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The Returns to Medical School: Evidence from Admission Lotteries†

By Nadine Ketel, Edwin Leuven, Hessel Oosterbeek, and Bas van der Klaauw*

We exploit admission lotteries to estimate the returns to medical school in the Netherlands. Using data from up to 22 years after the lottery, we find that in every single year after graduation doctors earn at least 20 percent more than people who end up in their next-best occupation. Twenty-two years after the lottery the earnings difference is almost 50 percent. Only a small fraction of this difference can be attributed to differences in working hours and human capital investments. The returns do not vary with gender or ability, and shift the entire earnings distribution. (*JEL* D44, I11, I26, J24, J31, J44)

Earnings do not only vary with level of schooling but also with field of study. For example, in the US median annual earnings of people with a bachelor's degree in engineering equal US$92,000 in 2011, while median annual earnings for people with a bachelor's degree in education equal US$51,000 (Ryan 2012). Yet, while a large literature deals with the causal effect of the level of schooling on earnings, little is known about the causal effects of field of study on earnings (Altonji, Blom, and Meghir 2012). Do people with an engineering degree earn so much more than people with an education degree because they were exposed to a different curriculum, or does the observed earnings difference mainly reflect preexisting differences between people who chose different fields of study?

Two recent papers make important advances in the study of returns to field of study by exploiting discontinuities in the admission into different fields of study. Hastings, Neilson, and Zimmerman (2013) use data from Chile and find that the payoffs to being offered a slot vary substantially across fields of study. Kirkebøen, Leuven, and Mogstad (forthcoming) use Norwegian data and instrumental variables to estimate the return to actually completing a field of study. Importantly, the authors also know applicants' next-best field of study. This allows them to estimate wage

* Ketel: Department of Economics, University of Gothenburg, PO Box 640, SE 405 30 Gothenburg, Sweden (e-mail: nadine.ketel@gu.se); Leuven: Department of Economics, University of Oslo, Postboks 1095 Blindern, 0317 Oslo, Norway (e-mail: edwin.leuven@econ.uio.no); Oosterbeek: School of Economics, University of Amsterdam, Roetersstraat 11, 1018 WB Amsterdam (e-mail: h.oosterbeek@uva.nl); Van der Klaauw: Department of Economics, VU University Amsterdam, De Boelelaan 1105, 1081 HV Amsterdam, Netherlands (e-mail: b.vander.klaauw@vu.nl). We gratefully acknowledge valuable comments from two anonymous referees, Maarten Lindeboom, Sarah Turner, Dinand Webbink, and seminar participants in Amsterdam, Bern, Bonn, Bristol, Lausanne, Madrid, Munich, New York, Oslo, The Hague, and Toulouse.

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premiums for different field-of-study pairs. A key finding of the paper is that fields of study have widely different payoffs depending on the next-best field.

The current paper contributes to this emerging literature by using admission lotteries to estimate the returns to one specific field of study: medical school. While the restriction to one specific field makes the current paper more narrow than the previous papers, the use of admission lotteries implies the most credible source of exogenous variation. Moreover, our setup makes it possible to have a close look at heterogeneity of returns to medical school with respect to the pretreatment exam score, which is the forcing variable in the papers that use a regression discontinuity approach.

Previous studies that looked at the return to medical school have done so from the perspective of monopoly rents. Since most countries regulate the supply side and the demand side of medical professions, it has been hypothesized that this results in higher earnings for doctors. Interest in this issue goes back to at least Friedman and Kuznets (1954), who quantify the rent for US doctors in the 1950s by comparing their earnings to earnings of dentists, for whom at the time entry was much less restrictive. They conclude that 16.5 percent of doctors' earnings is due to "barriers to entry," although they note that part of the observed earnings gap may reflect ability differences.[1] More recently, also using US data, Anderson et al. (2000) show that doctors in states with higher entry barriers due to stricter regulations earn significantly higher incomes. Although these studies are highly suggestive, they are unable to address selectivity issues in a rigorous fashion.[2]

This paper exploits the unique fact that in the Netherlands admission to medical school was entirely determined by admission lotteries. Admission to other study programs is in general not restricted in the Netherlands, so we estimate the returns to medical school compared to individuals' next-best alternative. The admission lotteries provide true randomization and allow us to eliminate bias arising from students self-selecting into medical school on the basis of unobservables such as ability and motivation. Because applicants who lose the lottery are allowed to reapply in the next year and because not all lottery winners complete medical school, we use the outcome of an individual's first lottery as the instrumental variable for completing medical school.

We have access to administrative data from the admission lotteries in the years 1988 to 1999, and to applicants' subsequent study career from the Dutch student registry. This information is merged at the individual level with registry data on labor market outcomes in the period 1999 to 2010. For the cohort that applied to medical school in 1988, we thus have labor market information of up to 22 years after application. We present separate estimates for each year since the first application thereby constructing synthetic experience-earnings profiles. Consequently we can estimate long-run returns, as well as opportunity costs and internal rates of return.

[1] Burstein and Cromwell (1985) follow the same approach and find that in 1978–1980 period in the United States, the income difference between doctors and dentists amounts to 35 percent, while the income difference between doctors and lawyers is 139 percent.

[2] Since only graduates of medical school are allowed to practice as physicians, the results of this paper also contribute to the literature on occupational licensing (see among others Kugler and Sauer 2005; Maurizi 1974; Kleiner 2000; Kleiner and Krueger 2013). The difference being, however, that in the current paper unlicensed individuals do not have the same education and training as licensed individuals.

We find substantial earnings returns to completing medical school. There is no single year after graduation in which the returns are less than 20 percent. The earnings profiles indicate that returns increase with experience. Twenty-two years after the first lottery doctors have, on average, almost 50 percent higher earnings. The returns are very similar for men and women, although in absolute terms men earn more than women. Discounted at 2 percent, the average net present value of completing medical school is more than 1 million euros, which corresponds to an average internal rate of return of 36 percent.

We do not find evidence that these large earnings differences are driven by differences in working hours. While doctors work longer hours than nondoctors, this difference is modest. At the start of their career doctors work annually around 300 hours more, but after 4 years this difference decreases to around 120 hours per year. There is also no evidence that doctors are more restricted in their family lives. Doctors are actually more likely to be married and to have children.

We do not find differential returns by gender or by ability, where five high school GPA categories measure ability. The homogeneity of the returns across high school GPA suggests that estimates that would have been obtained around one specific value of GPA (as in a regression discontinuity approach) would have been informative about returns at other values of GPA as well. Finally, using the approach developed by Imbens and Rubin (1997), we estimate the marginal distribution of earnings under different treatments. This reveals that the large earnings returns are not only driven by high returns in the top end of the distribution. Among doctors there are fewer people with zero earnings and the whole earnings distribution is shifted to the right.

Because the substantial earnings returns to medical school cannot be attributed to longer working hours, larger investments in human capital, or sacrifices in private lives, and because the returns are large for all GPA categories, monopoly rents seem the more likely explanation for the large returns.

Students in medical schools in the Netherlands pay the same (low) tuition fees as students in other fields of study. At the same time, the costs of attending medical school are much higher than the costs of other study programs. This implies that the government subsidizes students in medical schools much more than students in most other fields. In light of the high private returns that we document in this paper, it might be considered to shift a larger part of the costs of medical schools to the students. Our results suggest that there is sufficient scope for medical school students to pay higher tuition fees. This might also allow the government to increase the number of available places without increasing public expenditures. At the same time higher tuition fees can reduce the number of applicants for medical school. An increase in the supply of doctors and the resulting reduction of their earnings will also reduce the number of applicants.

The remainder of this paper is organized as follows. The next section provides further details about the institutional context and the admission lottery to medical school. Section II describes the data used in this paper. Section III discusses the empirical model and the identification. Section IV presents the main results, while Section V assesses the heterogeneity of treatment effects along three dimensions: gender, ability, and position in the earnings distribution. Section VI discusses several reasons for the large earnings premium that we document. We consider working hours, different human capital investments, sacrificing private life, and monopoly rents. Section VII concludes.

I. Background and Institutional Context

A. *Medical Schools in the Netherlands*

In the Netherlands a high school diploma makes people eligible for university studies in all fields and institutions.[3] Students choose their field as soon as they enter university, unlike, for example, in the United States where students specialize later. For the large majority of fields, universities have to accept all applicants, but some fields have a quota, implying that only a fixed number of students are admitted.

Medical school is the most prominent case of a study with a quota.[4] The quota for medical schools was introduced in 1976. Initially, the motivation behind the quota was to ensure the quality of the study program in a time of increasing numbers of applicants. More recently, the arguments in favor of the quota are threefold (Raad voor de Volksgezondheid en Zorg (RVZ) 2010). First, given the limited capacity of medical schools, increasing enrollment could reduce the quality of graduates. Second, since university education is largely publicly funded and medical school is much more expensive than the average study, educating "too many" doctors would be wasteful. And finally, there are concerns about supplier-induced demand (Hurley 2000), educating more doctors could increase the number of medical treatments.

The Minister of Education officially sets the quota. Until 1993 the annual quota was fixed at 1,458 students, after which it was gradually expanded to 1,815 students in 1995. In the years relevant for our paper it remained at this level. The size of the quota that the minister sets is largely based on the number of places in postgraduate specialization tracks, which are determined by the associations of specialists. For example, the association of neurologists decides how many places there are available for the specialization tracks in neurology. People can apply to these postgraduate specialization tracks after completing medical school.

If the number of applicants for medical schools exceeds the quota (which has always been the case), a lottery determines who is admitted.[5] Rejected applicants are allowed to reapply in the next year, and until 1999 they could do this as often as they wanted.[6] We observe that 69 percent of the rejected first-time applicants reapply a second time.[7]

[3] Students are tracked into different levels when they enter high school at age 12. Only the highest of three levels ensures direct admittance to university. Around 20 percent of primary school students enroll in the highest track.

[4] Other university studies that have quotas are dentistry, veterinary medicine, and (in some years) international business studies. However, the number of applicants for medicine is by far the largest.

[5] Since 2000, medical schools are allowed to admit at most 50 percent of the students using their own criteria. Medical schools have made increasing use of this, and selection is often based on motivation and previous experience. For this reason we restrict our analysis to students who first applied to medical school before this change.

[6] In our data, the maximum number of applications of one individual is nine. Since 1999, the maximum number of applications is limited to three.

[7] Alternatively, lottery losers can decide to enroll in medical school abroad. Below we will present evidence indicating that the share of lottery losers enrolling in a medical school abroad is at most very small.

