Videogames and the Gender Gap in Computer Science

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Abstract

In contrast to other STEM fields, over the last thirty years computer science has grown increasingly male-dominated. Using large-scale US survey data on field of education and occupation as well as data on computer and videogame playing from the mid-1980s to the early 2000s, I study the effect of the spread of videogames on the widening of the gender gap in computer science. Using two-way fixed effects regressions exploiting variation in the spread of videogames by state of birth and cohort, I find that for men, greater exposure to videogames when young is associated with (1) an increased probability of obtaining a bachelor's degree in computer science (2) an increased probability of working in a computer-related occupation, and (3) a decreased probability of obtaining any bachelor's degree. Among those who obtain a bachelor's degree, a 20% increase in the spread of videogames in their cohort (while teenagers) is associated with a 10% increase in the gender gap in the probability of studying computer science, and a 14% increase in the gender gap in the probability of working in a related field. To address potential endogeneity, I instrument for videogame exposure using the early prevalence of videogame arcades by state combined with national sales of games released each year. The IV analysis confirms the results, suggesting that videogame exposure may be an important driver of the gender gap in computer science, and providing additional evidence of the long-term role of non-academic activities during childhood on education and career choices and outcomes.

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1 Introduction

Despite being approximately half of the US workforce, women held only 35% of jobs in STEM occupations in 2020 (National Science Foundation, 2020). This gender gap is even more pronounced in computer science, where women earned only 21% of bachelor's degrees, a smaller share than in 1995. Qualitative evidence suggests that young men's greater experience with computers before college may be one factor behind their greater participation in computer science education (Margolis and Fisher 2002). In the last 40 years, the popularity of video games has surged, particularly among young men, who spent on average almost 2 hours per day on gaming in 2022 (BLS, 2023). The ubiquity of video games means that they have potentially an unprecedented influence on the interests, skills, and aspirations of young people.

In this paper, I study the effect of the spread of videogames on the widening of the gender gap in computer science. To do this, I combine large-scale US survey data on field of education and occupation from the American Community Survey (ACS) with survey data on videogame playing from the mid-1980s to the early 2000s to measure the popularity of videogames in a person's place of birth. In the main analysis I estimate two-way fixed effects regressions using variation in the spread of videogames in the respondent's state of birth during their childhood. In line with my hypotheses, I show that for men, greater exposure to videogames when young is associated with (1) an increased probability of obtaining a bachelor's degree in computer science and (2) an increased probability of working in a computer-related occupation. On the otherhand, I also find that for men, increased exposure to videogames is associated with a decreased probability of obtaining a bachelor´s degree in any subject.

Among those who obtain a bachelor's degree, a 20% increase in the spread of videogames in their cohort (while teenagers) is associated with a 10% increase in the gender gap in the probability of studying computer science, and a 15% increase in the gender gap in the probability of working in a related field. Meanwhile, an increase in videogame exposure of this magnitude is associated with a 23% larger gender gap in favor of women in the probability of obtaining a college degree.

Exposure to videogames may be correlated with other characteristics that vary by state and cohort, such as local economic conditions, employment in and prevalence of technology and related industries, or educational quality, which could directly affect demand for computer science education and work. To address this potential endogeneity, I use a shift-share instrument for videogame exposure constructed using per capita density of videogame arcades by state combined with total North American sales of games released in each year. Arcades were early physical locations where young people played videogames, and spread quickly throughout the US in the 70s and 80s. I argue that the early distribution of arcades was not (only) driven by demand factors. For example, parents and legislators concerned about the negative effects of videogames on children as well as dangerous influences in public arcades attempted to and succeeded in passing bans or restrictions on arcade locations in several states including Georgia, Rhode Island, New Hampshire, New York, California, Texas and Massachusetts (Kocurek 2012). As such, the density of arcades is likely to affect the exposure of young people to videogames but to not be directly related to other local characteristics. Moreover, there is evidence that arcades were highly male dominated spaces (Williams 2006), and thus may have had a greater impact on boys. My IV analysis confirms a significant effect for boys more exposed to videogames on the probability of obtaining a bachelor's degree in computer science, working in a related field, and on the likelihood of getting a university degree.

This paper contributes to the literature on the differences in how men and women choose their field of study and the causes of occupational segregation. Although women have closed the gap in human capital accumulation, large gender differences in occupation and industry remain (Cortes and Pan 2018, Blau and Kahn 2017). Researchers have pointed to several factors behind this persistent sorting, including discrimination, workplace flexibility, and environment, as well as differences in preferences and personality traits, gender identity and social norms (Bertrand and Duflo 2017, Goldin 2014, Bertrand 2011). I provide additional evidence on the long-term role of non-academic activities during childhood and cultural influences on education and career choices. This is particularly relevant given the frequently gendered nature of entertainment and online media.

I also contribute to the extensive literature investigating the persistent gender gap in STEM in higher education and the labor force (Kahn and Ginther 2017, Reuben et al. 2015, Ginther and Rosenbloom 2018). As noted by Kahn and Ginther (2017), women's underrepresentation in STEM bachelor's degrees continues to this day, and is concentrated in a subset of fields including physical and earth sciences, engineering, math, economics, and computer science. Of these fields, computer science has been a source of particular interest due to the sharp increase in the share of men obtaining bachelor's degrees in the field starting in the mid-1980's, as shown in figure 1 (Kahn and Ginther 2017, Ginther and Rosenbloom 2018, Card and Payne 2021).

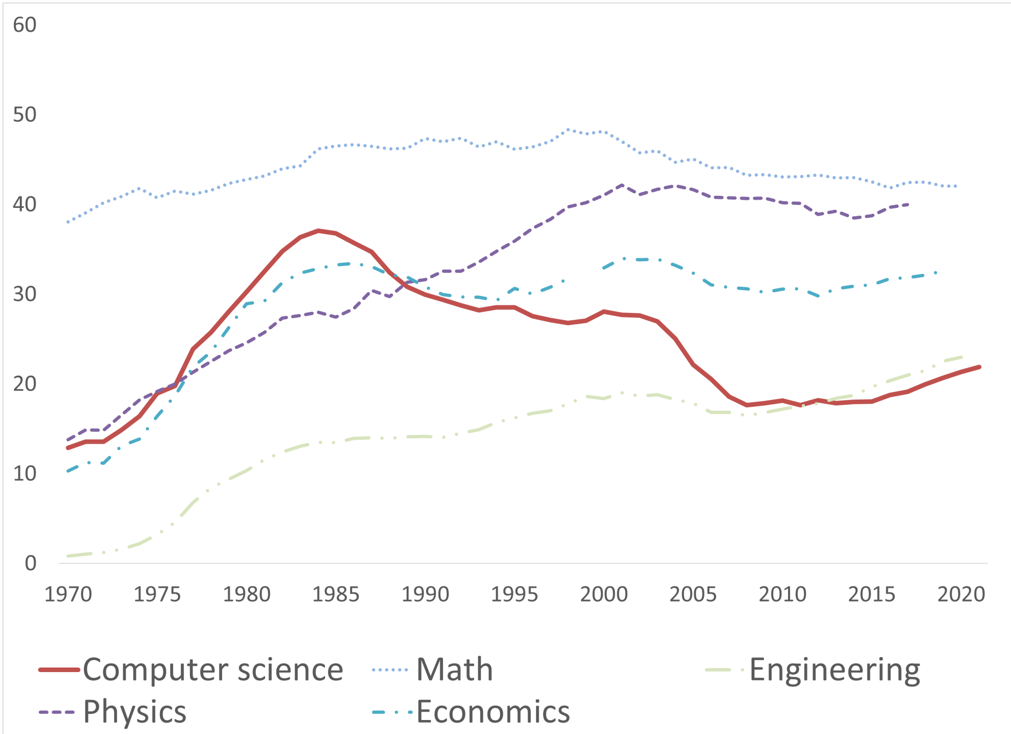

Figure 1: Fraction of women obtaining bachelor's degrees in the US by STEM subfield

This paper contributes to our understanding of the factors behind this growing gender gap, providing quantitative evidence that videogames may have played a role.

Additionally, this paper is related to the literature on the gender gap in college completion, which explores the reasons why women are now more likely than men to obtain a bachelor's degree in the US, as well as in other developed countries (Goldin et al. 2006). Research has pointed to various causes for boys' relative under-performance, including behavioral and developmental differences between girls and boys, such as higher prevalence of disciplinary problems and lower non-cognitive skills among boys, and differing effects of underpriviledged backgrounds ((Goldin et al. 2006, Almås et al. 2016, Autor et al. 2019). I provide evidence that exposure to video games may have also contributed to changes in the relative likelihood of attending college for boys.

