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College Majors in Limited Supply: The Case of Private Universities in Korea*

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The distribution of college majors often shows signs of rigidity despite evident changes in the world of work. As a possible explanation for the distribution rigidity in the Republic of Korea, this study focuses on supply-side restrictions, specifically a region-based cap on university enrollment. Using the national-level demand change for each major as an instrument for program-level demand change, this study finds a systematic difference between regulated and unregulated private universities in the responsiveness of program size to student demand. Analyses using sharp changes in regulatory status confirm that the enrollment regulation slows internal adjustments, showing the need for regulatory reform.

JEL Classification: I23, J24, R23
Keywords: Higher Education, Enrollment Regulation, College Major, Supply Side, Private Universities

I. Introduction

In this age of technological changes, the role of education, particularly higher education, is crucial for providing new skills and reducing economic inequality (Goldin and Katz, 2009). As demand for skills changes rapidly owing to new technologies that substitute for routine tasks (Autor, Levy, and Murnane, 2003;

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Acemoglu and Autor, 2011; Acemoglu and Restrepo, 2018), colleges and universities are expected to prepare students for the uncertain future through innovations in their organization and curricula.

Although interdisciplinary approaches are garnering increasing attention, the field of study of higher education remains a key decision. From an individual perspective, one's field of specialization can substantially impact one's lifetime earnings (Kinsler and Pavan, 2015; Altonji, Arcidiacono, and Maurel, 2016). From a societal perspective, individual choices can determine the aggregate endowment of skills in an economy, which is a key constraint of economic growth. Thus, the distribution of college majors is crucial to policymakers in developed and developing countries.

Nonetheless, the number of college graduates with majors of high social demand often does not increase correspondingly. For example, while STEM[1] professions such as computer scientist and software developer are projected to increase rapidly, the number of graduates with STEM degrees is not increasing proportionately. Earnings differentials across majors are significant and rise over time, which can be largely attributed to the shortage of skills related to STEM majors (e.g., Autor, Katz, and Krueger, 1998; Altonji, Kahn, and Speer, 2014).

While the slow change in the number of graduates can partly reflect demand-side frictions in the education market, such as lack of information or preparation,[2] it may also arise from supply-side limitations. For example, peer quality is an important input in higher education (Winston, 1999), and selective universities (and majors) are likely to limit the number of students admitted owing to quality concerns. In addition, as student fees cover only a small portion of educational costs (which may differ by major), universities are not likely to fully accommodate demand changes (Bound and Turner, 2007; Altonji and Zimmerman, 2018). Despite their potential importance, supply-side limitations are underexamined, and empirical evidence is relatively scarce.

The distribution of college majors in the Republic of Korea is an interesting case study. The higher education sector of Korea experienced a remarkable expansion. The population rate of individuals between the ages of 25 and 34 years with tertiary education was 36.8% in 2000 but 69.6% in 2018, far exceeding the average in the Organisation for Economic Cooperation and Development (OECD) countries, which was 44.5% in 2018. This rapid expansion was made possible by the strong demand for higher education, explained partly by education fever, rooted in the traditional culture. The expansion was also largely driven by successful skills supply in the early stages, as demonstrated by the achievement of high scores in

[1] Science, technology, engineering, and mathematics

[2] For example, Jensen (2010), Zafar (2011), Stange (2012), Stinebrickner and Stinebrickner (2014), Wiswall and Zafar (2015*a*), Wiswall and Zafar (2015*b*), Hastings et al. (2016), and Arcidiacono et al. (2017) showed evidence of imperfect information on labor market outcomes and/or academic ability.

international assessments such as the Trends in International Mathematics and Science Study and OECD's Programme for International Student Assessment and regulatory change from establishment by permission to establishment by rules in the mid-1990s (Grubb et al., 2009).

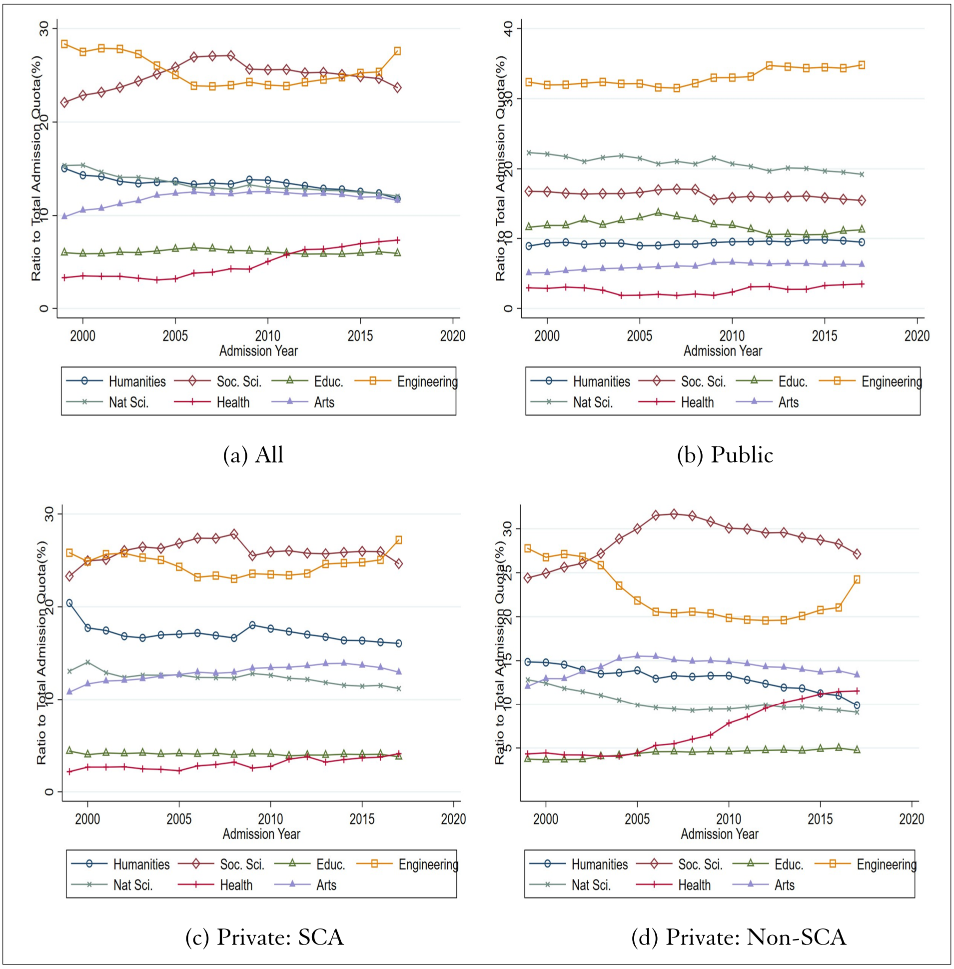
However, the distribution of college majors shows signs of rigidity. The distribution of college majors provided by four-year universities seems to change very slowly over time (Figure 1, panel a).[3] This slow change can be partly explained by the rigidity faced by public universities, whose enrollment limits are directly controlled by the government (panel b). However, as private universities admit four out of five college applicants in the country, the overall rigidity is striking. A further decomposition of private universities based on their location (panels c and d) reveals a clear difference in the speed of distributional changes between regions, thereby suggesting that the spatial dimension may be important in understanding the rigidity in the education supply.

Among the potential causes of this rigidity, in this study, I highlight the role of a traditional enrollment regulation in the Seoul Capital Area (SCA). A few enrollment regulations survived the liberalization in the mid-1990s as exceptional clauses. The most notable exception is the cap on the total number of (first-year) enrollment for all four-year universities located in the SCA. The enrollment cap operates as a university-wide enrollment cap within the confines of the SCA. This enrollment regulation is quantitatively meaningful, as nearly 50% of the national population lives in the area, and the regulated universities admit nearly 40% of all new college students. The regulation was introduced to suppress population growth within the SCA owing to a national security concern (proximity to the northern border) and remains owing to an equity concern (equal regional development).

To estimate the effect of the region-based enrollment cap on the responsiveness of universities to student demand, I construct a longitudinal dataset at the university-by-major level from Korean administrative data on higher education institutions (HEIs). The parameter of interest is the average difference between regulated and unregulated universities in their responsiveness to student demand. As the number of applicants per seat, which is a popular measure of student demand, is often fraught with errors related to the strategic motives in the admissions process, I adopt the instrumental variable (IV) strategy, using the nationwide change in number of applications for each major as an instrument for the actual change in number of applications at the university-by-major level.

[3] The distribution of bachelor's degrees conferred by four-year universities is very similar to the college major distribution of first-year students in Korea, except for the time lag. The dropout rate is typically low, and the possibility of changing college majors (i.e., transfers to other programs or universities) is limited.

[Figure 1] Distribution of College Majors Provided by Four-year Universities



Note: Daytime programs of general and education universities.
Source: Calculated from Statistics on Higher Education, Korean Education Development Institution (KEDI; 1999–2017).

