Market design of college-major switches for reducing student-major mismatch

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Outline

- Background
- New Mechanism
- Improvements
- Implementation at NTU
- Summary

College Admissions in Taiwan

- In Taiwan, most students have to choose college-major pairs jointly in college admissions. Similar practices can be found in Chile, Japan, Spain, and Turkey.
- Each college-major enrollment is subject to the **admission quota**, which is regulated by the government.
- When applying to college-major pairs, some students propose the ranking list based on colleges' prestige rather than their preference over majors, and their assigned majors might not be a good fit.

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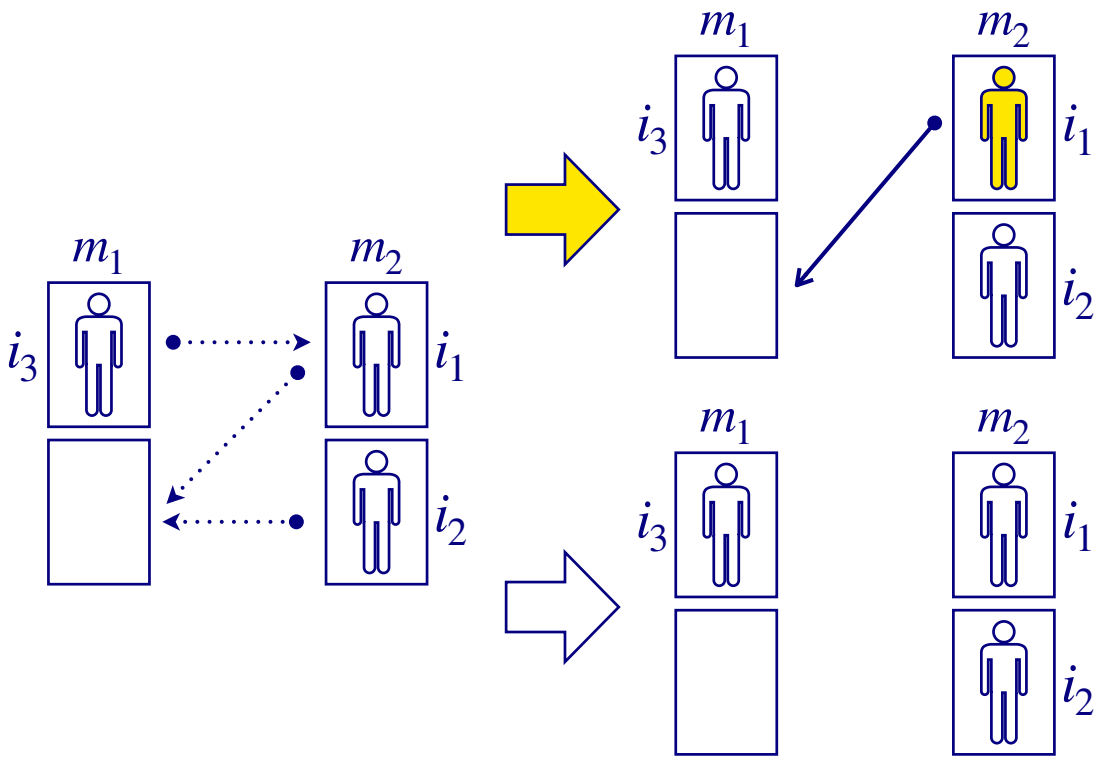
- Each college-major enrollment is subject to the **admission quota**, which is regulated by the government.
- When applying to college-major pairs, some students propose the ranking list based on colleges' prestige rather than their preference over majors, and their assigned majors might not be a good fit.
- As a result, those students are more likely to drop out.
- In a government survey in 2019, **24.6%** of Taiwanese students who drop out of college is due to the **mismatch** between students and majors.

Conventional Major Switching in Taiwan

- When some students drop out of a college, the demand for matching is from the reallocation of vacant seats to remaining students at that college, i.e., major switching.
- The conventional major-switching mechanism in Taiwan is a matching between students and majors (departments) who provides available seats (vacant seat), and the number of major switches is **constrained** by the total vacant seats.

Conventional Major Switching in Taiwan

- For example, a college has student i_3 from major m_1 desiring to switch to m_2. However, this college only has a vacant seat at m_1, and students i_1 and i_2 from m_2 apply to m_1 for major switching.
- In the conventional process, only one major switch can occur, i.e., either i_1 switches to m_1 or i_2 switches to m_1.



Conventional Major Switching in Taiwan

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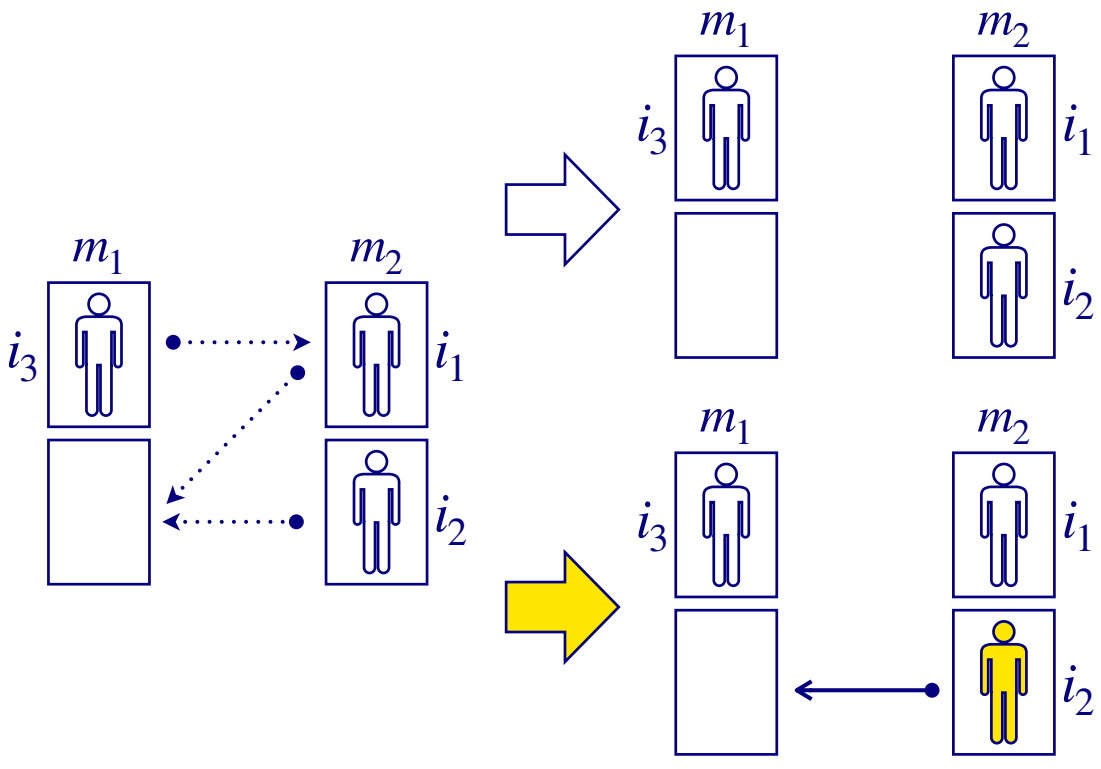

Problem

- Since many applicants are rejected by popular majors, the percentage of applicants who successfully switches to a new major (the success rate) is usually low.
- For example, in 2020, there were 634 applicants at National Taiwan University (NTU) and the **success rate** was **43.62%**.

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- For example, in 2020, there were 634 applicants at National Taiwan University (NTU) and the **success rate** was **43.62%**.
- We thus propose a new mechanism to deal with the problem.
- Our new mechanism has been adopted by NTU since 2022.

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Intuition behind the new mechanism

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- In the new mechanism, we expand a major's quota by adding the number of its students who have applied for major switching.