Finally, this paper is related to the literature on the effects of video game use and its relationship to gender. Research has found that the use of videogames can improve spatial skills and problem-solving skills (Spence and Feng 2010, Barr 2017, Subrahmanyam and Greenfield 1994). On the other hand, there is some evidence that time spent playing games may crowd-out time spent on other learning activities, and may have negative effects on academic performance (Weis and Cerankosky 2010). Studies have also found that men are more likely to play videogames than women, and that those who play spend more time doing so (Engelstätter and Ward 2022, Aguiar et al. 2021). Moreover, research has found strong gender biases in videogame content and advertising, with a greater proportion of characters being male, and female characters often depicted in sexualized and gender stereotyped ways (Scharrer 2004, Downs and Smith 2010, Bègue et al. 2017, Williams 2006). In addition, women who play online videogames often report experiencing sexual harassment (Kuznekoff and Rose 2013, Tang and Fox 2016). I build on this research by showing that videogame use may have lasting effects on academic and professional outcomes that differ by gender.

This paper proceeds as follows. In section 2 describe my data and the background for my instrumental variable. Then, in section 3 I present the empirical strategy in detail. Section 4 presents the main results, while section 5 discusses a series of robustness checks, and section 6 concludes.

2 Data

The main analysis is conducted using two main sources of data. First, I obtain information on education and occupation from the American Community Survey (ACS), for every year from 2009 to 2021. Data from the ACS is representative at the state level, and includes detailed questions about individuals' educational attainment, field of bachelor's degree, and field of occupation at the time of the survey. To isolate the effect on degree choice, I limit the sample to individuals aged 22 and over at the time of the survey, the minimum age at which individuals in the data report obtaining a degree. I obtain a sample of over 9.4 million individuals born between 1967 and 1994. Table 1a shows summary statistics for this sample.

In the main sample, only 36% of individuals had obtained at least a bachelor's degree. Moreover, around 1% of the sample had obtained a bachelor's degree in computer science. The average videogame exposure was 31% and approximately 2% of individuals listed their occupation as being computer related.

To further isolate the effect on the choice of college major, I also run all of the analyses related to computer science including only individuals who obtained (at least) a college degree. Summary statistics for this sample are shown in table 1b. In this smaller sample, 44% are men while computer

Table 1a: Summary statistics for ACS full sample

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Survey year	9,403,062	2015	3.538	2009	2021
Birth year	9,403,062	1980	7.748	1967	1994
Male	9,403,062	0.501	0.500	0	1
Bachelor's	9,403,062	0.355	0.479	0	1
Computer science bachelor's	9,403,062	0.0103	0.101	0	1
Videogame exposure	9,403,062	0.306	0.207	0.00775	0.810
Computer-related occupation	8,488,112	0.0223	0.148	0	1

The full sample includes people born between 1967 and 1994 who were interviewed in the American Community Survey at ages 22 and above in 2009-2019 or 2021. Birth cohorts are defined in 4-year intervals between 1967 and 1994. Videogame exposure is the share of each cohort playing videogames at ages 10-17 in a person's birth state is calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003.

science bachelor's are obtained by nearly 3% of individuals. Average videogame exposure is around 30%, as in the main sample, while almost 4% of people worked in computer-related occupations.

Table 1b: Summary statistics for ACS college sample

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Survey year	3,315,886	2015	3.555	2009	2021
Birth year	3,315,886	1979	7.572	1967	1994
Male	3,315,886	0.441	0.496	0	1
Bachelor's	3,315,886	1	0	1	1
Computer science bachelor's	3,315,886	0.0293	0.169	0	1
Videogame exposure	3,315,886	0.305	0.206	0.00775	0.810
Computer-related occupation	3,190,760	0.0392	0.194	0	1

The college sample includes people born between 1967 and 1994 who were interviewed in the American Community Survey at ages 22 and above in 2009-2019 or 2021 and had obtained a bachelor's degree at any point. Videogame exposure is the share of a person's cohort playing videogames at ages 10-17 in a person's birth state is calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003.

Next, I construct a measure of exposure to videogames by state of residence and year of birth using micro-data from the CPS Computer and Internet Use Supplement. All individuals in households included in the survey are asked whether they use computers at home to play games at the time of the survey. To identify exposure to videogames before individuals apply to college, I limit the sample to individuals who were between 10 and 17 years old at the time of the survey. I then create the exposure variable as the fraction of the sample born in each year and state that reported playing videogames. Pooling data from 1984, 1989, 1993, 1997, 2001 and 2003, I obtain a sample of 101,439 individuals born between 1967 and 1993. Table 1c shows summary statistics for this sample. The sample is 51% male, and 34% report using their computer at home to play videogames.

Table 1c: Summary statistics for CPS sample

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
Survey year	101,439	1994	6.794	1984	2003
Age	101,439	13.48	2.283	10	17
Year of birth	101,439	1981	7.193	1967	1993
Male	101,439	0.511	0.500	0	1
Plays videogames	101,439	0.345	0.475	0	1

The full sample includes people wer ages 10 to 17 and part of households interviewed in the CPS in 1984, 1989, 1993, 1997, 2001 and 2003. The variable "plays videogames" is an indicator variable equal to one if an individual answered yes when asked if they were use computers at home to play games at the time of the survey.

To obtain a measure of videogame exposure when young for individuals in the ACS, I connect the two datasets using year and state of birth.* I also conduct the analyses at a higher level of geographic disaggregation, by connecting the two datasets using the metropolitan area of residence at the time of each survey. However, due to the high rates of mobility within the US, this may introduce bias into the results as people are likely to select into locations with greater labor market opportunities.

2.1 Identification: Amusement arcades

Exposure to videogames may be correlated with other characteristics that vary by state and time, such as local economic conditions, employment in and prevalence of technology and related industries, or educational quality, which could directly affect demand for computer science education and work. To address this potential endogeneity, I use a shift-share instrument for videogame exposure constructed using density of videogame arcades by state combined with total North American sales of games released in each year.

Arcades were early physical locations where young people played videogames, and spread quickly throughout the US in the 70s and 80s. As arcades became increasingly popular and common, they also became a source of controversy, and numerous communities organized against them, passing zoning ordinances and other restrictions (Kocurek 2012). These restrictions were

*The implied assumption is that individuals are likely to have spent their teenage years in their state of birth. In the ACS data, over 80% of teenagers lived in their state of birth.

motivated by concerns over the negative effects of videogames on children, as well as by a general association of the arcade business with gambling and crime (Kocurek 2012, Skolnik and Conway 2019).

During this time, video game arcades were highly male dominated spaces (Kaplan 1983, Skolnik and Conway 2019)). This may in part be due to the association between early video arcades and older coin-operated amusement machines which often included female nudity and sexual content, and were often placed in male-populated venues (e.g. bars and pool halls) (Kocurek 2012, Skolnik and Conway 2019). When women did visit arcades, they were more likely to play non-violent games, however these types of games were less common. Moreover, there is some evidence that parents were less likely to allow their daughters to frequent arcades (Kaplan 1983, Ellis 1984).

In order to expand their client base and reduce the risk of further restriction, in the 1980s the amusement industry tried to recast arcades as wholesome entertainment centers for the entire family. New, often chain businesses, arcades were brightly-lit and located in shopping malls (Kaplan 1983, Skolnik and Conway 2019). Video game arcade machines could also be found in other businesses such as movie theaters, bowling alleys, pizza restaurants, grocery stores, pharmacies, etc. (Kocurek 2012). Despite continuing to be a minority at arcades, teenage girls and women did visit local arcades at a higher rate following the release of Pac-man, a game specifically designed to attract them (Newman 2018).

Given their popularity in this early period, the density of arcade machines likely affected the exposure of young people, especially boys, to videogames. Moreover, there is some evidence that children living in proximity to arcades are more likely to spend time there (Fisher 1995). Given their usual location in shopping malls and variation in their frequency due to local restrictions, their density is likely to be partially exogenous to education and labor market outcomes, after including controls.

In order to construct the instrument I first obtain a list of addresses of businesses which had arcade machines operating in the United States in the late 1980s from an industry trade magazine. I combine this with the land area of each state to calculate the number of arcades by state per area (per km squared). [†] Figure 2.1 shows a histogram of the log of this variable.

[†] As a robustness check I also run the analyses alternatively using the number of arcades by state per capita instead of per area, using population in 1990 from the US Census Bureau.