The empirical results reveal a systematic difference between the regulated and unregulated universities. While the unregulated universities show a 0.44% increase in the enrollment limit for a 1% increase in student demand, the regulated universities demonstrate much lower responsiveness, that is, about a 0.2% increase in the student quota for the same increase in student demand. The adjustment response among full-time faculty members shows a similar difference, specifically 0.29 and 0.06 for the unregulated and regulated groups, respectively. The log difference between the two measures, which corresponds to the measure of education quality, reveals that education quality deteriorates in the short run as a result of an increase in student demand, with little difference by regulatory status.

Two additional analyses confirm the negative effect of the regulation on program size adjustments within universities. First, I investigate the universities located near the southern border of the SCA. From the analysis based on a geographic regression discontinuity (RD) design, I find a clear difference in the adjustment response between both sides of the border among the geographically proximate universities, with nearly no adjustment response within the SCA. Second, I conduct a difference-in-differences (DID) analysis for once-industrial universities, whose regulatory status switched owing to a national policy change, and the estimation results are also consistent with the negative effect of the enrollment regulation.

This study contributes to the literature on the economics of higher education by empirically examining supply-side dynamics in relation to college majors. To the best of my knowledge, this study is the first to provide empirical evidence on adjustment response within private universities in relation to demand changes for college majors.

The rapid expansion in higher education and estimated effect of the enrollment regulation in Korea may have implications for higher education policies beyond the Korean context. First, a cap is often placed on university enrollment to avoid overeducation, which is an issue of growing importance in many countries.[4] While the return on college education differs substantially across college majors, price adjustments within universities are often limited. Enrollment regulations must be carefully designed given the long-term implications of quantitative adjustments within universities. Second, region-based enrollment regulations are also common. For example, China has strong region-based enrollment policies (e.g., Yang, 2021), and Japan has a similar enrollment regulation.[5] Such regulations are highly relevant in countries with rapid population aging. To stop the outflow of the youth population, expediting population aging at the regional level, local governments struggle to attract universities and create jobs for the youth. Capping university enrollment in metropolitan areas is a viable option in this context. However, policymakers should consider possible consequences, including college major distribution rigidity.

The remainder of this paper is organized as follows: Section 2 describes the institutional background, and Section 3 presents several theoretical predictions. Section 4 explains the data, and Section 5 introduces the econometric framework. Section 6 shows the estimation results, and Section 7 provides the concluding remarks.

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[4] For a recent example, the UK government considered the (re)introduction of university enrollment caps to avoid overrecruitment during the COVID-19 crisis (Adams, 2020).

[5] The Japanese government (re)introduced the cap on university enrollment in Tokyo in 2018 (Ross, 2018).

II. Background

2.1. Colleges and Universities in Korea

In Korea, HEIs are “colleges” providing two-to-three-year programs and “universities” providing four-to-five-year programs. In addition, two-year colleges (some programs are over three years) are vocational oriented, while four-year universities (some programs are over five years) are mostly academic oriented.

Four-year universities include general, education, industrial, distance, various, and special universities. Education universities train teachers for primary education, and industrial universities aim to cultivate industrial manpower. Distance universities include open universities, the Korea National Open University, and cyber universities, whereas various universities are de facto universities. Finally, special universities operate based on special laws, such as institutes for science and technology.

The first two categories, that is, general and education universities, are the main objects of this study. In this study, I analyze the general universities, which were once industrial universities, separately. As explained in detail in the subsection on the empirical results, such universities experienced a sudden change in their regulatory status.

Four-year universities in Korea are mostly nonprofit private universities. In 2017, the number of general universities (including special universities) in the country totaled 189, 154 (81.5%) of which were private institutions. The total number of students in general universities (including special universities) was 2,050,619 in 2017, 1,575,802 (76.8%) of whom were enrolled in private institutions. In 2017, the country had 10 education universities, all of which were public.

2.2. College Admissions System

After K-12 education (6-3-3 years), high school seniors and graduates may apply for college admissions. Applications are submitted to admissions units defined at the department level, as is the case in many countries outside the United States and Canada (OECD, 2019). College admissions in Korea is decentralized, that is, no centralized matching algorithm exists (Che and Koh, 2016).

In Korea, college admissions consists of two stages: (binding) early action and regular decision. First, the early action process mostly starts in September. Students may apply to up to six general and education universities.[6] Second, the regular decision process mostly starts in January, after the College Scholastic Aptitude Test scores are reported. General and education universities are divided into three groups,

[6] This upper limit was imposed from 2013 admissions.

and students can apply to only one admissions unit per group, that is, up to a total of three admissions units. Students admitted to (but not necessarily enrolled in) an admissions unit through early action cannot apply for a regular decision. Applications to other types of universities are unrestricted.

2.3. Enrollment Regulation

All the programs of HEIs in Korea have an explicit enrollment limit. Two reasons exist for this limit. First, the admissions system is decentralized at the program level. Although decisions must be finalized at the university level, each program determines its own education plan, including the number of students and faculty members. Second, the admissions units of HEIs are required to announce their enrollment limit (admissions quota) nearly a year before they start accepting applications.

Program-level enrollment limits are adjustable annually. The Enforcement Decree of the Higher Education Act allows HEIs to freely adjust their admissions quota once they satisfy the minimum conditions for educational facilities (land, building, and assets) and the number of full-time faculty per enrolled student. The minimum conditions differ across college majors, generating differences in educational costs between college majors. This rule-based approach was introduced in the mid-1990s, which contributed much to the unusually high enrollment rate in tertiary education in Korea (Grubb et al., 2009).[7]

However, the Enforcement Decree of the Higher Education Act enumerates the cases in which the government can directly regulate enrollment in HEIs. The most notable item is the total enrollment in four-year universities within the SCA. The regulation is a legacy of traditional regulations dating back to the 1960s, when the government initiated several restrictions on economic activities within the SCA to minimize Seoul's population growth.

The content of the higher education regulation in the SCA is presented in the Appendix (Table A1). The SCA comprises the Seoul Special City, Incheon Metropolitan City, and Gyeonggi Province and is divided into three zones: the overpopulation restriction zone (ORZ), growth management sone (GMZ), and natural preservation zone (NPZ; Figure 2).

It is noteworthy that the total enrollment cap imposes an upper limit on the number of incoming transfers (from other departments or universities). The availability of double majors and minors in general four-year universities can also be limited by enrollment regulations. Furthermore, the quota for transfers, double majors, or minors is typically proportional to the admissions quota.

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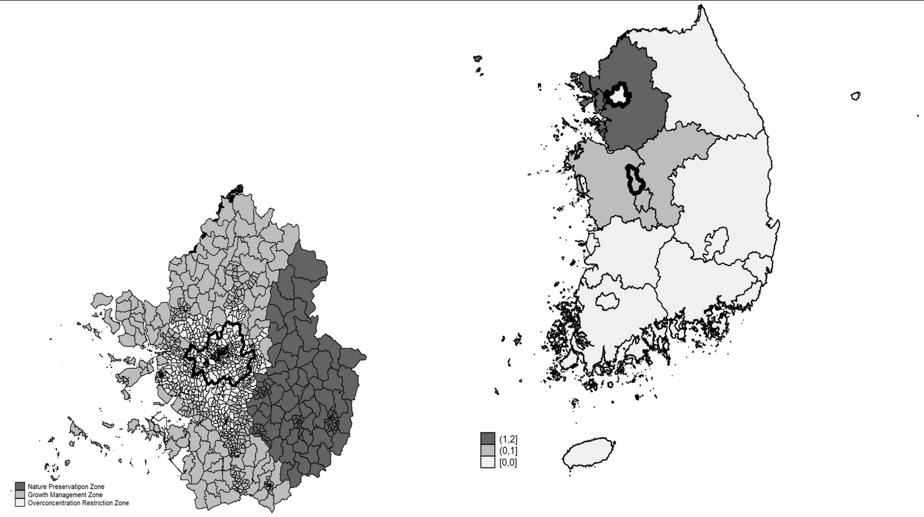
[7] Until 2013, new establishments had been automatically approved, with some exceptions in the SCA (see Appendix Table A1).

[Figure 2] SCA and Adjacent Provinces



(a) SCA (b) SCA and Chungcheong MA

Note: 1. The SCA comprises Seoul (inside the thick line), Incheon, and Gyeonggi Province. The area is divided into three zones: the ORZ, GMZ, and NPZ. The three island counties of Ongjin-gun, Incheon (Baengnyeongmyeon, Daecheongmyeon, and Yeonpyeongmyeon), are not shown on the map.
2. The adjacent provinces refer to North and South Chungcheong Provinces, Daejeon, and Sejong (administrative capital).