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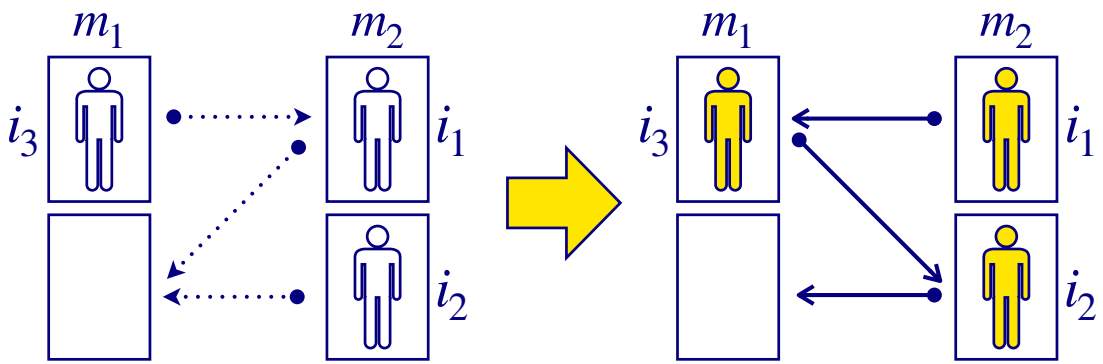
- In the new mechanism, we expand a major's quota by adding the number of its students who have applied for major switching.
- For example, a college only has **a vacant seat** at major m_1, and students i_1 and i_2 from major m_2 apply to m_1 for major switching.
- If we also have student i_3 from m_1 who applies to m_2, **three major switches** can occur, i.e., i_1 and i_2 switch to m_1, and i_3 switches to m_2.



Model

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- $q = (q_m)_{m \in M}$: Quota vector
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- $P = (P_i)_{i \in I}$: (Strict) Preference profile of students over $M \cup \emptyset$
- $\succ = (\succ_m)_{m \in M}$: (Strict) Ranking profile of majors over $I \cup \emptyset$

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5. According to the preferences of students and majors, the college matches students to majors via the student-proposing or major-proposing deferred acceptance algorithms (DASP or DAMP).

Example with $n = 2$

- We have three students i_1, i_2, and i_3 with the initial majors m_1, m_2, and m_3, respectively. In addition, m_2 has a vacant seat.
- Under the DASP mechanism, students can apply to m_1, m_2, or m_3 for major switching.
- The preferences are illustrated as follows:

$$i_1 : m_3 - m_2 - m_1 \qquad m_1 : i_1 - i_2 - i_3$$
$$i_2 : m_3 - m_1 - m_2 \qquad m_2 : i_2 - i_1 - i_3$$
$$i_3 : m_1 - m_2 - m_3 \qquad m_3 : i_3 - i_1 - i_2$$

DASP Algorithm

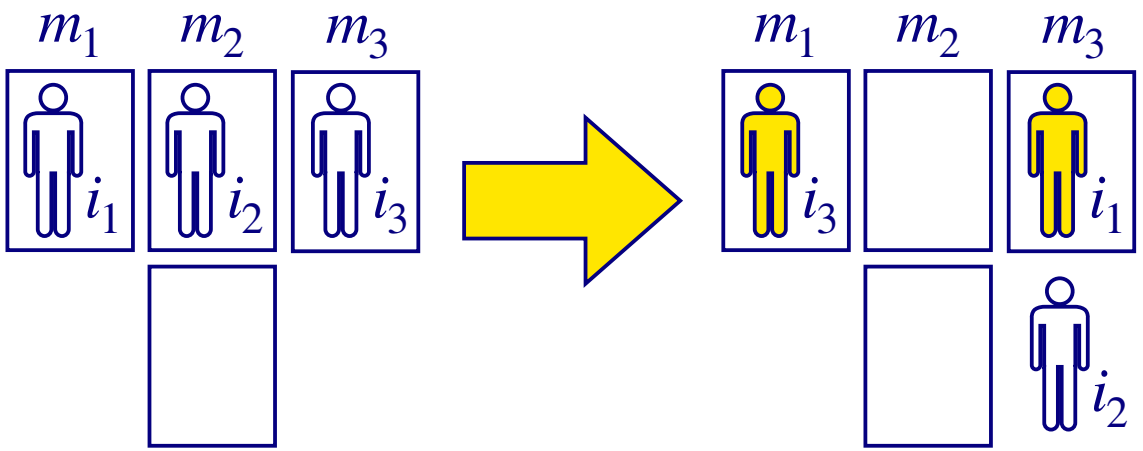
Preferences:

$i_1 : m_3 - m_2 - m_1$ $\qquad$ $m_1 : i_1 - i_2 - i_3$

$i_2 : m_3 - m_1 - m_2$ $\qquad$ $m_2 : i_2 - i_1 - i_3$

$i_3 : m_1 - m_2 - m_3$ $\qquad$ $m_3 : i_3 - i_1 - i_2$

- **Step 1**: Students apply to their first choice.
  Since m_3 prefers i_1 to i_2, i_2 is rejected.



DASP Algorithm and Matching Outcome

Preferences:

$$i_1 : m_3 - m_2 - m_1 \qquad m_1 : i_1 - i_2 - i_3$$
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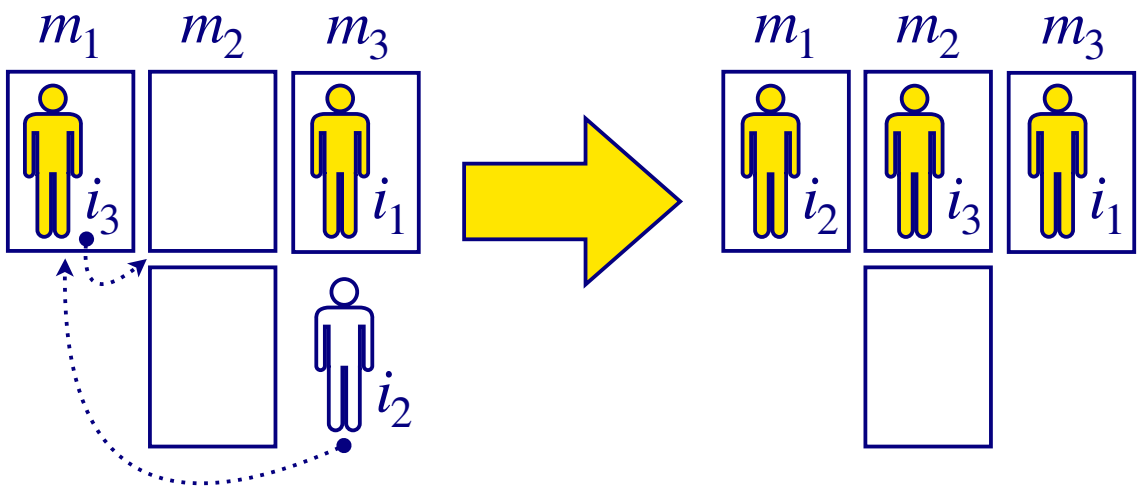
$$i_3 : m_1 - m_2 - m_3 \qquad m_3 : i_3 - i_1 - i_2$$

- **Step 2**: i_2 apply to her second choice m_1. Since m_1 prefers i_2 to i_3, i_3 is assigned to her second choice m_2.



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Matching under the Conventional Mechanism

Preferences:

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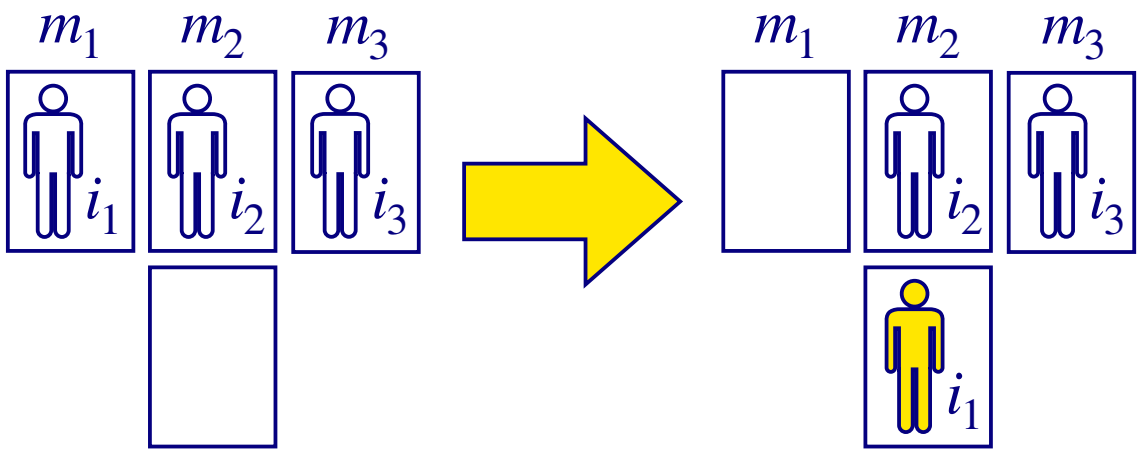
$i_3 : m_1 - m_2 - m_3$ $\qquad$ $m_3 : i_3 - i_1 - i_2$

- **Outcome**: Since there is one vacant seat at major m_2, students i_1 and i_3 apply to m_2 but only i_1 is assigned m_2.