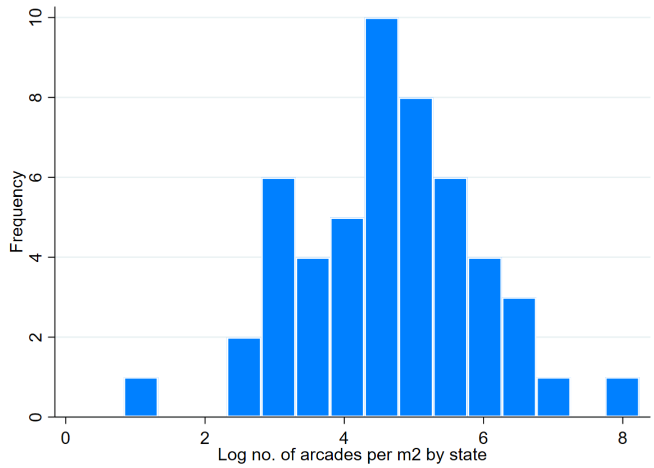

Figure 2: Frequency distribution of arcades per capita in late 1980s

I combine this measure of relative arcades per km^2 with a measure of the popularity of videogames released in each year. I aggregate sales by year of release from a database of sales to consumers of every videogame released in each year from VGChartz (`http://www.vgchartz.com/gamedb/`). This dataset was developed by VGChartz using data from a representative sample of small retailers combined with statistical prediction methods (VGChartz 2023) and has been used in recent research (Suziedelyte 2021). A limitation of this data is that yearly sales are not available for the study period, however the majority of sales usually occur within the first two years following the release of a game, meaning that all time-sales are likely to reflect the popularity of games released in any given year (Suziedelyte 2021).

3 Empirical Strategy

To investigate the role of videogames on the gender gap in computer science I start by estimating a two way fixed effects model which exploits variation in exposure to videogames by state and year of birth.

For each outcome I run the following regression at the individual level

$$Y_{is\tau t} = \alpha + \beta_1 videogames_{s\tau} + \beta_2 male_i + \beta_3 videogames_{s\tau} \times male_i + X_{s\tau} + \mu_s \times \tau + \mu_s + \lambda_\tau + \delta_t + \epsilon_{is\tau t} \quad (1)$$

where for each individual i observed in survey year t, $videogames_{s\tau}$ is the share of people in their four-year birth cohort τ and birth state s observed at ages 10-17 who report using a computer at home to play videogames, β_3 is the coefficient of interest. The outcome Y_{ist} is an indicator for studying a computer-related field in college or working in a related occupation. I cluster standard errors in all regressions at the state level, to allow for correlation in unobservable state characteristics.

In the main specification, I include as controls at the state cohort level the share of adults aged 22-65 who had a college degree, as well as mean and median household income. It is also important to include state fixed effects, μ_s, to control for time-invariant characteristics of a location which could impact both videogame exposure and a person's education and occupational outcomes. Similarly, I include cohort fixed effects, λ_τ, to capture the effect of changes in technology or other characteristics across time. Survey year fixed effects, δ_t, capture differences in educational and labor market decisions which may be due to the year in which the interview was conducted. In one specification I also include state specific time trends, $\mu_s \times \tau$, aggregating years at the cohort level, to capture differences in state characteristics over time unrelated to the spread of videogames.

The main analyses use variation in exposure to videogames at the state-cohort level. A greater level of geographic disaggregation is not available for individuals' past residence or location of birth. However, the results are robust to running the analyses at the metropolitan area level using individuals' location of residence at the time of the ACS survey. In this robustness analysis I also limit the sample to individuals who have always lived in the same state, to partially address potential selection into location of residence.

Exposure to videogames is measured at ages 10-17 in order to maximize the period of potential exposure prior to the age at which people usually apply to and begin higher education.

Moreover, the data on videogame use show that young people play the most games around the age of 15. The results are robust to using a shorter period of exposure from ages 12-15. Likewise, I run the main regressions using 4-year cohorts by year of birth, however the results are robust to using smaller cohorts. Figure 3 shows the average rate of videogame exposure for individuals in each cohort. The figure shows that videogame exposure grew throughout the sample period, increasing from less than 10% to over 50% for the youngest individuals in the sample. The figure also shows that there was a large jump in videogame exposure in the middle of the period, which coincided with the videogame boom in the US.

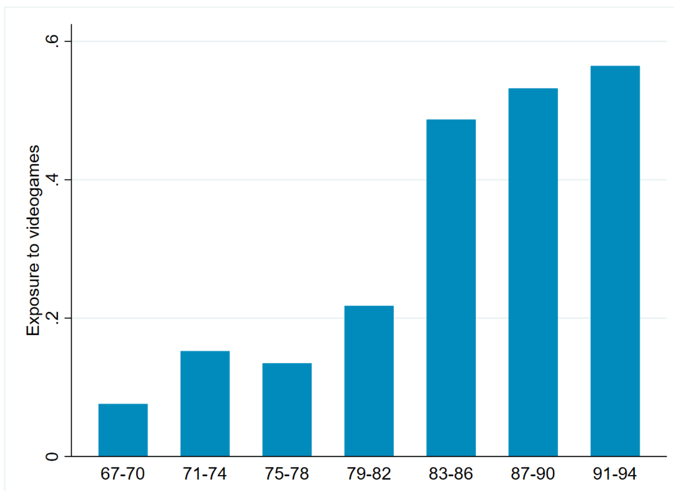

Figure 3: Average videogame exposure for individuals by birth year

Next, to address potential endogeneity in the measure of videogame exposure I use an instrumental variable approach. The videogame exposure instrument is a shift-share which aims to capture the relative popularity of videogames in each state when individuals were teenagers. The instrument is constructed as follows:

$$exposureIV_{s\tau} = NAsales_{\tau} \times \frac{1}{\sum_{r \in S} \frac{arcades_{r,1990}}{population_{r,1990}}} \times \frac{arcades_{s,1990}}{population_{s,1990}} \qquad (2)$$

where $NAsales_{\tau}$ is average all-time North American sales of videogames released in the years that individuals in cohort τ were aged 10-17 and $arcades_s$ is number of videogame arcades in state s in 1990 divided by population. This generates a variable that distributes annual sales of videogames across states according to the relative number of arcades that were open in that state in 1990, normalized by population.

The validity of my instrumental strategy relies on the idea that the per-capita density of arcades affects educational and occupational outcomes only through its effect on local exposure to videogames during a person's youth, after including controls and controlling for state, cohort and survey year fixed effects (Goldsmith-Pinkham et al. 2020).

First-stage. Using state and year of birth, I first assign videogame exposure and the exposure IV to each individual in the ACS sample. Given that the measure of videogame exposure is used both directly and interacted with an indicator for male, it is necessary to instrument for both variables. Thus I estimate the two following first-stage equations at the individual level:

$$\begin{aligned} videogames_{s\tau} =& \gamma_1 + \gamma_2 exposureIV_{s\tau} + \gamma_3 male_i + \beta_3 exposureIV_{s\tau} \times male_i + X_{s\tau} + \mu_s + \\ & \lambda_\tau + \delta_t + \epsilon_{ist\tau} \end{aligned} \tag{3}$$

$$\begin{aligned} videogames_{s\tau} \times male_i =& \gamma_1 + \gamma_2 exposureIV_{s\tau} + \gamma_3 male_i + \beta_3 exposureIV_{s\tau} \times male_i + X_{s\tau} + \mu_s + \\ & \lambda_\tau + \delta_t + \epsilon_{ist\tau} \end{aligned} \tag{4}$$

where $videogames_{s\tau}$ is the share of people in a person's birth cohort τ and birth state s observed at ages 10-17 who played videogames, $male_i$ is an indicator for men, $exposureIV_{s\tau}$ is the arcade and sales based exposure instrument, $X_{s\tau}$ are state-cohort level controls, μ_s is state fixed effects, λ_τ is cohort fixed effects, and δ_t is survey year fixed effects. Standard errors are clustered at the state level.

My instrumental strategy is thus to use both $exposureIV_{s\tau}$ and $exposureIV_{s\tau}$ interacted with a dummy for male as instruments.

4 Results

Table 2 presents the results from estimating equation (1), which assesses the relationship between exposure to videogames during early adolescence and the likelihood of studying computer science in college. Columns (1) and (2) show regressions using the full sample of individuals with and without controls and state-specific time trends, while columns (3) and (4) limit the sample to people who obtained at least a bachelor's degree.