2.4 Tuition Fees

Tuition fees were nearly constant (in nominal terms) during the sample period. Regulations on tuition fees have been reinforced since 2008, effectively suppressing the increase in such fees. The Higher Education Act introduced an upper limit for the rate of tuition increase in 2011, which is 150% of the three-year average inflation rate. Other policy measures to control tuition fee increases in HEIs exist, such as government subsidies conditional on tuition fee changes.

The annualized tuition fee in general universities was KRW 6,659,000 in 2008 and KRW 6,688,000 in 2017, according to the Ministry of Education. Tuition fees between public and private universities differ significantly. The tuition fee in public general universities was KRW 4,203, on average, in 2008, and KRW 4,177,000 in 2017. The tuition fee in private institutions was KRW 7,043,000, on average, in 2008, and KRW 7,397,000 in 2017.

Tuition fees are also differential by college major. The differences in tuition fees partly reflect the differences in educational costs between programs. However, the tuition fee differences between majors are not large, except for medicine. In 2017, the average tuition fee by major (broad field) in general universities was KRW

5,959,000 for the humanities and social sciences, KRW 6,788,100 for the natural sciences, KRW 7,114,600 for engineering, KRW 7,790,800 for the arts, and KRW 9,635,500 for medicine.

This institutional setting provides a rare opportunity to study quantitative adjustments within universities while controlling for price adjustments. If price adjustments were possible, universities may have chosen to change prices across majors, which was not the case in Korea during the sample period.

III. Theoretical Predictions

From the viewpoint of an HEI (in a country with many HEIs), student demand for majors may be affected by program-specific promotions and scholarships. However, student demand may also change for exogenous reasons. For example, national-level demand for majors can change as a response to the rapid technological and social changes. If the demand for majors changes for exogenous reasons, then the headquarters of an institution may consider adjusting major-specific enrollment limits (or quotas) to meet the demand changes.[8]

Universities have several reasons to be responsive to demand changes. First, universities try to minimize unfilled quotas, as unfilled quotas are important measures of university quality used for government subsidies (or private contributions). Second, regardless of whether excess demand exists for all the programs (i.e., no unfilled quotas), universities may be concerned about the declining average exam scores (or cutoffs) for some programs for admissions. Third, universities may want to expand programs with high demand. The additional tuition revenues are useful for operating a university. In addition, students may choose to leave a university if they become dissatisfied with the breadth of the educational content provided by the university (e.g., rationing of limited seats for popular majors). Such motives can be broadly summarized as a university's inclination to maximize the number of enrolled students.

Such adjustments depend on the HEI type. As noted in the literature (Winston, 1999; Bound and Turner, 2007), the subsidy function plays a key role in the operation of nonprofit HEIs. For example, public universities, whose tuition fees cover only a small proportion of the total educational expenses, have little incentive to respond to student demand. Although private universities have a strong incentive to admit a considerable number of students, subsidies (including private contributions) remain important. If the subsidy function is convex in relation to

[8] While I assume an effective headquarters function (centralized or coordinated decision making), the alternative assumption of an ineffective headquarters (decentralized decision making) does not change the direction of the predictions.

education quality, then two polar cases will exist (see the Appendix for the mathematical details).

First, some private HEIs may target the highest education quality. Such HEIs finance their high educational costs mostly with subsidies and determine program sizes mainly with (net) cost differences.[9] I predict that private HEIs will equate (net) educational costs per student across majors if their institutional objective is to educate as many students as possible without favoritism toward a specific major.

Second, other private HEIs can maximize enrollment, with relatively low education quality. With nearly zero subsidies, such institutions minimize educational costs to a level corresponding to the tuition fees. However, enrollment in such universities is constrained by student demand, which responds to education quality. As a result, the optimal quality will be (slightly) higher than the mandated minimum quality.[10] The HEIs in this case adjust their enrollment limit according to demand changes.

The introduction of a binding cap on university enrollment can create excess demand. While the regulation can have only scale effects on the HEIs in the first case, I predict that it will reduce the responsiveness of the HEIs in the second case. Such HEIs will be similar to the HEIs in the first case in that their program-specific enrollment is solely determined by the cost structure rather than student demand. Furthermore, I predict that education quality will (slightly) decrease with the enrollment cap, as the student demand is no longer binding.

IV. Data

In this study, I use administrative data on higher education and combine them with various data sources. The main dataset is based on the program-level information provided by the KEDI. The KEDI dataset includes program-level information such as admissions quotas, applications, enrollment, and faculty size for all colleges and universities in Korea. I combine the data with other publicly available information on universities, such as the university rankings (top 30, 2007–2017) provided by JoongAng Ilbo, which is a major daily newspaper in the country.

To construct a panel dataset at the university-by-major level (2007–2017), I must

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[9] Tuition fees typically differ across majors in Korean universities but only by a small magnitude compared with the differences in educational costs. Differential tuition fees across majors can be important in a general setting where students may change their field-of-study choice in response to price differences. However, this concept is not the primary focus of this study.

[10] The government requires universities to satisfy certain minimum conditions, mainly on teaching staff and educational facilities, before increasing enrollment. In addition, if student demand is strictly increasing in relation to education quality, then the optimal quality will be larger than the required minimum quality.

first define "university" and "major." I define a "university" as an independent legal entity at the metropolitan area (MA) level (broadly defined), which is defined as a major metropolitan city and adjacent province(s).[11] That is, I treat two campuses belonging to a legal entity as a university if they are located in an MA. Otherwise, I treat the remote campuses as separate universities.[12]

Furthermore, I define "college major" as the two-digit-level classification (35 categories in total) defined by the KEDI (see Appendix Table A2). The KEDI classification has been consistently applied to the classification of departments since 2002. The KEDI classification of university majors has seven categories at the one-digit level (the humanities, social sciences, education, engineering, natural sciences, health, and the arts), 35 major groups at the two-digit level (e.g., languages/literature, business/economics, and electrical engineering/electronics), and 121 majors at the three-digit level (e.g., Korean language/literature, economics, and electronics).[13] Owing to frequent entries/exits and name changes at the program level, the program-level data are aggregated at the two-digit level. In addition, while administrative information is available from 2002, I limit the sample period to after 2007. Before 2007, most nonselective universities, particularly those outside the SCA, had difficulty recruiting students owing to the rapid decline in the number of high school graduates between 2002 and 2006 (Figure 3).

I further limit the final sample to daytime programs in private four-year universities with a university-level admissions quota of over 100 students. First, I use only the observations from four-year universities, mainly because two-year colleges in the SCA are not restricted by the total enrollment cap. Moreover, the majors offered by four-year universities are not directly comparable to those offered by two-year colleges. Second, I consider only private universities, because public universities are under direct government control. Third, I discard all the observations from small universities authorized to admit only 100 or fewer students, as the higher education legal framework treats small universities differently from other universities. Fourth, I drop the evening programs from the sample, as they aim primarily at the working population, who differs significantly from students of

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[11] Korea has a total of seven MAs, which are commonly defined and used in the related literature. One of the MAs is the SCA, which includes Seoul, Incheon, and Gyeonggi. Another adjacent MA along the southern border of the SCA is Chungcheong, which comprises Daejeon, Sejong, and North and South Chungcheong. Gangwon and Jeju are defined as separate MAs, as they are geographically distinct.

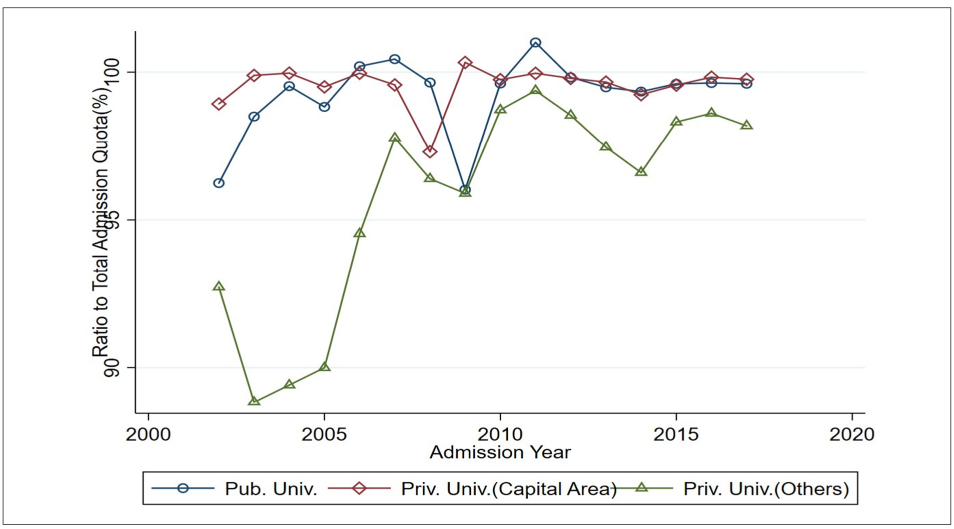
[12] While campuses are generally subunits of a university, with separate groups of majors (i.e., natural science and engineering majors in one campus and humanities and social science majors in another), the definition of a "campus" is not obvious in Korea. In some universities, campuses are, in practice, independent legal entities with duplicate majors. In addition, the administrative information is not consistent across universities in treating campuses.

