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"Video game play positively affects well-being: evidence from a natural experiment in Japan"

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Video game play positively affects well-being: evidence from a natural experiment in Japan

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Abstract

The number of people who play video games has become close to three billion during the COVID-19 pandemic. Yet, video games' causal effect on well-being has been understudied, and most studies have relied on correlation. We select k6 (mental health) and SWLS (life satisfaction) for measuring well-being and apply multiple causal inference methods—regression, propensity score matching, and difference-in-difference—to provide evidence of the game effect. We take advantage of a natural experiment where lotteries for purchasing video game consoles—the Nintendo Switch and the PlayStation 5—created a random variation in access to video games. Using online surveys with 100,000 responses from Japanese aged 10-69 in the COVID-19 pandemic, we find that playing video games impacts users' well-being positively. Winning the Nintendo Switch lottery positively affects mental health by 0.2 SD, while the PS5 lottery's positive effect is 0.1 SD. Additionally, winning the PS5 lottery has a positive impact of 0.2 SD on life satisfaction. The instrumental variable approach indicates that an additional hour per day of video game play—caused by purchasing a new video game console—has a positive impact on mental health by 0.2 SD and life satisfaction by 0.3 SD. A Machine learning method reveals a striking difference between the heterogenous effects of the Nintendo Switch and the PS5. While the PS5 effect is smaller for teenagers, those married, non-gamers, and females, such heterogeneity is not found for the Nintendo Switch effect.

Introduction

The COVID-19 pandemic has brought video games into the new spotlight as a leisure activity compatible with social distance policies. The number of people who play games has become historically high, close to three billion people worldwide, and the quantity of play increased [1]. Yet, the increase in video game engagement has also created a stronger concern about the possibility that games may negatively affect health (for example, [2]). In particular, policymakers, researchers, and public stakeholders have paid special attention to game addiction and potential harm to well-being or mental health.

Video games have appeared to the public with a negative image. Widely contested health policy decisions, including a recent discussion on the gaming disorder by the WHO (World Health Organization), have boosted a negative impression of gaming. The inclusion of Gaming Disorder in the International Classification of Diseases (ICD-11) has caused a significant stigma for millions of youths (and their caregivers) who play video games as a part of a normal life [3]. However, the current evidence base on the influence of game-play is inadequate.

There is a large amount of literature that studies how video games affect users (i.e., aggression, addiction, well-being, cognitive functioning, and else). Aggression has particularly attracted scholarly interest, but no conclusive evidence exists. In the last decade, scholarly and policy makers' interest has gradually shifted to the link between video games and well-being (or mental health)[4].

The findings of the literature examining how video game play is associated with well-being (or mental health) have been mixed. Negative associations are mostly reported by observational studies[5, 6, 7, 8, 2], while a few laboratory experiments studying the effect of violent games also report negative associations[9, 10]. Positive associations are reported by both observational studies and laboratory experiments[11, 12, 13, 14, 15, 16].

Importantly, the previous observational studies rely on correlation to draw policy implications. Unfortunately, there is little empirical evidence on the causal links between video games and well-being in the real world, not in the laboratory. For that, one has to exploit a quasi-experimental situation that answers some essential questions (i.e., Do users play video games because they have stressful days, or does playing video games induce stress?). However, finding a quasi-experimental situation satisfying unconfoundedness is very difficult. This study fills the gap.

The present research

In this study, we utilize a natural experiment that creates a random variation in access to video games. We use lotteries, in Japan, for video game consoles: Nintendo Switch and PlayStation 5 (hereafter, PS5). One can purchase the video game console only if one wins the lotteries (for Nintendo Switch or PS5, respectively). Therefore, whether or not one owns Nintendo Switch and PS5 is determined nearly randomly.

To identify the causal effect, we employ multiple causal inference methods widely used in economics, public health, or political science. In particular, we follow the empirical strategies used in a series of papers examining the effect of winning lotteries: Imbens et al. (2001)[17] and Imbens (2015)[18]. Imbens uses two approaches: a standard regression analysis with control variables and a propensity score matching method. Adding to those, we also show estimates of a difference-in-difference method exploiting the panel structure.

We conducted multiple-round omnibus online surveys to the 10-65 aged population (n = approximately 100,000) of all 47 prefectures in Japan from December 2020 to March 2022 and created our data set. We collected the lottery-related information, ownership of video game consoles, game play activities, and well-being measures (k6 and SWLS).

We collaborate with a gaming market research firm conducting a monthly survey of video game players and non-players. As a result, we get access to the data of survey respondent characteristics such as age, gender, household structure, job, and video gaming preferences. This enables us to employ a machine learning technique to conduct heterogeneity analysis and thereby explore the mechanism of the video game effect.

We find that playing video games impacts users' well-being positively. Firstly, winning the Nintendo Switch lottery positively affects mental health (measure: k6) by 0.2 SD, while winning the PS5 lottery positively affects mental health by 0.1 SD. As for happiness (measure: SWLS), winning the PS5 lottery have a positive impact of 0.2 SD (SWLS of the Nintendo Switch was not collected due to the limited budget). Secondly, winning a new video game console lottery increases the time spent playing games by 0.5

hours. Thirdly, playing video games for an additional hour per day responding to purchasing a new video game console positively affects mental health by 0.2 SD and happiness by 0.3 SD.

We show the robustness of the above findings by multiple causal inference methods—standard regression, propensity score matching, and difference-in-difference. Moreover, the placebo tests recommended in Athey and Imbens (2017)[19] support the unconfoundedness.

The machine learning approach reveals the heterogeneous impact of playing video games and contrasts the effect of the Nintendo Switch and PS5 on well-being. Firstly, the estimated individual treatment effects suggest that video games negatively affect a few people's well-being. Secondly, we find a striking difference between the Nintendo Switch and PS5 effects. The PS5's positive effect is smaller for teenagers, non-gamers, females, and caregivers (or households with children). In contrast, the Nintendo Switch does not have a differential impact on gender and the household structure. Moreover, the Nintendo Switch effect is larger for non-gamers.

Literature Review

This paper contributes to the scientific literature that explores how video games affect users. Researchers and policymakers have been interested in the well-being (or mental health) outcomes of video games. However, previous studies including observational studies and laboratory experiments have three methodological challenges. First, lack of evidence on the causal link between video games and well-being has been a problem[20, 21]. Nearly all observational studies rely on correlation analysis using either cross-sectional or longitudinal data. Even if one shows a negative correlation between video game play and well-being, little can be known about the causal relationship and thereby policy implications. Second, laboratory experiments, which have provided most of the causal evidence in this field, have not been tested the external validity and exposed to criticisms[22, 23, 16]. Typical studies that invite participants to play video games for a short time are far from capturing the play as it occurs naturally. Particularly, game play in recent days is associated with online communications (i.e., voice chat, in-game text chat, Twitter, and Discord) and such an environment is obviously difficult to imitate in a laboratory. Third, most observational studies rely on self-reports of game play behavior and well-being measures, which could be inaccurate and potentially biased.

Two recent outstanding studies that examine the link between video games and well-being (one is published[16] and the other is preprint[23]) attempt to overcome the challenges, in particular, the third problem: self-report. The studies utilize game play administrative data provided by video game companies and thereby capture accurate video game play time, though well-being is reported through surveys. They show that video game play time is positively correlated with well-being and—in terms of causal relationship—does not negatively affect well-being. Yet, there are some drawbacks to using video game administrative data. Firstly, the response rate of their survey is low at about one percent, thus the implications are drawn from a limited sample. Secondly, the data does not contain game players' individual and socio-contextual variables (i.e., age, gender, household structure, and geographic information of residence), possibly because of obtaining very sensitive private information—accurate video game play time. The drawbacks are not negligible because the literature has revealed that the video game effect depends on such 'outside variables'[24].

Complementing their studies, we attempt to overcome the challenges, in particular, the first and second problems: lack of causal evidence and external validity. Firstly, this study exploits a natural experiment and applies multiple methods of causal inference and thereby shows robust causal evidence, while the two studies show cross-sectional correlation or structural model-based estimates. Secondly, collaborating with a video game research firm, we use a large survey data covering a population of wide-ranged socio-contextual backgrounds. Moreover, our survey data captures the video game play as it occurs naturally; those benefits would increase the external validity of our study.

The motivation of our study is also close to that of Cunningham, Engelstatter, and Ward (2016) [22]. The study examines the effect of violent games on committing violent crimes in the real world and does not find a significant effect. Though some experimental studies have found evidence suggesting that violent games increase aggression, Cunningham et al. (2016)'s quasi-experimental approach reveals that such a causal relationship may not exist in the real world. Our approach is similar in the sense that we attempt to identify the causal relationship between video game play and well-being in the real world.

Materials and methods

Study setting

After the first debut in 2017 of the Nintendo Switch and 2020 of the PS5, both video game consoles have been globally well-known. The global sales reached 100 million for the Nintendo Switch and 10 million for PS5 in 2022. The number of players increased during the COVID-19 pandemic, and the game consoles have been used as online communication devices with friends, or family members [25].

Due to the limited supply of semiconductors for the Nintendo Switch and PS5, people in Japan have been rarely able to purchase the game consoles by a standard method such as online shopping or shopping on-site. Hence the major way to buy the game consoles has been to join lotteries managed by retailers, otherwise one has to seek the game consoles in second-hand markets. Yet, one needs to pay a large amount of extra costs. While the supply-side problem of the PS5 is still ongoing, the problem of the Switch was resolved by the beginning of 2021. See Appendix E for the price history of PS5.

To join the lotteries, people first register their information such as name and email address at retailers' websites (or on-site registrations are sometimes open). After a few weeks, if one wins a lottery, one obtains the right to purchase the game console. Some retailers require being a member of their member clubs to join the game console lotteries, yet the membership is open to anyone.

