# The Timing of Educational Inequality: Early Mechanisms Behind Gender Gaps in Maths Achievement

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# Motivation: The Economic Stakes

- **The Core Problem:** Gender gaps in Maths are a primary driver of female underrepresentation in high-paying STEM fields. This is both an education and an economic issue.
- **Labor Market Consequences:** This gap acts as a foundational sorting mechanism in the labor market. By steering women away from the most remunerative, math-intensive professions, it contributes significantly to occupational segregation and the aggregate gender pay gap, even before factors like the motherhood penalty take effect.
- **The Knowledge Gap:** While we know gaps exist, we have an incomplete picture of *when* and *how* they develop.
- **This Study:** Pinpoints the timing of this evolution, tracing the gap from childhood to adolescence to understand its mechanisms.

# Research Questions

This study explores the male advantage in Maths by asking:

1. How much of boys' advantage is due to having stronger average skills and a more favorable background?
2. How much is due to boys receiving better returns for their skills?
3. How does the importance of these factors change between childhood (age 9) and adolescence (age 13)?
4. How does father absence contribute to these gaps for both boys and girls?

# Method: The Oaxaca-Blinder Decomposition

To analyze the Maths gap, I employ the Oaxaca-Blinder decomposition method, a technique developed by economists Alan Blinder (1973) and Ronald Oaxaca (1973).

**The Three-Fold Decomposition Equation:** The mean difference between two groups (e.g., Girls (G) and Boys (B)) is broken down as follows:

$$\underbrace{\overline{Y}_G - \overline{Y}_B}_{\text{Total Gap}} = \underbrace{(\overline{X}_G - \overline{X}_B)\hat{\beta}_G}_{\text{Endowments}} + \underbrace{\overline{X}_B(\hat{\beta}_G - \hat{\beta}_B)}_{\text{Coefficients}} + \underbrace{(\overline{X}_G - \overline{X}_B)(\hat{\beta}_G - \hat{\beta}_B)}_{\text{Interaction}}$$

**Where:** $\overline{Y}$ is the average Leaving Certificate Maths score; $\overline{X}$ is the vector of average characteristics (prior skills, family background, etc.); $\hat{\beta}$ is the vector of **coefficients** (returns). Each element in $\hat{\beta}$ represents how much a one-unit change in a characteristic (like prior Maths ability) is expected to change the final Maths score. It is the **reward** the system gives for that specific skill or trait. The coefficients part of the decomposition is driven by the difference between $\hat{\beta}_G$ and $\hat{\beta}_B$.

# Method: Analytical Strategy

- **Dependent Variable (Fixed Outcome):** The Leaving Certificate Maths score, measured once at age 17/18.
- **Independent Variables (Changing Predictors):** I use factors measured at two different points in time:
  - Age 9 (Childhood)
  - Age 13 (Adolescence)
- **Longitudinal Sample:** The analysis follows a consistent panel of students who are present in all relevant survey waves.
- **Key Goal:** To see how the explanation for the *same final math gap* changes, depending on when we measure the predictors.

# Data: Growing Up in Ireland

| Event | Date | Age (in years) | Variables of interest |
|---|---|---|---|
| Study-child is born | Nov/97 - Oct/98 | 0 | - |
| Wave 1 data collection | Aug/07 - May/08 | 9 | 2 Cognitive variables (Reading and Maths logit scores), 4 SDQ scales, Parental Education, Income, School Type |
| Wave 2 data collection | Aug/11 - Mar/12 | 13 | 3 Cognitive variables (Verbal/Numerical Reasoning, BAS), 4 SDQ scales, Parental Education, Income, School Type |
| Wave 3 data collection | Apr/15 - Aug/16 | 17/18 | Most participants had *not yet sat* the Leaving Cert |
| Study-child sits the Leaving Cert | Jun/16 - Jun/17 | 17/18 | - |
| Wave 4 data collection | Aug/18 - Jun/19 | 20 | **Outcome: Leaving Cert points in Maths scores** |