[13] This classification does not allow one-to-one mappings with the International Standard Classification of Education (2013).

daytime programs. Fifth, I also discard all the observations from other types of four-year universities, such as industrial, distance, and special universities. Nonetheless, industrial universities, most of which became general four-year universities during the sample period, provide a unique opportunity to consider the effect of the introduction of the regulation. I analyze and explain such universities separately in the related subsection on the estimation results.

Additionally, I drop some observations to eliminate influential outliers. First, I discard all the observations from the universities that shut down until 2018, as they are highly likely to show different enrollment patterns. Second, I consider a few cases in which the enrollment rate (within the quota) was below 80% or above 120% as missing, as such cases are clearly far from the normal operation.[14] While I report the results without the enrolled-to-quota ratio (enrollment rate), the results do not meaningfully change with or without the additional control of enrollment rate. Third, I also consider the observations from some majors with a quota below 20 freshmen as missing to avoid potentially influential outliers. Table 1 summarizes the final sample.

[Figure 3] Enrollment Rate of First-year Students



Note: The enrollment rate is defined as the ratio of first-year student enrollment (admitted within the quota) to the admissions quota. This ratio may exceed one, as the actual admissions quota can temporarily deviate from the official quota for enrollment smoothing purposes (i.e., an increase in one year, then a decrease the following year).

[14] Although the 0.8 criterion may be arbitrary, alternative criteria do not significantly alter the regression results. In addition, though very rare, the number of enrolled students (within the quota) may exceed the official admissions quota. The actual quota could slightly differ from the official quota for smoothing purposes (a small increase in one year, then a small decrease the following year).

[Table 1] Descriptive Statistics

Variable	N	Mean	SD	Min	Max	P50
Private universities outside SCA						
(University-by-campus)	82					
University-by-major	1,400					
Admissions quota (Q)	12,482	117.80	114.04	20	985	80
Applicants (A)	12,482	754.82	821.02	19	8272	479
Competition rate (A-to-Q)	12,482	6.60	4.34	0.80	95.97	5.64
Enrollment rate (E-to-Q)	12,482	0.99	0.03	0.80	1.19	1
Full-time faculty per enrolled student	12,482	0.04	0.05	0.00	3.16	0.03
Female ratio among first-year students	12,482	0.48	0.27	0.00	1.00	0.47
Ever-ranked top 10	12,482	0.00	0.00	0.00	0.00	0.00
Ever-ranked top 30	12,482	0.10	0.30	0.00	1.00	0.00
Private universities within SCA						
(University-by-campus)	62					
University-by-major	920					
Admissions quota (Q)	8,590	126.23	125.92	20	1807	90
Applicants (A)	8,590	1877.69	2402.76	24	26758	1132
Competition rate (A-to-Q)	8,590	14.28	10.55	1.02	189.63	12.24
Enrollment rate (E-to-Q)	8,590	1.00	0.03	0.80	1.19	1.00
Full-time faculty per enrolled student	8,590	0.05	0.10	0.00	5.18	0.04
Female ratio among first-year students	8,590	0.55	0.27	0.00	1.00	0.53
Ever-ranked top 10	8,590	0.25	0.44	0.00	1.00	0.00
Ever-ranked top 30	8,590	0.49	0.50	0.00	1.00	0.00
Once-industrial universities: Private						
institutions (University-by-campus)	7					
University-by-major	102					
Admissions quota (Q)	832	117.47	111.98	20	850	90
Applicants (A)	832	1098.75	1385.64	43	10904	667
Competition rate (A-to-Q)	832	9.65	10.13	1.29	103.21	7.14
Enrollment rate (E-to-Q)	832	0.99	0.04	0.80	1.14	1.00
Full-time faculty per enrolled student	832	0.04	0.04	0.00	0.72	0.03
Female ratio among first-year students	832	0.43	0.28	0.00	1.00	0.38

V. Econometric Framework

The main empirical question in this study is whether a systematic difference exists between regulated and unregulated universities by the total enrollment cap in their responsiveness to demand for majors. A key measure of responsiveness is the elasticity of program-level enrollment limits (or admissions quotas) to student demand within each university. In addition, determining the extent to which the size of the faculty changes along with the change in the maximum number of first-year students is important.

A major challenge in this empirical analysis is the construction of demand for majors. While the number of received applications, which is observed for all the admissions units in the administrative data, may serve as a proxy for student demand, the numbers do not consistently match actual student demand. Under the decentralized admissions system of Korea (Che and Koh, 2016), application decisions are likely strategic. Many students include "risky" and "safe" choices in their application portfolio, especially given the upper limit of applications.[15] As a result, top-ranked programs do not consistently receive the highest number of applications. Middle-ranked programs receive many applications that will not eventually lead to enrollment. It is reasonable that such programs do not respond to this type of application, which differs from actual demand.

However, a change in the number of applications within a program (or a college-by-major unit) can signal a meaningful change in student demand. For example, some college majors, such as artificial intelligence and software engineering, can become popular nationwide, raising student demand for such majors across universities. Conversely, other college majors, such as the humanities and social sciences, may lose student interest owing to continuing gloomy job prospects. Furthermore, this nationwide change in major-level popularity is unlikely to be correlated with the strategic decision of application at the program level.

Many other factors can affect the within-program changes in received applications. For example, an increase in the local student population will obviously raise the number of received applications across all college majors within the region. As the local student population is quite predictable, universities may be prepared for such changes. Local labor market conditions may also affect application decisions at extensive and intensive margins (e.g., Black, McKinnish, and Sanders, 2005; Emery, Ferrer, and Green, 2012; Han and Winters, 2020; Blom, Cadena, and Keys, 2021). University-specific or program-specific factors may also exist. Universities and/or programs can expand or shrink depending on their financial situation or long-term strategy.

To focus on the nationwide change exogenous from the perspective of each program, I adopt the IV strategy. The basic assumption for identification is that the nationwide change in applications for a college-by-major unit is correlated with the change in applications for a program of the same major but uncorrelated with the change in strategic applications at the program level. Moreover, by using the nationwide change in major-specific applications as an instrument for the change in applications for a college-major unit, I can overcome the (nonstandard) measurement error issue raised by the strategic motive in application decisions. That is,

[15] A student can apply to up to six admissions units in the early process and three admissions units in the regular process. Upper limits were introduced to reduce the financial burden of students and parents (i.e., total application fees per student).

$$\Delta_t \ln(a_{smt}) \propto \Delta_t \ln(a_{mt}),$$

where a_{smt} is the number of applications for a college(s)-by-major (m) unit in year t, and a_{mt} is the number of nationwide applications for major m in year t.

The second-stage regression equation is as follows:

$$\ln(y_{smt}) = \alpha_0 \ln(\hat{a}_{smt-1}) + \alpha_1 \ln(\hat{a}_{smt-1}) \times R_s + Z_{smt-1}\gamma + \mu_{sm} + \pi_{r(s)t} + \delta_s \times t + \varepsilon_{smt}, \quad (1)$$

where y_{smt} is an outcome variable, such as the admissions quota or faculty size, R_s is an indicator of the universities regulated by the total enrollment cap, and z_{smt} represents the characteristics of a college-major unit, such as the enrollment rate. The error term is a linear sum of two-way fixed effects (FE; μ_{sm}, δ_{st}) and an idiosyncratic error (ε_{smt}).

The parameters of interest are α_0 and α_1. The sign of α_0 is expected to be positive if the universities respond to the change in applications, and α_1 will be negative if the total enrollment cap systematically reduces the responsiveness of the regulated universities and zero if this effect does not exist. In addition to the college-by-major FE (μ_{sm}), I control for the region-by-time FE, which include changes in the local student population, along with other regional changes. I additionally control for university-specific linear time trends to verify whether the estimates are driven by some expanding or shrinking universities.[16]

The estimated parameters (α_0 , α_1) capture the systematic difference in responsiveness across the universities, particularly those with a regulatory status. As department-level decisions on the admissions quota and faculty size are typically coordinated and finalized at the university level, university-average responsiveness is relevant to the empirical analyses.

However, further evidence is necessary to understand the mechanism behind the systematic difference, if any. As the regulatory status is strongly correlated with university prestige and the local labor demand, the unresponsiveness of the regulated universities may be explained by quality concerns among the prestigious universities or excess student demand owing to the strong local labor demand.