Matching under the DASP

Preferences:

$i_1 : m_3 - m_2 - m_1$ $\qquad$ $m_1 : i_1 - i_2 - i_3$

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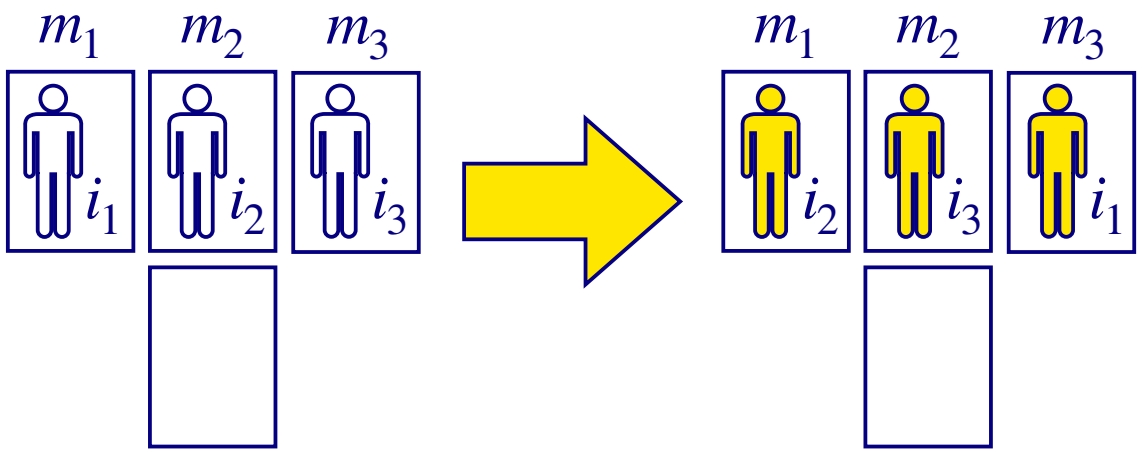
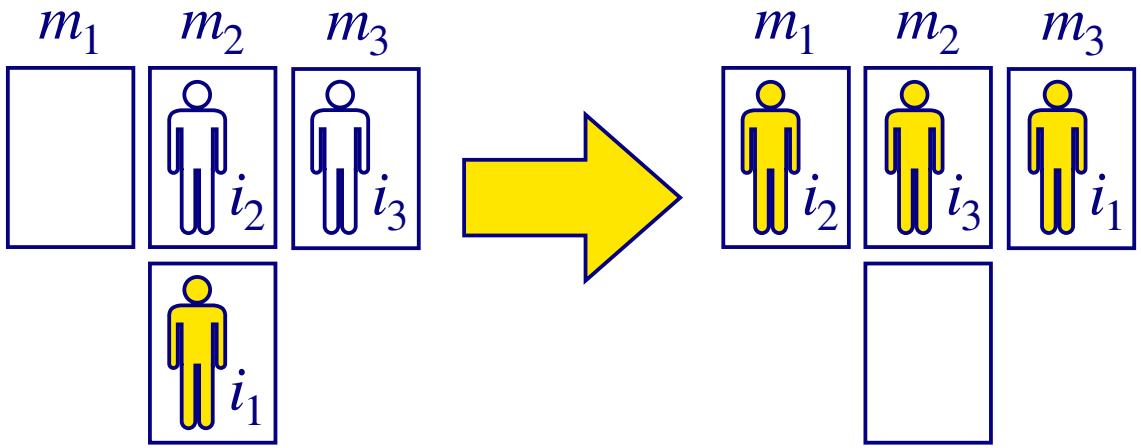
$i_3 : m_1 - m_2 - m_3$ $\qquad$ $m_3 : i_3 - i_1 - i_2$

- **Outcome**: i_1 is assigned her first choice.
  i_2 and i_3 are assigned their second choice.



Improvements

- Compared to the conventional mechanism, the DASP mechanism improves students' welfare in the following sense:
  - → Student i_1 is assigned her most preferred major under the DASP while she is assigned the second choice under the conventional mechanism.
  - → Students i_2 and i_3 switch to new majors under the DASP while they stay at the initial majors under the conventional mechanism.
  - → The success rate has increased from 50% to 100%.



Gains from the new mechanisms

- In general, the new mechanisms has the following features:
  - → (**Secure**) Students are ensured to be assigned a new major or keep their initial major.
  - → (**Non-wasteful**) No vacant seats will be wasted, in the sense that whenever a student prefers a new major to her assignment, it must be the case that the major has no vacant seats for her.

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  - → (**Non-wasteful**) No vacant seats will be wasted, in the sense that whenever a student prefers a new major to her assignment, it must be the case that the major has no vacant seats for her.
- Compared to the conventional mechanism (π'), no students is hurt and some students will be better off under the new mechanisms, i.e., they **Pareto dominate** π'.
- In addition, DASP (weakly) Pareto dominates DAMP.
- Moreover, the number of major switchers is not constrained by the vacant seats, which implies that the **success rate** can be improved under the new mechanism.