Data

Our data is collected through 5-round online surveys obtaining answers from around 15,000-20,000 respondents for each. We contacted 25,000-50,000 people each time, thus the response rate is approximately 60 percent. We designed surveys measuring respondents' mental health (Kessler 6 scale, k6) and happiness (Satisfaction with Life Scale, SWLS), used in previous studies [6, 26]. We also collected self-reported play time and information about lotteries of the Switch and PS5. The survey schedule is shown in Fig 1. Due to a limited budget, we could not measure all the variables listed above in every round. In particular, as for the Switch, we could not collect SWLS and self-reported play time. See Appendix F for more details on the outcome variables collected in each round.

We conducted omnibus surveys with a gaming market research comapny: the gameage R&I (GRI). The GRI regularly conducts monthly surveys—collecting information related to video games—to pre-registered people via the Cross Marketing (a

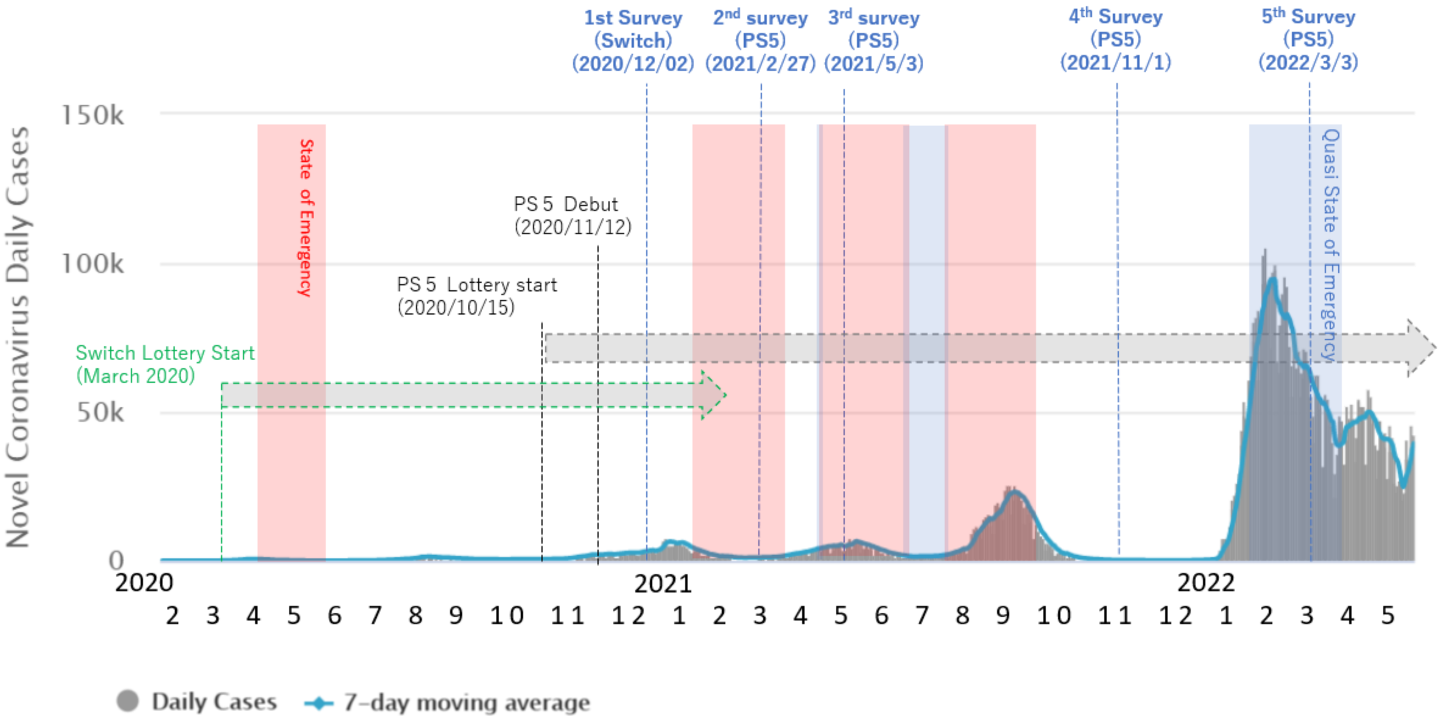


Fig 1. Survey schedule and video game consoles' lotteries.
Red shadow indicates the period of the State of Emergency in Japan due to the COVID-19 pandemic. Blue shadow indicates the Quasi State of Emergency. Source: https://www.worldometers.info/coronavirus/country/japan/

survey agency); we added some questions to five rounds of their surveys (December 2020, February, May, November 2021, and March 2022). Thus, the number of samples is determined by the GRI, not by us. As a result, the number of samples differs for each survey; more details can be found in Appendix J. In addition, the respondents' characteristics such as age, gender, marital status, job status, and gaming preference are provided by the research companies. Gaming preference is a measure created and calculated by the GRI. The GRI measures the gaming preference of respondents in November every year. Time spent playing games and other factors indicating game engagement are used for calculation. See Appendix D for more details about the gaming preference.

Our survey, contacting randomly selected samples from the pool of approximately 150,000 potential respondents (see more details of the sampling procedure in Appendix B), is close to a repeated cross-sectional survey with some important differences. Firstly, we have the identifiers of samples, thus we can construct a panel structure for the people who joined our survey more than once. Secondly, once a year—usually from October to December—the research companies refresh their pool of samples, though they do not replace all the samples. Such a limited panel structure is used for robustness checks.

Measures (See Appendix A for more details)

Well-being measure 1: mental health

We assessed well-being from two aspects. Firstly, we measured mental health with a scale of psychological distress, k6 [27]. K6 is composed of 6-item questions that measure the scale of nonspecific psychological distress in the past 30 days and score the degree of the psychological distress from 0 (the lowest) to 24(the highest).

Well-being measure 2: life satisfaction

Secondly, we measured well-being with a scale of life satisfaction, SWLS [28]. The SWLS consists of five statements about judgement of respondents' life, scored on a scale ranging from 1 (completely disagree) to 7 (completely agree). The sum scores the degree of life satisfaction from 5 (the lowest) to 35 (the highest).

Video game engagement measure 1: Nintendo Switch

Respondents reported whether their household had a Nintendo Switch and whether he/she played it during the last 30 days.

Video game engagement measure 2: PS5

Respondents reported whether their household had a PS5 and whether he/she played it during the last 30 days.

Video game engagement measure 3: Self-reported play time

Respondents also reported how much total time they spent playing video games on the weekdays (and in another question, the weekends) over the past 30 days. We separately asked i) the time spent playing smartphone games and ii) video games on TV/computer. This is not limited to playing the Nintendo Switch or PS5. Additionally, we asked about the time spent for iii) web browsing, SNS, and video apps such as Youtube as far as it is related to video games.

Empirical strategy

Reduced form analysis

Using a dummy indicating whether people have PS5 or not as a variable of interest causes endogeneity. Instead, we exploit the quasi-experimental situation occurred due to the supply-side problem of the Nintendo Switch and PS5. We assume unconfoundedness of the video game consoles' lotteries and thereby use a dummy variable indicating whether one won lotteries or not as a treatment variable and conduct regular regression analysis. We employ equation (1) as our baseline specification to measure the causal impact of winning game console lotteries, following Imbens et al. (2001)[17]. It is worth noting that the target population of our analysis is the people who joined the video game consoles' lottery (n = 1773 for the Nintendo Switch, 6419 for the PS5).

$$Y_{ip} = \beta lottery_{ip} + \psi X_{ip} + \phi join_{ip} + \alpha_p + \epsilon_{ip} \tag{1}$$

where Y_{ip} is an outcome of interest such as well-being measures for an individual i in prefecture p. $lottery$ is a dummy taking 1 if an individual wins the lotteries and 0 otherwise. The coefficient β is the parameter of interest. X_{ip} is a set of control variables consisting of individual characteristics, including age, gender, marital status, job status, whether having children or not. We also include gaming preference as control variables: dummies of each scale (heavy gamer: 1, middle gamer: 2, light gamer: 3, super light gamer: 4, non-gamer: 5). $join_{ip}$ is the number of times of joining the lotteries for the household of individual i (see more details about questions regarding lotteries in Appendix C). α_{ip} are prefecture dummies.

Propensity Score Matching (PSM)

Following Imbens (2015)[18]—Imbens revisits the "lottery data" used in Imbens et al. (2001)[17] as a good example to apply the propensity score matching method—we use a PSM approach to estimate the ATT effect in terms of winning the lotteries. We follow the recommendation of Imbens (2015) to select variables for matching and construct a subsample of the original data set. While the linear regression approach relies on assumptions of linearity and extrapolations beyond observed variable combinations to correct for differences between treatment group and control group, the PSM approach does not rely on such parametric assumptions. More detailed specification is found in Appendix M.

Fixed effect difference-in-difference

We use a difference-in-difference approach with individual fixed effects to test robustness. We use the following specification:

$$Y_{ipt} = \beta lottery_{ipt} + \phi join_{ipt} + \gamma_i + \mu_t + \epsilon_{ipt} \tag{2}$$

where γ_i are individual fixed effects and μ_t are time (round) fixed effects. The rest of the variables are as defined above.

Instrumental variable regressions

We can also treat the lottery data as instruments and employ standard IV methods to control for the endogeneity of Nintendo Switch/PS5 users. As excluded instruments, we use the dummy indicating whether one wins a lottery for the Nintendo Switch and PS5, respectively.

Assumption checks

To conduct a valid causal inference, we have to assume that there is no self-selection into winning Switch/PS5 lotteries. The biggest threat to our identification strategy is the number of times that one participated in Switch/PS5 lotteries because the more times that one participates in the lotteries, the more likely one is to win. To mitigate the problem, following the literature [17], we control for the number of times participating in lotteries in Eq 1. By checking whether controlling for such covariates affects the estimate or not, one can see how far the self-selection problem is serious. Moreover, we conduct PSM and compare a sub-sample whose characteristics are similar, following Imbens (2015) [18].