As shown in the first row, men are significantly more likely to study computer science. In the full sample, without exposure to videogames, the average man has a 1 percentage point larger probability of obtaining a degree in computer science than the average woman. This is a large gender gap in probability, approximately equivalent to the full sample mean probability of studying computer science. Focusing on the sample of people who obtained a bachelor's degree, this gap is larger, with men being 3.5pp more likely to study computer science.

Table 2: Probability of studying a computer-related field, for full sample and college sample

	(1)	(2)	(3)	(4)
VARIABLES	Full sample		College sample	
Male	0.0104***	0.0104***	0.0351***	0.0351***
	(0.000504)	(0.000504)	(0.000845)	(0.000842)
Videogame exposure	-0.00127	-0.00643**	-0.00982	-0.0164**
	(0.00251)	(0.00303)	(0.00608)	(0.00775)
Male × Videogame exposure	0.00417***	0.00417***	0.0189***	0.0188***
	(0.00107)	(0.00107)	(0.00219)	(0.00219)
Observations	9,403,062	9,403,062	3,315,886	3,315,886
Dependent var. mean	0.0103	0.0103	0.029	0.029
Cohort FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
State time trend	No	Yes	No	Yes

Note. The outcome is a variable equal to 1 if a person obtained a bachelor's degree in a computer-related field and 0 otherwise. Videogame share is the share of a person's four-year birth cohort that was playing videogames at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Standard errors clustered at the state level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The second row of the table shows the effect of exposure to videogames on the probability of studying computer science, while the third shows the additional effect for men. The OLS estimates suggest that videogame exposure has a positive effect on men, but a negative or insignificant effect on women. However, given the likely existence of omitted variables which affect videogame exposure at the state and cohort level for both boys and girls, the coefficient on videogame exposure should be interpreted with caution. In addition, the marginal effect of videogame exposure uninteracted with the male dummy is insignificant in all specifications. As such, I focus on interpreting the effect on the gender gap in computer science, shown in the third row.

In line with my hypothesis, in models (1) and (2) using the full sample, the coefficient on the interaction of male and videogame exposure is positive and significant and has a magnitude of 0.4 percentage points. This implies that a one standard deviation or 21 percentage point increase in the rate of videogame exposure is associated with a 5% increase in the likelihood that a man in the full sample studied computer science in college. Focusing on the subset of individuals who obtained at least a bachelor's degree (columns (3) and (4)) the effect is larger, with a coefficient of 1.9 percentage points, approximately 65% of the sample mean.

The OLS results suggest a large effect of exposure to videogames on the gender gap at the college level. Over the whole period, the average person in the full sample was born in a state and cohort in which 30% of teenagers played videogames. Thus a one standard deviation or 21 percentage point increase in the rate of videogame exposure is associated with an 8% larger gender gap in computer science at the undergraduate level or an 11% larger gap when limiting the sample to those who obtained a bachelor's degree.

I obtain similar results when instrumenting for videogame exposure, as shown in Table 3. The table shows the second stage results of a 2SLS regression, where I instrument for both videogame exposure and for its interaction with male. Columns (1) and (2) show regressions using the full sample of individuals with and without controls, while columns (3) and (4) limit the sample to people who obtained at least a bachelor's degree. As before, the coefficient on male is positive and significant in all specifications, and is larger when using the college sample (columns 3 and 4). The IV results suggest that without exposure to videogames, men are on average 0.8 percentage points likelier than women to obtain a degree in computer science.

In this table the estimated effect of videogame exposure without the interaction, shown in the second row, is negative and insignificant in all specifications. When compared to the OLS results in Table 2, this suggests that the instrumental variable is able to address some of the endogeneity in videogame exposure as the coefficients go from significant to insignificant.

In the full sample, the effect of videogame exposure on the gender gap on the otherhand becomes larger and remains strongly significant (third row). In specifications (1) and (2), the estimated

Table 3: Probability of studying a computer-related field, instrumenting for videogame exposure

	(1)	(2)	(3)	(4)
VARIABLES	Full sample		College sample	
Male	0.00836***	0.00837***	0.0360***	0.0360***
	(0.000889)	(0.000893)	(0.00134)	(0.00135)
Videogame exposure	-0.0443	0.287	-0.0392	0.393
	(0.0865)	(0.632)	(0.0791)	(0.742)
Male × videogame exposure	0.0109***	0.0109***	0.0160***	0.0160***
	(0.00261)	(0.00261)	(0.00409)	(0.0010)
Observations	9,403,062	9,403,062	3,315,886	3,315,886
Dependent var. mean	0.0103	0.0103	0.029	0.029
First stage coef. of Male × Exposure IV	0.00225**	0.00225**	0.00204**	0.00203**
Cohort FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
State time trend	No	Yes	No	Yes

Note. The sales instrument is equal to average north American sales of videogames released when the members of each cohort were ages 10-17, distributed by state according to each state's total number of arcades in 1990, multiplied by 100,000 and divided by population. The outcome is a variable equal to 1 if a person obtained a bachelor's degree in a computer-related field and 0 otherwise. Videogame share is the share of a person's four-year birth cohort that was playing videogames at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Standard errors clustered at the state level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

coefficient on the gender gap is around 1.1 percentage points, which implies that a one standard deviation increase in the rate of videogame exposure is associated with a 27% increase in the gap in the likelihood that men study computer science, relative to women. Columns (3) and (4) limit the sample to those who obtained a bachelor's degree. In this case, the estimated effect associated with a one standard deviation increase in exposure is around an 8% increase in the gender gap, a smaller relative effect driven by the larger estimated baseline gap.

Next I investigate the relationship between exposure to videogames during adolescence and field of occupation. Table 4 shows the results of estimating equation (1) with an outcome equal to 1 if an individual worked in a computer-related field at the time of the interview and 0 otherwise. In the full sample, 2% of individuals were employed in a computer-related occupation. As shown in column (2), after including controls state-time trends, men were 2 percentage points more likely than women to work in this field, with a larger gender gap among those who obtained bachelor's degrees (column 4).

Consistent with the effect on field of study, the results suggest that exposure to videogames during childhood is associated with the likelihood that an individual works in a computer-related occupation. Focusing on the full sample, the coefficient on videogame exposure, shown in the second row, is negative and only significant once controls and state-specific time trends are included (column 2). As before, the coefficient on videogame exposure interacted with the dummy for male is positive and significant in all specifications, indicating an effect on increasing the gender gap in employment in this field. The estimates in columns (1) and (2), in which the full sample is included, imply that a one standard deviation or 21 percentage point increase in the rate of videogame exposure is associated with only a 6% increase in the size of the gender gap. If people who did not obtain bachelor's degrees are excluded, as in columns (3) and (4), this increases to 15%.

Table 4: Probability of working in a computer-related occupation, for full sample and college sample

	(1)	(2)	(3)	(4)
VARIABLES	Full sample		College sample	
Male	0.0208***	0.0208***	0.0397***	0.0397***
	(0.000932)	(0.000931)	(0.00105)	(0.00105)
Videogame exposure	-0.00185	-0.00612**	-0.0232***	-0.0213***
	(0.00273)	(0.00257)	(0.00549)	(0.00433)
Male $\times$ videogame exposure	0.00548***	0.00548***	0.0292***	0.0291***
	(0.00167)	(0.00167)	(0.00154)	(0.00154)
Observations	8,488,112	8,488,112	3,190,760	3,190,760
Dependent var. mean	0.022	0.022	0.039	0.039
Cohort FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
State time trend	No	Yes	No	Yes

Note. The outcome is a variable equal to 1 if a person lists their main occupation as being computer-related. The sample is limited to people who work or have worked in the last 5 years. Videogame share is the share of a person's four-year birth cohort that was playing videogames at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Standard errors clustered at the state level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Once again, the 2sls estimates suggest a larger effect of videogame exposure on the gender gap than the OLS estimates. As with education, the effect of videogame exposure itself is negative and insignificant in all specifications as shown in the second row. In contrast, the estimated coefficient on the interaction with the male dummy is positive and strongly significant. In column (1), when the full sample is used, the coefficient is around 0.013, and almost unaffected by the inclusion of controls in column (2). In this case, a 20 percentage point increase in the rate of videogame exposure is associated with a 14% increase in the gap in the probability that men are occupied in a computer-related field, compared to women. Excluding individuals who did not obtain a bachelor's degree, as in columns (3) and (4), the coefficient on the interaction of videogame exposure with the dummy for male is twice as large. However the given the larger gender gap in the probability of working in a computer-related field in this sample, the effect of a one standard deviation increase in videogame exposure is also an approximately 14% increase in the difference in this likelihood.