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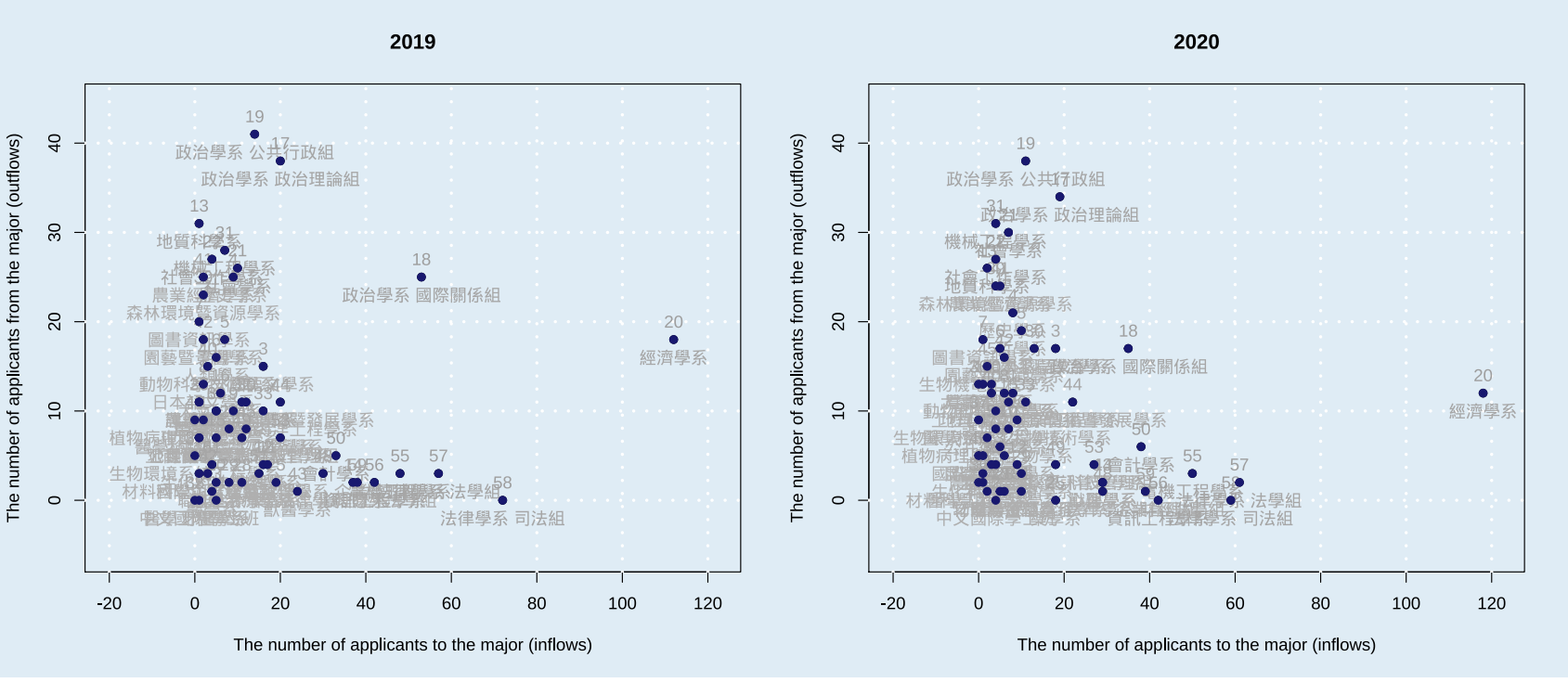
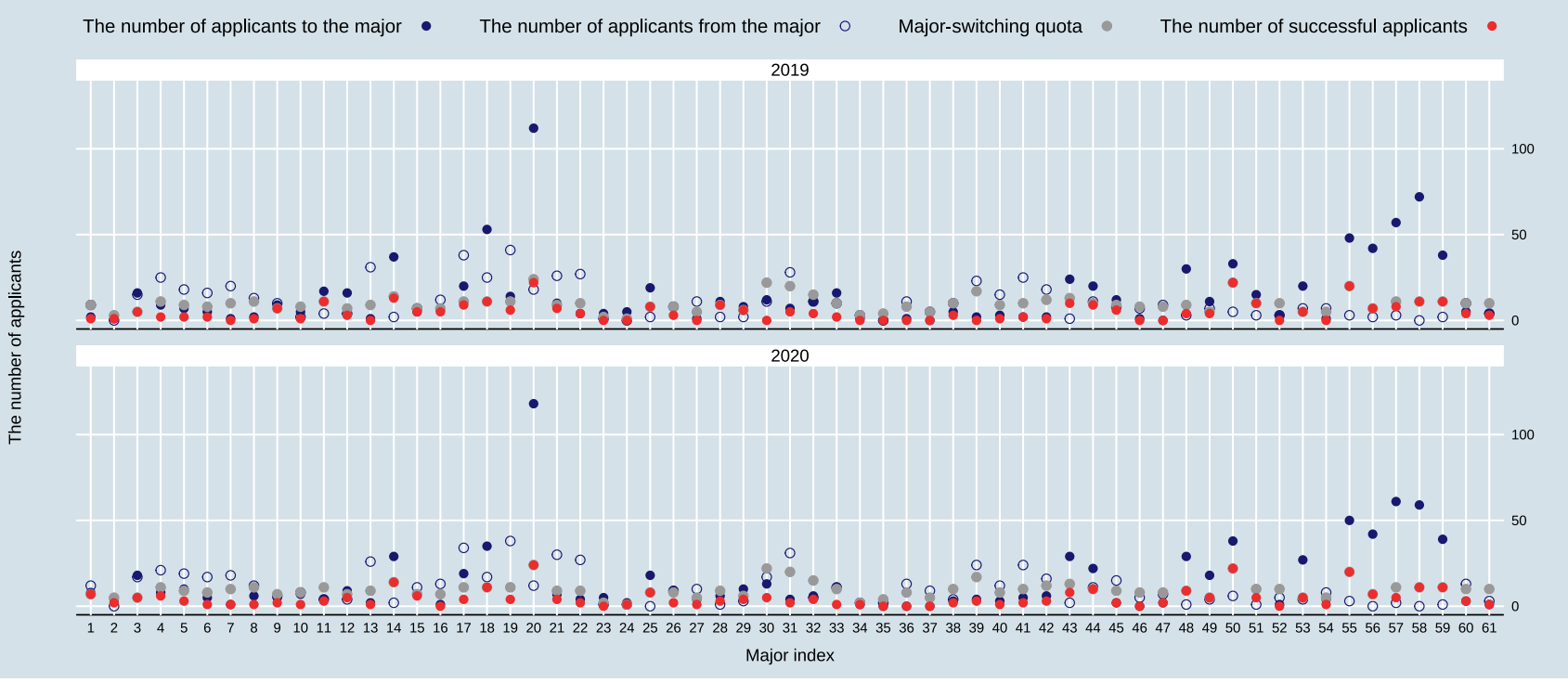
Major Switching at NTU



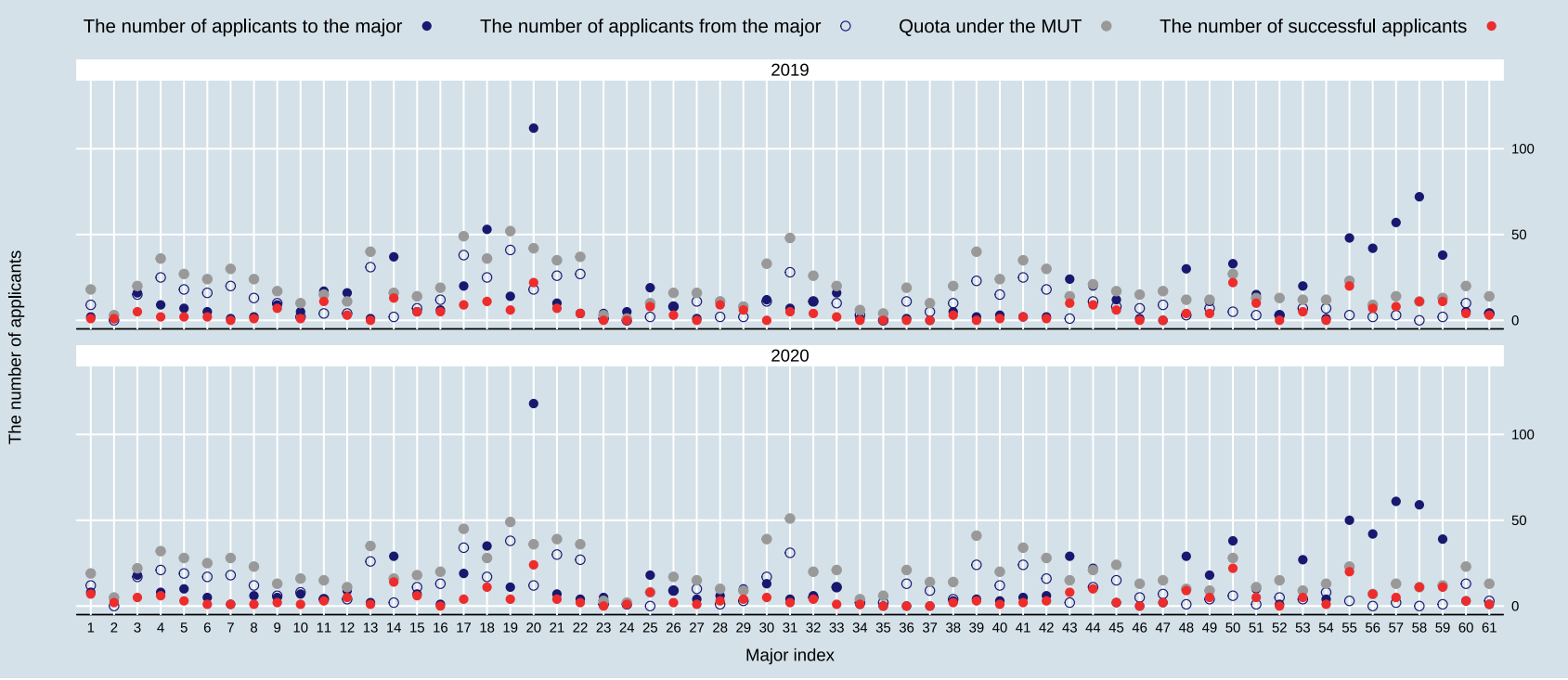
- There were 654 and 635 applicants at NTU in 2019 and 2020.
- Imbalances between inflows and outflows exist at many majors.
- For example, in 2020, the number of applicants to major 20 (economics) and the number of applicants from it were 118 and 12, respectively.