Table: Timeline of Events - Growing Up in Ireland '98 Cohort

*Note I: The Leaving Certificate grading system changed in 2017. Scores were harmonized across schemes to ensure comparability.*
*Note II: The SDQ (Strengths and Difficulties Questionnaire) measures socioemotional traits. This study uses four subscales: Emotional Symptoms, Conduct Problems, Hyperactivity/Inattention, and Peer Problems. Higher scores indicate greater difficulties.*
*Note III: The Leaving Certificate is the final national exam of the Irish secondary school system, used for university admissions (analogous to A-Levels in the UK or the SAT in the US).*

# Summary Statistics

- **Sample:** 4,333 students from the GUI '98 Cohort.
- **Maths LC (Harmonized):** Mean = 56.03 (out of 100).
- **Father Absence:** About 11–12% were consistently absent across both waves.
- **Father Absence Penalty:**
  - Boys with absent fathers score on average **13.6 points lower**.
  - Girls with absent fathers score on average **15.2 points lower**.
- **Other Group Differences:**
  - Lower cognitive scores at both ages.
  - Higher behavioural difficulties (SDQ).
  - Lower socioeconomic status and maternal education.
  - More likely to attend disadvantaged (DEIS) schools.

# Decomposition Design: Gender Gap

- I decompose the **same, fixed outcome**—the final Maths score gap at age 17/18—using predictors from two different time periods:
  - **Wave 1 (Age 9)** to capture childhood traits.
  - **Wave 2 (Age 13)** to capture early adolescence traits.
- For each wave, I estimate two models:
  - *Model A:* Excludes father's education.
  - *Model B:* Includes father's education to test its role.
- **Aim:** To see if the gap is better explained by differences in skills and background or by differences in returns to those skills.
- **Core Question:** Do early differences in *how skills are rewarded* later become real *differences in skills*?