In addition to the subgroup analyses on similarly ranked and similarly located universities, I conduct two analyses to identify the causal effect of the regulation. The first analysis, which involves universities near the border of the SCA, is based on a geographic RD design. The second analysis uses a DID framework that focuses on a natural experiment of the implementation of the enrollment cap on previously

[16] Additionally controlling for the lagged dependent variable (e.g., the program size matters for flexibility) is possible, but the conditions to get consistent estimates become increasingly demanding (Angrist and Pischke, 2008). The estimation results remain qualitatively the same regardless of the additional control variable.

unregulated universities.

VI. Estimation Results

6.1. Baseline Results

The estimation results of Eq. (1) are summarized in Tables 2 and 3. Table 2 reports the estimation results of the quota adjustment. The ordinary least squares (OLS) estimate of α_0 indicates a 0.28% increase in the admissions quota for a 1% increase in the previous year's applications among the unregulated universities (column 1). As I control for the university-by-major FE, the estimate can be interpreted as elasticity. The estimated elasticity of quota to student demand is, on average, 0.07 lower among the regulated universities.[17]

As the observed number of received applications measures student demand, with errors, the OLS estimate is likely biased. With the nationwide change in applications for each major as the instrument, column (2) reports the IV estimation results. The IV estimate of the elasticity is 0.46 for the unregulated universities, which is much larger than its OLS counterpart. For the regulated universities, the IV estimate is lower by 0.26, which means that the elasticity for the regulated group is less than half of the elasticity for the unregulated group. This result agrees with panels (c) and (d) of Figure A1. Adding university-specific trends as control variables does not meaningfully alter the results (column 3). The IV estimate of the elasticity is 0.44 for the unregulated universities and 0.20 for the regulated universities. The estimates from the separate analyses are also consistent with the systematic difference between the two groups (columns 4 and 5). The first-stage F-statistics according to Sanderson and Windmeijer (2016) attest to the relevance of the instrument in all the specifications.

Table 3 reports the estimation results of the full-time faculty members. The qualitative patterns are similar to those in Table 2, but the estimates are smaller in magnitude, and the difference between the regulated and unregulated groups is more salient. The OLS estimate indicates a 0.23% increase in the full-time faculty members for a 1% increase in applications among the unregulated group and a 0.10% lower estimate among the regulated group (column 1). The IV estimate of the elasticity is larger for the unregulated group, that is, 0.29, but much smaller for the regulated group of 0.06 (column 3). The separate estimation results are similar, thereby showing that the IV estimate for the regulated group is statistically not different from zero at the 10% significance level.

[17] Although not reported here, the estimation results with additional control of the lagged enrollment rate are nearly identical.

As the ratio of full-time faculty members to enrolled students is a measure of education quality, the difference between Tables 2 and 3 is also noteworthy. Table 4 reports the estimation results of the quality measure on student demand. The OLS and IV estimates show that education quality deteriorates when student demand increases (columns 1–3), mainly owing to the slow adjustment among the full-time faculty. I observe little difference in the quality adjustment depending on the regulatory status (columns 2 and 3).

[Table 2] Quota Adjustment: Regulated and Unregulated Universities

Dep. Var.: Ln (Student quota)	(1) OLS All	(2) IV All	(3) IV All	(4) IV Unreg.	(5) IV Reg.
(L1) Ln (Applications)	0.281***	0.457***	0.442***	0.443***	0.195***
	(0.017)	(0.060)	(0.056)	(0.057)	(0.037)
× Regulated	-0.072***	-0.260***	-0.245***	-	-
	(0.023)	(0.070)	(0.066)	-	-
Region-by-year FE	Y	Y	Y	Y	Y
Univ.-by-major FE	Y	Y	Y	Y	Y
Univ.-specific trends	N	N	Y	Y	Y
First stage	Y	Y	Y	Y	Y
F-Stat. (SW) on Ln (A)	-	187.4	217.2	209.1	121.5
F-Stat. (SW) on Ln (A) × Regulated	-	295.5	338.3	-	-
N (Obs.)	18,380	18,380	18,380	10,841	7,539

Note: Standard errors in parentheses are clustered at the university-by-major level; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

[Table 3] Full-time Faculty: Regulated and Unregulated Universities

Dep. Var.: Ln (Full-time faculty members)	(1) OLS All	(2) IV All	(3) IV All	(4) IV Unreg.	(5) IV Reg.
(L1) Ln (Applications)	0.228***	0.331***	0.290***	0.294***	0.062
	(0.019)	(0.077)	(0.071)	(0.072)	(0.044)
× Regulated	-0.100***	-0.278***	-0.223***	-	-
	(0.026)	(0.088)	(0.082)	-	-
Region-by-year FE	Y	Y	Y	Y	Y
Univ.-by-major FE	Y	Y	Y	Y	Y
Univ.-specific trends	N	N	Y	Y	Y
First stage	Y	Y	Y	Y	Y
F-Stat. (SW) on Ln (A)	-	187.4	217.2	209.1	121.5
F-Stat. (SW) on Ln (A) × Regulated	-	295.5	338.3	-	-
N (Obs.)	18,380	18,380	18,380	10,841	7,539

Note: Standard errors in parentheses are clustered at the university-by-major level; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

[Table 4] Quality Adjustment: Regulated and Unregulated Universities

Dep. Var.: Ln (Full-time faculty members)	(1) OLS All	(2) IV All	(3) IV All	(4) IV Unreg.	(5) IV Reg.
(L1) Ln (Applications)	-0.052***	-0.126**	-0.153***	-0.150***	-0.133***
	(0.015)	(0.053)	(0.049)	(0.049)	(0.044)
× Regulated	-0.028	-0.018	0.022	-	-
	(0.022)	(0.069)	(0.065)	-	-
Region-by-year FE	Y	Y	Y	Y	Y
Univ.-by-major FE	Y	Y	Y	Y	Y
Univ.-specific trends	N	N	Y	Y	Y
First stage	Y	Y	Y	Y	Y
F-Stat. (SW) on Ln (A)	-	187.4	217.2	209.1	121.5
F-Stat. (SW) on Ln (A) × Regulated	-	295.5	338.3	-	-
N (Obs.)	18,380	18,380	18,380	10,841	7,539

Note: Standard errors in parentheses are clustered at the university-by-major level; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$

6.2 Robustness Checks

To test the robustness of the results in the previous subsection, I perform various analyses using the specification used for column (4) in the previous tables. The results are reported in Table 5.

First, though the final sample defined at the university-by-major level is mostly balanced, it is unbalanced for a small number of university-by-major units. The estimation results from the strongly balanced sample are reported in column (1), which are largely similar to the previous results.

Second, I introduce the maximum number of applications per student in the early admissions process from the 2013 admissions, which lowered the total number of received applications per admissions unit in 2013. Although the region-by-year FE are likely to absorb this variation, the robustness of the previous results should be tested using only the observations after 2013 (or 2014 by the current year). The estimation results in column (2) show small but qualitatively similar estimates. The statistical significance of the difference between the regulated and unregulated university is weak in the case of the full-time faculty members.

Third, I also report the estimation results with two-year lags. This test is related to institutional settings, as Korean universities are required to announce a preliminary admissions plan approximately two years[18] before the commencement of admissions. Institutions announce a final plan up to approximately one year

[18] The deadline for the pre-announcement was 18 months before the commencement of admissions until 2016 and 22 months before the commencement since 2017.

before the commencement date. If university staff members honor their first announcement, then adding two-year lags is appropriate. The results show that one-year lags are important in adjusting the admissions quota; the regulated and unregulated universities demonstrated strong responsiveness to the demand changes one year ago. Conversely, two-year lags seem relevant in adjusting the full-time faculty members; both groups responded considerably to the demand changes two years ago. This result is not surprising, considering the long process to recruit a new full-time faculty member in Korea.

Lastly, the standard errors are clustered at the university level instead of the university-by-major level. By allowing any correlation structure within the universities, the standard errors may change. The results in column (4) reveal that the standard errors are slightly large, with slightly small first-stage F-statistics. However, the results are similar to the previous results by any standard.

