility	FALSE
There is a significant negative correlation between mental health and human mobility.	FALSE
There is a significant negative correlation between COVID-19 and human mobility.	FALSE

There is significant positive correlation among employment status, security, household spending and human mobility.	TRUE
There is a two-way negative correlation between economic environment and government restriction	TRUE
There is a significant positive relationship between the COVID-19 scale and the government restriction	TRUE

In the coefficient estimation results of PCA_{eco_t} structure, except the constant term, all the other variables have significant influence on the economic environment. The six economic dimensions have significant positive impact on economic environment. In addition, it is worth noting that the variance of economic environment and people attitude to taking trip is small, indicating that the overall fluctuation of these two variables is not strong and relatively stable. The variance of government restriction is relatively large, indicating that it fluctuates violently. This is closely related to the containment of COVID-19 scale and the economic environment. When the COVID-19 death rate and new confirmed cases are under control, the government will relax restrictions to expand economic development.

Four control variables: PC_{est} , PC_{mht} , PC_{st} and PC_{sst} have a significant positive impact on the dependent variable PCA_{yt} . It is worth noting that these four variables also have a significant positive impact on the economic environment PCA_{eco_t} , while the economic environment has a significant negative impact on PCA_{yt} . To compare the significant effects of four control variables, we performed a *Wald* test on these control variables to see if there was a significant difference between the coefficients (which had the greater effect). Table 5 shows the Wald test results.

Table 5. Wald test results

Variables	Wald Test
$PC_{est} \rightarrow PCA_{yt}$ $PC_{est} \rightarrow PCA_{eco_t}$	$\chi^2 = 164.60$
$PC_{mht} \rightarrow PCA_{yt}$ $PC_{mht} \rightarrow PCA_{eco_t}$	$\chi^2 = 0.41$
$PC_{st} \rightarrow PCA_{yt}$ $PC_{st} \rightarrow PCA_{eco_t}$	$\chi^2 = 0.21$
$PC_{sst} \rightarrow PCA_{yt}$ $PC_{sst} \rightarrow PCA_{eco_t}$	$\chi^2 = 0.94$

Table 5 shows that the χ^2 value of PC_{mht} , PC_{st} and PC_{sst} do not pass the Wald test, thus, we accept the null hypothesis with significant difference, namely, PC_{mht} , PC_{st} and PC_{sst} significant effect on PCA_{yt} differs significantly from their significant effect on PCA_{eco_t} . χ^2 value of PC_{est} is 164.6, which can be accepted in Wald test. PC_{est} significant effect on PCA_{yt} differs significantly from its significant effect on PCA_{eco_t} .

Through the path regression results of SEM model, our first research question has been answered. Based on the background of the second research question, we find that the result of coefficient estimation of government restriction in PCA_{yt} structure seems to contradict our original conception about it. Furthermore, we find from the PCA_{eco_t} and PCA_{gov_t} structure coefficient estimation results in Table 3 that economic environment and government restrictions have significant two-way influence. There is a significant negative correlation between government restriction level and economic environment. If the government restriction level increases by one unit, the economic environment decreases by 0.009 units. When economic environment decreases by 1 unit, the government restriction level increases by 1.142 units. Because of the economic environment has significant influence on human mobility, while the government restriction has no significant influence on human mobility, and the economic environment and the government restriction have two-way significant negative correlation relationship, we give an important hypothesis: the government restriction is not a direct effect on human mobility,

but by the economic environment as the intervening variable indirectly effect human mobility. Based on the coefficient estimation results of SEM model, Table 6 shows the indirect, direct, and total effects of each variable.

Table 6. Effect decomposition coefficient results

PCA_{y_t}	Direct effect	Indirect effect	Total effect
PCA_{eco_t}	-0.317*** (-5.39)	-0.004 (-0.56)	-0.321*** (-5.46)
PCA_{gov_t}	0.001 (0.07)	0.003** (2.56)	0.003 (0.57)
PC_{est_t}	1.081*** (15.53)	-0.140*** (-5.46)	0.941*** (13.24)
PC_{fst_t}	No path	-0.115*** (-5.46)	-0.115*** (-5.43)
PC_{hmt_t}	No path	-0.115*** (-5.46)	-0.115*** (-5.46)
PC_{mht_t}	0.108 (1.33)	-0.118*** (-5.46)	-0.010 (-0.12)
PC_{st_t}	0.272*** (3.58)	-0.164*** (-4.81)	0.108** (1.96)
PC_{sst_t}	0.237*** (3.00)	-0.118*** (-5.46)	0.119* (1.65)
$PCA_{covid19_t}$	0.001 (0.09)	-0.000 (-0.58)	0.001 (0.08)
<hr/>			
PCA_{eco_t}			
PCA_{gov_t}	-0.009*** (-2.91)	-0.000 (-1.36)	-0.009*** (2.38)

Notes: *** denotes significance level at 1%, ** denotes significance level at 5% and * denotes significance level at 10%.