Quota Constraint



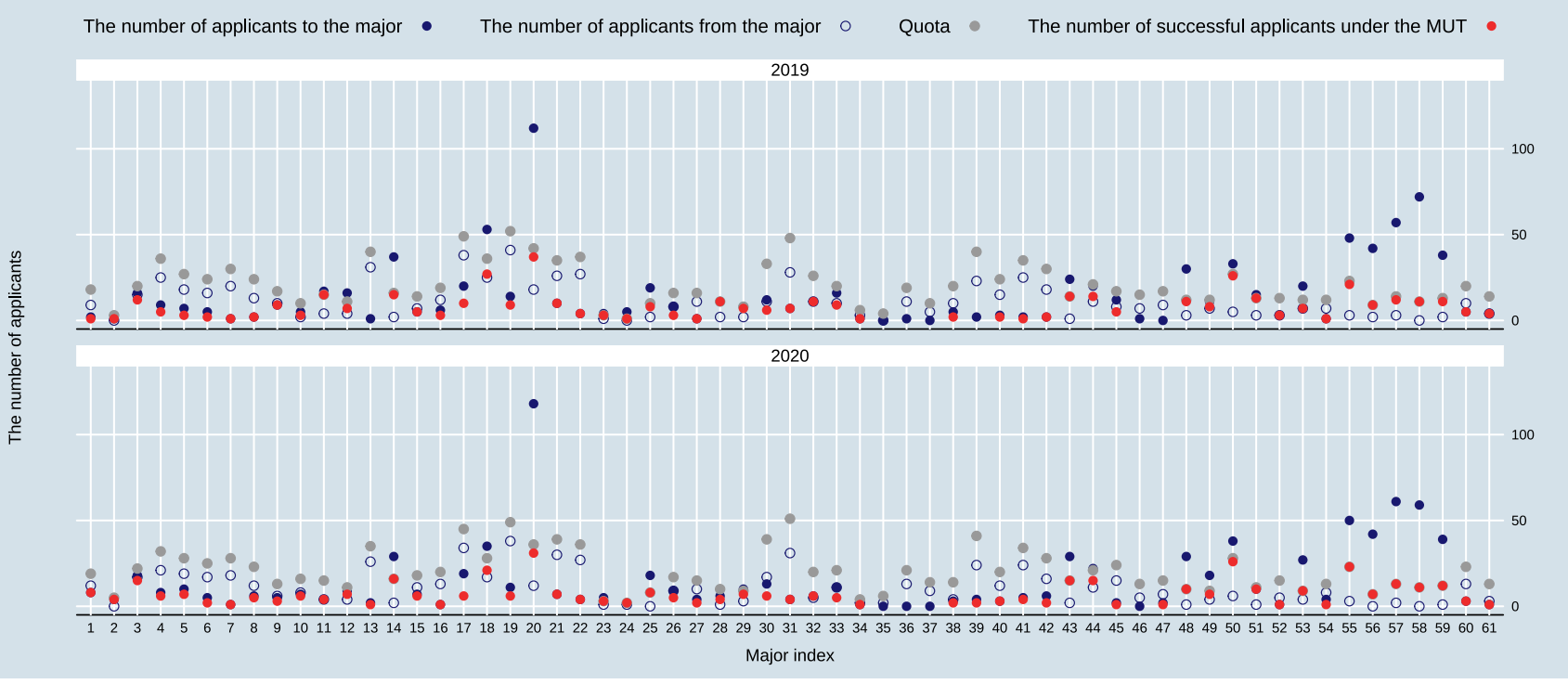
- The number of successful applicants to a major is constrained by its vacant seats.
- For example, in 2020, the number of vacant seats for major 20 was 24, and the success rate in this major was only 20.34%.

Quota Expansion under the new Mechanisms



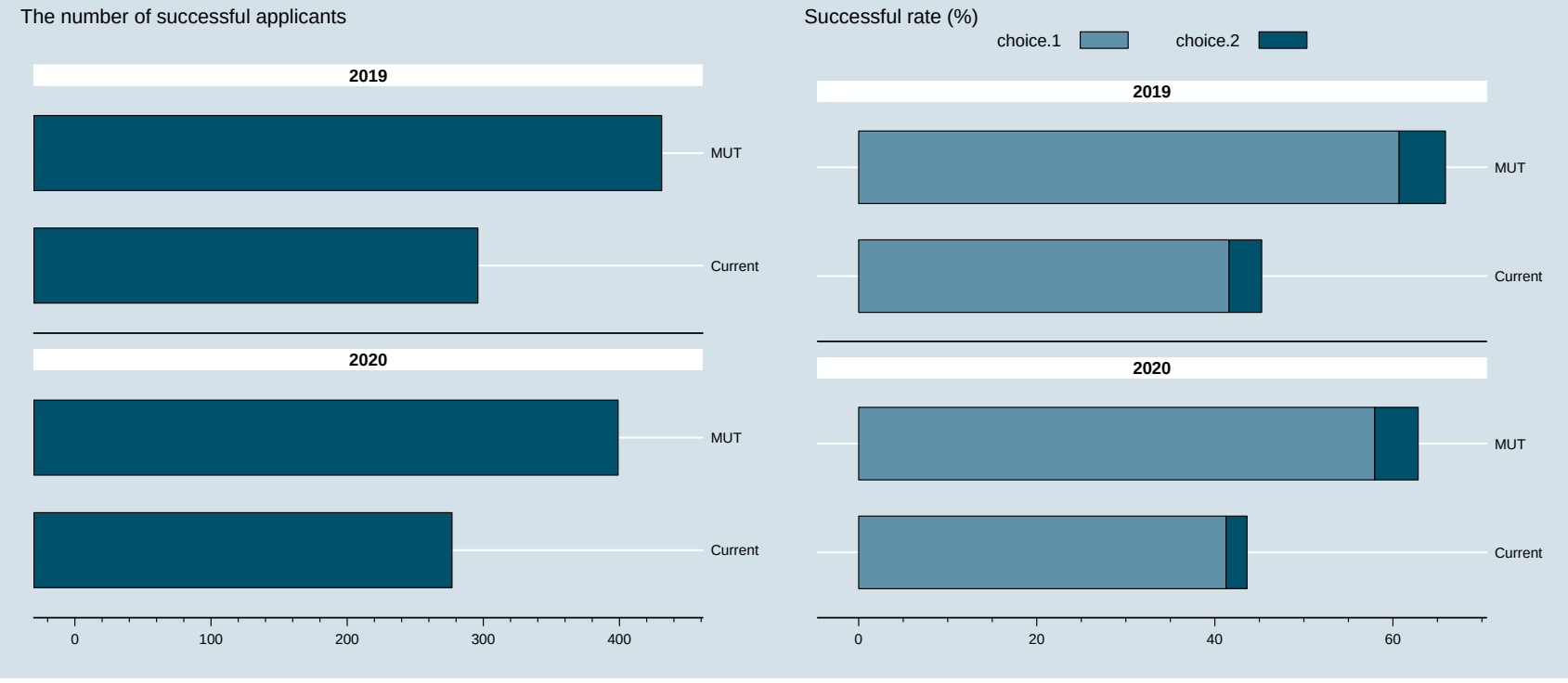
- A major's quota could be expanded by adding the number of its students who have applied for major switching.
- Thus, more students could have been assigned their desired majors under the new mechanism.

More Switchers under the new mechanism



- According to the student and major preferences, we apply the new mechanism for major switching at NTU in 2019 and 2020.
- The result shows that the number of successful applicants **weakly increases** in all majors.

Improvements



- Compared to the current mechanism at NTU, the success rates under the DASP mechanism are from 45.26% and 43.62% to 62.69% and 60.00% in 2019 and 2020, respectively.
- More students are assigned their first or second choices under the new mechanism.