Table 1 presents the comparison of summary statistics for the covariates for lottery winners and non-winners of the PS5 lotteries. Following the literature [18], we show the normalized difference (or standardized difference) between the two groups. The differences are small, with only one out of 30 normalized differences larger than 0.30 in absolute value. That is the number of times joining lotteries, which is expected to be larger for lottery winners. Considering that the threshold of normalized differences for checking the balance after using PSM is 0.1[29], one can find the characteristics are well-balanced, even before using PSM. A similar comparison table for the Nintendo Switch lotteries is shown in Appendix G, and the characteristics are also well-balanced.

Heterogeneity analysis

We employ a machine learning algorithm called causal forest developed by Wager and Athey (2018)[30], predicting treatment effects on each individual based on their

Table 1. Balance table for PS5 lottery winners and non-winners.

Variable	N	(1) Did not win PS5 lottery Mean/SD	N	(2) Won PS5 lottery Mean/SD	Normalized difference (1)-(2)
# of times joined lottery	5022	3.958	1397	5.555	-0.326
		[4.569]		[5.735]	
Age	5022	36.988	1397	37.425	-0.028
		[15.724]		[15.454]	
Gender (Male = 1)	5022	0.619	1397	0.598	0.042
		[0.486]		[0.490]	
Respondent/household head is married (=1)	5022	0.593	1397	0.592	0.003
		[0.491]		[0.492]	
Respondent/household head is divorced (=1)	5022	0.051	1397	0.052	-0.005
		[0.220]		[0.223]	
Respondent/household head has child(ren) (=1)	5022	0.511	1397	0.516	-0.010
		[0.500]		[0.500]	
Student (=1)	5022	0.212	1397	0.199	0.032
		[0.409]		[0.399]	
Stay-at-home wife/husband (=1)	5022	0.069	1397	0.081	-0.047
		[0.253]		[0.273]	
Full-time employee (=1)	5022	0.499	1397	0.458	0.082
		[0.500]		[0.498]	
Part-time employee (=1)	5022	0.088	1397	0.112	-0.083
		[0.283]		[0.315]	
Self employed / other types worker (=1)	5022	0.063	1397	0.069	-0.027
		[0.243]		[0.254]	
Unemployed / currently not study (=1)	5022	0.070	1397	0.081	-0.042
		[0.255]		[0.273]	
Gaming preference: Heavy gamer=1	5022	0.432	1397	0.411	0.042
		[0.495]		[0.492]	
Gaming preference: Middle gamer=1	5022	0.265	1397	0.258	0.016
		[0.441]		[0.438]	
Gaming preference: Light gamer=1	5022	0.165	1397	0.173	-0.022
		[0.371]		[0.379]	
Gaming preference: Super light gamer=1	5022	0.097	1397	0.105	-0.024
		[0.296]		[0.306]	
Gaming preference: Non-gamer=1	5022	0.041	1397	0.054	-0.060
		[0.199]		[0.225]	
Job: Civil engineering, Construction, Real estate, Housing and building services	5022	0.065	1397	0.077	-0.049
		[0.246]		[0.267]	
Job: Daily necessaries, Textile and apparels, Cosmetics, Food and Beverages=1	5022	0.070	1397	0.060	0.039
		[0.255]		[0.238]	
Job: Manufacturing=1	5022	0.134	1397	0.155	-0.062
		[0.340]		[0.362]	
Job: Trading companies, Publishing, Printing, Mass media=1	5022	0.037	1397	0.030	0.037
		[0.188]		[0.171]	
Job: Distributors, Retailers=1	5022	0.046	1397	0.038	0.040
		[0.210]		[0.191]	
Job: Carriers, Warehousing, Logistics=1	5022	0.045	1397	0.041	0.019
		[0.206]		[0.198]	
Job: Public works=1	5022	0.054	1397	0.062	-0.034
		[0.226]		[0.240]	
Job: Software and Information services=1	5022	0.067	1397	0.059	0.034
		[0.250]		[0.235]	
Job: Banks and Financial services=1	5022	0.036	1397	0.026	0.055
		[0.187]		[0.161]	
Job: Food services, Hairdressing, Cosmetology, Other Services=1	5022	0.104	1397	0.096	0.027
		[0.305]		[0.295]	
Job: Medical care, Welfare=1	5022	0.063	1397	0.059	0.015
		[0.243]		[0.236]	
Job: Education=1	5022	0.035	1397	0.033	0.009
		[0.183]		[0.179]	
Job: Other industries and types of business=1	5022	0.067	1397	0.066	0.003
		[0.249]		[0.248]	

Notes. Respondents or their household heads' characteristics are used.

characteristics. This method, used in recent studies (i.e.,[31, 32]), allows flexible, high-dimensional combinations of covariates to identify the video game effect on each individual. For this prediction, we focus on estimating conditional ATEs ($E(Y_1 - Y_0|X = x)$) capturing differences in lottery winners and non-winners.

Results and Discussion

Preliminary analysis

Before beginning our main analysis, as a preliminary analysis, we first check the correlation between playing video games and well-being. Many previous papers have shown that video game engagement has a negative correlation with well-being measures. We use multiple measures of game engagement: i) whether respondent households have Nintendo Switch, ii) whether respondents play Nintendo Switch this month, iii) whether respondent households have PS5, iv) whether respondents play PS5 this month, v) video game play time (including any video game consoles and computer games). We use the following specification:

$$Y_{ip} = \beta Game_{ip} + \zeta X_{ip} + \alpha_p + \epsilon_{ip} \quad (3)$$

where $Game_{ip}$ is a measure of video game engagement for individual i in prefecture p. The rest of the variables are as defined above.

In Table 2, for each outcome variables, we show estimates of three specifications: without control variables, with control variables except for gaming preference dummies, and with a full set of control variables. By comparing the multiple estimates, we can see how much the correlation is affected by the selection of control variables.

As expected, we find that specifications having less number of control variables tend to show negative correlations between the video engagement measures and well-being measures. One can see that that the correlation is strongly affected by control variables. In particular, video gaming preference dummies strongly affect the estimates and in some cases reverse the sign. This sensitivity suggests that drawing policy implications on video games based on correlation studies should be avoided.

Table 2. Correlation between game engagement and psychological distress scale.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8) k6	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1 if have Nintendo Switch	.125 (.102)	.389*** (.104)	-.153 (.105)												
1 if play Switch this month				.452*** (.128)	.522*** (.129)	-.16 (.132)									
1 if have PS5							.46** (.202)	.71*** (.207)	.229 (.195)						
1 if play PS5 this month										.308 (.231)	.395 (.245)	-.276 (.238)			
Video Game play time (Hours/Day)													.218*** (.0238)	.153*** (.0213)	.0565** (.0245)
Observations	18,912	18,912	18,912	18,912	18,912	18,912	78,690	78,690	78,690	78,690	78,690	78,690	42,022	42,022	42,022
Controls	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Gaming Preference	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
Prefecture FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean	5.528	5.528	5.528	5.528	5.528	5.528	5.492	5.492	5.492	5.492	5.492	5.492	5.205	5.205	5.205

Notes. Standard errors are clustered by prefectures. $***p < 0.01, **p < 0.05, *p < 0.1$.

We also find that SWLS shows a consistent positive correlation with video game engagement measures (shown in Appendix H). This is possible considering that some previous studies have reported positive correlations between video game engagement and well-being. Yet, whether this is causal or not has to be examined through causal inference.

Reduced form analysis: Video game play time

Purchasing new video game consoles (i.e., Nintendo Switch or PS5) would increase the time spent playing video game. It may also affect the time spent online browsing related to video games (i.e., Youtube and SNS). We first confirm those hypotheses and thereby show that the video game lottery effect is due to the purchased new video game consoles. We use the following specification:

$$Playtime_{ip} = \beta lottery_{ip} + \psi X_{ip} + \phi join_{ip} + \alpha_p + \epsilon_{ip} \tag{4}$$

where $Playtime_{ip}$ is video game play time for individual i in prefecture p. As the outcome variables, we also test other variables such as online browsing time related to video games and smartphone game play time. *lottery* is a dummy taking 1 if an individual wins the lotteries and 0 otherwise. The coefficient β is the parameter of interest. We control for a set of control variables explained before.

We show the estimated results in Table 3. As expected, winning the lottery increases video game play time and online browsing time (though web browsing time is marginally significant). In contrast, smartphone game play time is not affected. The outcome variable for Columns 7 and 8, shown for reference, is a sum of that for columns 1-2 and 3-4. In a nutshell, the results support our argument.

Table 3. Winning game console lottery increases video game play time.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Video game play time		Web browsing time related to game		Smartphone game playtime		Time for video game play and web browsing	
Win the lottery	.568***	.532***	.213*	.16	.128*	.0937	.781***	.692***
	(.106)	(.102)	(.109)	(.107)	(.0638)	(.0662)	(.203)	(.197)
# of times joined lottery		.0375***		.0368***		.0302***		.0744***
		(.0072)		(.00677)		(.00792)		(.0133)
Observations	3,491	3,491	3,491	3,491	3,491	3,491	3,491	3,491
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Prefecture FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean	1.518	1.518	1.314	1.314	1.395	1.395	2.831	2.831

Notes. Standard errors are clustered by prefectures. $***p < 0.01, **p < 0.05, *p < 0.1$.

Reduced form analysis: well-being measures

The estimates of the effects of winning the lotteries from our baseline specification (Eq 1) are shown in Table 4. We show the estimates taking k6 as an outcome variable in columns (1)-(4) while we use the Nintendo Switch lotteries in columns (1)-(2) and the PS5 lotteries in columns (3)-(4), respectively. In columns (5)-(6), the estimates taking SWLS as an outcome variable are shown. In contrast to the correlation estimates in Table 2, the estimated coefficients of interest in Table 4 only slightly change by including control variables. The estimates for k6 in columns (1)-(4) consistently indicate that winning the Nintendo Switch / PS5 lotteries improves mental health (or well-being). Also, the estimates for SWLS in columns (5)-(6) indicate that winning the PS5 lotteries increases satisfaction with life.