Table 1—Lottery Categories

Category	GPA	Share	Weight
A	$GPA \geq 8.5$	0.02	2.00
B	$8.0 \leq GPA < 8.5$	0.05	1.50
C	$7.5 \leq GPA < 8.0$	0.09	1.25
D	$7.0 \leq GPA < 7.5$	0.21	1.00
E	$6.5 \leq GPA < 7.0$	0.22	0.80
F	$GPA < 6.5$	0.30	0.67
Other	—	0.11	1.00

Notes: GPA is grade point average on the final exams in high school. Share is the share of applicants in the different categories that applied for the lotteries in the years 1988–1999. Weight indicates the relative probability of being admitted. The category "other" refers to students who did not participate in the nationwide high school exams, such as foreign students. This category will be excluded from the analysis.

The lottery is weighted such that students with a higher GPA on the high school exams have a higher probability of being admitted.[8] High school exams are nationwide and externally graded on a scale from one to ten, where six and above indicates a pass. Table 1 shows which GPA intervals are assigned to the different lottery categories—labeled A to F—together with the shares of applicants in each category. The category "Other" refers to students who did not attend high school in the Netherlands and therefore did not participate in the high school exams, such as foreign students. The final column indicates the weights of the different categories in the lottery. The total number of available places are divided over categories A to F such that for the number of available places divided by the number of applicants in a category, the weights as in Table 1 hold. [9]

Figure 1 shows the admission rates per year by lottery category.[10] In the early years applicants in category A are almost certainly admitted, but this category contains only 2 percent of all applicants (see Table 1). The majority of applicants are in categories C to F, for which the admittance rates range from 35 to 60 percent. Since applicants can participate in multiple lotteries, eventually almost 72 percent of all first-time applicants between 1988 and 1999 are admitted.[11]

The admission lottery is centrally executed. Applicants are allowed to list their three most preferred medical schools, but which schools they list does not affect the outcome of the admission lottery. After the result from the lottery is known, admitted

[8] Graduating from high school requires an exam in seven subjects, including Dutch and English. Applicants for medical school should also have included biology, chemistry, physics, and math and should have passed these subjects. Once the exam is passed it cannot be retaken. Applicants can thus not retake the exam in order to end up in a higher lottery category.

[9] This implies that the probability of being admitted in category k equals $p_k = w_k P / \sum_j w_j N_j$, where w_k is the weight given to category $k \in \{A, \ldots, F, Other\}$, N_k the number of applicants of category k, and P the total number of places. In case the number of available places in a category exceeds the number of applicants, all applicants in that category are admitted. For the remaining categories the weights between the ratios of available places and the number of applicants per category will remain the same.

[10] Table A1 in the Appendix contains more detailed information on the admission probabilities together with the number of applicants per category per year.

[11] In 1999, a reform was implemented that implied that applicants with a GPA above eight (category A and B) are automatically admitted. This reform was implemented as a response to a large public discussion about a girl that finished high school with an exceptionally high GPA of 9.6 but lost the lottery three times in a row. The weights for the other categories remained the same.

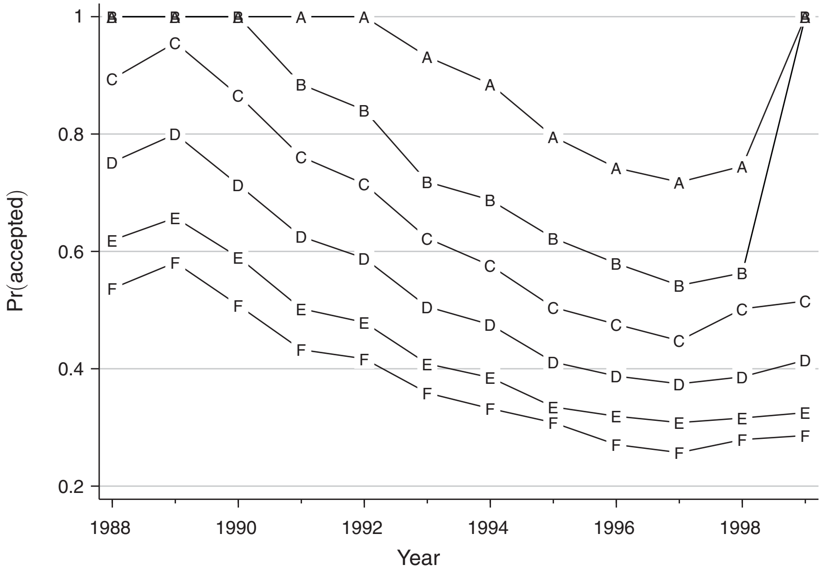

Figure 1. Probability of Being Admitted by Year of Application

Note: In 1999, a reform was implemented that implied from that year on applicants with a GPA above 8 (category A and B) are automatically admitted.

students are divided over the medical schools taking into account their preferences where possible.[12] In the Netherlands, eight universities have a medical school, which offer programs that are similar in content and quality. Universities are publicly funded and the nationwide tuition fee is low, and this is the same for all study programs. There are no private institutes offering the same education. Table A2 provides evidence on the similarity in content and quality of different medical schools in the Netherlands. There are only small differences in the GPA of the students that list the school as their most preferred school. In addition, the two main rankings of Dutch higher education institutes produce a very different ranking, even though both are based on a combination of student evaluations and expert committees. These rankings also show no relation to the GPA of the entering students.

The study program of medical schools consists of different phases. After completing four years of mainly theoretical education, students receive their undergraduate diploma. To enter the labor market for medical doctors, two more years of on-the-job training are required. During these first six years students are entitled to the same general study allowance that all Dutch students receive, and students pay a tuition fee of around 1,000 euro per year (at that time). After obtaining the basic medical degree, students can choose to specialize or take a PhD. The specialization track for a general practitioner takes three additional years, while the most advanced specializations, such as neurologist, cardiologist, or surgeon, require an additional four to six years of training. In order to be hired in one of the medical specialization

[12] In the end, 83 percent of the students are placed at the medical school of their first preference.

tracks it is common to first get a PhD degree. There are no tuition fees during the PhD and specialization track, and students have a formal employment contract and receive a salary. In total, the complete medical education can take between 6 and 15 years.

B. *The Labor Market for Doctors in the Netherlands*

On average, 45 percent of all licensed doctors in the Netherlands are registered as a specialist.[13] General practitioners constitute around 30 percent of the physician population. The remainder pursues a career as a social doctor (10 percent)[14] or does not specialize at all (15 percent). The latter group can either be non-specialized doctors that work as so-called "basisarts" or those that completed a medical degree, registered as a health care professional but are no longer active as a doctor. There are gender differences in the career choices of doctors. Men are more likely than women to become specialists (52 versus 39 percent) and less likely to become general practitioners (25 versus 31 percent), social doctors (8 versus 10 percent), or to never specialize (15 versus 20 percent).

A medical specialist can either become an employee of a hospital or can join a medical partnership, which is a joint venture of self-employed individuals. Within hospitals, most specialists (75 percent) are organized in such partnerships (Schäfer et al. 2010). Members of a partnership are considered to be self-employed and are taxed as such. The hospital buys the services of these partnerships. During our observation period (1999–2010), two payment regimes applied for self-employed specialists. From 1999 to 2005, each partnership received a lump-sum payment, negotiated by local initiatives of partnerships, insurance companies, and hospitals. After 2005, the lump-sum payments were combined with fees per service, in order to introduce incentives for providing services. The lump-sum payments and (afterwards) fees are determined in central negotiations and restrict what doctors can charge.

The number of practicing doctors in the Netherlands is 2.9 per 1,000 inhabitants; close to the OECD average of 3.1.[15] Also the division among general practitioners, specialists, and other doctors in the Netherlands is close to the OECD average. The same holds for the number of medical graduates; in 2009, 9.9 per 100,000 inhabitants. In terms of remuneration, general practitioners in the Netherlands earn 1.7 or 3.5 times the average income depending on whether they are regular employees or self-employed. Self-employed GPs in the United Kingdom, Ireland, Germany, and Canada have comparable relative remuneration rates. Specialists in the Netherlands are well paid at 5.5 times the average income. There is no other country where this ratio is so high, although this ratio exceeds four in several other countries (including Australia, Austria, Canada, Ireland, and Germany).

Doctors with a non-Dutch diploma can practice in the Netherlands if the Dutch registration authority recognizes their diploma. They often have to follow a number

[13] In order to practice as a physician a doctor needs to be registered in the Dutch registration of health care professionals.

[14] The category of social doctors includes, for example, occupational health doctors, doctors for mentally disabled, community doctors, etc.

[15] The information in this paragraph comes from OECD (2010).

of years of additional training, depending on the assessment of their diploma. In the period 2000–2004, 191 non-EU doctors obtained a medical degree following this procedure (Herfs 2009). Since 2005 non-EU citizens also have to pass a language test and a medical ability test. The language tests are a considerable barrier; in the years 2005–2009, only 19 participants (one-quarter of all participants) passed the tests (Herfs 2009). For EU-citizens the Dutch government is not allowed to demand a language requirement, but employers can. In practice, many employers ask candidates to pass the same language test as non-EU citizens. There are no exact numbers on the number of foreign doctors practicing in the Netherlands. By linking information from the Dutch registration authority to study registrations, we observe that 94 percent of the licensed doctors born after 1970 attended medical school in the Netherlands. The remaining 6 percent will be a combination of Dutch students that attended medical school abroad and foreign doctors that registered in the Netherlands.

II. Data

A. *Data Sources and Sample*

Our data come from three sources. The first source is the administrative records from the agency (DUO) that registers enrollment of all Dutch students in higher education and that conducts the admission lotteries. Hence, we observe all applicants for medical school together with their lottery category (but not their exact GPA) and the outcomes of the lotteries. Furthermore, we know the actual study choices of both winning and losing lottery applicants. Information on study progress is also available, as the agency registers when and whether students successfully complete certain stages.

We have lottery data of individuals that applied for a lottery between 1987 and 2004. Because we are interested in the full history of lottery participation, we exclude individuals who participated in the lottery in 1987. For that year, we cannot observe if participation in the lottery is preceded by losing previous year's lottery. Our data show that people very rarely skip lottery years. But if someone applied in 1986 and next in 1988 (so skipped 1987), we would mistakenly consider the lottery participation in 1988 as the start of the application history. To minimize such mistakes, we exclude applicants that are older than 20 at the moment of their first observed application.[16] Since 2000, Dutch medical schools can admit at most 50 percent of their students using their own criteria. Therefore, we exclude all applicants that applied for the first time after 1999. Applicants in lottery category A are excluded since almost all of them are admitted (some after participating in a second or third lottery) to medical school. Finally, we exclude 98 applicants that were admitted to medical school through a so-called ministers' placement. These are approximately ten places per year that are reserved for students from the former Dutch colony the Dutch Antilles. This leaves us with 25,393 individuals.