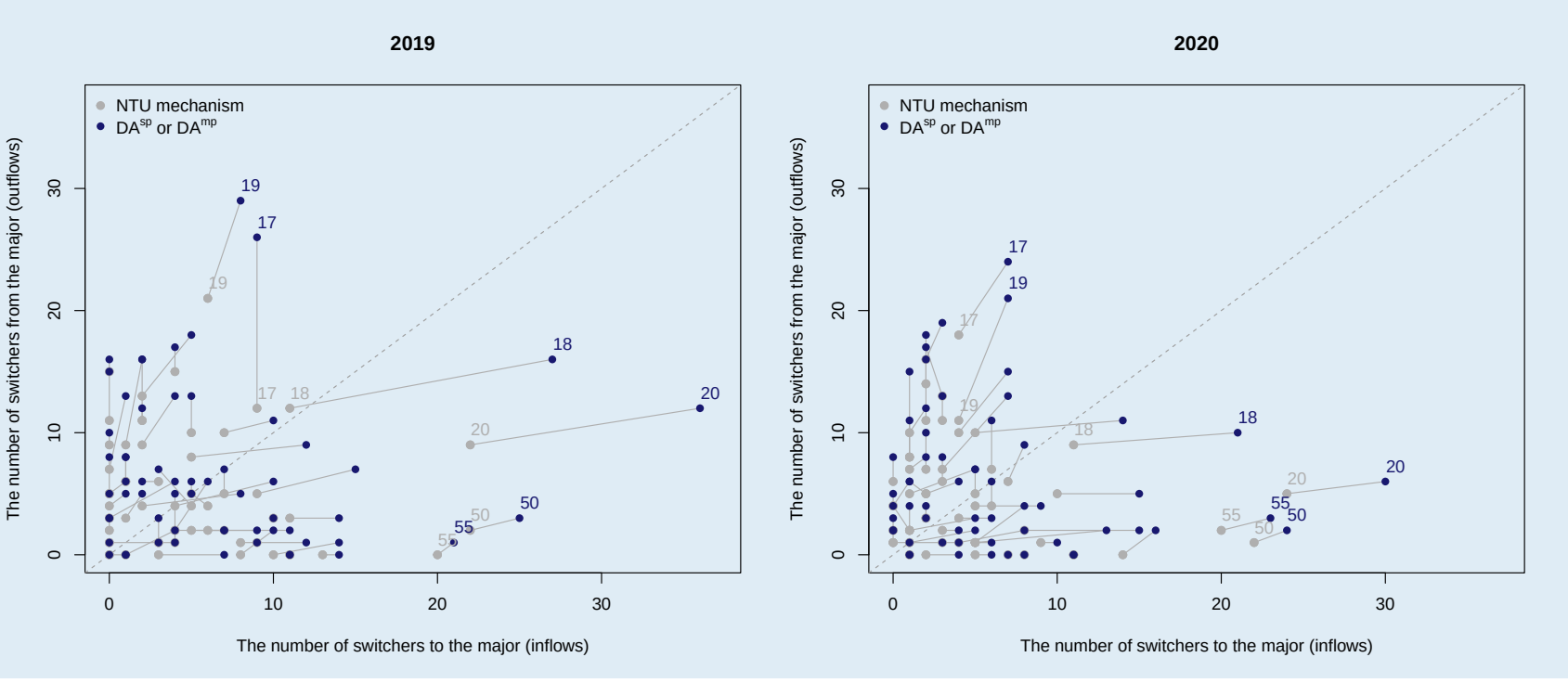
Success Rate (%) under Different Mechanisms

	2019		
	Current	DASP	DAMP
First choice	41.59	56.73	56.73
Second choice	3.67	5.96	5.96
Total success rate	45.26	62.69	62.69

	2020		
	Current	DASP	DAMP
First choice	41.26	55.59	55.59
Second choice	2.36	4.41	4.41
Total success rate	43.62	60.00	60.00

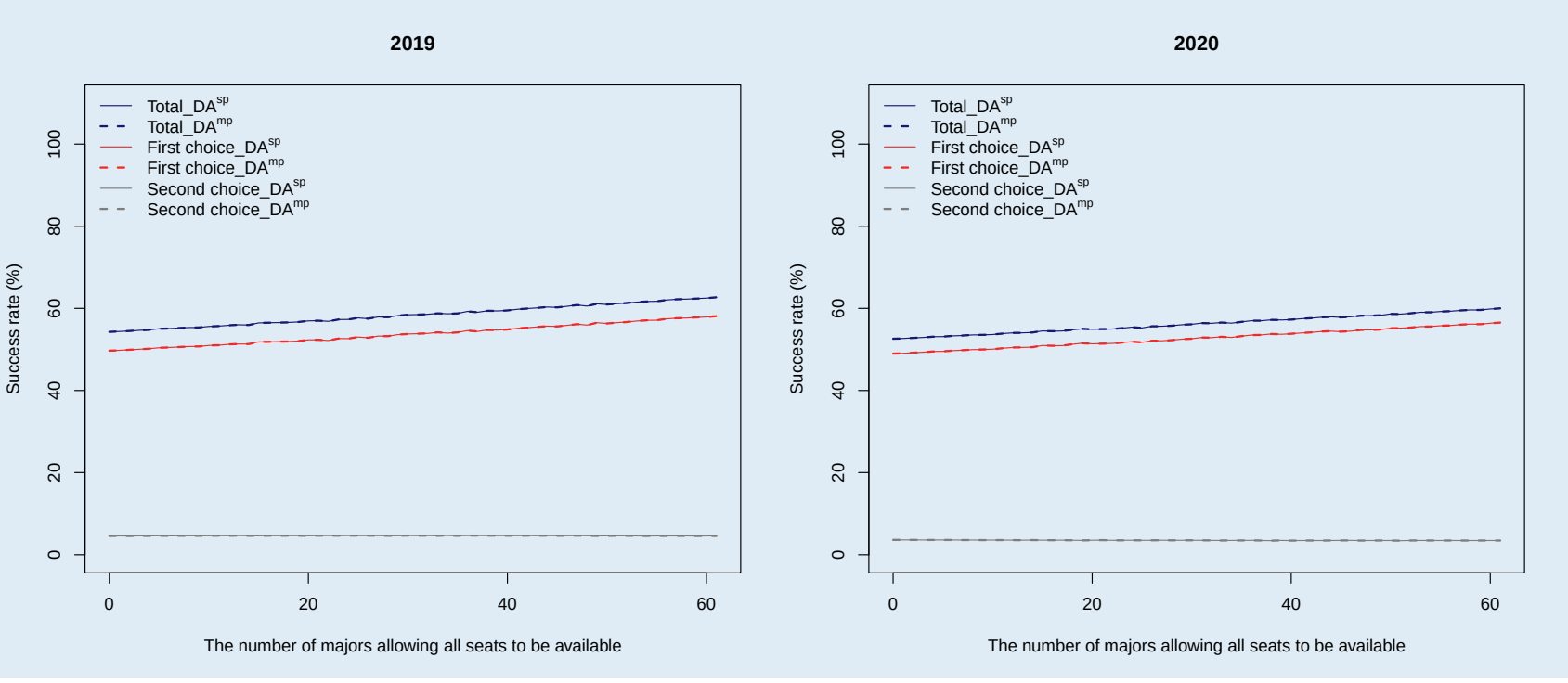
Note: The simulation is based on the assumption that all majors join the new mechanism and provide a complete ranking of eligible students.

Inflows and Outflows under Different Mechanisms



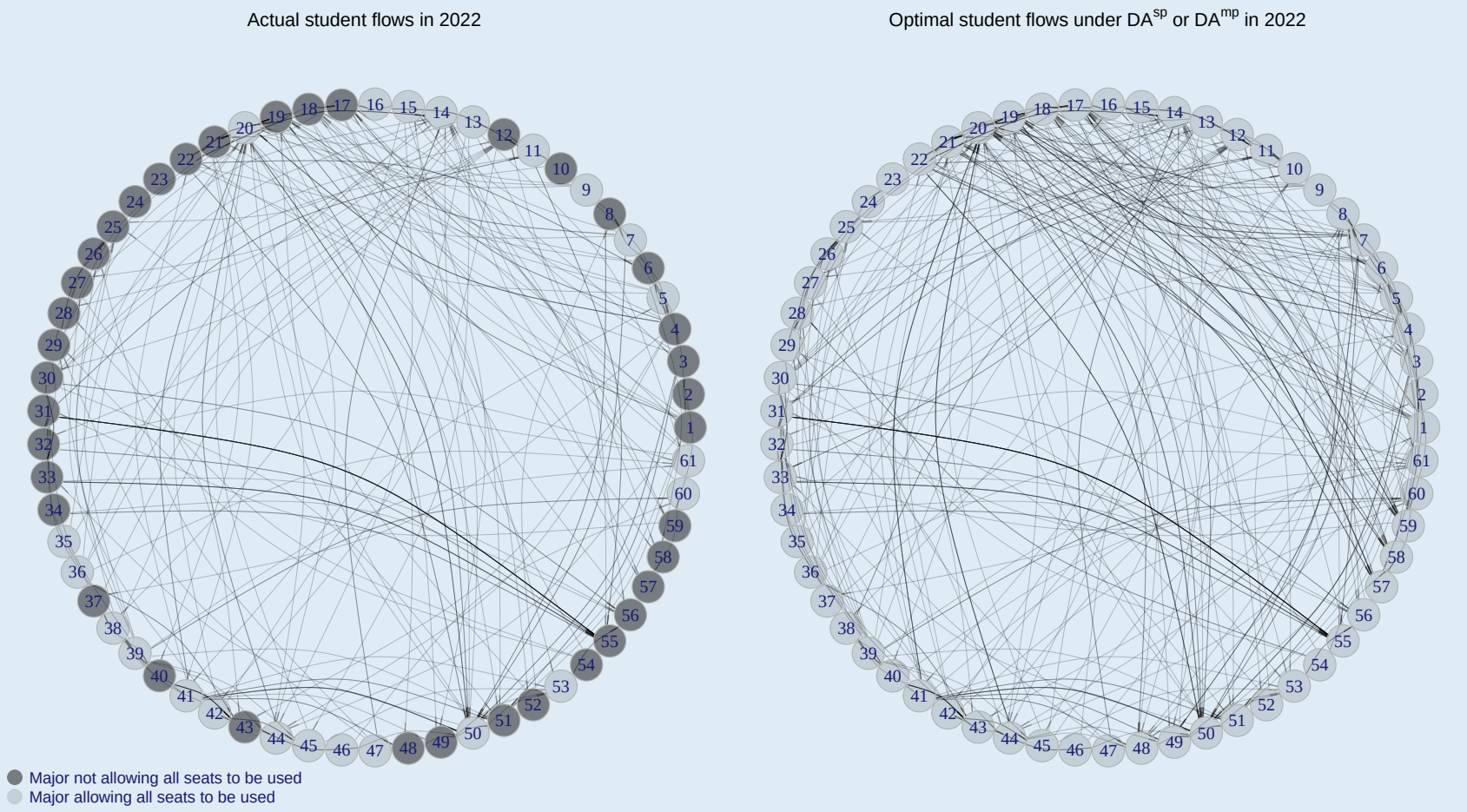
- Major 20 has the largest increase of students in 2019 and 2020.
- Majors 19 and 17 have the largest decrease of students in 2019 and 2020, respectively.