Table 5: Probability of working in a computer-related field, instrumenting for videogame exposure

	(1)	(2)	(3)	(4)
VARIABLES	Full sample		College sample	
Male	0.0184***	0.0185***	0.0401***	0.0401***
	(0.00157)	(0.00158)	(0.00189)	(0.00190)
Videogame exposure	-0.0171	-0.0454	-0.0357	0.143
	(0.0705)	(0.0801)	(0.0658)	(0.399)
Male × videogame exposure	0.0133***	0.0132***	0.0279***	0.0278***
	(0.00406)	(0.00407)	(0.00463)	(0.00466)
Observations	8,488,112	8,488,112	3,190,760	3,190,760
Dependent var. mean	0.022	0.022	0.039	0.039
First stage coef. of Male × Exposure IV	0.00225**	0.00225**	0.00204**	0.00203**
Cohort FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
State time trend	No	Yes	No	Yes

Note. The sales instrument is equal to average north American sales of videogames released when the members of each cohort were ages 10-17, distributed by state according to each state's total number of arcades in 1990, divided by its land area in kilometers squared. The outcome is a variable equal to 1 if a person lists their main occupation as being computer-related. The sample is limited to people who work or have worked in the last 5 years. Videogame share is the share of a person's four-year birth cohort that was playing videogames at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Standard errors clustered at the state level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Overall, given the large increase in videogame exposure between the oldest and youngest cohorts in the sample, the results suggest that videogames could explain a significant part of the growth in the gender gap in computer science throughout this period. In particular, videogame exposure grew from 13% to 59%, which using the full-sample IV results and preferred specification with controls, suggests that the expansion of this technology could explain around 29% of the difference in the probability that men studied computer science, relative to women, and 27% of the difference in probability that they worked in a related field.

These results on the effect of videogame exposure on the probability of studying computer science degrees, particularly for men, raise the question of whether individuals are being drawn away from other fields of study and whether this affects the gender gap in these fields. To assess this question, I re-run the main specification on the full sample using indicator variables for studying other fields at the bachelor level as the outcome. Table 6 presents the results on the probability of studying arts or humanities (in columns 1 and 2) and of studying a social science field (in columns

3 and 4). I include 2 specifications for each, the with and without state-cohort level controls and a state-specific time trend. On average, men are less likely to study these non-STEM fields, as shown by the negative and significant coefficient estimate for the male dummy in the first row of -0.0141 for arts or humanities and -0.0174 for social science. In contrast to the results on Computer Science, table 6 suggests that there is a negative and significant effect of videogame exposure on the gender gap in these non-science fields, shown in the third row. Specifically, a 1 SD higher exposure to videogames is associated with a 47 % larger gap in favor of women in the probability of studying arts or humanities and a 30 % larger gap in the social sciences. This result is consistent with some men being drawn away from these fields into computer science due to their exposure to computer games as teenagers.

Table 6: Probability of studying an arts, social science or humanities field, for full sample

	(1)	(2)	(3)	(4)
VARIABLES	Arts or humanities		Social science	
Male	-0.0141***	-0.0141***	-0.0174***	-0.0174***
	(0.00168)	(0.00168)	(0.00132)	(0.00132)
Videogame exposure	0.0473***	0.0271***	0.0138**	0.00997
	(0.0148)	(0.00657)	(0.00658)	(0.00656)
Male × videogame exposure	-0.0313***	-0.0313***	-0.0215***	-0.0215***
	(0.00153)	(0.00154)	(0.00169)	(0.00169)
Observations	9,403,062	9,403,062	9,403,062	9,403,062
Dependent var. mean	0.070	0.070	0.053	0.053
Cohort FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
State time trend	No	Yes	No	Yes

Note. The outcome in is a variable equal to 1 if a person obtained a bachelor's degree in an arts or humanities field in columns 1 and 2 or in a social science field in columns 3 and 4, and 0 otherwise. Videogame share is the share of a person's four-year birth cohort that was playing videogames at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Standard errors clustered at the state level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 7 shows the result of performing the same exercise using several groups of science fields instead. These fields are more male dominated, with men 0.3 percentage points more likely to study a physical science or a biological field and 3 percentage points more likely to study engineering (row 1). The coefficients of interest in row three are negative and significant in this case, suggesting that greater videogame exposure is associated with a decrease in the likelihood that men study these science fields relative to women, and thus with a smaller gender gap. In terms of magnitude, a 1 SD increase in videogames would result in a 21% smaller gender gap in the physical sciences, a 14% smaller gender gap in biological sciences and a 5% smaller gap in engineering participation.

However, in absolute terms, the largest effect on the gender gap from videogame exposure is on the biological sciences, where the coefficient is one order of magnitude larger. These results suggest that boys more exposed to videogames are less likely to study physical, engineering and especially biological sciences.

Table 7: Probability of studying another science field, for full sample

VARIABLES	(1) physical	(2) physical	(3) biological	(4) biological	(5) engineering	(6) engineering
Male	0.00340***	0.00340***	0.00294***	0.00295***	0.0304***	0.0304***
	(0.000222)	(0.000222)	(0.000636)	(0.000637)	(0.00109)	(0.00109)
Videogame exposure	0.00270*	0.00207	0.0230***	0.00604	0.00118	-0.00237
	(0.00142)	(0.00215)	(0.00432)	(0.00541)	(0.00525)	(0.00486)
Male × Videogame exposure	-0.00338***	-0.00338***	-0.0208***	-0.0208***	-0.00659***	-0.00658***
	(0.000422)	(0.000422)	(0.000963)	(0.000964)	(0.00119)	(0.00119)
Observations	9,403,062	9,403,062	9,403,062	9,403,062	9,403,062	9,403,062
Dependent var. mean	0.008	0.008	0.026	0.026	0.022	0.022
Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes
State time trend	No	Yes	No	Yes	No	Yes

Note. The outcome is a variable equal to 1 if a person obtained a bachelor's degree in the science field listed at the top of each column and 0 otherwise. Videogame share is the share of a person's four-year birth cohort that was playing videogames at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Standard errors clustered at the state level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The regression results in tables 2-5 also point to a larger effect of videogame exposure on the gender gap in computer science when focusing on the college sub-sample. In order to better understand differences in the magnitude of estimated effects in the two samples, I re-run the analyses using an indicator for obtaining a bachelor's degree as the outcome. Table 8 shows the OLS and 2SLS estimates.

The first row of table 8 shows that on average, men are approximately 6 percentage points less likely to obtain a bachelor's degree than women in the sample. This estimate is unchanged when I include controls and state-specific time trends in column 2, and when I use an IV strategy in columns 3 and 4. Moreover, the results suggest that the effect of videogame exposure on the probability that an individual obtained at least a bachelor's degree is in the opposite direction to the effects on studying computer science.

In the OLS, the coefficient on videogame exposure in the second row is positive and significant, although it becomes smaller when controls are included. Meanwhile, the coefficient on the interaction of male and videogame exposure is large, negative and highly significant in all specifications. Focusing on the preferred OLS specification in the second column, this suggests that higher exposure to videogames is negatively associated with the probability of attending college for men, and weakly or unrelated with this probability for women. The estimated effects suggest that a one standard deviation increase in exposure to videogames would result in an increase in the gender gap by 23% from 6% to 7.5% in favor of women.

Table 8: Probability of obtaining a bachelor's degree, OLS and 2SLS

	(1)	(2)	(3)	(4)
VARIABLES	Bachelor's: OLS		Bachelor's: 2SLS	
Male	-0.0627***	-0.0627***	-0.0568***	-0.0563***
	(0.00213)	(0.00212)	(0.00402)	(0.00404)
Videogame exposure	0.110***	0.0188	-1.005	0.111
	(0.0337)	(0.0167)	(1.913)	(0.348)
Male × videogame exposure	-0.0733***	-0.0734***	-0.0926***	-0.0940***
	(0.00436)	(0.00435)	(0.00839)	(0.00844)
Observations	9,338,689	9,338,689	9,338,689	9,338,689
Dependent var. mean	0.355	0.355	0.355	0.355
Cohort FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
State time trend	No	Yes	No	Yes

Note. The outcome is a variable equal to 1 if a person obtained a bachelor's degree and 0 otherwise. Videogame share is the share of a person's four-year birth cohort that was playing videogames at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Columns 1 and 2 show the OLS estimates and columns 3 and 4, the 2SLS estimates instrumenting for vidoegame exposure. The videogame exposure instrument is equal to average north American sales of videogames released when the members of each cohort were ages 10-17, distributed by state according to each state's total number of arcades in 1990, divided by its land area in kilometers squared. Standard errors clustered at the state level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Columns 3 and 4 show the results of instrumenting for videogame exposure. In contrast to the OLS, the uninteracted effect of exposure to videogames in the second row becomes negative and insignificant, suggesting that there may be endogeneity in this variable which is addressed through the instrumental variable. On the other hand, the coefficient on videogame exposure interacted with male becomes larger and stays significant, with a small change after controls are included. Using this estimate, a one standard deviation increase in videogame exposure would result in a 35% growth in the gap in the probability that a woman obtained a bachelor's degree relative to a man in the full sample.

