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ABSTRACT

Housing Unaffordability and Adolescent Academic Achievement in Urban China

Rising housing prices in China have placed significant financial strain on many households, pushing them into the quagmire of housing unaffordability. Such economic pressures may have repercussions beyond just shelter, potentially impacting the cognitive development of children. Our study, based on longitudinal data from the 2010-2018 China Family Panel Studies, analyses the effect of housing unaffordability on the academic achievements of Chinese adolescents aged 10-18. To address the inherent endogeneity issues associated with housing unaffordability, we employed a fixed effects instrumental variable approach. Our findings reveal that housing unaffordability leads to a decline in academic performance for these adolescents by an average of 12%. This negative effect is more pronounced for specific groups: rural-to-urban migrant families, girls who have male siblings, families who rent, older adolescents (aged 13 to 18), and those residing in less developed regions. Moreover, the results suggest that housing unaffordability adversely affects academic performance indirectly by diminishing household expenditures in critical areas. When housing becomes unaffordable, families have less to spend on food, social capital, and education, further exacerbating the challenges faced by their adolescent children in the academic arena.

JEL Classification: I20, I31, R20

Keywords: housing unaffordability, academic achievement, adolescents, China

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1 Introduction

Child development has been recognized as a major source of sustainable social and economic development (Michael et al., 2016). In China, the National Program for Child Development (2021–2030) proposed a series of strategies to promote children's lives in various aspects, including health, safety, education, welfare, family, environment, and legal protection. As an crucial component of child development, academic achievement not only affects child well-being, but predicts educational attainment and earnings in adulthood (French et al., 2015). Although parents would purchase products, services, and experiences that contribute to the development of their children (Newman & Holupka, 2014), living in housing unaffordability (defined as household spending more than 30 percent of income on housing) directly limits household disposable income. This may reduce parental investments, thereby impeding child development such as cognitive achievement (Newman & Holupka, 2016).

Despite the fact that housing unaffordability has become one of the biggest threats to child development, evidence on the impact of housing unaffordability on child cognitive ability remains scarce. Existing results are mixed: either no association (Coley et al., 2013; Harkness et al., 2009; Kull & Coley, 2014), or a U shape (Harkness & Newman, 2005; Newman & Holupka, 2016; Newman & Holupka, 2015) have been identified. Moreover, except for Newman and Holupka (2015) and Newman and Holupka (2016), most existing studies are associational. Furthermore, existing literature is strongly dominated by research in the U.S., thereby making generalizations for developing economies such as China difficult.

The aim of this study, therefore, is to employ the longitudinal data from the 2010-2018 China Family Panel Studies (CFPS) to explore the causal impact of housing unaffordability on academic achievement among adolescents aged 10-18. China offers an interesting case for two main reasons: First, since the market-oriented reform of the housing system in the late 1990s, China's housing market prices continue to soar, posing great pressure on household housing expenditure. The Chinese government has introduced a series of policies, including property tax scheme, housing purchase restriction policy and differentiated housing credit policies to control rising housing

price. Nonetheless, these policies have had limited success, especially in mega-cities such as Beijing. Housing prices in urban China more than doubled during 2007–2014 (Nie et al., 2021). Secondly, influenced by traditional Chinese culture deeply rooted in Confucianism, which venerates scholars as the highest social class (Huang & Gove, 2015), many Chinese parents place immense emphasis on their children's education (Lu et al., 2021). This often results in heightened academic pressure for adolescents.

We thus extend the research on the linkage between housing unaffordability and cognition development in several ways: First, as existing studies in developing economies are scarce, we are the first to explore the relationship between housing unaffordability and cognitive ability in China. Second, our paper complements the prior literature by exploring the causal relation between housing unaffordability and adolescent academic performance. Third, we perform heterogeneity analyses by residence, age groups, gender, household child gender composition, housing type, and region, which may shed light on targeting of potential policy interventions. Lastly, by introducing housing expenditures on food, social capital and education, we examine the underlying mechanisms through which housing unaffordability operates on academic achievement.

The remainder of this paper proceeds as follows. Section 2 summarizes the literature on housing unaffordability and adolescent academic achievement. Section 3 documents a conceptual framework for possible mechanisms. Section 4 describes the data and empirical strategy. Section 5 presents the empirical results of the effects of housing unaffordability on academic achievement. Section 6 examines potential channels. Section 7 concludes.

2 Literature review

2.1 Concept of housing unaffordability

The housing unaffordability concept can be traced back to the 19th century, when studies on household budget posit "one week's pay for one month's rent" (Hulchanski, 1995). This definition, generally known as the housing expenditure-to-income ratio (HEIR), is the most commonly used indicator of housing unaffordability. The rationale

behind this definition is that, if housing expenses exceed a certain share of income, the remaining would be difficult to cover non-housing needs. Using the HEIR method, housing unaffordability is typically defined as households spending more than 30 percent of their income on housing (Nepal et al., 2010).

Additionally, a ratio of housing price to income (HPIR) is another widely used housing unaffordability measurement (Cai & Lu, 2015; Li et al., 2020). The World Bank considers 3 to 6 as an acceptable range for this measure (Lau & Li, 2006). Several studies also use local area housing prices as proxies for housing unaffordability (e.g. the Fair Market Rent in U.S., Harkness & Newman, 2005). Although housing price-related definitions may represent the local average housing cost pressure, they cannot reflect the actual housing cost burden that a household experiences.

2.2 Housing unaffordability on adolescent academic performance

Existing studies on the relationship between housing unaffordability and adolescent academic achievement is limited and predominated by the research from the U.S. (Coley et al., 2013; Harkness et al., 2009; Harkness & Newman, 2005; Kull & Coley, 2014; Newman & Holupka, 2016; Newman & Holupka, 2015). Specifically, Harkness and Newman (2005) show that there is no linkage between housing unaffordability (proxied by Fair Market Rent) and grade promotion. Similarly, Harkness et al. (2009) also argue that children living in higher-rent housing markets fare no worse than those in lower-rent markets on academic achievement. By including housing costs, quality, stability, ownership and subsidy status, Coley et al. (2013) find that housing cost ratio is unassociated with reading and math skills for both young children and adolescents in low-income families. This observation is further echoed by Kull and Coley (2014).