Table 6 shows two key pieces of information. First, economic environment has a significant negative influence on the dependent variable (PCA_{y_t}) under the direct effect, while its coefficient under the indirect effect does not pass the z-test under the significance level of 5%. The coefficient of the government restriction under the direct effect cannot pass the z-test under the significance level of 5%, while it has a significant positive influence on the dependent variable (PCA_{y_t}) under the indirect effect. Second, there are six dimensions that reflect the characteristics of economic environment: employment status (PC_{est_t}), food sufficiency (PC_{fst_t}), security (PC_{sst_t}), household mortgage (PC_{hmt_t}), household spending (PC_{st_t}) and mental health (PC_{mht_t}). Under the indirect effect, all of them have a significant negative influence on the dependent variable (PCA_{y_t}). The first piece of information is important because it reveals a more complex relationship between economic conditions, government restriction and human mobility. By decomposing the effects of path, we came to an important conclusion: government restriction has no direct effect on human mobility. It indirectly influences people to leave home through the economic environment. The economic environment has a direct impact on human mobility, that is, the underlying reason human mobility is because the economic environment is worse. Combined with the path coefficient estimation results in Table 3, government restriction has a significant negative two-way relationship with economic environment. We further draw another important conclusion: government restriction has a positive impact on human mobility, that is, the higher the level of government restriction, the more inclined people are to leave home. We completed the answer to the second research question: government restriction is through indirect effects affecting human mobility. Government restriction indirectly influenced human mobility through economic environment as a mediating variable. Figure 2 shows the influence path.

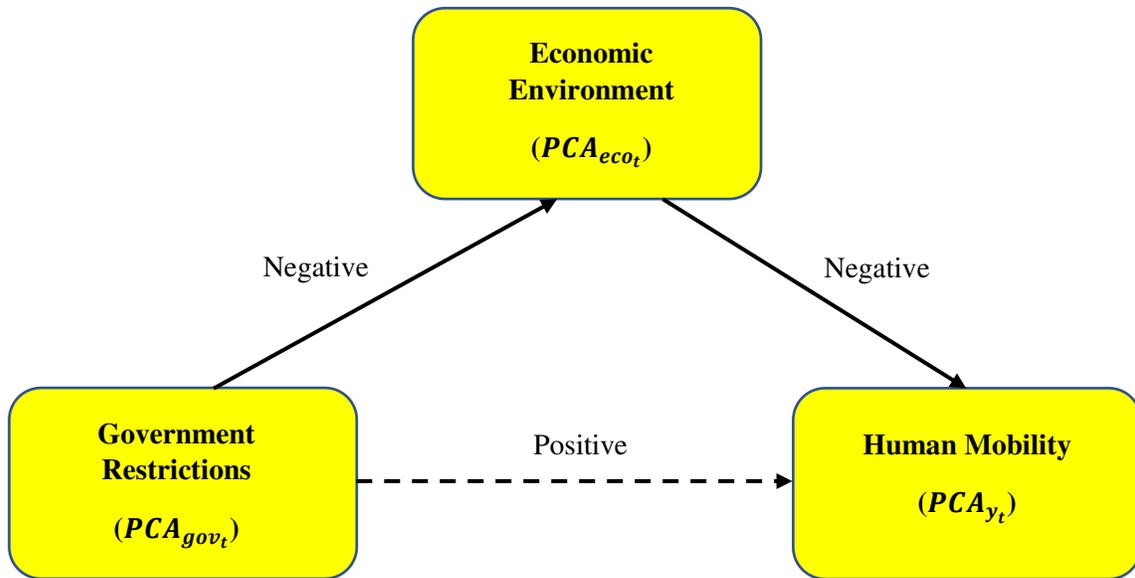


Figure 2. Influence path and relationship among the three variables

If we look directly at the relationship between government restriction and human mobility, there is conflict with our economic intuition. The results also explain why some citizens in many countries ignore government restrictions. The positive relationship between government restriction and human mobility is precisely because of the existence of economic environment as a mediating variable. Using the SEM model, we made predictions about human mobility. Let prediction sequence as PRD_{y_t} . Figure 3 shows a comparison of the predicted results with the actual sample.