# Finding 1: The Evolving Gender Gap

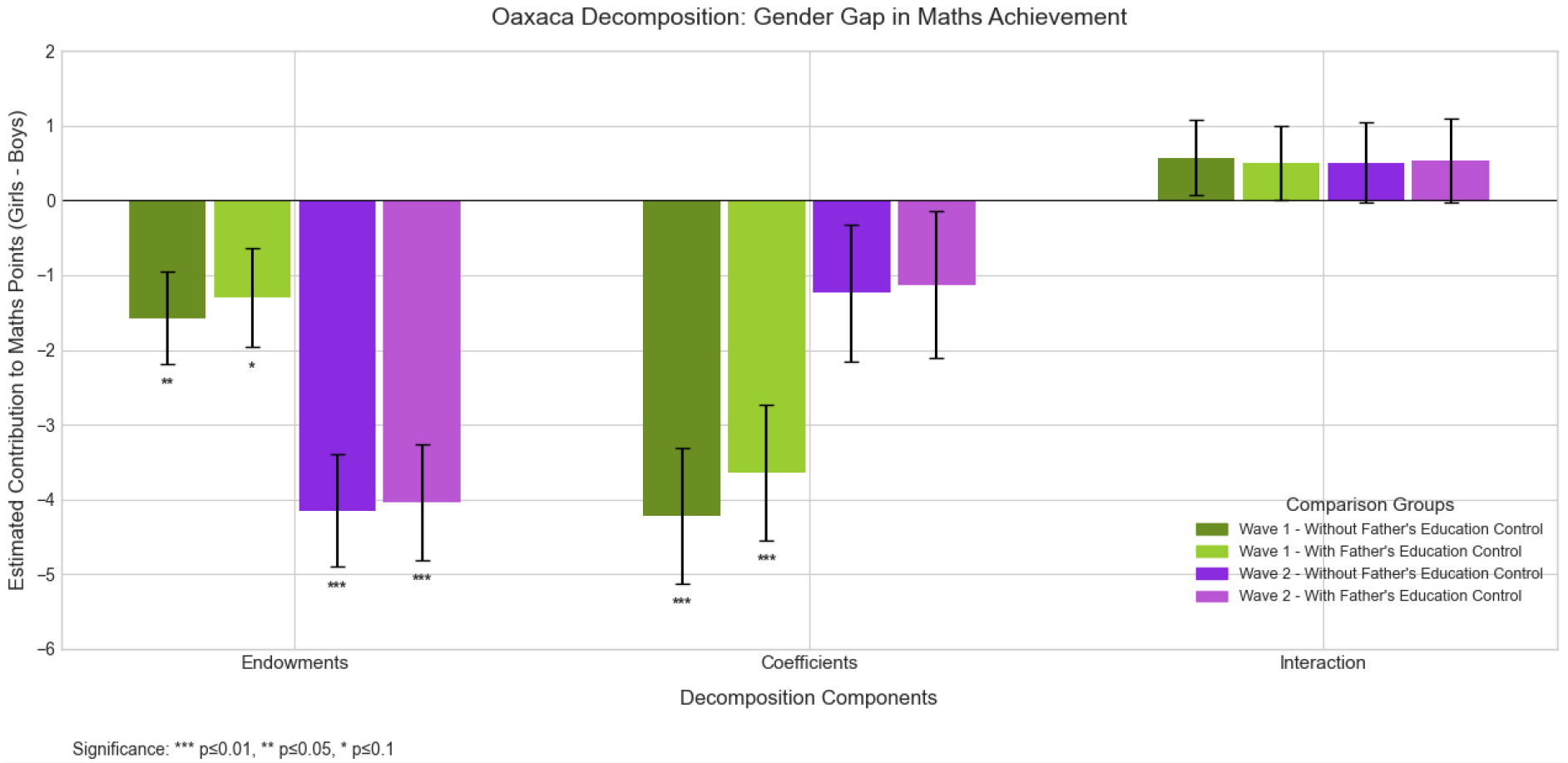


Figure: Oaxaca-Blinder Decomposition of the Gender Gap in Maths

# Finding 1 Explained: The Story Changes with Age

- **The Overall Gap:** Boys outperform girls in Maths by **4.4–5.2 points** on average.
- **At Age 9 (Green Bars):** The gap is mainly explained by **Coefficients**.
  - At this age, the difference is less about skills and more about how boys' and girls' skills are translated into outcomes.
  - Note: the coefficients component also reflects unobserved factors and model residuals, not just bias in treatment.
- **At Age 13 (Purple Bars):** The gap is now mostly explained by **Endowments**.
  - By adolescence, a real, measurable skill gap has emerged, driven primarily by boys' higher average numerical ability.
- **Key Takeaway:** What begins as differences in how skills are rewarded at age 9 becomes differences in actual skills by age 13.

Sources: Fortin, Lemieux & Firpo (2011); Carlana (2019); Lavy & Sand (2018).

# Decomposition Design: Father Absence

- **Defining the Groups:** I compare students with a present father against those with a consistently absent father.
  - **Father Absence** = The father did not complete the survey in Wave 1 (age 9) **and** Wave 2 (age 13) $\rightarrow$ captures sustained paternal disengagement. About 80% of these cases involve a single-mother household where the father is not resident.

- **Analytical Approach:** To see if the impact differs by gender, I run separate decompositions for boys and girls.
  - Boys (Father Present vs. Absent)
  - Girls (Father Present vs. Absent)

- **A Note on Attrition:** Students from the father-absent group were significantly more likely to drop out of the study later on $\rightarrow$ results are likely a **conservative estimate** of the true negative impact of father absence.