Table 4. Winning game console lottery improves well-being.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	k6: psychological distress scale				SWLS: life satisfaction	
Win the lottery	-1.43***	-1.29***	-.408*	-.517**	1.06***	1.01***
	(.246)	(.189)	(.209)	(.197)	(.175)	(.166)
# of times joined lottery		.0961*		.0502**		.0393**
		(.0565)		(.0187)		(.017)
Observations	1,773	1,773	6,419	6,419	6,419	6,419
Controls	No	Yes	No	Yes	No	No
Prefecture FE	Yes	Yes	Yes	Yes	Yes	Yes
Mean	8.249	8.249	7.202	7.202	16.867	16.867
Lottery	Switch	Switch	PS5	PS5	PS5	PS5

Notes. Standard errors are clustered by prefectures. $***p < 0.01, **p < 0.05, *p < 0.1$.

PSM

We next use the PSM approach to estimate coefficients of the key variables estimated in Table 3 and Table 4. Both the estimates from the linear regressions and the PSM approach are shown in Fig 2 and Fig 3. Note that the estimates are standardized by the standard deviations of the samples for estimation. One can see that all the estimates from the linear regressions and the PSM approach are close to each other.

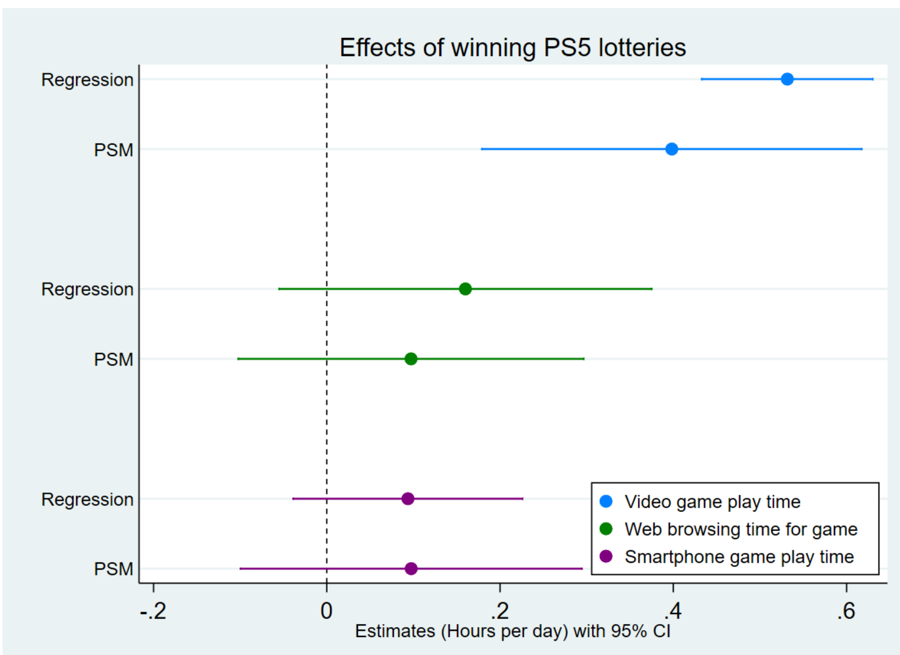


Fig 2. Winning game console lotteries increases game play time.

Notes. PSM : Propensity Score Matching. Approximate standard errors are shown for PSM. Equation (1) is used for the regression estimates. Regression standard errors are clustered by prefectures.

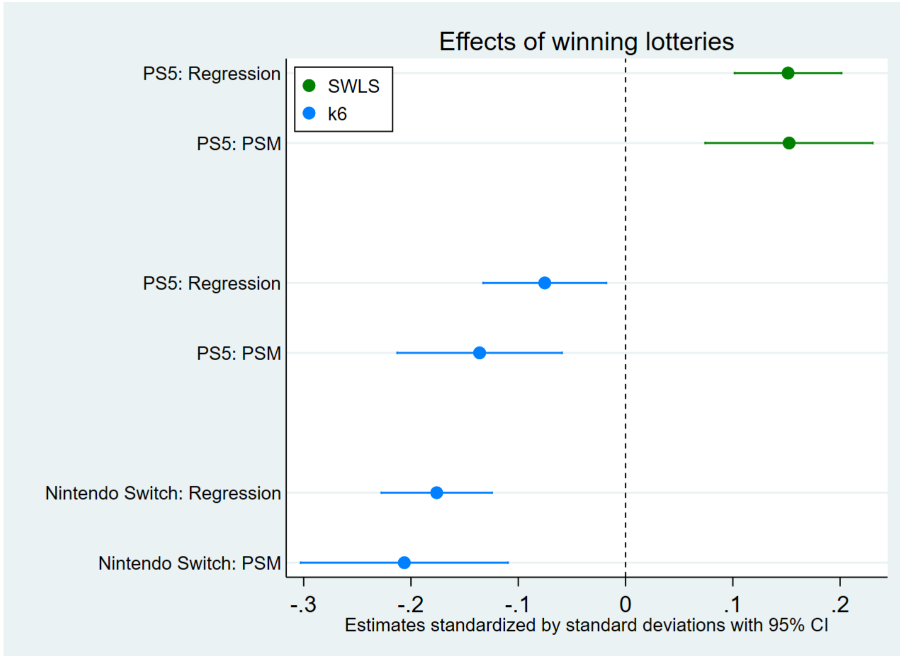


Fig 3. Nintendo Switch and PS5 positively affect well-being.
Notes. PSM : Propensity Score Matching. Approximate standard errors are shown for PSM. Equation (1) is used for the regression estimates. Regression standard errors are clustered by prefectures.

Robustness checks

Placebo tests

We next do placebo analyses to assess the plausibility of unconfoundedness for the video game consoles' lotteries. As for the Nintendo Switch lotteries, we cannot conduct a placebo test because we do not have pre-lottery outcomes. Thereby we do placebo analyses for the PS5 lotteries.

We treat pre-lottery (lagged) outcomes for k6 and SWLS as pseudo-outcomes. We use k6 and SWLS of round 2—the first round that we collected information on the PS5 lotteries—as a pseudo outcome and run regressions using observations of rounds 3-5. See Appendix F for the list of outcome variables collected in each round.

The estimated average causal effect on pre-lottery outcomes is shown in Table 5. The mean estimates are small in magnitude and statistically insignificant, suggesting that nonconfoundedness holds.

From the placebo analyses samples, we removed people who won PS5 lotteries in round 2. Otherwise, outcomes of people who were treated are included as pseudo-outcomes. Notice that at the time of rounds 1 and 2 survey, the PS5 lotteries were already open and people won PS5 lotteries (see Fig 1).

Individual panel regression

As a robustness check, we use a subsample of the data set and run regressions with individual fixed effects—individual panel estimation—to estimate the PS5 lottery winning effect (Eq 2). By construction, we restrict our sample to those who responded more than two times and thus the number of observations become less than half. Recall that our survey partly refreshes the sample every year. Further, the survey agency have approximately 150,000 potential respondents thereby the same respondents do not

Table 5. Assessing unconfoundedness for the lottery data: pseudo outcomes.

Outcome variables	k6_R2		SWLS_R2	
	(1) Regression	(2) PSM	(3) Regression	(4) PSM
Win the lottery	.266	-0.077	-.0211	-0.236
	(.528)	(0.626)	(.625)	(0.5676)
Observations	1,621	1,579	1,621	1,579
Controls	Yes	-	Yes	-
Prefecture FE	Yes	-	Yes	-
Mean	7.321	7.34	16.405	16.37
Lottery	PS5	PS5	PS5	PS5

Notes. Regression standard errors are clustered by prefectures. Approximate standard errors are shown for PSM. $***p < 0.01, **p < 0.05, *p < 0.1$.

always receive survey offers. Therefore, what we can obtain from the longitudinal regression is the ATE of a subsample with larger standard errors.

The results shown in Table 6 largely support the robustness of our findings. The PS5 lottery winning increases the time spent playing video game and browsing the internet and consequently improves the life satisfaction (SWLS). Yet, the estimates for k6 is not statistically significant.

Table 6. Individual panel estimates of a subsample of the data set.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	k6		SWLS		Video game play time		web browsing time for game		Smartphone game playtime	
Win the lottery	.192	.166	.582*	.547*	1.3*	1.18*	1.31*	1.25*	-.0695	-.195
	(.363)	(.368)	(.295)	(.302)	(.67)	(.662)	(.705)	(.683)	(.386)	(.372)
# of times joined lottery		.0274		.0373		.0467*		.0257		.0523*
		(.0267)		(.0385)		(.0262)		(.0216)		(.0278)
Observations	2,570	2,570	2,570	2,570	502	502	502	502	502	502
Controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean	7.236	7.236	16.674	16.674	1.872	1.872	1.367	1.367	1.417	1.417

Notes. Standard errors are clustered by prefectures. $***p < 0.01, **p < 0.05, *p < 0.1$.

Instrumental variable approach

We estimate the causal impact of the video game engagement on well-being by the IV approach exploiting lottery winning as an instrument. The estimated coefficients of selected endogenous variables—video engagement measures—on k6 and SWLS are shown in Fig 4 (A table with weak IV tests is found in Appendix K. Additional outcome variables are tested in Appendix L). For example, the estimated coefficients of "Time for video game play and web browsing for game (Hour/Day)" indicate that one hour per day of video game play and related web-use improves both the satisfying with life and k6 by approximately 0.2 SD.

The estimates should be understood as upper-bounds, respectively, because exclusion restriction does not seem viable. For example, after winning a lottery, one increases time spent playing video game. At the same time, one would spend time browsing the internet and using Twitter in terms of topics related to video games. One may also increase time spent using voice/video chat. All of those may contribute to the improvement of well-being. If so, i) whether one has the video game console (of the lottery), ii) whether one plays the video game console, or iii) increased time spent for video game play, would probably not satisfy exclusiveness. We believe the sum of video game play time and web browsing time (including Youtube, Twitter and other SNS)—related to video games—is most comprehensive. Thereby, the estimates on the variable is closer to a valid IV estimate than those on the rest of the variables.