These results point to a negative effect of videogame exposure on the probability that men obtain bachelor's degrees. I explore the effect on alternative further education by re-running the analysis using whether individuals obtained an associate's degree as the main outcome. Table 9 shows the OLS and IV results.

As with bachelor's degrees, men are less likely to obtain associate's degrees, as shown in the first row. On average, men are 3 percentage points less likely to obtain one of these degrees.

Videogame exposure uninteracted with a dummy for male, has no significant effect in any specification. However, when interacted with male, videogame exposure has a positive and significant effect. In the OLS, the coefficient in both specifications is 1.96 percentage points which implies that a 1 SD increase in exposure to videogames is be associated with a 13% smaller gender gap in favor of women in the probability of obtaining an associates degree.

Instrumenting for videogame exposure confirms these results. As in the OLS, the coefficient on its interaction with a dummy for male is positive and significant. However, the IV estimate of the effect on the gender gap however is larger, with a one standard deviation increase in videogame exposure being associated with around a 22% reduction in the female advantage relative to men.

Table 9: Probability of getting an associate's degree, OLS and 2SLS

	(1)	(2)	(3)	(4)
VARIABLES	Associate's: OLS			Associate's: 2SLS
Male	-0.0306***	-0.0306***	-0.0365***	-0.0365***
	(0.00222)	(0.00222)	(0.00364)	(0.00364)
Videogame exposure	-0.00652	-0.000326	0.0587	-1.005
	(0.0129)	(0.00953)	(0.164)	(1.722)
Male × Videogame exposure	0.0196***	0.0196***	0.0388***	0.0387***
	(0.00390)	(0.00391)	(0.00975)	(0.00973)
Observations	9,403,062	9,403,062	9,403,062	9,403,062
Dependent var. mean	0.097	0.097	0.097	0.097
Cohort FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
State time trend	No	Yes	No	Yes

Note. The outcome is a variable equal to 1 if a person obtained an associate's degree and 0 otherwise. Videogame share is the share of a person's four-year birth cohort that was playing videogames at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Columns 1 and 2 show the OLS estimates and columns 3 and 4, the 2SLS estimates instrumenting for vidoegame exposure. The videogame exposure instrument is equal to average north American sales of videogames released when the members of each cohort were ages 10-17, distributed by state according to each state's total number of arcades in 1990, divided by its land area in kilometers squared. Standard errors clustered at the state level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Altogether these results suggest that videogame exposure may have two opposing effects on men: first, men more exposed to games are less likely to obtain a bachelor's degree, with some obtaining associate's degrees instead, and second, those who do obtain bachelor's degrees are more likely to study computer science, and less likely to study arts, social sciences or other science fields.

5 Robustness

I conduct a wide array of robustness checks. First, I re-do the analysis using videogame exposure measured during a shorter age-range, using individuals observed at ages 12-15 instead of 10-17.

Table 10 shows the results on education, while table 11, that on occupation. Focusing on education, the estimates are consistent with those of the main analysis in table 2. In particular, in the full sample and main specification shown in column 2, the coefficient on male is positive and significant and of a similar magnitude. However, the estimated effect of videogame exposure in the second row becomes insignificant in all specifications. Finally, in the full sample, the effect of videogames on the gender gap shown in the third row is positive and significant but approximately 70% of the estimates using the larger age range, likely due to the shorter period of exposure.

Using a shorter age range similarly yields consistent results on the effect of videogames on the probability of working in a computer-related occupation. Focusing on the estimated effect of videogames, rows two and three show that the shorter period of exposure results in smaller coefficient estimates, but with the same direction and significance. Similar to the results with education, the effect of the interaction of videogame exposure with the dummy for male using the 12-15 age range is 72% of the estimate using the wider age range.

Table 10: Probability of studying a computer-related field, using exposure from ages 12-15

	(1)	(2)	(3)	(4)
VARIABLES	Full sample		College sample	
Male	0.0110***	0.0110***	0.0371***	0.0372***
	(0.000537)	(0.000537)	(0.000956)	(0.000952)
Videogame exposure	-0.000206	-0.000625	-0.00430	-0.00295
	(0.00204)	(0.00213)	(0.00516)	(0.00536)
Male × Videogame exposure	0.00288**	0.00288**	0.0130***	0.0130***
	(0.00110)	(0.00110)	(0.00251)	(0.00251)
Observations	8,284,765	8,284,765	2,952,243	2,952,243
Cohort FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
State time trend	No	Yes	No	Yes

Note. The outcome is a variable equal to 1 if a person obtained a bachelor's degree in a computer-related field and 0 otherwise. Videogame share is the share of a person's four-year birth cohort that was playing videogames at ages 12-15 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Standard errors clustered at the state level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Next I re-do the analyses using 2-year birth cohorts instead of 4-year ones. These results are shown in tables 12 and 13. The estimates of the effect of videogame exposure largely unchanged from the main analysis. The effect on the gender gap in computer science education in the third

Table 11: Probability of working in a computer-related occupation, using exposure from ages 12-15

	(1)	(2)	(3)	(4)
VARIABLES	Full sample		College sample	
Male	0.0217***	0.0217***	0.0410***	0.0410***
	(0.00100)	(0.00100)	(0.00113)	(0.00113)
Videogame exposure	-0.00138	-0.00209	-0.0172***	-0.0131***
	(0.00218)	(0.00218)	(0.00402)	(0.00328)
Male × Videogame exposure	0.00396**	0.00397**	0.0245***	0.0244***
	(0.00175)	(0.00175)	(0.00193)	(0.00193)
Observations	7,494,966	7,494,966	2,845,445	2,845,445
Cohort FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
State time trend	No	Yes	No	Yes

Note. The outcome is a variable equal to 1 if a person lists their main occupation as being computer-related. The sample is limited to people who work or have worked in the last 5 years. Videogame share is the share of a person's four-year birth cohort that was playing videogames at ages 12-15 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Standard errors clustered at the state level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

row of table 12 is similarly estimated to be positive and significant. A 1 SD increase in videogame exposure in this case is associated with a 6% increase in the gender gap in the full sample and a 7% increase among individuals in the college sample.

The results on occupation using smaller sized cohorts are shown in table 13. Once again the coefficients have the same sign, however the estimates of the effect of videogame exposure on the gender gap are smaller and less significant. This may be due to noise in the estimates due to the smaller size of the cohorts and to a decrease in the sample size used. Nevertheless, the coefficient on the interaction term is approximately 0.5% implying a that a 1 SD increase in exposure would result in a 4% increase in the gender gap in the share of people working in a computer-related occupation.

Re-doing the analyses at the metropolitan area level of residence, which is only available for a subset of observations and is measured at the time of the survey (rather than at birth), gives largely consistent results. However, the estimated negative effect on the likelihood that boys obtain bachelor's degrees is larger, resulting in a negative effect on the gender gap in computer science in the full sample.