[Table 5] Robustness Checks

	(1) IV Balanced sample		(2) IV After 2013 (t ≥ 2014)		(3) IV Two-year lags		(4) IV Clustered at university level	
Dep. Var.	lnQ	lnF	lnQ	lnF	lnQ	lnF	lnQ	lnF
(L1) Ln (Applications)	0.425***	0.248***	0.272***	0.195***	0.281***	0.099**	0.442***	0.290***
	(0.064)	(0.075)	(0.059)	(0.074)	(0.043)	(0.045)	(0.058)	(0.075)
× Regulated	-0.194**	-0.159*	-0.147*	-0.113	-0.074	-0.116*	-0.245***	-0.223**
	(0.077)	(0.090)	(0.078)	(0.101)	(0.059)	(0.064)	(0.070)	(0.090)
(L2) Ln (Applications)					0.142	0.163**		
					(0.087)	(0.067)		
× Regulated					-0.200*	-0.073		
					(0.109)	(0.082)		
Region-by-year FE	Y	Y	Y	Y	Y	Y	Y	Y
Univ.-by-major FE	Y	Y	Y	Y	Y	Y	Y	Y
Univ.-specific trends	Y	Y	Y	Y	Y	Y	Y	Y
First stage								
F-Stat. (SW) on L1. Ln (A)	179.1		107.6		422.0		206.3	
F-Stat. (SW) on L1. Ln (A) × Reg.	256.4		172.1		274.2		274.0	
F-Stat. (SW) on L5. Ln (A)					505.3			
F-Stat. (SW) on L5. Ln (A) × Reg.					311.6			
N (Obs.)	13,000		7,561		16,046		18,380	

Note: Standard errors in parentheses are clustered at the university-by-major level, except for column 4; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

6.3. Subgroup Analyses

Although a systematic difference exists between the regulated and unregulated universities in their responsiveness to student demand, which matches the theoretical predictions, I cannot rule out the possibility that it arises from another mechanism. As evident from the descriptive statistics (Table 1), the top-ranking universities are nearly entirely located within the SCA, particularly in Seoul. Hence, the observed difference between the SCA and non-SCA universities may reflect the quality difference across the regions rather than the actual effect of the enrollment regulation. I conduct subgroup analyses to test such possibilities.

Columns (1)–(2) of Table 6 report the estimation results without the top-ranking universities. Column (1) shows the estimates without the universities that have appeared in the top 10 list according to the most cited university ranking in South Korea, published by JoongAng Ilbo (a national daily newspaper). Column (2) lists the estimates without the universities that have appeared in the top 30 list. All the results are qualitatively consistent with the baseline results. While quality concerns may also be a source of the rigidity, the estimation results clearly indicate that the region-based enrollment cap is another important source of the rigidity for the regulated universities.

[Table 6] Subgroup Analyses

	(1) IV Excluding top 10 (ever)		(2) IV Excluding top 30 (ever)		(3) IV Excluding Seoul		(4) IV Adjacent provinces	
Dep. Var.	lnQ	lnF	lnQ	lnF	lnQ	lnF	lnQ	lnF
(L1) Ln (Applications)	0.442***	0.290***	0.433***	0.288***	0.442***	0.290***	0.376***	0.276**
	(0.056)	(0.071)	(0.059)	(0.075)	(0.056)	(0.071)	(0.080)	(0.108)
× Regulated	-0.294***	-0.208**	-0.315***	-0.205**	-0.309***	-0.233**	-0.246**	-0.219*
	(0.071)	(0.087)	(0.077)	(0.092)	(0.086)	(0.105)	(0.102)	(0.131)
Region-by-year FE	Y	Y	Y	Y	Y	Y	Y	Y
Univ.-by-major FE	Y	Y	Y	Y	Y	Y	Y	Y
Univ.-specific trends	Y	Y	Y	Y	Y	Y	Y	Y
First stage								
F-Stat. (SW) on Ln (A)	217.2		194.7		214.7		58.1	
F-Stat. (SW) on Ln (A) × Reg.	325.5		278.8		283.7		124.4	
N (Obs.)	16,499		13,649		14,043		7,104	

Note: Standard errors in parentheses are clustered at the university-by-major level; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.
Columns (1)–(2) are based on the university rankings published by the JoongAng Daily (from 2007 to 2017). All the observations from the universities that have been listed in the top 10 or 30 are discarded. Columns (3)–(4) are based on a subsample of universities located outside Seoul. Column (4) further restricts the sample to the SCA (including Gyeonggi Province and Incheon) and adjacent provinces (the two Chungcheong Provinces, Daejeon, and Sejong).

Columns (3)–(4) report the estimation results without the universities located in Seoul. Column (3) shows the estimates from the sample across all the MAs. Column (4) lists the estimates from the sample from only two adjacent MAs, that is, the SCA and Chungcheong MA. Once again, the estimated coefficients clearly indicate that the regulated private universities are unresponsive to student demand.

6.4. Near the Southern Border of the SCA: A Geographic RD Design

As the enrollment regulation is region based, thinking about the difference between adjacent regions near the border of the SCA is natural. Local labor demand, which is one of the main factors considered in the decision to enroll, will change continuously near the border,[19] whereas the regulatory status will change sharply at the border. Owing to geographic constraints (mountains and rivers), the only possible investigation is along the southern border of the SCA (Figure 2).

[Table 7] Geographic RD Design: Along the Southern Border of the SCA

	(1)		(2)		(3)		(4)	
	OLS		IV		OLS		IV	
	Universities between Seoul and Sejong				+/- 30 km from the border			
Dep. Var.	lnQ	lnF	lnQ	lnF	lnQ	lnF	lnQ	lnF
(L1) Ln (Applications)	0.269***	0.242***	0.379***	0.331**	0.209***	0.200***	0.304**	0.349**
	(0.033)	(0.036)	(0.102)	(0.141)	(0.038)	(0.035)	(0.125)	(0.176)
× Regulated	-0.065	-0.097*	-0.301**	-0.217	-0.036	-0.084*	-0.403**	-0.386**
	(0.042)	(0.053)	(0.132)	(0.165)	(0.053)	(0.049)	(0.174)	(0.195)
Region-by-year FE	Y	Y	Y	Y	Y	Y	Y	Y
Univ.-by-major FE	Y	Y	Y	Y	Y	Y	Y	Y
Univ.-specific trends	Y	Y	Y	Y	Y	Y	Y	Y
First stage								
F-Stat. (SW) on Ln (A)			41.0				24.6	
F-Stat. (SW) on Ln (A) × Reg.			83.2				43.4	
N (Obs.)	4,875		4,875		2,729		2,729	

Note: Standard errors in parentheses are clustered at the university-by-major level; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$

Columns (1)–(2) restrict the sample to universities located between Seoul and Sejong: the southern part of Gyeonggi Province and northern part of the Chungcheong MA. Columns (3)–(4) further restrict the sample to universities near the southern border of the SCA (within a range of +/-30 km) located in Yongin, Hwaseong, Osan, Anseong, and Pyeongtaek in Gyeonggi Province and Cheonan and Asan in the Chungcheong MA.

[19] While companies and factories are often discontinuously distributed, the labor demand for college graduates remains continuously distributed with regard to the location of colleges and universities, especially owing to the high mobility of college graduates.

Table 7 reports the estimates from the restricted sample. The OLS estimates do not show clear patterns between the regulated and unregulated universities (columns 1 and 3). However, the IV estimates demonstrate a clear difference between the two groups. The regulated universities are virtually unresponsive to changes in student demand for majors, whereas the unregulated universities adjust their enrollment limit and faculty size across majors (columns 2 and 4).

The universities located outside the SCA near the border may have chosen their location owing to the regulation, which may invalidate the geographic RD design. However, it should be noted that the main focus of this empirical analysis is how universities respond to changes in student demand. Specifically, the concurrent change in the nationwide distribution of demand for majors is unlikely to be correlated with the initial sorting of universities near the border.

6.5. Once-industrial Universities

Finally, I focus on a small group of universities that changed from industrial to general universities. Industrial universities were established to meet industrial needs. The four-year universities were subjected to special admissions rules[20] and regulated differently from other four-year universities, specifically the enrollment regulations for industrial universities were relatively mild (see Appendix Table A1). The industrial universities became increasingly similar to the general universities in many aspects, such as student quality and field composition. Moreover, there was a growing need to transform such universities into general universities.

A national policy change was implemented in 2008, along with the new administration. The transformation into general universities was temporarily facilitated within a narrow time window from 2009 to 2012. Most conversions occurred between 2010 and 2012.

The changes in the regulatory status based on location created an interesting variation for research purposes. Industrial universities were regulated differently from other four-year universities and widely distributed across the nation. Thus, the transformation can be used to identify the effect of the introduction of the SCA regulation.

Table 8 shows the estimation results from the private universities that were once industrial universities. While the estimated responsiveness to student demand is initially larger among the regulated universities, the sign is reversed after the conversion of the industrial universities into general universities. The separate estimation for each group (columns 3 and 4) clearly shows this pattern. While the industrial universities outside the SCA remained the same or became slightly more responsive to student demand after their institutional type change, those within the

[20] Applications to industrial universities were not counted in the maximum number of applications.

SCA became much less responsive to student demand. Although not without limitations,[21] this evidence is consistent with the negative effect of the enrollment regulation.