After that, quite few studies attempt to address the endogeneity issue of housing unaffordability by employing local housing prices as IV candidates. Newman and Holupka (2015), drawing on propensity score matching (PSM) and IV estimation, find an inverted-U-shaped relationship between housing cost ratio and children's reading and math ability, with its apex of approximately 30% (the longstanding rule-of-thumb definition of housing unaffordability). This finding is further confirmed by Newman

and Holupka (2016), showing an inverted U-shaped relation between housing cost burden and child cognitive achievement.

Several aspects of the prior literature are worth highlighting: First, the evidence is not only mixed but nearly exclusively for the U.S. There are no studies on this topic in developing economies like China. Second, most existing studies are cross-sectional and associational. Besides, studies using housing prices are unable to reflect actual housing cost pressures, although it may partially address the endogeneity of housing cost burden. Third, little is known about the possible pathways through which housing unaffordability operates on academic achievement. Thus, this study extends the literature by investigating the causal effect of housing unaffordability on adolescent academic achievement in China, and exploring the possible mechanisms.

3 Underlying mechanisms

There are several potential mechanisms through which housing unaffordability may operate on adolescent academic achievement. We focus on three main channels (see Figure 1 below): (*i*) household food expenditures, (*ii*) household social capital investment, and (*iii*) parental investment on child education.

The first pathway operates through household food expenditures. Housing cost burden is linked with food insecurity (inadequate quality and quantity) (Lee et al., 2021; Seo & Park, 2021). Falling into housing unaffordability not only limits their food access (Seo & Park, 2021), but also predicts unhealthy diet (Chang & Chatterjee, 2022), especially for low-income families. For instance, Kirkpatrick and Tarasuk (2007) find that, when the proportion of housing spending increases, Canadian families will spend significantly less on food. King (2018) also confirms that missed rent and mortgage payments, or homeless, is associated with difficulties in food purchases.

Existing literature also confirms the negative impact of inadequate food (quality and quantity) on adolescent academic performance. Specifically, children without enough food have lower test scores in reading, mathematics, science, literacy, spelling, composition and social science (Esfandiari et al., 2018; Faught et al., 2017; Hannum et al., 2014), lower GPA (Shanafelt et al., 2016) and higher school absenteeism (Belachew

et al., 2011). Additionally, food insecurity is also linked to higher rates of hyperactivity and inattention (Melchior et al., 2012; Murphy et al., 1998), thereby resulting in poor academic performance. Drawing on these observations, we formulate the following hypothesis:

Hypothesis 1: *Housing unaffordability negatively affects adolescent academic performance through lowering household food expenditures.*

A second possible channel may be household expenditures on social capital. Coleman (1988) defines the concept of social capital as supportive social relationships both from within and outside a family. Outside-family social capital is represented by household social networks, especially relationships with other parents, community members, and school staff. Dufur et al. (2013) define outside family social capital as the sum of gift expenditures and financial support received by a household in the previous year. As outside-family social capital can allocate additional educational resources from external sources (e.g., teachers and counselors, Sun, 1999)[1], it plays a pivotal role in improving adolescent academic achievement and reducing the likelihood of high-school dropout (Coleman, 1988; Dufur et al., 2013).

In contrast to Western countries, China places a high value on social relationships, emphasizing that individuals are not isolated entities but rather parts of a larger system of interdependent relationships (Zhang, Han, et al., 2021). As a result, interpersonal relationships are fundamental in the closely-knit Chinese society. Gift-giving and receiving represent one of the most significant forms of social capital investment in Chinese societies (Hudik & Fang, 2020). We thus formulate our hypothesis 2 as follows:

Hypothesis 2: *Housing unaffordability negatively affects adolescent academic performance through reducing household expenditures on social capital.*

The third mechanism is parental investment on children's education. Due to constrained budgets, children living in unaffordable housing generally receive less enrichment spending[2] and are less likely to benefit from parental investments

[1] Additional educational resources include academic help, appropriate guidance for school programs, and information about college admission.

[2] Child enrichment expenditure is defined as expense on child care school, school resources, toys, musical instruments and instruction, playground equipment, admission costs for movies, theater and opera, and reading materials (Newman & Holupka, 2014).

(Newman & Holupka, 2014). Relative to households with moderate housing cost burdens, those with very-high housing costs have the lowest enrichment expenditures on children (Newman & Holupka, 2014). According to the parent investment model (Foster, 2002; Mayer, 1997), child development depends on the investment of time, goods and services by their parents. Existing literature confirms a positive relation between educational investments and child academic achievement (Gershoff et al., 2007; Newman & Holupka, 2023). Thus, we propose our third hypothesis:

Hypothesis 3: *Housing unaffordability negatively affects adolescent academic performance through decreasing parental investments on adolescent education.*

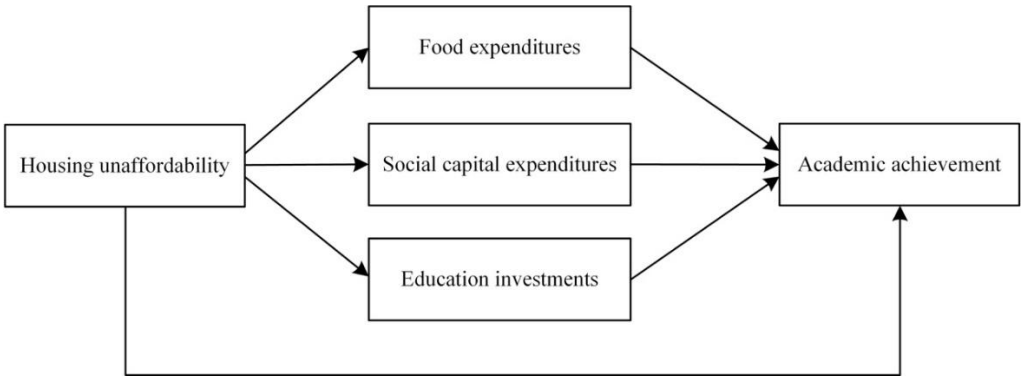

Figure 1 Underlying mechanisms through which housing unaffordability impacts adolescent academic achievement

4 Data and methods

4.1 Study design and population

Our data are drawn from the CFPS data set, administered by Peking University's Institute of Social Science Survey, which currently encompasses five waves: 2010, 2012, 2014, 2016, and 2018. Since the survey covers 25 provinces, representing 94.5% of China's total population, it constitutes a nationally representative sample that captures both the socioeconomic development and the economic and noneconomic well-being of Chinese households (Xie & Lu, 2015). Given the aim of this study, we restrict our analytic sample to urban adolescents aged 10-18 for which detailed information on academic achievement (Chinese and mathematics), adolescent and household demographic and socioeconomic characteristics is available. Our final sample is an unbalanced panel of 992 adolescents and 2,279 observations.