I also use alternative definitions of the instrumental variable. First I construct a version of the

Table 12: Probability of studying a computer-related field, using 2-year cohorts

	(1)	(2)	(3)	(4)
VARIABLES	Full sample		College sample	
Male	0.0110***	0.0111***	0.0373***	0.0373***
	(0.000541)	(0.000541)	(0.000941)	(0.000937)
Videogame exposure	-0.00132	-0.00405*	-0.00645	-0.0104**
	(0.00221)	(0.00205)	(0.00532)	(0.00488)
Male × Videogame exposure	0.00315***	0.00315***	0.0133***	0.0133***
	(0.00115)	(0.00115)	(0.00249)	(0.00249)
Observations	8,055,561	8,055,561	2,880,286	2,880,286
Cohort FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
State-time trend	No	Yes	No	Yes

Note. The videogame exposure instrument is equal to average north American sales of videogames released when the members of each cohort were ages 10-17, distributed by state according to each state's total number of arcades in 1990, multiplied by 100,000 and divided by population. The outcome is a variable equal to 1 if a person obtained a bachelor's degree in a computer-related field and 0 otherwise. Videogame share is the share of a person's 2-year birth cohort that was playing videogames at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Standard errors clustered at the state level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 13: Probability of working in a computer-related field, using 2-year cohorts

	(1)	(2)	(3)	(4)
VARIABLES	Full sample		College sample	
Male	0.0217***	0.0217***	0.0411***	0.0411***
	(0.000977)	(0.000977)	(0.00107)	(0.00107)
Videogame exposure	-0.00259	-0.00477**	-0.0180***	-0.0158***
	(0.00215)	(0.00199)	(0.00432)	(0.00334)
Male × Videogame exposure	0.00450**	0.00450**	0.0254***	0.0253***
	(0.00170)	(0.00170)	(0.00179)	(0.00179)
Observations	7,286,294	7,286,294	2,775,439	2,775,439
Cohort FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
State time trend	No	Yes	No	Yes

Note. The outcome is a variable equal to 1 if a person lists their main occupation as being computer-related. The sample is limited to people who work or have worked in the last 5 years. Videogame share is the share of a person's two-year birth cohort that was playing videogames at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Standard errors clustered at the state level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

variable which divides the number of arcades by state population, instead of by land area. These results are shown in table 14.

Table 14: Probability of studying a computer-related field, using IV normalized by population

	(1)	(2)	(3)	(4)
VARIABLES	Full sample		College sample	
Male	0.00836***	0.00837***	0.0360***	0.0360***
	(0.000889)	(0.000893)	(0.00134)	(0.00135)
Videogame exposure	-0.0443	0.287	-0.0392	0.393
	(0.0865)	(0.632)	(0.0791)	(0.742)
Male × videogame exposure	0.0109***	0.0109***	0.0160***	0.0160***
	(0.00261)	(0.00261)	(0.00409)	(0.0010)
Observations	9,403,062	9,403,062	3,315,886	3,315,886
Dependent var. mean	0.0103	0.0103	0.029	0.029
First stage coef. of Male × Exposure IV	0.00225**	0.00225**	0.00204**	0.00203**
Cohort FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
State time trend	No	Yes	No	Yes

Note. The sales instrument is equal to average north American sales of videogames released when the members of each cohort were ages 10-17, distributed by state according to each state's total number of arcades in 1990, multiplied by 100,000 and divided by population. The outcome is a variable equal to 1 if a person obtained a bachelor's degree in a computer-related field and 0 otherwise. Videogame share is the share of a person's four-year birth cohort that was playing videogames at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Standard errors clustered at the state level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Further, one concern with the instrumental variable is that arcades are measured in the late 1980s, rather than earlier during the arcade boom and may reflect demand for videogames as well. In order to address this concern, I obtain alternative data on the number of coin-operated amusement businesses from the Quarterly Census of Employment and Wages (QCEW) (Bureau of Labor Statistics). Unlike the arcade location dataset, this includes only businesses which are dedicated to arcades. However, I verify that the number of arcades businesses in 1980 is strongly correlated with the original dataset and re-do the analysis using this data, obtaining consistent results (table 15).

Finally, the results point to a causal effect of exposure to videogames on educational outcomes. However, exposure to computer games, as measured in the data, is almost certainly correlated with exposure to computers. Thus, one may be concerned that the observed results are in fact caused by exposure to computers directly, rather than by exposure to games.

Table 15: Probability of studying a computer-related field, 2SLS using arcades in 1980

	(1)	(2)	(3)	(4)
	Full sample	Full sample	College sample	College sample
Male	0.00873***	0.00867***	0.0364***	0.0363***
	(0.000687)	(0.000909)	(0.00107)	(0.00148)
Videogame exposure	0.221	-1.432	0.365	1.278
	(0.347)	(38.41)	(0.778)	(22.72)
Male × Videogame exposure	0.00978***	0.00995***	0.0148***	0.0151***
	(0.00217)	(0.00349)	(0.00337)	(0.00303)
Observations	9,403,062	9,403,062	3,315,886	3,315,886
Dependent var. mean	0.0103	0.0103	0.029	0.029
First stage coef. of Male × Exposure IV	0.00264 ***	0.00264 ***	.00243**	0.00243**
Cohort FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
State time trend	No	Yes	No	Yes

Note. The videogame exposure instrument is equal to average North American sales of videogames released when the members of each cohort were ages 10-17, distributed by state according to each state's total number of arcades in 1980, divided by its land area in kilometers squared. The number of arcades corresponds to the number of establishments in the "Coin-operated amusement device" industry from the Quarterly Census of Employment and Wages in 1980. The outcome is a variable equal to 1 if a person obtained a bachelor's degree in a computer-related field and 0 otherwise. Videogame share is the share of a person's four-year birth cohort that was playing videogames at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Standard errors clustered at the state level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

I partially address this concern using the instrumental variable strategy, which aims to capture the part of the variation in exposure to videogames which is caused by local exposure to arcades and the growth of videogame sales. Nevertheless, in tables 16-20 I explore the effects of exposure to computers, by using the share of individuals in a person's birth cohort by state which had access to a computer in their homes when they were 10-17.

Table 16 shows effect of exposure to computers as a teenager on the probability of studying a computer-related field at the bachelor level. As expected, the estimated effects are similar to those obtained using exposure to videogames, given the likely correlation between the two variables. However, the coefficient estimate of the effect on the gender gap in the full sample is signficantly smaller than in the main estimates. Specifically, in the full sample, the estimate of 0.00173 in the third row is around 41% of the corresponding estimate of the effect of videogames.

Likewise, table 17 shows the results on occupation from exposure to computers. Again, the estimated effect of computers is similar to that of videogames, likely reflecting the difficulty of separating the two. However, the estimated effect on the gender gap is approximately half the

Table 16: Probability of studying a computer-related field, effect of exposure to computers

	(1)	(2)	(3)	(4)
VARIABLES	VARIABLES	Full sample		
College sample				
Male	0.0111***	0.0111***	0.0372***	0.0372***
	(0.000426)	(0.000426)	(0.00116)	(0.00116)
Exposure to computers	-0.00126	-0.00431**	-0.00314	-0.00637
	(0.00171)	(0.00179)	(0.00432)	(0.00455)
Male × Exposure to computers	0.00174**	0.00173**	0.0104***	0.0103***
	(0.000858)	(0.000858)	(0.00203)	(0.00203)
Observations	9,403,062	9,403,062	3,315,886	3,315,886
Cohort FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
State time trend	No	Yes	No	Yes

Note. The outcome is a variable equal to 1 if a person obtained a bachelor's degree in a computer-related field and 0 otherwise. The sample is limited to people who work or have worked in the last 5 years. Exposure to computers is the share of a person's four-year birth cohort that lived in a house with a computer at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Standard errors clustered at the state x cohort level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

size when using exposure to computers. This suggests that although computers and videogames are highly correlated, videogame exposure can explain a larger portion of the gender gap in both education and occupation in computer-related fields.

Table 17: Probability of working in a computer-related field, effect of exposure to computers

	(1)	(2)	(3)	(4)
VARIABLES	Full sample			College sample
Male	0.0215***	0.0215***	0.0413***	0.0413***
	(0.000566)	(0.000566)	(0.000873)	(0.000872)
Exposure to computers	-0.000996	-0.00157	-0.0104***	-0.00721*
	(0.00175)	(0.00180)	(0.00355)	(0.00378)
Male × Exposure to computers	0.00280**	0.00280**	0.0205***	0.0204***
	(0.00111)	(0.00111)	(0.00172)	(0.00172)
Observations	8,488,112	8,488,112	3,190,760	3,190,760
Cohort FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
State time trend	No	Yes	No	Yes

Note. The outcome is a variable equal to 1 if a person lists their main occupation as being computer-related. The sample is limited to people who work or have worked in the last 5 years. Exposure to computers is the share of a person's four-year birth cohort that lived in a house with a computer at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Standard errors clustered at the state x cohort level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Finally, table 18 shows the results on the likelihood of obtaining a bachelor's degree when using exposure to computers rather than exposure to videogames. The results show that the variable exposure to computers interacted with the dummy for male is negatively related to the likelihood that boys obtain bachelor's degrees. This may be due to an independent effect of computers or to its correlation with videogame exposure. However, as with the results on education and occupation, the estimated effect on the gender gap is significantly smaller (66%) when using this variable instead of the videogame exposure variable.