[16] In the Netherlands, the nominal age of finishing high school is 18.

Using social security numbers, the information from DUO is merged to individual records of all Dutch citizens kept by Statistics Netherlands. We lose 60 observations without a valid social security number, which are evenly distributed among the winners and losers of the first lottery (p-value of equality is 0.18). The records of Statistics Netherlands include information from municipalities, tax authorities, and social insurance administrations. Therefore, they contain detailed information on earnings from various sources, labor supply, and characteristics such as age, gender, ethnicity, and marital status. All inhabitants of the Netherlands are registered at a municipality, which implies that if a person is not in our data in a particular year, this person did not live in the Netherlands in that year. Data from Statistics Netherlands cover the years 1999 to 2010, with the exception of working hours, which are only available for the years 2006–2010.[17]

Finally, we have records from the BIG-register, that include all health care professionals in the Netherlands. This register provides information regarding individual qualifications and entitlement to practice. From this register we know whether someone is licensed as a doctor.

B. *Descriptive Statistics*

Table 2 presents the balancing of some pretreatment individual characteristics between winners and losers of their first lottery.[18] For each lottery category we show the sample means of the individual characteristics and report the p-value for equality obtained from regressing winning the lottery on this characteristic and year of lottery fixed effects. Each p-value thus comes from a separate regression. About 60 percent of the applicants are female, the average age at the first application is 18.3, and 8 percent of the sample are from non-Western origin. In the lottery categories with a higher GPA, there are, on average, more women, individuals are younger, and fewer non-Western immigrants. The p-values for randomness of the admission lotteries show no sign of concern, only 1 of the 15 p-values is below 0.05.

Table 3 presents summary statistics on study achievement and labor market outcomes. The outcome of the first lottery is associated with almost a 50 percentage point increase in enrollment into medical school. Not everyone who wins the first lottery actually enrolls in medical school; 6 percent do not enroll. Among the losers of the first lottery, 45 percent end up enrolling in medical school (after winning a subsequent lottery). Of the winners, 82 percent complete medical school, compared to 41 percent for the losers. Finally, almost all individuals who complete medical school also register as a doctor, and are therefore licensed. The small difference between completion and registration rates may be caused by the fact that completion data currently run to 2010, while the register of licensed doctors only runs to 2008. Additionally, for lottery losers it might be that some individuals obtained a medical degree abroad and afterward registered as a doctor in the Netherlands. In

[17] This implies that working hours are only observed during the period when the lump-sum payments were combined with fees per service. Since this payment scheme could give doctors an incentive to work more hours, it would increase the difference in working hours between doctors and nondoctors.

[18] When there can be no confusion we sometimes refer to winners and losers of their first lottery as "lottery winners" and "lottery losers."

Table 2—Balancing of Personal Characteristics by Admission Status of the First Lottery Application

	Lottery winners	Lottery losers	*p*-value
Lottery category B			
Female	61.1%	60.1%	0.67
Age at first application	17.9	18.0	0.64
Non-Western immigrant	4.1%	5.0%	0.60
Number of individuals	1,805		
Lottery category C			
Female	63.0%	62.2%	0.43
Age at first application	18.0	18.0	0.28
Non-Western immigrant	4.0%	4.2%	0.50
Number of individuals	2,721		
Lottery category D			
Female	59.5%	59.0%	0.71
Age at first application	18.2	18.2	0.91
Non-Western immigrant	5.5%	5.5%	0.68
Number of individuals	6,069		
Lottery category E			
Female	58.8%	57.4%	0.25
Age at first application	18.3	18.4	0.72
Non-Western immigrant	7.5%	7.7%	0.32
Number of individuals	6,414		
Lottery category F			
Female	56.2%	56.0%	0.77
Age at first application	18.5	18.6	0.02
Non-Western immigrant	10.4%	10.7%	0.31
Number of individuals	8,384		

Note: The *p*-values in the final column are weighted by the admittance probabilities for students in different years of application.

Table 3—Descriptive Statistics by Admission Status of the First Lottery Application

	Lottery winners	Lottery losers
Study enrollment and completion		
Enrolled in medical school	94%	45%
Completed medical school (by 2010)	82%	41%
Licensed as doctor (by 2008)	81%	42%
Enrolled in study program in the Netherlands	99%	95%
Completed study program in the Netherlands	96%	89%
Labor market outcomes		
Annual real (2010) taxable earnings (1999–2010)	39,284	28,274
Annual working hours (2006–2010)	1,756	1,693
Hourly earnings (2006–2010)	31.6	24.1
Household composition		
Married in 2010	51%	45%
Children in 2010	60%	51%
Number of individuals	11,726	13,667

Note: Recall that the lottery is weighted so that the observed differences between lottery losers and lottery winners cannot be given a causal interpretation.

the analyses these individuals are treated as noncompleters of medical school. This is likely to bias the estimates of the returns to medical school slightly downward.

Enrollment, completion, and being licensed all give very similar first stages, (with correspondingly similar IV estimates of the effects of "enrollment in medical school," "completion of medical school," and "being licensed as a doctor"). We will therefore focus on completion of medical school.

For the interpretation of the estimated returns to medical school it is important to know which alternatives the lottery losers choose. Most lottery losers attend a study program in the Netherlands.[19] Only 5 percent of the lottery losers never register for higher education in the Netherlands. These individuals may not have enrolled in any study program or may have studied abroad. Of the lottery participants that do not enroll in medical school but do enroll for Dutch higher education, 32 percent enroll in a health-related field. Other regularly chosen fields are sciences (15 percent), social and behavioral sciences (15 percent), engineering (10 percent), economics (9 percent), and law (6 percent).

Lottery losers are 7 percentage points less likely to complete a study program. This may be due to the fact that medical schools have much lower dropout rates than other study programs. It is often argued that this is the consequence of the intensity of the study program at medical school (more workgroup classes and fewer exams). Lottery losers also have, on average, a lower ability (GPA), which may explain their lower graduation rate. This latter explanation is supported by results from a regression of having a diploma on dummies for the different lottery categories. Applicants in lottery category F are 7 percentage points less likely to obtain a diploma than applicants in lottery category B.

Table 3 shows descriptive statistics for several labor market outcomes. We focus on the following outcomes: earnings, working hours, and hourly earnings. Earnings are measured as the sum of before-tax income from employment, income from self-employment, income from abroad, and other income from labor. Earnings are observed annually for all residents in the Netherlands.[20] All amounts are corrected for the average wage development of university graduates over the observation period and converted to 2010 euros. Table 3 shows that earnings are, on average, around 39 percent higher for winners than for losers.

Information on working hours is only available for 2006 to 2010 and only for employed workers. We assume that self-employed workers have a full-time job (1,872 hours per year).[21] Average working hours are close to 1,700, but winners work approximately 4 percent more hours than losers. This difference is not sufficient to equalize hourly earnings, these are about 31 percent higher for winners.

Finally, the bottom part of the table shows descriptive statistics for the household situation in 2010. Winners of the lottery are more likely to be married and to have at least one child.

[19] Recall that enrollment for almost all study programs in the Netherlands is unlimited and unrestricted.

[20] The fraction of people that live abroad or died increases over time and is 6 percent in 2010. Given that this fraction is virtually identical for winners and losers Lee-bounds would be very narrow.

[21] In case a person has income both from employment and from self-employment we take a weighted average: hours worked = hours from employment + (income from self-employment/total income) × 1,872 hours.

III. Empirical Approach

To estimate the return to medical school we assume a linear relationship between the labor market outcome of individual i in year t who applied for the first time to medical school in year τ $(Y_{it\tau})$, and having completed medical school (D_i):

$$(1) \qquad Y_{it\tau} = \alpha_t + \gamma_{t-\tau} + \delta_{t-\tau} D_i + X_i \beta_{t-\tau} + LC_{i\tau} + U_{it\tau},$$

where $t - \tau$ indicates the number of years elapsed between the year of the first lottery and the year in which the outcome is observed. X_i is a vector of controls including gender, ethnicity, and age at first lottery; and $LC_{i\tau}$ is the interaction between lottery category and year of first lottery. α_t and $\gamma_{t-\tau}$ are fixed effects for the year in which the outcome is observed and the number of years since the first application. $U_{it\tau}$ is the error term. The parameters of interest are $\delta_{t-\tau}$, which describe the returns to medical school $t - \tau$ years after first applying. We estimate equation (1) separately for each year since the first lottery participation $(t - \tau)$.

If high-ability students self-select into medical school, the OLS estimator of $\delta_{t-\tau}$ will be biased. The lottery seems to solve this problem, but completing medical school remains potentially endogenous. Not all admitted students actually complete medical school, and lottery losers often reapply in subsequent years. Therefore, we instrument D_i with the result $(0/1)$ of the first lottery (LR_{1i}) in which individual i participated. We estimate a first-stage equation of the form

$$(2) \qquad D_i = \kappa_{t-\tau} + \lambda_{t-\tau} LR_{1i} + X_i \theta_{t-\tau} + LC_{i\tau} + V_{it-\tau}.$$

The identifying assumption is that conditional on X_i and $LC_{i\tau}$ the result in the first lottery is mean independent of $U_{it\tau}$: $E[U_{it\tau} | X_i, LC_{i\tau}, LR_{1i}] = E[U_{it\tau} | X_i, LC_{i\tau}]$. Recall from above that individuals have the same probability of being admitted conditional on year and lottery category. This conditional random assignment guarantees that the mean conditional independence assumption holds.

In equation (2), the parameter $\lambda_{t-\tau}$ reflects compliance, the difference in completion rates between winners and losers of the first lottery.[22] Compliance is not perfect for three reasons. First, not all winners of the first lottery enroll in medical school. Second, among those who enroll, not everybody completes medical school. And third, losers can still obtain a medical degree if they win a subsequent lottery. An interpretation of $\lambda_{t-\tau}$ is that it describes the fraction of compliers in the data, which are applicants for whom graduating from medical school is determined by the result of the first lottery.[23]

By estimating equation (1) separately for each year following the first lottery, we estimate how the earnings differential develops during the first 22 years after the first lottery. This period captures the longer study duration in medical schools

[22] Because we perform separate regressions for the number of years since the first lottery $(t - \tau)$, we also estimate for each value $t - \tau$ a separate λ.

[23] Hence, compliers are applicants who complete medical school after winning the first lottery and do not complete medical school after losing the first lottery. Note that the latter may also be the result of losing the first lottery, participate in a second (or higher) lottery, and also lose that lottery.