4.2 Academic achievement measures

Following the existing literature (Fang et al., 2018; Qi & Wu, 2020), we adopt parent-rated adolescent academic performance on Chinese and mathematics. In CFPS, children's parents/guardians are asked, "What was the child's average grade in Chinese and mathematics last semester?", measured on a 4-point scale, ranging from 1 = poor, 2 = average, 3 = good, to 4 = excellent.

4.3 Housing unaffordability

Although the 30-percent indicator is the long-standing rule of thumb definition of housing unaffordability, it can be biased because it may include higher income households who prefer housing consumption. Considering this, we employ the 30/40 measure to identify households living in housing unaffordability (Bentley et al., 2022; Nepal et al., 2010). The 30/40 measure circumvents the drawbacks of 30-percent indicator by excluding households with higher income. Specifically, households are identified as housing unaffordability if (*i*) they spend over 30% of their income on housing (including rents, mortgage and housing related fees such as water, electricity, fuel, heating, repairs and property management fee) (Newman & Holupka, 2014), and (*ii*) the equivalized household income is at the bottom 40 percent of equivalized household income distribution.[3] In robustness checks, we also employ alternative definitions of the housing cost ratio (housing costs to income), 30/40 method using the OECD-modified equivalization scale, 30% threshold (housing costs consists more than 30% of income) (Nepal et al., 2010), and 50% threshold (housing costs consists more than 50% of income) (HUD, 2007).

4.4 Control variables

Like Newman and Holupka (2015), we control for adolescent characteristics (age, self-reported health (SRH, from 1 = poor to 5 = excellent, with poor as reference)), parental education (measured by years of schooling) and employment status (1 = employed, 0 = unemployed), and the number of children under 18 years old in the household. We also

[3] There is no generally accepted equivalence scale. Following Arundel and Lennartz (2020), we use "OECD-square root scale" to equivalize household income in our baseline analysis. For robustness checks, we also apply "OECD-modified scale" for equivalization.

control for wave dummies (with 2010 as the reference year) and provincial dummies (with Beijing as the reference).

4.5 Empirical strategy

When analysing the relationship between housing unaffordability on adolescent academic performance, the endogeneity of housing unaffordability should be taken into account. Specifically, the estimates may be biased due to omitted variables. Although we control for individual-level fixed effect to address time-invariant observables, we cannot rule out bias from time-variant omitted variables. For instance, as better community environment is capitalized in high housing prices, households living in unaffordable housing may benefit from desirable community features (i.e., high-quality educational resources and lower crime rates) (Newman & Holupka, 2015). Meanwhile, an improved living environment can benefit adolescent academic performance through the access to better facilities, a more child-friendly built environment, stronger social capital among residents, and reduced exposure to community violence (Villanueva et al., 2016). Failure to control neighborhood environment may lead to underestimation.

Another concern is reverse causality. In our case, living in unaffordable housing may harm adolescent academic performance. However, poor academic performance may also increase the likelihood of household housing unaffordability. For instance, poor child academic performance is found to be positively correlated with lower parental mental health (Chen et al., 2021), which in turn may reduce their productivity and earnings (DiMaria et al., 2020), thereby increasing the likelihood of housing unaffordability.

To identify a causal relationship between housing unaffordability and adolescent academic achievement, we turn to a fixed effects instrumental variable (FE-IV) approach. In doing so, similar to Zou and Deng (2022), we construct our IV by classifying households into different groups according to wave (2010, 2012, 2014, 2016, and 2018), average age of household head and their spouse (20-29, 30-49, and 50+), average education level of household head and their spouse (lower than middle school, middle school to high school, and higher than high school) and household income (divided by quintiles). Thus, we classified 225 groups, and our sample fall into 135

groups in total.[4] We calculate other households' housing unaffordability rate ($Other\_HA_i$) within group G as the IV of individual *i*'s household housing unaffordability:

$$Other\_HA_i = \frac{\sum_{j \neq i, j \in G} HA_j}{N_G - 1} \quad (2)$$

where *G* is the group which household *i* belongs to, and N_G is the total number of households in group *G*. Our IV is plausible for the following reasons: First, since households with similar household income, age group, education, and survey wave experience similar stress of housing unaffordability, the likelihood of housing unaffordability for a given household is closely linked to the average housing unaffordability rate of other households in the same group. Additionally, it is unlikely that the average housing unaffordability rate of other households in the same group directly impacts adolescent academic performance. Although Chinese and mathematics performances are ordinal, they are generally taken as continuous (Qi & Wu, 2020; Zhang, Appau, et al., 2021). The FE-IV is therefore described as follows:

$$HA_{it} = \gamma_1 Other\_HA_{it} + \gamma_2 X_{it} + \gamma_3 P_j + \gamma_4 W_t + \gamma_5 P_{jt} + \tau_i + \epsilon_{it} \quad (3)$$

$$Academic_{it} = \varphi_1 \widehat{HA_{it}} + \varphi_2 X_{it} + \varphi_3 P_j + \varphi_4 W_t + \varphi_5 P_{jt} + \omega_i + \pi_{it} \quad (4)$$

where HA_{it} is adolescent *i*'s household housing unaffordability status at wave *t*; $\widehat{HA_{it}}$ represents predicted adolescent *i*'s academic performance at wave *t*; $Academic_{it}$ is adolescent *i*'s academic performance at wave *t*; X_{it} denotes a set of time-variant adolescent, parental and household controls; P_j and W_t are provincial and wave dummies, respectively; P_{jt} denotes a set of province-specific time trends, which accounts for unobserved, time-varying differences in academic performance across provinces; τ_i and ω_i capture the unobservable time-invariant individual effect. For the mechanism analysis, we also employ FE-IV to examine how housing unaffordability affects household expenditures on food, social capital and education.