# Finding 2: The Impact of Father Absence

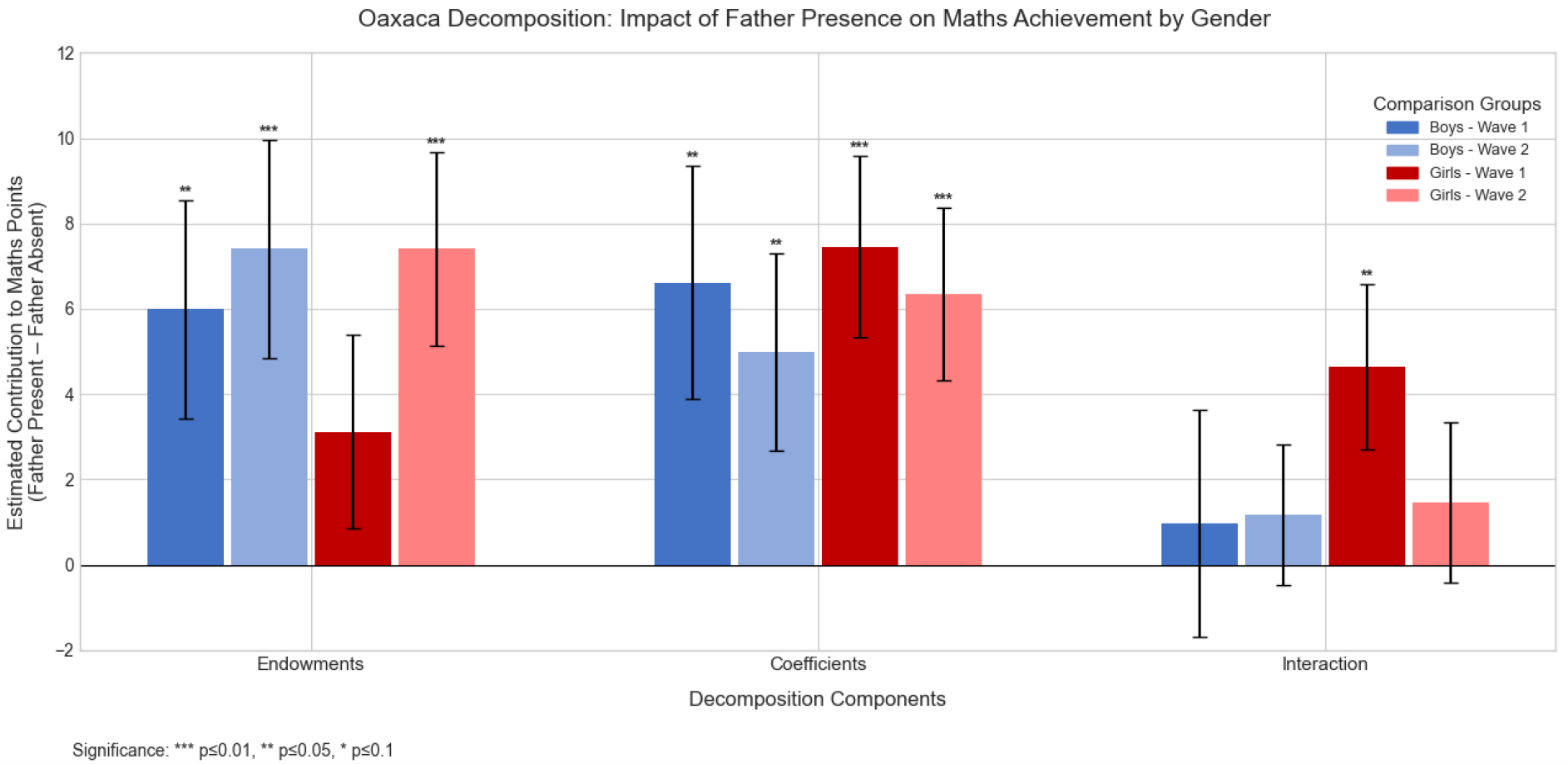


Figure: Decomposition of the Father Absence Effect on Maths, by Gender

# Finding 2 Explained: A Profound and Gendered Penalty

- **A Large Penalty:** Sustained father absence is linked to a massive drop in Maths scores for both genders:
  - **Boys:** 13.6 points lower
  - **Girls:** 15.2 points lower
- **Different Pathways of Disadvantage:**
  - **For Boys (Blue Bars):** The penalty comes from *both* weaker skills and lower returns on those skills at both ages. This aligns with research suggesting boys are more vulnerable to family instability.
  - **For Girls (Red Bars):** The story is more about *returns* at age 9. The disadvantage seems more tied to family resources and support. By age 13, it becomes a mix of weaker skills and lower returns.
- **Key Takeaway:** Family structure is a powerful driver of inequality, and its negative effects operate through different channels for boys and girls.