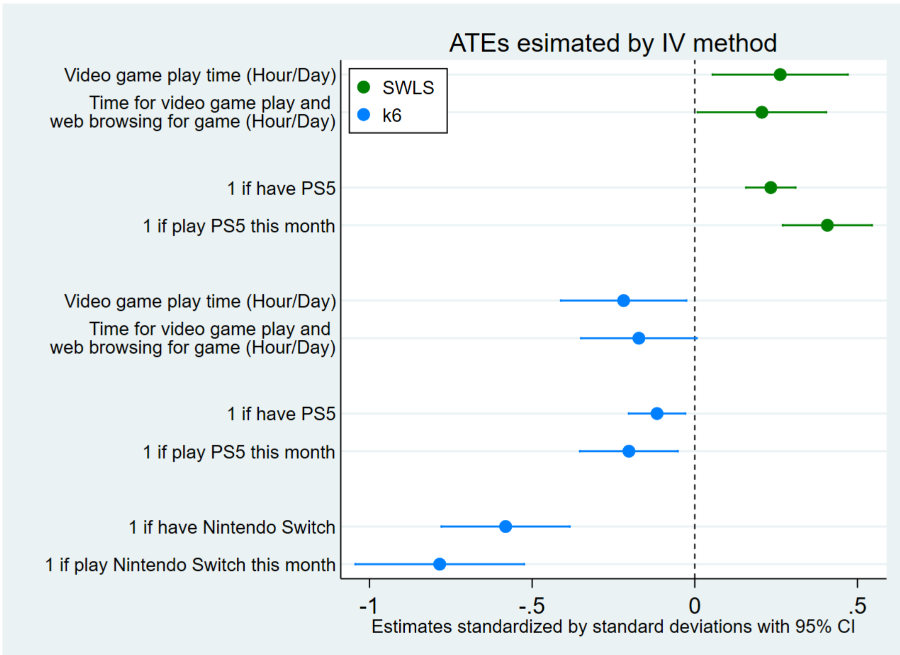
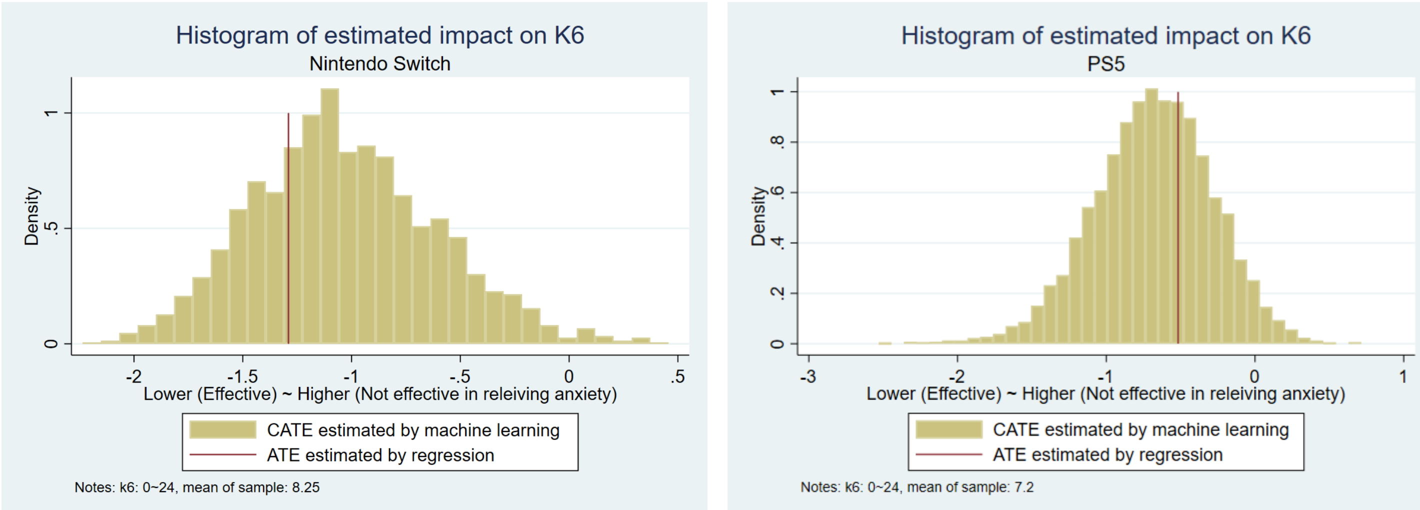


Fig 4. The video game engagement improves well-being.
Notes. Standard errors are clustered by prefectures.

Heterogeneity analysis

We use the machine learning technique to analyze the heterogeneity of the effect of playing video games through examining the effect of lottery winning. We separately examine the heterogeneity of the Nintendo Switch effect and the PS5 effect. We mainly argue the heterogeneous effect on k6. We also examine the heterogeneity in terms of SWLS, but for brevity figures are not shown; it is similar to that of k6.

We first show the distribution of the conditional ATEs estimated by causal forest in Fig 5. The results indicate that video games positively affect most of the people's well-being, while a few people receive a small negative effect.



(a) Nintendo Switch **(b)** PS5

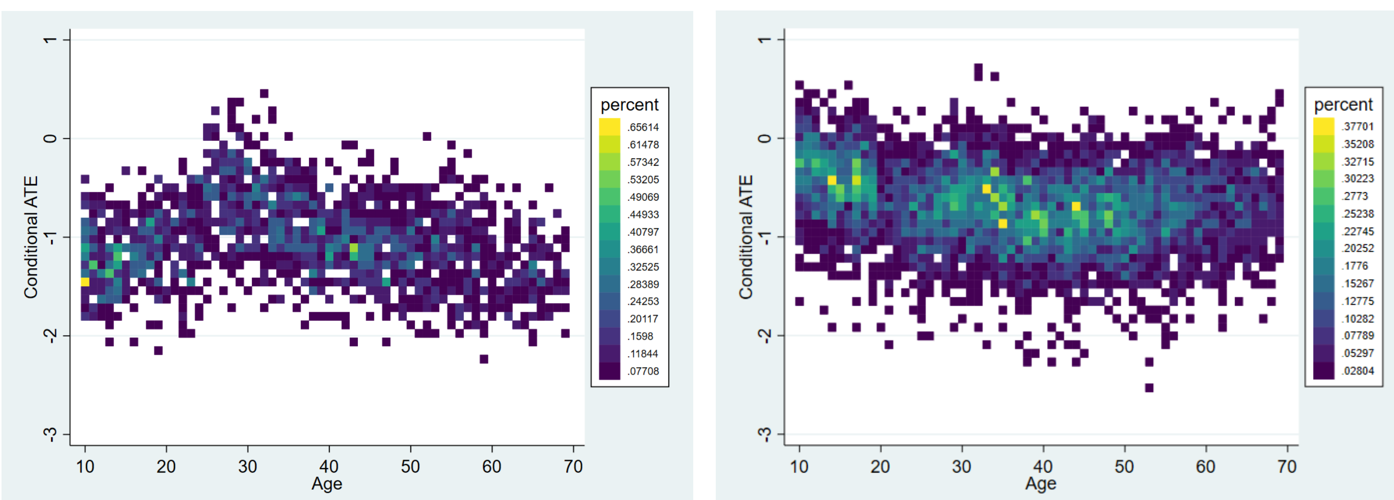
Fig 5. The video games positively affect most users' well-being.

Notes. The conditional ATEs are estimated by causal forest.

We next show the heterogeneity in the video game effect due to some important characteristics: age, gaming preference, gender, and household structure. In addition, we argue the combination of those characteristics.

Age

The heterogeneity with age is shown in Fig 6. We find a striking difference between the Nintendo Switch effect and the PS5 effect. While the PS5 is less beneficial for well-being of teenagers, such a tendency is not found for the Nintendo Switch. One can find the distribution of the conditional ATEs among students in 13.



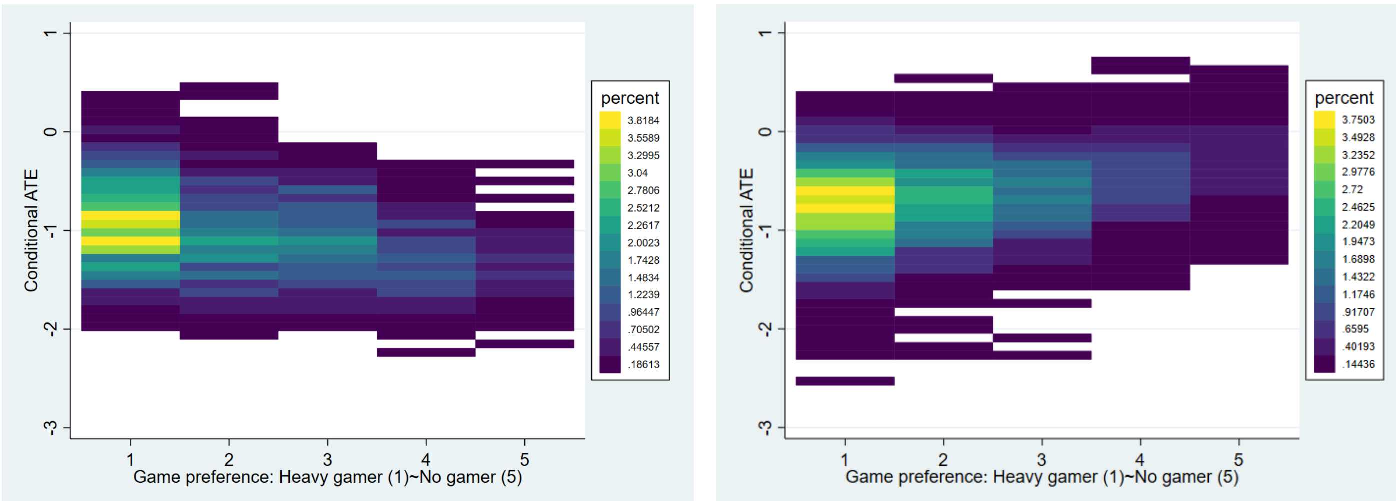
(a) Nintendo Switch **(b)** PS5

Fig 6. Contrasting heterogeneous effect with age.