In addition to the FE-IV approach, to further reduce the concern of omitted variable bias, we employ Oster's omitted variable test (Oster, 2019) as robustness check

[4] To ensure the accuracy of the IV, we exclude those groups with less than 20 households (less than 1% in our sample).

(a detailed introduction for Oster's test, see Appendix A).

5 Results

5.1 Descriptive statistics

Figure 2 shows an increasing trend of average housing cost burden during the period of 2010-2018. Using the 30% threshold definition of housing unaffordability, approximately 21.2% of adolescents live in housing unaffordable families. This is larger than existing studies for Chinese migrants (8.9%) (Li & Liu, 2018) and for adults (5.2%) (Wang et al., 2023). When using the 30/40 method with square root equivalence scale (our baseline definition of housing unaffordability), we find that around 12.8% of adolescents live in unaffordable housing, which is much lower than when using the 30% threshold. This is due to the fact that the 30/40 measurement excludes households with higher income and preferences for housing consumption. Moreover, the average scores of Chinese (2.8) and mathematics scores (2.9) are similar to these of existing studies (Qi & Wu, 2020; Zhang, Appau, et al., 2021).

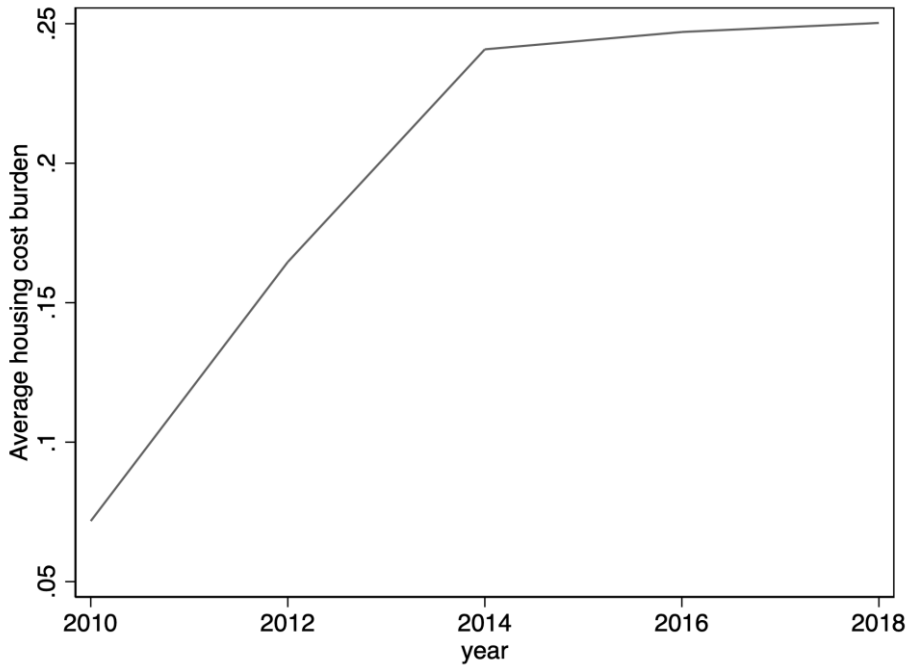

Figure 2 Average housing cost burden over time: 2010-2018 CFPS

Notes: Average housing cost burden is the average of housing cost ratio calculated by wave

Table 1 Descriptive statistics for Chinese adolescents aged 10-18: CFPS 2010–2018

Variables	Obs.	Mean/percentage	S.D.
Dependent variables			
Academic achievement			
Chinese performance	2279	2.831	0.925
Mathematics performance	2279	2.860	1.025
Class rank	2510	3.648	1.153
Independent variables			
Housing unaffordability	2279	0.128	0.334
Housing cost ratio	2279	0.221	0.309
30/40 oms	2279	0.129	0.335
30% threshold	2279	0.212	0.409
50% threshold	2279	0.149	0.356
Individual characteristics			
Age	2279	12.455	1.628
Self-rated health	2279	4.124	0.913
Parental characteristics			
Maternal education [c]	2279	8.796	4.201
Maternal employment status [d]	2279	0.780	0.414
Paternal education	2279	9.692	3.605
Paternal employment status [d]	2279	0.897	0.304
Household characteristics			
Number of children under 18	2279	1.609	0.831

Notes: Academic performance is measured by parent/guardian ratings of the child's average grade in Chinese and mathematics for the previous semester (on a scale from 1 = poor to 4 = excellent). Class rank is measured at a 5-point scale (1 = bottom 24%, 2 = top 51–75%, 3 = top 26–50%, 4 = top 11–25%, and 5 = top 10%). Maternal and paternal education are measured by years of schooling. Maternal and paternal employment status is one dummy indicating whether he/she is employed (1 = yes, 0 = no).

5.2 Baseline estimation

Table 2 reports FE-IV estimates for the relationship between housing unaffordability and adolescent academic achievement. In the odd columns, we do not control for socio-demographics, wave, provincial dummies and province-specific time fixed effects, whereas we do in the even columns. The first-stage estimation indicates a significant and positive association between the instrument and adolescent household housing unaffordability, validating our assumption that the likelihood of housing unaffordability for a given household is closely linked to the average housing unaffordability rate of other households in the same sociodemographic group. The first-stage *F* test results

also reject the possibility of a weak instrument.[5] The second-stage results reveal that housing unaffordability significantly reduces adolescent Chinese performance by 0.33 point (equivalent to about 12% of the average) (Column 2) [6]. However, such effects are insignificant for mathematics performance (Columns 3 and 4). One possibility is that, students learn mathematics primarily at school, whilst their verbal ability is influenced by home environment and in-home daily activities (Rich, 2007).