[Table 8] DID Analysis: Once-industrial Universities

Dep. Var.: Ln (Quota)	(1) All	(2) All	(3) Unreg.	(4) Reg.	(5) 2010–2014 only	(6) Excluding 1st & 2nd yrs.
(L1) Ln (Applications)	0.347***	0.380***	0.380***	0.628**	0.118	0.412***
	(0.067)	(0.066)	(0.066)	(0.252)	(0.095)	(0.067)
× SCA	0.281	0.248			0.369*	0.334
	(0.238)	(0.239)			(0.192)	(0.286)
× Post	0.041***	0.020	0.020	-0.326**	-0.003	0.045***
	(0.011)	(0.014)	(0.014)	(0.118)	(0.015)	(0.012)
× SCA × Post	-0.367***	-0.346***			-0.325**	-0.304***
	(0.108)	(0.109)			(0.131)	(0.067)
Region-by-year FE	Y	Y	Y	Y	Y	Y
Univ.-by-major FE	Y	Y	Y	Y	Y	Y
Univ.-specific trends	N	Y	Y	Y	Y	Y
N (Obs.)	640	640	564	76	307	574

Note: Standard errors in parentheses are clustered at the university-by-year level; $^{*}p < 0.1$, $^{**}p < 0.05$, and $^{***}p < 0.01$

The pre period (industrial univ.) and post period (general four-year univ.) are defined by university type in each year. All estimation results do not use the observations from the first year of the type change.

6.6. Effect Heterogeneity

Tables 9 and 10 report the estimation results by college major (broad fields). When (net) instructional costs differ across majors, universities are predicted to change the size of the low (net)-cost majors.

The estimation results show that social and natural sciences programs, whose instructional costs are typically low, are adjusted rapidly. The elasticity of the student quota for such majors is close to one. While the humanities majors also have low instructional costs, the first-stage result is very weak, and the program-level change in applications is uncorrelated with the national-level change in applications for the specific majors.

The enrollment cap reduces the adjustment of program size within the universities for most majors. While the humanities, social sciences, engineering, and natural sciences show low adjustment response, the difference between the regulated and unregulated universities is statistically significant at the conventional

[21] The IV strategy cannot be used here owing to the weak first-stage results.

level only for the social science majors. The social science majors in the regulated universities are virtually unresponsive to changes in student demand.

[Table 9] Effect Heterogeneity by College Major: Enrollment Limit

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. Var: ln (Quota)	Hum.	Soc. sci.	Educ.	Engr.	Nat. sci.	Health	Arts
(L1) Ln (Applications)	0.510	1.009***	-0.039	0.695***	1.190***	0.207***	-0.082
	(0.488)	(0.233)	(0.060)	(0.135)	(0.254)	(0.039)	(0.368)
× Regulated	-0.248	-1.086**	-0.040	-0.313	-0.317	0.046	0.154
	(0.323)	(0.485)	(0.108)	(0.203)	(0.310)	(0.058)	(0.372)
Region-by-year FE	Y	Y	Y	Y	Y	Y	Y
Univ.-by-major FE	Y	Y	Y	Y	Y	Y	Y
Univ.-specific trends	Y	Y	Y	Y	Y	Y	Y
First stage							
F-Stat. (SW) on Ln (A)	1.8	12.7	47.8	32.3	3.8	81.3	4.8
F-Stat. (SW) on Ln (A) × Reg.	2.4	11.0	71.2	43.8	12.6	118.7	45.4
N (Obs.)	1,915	2,706	1,572	4,797	2,111	1,677	3,602

Note: Standard errors in parentheses are clustered at the university-by-major level; $^{*}p < 0.1$, $^{**}p < 0.05$, and $^{***}p < 0.01$

[Table 10] Effect Heterogeneity by College Major: Full-time Faculty Members

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. Var: ln (Full-time faculty members)	Hum.	Soc. Sci.	Educ.	Engr.	Nat. Sci.	Health	Arts
(L1) Ln (Applications)	1.100	0.751*	-0.304**	0.784***	0.539	0.039	0.521
	(1.517)	(0.385)	(0.120)	(0.210)	(0.359)	(0.055)	(0.396)
× Regulated	0.817	-1.479*	0.268	-0.360	-0.061	0.073	-0.336
	(0.979)	(0.778)	(0.178)	(0.281)	(0.447)	(0.090)	(0.409)
Region-by-year FE	Y	Y	Y	Y	Y	Y	Y
Univ.-by-major FE	Y	Y	Y	Y	Y	Y	Y
Univ.-specific trends	Y	Y	Y	Y	Y	Y	Y
First stage							
F-Stat. (SW) on Ln (A)	1.8	12.7	47.8	32.3	3.8	81.3	4.8
F-Stat. (SW) on Ln (A) × Reg.	2.4	11.0	71.2	43.8	12.6	118.7	45.4
N (Obs.)	1,915	2,706	1,572	4,797	2,111	1,677	3,602

Note: Standard errors in parentheses are clustered at the university-by-major level; $^{*}p < 0.1$, $^{**}p < 0.05$, and $^{***}p < 0.01$

6.7. Discussion

The estimation results in the previous subsections show that the region-based enrollment cap is a major factor in the rigidity in the distribution of college majors in Korea. Although the regulation-induced rigidity suggests a need for regulatory reform, a few points must be discussed.

First, student demand for majors may not consistently reflect social demand. For example, students may have insufficient information on their comparative advantages or potential labor market outcomes by graduating from each major. The decentralized admissions procedures make it exceedingly difficult to predict the impact of the supply-side restriction on social welfare owing to strategic decisions.

Nevertheless, the supply-side rigidity is not likely to improve social welfare, particularly in the age of rapid technological changes. Efficiency losses through mismatches in skills between labor demand and labor supply are highly likely to increase over time. Demand-side frictions must be addressed by providing students with more information.

Second, a tradeoff may exist between efficiency and equity. Regardless of whether the enrollment cap is harmful to national-level efficiency in human capital accumulation, a possibility that the cap may increase equity across regions by retaining the youth population remains. In essence, the main rationale of the enrollment cap in Korea is to achieve equal development across regions, especially by reducing the outflow of the youth population from local areas outside the SCA.

However, the feasibility of retaining the youth population through government interventions is controversial. For example, though government interventions can significantly increase college enrollment in a state (e.g., Dynarski, 2003; Kane, 2006), the stock of college graduates in the state may not increase (e.g., Bound et al., 2004; Groen, 2004; Winters, 2011; Liu, 2015). Thus, knowing what types of students respond to such interventions is crucial (Kennan, 2015).

Although the design of a full-scale regulatory reform is beyond the scope of this study, a partial deregulation for some programs with increasing social demand is expected to improve student–major matching immediately. For example, some college majors can be exempted from the total enrollment cap. It is unlikely that the outflow of youths across regions would be quantitatively significant under the partial deregulation.

Other solutions exist, such as changing the quota based on manpower forecasting or increasing internal flexibility (easy switching of college majors). However, such solutions were unsuccessful in the Korean context. The Ministry of Education relies on a type of manpower forecasting, whose accuracy is questionable (Grubb et al., 2009). Government-initiated changes are also likely to confront strong opposition. Although increasing internal flexibility is certainly a highly attractive strategy, it is critical how the burden of flexibility is distributed across programs. Conflicts of interest between popular and unpopular majors often block the necessary changes. The administrative system for transfers, double majors, and interdisciplinary programs, which is mostly determined by the enrollment cap, must also change along with the admissions system.

VII. Concluding Remarks

The distribution of college majors in Korea shows signs of rigidity regardless of the tertiary enrollment rate, which is the highest among the OECD countries. Motivated by the difference in the speed of change in the distribution across regions, in this study, I investigate the effect of a traditional regulation, that is, a cap on the total enrollment of universities in the SCA, as a possible explanation for the rigidity.

From the university-by-major-level panel data based on administrative data, I find that responsiveness to student demand is low among the regulated universities. The systematic difference between the regulated and unregulated universities in terms of adjustment response to demand changes is robust only in the similarly ranked or located universities. The negative effect of the enrollment regulation is also confirmed by two additional analyses that use the sharp changes in the regulatory status of the universities near the southern border of the SCA or the national policy change on industrial universities.

Introduced to suppress population growth within the SCA, the regulation hinders urgent changes within the regulated universities, particularly enlarging high-demand programs. The hidden costs of the regulation will increase further when economic changes progress rapidly. Thus, the enrollment regulation should be carefully redesigned to improve correspondence between students and college majors.

Appendix: Additional Tables

[Table A1] Enrollment Regulations on HEIs in SCA

	ORZ		GMZ	NPZ
	In Seoul	Outside Seoul		
New Establishment				
General university[1]	N	N	N	N
Small university[2]	N	N	Y	Y
Industrial university	N	Y	Y	N
Two-year college	N	Y	Y	Y
Enrollment Capacity				
General university[1]	N			
Small university[2,3]	Y			
Industrial university[4]	Y			
Two-year college[4]	Y			

Note: The SCA includes three zones: the ORZ, GMZ, and NPZ (see Figure 2).

1. Including education universities
2. Less than or equal to 100 students by admissions quota
3. An increase in enrollment capacity for a small university less than eight years is allowed within a limited range; 100% of the initial quota
4. An increase in enrollment capacity for industrial university or two-year college is allowed within a limited range; 10% of the national enrollment increase

Source: Ministry of Education (2006, 2012).