Notes. The conditional ATEs are estimated by causal forest.

Gaming preference

The heterogeneity with gaming preference is shown in Fig 7. We find another striking difference; while the Nintendo Switch is more beneficial for well-being of non-gamers, the PS5 is more beneficial for heavy gamers.



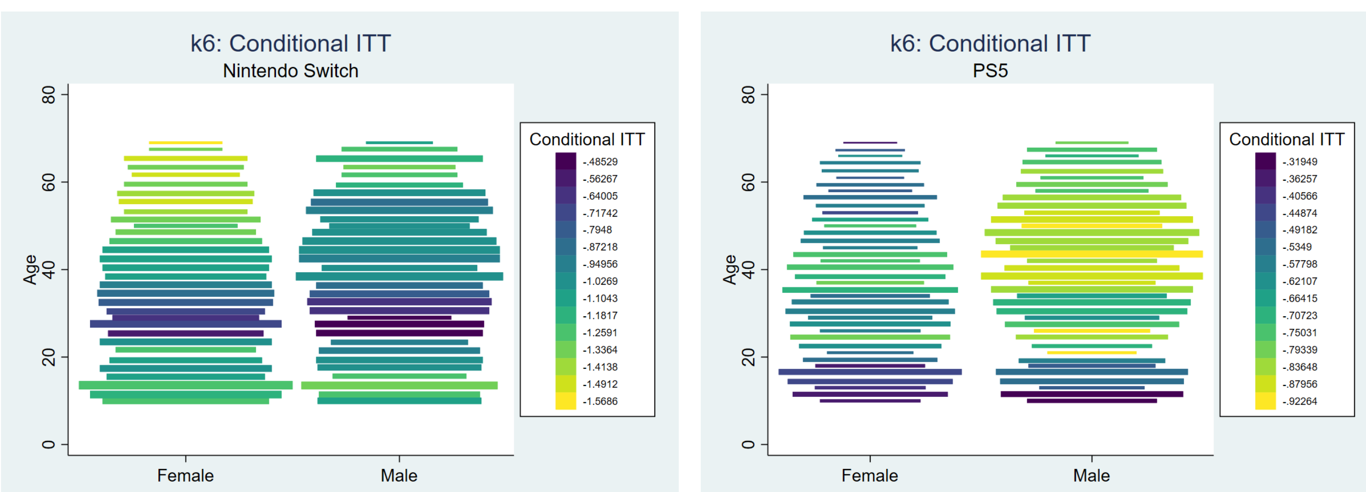
(a) Nintendo Switch **(b)** PS5

Fig 7. Contrasting heterogeneous effect with gaming preference.

Notes. The conditional ATEs are estimated by causal forest.

Gender

The heterogeneity with gender is shown in Fig 8. We also find a difference; while the Nintendo Switch is beneficial for both females and males, the PS5 is more beneficial for males.



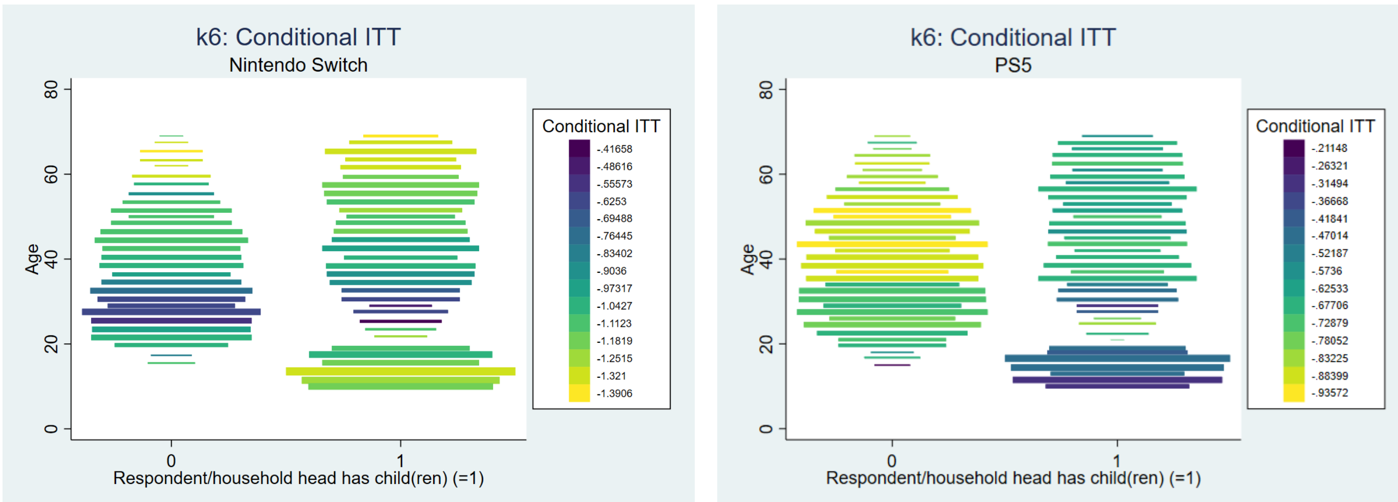
(a) Nintendo Switch **(b)** PS5

Fig 8. Contrasting heterogeneous effect with gender.

Notes. The conditional ATEs are estimated by causal forest.

Household structure

The heterogeneity with whether households have children is shown in Fig 9. While the PS5 is more beneficial for households without children, such a tendency is not found for the Nintendo Switch effect.



(a) Nintendo Switch **(b)** PS5

Fig 9. Contrasting heterogeneous effect with household structures.
Notes. The conditional ATEs are estimated by causal forest.

Correlation between the Nintendo Switch effect and the PS5 effect

The heterogeneity analysis so far reveals that there is a striking difference between the people who receive a larger benefit—in improving well-being—from the Nintendo Switch and those from the PS5. As a result, we find no correlation between the Nintendo Switch effect and the PS5 effect (Fig 10). People who joined both the Nintendo Switch lottery and the PS5 lottery is used for calculation (n=678).

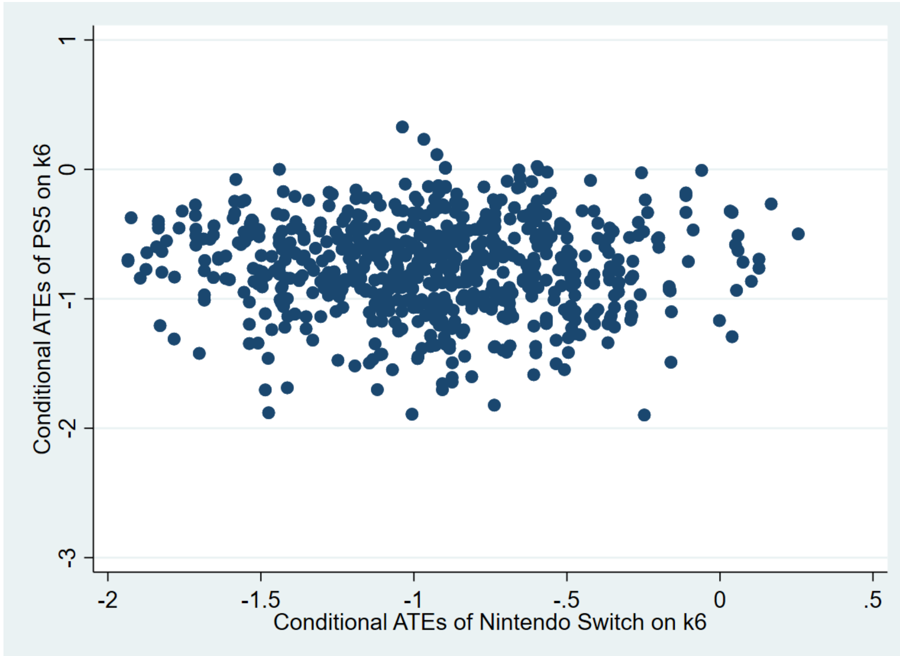
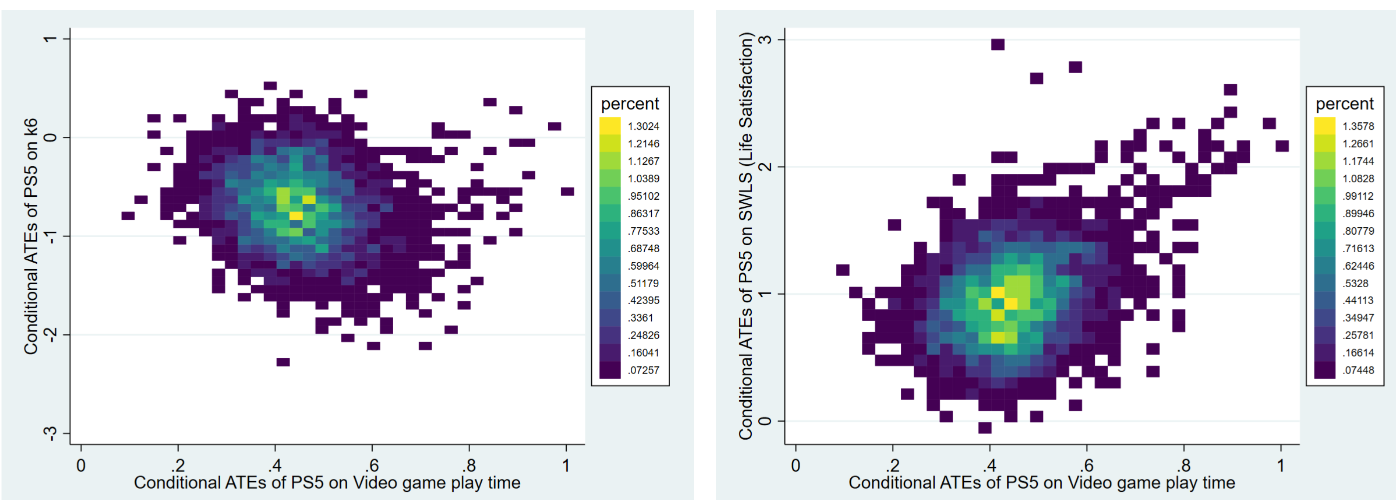


Fig 10. No correlation between the Nintendo Switch effect and the PS5 effect.
Notes. The conditional ATEs are estimated by causal forest.