Table 2 FE-IV estimates of housing unaffordability on academic achievements among Chinese adolescent aged 10-18: CFPS 2010-2018

	(1)	(2)	(3)	(4)
	Chinese		Mathematics	
Second stage				
Housing unaffordability	-0.334***	-0.329***	-0.159	-0.158
	(0.113)	(0.114)	(0.122)	(0.121)
First stage				
Average housing unaffordability	1.024***	1.018***	1.024***	1.018***
	(0.063)	(0.063)	(0.063)	(0.063)
Wald *F*-statistics	265.0	258.9	265.0	258.9
Controls	No	Yes	No	Yes
Individual FE	Yes	Yes	Yes	Yes
Number of Individuals	992	992	992	992
Obs.	2279	2279	2279	2279

Notes: The dependent variables are academic performance on Chinese and mathematics (from 1 = poor to 4 = excellent); controls include age, SRH (from 1 = poor to 5 = excellent, with poor as reference), maternal and paternal years of schooling and employment status (1 = yes, 0 = no), number of children under 18, wave dummies (with 2010 as the reference), provincial dummies (with Beijing as the reference) and provincial time-varying effects. Household-level adjusted standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.3 Robustness checks

5.3.1 Alternative definition of housing unaffordability

We apply alternative definitions of housing unaffordability, including housing cost ratio, 30/40 threshold using OECD-modified equivalence scale, 30% threshold, and 50% threshold. Consistent with our main results, housing unaffordability significantly decreases adolescent Chinese performance by 0.34-0.57 points, depending on different

[5] Since we use cluster–robust estimator at household level, we thus apply Kleibergen-Paap rk Wald *F*-statistics for our weak IV test.

[6] We also try to explore the non-linear effects, but the results are not significant.

proxies of housing unaffordability (approximately 12%-20% of the average, see Figure 3).[7] For mathematics performance, however, we still observe none.

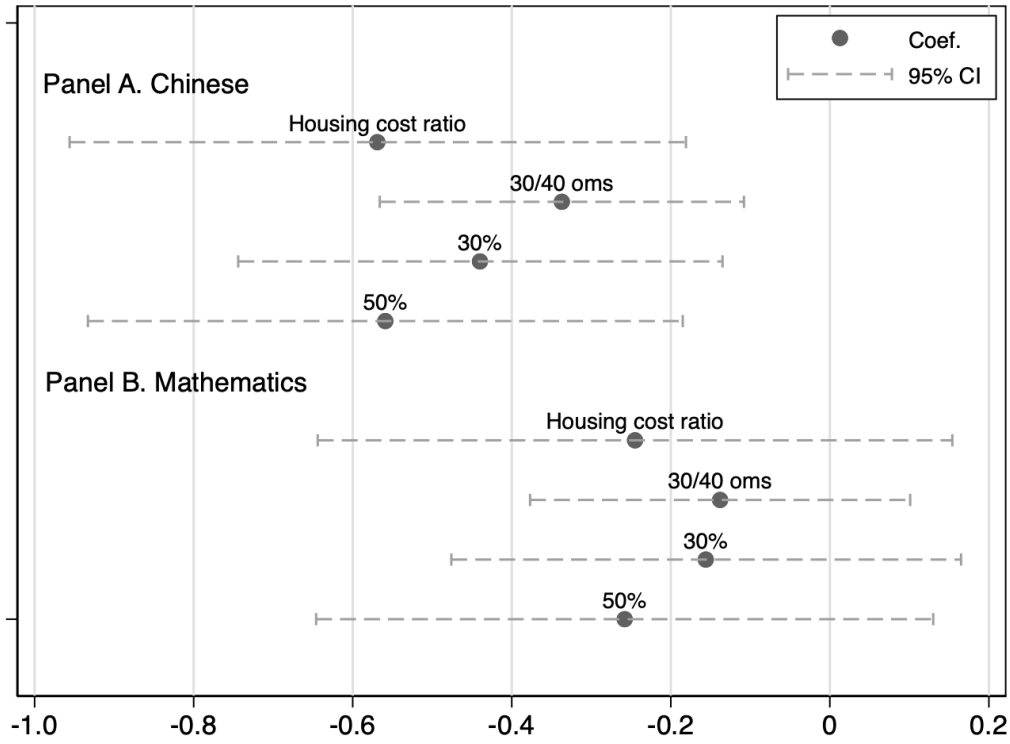

Figure 3 Effect of housing unaffordability on academic achievements among Chinese adolescents aged 10-18

Notes: Alternative definitions of housing unaffordability include housing cost ratio, 30/40 threshold using OECD-modified equivalence scale, 30% threshold, and 50% threshold. The dependent variables are academic performances on Chinese and mathematics (from 1 = poor to 4 = excellent). Controls include age, SRH (from 1 = poor to 5 = excellent, with poor as reference), maternal and paternal years of schooling and employment status (1 = yes, 0 = no), number of children under 18, wave dummies (with 2010 as the reference), provincial dummies (with Beijing as the reference) and provincial time-varying effects. We cluster standard errors at household level.

5.3.2 Alternative measure of academic performance

Our subjective measure of academic achievement might be inaccurate because both adolescents and their parents tend to overestimate school performance (Maguin & Loeber, 1996). Additionally, self- and parent-reported school performances are only moderately correlated with actual grades (Boschloo et al., 2013). Considering this, we use adolescent class rank as an additional proxy of adolescent academic performance

[7] The detailed results are shown in Appendix Table A1.

(Chen et al., 2021). In the CFPS, class rank is measured at a 5-point scale (1 = bottom 24%, 2 = top 51–75%, 3 = top 26–50%, 4 = top 11–25%, and 5 = top 10%). Here, we do not use class rank in the main analysis because we are unable to control for class-level characteristics.[8] In addition, unlike parent-reported academic performance, class rank does not distinguish between subjects. Given that class rank is ordinal, we use IV ordered probit estimation. Once again, the first-stage Wald *F*-statistic confirms that our IV is not weak. Housing unaffordability significantly reduces class rank by 0.24 point (approximately 6% of the average).