Table 4—Instrumental Variable Estimates of the Effects of Completing Medical School on Earnings $t - \tau$ Years after First Applying

			Earnings (× €1000)			
$t - \tau$	N	1st stage	IV	OLS	log(Earnings)	I[Earnings > Welfare]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	2,147	0.36 (0.02)***	−1.0 (0.3)***	0.0 (0.1)	−0.33 (0.15)**	−0.01 (0.02)
1	4,582	0.36 (0.01)***	−2.2 (0.3)***	−0.6 (0.1)***	−0.65 (0.12)***	−0.14 (0.02)***
2	7,125	0.37 (0.01)***	−0.5 (0.2)**	−0.6 (0.1)***	0.00 (0.08)	−0.06 (0.02)***
3	9,832	0.38 (0.01)***	0.1 (0.2)	−0.7 (0.1)***	0.08 (0.07)	0.01 (0.02)
4	12,372	0.39 (0.01)***	−1.2 (0.3)***	−1.6 (0.1)***	−0.16 (0.06)***	−0.03 (0.02)*
5	14,876	0.39 (0.01)***	−6.6 (0.3)***	−4.9 (0.2)***	−1.34 (0.07)***	−0.30 (0.02)***
6	17,069	0.39 (0.01)***	−10.1 (0.4)***	−9.6 (0.2)***	−1.30 (0.07)***	−0.33 (0.02)***
7	18,856	0.38 (0.01)***	10.8 (0.7)***	−7.8 (0.2)***	0.77 (0.06)***	0.28 (0.02)***
8	20,616	0.38 (0.01)***	19.2 (0.8)***	−1.6 (0.1)***	0.85 (0.05)***	0.31 (0.02)***
9	22,094	0.38 (0.01)***	13.1 (0.7)***	2.7 (0.3)***	0.52 (0.03)***	0.20 (0.01)***
10	23,396	0.38 (0.01)***	9.4 (0.6)***	4.8 (0.3)***	0.35 (0.03)***	0.11 (0.01)***
11	24,759	0.38 (0.01)***	7.4 (0.7)***	5.2 (0.3)***	0.22 (0.02)***	0.09 (0.01)***
12	22,531	0.38 (0.01)***	7.4 (0.8)***	5.3 (0.3)***	0.23 (0.02)***	0.06 (0.01)***
13	20,054	0.39 (0.01)***	9.0 (0.9)***	6.6 (0.4)***	0.24 (0.02)***	0.06 (0.01)***
14	17,519	0.39 (0.01)***	11.1 (1.2)***	9.0 (0.5)***	0.25 (0.03)***	0.05 (0.01)***
15	14,855	0.39 (0.01)***	15.9 (1.6)***	13.4 (0.6)***	0.31 (0.03)***	0.05 (0.01)***
16	12,386	0.38 (0.01)***	24.7 (2.2)***	18.9 (0.8)***	0.34 (0.03)***	0.06 (0.01)***
17	9,932	0.39 (0.01)***	29.0 (2.7)***	26.2 (1.0)***	0.40 (0.04)***	0.05 (0.01)***
18	7,799	0.39 (0.01)***	30.0 (3.6)***	32.3 (1.3)***	0.39 (0.05)***	0.03 (0.02)**
19	6,050	0.40 (0.01)***	42.0 (4.1)***	39.4 (1.6)***	0.54 (0.06)***	0.04 (0.02)**
20	4,300	0.41 (0.02)***	41.4 (5.3)***	42.5 (2.1)***	0.49 (0.07)***	0.00 (0.02)
21	2,779	0.41 (0.02)***	42.3 (6.9)***	49.6 (2.5)***	0.45 (0.08)***	0.02 (0.03)
22	1,425	0.45 (0.03)***	39.4 (7.3)***	39.0 (3.0)***	0.48 (0.12)***	0.05 (0.04)

Notes: Standard errors are in parentheses. The total number of individuals is 25,393. Every cell in this table represents a separate regression, which include controls for gender, ethnicity, age in the first lottery year, lottery category, year of first lottery, and interaction terms of the year of first lottery and lottery category.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

compared to alternative studies, and thereby an estimate of the opportunity costs of the longer investment in human capital.

IV. The Return to Medical School

This section presents and discusses estimates of the effect of medical school on (log) annual earnings. We perform our regressions separately by year after the first lottery $(t - \tau)$, which implies that each regression uses different subsamples. Table 4 reports the estimation results for earnings and log earnings as the outcome variables. The second column reports the number of observations in each regression and shows how this varies across rows. The final row $(t - \tau = 22)$ is only based on 2010 earnings information of people who first applied in 1988. The penultimate row is based on 2010 earnings information of people who first applied in 1989 and on 2009 earnings information of people who first applied in 1988, and so on. Because the admission lotteries in our sample end in the same year in which the earnings data start (1999), the estimates in the first row are also based on just a single cohort.

The first-stage regression describes the effect of winning the first lottery on the probability to complete medical school. The third column reports first-stage estimates. The first-stage estimates are highly significant (the F-statistic is never below

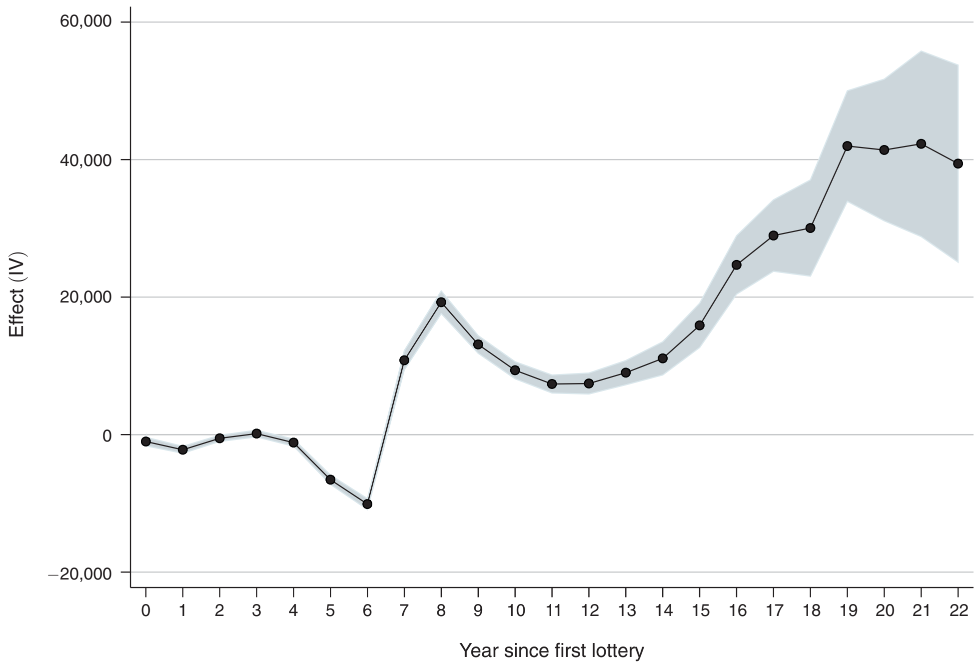

Figure 2. Instrumental Variable Estimates of the Effects of Completing Medical School on Earnings $t - \tau$ Years after First Applying (*colored area is 95 percent confidence interval*)

290) and are all close to 0.39. So winning the first lottery increases the probability to complete medical school with around 39 percentage points.

The fourth column of Table 4 presents the instrumental variable estimates of the effect of completing medical school on annual earnings (in thousands of euros). The estimates are also plotted in Figure 2. During the first six years after the first lottery, the effect is negative or close to zero. The small negative effect during the first four years can be attributed to two factors. First, students who are not in medical school more often have a small job while studying than medical school students. Second, some people that are not admitted to medical school will decide to work rather than to study. In the fifth and the sixth year after first applying the negative effect of medical school on earnings is more substantial. This reflects that most alternative studies have a shorter duration than the six years required for medical school. Individuals who do not attend medical school enter the labor market earlier and start receiving income earlier than individuals attending medical school. The negative earnings effects in the fifth and sixth years express the opportunity cost of the larger investment in human capital of people who complete medical school.

The picture reverses from the seventh year onward when students from medical school graduate and start earning, either in the labor market or while being employed in a specialization track. From then on the returns to medical school are always positive and significant. After a big jump in years seven and eight, the earnings differential remains positive but decreases until the twelfth year; the 19,000 euro per year difference in the eighth year reduces to less than half of that in the twelfth year. During that period many students from medical school are in specialization tracks.

Starting wages in specialization tracks are relatively high but hardly rise while being in the track. From the twelfth year onward, students from medical school finish their specialization track and begin working as a (self-employed) specialist or GP. The earnings difference increases again and eventually amounts to almost 40,000 euro per year in the twenty-second year.

Column 5 presents results from a simple OLS-regression of equation (1) (still using the sample of applicants for medical school). This estimation procedure does not take repeated lottery participation into account. Compared to the instrumental variable estimates the pattern of the returns is, therefore, less in line with the time path of medical schools. However, the returns are still negative in the first years and large and positive in the later years.

The sixth column of Table 4 shows results for the effect of medical school on the logarithm of earnings, conditional on having positive earnings. The observed pattern is very similar to the pattern for the level of earnings (which includes zeros). During the first six years after the lottery, medical school graduates have lower log earnings than they would have had without a medical degree, and this reverses in the seventh year. From the eleventh year, the return steadily increases up to 0.54 in the nineteenth year. From then on it remains stable around 0.50; in the last year covered by the data the return is 0.48.

The final column shows the effect of medical school on the probability of having earnings above the level of welfare benefits. In the fifth and sixth year after the first lottery, students in medical school have not yet entered the labor market. Therefore, they are less likely to earn above the level of welfare benefits than those not in medical school. But this reverses in the seventh year after the first lottery. The effect is particularly large seven to nine years after the first lottery. While most students from medical school find (full-time) work immediately after graduating, other students need more time to find stable employment. From year ten onward, medical school graduates are around 6 percentage points more likely to have earnings above the level of welfare benefits than other students, relative to a base of 0.91.

In Figure 3, we show the predicted earnings profiles for an average individual with and without completion of medical school. We compute the expected earnings using

$$Y_{it\tau} \times D_i = \alpha_t + \gamma_{t-\tau} + \delta_{1,t-\tau} D_i + X_i \beta_{t-\tau} + LC_{i\tau} + U_{it\tau} \tag{3}$$

$$Y_{it\tau} \times (1 - D_i) = \alpha_t + \gamma_{t-\tau} + \delta_{0,t-\tau}(1 - D_i) + X_i \beta_{t-\tau} + LC_{i\tau} + U_{it\tau}, \tag{4}$$

where both D_i in equation (3) and $1 - D_i$ in equation (4) are instrumented using the result of the first lottery (LR_i). The coefficient $\delta_{1,t-\tau}(\delta_{0,t-\tau})$ gives the expected earnings of an average individual with (without) completion of medical school, $\hat{Y}_{1,t-\tau}(\hat{Y}_{0,t-\tau})$. In the figure, we assume that individuals first apply to medical school at age 18. The two expected earnings profiles are indicated by the two lines in the graph that end at age 40 (since we have data for at most 22 years after the first application).