# Discussion: The Story of Inequality

- **A Dynamic Process:** The *reasons* for the Maths gap evolve. Early differences in how skills are rewarded solidify into real skill gaps by adolescence.

- **Why the Shift? Potential Mechanisms:**
  - **Human Capital:** Early skill advantages compound over time (Cunha & Heckman, 2007).
  - **Stereotype Threat:** Gender stereotypes in adolescence can hinder girls' performance (Spencer et al., 1999).
  - **Teacher Bias:** Implicit teacher stereotypes shape expectations and outcomes (Carlana, 2019; Lavy & Sand, 2018).

- **Compounded Disadvantage:** Father absence interacts with gender, amplifying inequality in different ways for boys and girls.

# Main Takeaways & Policy Implications

- **Timing is Everything:** The nature of the Maths gender gap *changes* from childhood to adolescence.
  - At age 9, gaps are driven by **differential returns** to skills.
  - By age 13, gaps are driven by **actual skill differences**.
- **Policy Must Be Targeted and Timely:**
  - **In Childhood:** Focus on teacher awareness and fair assessment practices to ensure girls' skills are equally recognised (Carlana, 2019).
  - **In Adolescence:** Support direct development of girls' numerical skills and confidence-building (Yeager et al., 2019).
- **Support At-Risk Families:** Father absence is a major risk factor. Interventions should account for different pathways of disadvantage for boys and girls (Autor et al., 2019; Brenøe & Lundberg, 2018).

# Conclusion

Thank you so much.
Any questions or suggestions?
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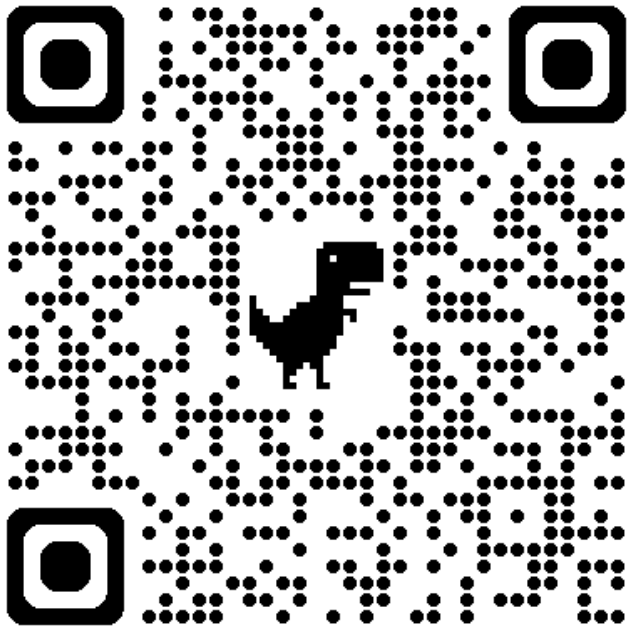

# Supplementary: Robustness Distributional Effects

**Does this pattern hold for other subjects?**

- **English:** The story reverses. Girls outperform boys. Interestingly, this gap is almost entirely explained by **Coefficients** (better returns for girls) at *both* ages. This suggests the mechanisms behind achievement gaps are highly subject-specific.

**Is this just an effect at the average?**

- A DiNardo-Fortin-Lemieux (nonlinear) decomposition was also performed.
- **Gender Gap:** The math gap is not uniform. It is dramatically concentrated around the **median** of the performance distribution. The gap is much smaller for low- and high-achieving students.
- **Father Absence:** The penalty is large across the *entire* distribution, but the *reasons* for it change. For middle-performing students, the gap is mostly explained by observable skills (composition), while for low-performers, unobserved factors or different returns (structure) matter more.