Table 3 IV ordered probit estimates of marginal effects of housing unaffordability on academic achievements among Chinese adolescent aged 10-18: CFPS 2010-2018 (proxied by class rank)

Second stage	
Housing unaffordability	-0.236*
	(0.132)
First stage	
Average housing unaffordability	1.077***
	(0.043)
Wald F-statistics	626.191
Mean of dep. var.	3.648
Obs.	2510
Controls	Yes

Notes: The dependent variable is class rank (1 = bottom 24%, 2 = top 51–75%, 3 = top 26–50%, 4 = top 11–25%, 5 = top 10%); controls include age, SRH (from 1 = poor to 5 = excellent, with poor as reference), maternal and paternal years of schooling and employment status (1 = yes, 0 = no), number of children under 18, number of students in class, wave dummies (with 2010 as the reference), provincial dummies (with Beijing as the reference) and provincial time-varying effects. Household-level adjusted standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.3.3 Omitted variable bias

We also use Oster (2019) omitted variable test to rule out the possible omitted variable bias (Table 4). An estimated bounded set that excludes zero can be interpreted as evidence of robust non-zero effects, as shown in Column 4. Additionally, the effect of housing unaffordability on Chinese and mathematics scores will turn to zero if the

[8] In China, there exist vast differences between classes. Some schools group students into regular classes and honors classes based on their academic performance, thereby resulting in large disparities in educational resources and peer influences between classes (Wang et al., 2018). Therefore, students in classes with the same class rank may still have distinct academic performance.

omitted variables are approximately 7 and 4 times as important as the included controls (Column 5), indicating that our main results are quite robust to omitted variable bias.

Table 4 Oster's test for omitted variable bias

	(1)	(2)	(3)	(4)	(5)
Dependent variable	Controlled effect $\tilde{\beta}$ $(\tilde{R}^2)$	Controlled effect 95% conf. interval	Bias adjusted β^* (δ=1, $R_{max} = 1.3\tilde{R}^2$)	Identified set $[\tilde{\beta},\beta^*]$	δ for β=0 given $R_{max} = 1.3\tilde{R}^2$)
Chinese	-0.329 (0.129)	[-0.556, -0.103]	-0.314	[-0.329, -0.314]	7.054
Mathematics	-0.158 (0.124)	[-0.399, 0.083]	-0.128	[-0.158, -0.128]	3.743

Notes: R-squared in brackets.

5.4 Heterogeneity analysis

To better understand the links between housing unaffordability and academic performance, we conducted in-depth analyses considering factors such as type of residence, age groups, gender, gender composition of children in the household, type of housing, and geographical region.

By residence (urban locals and migrants). For the heterogeneity analysis, Chinese and mathematics performances of rural-to-urban migrants are negatively affected by housing unaffordability (Chinese: -0.432; Mathematics: -0.329, see Table 5, Panel A). But this is not the case for urban local adolescents. This observation may be attributable to the fact that most migrants lack access to advantageous urban resources. Unlike urban residents, migrant families are ineligible for affordable housing and public rental housing programs, as well as monetary subsidies, because they lack an official permanent residency permit (Liu et al., 2020). In addition, migrant children cannot attend urban public schools, unless there is space available and their parents are able and willing to pay expensive out-of-district tuition fees (Lai et al., 2014). Due to financial constraints, they are more likely to attend migrant schools with inferior educational resources and teachers.

By age group. Regarding the heterogeneity by age groups (aged 10-12 vs. aged 13-18), housing unaffordability has a larger negative impact on academic performance

among adolescents aged 13 to 18 (Chinese: -0.54; mathematics: -0.40), although statistically insignificant for mathematics performance. These results perhaps imply that the adverse effects of unaffordable housing on children may be cumulative.

By gender. Panel C shows that the negative effect of housing unaffordability on Chinese performance is more pronounced among boys compared to girls (Table 5, Columns 1 and 3). For mathematics performance, we only observe the negative effect of housing unaffordability for boys.

Furthermore, we also explore the heterogeneity by household child gender composition (see Panel D). Interestingly, girls and boys in households with single-gender children seem unaffected by housing unaffordability. This is also the case for boys in household with both genders. In particular, girls living in household with both genders experience the largest decline in Chinese score (-0.94), suggesting that our main results might be mainly driven by girls with male siblings. Our results may also imply that, for households with both genders, housing unaffordability results in a significant gender disparity in academic performance. This may be attributable to son preference in China, where parents prefer to invest more in sons compared to daughters.

By housing type (renters vs. owners). Regarding the heterogeneity by housing type (renter vs. owner), we find that adolescents living in renter families are more likely to be negatively affected by housing unaffordability (Chinese: -0.46; mathematics: 0.95). One possible explanation is that, for housing-owner families, parents would invest more in child education and home maintenance (Prakash & Smyth, 2019). These families are more prone to reside in high-quality neighborhoods, and their children may also receive better parental emotional support.

By region. We finally examine the heterogeneity by region due to the remarkable geographic differences in economic development and housing prices across China. The negative impact of housing unaffordability is greater in less economically developed region (i.e. the West). We then take a further look at regional housing cost burdens. In our sample, the average housing cost ratio in the West is about 29%, followed by Middle (22%), East (20%), and Northeast (20%). This may attribute to the fact that the average

level of economic development and household income in the West lag behind than other regions.