To get an idea how these earnings profiles evolve until retirement, we also plot rescaled average wage profiles of medical school graduates and other university

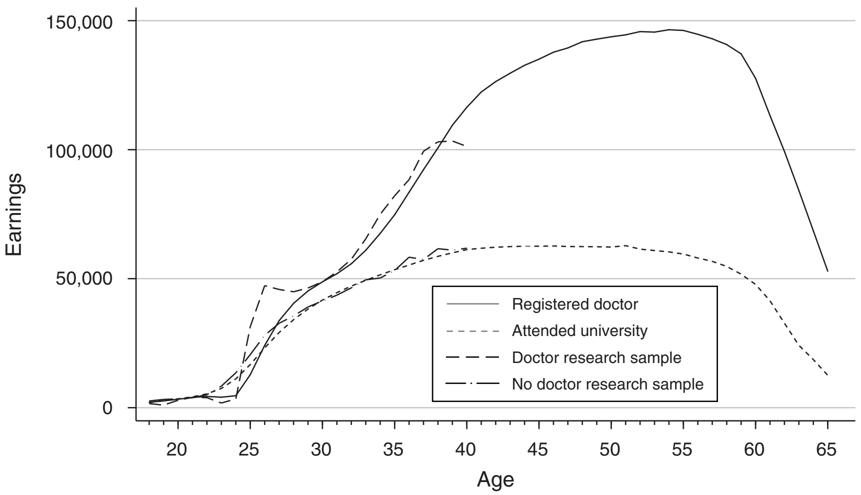

Figure 3. Predicted Counterfactual Earnings Levels

attenders, where the latter serves as reference group for the "nondoctors."[24] We regress the observed average wage profile of medical school graduates on the predicted wage profile for the years in which we observe both, to obtain the scaling factor. We repeated this exercise for other university attenders and nondoctors. The wage profiles show that while being in medical school, students earn less than if they would have attended another study, or started to work immediately. At the age of 24, after they have finished medical school, they start earning substantially more and remain to do so for the rest of their career. We can only make causal inferences on the effect of completing medical school up to 22 years after participating in the first lottery, but the fitted earnings profiles suggest that the earnings difference is still increasing in the remaining years of the career.

We calculated net present values from completing medical school relative to the next-best alternative for a representative individual. For the first 22 years the estimated differences from Table 4 are used, so this takes the opportunity cost of the longer study period and of the two years of unpaid residencies into account. We assume that in addition to the 22 years since the first lottery that were already estimated, an average career lasts another 24 more years. For the earnings difference in the remaining years we use the difference between the two rescaled wage profiles from Figure 3. At a discount rate of 0.02 this gives a net present value of more than one million euros (1,187,656), while at a discount rate of 0.05 the net present value is still more than half a million euros (506,531). The internal rate of return equals 36 percent.

[24] We have information on all registered doctors in the Netherlands so we can plot their earnings profile until the (retirement) age of 65. The wage profile for other university attenders is the average wage profile of all people for whom it is registered that they attended university and weighted using sampling probabilities. We do not have information on retirement benefits, so we can only take account of earnings while being active on the labor market.

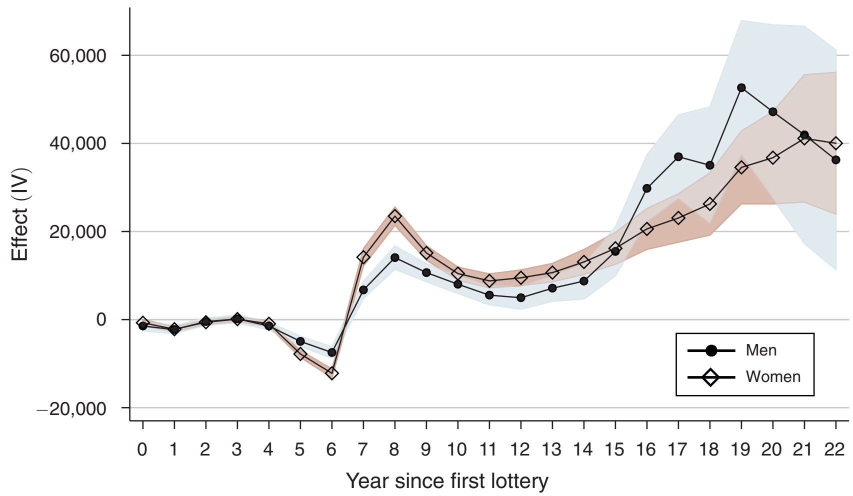

Figure 4. IV Estimates of Effects of Medical School Completion on Earnings, by Year since First Lottery and Gender (*colored areas are 95 percent confidence intervals*)

V. Heterogeneous Treatment Effects

We now turn to heterogeneity in the returns to medical school. We first examine whether returns differ between men and women. While less than half of the university students are female in the Netherlands during the period 1988–1999, women form the majority in medical schools (58 percent is female during our observation period). This raises the question whether women have a comparative advantage in medical school. Next, we investigate whether returns differ by ability. As described in Section I, the admission lottery uses weights based on applicants' GPA on secondary school exams. Applicants with a higher GPA have a higher probability of being admitted. This system of a weighted admission lottery justifies the question whether the available places are allocated efficiently. Finally, we study variation in returns over the earnings distribution. This is motivated by the concern often expressed by policy makers, that some medical specializations pay very high wages.

Gender.—Figure 4 shows the estimates of the earnings returns separately for men and women.[25] Until the sixth year both men and women experience an earnings loss from studying in medical school. This loss is very similar across genders. In years 7 to 14, the returns are larger for women than for men, but from year 15 onward men catch up and in the final years the returns to medical school are slightly larger for men than for women.

Figure 5 repeats Figure 3 by showing predicted earnings profiles, but now for men and women separately. These graphs reveal two important facts. First, while the estimated returns to medical school for men and women are very similar, earnings levels are much higher for men than for women. Female doctors earn more or less the

[25] Table A3 in the Appendix reports the results.

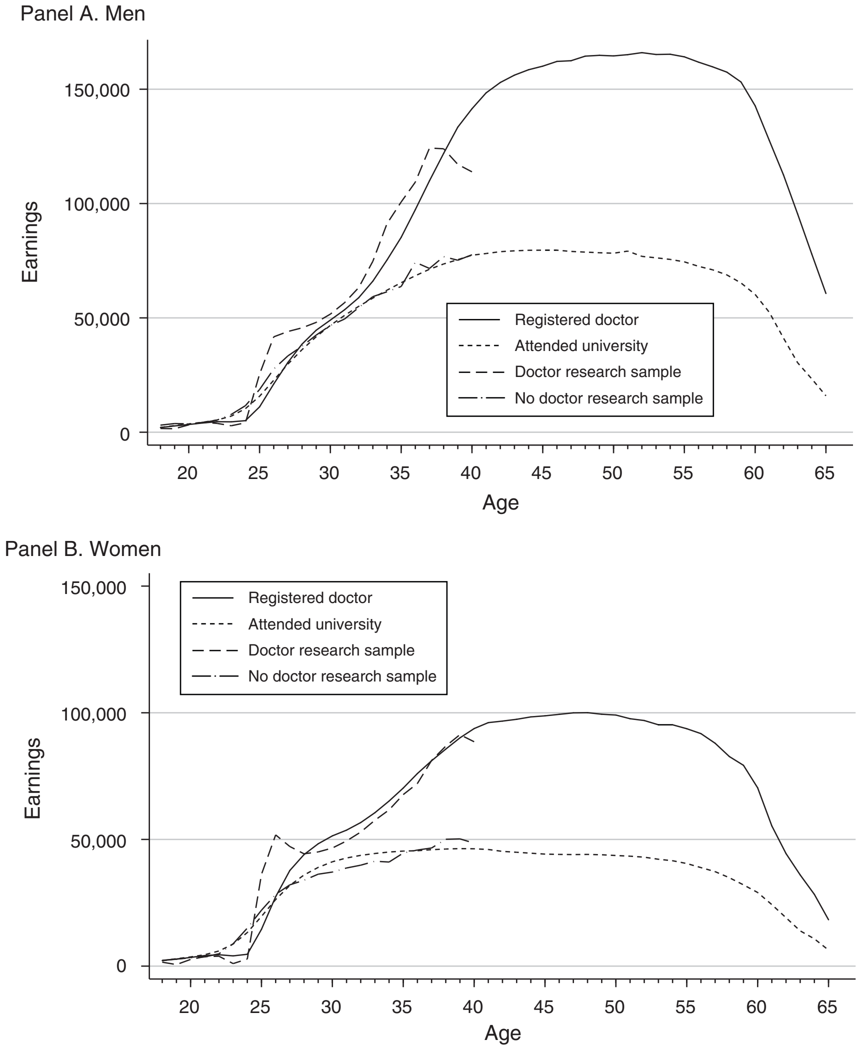

Figure 5. Predicted Counterfactual Earnings Levels by Gender

same as male nondoctors. Second, while the age-earnings profile for female doctors seems to flatten out after age 40, the extrapolation of the age-earnings profile for male doctors suggests that their earnings will still increase sharply between age 40 and 45. While this result is somewhat more tentative because it is based on our extrapolation, it is consistent with a larger fraction of male doctors being medical specialists.

Calculation of net present values of completion of medical school gives, at a discount rate of 0.02, a value of 1.3 million euros for men and 0.83 million euros for women. At a discount rate of 0.05 these amounts are 0.54 and 0.38 million euros. The internal rates of return are 33 percent for men and 38 percent for women.