(a) k6 (psychological distress scale)

(b) SWLS (Life satisfaction)

Fig 11. Correlation between the effects on game playtime and well-being.
Notes. The conditional ATEs are estimated by causal forest.

Conclusion

The present evidence base of video game effect on well-being has lacked causal evidence in the real world. Using original survey data, we studied the impact of video game play with two major video game consoles: the Nintendo Switch and PS5. The measures of well-being are k6 and SWLS. Exploiting a random variation created by video game consoles' lotteries, we found video games' positive effect on well-being.

The heterogeneity of video game play effects has been understudied because causal inference studies in the real world were scarce. We conducted causal inference and found heterogeneity with age, gender, gaming preference, and household structures. Moreover, we found a striking difference between the heterogeneity of the Nintendo Switch effect and the PS5 effect.

Our findings contribute to a more comprehensive understanding of the mechanism of Gaming Disorder. We find that video games affect a few people's mental health negatively. This is consistent with the fact that there are a few people with Gaming Disorder.

The heterogeneous video game impact with age and household structures implies that the environment at home affects the video game effect. The positive PS5 effect is more prominent for people living alone. This suggests that the environment in which one can play the PS5 without being disturbed by others enhances the game effects the most. This implies the importance of examining the video game play effect in the real world.

How game genre affects the video game effect has been examined only in laboratory experiments, not in the field. In future work, using the data used in this paper, we intend to study how the type of games affects the effect on well-being in the real world. This is difficult because the game purchase has self-selection bias (i.e., a specific kind of person likes to play a particular game). Thereby, for example, an observational study with a regression using a variable capturing game play time of a particular type of game (i,e., action game) gives a biased estimate. We intend to overcome this challenge by using respondents' history of game purchases in our natural experimental setting.

Appendix A. Measures.

k6 We use the Japanese translation of K6, following the literature such as Yamamoto et al (2020) [33]. Given its brevity and high accuracy, the K6 is used for screening for mental disorders in population-based health surveys in Japan [34].

SWLS We use the Japanese translation of the Satisfaction with Life Scale (SWLS), following the literature such as Sumino (1994) [35]. The SWLS is useful for evaluating the overall life satisfaction and valid measurement in Japan[36].

Work productivity The respondents reported self-assessment of their work productivity, though we do not elaborate on it in the current draft. We use 9-item questions. We find neither positive nor negative significant impact of playing video game on work productivity.

Appendix B. Sampling process. Our data is not collected through a simple random sampling procedure. The GRI uses sampling strata composed of gender, age, and gaming preference. Thus, our data is guaranteed to have a certain number of samples for each strata. Yet, the number of samples for each strata is not the same. As the GRI's purpose is collecting information about video games, GRI tries to obtain more samples for people who like video games. As a result, our data tends to have larger samples for younger people and smaller samples for non-gamers.

Appendix C. Lottery questionnaire. We collected the information on Nintendo Switch/PS5's lotteries by two types of questions. Firstly, we asked respondents: the time that you, your household members, or relatives joined the lotteries to purchase your household's video game consoles, respectively. We then sum the number for each and use it as the number of times the respondent joined the lotteries. Secondly, we also asked about the retailers (i.e., Amazon, Yodobashi Camera, and Sony Store) where any of the household members joined the lotteries and the number of times for each. We then also sum the number for each and use it as the total number of joining lotteries. As expected, the figures for the total number of joining lotteries calculated by the two questions are similar. Therefore, through two types of questions, we attempted to make the respondents recall the number of times of participating in the lotteries as accurately as possible. We use the first one in our analysis while using the other does not affect the analysis results.

Some respondents answered that they did not receive the lottery result yet. We include them as people that did "not win lottery=lose lottery."

Appendix D. Video gaming preference. The GRI uses cluster analysis for the calculation, though we are not allowed to show the details. The algorithm considers not only video games but also smartphone and computer games. Factors such as frequency of game-play or game purchase are used. Also, one can see that game play time is closely related to the video gaming preference in the table below.

In our analysis, the video gaming preference measured at the beginning of November 2020 is used where available (if not available, the one measured in November 2021 is used instead). This is for using the characteristics measured before the interventions (where available) and avoiding "bad controls." We are considering obtaining November 2019 data (where available) from the GRI and using it for the Nintendo Switch analysis in future updates.

Table 7. Video gaming preference and video game play time.

		(1)		(2)		(3)		(4)		(5)
		Heavy gamer		Middle gamer		Light gamer		Super light gamer		Non-gamer
Variable	N	Mean/SD	N	Mean/SD	N	Mean/SD	N	Mean/SD	N	Mean/SD
game play time (Hour/Day)	6975	1.626	9604	1.113	11067	0.615	9333	0.319	5043	0.144
		[2.281]		[1.852]		[1.355]		[0.963]		[0.743]
web browsing time for game (Hour/Day)	6975	1.305	9604	0.987	11067	0.689	9333	0.411	5043	0.201
		[1.968]		[1.727]		[1.413]		[1.131]		[0.887]
smartphone game playtime (Hour/Day)	6975	1.372	9604	1.269	11067	1.059	9333	0.671	5043	0.223
		[2.066]		[1.959]		[1.646]		[1.347]		[0.929]

Notes: Observations of round 4 and 5 are used.

Appendix E. Price history of PS5.

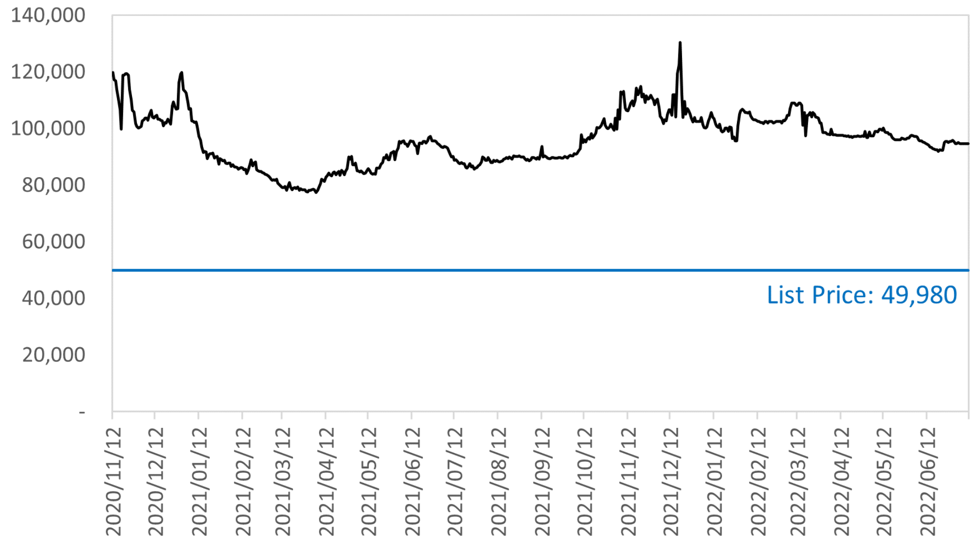


Fig 12. Price history of second-hand PS5 (Yen).
Source: https://kakaku.com//

Appendix F. Outcome variables collected in each survey round.

Table 8. Outcome variables collected in each round.

Outcome variables	Round				
	1	2	3	4	5
	Switch	PS5	PS5	PS5	PS5
K6	✓	✓	✓	✓	✓
SWLS		✓	✓	✓	✓
Video game play time				✓	✓
Work productivity					✓
Have Nintendo Switch	✓	✓	✓	✓	✓
Play Nintendo Switch this month	✓	✓	✓	✓	✓
Have PS5	✓	✓	✓	✓	✓
Play PS5 this month	✓	✓	✓	✓	✓

Notes. Round one survey collected the Nintendo Switch lotteries' information. From round two, we collected the PS5 lotteries' information. K6: Kessler psychological distress scale, SWLS: The Satisfaction with Life Scale.

Appendix G.

Table 9. Balance table for Nintendo Switch lottery winners and non-winners.