# Supplementary: Leaving Certificate Grading System

**Leaving Certificate Grading Systems: Harmonised Points**

| Old Grade | % Marks | New Grade (Post–2017) | New Code | Points (Higher) | Points (Ordinary |
|---|---|---|---|---|---|
| A1 | 90–100 | H1 | 01 | 100 | 56 |
| A2 | 85–90 | H2 | 02 | 88 | 46 |
| B1 | 75–80 | H3 | 02 | 88 | 77 |
| B2 | 70–75 | H3 | 03 | 77 | 37 |
| C1 | 65–60 | H4 | 04 | 66 | 28 |
| C2 | 55–60 | H4 | 04 | 66 | 20 |
| C3 | 55–60 | H5 | 05 | 56 | 20 |
| D1 | 50–55 | H5 | 05 | 56 | 20 |
| D2 | 45–60 | H6 | 06 | 46 | 12 |
| E | 25–40 | H7 | H7 | 33 | 0 |
| F | 10–25 | H8 | H8 | 0 | 0 |

Figure: Leaving Certificate Points System Harmonization

# Descriptives: The Achievement and Skills Gap

Before the main analysis, a simple comparison of means shows students with absent fathers are at a significant disadvantage:

1. **Large Gaps in Final Maths Performance:**
   - Students with a present father score nearly **16 points higher** on the final Leaving Certificate Maths exam.
2. **Weaker Cognitive Skills from an Early Age:**
   - **At Age 9:** They already have lower average scores in both Reading and Maths ability.
   - **At Age 13:** These gaps persist across Verbal Reasoning, Numerical Ability, and Matrix Reasoning.

*This shows that the performance gap seen at age 18 is preceded by significant, measurable cognitive skill gaps throughout childhood and adolescence.*

# Descriptives: Behavioral and Family Gaps

The disadvantage extends to non-cognitive skills and family resources:

1. **Higher Rates of Behavioral Difficulties:**
   - At both ages 9 and 13, children with absent fathers show significantly higher average scores for:
     - Emotional Symptoms
     - Conduct Problems
     - Hyperactivity
     - Peer Problems
2. **Lower Socioeconomic Status (SES):**
   - Households with an absent father have, on average, lower maternal education and belong to lower income quintiles.

# Descriptives: The Motivation for Decomposition

**A Cluster of Disadvantage:**

- A simple comparison of means shows that children with absent fathers are at a significant disadvantage. They have lower average cognitive scores, more behavioral difficulties, and are more likely to come from lower-income households and attend disadvantaged (DEIS) schools.

**This Raises a Key Selection Question:**

- Is the "father absence" penalty just a proxy for this cluster of pre-existing socioeconomic disadvantages?

**This Is Exactly Why We Use a Decomposition:**

- The Oaxaca-Blinder method allows us to statistically account for these observable differences.
- It helps us disentangle the effect of these SES and background characteristics (the **Endowments** component) from any remaining "unexplained" part of the gap (the **Coefficients** and **Interaction** components).

# Developmental Changes Between Primary/2ndary School

- Around age 9, most children are still in the concrete operational stage (Piaget), meaning they can think logically but mostly about tangible concepts.
- By age 13, many are transitioning into the formal operational stage, developing abstract thinking, reasoning, and metacognition — this can lead to divergence in academic engagement, especially in subjects like Maths and Science.
- Girls tend to mature earlier cognitively, and often outperform boys in school settings that reward organization, verbal fluency, and sustained attention.
- Girls typically enter puberty earlier than boys (often starting around 10–11 for girls vs. 11–12 for boys).

# Developmental Changes Between Primary/2ndary School

- This earlier maturation affects emotional regulation, self-concept, and motivation — and it often results in girls becoming more goal-oriented and compliant with school expectations.
- Boys, on the other hand, may still be in a more immature behavioural phase, with issues like inattention, impulsivity, and lower emotional regulation more prominent — especially in less structured settings.
- Hyperactivity and externalising behaviours (e.g., conduct issues) are more prevalent in boys and become more noticeable in early adolescence.
- Internalising behaviours (e.g., anxiety, perfectionism) rise more in girls but are often less disruptive to academic performance.

# School Transition

- The move to secondary school is a major environmental shock, often around age 12 in many systems.
- It tends to reward executive functioning skills (planning, time management), which girls often develop earlier.
- Boys — especially those with higher hyperactivity/inattention — may struggle more with the demands of self-regulation, leading to emerging gender gaps in academic performance.