Ability.—The lottery gives applicants with a higher GPA on their secondary school exams a higher probability to be admitted. This justifies the question whether

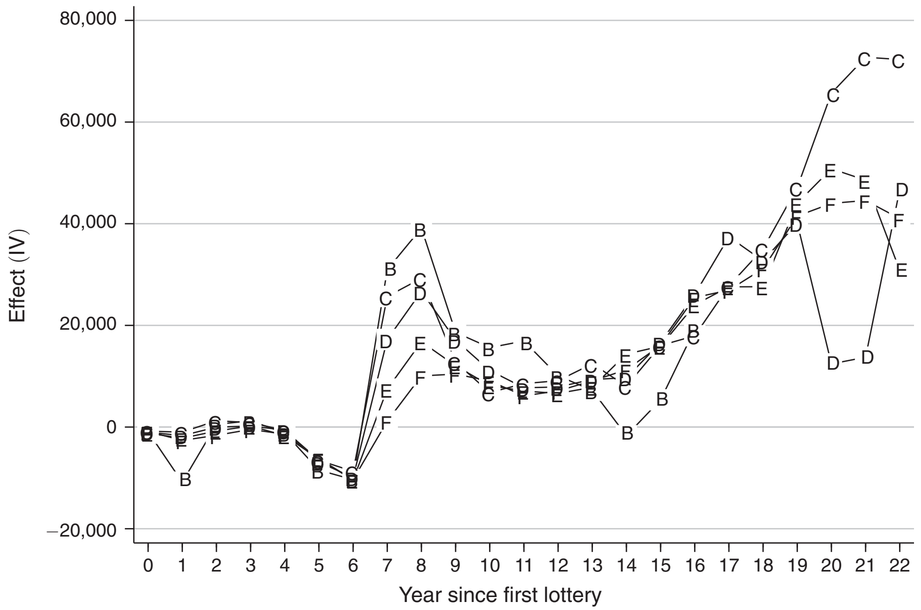

Figure 6. IV Estimates of Effects of Medical School Completion on Earnings, by Year since First Lottery and Lottery Category

there is a difference in earnings gain between people with different GPAs. To examine this, we estimated earnings returns by year after first lottery separately for lottery categories B to F.[26] Figure 6 reports the results.[27] The estimates for the early and late years of categories B, C, and D are not very precise due to small sample sizes. The results show that the returns are very similar for the different lottery categories with exception of the seventh and eighth year. In these years, returns are higher for the higher GPA categories. This is probably driven by applicants with a higher GPA finishing medical school earlier. If we regress time until diploma on lottery category (conditional on winning the first lottery), we find that students in category F study, on average, half a year longer than students in category B.

As soon as all students have entered the labor market, the returns are very similar for the different lottery categories. We do find that the proportion of applicants that become a specialist increases with GPA. Conditional on completing medical school, the percentage of specialists decreases monotonically from 59 percent in category B to 42 percent in category F. That we do not find differences in the returns for the different lottery categories is driven by the worse outside opportunities that applicants in the lower lottery categories face. Conditional on winning the first lottery, applicants in category F have an 11 percentage points lower probability to complete a degree than applicants in category B. Conditional on losing the first lottery, this difference is 26 percentage points.

If earnings reflect productivity accurately (both in the medical profession and in the second-best professions) and if applicants' GPAs do not respond to changes in

[26] Recall that category A is omitted since there are so few lottery losers in this category.
[27] The results can also be found in Table A4 in the Appendix.

the probabilities to be admitted, this implies that there is no clear support for a system in which only students with the highest GPA are selected. The only advantage is that applicants with a high GPA finish their studies somewhat faster than students with a low GPA.

Our dataset does not include students' exact GPAs, only their GPA categories, which are used to determine the lottery weights. Due to this we cannot apply a regression discontinuity approach and assess the difference between RD-estimates and estimates based on admission lotteries. However, the fact that the estimates of the returns to medical school are very similar across GPA categories indicates that RD estimates would not have been much different from the results we present. This suggests that RD estimates as reported by Hastings, Neilson, and Zimmerman (2013) and Kirkebøen, Leuven, and Mogstad (forthcoming) could be informative about returns to a larger group of students and not only about returns to a specific group of compliers.

Distributional Impact.—The common view about the remuneration of doctors in the Netherlands (and elsewhere) is that especially medical specialists are highly paid. The figures about the relative pay of GPs and specialists reported in Section I, confirm this. This suggests that the earnings gain is distributed unequally across the earnings distribution. To inquire this further we estimate the marginal distribution of the outcome under different treatments for the subpopulation of compliers, following Imbens and Rubin (1997).[28]

Figure 7 plots the estimated earnings distributions for winning and losing compliers 12, 16, 18, and 20 years after the first lottery. We see that in all these years after the first lottery the distribution of winning compliers has less mass at low incomes than the distribution for losing compliers. After 12 years there is very little dispersion in winning compliers' earnings. This is the time when they do their specialization tracks in which wages are fixed. After 16 years most winning compliers will have finished their specialization track, and the density function of the winning compliers has a similar shape, but is shifted to the right compared to the losing compliers. After 18 years the earnings of winning compliers are more dispersed and the right tail of the winning compliers becomes much fatter, which implies that there are more top earners among the winning compliers. This is even more pronounced after 20 years. These figures show that the earnings gains from medical school that we found in Section IV are not only driven by high gains in the top end of the distribution. Among the winning compliers there are always fewer people who have zero earnings, and the distribution of winning compliers is to the right of the distribution of losing compliers.

VI. Mechanisms

In this section, we discuss possible pathways for the high returns to medical school that we have documented. The possible pathways that we consider are: working hours, human capital investments, sacrifices in family life, and monopoly rents.

[28] Their method is briefly explained in Appendix B.

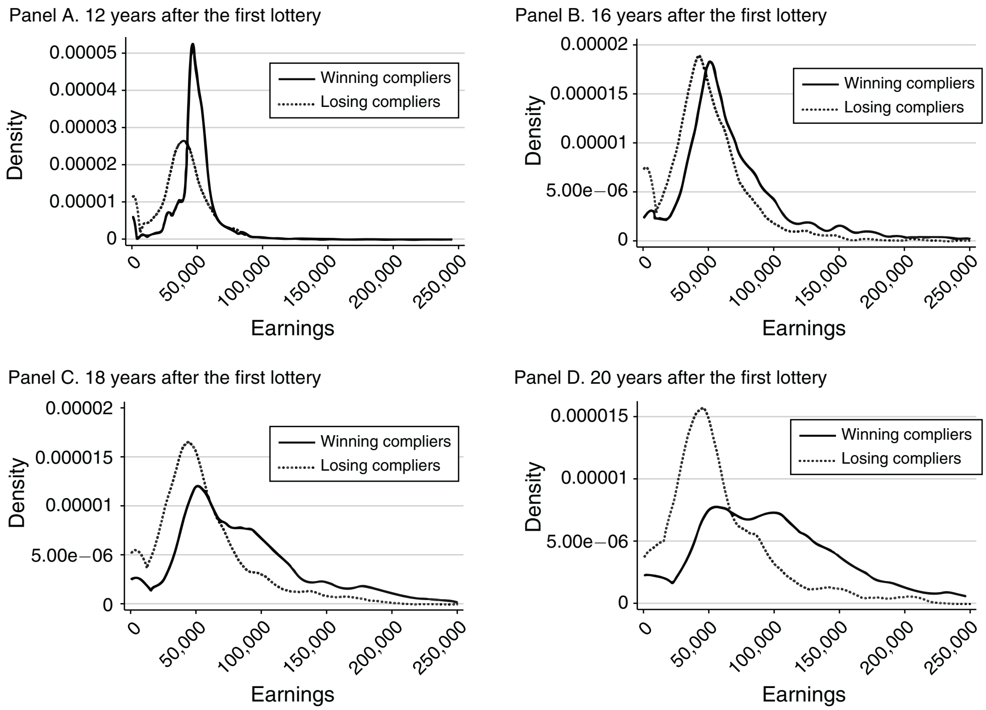

FIGURE 7. EARNINGS DISTRIBUTION OF WINNING AND LOSING COMPLIERS

Hours.—It is often argued that doctors make longer working hours, which could explain (part of) the earnings return. Panel A of Figure 8 reports estimates where annual working hours is the dependent variable. Information about hours is only available for the years 2006 until 2010, and therefore only for the seventh to twenty-second year after the first lottery. The results reveal that doctors work more hours during the first four years after finishing the initial phase of their study. During these 4 years doctors work a total of 1,240 hours more than nondoctors. The average number of working hours during these 4 years together is around 6,600 hours, so that doctors work around 19 percent more than those that did not complete medical school. After these first 4 years doctors work about 120 hours more per year than nondoctors. Compared to a baseline of 1,700 hours, this is a 7 percent difference. Differences in working hours can therefore not explain the large earnings gain to medical school.[29] This is confirmed by the results in panel B of Figure 8, where log earnings per hour is the dependent variable. The effect on log earnings per hour

[29] The estimated effect on hours is downward biased if self-employed doctors work more hours than the 1872 hours that we imputed for them. This is unlikely to be the case. Leuven, Oosterbeek, and de Wolf (2013) conducted a survey among around 60 percent of the people that applied to medical school in the period 1988–1993. One of the survey questions asked about actual working hours per week. Their 2SLS estimate of the effect of medical school on the log of hours worked per week equals 0.080 (s.e. 0.019), which is close to our estimates. They find no significant effect on the probability of working more than 60 hours per week (estimate 0.018, s.e. 0.018).

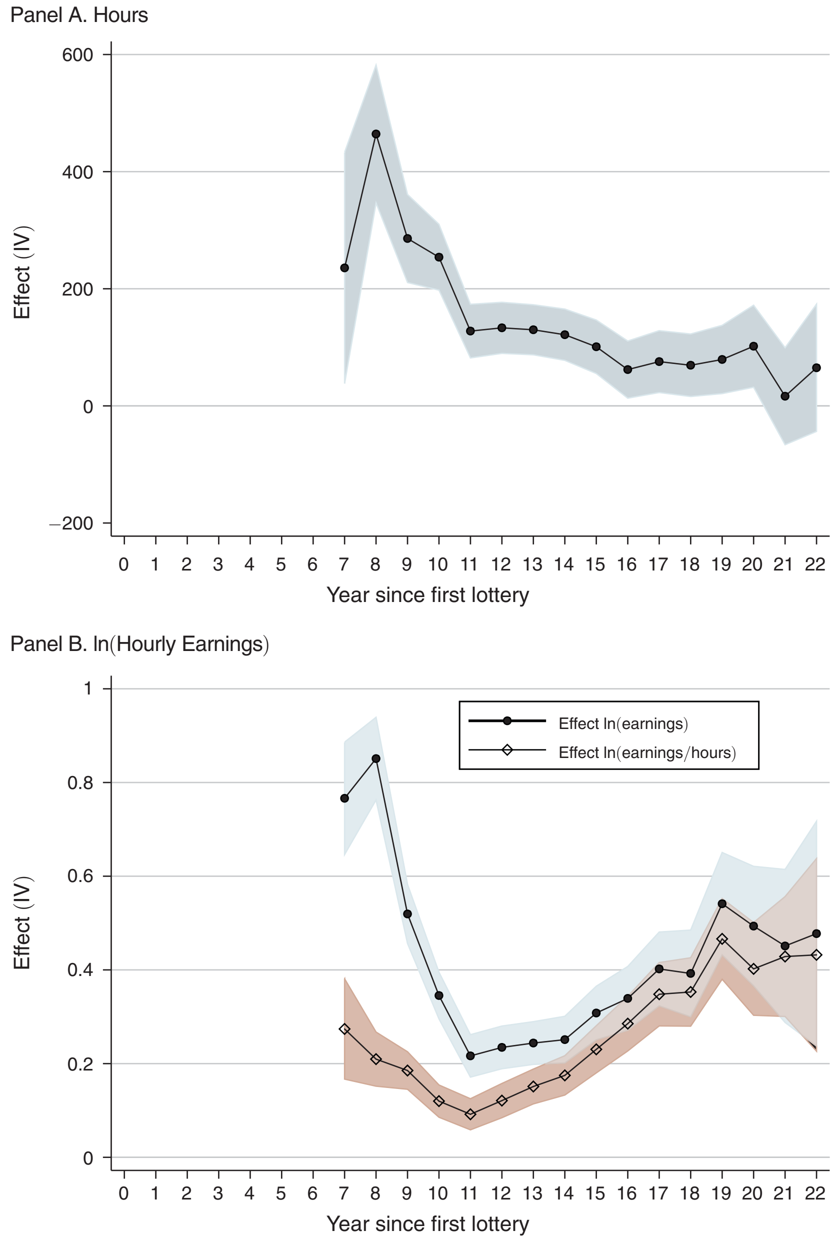

Figure 8. Instrumental Variable Estimates of the Effects of Completing Medical School on Hours and (ln)Hourly Earnings $t - \tau$ Years after First Applying (*colored areas are 95 percent confidence intervals*)

is only marginally smaller than the effect on log earnings. From the eleventh year onward, the gain in the log of per hour earnings increases to 0.43.[30]