Number of Majors joining the New Mechanism



- Overall, the success rates under DASP and DAMP are quite similar.
- The welfare gains from more majors allowing all seats to be available is increasing under the two mechanisms.

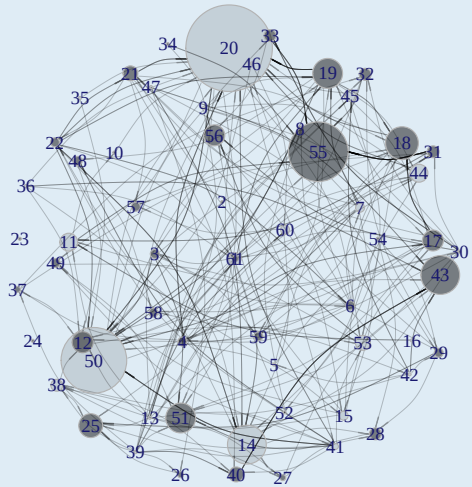
Implementation Challenges



- Many majors do not joint the new mechanism and do not provide a complete ranking of eligible students.

Inflow and Outflow Bubbles

Actual student flows in 2022
(bubble size: the number of switchers to the major)



Optimal student flows under DA^{sp} or DA^{mp} in 2022
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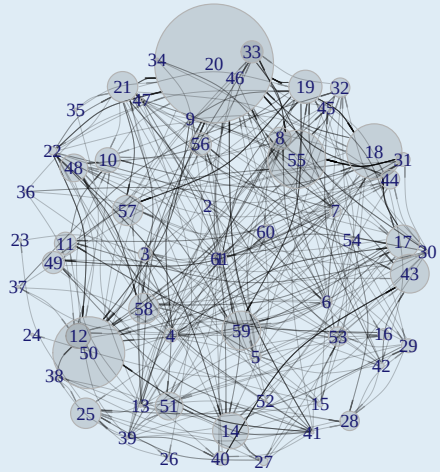
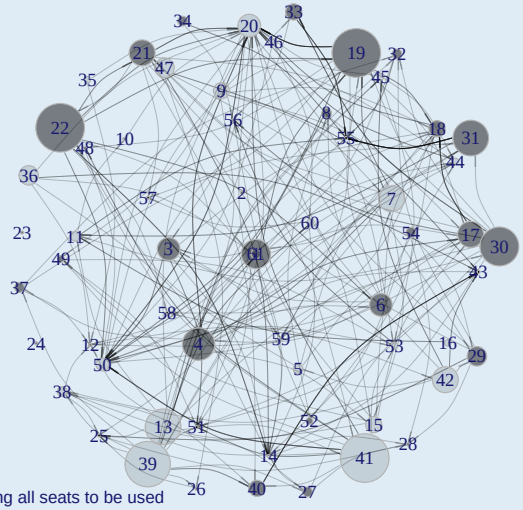


Actual student flows in 2022
(bubble size: the number of switchers from the major)



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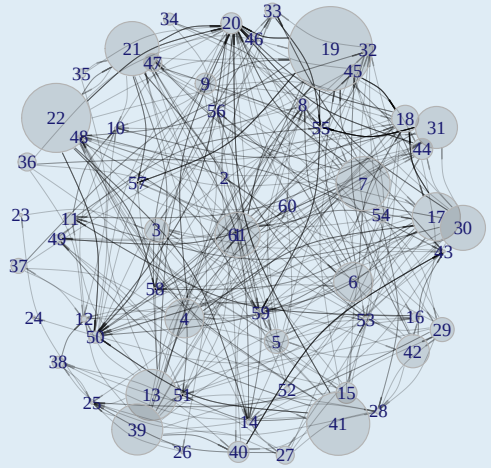

Major not allowing all seats to be used
Major allowing all seats to be used

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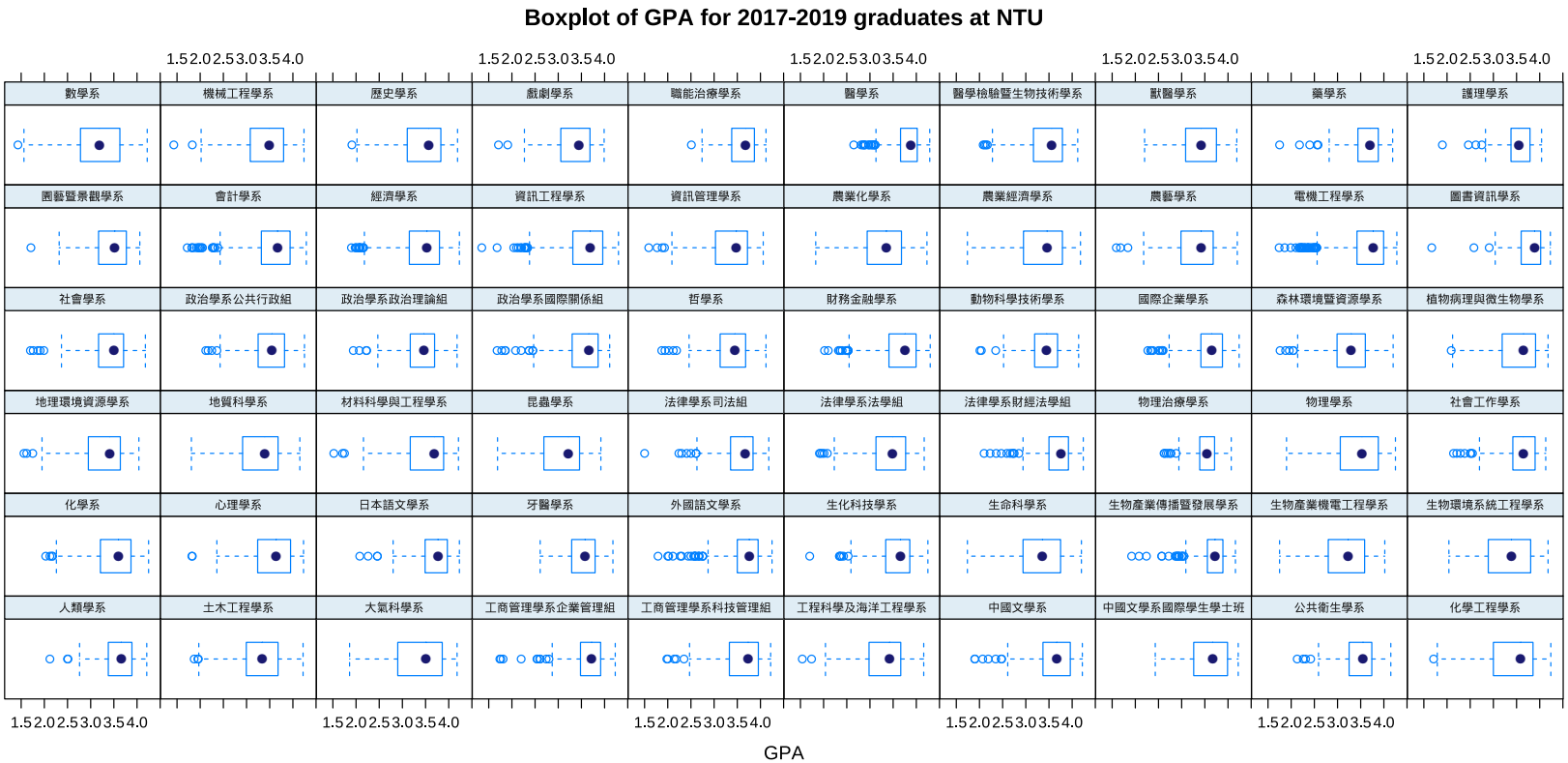
Summary

- The demand for major switching exists because of the mismatch between students and majors.
- Under the conventional mechanism, the success rate of major switching is low at many universities in Taiwan.
- We propose a new mechanism to resolve the problem.
  - Quota expansion
  - Secure matching process
- Our counterfactual analysis for NTU shows that the success rate can increase under the new mechanism.
- More students are assigned their first choice under the new mechanism.
- Implementation challenges:
  - Some majors do not joint the new mechanism
  - Majors do not provide a complete ranking of eligible students

Thank **You**

Appendix: Student Performance after Major Switching

- Why do we want to increase the success rate?
- We collect the data of GPA for 2017-2019 graduates at NTU to examine student performance after major switching.
- Since the distributions of GPA are quite different between majors, the data needs to be standardized for comparison.