Table 18: Probability of obtaining a bachelor's degree, effect of exposure to computers

	(1)	(2)
VARIABLES	Bachelor's	Bachelor's
Male	-0.0677***	-0.0677***
	(0.00281)	(0.00281)
Exposure to computers	0.0549***	0.0116
	(0.0150)	(0.00917)
Male × Exposure to computers	-0.0484***	-0.0484***
	(0.00451)	(0.00451)
Observations	9,338,689	9,338,689
Cohort FE	Yes	Yes
State FE	Yes	Yes
Controls	No	Yes
State time trend	No	Yes

Note. The outcome is a variable equal to 1 if a person obtained a bachelor's degree and 0 otherwise. Computer share is the share of a person's four-year birth cohort that lived in a house with a computer at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Standard errors clustered at the state level x cohort in parentheses. *** p<0.01, ** p<0.05, * p<0.1

As an additional check, I also run regressions in which I include both the computer and the videogame variable and find that exposure to videogames interacted with the dummy for male is always significant. This suggests that an alternative hypothesis that computer exposure is responsible for the effects on the gender gap cannot fully explain the results.

In table 19, for example, I include exposure to computers as well as its interaction with the dummy for male. Interestingly, the sign of the coefficients of the two interaction terms are in the opposite direction in every specification. This suggests that exposure to computers does not have the same gender-specific effects on the likelihood of studying computer science, working in a related occupation or obtaining a degree.

In addition, in I also run the main analyses instead controlling for exposure to computers. As shown in table 20, the estimated effects of videogame exposure for men are robust to this alternative specification. On the otherhand, exposure to computers, shown in the 4th row, appears to have no effect on these outcomes as the coefficient estimates are insignificant in all specifications.

Table 19: Probability of studying computer science, working in a computer-related occupation or obtaining a bachelor's degree, including exposure to computers and videogames

VARIABLES	(1) Computer Science	(2)	(3) Computer Occupation	(4)	(5) Bachelor Degree	(6)
Male	0.00985***	0.00985***	0.0203***	0.0203***	-0.0600***	-0.0600***
	(0.000378)	(0.000378)	(0.000601)	(0.000601)	(0.00247)	(0.00247)
Exposure to computers	0.00996***	0.00924***	0.0107***	0.0125***	-0.0751**	-0.0597***
	(0.00265)	(0.00230)	(0.00332)	(0.00301)	(0.0310)	(0.0148)
Male × exposure to computers	-0.0230***	-0.0230***	-0.0215***	-0.0215***	0.105***	0.105***
	(0.00362)	(0.00362)	(0.00412)	(0.00411)	(0.0189)	(0.0189)
Exposure to videogames	-0.0147***	-0.0196***	-0.0155***	-0.0209***	0.194***	0.0897***
	(0.00311)	(0.00319)	(0.00395)	(0.00358)	(0.0409)	(0.0195)
Male × Exposure to videogames	0.0332***	0.0332***	0.0326***	0.0326***	-0.206***	-0.206***
	(0.00460)	(0.00460)	(0.00551)	(0.00551)	(0.0255)	(0.0255)
Observations	9,403,062	9,403,062	8,488,112	8,488,112	9,338,689	9,338,689
Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes
State time trend	No	Yes	No	Yes	No	Yes

Note. The outcome is a variable equal to 1 if a person obtained a bachelor's degree in a computer-related field (columns 1 and 2) and worked in a computer-related occupation (columns 3 and 4) and obtained a bachelor's degree (columns 5 and 6) or 0 otherwise. Exposure to videogames is the share of a person's four-year birth cohort that was playing videogames at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Exposure to computers is the share of a person's four-year birth cohort that lived in a home with a computer at ages 10-17 in a person's birth state. Standard errors clustered at the state x cohort level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 20: Probability of studying computer science, working in a computer-related occupation or obtaining a bachelor's degree, including exposure to computers and videogames

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Computer Science		Computer Occupation		Bachelor Degree	
Male	0.0104***	0.0104***	0.0208***	0.0208***	-0.0627***	-0.0627***
	(0.000504)	(0.000504)	(0.000932)	(0.000931)	(0.00213)	(0.00212)
Videogame exposure	-0.000107	-0.00502	-0.00166	-0.00709**	0.127**	0.0232
	(0.00273)	(0.00333)	(0.00348)	(0.00276)	(0.0485)	(0.0147)
Male × Videogame exposure	0.00417***	0.00417***	0.00548***	0.00548***	-0.0733***	-0.0734***
	(0.00107)	(0.00107)	(0.00167)	(0.00167)	(0.00435)	(0.00435)
Exposure to computers	-0.00158	-0.00228	-0.000258	0.00158	-0.0226	-0.00714
	(0.00259)	(0.00222)	(0.00230)	(0.00209)	(0.0311)	(0.0129)
Observations	9,403,062	9,403,062	8,488,112	8,488,112	9,338,689	9,338,689
Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes
State time trend	No	Yes	No	Yes	No	Yes

Note. The outcome is a variable equal to 1 if a person obtained a bachelor's degree in a computer-related field (columns 1 and 2) and worked in a computer-related occupation (columns 3 and 4) and obtained a bachelor's degree (columns 5 and 6) or 0 otherwise. Exposure to videogames is the share of a person's four-year birth cohort that was playing videogames at ages 10-17 in a person's birth state calculated using CPS waves in 1984, 1989, 1993, 1997, 2001 and 2003. Exposure to computers is the share of a person's four-year birth cohort that lived in a home with a computer at ages 10-17 in a person's birth state. Standard errors clustered at the state level in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

6 Conclusion

In this paper, I investigate the role played by videogame in the widening of the gender gap in computer science. The results suggest that since the early 1980s, greater exposure to videogames has been associated with attracting a larger share of boys to study and work in computer-related fields. In particular, boys more exposed to games are significantly more likely than similar girls to have studied computer science. This suggests that the spread of videogames may have contributed to the growing and persistent gender gap in this field.

Computer science is not only a foundational field in technology but also a gateway to numerous high-paying and influential careers. However, women remain significantly underrepresented in this field, resulting in a considerable loss of diverse perspectives and talents. The potential impact of video games on this gap is profound, as these games serve as a formative source of exposure to technology and problem-solving for young individuals.

Nevertheless, I also find that videogames may have had complex effects on boys' educational outcomes, with those more exposed being less likely to obtain bachelor level degrees. This evidence suggests that videogames may have contributed to the growth of the gender gap in favor of girls in higher education enrollment in the US, and should be further explored.

Overall my results highlight the important role that non-academic activities can play in shaping young people's choices and economic outcomes. This is particularly relevant given the increasing popularity of online gaming, and ongoing debates about smartphone use in children and teenagers.

Moreover, the findings point to long-term impacts of differences in leisure-time and hobbies by gender during adolescence, which may have many policy implications. For instance, policymakers and parents concerned about gender segregation by occupation or about differences in economic outcomes by gender, should perhaps pay greater attention to children's non-academic interests and time-use.

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Appendix

Table A1 shows the two first stage regressions using the full sample. Column (1) shows the results of estimating equation (3), where the outcome is exposure to videogames, while column (2) shows the result of estimating equation (4), where the outcome is this variable interacted with a male dummy. The table shows that the interacted instrument is a particularly strong instrument. The F-statistic is large for column (2) but small for column (1). However, the Cragg-Donaldson statistic is 19,775 suggesting that the combined instruments are not weak.

Table A1: First stage of 2sls, instrumenting for videogame exposure and videogame exposure × male using **total** sales and arcades/km^2

	(1) Total 1990: Videogame exposure × male	(2) Total 1990: Videogame exposure
Male	0.267***	-0.0000571**
	(0.0162)	(0.0000221)
Exposure IV	-0.00126***	-0.000218***
	(0.000313)	(0.0000405)
Male × Exposure IV	0.00225***	0.00000117
	(0.000613)	(0.000000722)
Observations	9403062	9403062
State FE	Yes	Yes
Cohort FE	Yes	Yes
Controls	Yes	Yes

Standard errors clustered at the state cohort level in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A2: First stage of 2sls, instrumenting for videogame exposure and videogame exposure × male using **total** sales and arcades in 1980/km^2

	(1) Total: vgame1017 x male	(2) Total: vgame1017
Male	0.244***	-0.0000615**
	(0.0163)	(0.0000240)
Exposure IV	-0.00140***	-0.000101**
	(0.000252)	(0.0000506)
Male × Exposure IV	0.00264***	0.000000909
	(0.000493)	(0.000000560)
Observations	9403062	9403062
State FE	Yes	Yes
Cohort FE	Yes	Yes
Controls	Yes	Yes

Standard errors clustered at the state cohort level in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$