Figure 9 shows results for differential effects of medical school effects on working hours by gender. This shows that from the seventh to the tenth year after the first

[30] Calculation of predicted hours for an average individual with and without medical school reveals that the large effects in years seven to nine are mainly driven by the fact that doctors more often have a full-time job.

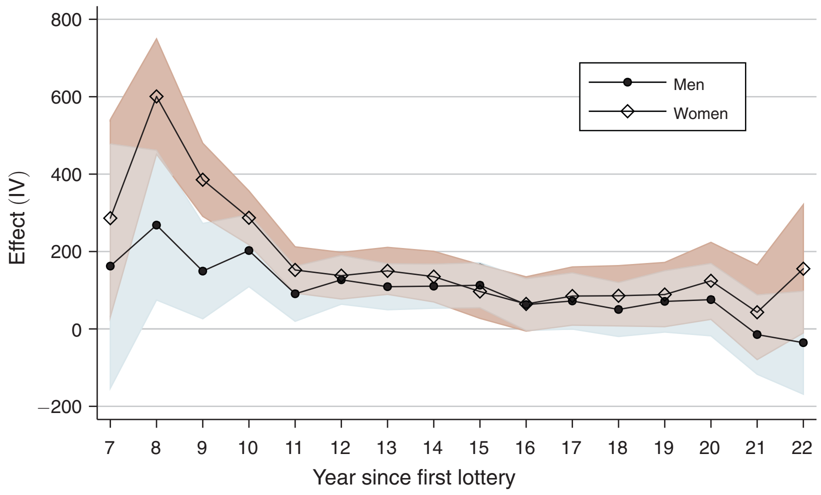

Figure 9. IV Estimates of Effects of Medical School Completion on Hours, by Year since First Lottery and Gender (*colored areas are 95 percent confidence intervals*)

lottery, doctors work longer hours than nondoctors of the same gender. The difference is larger for women than for men, although the effects are not significantly different from each other. The effects on hours disappear after the tenth year, and later in their career male doctors even work fewer hours than male nondoctors.

Human Capital Investments.—After the completion of medical school, winning compliers possess a different set of knowledge and skills than compliers who lost the lottery. It is not possible to assess what share of the return to medical school should be attributed to the specific knowledge and skills bundle without detailed information on peoples' human capital. We do, however, have information about the opportunity costs of the different human capital acquisition. Because we have estimated effects of medical school on annual earnings starting in the year of the first lottery, the estimates also cover the period that applicants were enrolled in (medical) school.

Inspection of Table 4 and Figure 2 reveals that winning compliers have lower annual earnings than losing compliers until six years after the first lottery, but the differences are modest and completely wiped out by the substantially higher earnings for winning compliers in later years. This is also reflected in the net present values and internal rates of return that we reported above.

Family Outcomes.—To assess whether the high earnings of doctors are a compensating differential for large sacrifices in their personal life, we look at the impact of completing medical school on the probabilities of being married and having children (both measured in 2010). Being less likely to be married or to have children may signal restrictions in the possibility to build a family life.[31] Our 2SLS estimates

[31] This assumes that being married and having children represent voluntary choices, while being single or not having children may not.

point in the opposite direction. Completion of medical school increases the probability of being married by 5 percentage points (s.e. 2 percentage points) and the probability of having children by 8 percentage points (s.e. 2 percentage points).

The impact of medical school on family outcomes are somewhat more favorable for men than for women. For women there is no significant impact on being married, while for men there is a significant 9 percentage points impact on being married (s.e. 3 percentage points). Medical school raises the probability to have children by 5 percentage points for women and by 12 percentage points for men (both with a s.e. of 2 percentage points).

Monopoly Rents.—The quota that the Dutch government sets on the inflow into medical schools and the restrictions that apply to medical doctors from other countries restrain the supply of medical doctors in the Netherlands. Whether the supply restriction results in a monopoly rent depends on the elasticity of the demand for doctors and on what the equilibrium number of doctors would have been. The demand for health care services is considered to be rather inelastic, with price elasticities around -0.2 (e.g., Liu and Chollet 2006), while the estimates in the final column of Table 2 indicate that an oversupply of doctors is unlikely. Two necessary conditions for supply restrictions to lead to monopoly rents are therefore satisfied. Suggestive evidence for this pathway is presented by Fujisawa and Lafortune (2008) who plot country averages of the remuneration of GPs and specialists against country averages of the numbers of GPs and specialists per 1,000 inhabitants. For specialists (but not for GPs) there is a clear negative correlation: the lower the density of specialists in a country the higher their pay levels. We acknowledge, however, that our research design does not provide any direct proof of the importance of monopoly rents for the returns to medical school.

VII. Conclusion

Our empirical results provide evidence of substantial earnings returns to medical school. In each year after graduating these returns are at least 20 percent compared to the second-best study, and the returns increase to almost 50 percent 22 years after first applying to medical school. Only a small part of this earnings difference can be attributed to differences in working hours or more investment in human capital. In combination with the finding that the returns are large for all GPA categories, this suggests that monopoly rents are the more likely explanation for the large returns to medical school in the Netherlands.

Releasing the quota might reduce the returns to medical school. If we assume that earnings in the applicant's next-best option are not influenced by a release of the quota, such a release can reduce doctors' earnings to the level in their next-best option.[32] Releasing the quota is costly in a situation in which the government

[32] Earnings levels in applicants' next-best option will be affected if releasing the quota significantly reduces labor supply in these sectors. In most alternative fields in which rejected medical school applicants apply they form only a small proportion of the total amount of students (for example law or psychology), so this is not likely to be the case.

heavily subsidizes study costs, as is currently the case in the Netherlands. The costs of attending medical school are much higher than the costs of other study programs. The total costs of attending medical school are estimated to be at least 167,000 euros compared to an average amount of 55,000 euros for other university study programs (Houkes-Hommes 2009).[33] Students pay only a tuition fee of around 1,000 euros per year, which is not differentiated across studies. Furthermore, the majority of the medical school students starts a specialization track. The costs of a specialization track are completely covered by the government and range from 40,000 to 145,000 euro.[34]

Releasing the quota may not only increase public expenditures on university education, but it is often argued that due to supplier-induced demand health care costs also may increase. However, one might question whether the coexistence of high private returns and high public investment is desirable. Policy makers can either consider to set a cap on the earnings levels of medical professionals or shift part of the study costs to students by raising tuition fees. Our results suggest that there is sufficient scope for medical school students in the Netherlands to pay higher tuition fees. This might also allow the government to increase the number of available places without increasing public expenditures. At the same time higher tuition fees can reduce the number of applicants for medical school. An increase in the supply of doctors and the resulting reduction of their earnings will also reduce the number of applicants.

[33] Part of the difference in costs reflects the fact that medical school takes longer than the alternative study programs.

[34] The specialization tracks are an exception among other post-graduate programs; in most cases the government does not bear the (full) costs of post-graduate education.

Appendix

A. *Tables*

Table A1—Fraction *p* Admitted and Number of Applicants *N* by Year and Lottery Category (A–F)

Year	A	B	C	D	E	F	Total
	p (*N*)	*p* (*N*)	*p* (*N*)	*p* (*N*)	*p* (*N*)	*p* (*N*)	*p* (*N*)
1988	1.00	1.00	0.89	0.75	0.62	0.54	0.67
	(29)	(96)	(179)	(495)	(537)	(749)	(2,085)
1989	1.00	1.00	0.96	0.80	0.66	0.58	0.71
	(30)	(84)	(158)	(429)	(531)	(697)	(1929)
1990	1.00	1.00	0.87	0.71	0.59	0.51	0.64
	(36)	(111)	(194)	(468)	(571)	(746)	(2,126)
1991	1.00	0.89	0.76	0.63	0.50	0.43	0.56
	(41)	(130)	(201)	(547)	(649)	(881)	(2,449)
1992	1.00	0.84	0.72	0.59	0.48	0.42	0.53
	(51)	(113)	(235)	(600)	(689)	(1,036)	(2,724)
1993	0.93	0.72	0.62	0.51	0.41	0.36	0.45
	(44)	(167)	(241)	(702)	(847)	(1,299)	(3,300)
1994	0.89	0.69	0.58	0.48	0.39	0.33	0.43
	(61)	(208)	(389)	(905)	(1,034)	(1,331)	(3,928)
1995	0.80	0.62	0.51	0.41	0.34	0.31	0.39
	(88)	(265)	(430)	(982)	(1,024)	(1,402)	(4,191)
1996	0.74	0.58	0.48	0.39	0.32	0.27	0.36
	(97)	(283)	(494)	(1,084)	(1,119)	(1,496)	(4,573)
1997	0.72	0.54	0.45	0.37	0.31	0.26	0.35
	(117)	(310)	(498)	(1,114)	(1,129)	(1,486)	(4,654)
1998	0.75	0.56	0.50	0.39	0.32	0.28	0.37
	(106)	(332)	(492)	(1,121)	(1,041)	(1,325)	(4,417)
1999	1.00[a]	1.00[a]	0.52	0.42	0.33	0.29	0.43
	(87)	(341)	(421)	(1,025)	(898)	(1,146)	(3,918)
Total	0.86	0.73	0.59	0.49	0.41	0.36	0.46
	(787)	(2,440)	(3,932)	(9,472)	(10,069)	(13,594)	(40,294)

[a] In 1999 a reform was implemented which implied that from that year on applicants with a GPA above 8 (category A and B) are automatically admitted.