Variable	N	(1) Did not win PS5 lottery Mean/SD	N	(2) Won PS5 lottery Mean/SD	Normalized difference (1)-(2)
# of times joined lottery	847	3.268	926	4.305	-0.251
		[3.663]		[4.467]	
Age	847	35.967	926	36.254	-0.018
		[16.575]		[15.919]	
Gender (Male = 1)	847	0.564	926	0.504	0.120
		[0.496]		[0.500]	
Respondent/household head is married (=1)	847	0.643	926	0.692	-0.104
		[0.479]		[0.462]	
Respondent/household head is divorced (=1)	847	0.052	926	0.039	0.063
		[0.222]		[0.193]	
Respondent/household head has child(ren) (=1)	847	0.580	926	0.609	-0.060
		[0.494]		[0.488]	
Student (=1)	847	0.241	926	0.233	0.018
		[0.428]		[0.423]	
Stay-at-home wife/husband (=1)	847	0.084	926	0.102	-0.061
		[0.277]		[0.302]	
Full-time employee (=1)	847	0.442	926	0.455	-0.026
		[0.497]		[0.498]	
Part-time employee (=1)	847	0.096	926	0.098	-0.009
		[0.294]		[0.298]	
Self employed / other types worker (=1)	847	0.074	926	0.058	0.065
		[0.263]		[0.234]	
Unemployed / currently not study (=1)	847	0.064	926	0.054	0.042
		[0.244]		[0.226]	
Gaming preference: Heavy gamer=1	847	0.436	926	0.402	0.069
		[0.496]		[0.491]	
Gaming preference: Middle gamer=1	847	0.194	926	0.242	-0.117
		[0.395]		[0.428]	
Gaming preference: Light gamer=1	847	0.185	926	0.190	-0.012
		[0.389]		[0.393]	
Gaming preference: Super light gamer=1	847	0.118	926	0.121	-0.009
		[0.323]		[0.326]	
Gaming preference: Non-gamer=1	847	0.067	926	0.045	0.096
		[0.251]		[0.208]	
Job: Civil engineering, Construction, Real estate, Housing and building services	847	0.071	926	0.070	0.003
		[0.257]		[0.256]	
Job: Daily necessaries, Textile and apparels, Cosmetics, Food and Beverages=1	847	0.051	926	0.066	-0.064
		[0.220]		[0.248]	
Job: Manufacturing=1	847	0.129	926	0.103	0.082
		[0.335]		[0.304]	
Job: Trading companies, Publishing, Printing, Mass media=1	847	0.037	926	0.037	-0.001
		[0.188]		[0.188]	
Job: Distributors, Retailers=1	847	0.045	926	0.044	0.003
		[0.207]		[0.206]	
Job: Carriers, Warehousing, Logistics=1	847	0.052	926	0.032	0.098
		[0.222]		[0.177]	
Job: Public works=1	847	0.059	926	0.051	0.036
		[0.236]		[0.220]	
Job: Software and Information services=1	847	0.055	926	0.070	-0.060
		[0.229]		[0.256]	
Job: Banks and Financial services=1	847	0.034	926	0.036	-0.008
		[0.182]		[0.185]	
Job: Food services, Hairdressing, Cosmetology, Other Services=1	847	0.105	926	0.103	0.008
		[0.307]		[0.304]	
Job: Medical care, Welfare=1	847	0.071	926	0.070	0.003
		[0.257]		[0.256]	
Job: Education=1	847	0.032	926	0.025	0.043
		[0.176]		[0.156]	
Job: Other industries and types of business=1	847	0.079	926	0.068	0.042
		[0.270]		[0.252]	

Appendix H.

Table 10. Correlation between game engagement and life satisfaction.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
VARIABLES	SWLS (life satisfaction)														
1 if have Nintendo Switch	.908***	.237***	.339***												
	(.0541)	(.0508)	(.057)												
1 if play Nintendo Switch this month				.852***	.406***	.535***									
				(.0617)	(.0558)	(.0561)									
1 if having PS5							.977***	.795***	.922***						
							(.218)	(.193)	(.192)						
1 if playing PS5 this month										1.41***	1.49***	1.67***			
										(.304)	(.281)	(.283)			
Video game play time													-.0849***	.047**	.0679***
													(.0186)	(.0175)	(.019)
Observations	78,690	78,690	78,690	78,690	78,690	78,690	78,690	78,690	78,690	78,690	78,690	78,690	42,022	42,022	42,022
R-squared	.00765	.0862	.0872	.00619	.0865	.0876	.00414	.0863	.0872	.00422	.0866	.0876	.00462	.0925	.0928
Controls	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Gaming preference dummies	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
Prefecture FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.115	17.115	17.115

Appendix I.

Table 11. Alternative outcome variables: PD and SPD.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	PD: Psychological distress; k6>=5 (=1)				SPD: Serious psychological distress; k6>=13 (=1)			
Win the lottery	-.109***	-.0983***	-.0405***	-.047***	-.0581***	-.0571***	-.0113	-.0174
	(.0219)	(.0167)	(.0145)	(.0122)	(.0179)	(.0173)	(.0123)	(.0124)
# of times joined lottery		.0022		.00303**		.00851**		.00291**
		(.0028)		(.00137)		(.00337)		(.0013)
Observations	1,773	1,773	6,419	6,419	1,773	1,773	6,419	6,419
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Prefecture FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean	.6	.6	.548	.548	.291	.291	.228	.228
Lottery	Switch	Switch	PS5	PS5	Switch	Switch	PS5	PS5

Appendix J.

Table 12. Number of observations for each round.

Round	# of people that were sent survey offers	# of people that answered survey	# of people who joined lotteries	# of people who won lotteries	Switch lotteries or PS5 lotteries
1	34,615	18,912	1,773	926	Switch
2	27,186	18,189	1,481	254	PS5
3	29,462	18,479	1,447	332	PS5
4	47,183	26,996	2,127	499	PS5
5	26,143	15,026	1,364	312	PS5

Appendix K.

Table 13. Average treatment effects estimated by the instrumental variable approach.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	k6: psychological distress scale						SWLS: life satisfaction			
1 if have Nintendo Switch	-4.25***									
	(.721)									
1 if play Nintendo Switch this month		-5.73***								
		(.949)								
1 if having PS5			-.797**				1.55***			
			(.299)				(.253)			
1 if playing PS5 this month				-1.39**				2.71***		
				(.518)				(.456)		
Video game play time					-1.41**				1.72**	
					(.621)				(.68)	
Time for video game play and web browsing for game (Hour/Day)						-1.11*				1.35**
						(.573)				(.646)
Observations	1,773	1,773	6,419	6,419	3,491	3,491	6,419	6,419	3,491	3,491
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean	8.249	8.249	7.202	7.202	6.6	6.6	16.867	16.867	17.269	17.269
Lottery	Switch	Switch	PS5	PS5	PS5	PS5	PS5	PS5	PS5	PS5
Kleibergen-Paap rk Wald F statistic	150.1	83.24	1614	422.5	29.04	12.61	1614	422.5	29.04	12.61

Notes. Standard errors are clustered by prefectures. $***p < 0.01, **p < 0.05, *p < 0.1$.

Appendix L.

Table 14. ATEs on PD and SPD estimated by the IV approach.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	PD: Psychological distress; k6>=5 (=1)				SPD: Serious psychological distress; k6>=13 (=1)			
1 if having PS5	-.0725***				-.0269			
	(.0186)				(.0188)			
1 if playing PS5 this month		-.126***				-.0469		
		(.0321)				(.0327)		
Video game play time			-.129***				-.0459	
			(.04)				(.0348)	
Time for video game play and web browsing for game (Hour/Day)				-.102**				-.036
				(.0399)				(.0296)
Observations	6,419	6,419	3,491	3,491	6,419	6,419	3,491	3,491
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean	.548	.548	.524	.524	.228	.228	.19	.19
Lottery	PS5	PS5	PS5	PS5	PS5	PS5	PS5	PS5
Kleibergen-Paap rk Wald F statistic	1614	422.5	29.04	12.61	1614	422.5	29.04	12.61

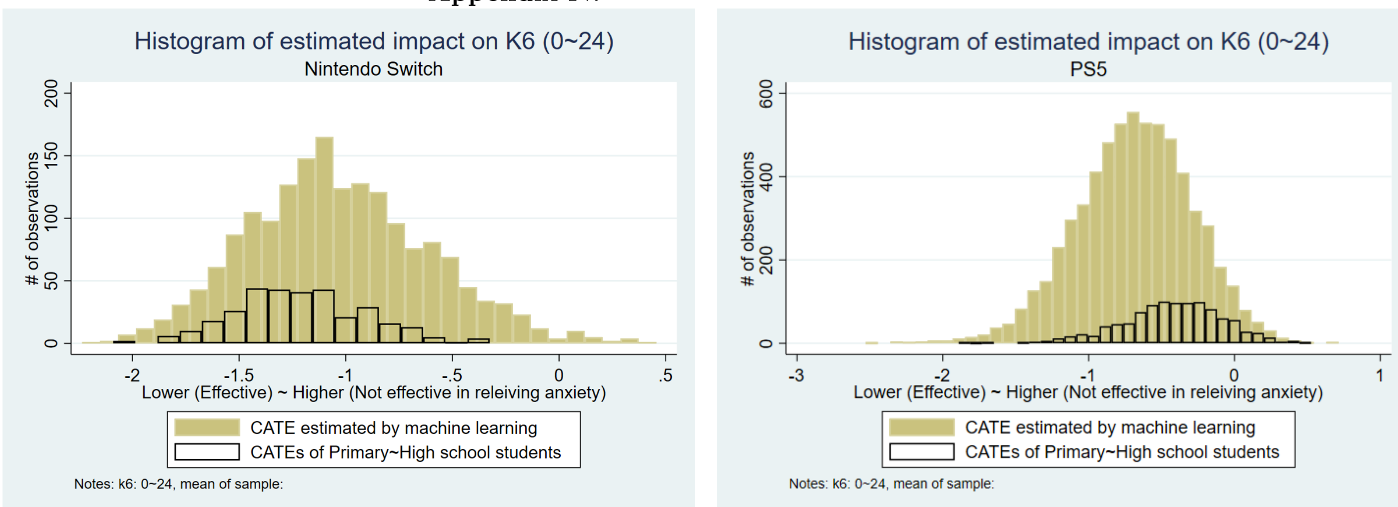
Notes. Standard errors are clustered by prefectures. $***p < 0.01, **p < 0.05, *p < 0.1$.

Appendix M. Below is details of our PSM specification.

- One to one matching without replacement.
- Logit model.

- Descending method.
- psmatch2 in STATA.

Appendix N.



(a) Nintendo Switch **(b)** PS5

Fig 13. Histogram of CATE of students.

Notes. The conditional ATEs are estimated by causal forest.

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Data availability

The data set supporting our findings is not publicly available due to access restrictions based on the agreement with the gameage R&I. The data set is available on reasonable request.

Conflicts of interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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