Table 5 FE-IV estimates of housing unaffordability on academic achievements among Chinese adolescent aged 10-18 by socio-demographics: CFPS 2010-2018

	(1)	(2)	(3)	(4)
Panel A: Locals vs. migrants	Urban locals		Rural-to-urban migrants	
	Chinese	Mathematics	Chinese	Mathematics
Housing unaffordability	-0.261	0.259	-0.432***	-0.329**
	(0.206)	(0.231)	(0.147)	(0.162)
First stage: Wald F-statistics	77.09	77.09	166.0	166.0
Obs.	1030	1030	1181	1181
Number of Individuals	444	444	523	523
Panel B: By age groups	Aged 10-12		Aged 13-18	
	Chinese	Mathematics	Chinese	Mathematics
Housing unaffordability	-0.220	0.020	-0.537*	-0.400
	(0.154)	(0.167)	(0.306)	(0.286)
First stage: Wald F-statistics	124.6	124.6	52.26	52.26
Obs.	630	630	534	534
Number of Individuals	315	315	267	267
Panel C: By gender	Girls		Boys	
	Chinese	Mathematics	Chinese	Mathematics
Housing unaffordability	-0.326*	-0.010	-0.332**	-0.280*
	(0.171)	(0.190)	(0.159)	(0.165)
First stage: Wald F-statistics	110.8	110.8	167.0	167.0
Obs.	1058	1058	1221	1221
Number of Individuals	466	466	526	526
Panel D: By gender & household child gender composition	Girls in household with girls only		Boys in household with boys only	
	Chinese	Mathematics	Chinese	Mathematics
Housing unaffordability	0.062	0.200	-0.271	-0.250
	(0.172)	(0.198)	(0.188)	(0.195)
First stage: Wald F-statistics	92.69	92.69	98.59	98.59
Obs.	720	720	915	915
Number of Individuals	321	321	398	398
	Girls in household with both genders		Boys in household with both genders	
	Chinese	Mathematics	Chinese	Mathematics
Housing unaffordability	-0.944**	-0.321	-0.502	-0.374
	(0.453)	(0.490)	(0.310)	(0.305)
First stage: Wald F-statistics	19.77	19.77	35.24	35.24
Obs.	250	250	216	216
Number of Individuals	115	115	95	95

Panel E: By housing type	Renter		Owner	
	Chinese	Mathematics	Chinese	Mathematics
Housing unaffordability	-0.458	-0.949***	-0.088	-0.056
	(0.420)	(0.343)	(0.092)	(0.096)
First stage: Wald F-statistics	22.48	22.48	662.1	662.1
Obs.	127	127	2991	2991
Panel F: By regions	East		Middle	
	Chinese	Mathematics	Chinese	Mathematics
Housing unaffordability	-0.138	0.036	-0.481**	-0.446
	(0.159)	(0.187)	(0.225)	(0.283)
First stage: Wald F-statistics	107.3	107.3	65.66	65.66
Obs.	860	860	647	647
Number of Individuals	377	377	279	279
	West		Northeast	
	Chinese	Mathematics	Chinese	Mathematics
Housing unaffordability	-0.767***	-0.259	0.365	0.145
	(0.258)	(0.234)	(0.305)	(0.303)
First stage: Wald F-statistics	59.62	59.62	25.56	25.56
Obs.	475	475	293	293
Number of Individuals	209	209	126	126

Notes: We define rural-to-urban migrants as adolescents who are currently living in urban areas but hold a rural Hukou. For Panel E, due to small sample sizes of renters, we use IV instead of FE-IV. The dependent variables are academic performance on Chinese and mathematics (from 1 = poor to 4 = excellent); controls include age, SRH (from 1 = poor to 5 = excellent, with poor as reference), maternal and paternal years of schooling and employment status (1 = yes, 0 = no), number of children under 18, wave dummies (with 2010 as the reference), provincial dummies (with Beijing as the reference) and provincial time-varying effects. Household-level adjusted standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

6 Underlying mechanisms

We further explore three potential mechanisms, including food expenditures, social capital expenditures and child education investments. We find that, housing unaffordability decreases household food expenditures and social capital expenditures (Columns 1 and 2, Table 6), which supports our hypotheses 1 and 2. Given a certain household disposable income, housing unaffordable families pay a higher proportion of income on housing, thereby forcing them to reduce expenditures on food and social capital. These downsized expenditures may harm adolescent academic achievement through malnutrition (Burrows et al., 2017) and decreased household resources, especially educational resources (Sun, 1999).

As CFPS contains information on educational expenditures on one child, we further explore our third mechanism, namely, educational investments[9]. The results indicate that adolescents living in unaffordable housing have significantly lower educational expenditures than those living in an affordable housing (Column 3). This finding is in accordance with Newman and Holupka (2016), confirming that housing unaffordability would significantly decrease child enrichment expenditure in the U.S.

Table 6 FE-IV estimates of housing unaffordability on household expenditures among Chinese adolescent aged 10-18: CFPS 2010-2018

	(1)	(2)	(3)
	Log (food expenditures)	Log (social relations expenditures)	Log (education investments)
Second stage			
Housing unaffordability	-0.305**	-1.060*	-0.400*
	(0.146)	(0.619)	(0.232)
First stage			
Average housing unaffordability	1.042***	1.001***	1.040***
	(0.063)	(0.083)	(0.066)
Wald F-statistics	276.4	145.8	251.4
Obs.	2189	1075	1950
Number of individuals	958	488	867
Controls	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes

Notes: The dependent variables are log of food expenditures, log of social relations expenditures and log of education investments. Food expenditures are the total amount of money household spend on food and purchasing snacks, beverage, cigarettes and alcohol, including having meals at home and eating out. Social relations expenditures are defined as the total amount of money household spent on gifts for social relations, because of the events of their relatives or friends. Those events including marriage, entering college/university, giving birth, death, New Year's visit (giving money to children), and others. Education investments encompass all direct household expenditures on a child's education. All the expenditures are measured in Yuan/year and deflated to 2018 prices. Controls include age, SRH (from 1 = poor to 5 = excellent, with poor as reference), maternal and paternal years of schooling and employment status (1 = yes, 0 = no), number of children under 18, log of household total expenditures, wave dummies (with 2010 as the reference), provincial dummies (with Beijing as the reference) and provincial time-varying effects. Household-level adjusted standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

[9] Adolescent received educational investments is the direct payment of household for all kinds of payment to an adolescent's education. However, CFPS does not contain information on adolescent received food and social capital expenditures.

7 Discussions and conclusion

Academic achievement is undeniably a cornerstone of child development, forecasting educational attainment and earnings in adulthood (French et al., 2015). Yet, a significant gap exists in our understanding of how escalating housing costs influence a child's academic performance. We thus embarked on a study to ascertain the causal effect of housing unaffordability on the academic outcomes of Chinese adolescents, delving deeply into the processes through which housing costs impact academic achievement. This research offers insights into the interplay between housing unaffordability and child human capital development, not only in China but also in other developing nations.