[Table A2] KEDI Classification of Departments (Majors)

Broad field (large series)	Narrow field (medium divisions)	Broad field (large series)	Narrow field (medium divisions)
Humanities	Languages (12)	Engineering	Architecture (3)
	Humanities (except languages) (8)		Building and civil engineering (2)
Social sciences	Business and economics (7)		Traffic and transportation (3)
	Law (1)		Mechanical and metallurgical engineering (3)
	Social sciences (8)		
Education	Education science (1)		Electrical and electronics engineering (3)
	Early childhood education (1)		Precision and energy (2)
	Special education (1)		Materials engineering (4)
	Primary education (1)		Computer science and ICT (3)
	Secondary education (6)		Industrial engineering (1)
Natural sciences	Agriculture, forestry, fisheries (3)		Chemical engineering (1)
	Biology, chemistry, and related sciences		Unclassified (3)
	Human ecology (4)	Arts	Fashion, industrial, visual design (5)
	Mathematics and physical sciences (6)		Applied arts (3)
Health	Medicine (3)		Dance and gymnastics (2)
	Nursing (1)		Fine arts and handicrafts (3)

	Pharmacy (1) Therapy and treatment Technology (3)		Theater and film (1) Music (6)

Note: This table is (mostly) translated from the Korean classification, with a few categories paraphrased to provide improved information about the subcategories. The numbers of subcategories are in parentheses.
Source: Park et al. (2015; in Korean).

[Table A3] Majors with Relatively High/Low Demand (2007–2017)

	High student demand			Low student demand	
Top	SCA	Non-SCA	Top	SCA	Non-SCA
1	Theater and film	Medicine	1	Dance and gym.	Fine arts & handicrafts
2	Medicine	Nursing	2	Agr., For. & Fish.	Math & physical sci.
3	Chem. engr.	Pharmacy	3	Fine arts & handicrafts	Law
4	Soc. sci.	Early child. educ.	4	Special educ.	Dance and gym.
5	Nursing	Theater and film	5	Secondary educ.	Agr., For. & Fish.
6	Bus. and econ.	Tfc. and Trans.	6	Engr. (unclas.)	Bio., chem. & related
7	Early child. educ.	Therapy and treat.	7	Bldg. and civil engr.	Languages
8	Applied arts	Mech. and metal. engr.	8	Precision and energy	Humanities
9	Languages	Bus. and econ.	9	Tfc. and Trans.	Soc. sci.
10	Mech. and metal. engr.	Elect. and electron. engr.	10	Architecture	Precision and energy

[Table A4] Asymmetric Adjustment

	(1) All		(2) Regulated		(3) Unregulated	
Dep. Var.	lnQ	lnF	lnQ	lnF	lnQ	lnF
(L1) Ln (Applications)	0.452***	0.297***	0.453***	0.301***	0.202***	0.064
	(0.057)	(0.073)	(0.058)	(0.074)	(0.037)	(0.045)
× Regulated	-0.249***	-0.229***				
	(0.068)	(0.085)				
× Unpopular	0.003***	0.002	0.003***	0.002	0.003**	0.001
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)
× Unpopular × Regulated	-0.000	-0.002				
	(0.002)	(0.002)				
Region-by-year FE	Y	Y	Y	Y	Y	Y
Univ.-by-major FE	Y	Y	Y	Y	Y	Y
Univ.-specific trends	Y	Y	Y	Y	Y	Y
N (Obs.)	18,380	18,380	10,841	10,841	7,539	7,539

Note: Standard errors in parentheses are clustered at the university-by-major level; * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$
The dummy variable for unpopular majors indicates a major-level application rate (the ratio of applications to major-level quota) less than the university-average application rate.

[Table A5] Alternative Specifications

	(1) Add control: Univ-by-year FE		(2) Add control: Enrollment		(3) Long difference 5 years	
Dep. Var.	lnQ	lnF	lnQ	lnF	lnQ	lnF
(L1) Ln (Applications)	0.448***	0.291***	0.443***	0.289***		
	(0.058)	(0.074)	(0.056)	(0.071)		
× Regulated	-0.246***	-0.215**	-0.246***	-0.222***		
	(0.070)	(0.088)	(0.066)	(0.082)		
(L1) Ln (Enrollments)			-0.072	0.167**		
			(0.071)	(0.082)		
(L5) Ln (Applications)					0.247***	0.220**
					(0.059)	(0.087)
× Regulated					-0.204**	-0.051
					(0.091)	(0.122)
Region-by-year FE	Y	Y	Y	Y	Y	Y
Univ.-by-major FE	Y	Y	Y	Y	Y	Y
Univ.-specific trends	N	N	Y	Y	Y	Y
Univ.-by-year FE	Y	Y	N	N	N	N
N (Obs.)	18,326	18,326	18,380	18,380	10,135	10,135

Note: Standard errors in parentheses are clustered at the university-by-major level; $^{*}p < 0.1$, $^{**}p < 0.05$, and $^{***}p < 0.01$

Appendix: A simple model of college major seats within a university

In an environment with many universities, this model focuses on the decision of each university. For simplicity, we assume that only two majors exist ($m = 1,2$). Major-specific enrollment is denoted by n_m and cannot exceed the number of applicants who are ready to enroll (student demand), a_m. We assume that each department observes (or perfectly foresees) the student demand. The major-specific enrollment is consistently equal to the quotas (i.e., enrollment rates are consistently 100%).

Educational costs per student are a major-specific function of education quality (q_m). The cost function $c_m(q_m)$ is increasing in quality (i.e., $c'_m(q_m) > 0$). Tuition fees are exogenously given by T. Without loss of generality, we assume that tuition fees are constant across majors.

The university receives subsidies L, which is strictly increasing and convex in relation to education quality (i.e., $L'(q) > 0, L''(q) > 0$) and defined on a bounded support $[0, \bar{q}]$. The amount of the (net) subsidy is zero if education quality is zero. The overall quality (q) is a weighted sum of the major-level education quality.

$$\underset{n_1, n_2, q_1, q_2}{Max}\ U(n_1, n_2)$$

s.t.

(1) (Resource constraint) $n_1 c_1(q_1) + n_2 c_2(q_2) = L(wq_1 + (1-w)q_2) + T(n_1 + n_2)$

(2) (Student demand) $n_m \le a(q_m, Z_m), \forall m$

(3) (Total enrollment cap) $n_1 + n_2 \le \overline{n}$

(4) (Non-negativity constraints) $q_m \ge 0, n_m \ge 0$,

where a (.) is the student demand that is a function of q_m and Z_m, which is an exogenous factor.

The university maximizes its objective function given various constraints, including the resource constraint. The resource constraint is consistently binding (i.e., a zero-profit condition), but the other constraints may or may not be binding. Education quality plays a key role in characterizing the solutions. The education quality can be either high or low given the convexity of the subsidy function.

In the case of the HEI with high education quality, the student demand restrictions are not binding. When the HEI maximizes the number of students enrolled without any favoritism toward a specific major ($U(n_1, n_2) = n_1 + n_2$), it will equate the (net) educational costs per student across all majors ($c_1(q_1) = c_2(q_2)$). Given this relationship, the resource constraint requires the per student subsidy to be equal across all majors ($c_m(q_m) - T = L(q)/n$). The enrollment is determined by the marginal costs and weights of the education quality in the overall quality ($n_1 c_1'(q_1)/w = n_2 c_2'(q_2)/(1-w)$) regardless of student demand. If the cost function is linear, then the enrollment in the major with low marginal cost is large.

In the case of the HEI with low education quality, the student demand restrictions are binding, and educational costs are no longer equated across programs. The optimal education quality is determined by the elasticity of student demand to education quality as well as the cost structure.

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대학전공(자) 공급부족: 대한민국 사립대학의 사례*

한 요 셉**

초 록 일자리 및 직무의 급속한 변화에도 불구하고 대학 전공의 분포는 경직성을 나타내는 경향이 있다. 대한민국 사립대학에서 관찰되는 전공 분포의 경직성을 설명하기 위해, 본 연구에서는 교육공급 측면 제약에 주목하면서 특히 지역별 대학 정원의 상한에 주목한다. 전국의 전공별 교육수요 변화를 각 학과단위 교육수요 변화에 대한 도구변수로 사용하여 추정한 결과, 총량적 정원 규제의 영향을 받는 대학과 그렇지 않은 대학의 수요에 대한 반응성 간에 통계적으로 유의미한 차이가 발견되었다. 규제 상태와 관련하여 공간적으로나 시간적으로 급격한 변화가 발생하는 경우로 한정한 분석 결과에서도, 총량적 정원 규제가 내적 조정을 약화시킴을 확인할 수 있었다. 이러한 결과는 정원 규제 개혁의 필요성을 시사한다.

핵심 주제어: 고등교육, 정원 규제, 대학 전공, 공급 측면, 사립대학
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