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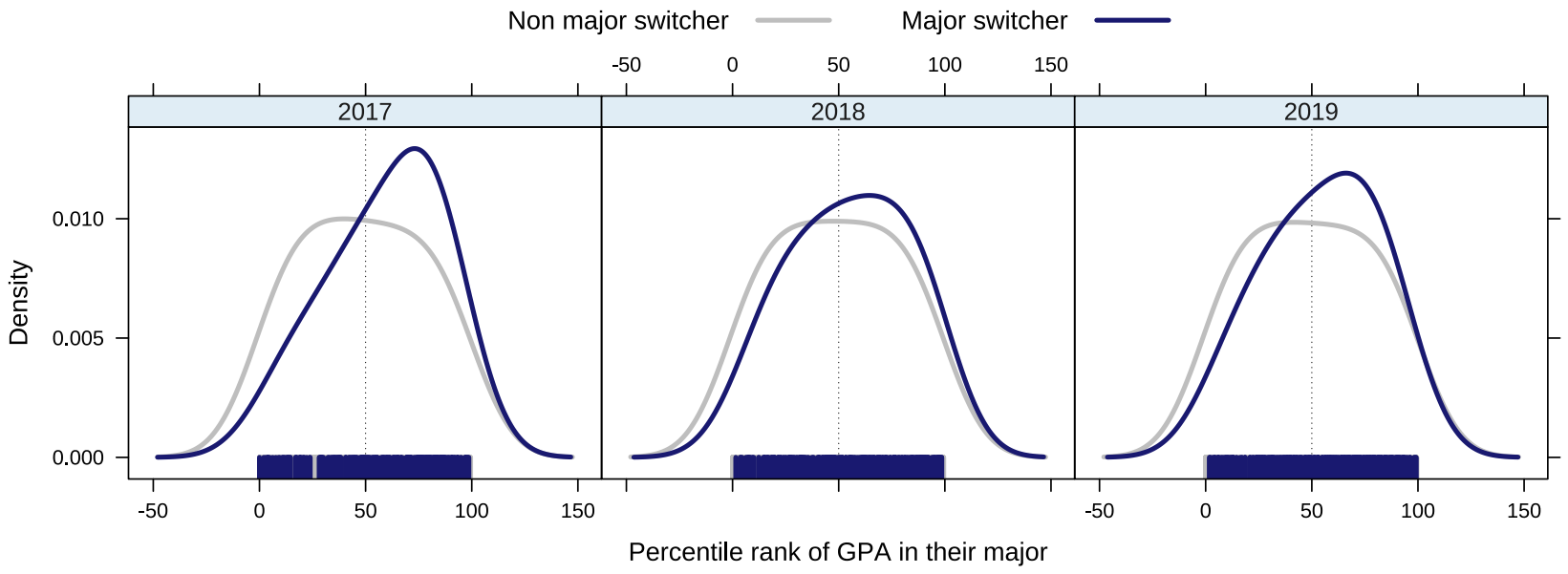

- We calculate students' percentile rank (PR) of GPA in their major. For example, PR $= 50$ means that the student's GPA is the median of the major, and PR $= 100$ indicates the best GPA.
- The Wilcoxon rank sum test suggests that, **major switchers** tend to have a **higher** PR than their peers in the new major. (with p-value $< 1\%$ to reject the null hypothesis of equal PR between two groups each year).

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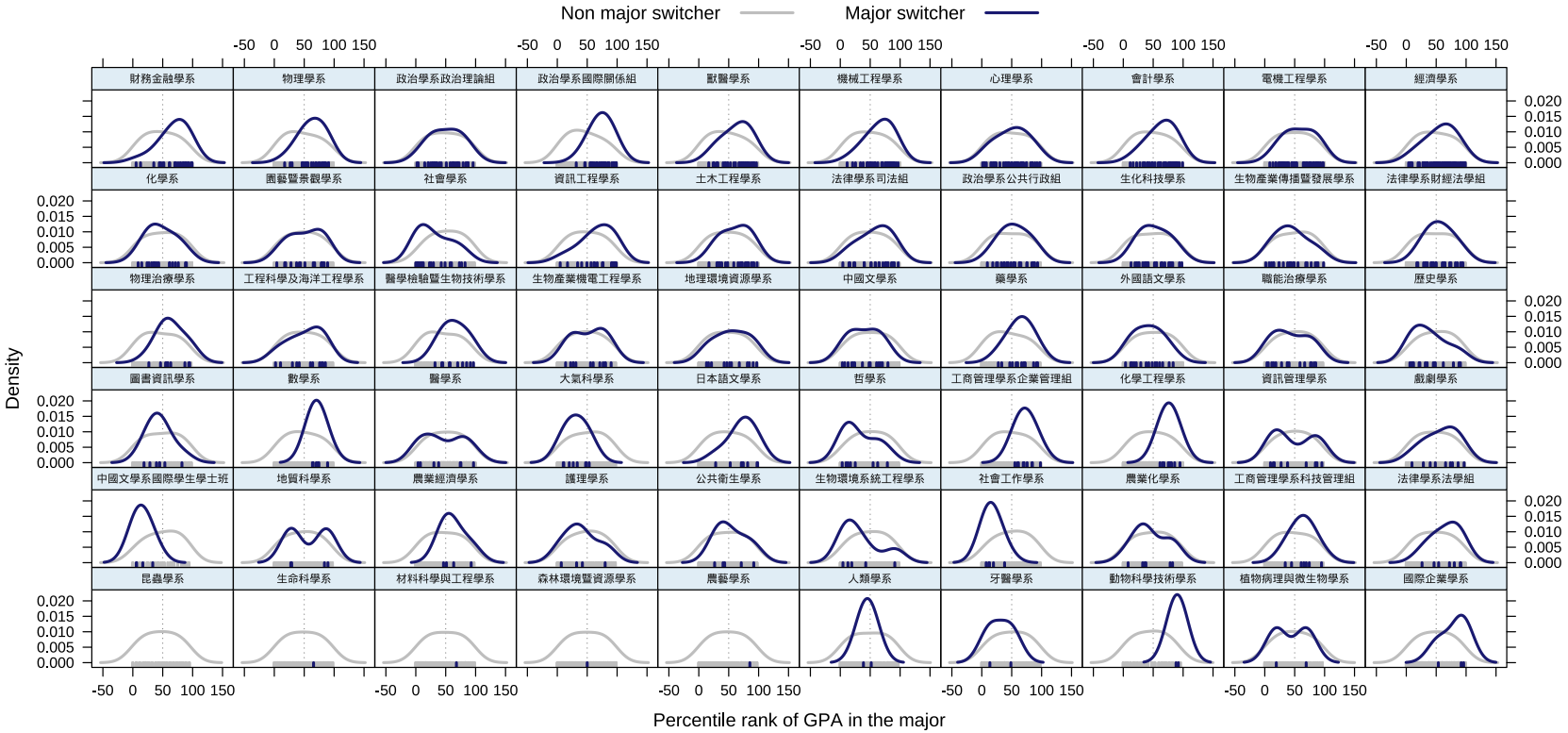

- The first row of the above figure depicts the distributions of the PR in majors who have more major-switching students.
- In most cases, major switchers in those **popular** majors have a **higher** mean in PR during this period.