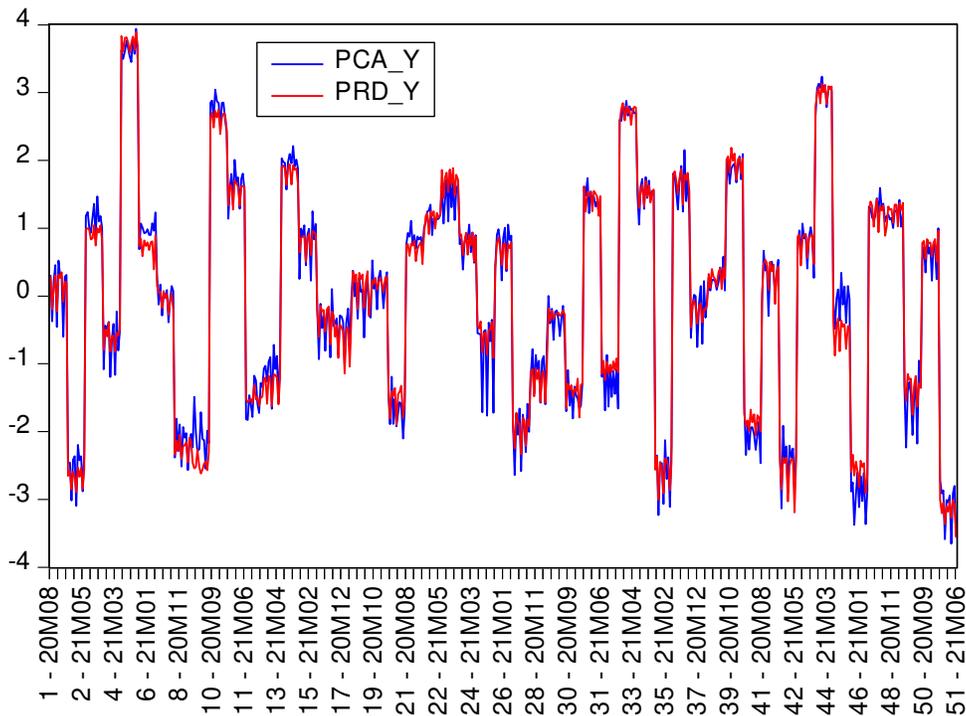


Figure 3. Dependent variable prediction results

The predicted sequence of human mobility (PRD_{y_t}) shown in Figure 3 is basically consistent with the fluctuation of our sample sequence (PCA_{y_t}). It indicates that our model and test are successful and can fully explain our research question. The consistency of predicted value and sample value also indicate that the model shows the correct relationship between variables. It also can prove our model scientific and rigorous.

5. Conclusions and policy implications

This paper has analyzed the impact of government restrictions on human mobility by using mediating variables. Basically, we tried to have the answers of two research questions: What are the important factors that influence human mobility? How does the government restriction affect human mobility? Our empirical findings, based on the results of SEM approach, are as follows:

The most important factor affecting human mobility is the economic environment, which has a significant negative correlation with human mobility. That is, worse economic conditions will reduce the willingness and/or ability of individuals to stay at home. This might be driven by the need to leave home for employment or the inability to substitute out-of-home for in-home leisure activities.

The direct impact of government restriction and the scale of COVID-19 on human mobility is not significant, but these do have an important indirect effect. As a mediating variable, economic environment plays an important mediating role between government restriction and human mobility. Because of the existence of economic environment as a mediating variable, government restriction/restriction can indirectly influence human mobility by influencing economic environment. Therefore, government restriction/restriction is not the essential cause of human mobility.

Based on these two important conclusions, the following policy suggestions can be made. First, the economic environment is the fundamental and direct factor affecting human mobility. Governments cannot therefore treat the pandemic and the economy as distinct in policy terms. Second, because the government restriction indirectly affects human mobility through the economic environment, if the government only increases the level of government restriction, it cannot effectively prevent people from leaving their homes and control the epidemic. More social welfare, effective financial subsidies will be the useful way to keep people staying at home.

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