Table A2—Quality Measures of the Universities Providing Medical Education

University	Mean GPA first preference	Keuzegids 2011		Elsevier 2014	
		Points	Rank	Points	Rank
1	6.89	72	4	64	2
2	6.94	70	7	61	4
3	6.91	74	3	65	1
4	6.95	72	4	59	5
5	6.95	70	8	64	2
6	6.89	72	4	55	7
7	6.89	78	1	53	8
8	6.92	78	1	58	6

TABLE A3—IV ESTIMATES OF EFFECTS OF MEDICAL SCHOOL COMPLETION ON EARNINGS AND HOURS, BY YEAR SINCE FIRST LOTTERY AND GENDER

	Earnings (× €1,000)		Hours	
$t - \tau$	Men	Women	Men	Women
0	−1.5 (0.6)***	−0.7 (0.4)*		
1	−2.3 (0.5)***	−2.2 (0.3)***		
2	−0.5 (0.4)	−0.6 (0.3)**		
3	0.2 (0.5)	0.1 (0.3)		
4	−1.5 (0.4)***	−1.0 (0.3)***		
5	−5.0 (0.6)***	−7.8 (0.4)***		
6	−7.5 (0.7)***	−12.2 (0.5)***		
7	6.7 (1.0)***	14.2 (1.0)***	162 (161)	286 (130)**
8	14.1 (1.3)***	23.5 (1.1)***	268 (99)***	601 (76)***
9	10.7 (1.0)***	15.1 (0.8)***	149 (63)**	385 (48)***
10	8.0 (1.1)***	10.4 (0.8)***	203 (48)***	287 (35)***
11	5.5 (1.1)***	8.8 (0.8)***	91 (36)**	152 (31)***
12	5.0 (1.3)***	9.5 (0.9)***	127 (32)***	138 (31)***
13	7.1 (1.5)***	10.7 (1.1)***	109 (30)***	150 (31)***
14	8.7 (2.1)***	13.1 (1.4)***	110 (29)***	135 (33)***
15	15.5 (2.8)***	16.2 (1.8)***	113 (30)***	97 (35)***
16	29.8 (3.9)***	20.6 (2.4)***	63 (34)*	65 (36)*
17	37.0 (4.9)***	23.1 (2.8)***	72 (37)*	85 (38)**
18	35.0 (6.8)***	26.3 (3.6)***	50 (36)	86 (40)**
19	52.6 (7.8)***	34.6 (4.2)***	71 (40)*	89 (42)**
20	47.2 (10.1)***	36.8 (5.3)***	76 (48)	124 (51)**
21	41.9 (12.6)***	41.1 (7.4)***	−15 (52)	43 (62)
22	36.3 (12.7)***	40.0 (8.2)***	−36 (68)	155 (85)*

Notes: Standard errors are in parentheses. The total number of individuals is 25,393, of which 10,569 are men and 14,824 are women. Every cell in this table represents a separate regression, which includes controls for ethnicity, age in the first lottery year, lottery category, year of first lottery, and interaction terms of the year of first lottery and lottery category.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

TABLE A4—IV ESTIMATES OF EFFECTS OF MEDICAL SCHOOL COMPLETIONS ON EARNINGS (× €1,000), BY YEAR SINCE FIRST LOTTERY AND LOTTERY CATEGORY

$t - \tau$	B	C	D	E	F
0	−0.9 (1.5)	−0.8 (0.9)	−1.0 (0.5)**	−1.2 (0.5)**	−0.9 (0.7)
1	−10.8 (5.9)*	−1.0 (0.8)	−1.7 (0.5)***	−2.2 (0.4)***	−2.6 (0.5)***
2	0.5 (1.2)	1.2 (0.7)*	0.0 (0.4)	−0.8 (0.4)*	−1.6 (0.5)***
3	1.2 (1.6)	0.9 (0.6)	0.2 (0.4)	0.2 (0.4)	−0.5 (0.5)
4	−1.2 (1.1)	−0.7 (0.7)	−0.6 (0.5)	−1.7 (0.5)***	−1.4 (0.6)**
5	−8.5 (1.8)***	−6.5 (1.0)***	−6.9 (0.7)***	−6.3 (0.6)***	−6.2 (0.6)***
6	−10.4 (2.1)***	−8.7 (1.3)***	−10.0 (0.8)***	−10.4 (0.7)***	−10.3 (0.7)***
7	31.0 (5.1)***	25.7 (3.0)***	17.2 (1.5)***	7.5 (1.3)***	1.2 (1.1)
8	39.1 (5.5)***	29.3 (3.0)***	26.7 (1.6)***	16.8 (1.8)***	10.1 (1.3)***
9	18.6 (4.1)***	12.8 (2.2)***	17.1 (1.3)***	12.1 (1.2)***	10.4 (1.1)***
10	15.6 (4.0)***	6.8 (2.0)***	11.1 (1.2)***	8.2 (1.2)***	9.1 (1.1)***
11	16.9 (4.4)***	8.5 (2.3)***	7.7 (1.4)***	7.1 (1.3)***	6.1 (1.1)***
12	10.1 (5.3)*	9.1 (2.8)***	7.9 (1.5)***	6.6 (1.5)***	7.1 (1.3)***

(*continued*)

Table A4—IV Estimates of Effects of Medical School Completions on Earnings (× €1,000), by Year since First Lottery and Lottery Category (*continued*)

$t - \tau$	B	C	D	E	F
13	7.2 (6.7)	12.4 (3.3)***	9.4 (1.9)***	7.8 (1.6)***	9.1 (1.4)***
14	−1.7 (10.5)	8.0 (4.5)*	9.7 (2.6)***	14.4 (2.2)***	11.3 (1.9)***
15	5.3 (14.5)	16.0 (7.0)**	16.6 (3.7)***	15.9 (2.9)***	16.1 (2.4)***
16	19.2 (17.4)	18.0 (10.5)*	26.1 (4.8)***	24.0 (3.7)***	25.5 (3.4)***
17	2.6 (31.4)	27.8 (10.7)***	37.4 (6.9)***	27.6 (4.6)***	26.9 (3.8)***
18	−124.1 (229.0)	35.1 (14.5)**	32.7 (9.1)***	27.6 (6.8)***	31.2 (4.7)***
19		47.1 (13.9)***	40.1 (11.8)***	44.0 (7.1)***	41.5 (5.5)***
20		65.7 (18.6)***	12.4 (18.0)	50.8 (8.6)***	44.0 (6.7)***
21		72.8 (35.7)**	13.7 (26.2)	48.6 (11.0)***	44.6 (8.3)***
22		72.3 (60.0)	46.7 (21.9)**	30.8 (13.4)**	41.0 (9.0)***

Notes: Standard errors are in parentheses. The total number of individuals in categories B, C, D, E, and F are, respectively, 1,805, 2,721, 6,069, 6,414, and 8,384. Every cell in this table represents a separate regression, which includes controls for gender, ethnicity, age in the first lottery year, and year of first lottery.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Table A5—Instrumental Variable Estimates of the Effects of Completing Medical School on Labor Market Outcomes $t - \tau$ Years after First Applying

$t - \tau$ (1)	N (2)	Hours (3)	log(Earnings/Hrs.) (4)
7	18,856	236 (101)**	0.27 (0.05)***
8	20,616	464 (60)***	0.21 (0.03)***
9	22,094	286 (38)***	0.19 (0.02)***
10	23,396	254 (29)***	0.12 (0.02)***
11	24,759	128 (23)***	0.09 (0.02)***
12	22,531	133 (22)***	0.12 (0.02)***
13	20,054	130 (22)***	0.15 (0.02)***
14	17,519	122 (22)***	0.17 (0.02)***
15	14,855	101 (23)***	0.23 (0.03)***
16	12,386	62 (25)**	0.29 (0.03)***
17	9,932	76 (27)***	0.35 (0.03)***
18	7,799	69 (27)**	0.35 (0.04)***
19	6,050	79 (30)***	0.47 (0.04)***
20	4,300	102 (36)***	0.40 (0.05)***
21	2,779	16 (42)	0.43 (0.07)***
22	1,425	65 (55)	0.43 (0.10)***

Notes: Standard errors are in parentheses. The total number of individuals is 25,393. Every cell in this table represents a separate regression, which includes controls for gender, ethnicity, age in the first lottery year, lottery category, year of first lottery, and interaction terms of the year of first lottery and lottery category.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

B. *Estimation of Outcome Distributions for Compliers*

Imbens and Rubin (1997) show how to derive distributions of outcome for both winning and losing compliers. Below we briefly review this approach. $Y_i(1)$ and $Y_i(0)$ denote the potential earnings with and without completing medical school, respectively. For each observation we observe the triple (LR_{1i}, D_i, Y_i). We cannot directly identify compliers from the data, but we can identify some never takers (for whom $LR_{1i} = 1$ and $D_i = 0$) and some always takers ($LR_{1i} = 0$ and $D_i = 1$). Because of the randomization, the instrument will be independent of a person's type, so in a large sample we can infer the distribution of $Y_i(1)$ for always takers and $Y_i(0)$ for never takers. These distributions are described by $g_a(y)$ and $g_n(y)$. Furthermore, we know the population proportions ϕ_c, ϕ_a, and ϕ_n of compliers, always takers and never takers, respectively.

The distributions of interest are the distributions of $Y_i(0)$ and $Y_i(1)$ for compliers, denoted as $g_{c0}(y)$ and $g_{c1}(y)$. These cannot be observed directly from the data because the group of lottery losers that do not complete medical school (with $LR_{1i} = 0$ and $D_i = 0$) consists of compliers and never takers. Analogously, in the outcome distribution of lottery winners that complete medical school ($LR_{1i} = 1$ and $D_i = 1$) there will be compliers and always takers.

We write the directly estimable distributions of Y_i for the subsample defined by $LR_{1i} = lr$ and $D_i = d$ as $f_{lr,d}(y)$. This implies that $g_a(y) = f_{01}(y)$ and $g_n(y) = f_{10}(y)$. show that the distributions for the winning and losing compliers can be expressed in terms of the directly estimable distributions in the following way:

$$\text{(B1)} \qquad g_{c0}(y) = \frac{\phi_n + \phi_c}{\phi_c} f_{00}(y) - \frac{\phi_n}{\phi_c} f_{10}(y),$$

and,

$$\text{(B2)} \qquad g_{c0}(y) = \frac{\phi_a + \phi_c}{\phi_c} f_{11}(y) - \frac{\phi_a}{\phi_c} f_{01}(y).$$

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