From our study, three pivotal findings emerge, each reflecting a different aspect of the housing unaffordability issue and its impact on adolescent academics. The first discovery highlights a noticeable decline in academic performance among adolescents, a phenomenon directly linked to housing unaffordability. Furthermore, our research shows that this negative impact is not uniform but is particularly pronounced in specific demographic groups. These include rural-to-urban migrant families, girls with male siblings, adolescents in the 13-18 age bracket, children hailing from families that rent their living spaces, and those residing in less economically prosperous regions. Lastly, we traced the underlying causes of these adverse effects, finding that housing unaffordability leads to diminished investments in crucial areas such as food, social capital, and educational resources, thereby impacting academic achievement.

These insights carry substantial policy implications. Notwithstanding the suite of policies introduced by China's central and local governments to enhance housing affordability, the issue persists under the current policy environment (Nie et al., 2022). There's an immediate call to action to alleviate the weighty housing cost burden. Merging affordable housing strategies with those aimed at human capital development is crucial. Moreover, policy-makers should recognize and address the varied impacts of housing unaffordability on different sociodemographic groups, particularly the more

vulnerable segments such as migrant and renting families, girls with male siblings, and residents of underdeveloped areas. Recognizing that food, social connections, and education are key channels affected by housing unaffordability, greater emphasis should be placed on ensuring food security, and accessible and affordable education. For example, advancing nutritious school lunch programs would be a step in the right direction. Considering the long-term value of human capital development and the role of education in China's vision for a modern socialist nation, easing the housing financial strain on families can be a strategic move to elevate adolescent cognitive capabilities and thereby fuel the sustained and quality-driven growth of China's economy.

Declaration of competing interest

None.

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Data availability statement

The data that support the findings of this study are openly available in CFPS official website at https://opendata.pku.edu.cn/dataverse/CFPS.

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Appendix:

Appendix A. Oster's omitted variable test

Due to bias from unobserved omitted variables, we perform the omitted variable test proposed by Oster (2019), which has been employed by a large number of existing studies (Cheng et al., 2020; von Simson & Umblijs, 2021). Drawing on the relation between treatment variable and observables, Oster's test estimates the size of the omitted variable bias by calculating the relation between the treatment variable and unobservables. The identification precedes through the following estimates:

$$Y = \alpha + \beta M + \varepsilon \quad \text{(A.1)}$$

$$Y = \alpha + \beta M + W_1 + \varepsilon \quad \text{(A.2)}$$

$$Y = \alpha + \beta M + W_1 + W_2 + \varepsilon \quad \text{(A.3)}$$

where *Y* represents academic performance; *M* is our treatment variable (housing unaffordability). W_1 denotes a linear combination of observed controls, including adolescent, parental, and household characteristics, provincial and wave dummies, provincial time-varying effects and time-invariant individual effect; W_2 represents an assumed linear combination of unobservables. The estimated coefficients and *R*-squares are $\dot{\beta}$ and $\dot{R}^2$ for A.1, $\tilde{\beta}$ and $\tilde{R}^2$ for A.2, β^* and R^2_{max} for A.3, respectively.

There are two common ways to test the stability of coefficient. The first approach is to calculate the identified set $[\tilde{\beta}, \beta^*]$ and see whether the inclusion of unobservable significantly changes the estimated coefficient. If the identified set excludes zero, then we conclude that our estimate is robust to omitted variables. The bias adjusted coefficient β^* can be estimated as $\beta^* = \tilde{\beta} - \delta(\dot{\beta} - \tilde{\beta})\frac{R^2_{max} - \tilde{R}^2}{\tilde{R}^2 - \dot{R}^2}$, where δ is the relative importance of unobservables to observables. Here, two settings need to be defined, and Oster (2019) suggests that $\delta = 1$ and $R^2_{max} = 1.3\tilde{R}^2$.

The second approach is to assume a value for R^2_{max} and calculate the value of δ for which $\beta = 0$. Oster recommends setting R^2_{max} to $1.3\tilde{R}^2$. The value of δ can thus be interpreted as the importance of unobservables compared to the observables, thereby generating a treatment effect of zero. For instance, a value of $\delta = 2$ implies

that the unobservables are twice as important as the observables to eliminate the estimated effect. Typically, δ larger than 1 would be enough to confirm the robustness of omitted variables.

Table A1 FE-IV estimates of different housing unaffordability measures on academic achievements among Chinese adolescent aged 10-18: CFPS 2010-2018

	(1)	(2)	(3)	(4)
Panel A: Chinese				
Second stage				
Housing cost ratio	-0.569***			
	(0.198)			
30/40 oms		-0.337***		
		(0.117)		
30% threshold			-0.440***	
			(0.155)	
50% threshold				-0.559***
				(0.191)
First stage				
	0.876***	1.008***	0.905***	0.871***
	(0.076)	(0.064)	(0.080)	(0.096)
Wald F-statistics	134.4	251.8	128.4	83.06
Observations	2279	2279	2279	2279
Number of Individuals	992	992	992	992
	(5)	(6)	(7)	(8)
Panel B: Mathematics				
Second stage				
Housing cost ratio	-0.245			
	(0.203)			
30/40 oms		-0.138		
		(0.122)		
30% threshold			-0.156	
			(0.164)	
50% threshold				-0.258
				(0.198)
First stage				
	0.876***	1.008***	0.905***	0.871***
	(0.076)	(0.064)	(0.080)	(0.096)
Wald F-statistics	134.4	251.8	128.4	83.06
Observations	2279	2279	2279	2279
Number of Individuals	992	992	992	992

Notes: The dependent variables are academic performance on Chinese and mathematics (from 1 = poor to 4 = excellent); controls include age, SRH (from 1 = poor to 5 = excellent, with poor as reference), maternal and paternal years of schooling and employment status (1 = yes, 0 = no), number of children under 18, wave dummies (with 2010 as the reference), provincial dummies (with Beijing as the reference) and provincial time-varying effects. Household-level adjusted standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.