The returns to medical school in a regulated labor market: evidence from admission lotteries

Ketel, N.; Leuven, E.; Oosterbeek, H.; van der Klaauw, B.

Publication date
2012

Document Version
Submitted manuscript

The returns to medical school in a regulated labor market: Evidence from admission lotteries*

Nadine Ketel†

Edwin Leuven‡

Hessel Oosterbeek§

Bas van der Klaauw¶

Abstract

We estimate the returns to medical school by exploiting that admittance to medical school in the Netherlands is determined by a lottery. Using data from up to 21 years after the lottery, we find that doctors earn at least 20 percent more than people who end up in their next-best occupation. Estimated earnings profiles suggest that the life-time difference is even much larger: 21 years after the lottery the earnings difference exceeds 60 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, but are higher for the less motivated.

JEL-codes: J44; I18; I23; C36

Keywords: Medical school, returns to education, occupational licensing, random assignment

*This version: September 2012. We gratefully acknowledge valuable comments from Maarten Lindeboom, Sarah Turner, Dinand Webbink and seminar participants in Amsterdam, Bern, Bristol, Lausanne, Munich, Oslo, The Hague and Toulouse.

†VU University Amsterdam; University of Amsterdam; Tinbergen Institute

‡University of Oslo. Also affiliated with CEPR, CESifo, IZA and Statistics Norway.

§University of Amsterdam; TIER

¶VU University Amsterdam; Tinbergen Institute; CEPR; IZA

1 Introduction

Many countries restrict the supply of doctors by centrally fixing the number of places in medical schools (Simoens and Hurst, 2006). This might result in a monopoly rent with doctors' earnings exceeding their reservation earnings to enter the profession. This paper estimates the earnings gain from working as a doctor instead of working in the next-best occupation. These estimates are important to inform the policy debate about remuneration levels of doctors.

Previous studies that looked at the monopoly rent of doctors have either ignored selectivity issues or examined very specific groups. Friedman and Kuznets (1954) quantify the rent for doctors in the 1950s in the US by comparing earnings of doctors to earnings of dentists, for whom at the time entry was much less restrictive. They find that 16.5 percent of doctors' earnings is due to "barriers to entry". They admit, however, that part of the observed earnings difference may reflect ability differences. Burstein and Cromwell (1985) follow the same approach and find that in 1978-1980 in the US, the income difference between doctors and dentists amounts to 35 percent, while the income difference between doctors and lawyers is 139 percent. 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. Finally, Kugler and Sauer (2005) measure the effects of licensing by exploiting a retraining assignment rule for immigrant doctors in Israel. They find that immigrant doctors have mean monthly earnings that are 180 percent to 340 percent higher after obtaining a license. These returns only apply to immigrants who have at least 20 years of experience as a doctor.

Our study is also informative about the earnings elasticity of entry into the medical profession. This extensive margin of doctors' labor supply has not been examined before. Earlier studies have only looked at the labor supply elasticity of doctors at the intensive (hours) margin (Baltagi et al., 2005; Noether, 1986; Rizzo and Blumenthal, 1994; Showalter and Thurston, 1997; Sloan, 1975).

In this paper we exploit that the limited number of places in Dutch medical schools are assigned to applicants through admission lotteries. We use administrative data from admission lotteries in the years 1988 to 1999, and of applicants' subsequent study career from the Dutch student registry. This information is merged at the individual level with data on labor market outcomes in the period 1999 to 2009. For the cohort that applied to medical school in 1988, we thus have labor market information of up to 21 years after their application. Using these data we estimate returns to completing medical school, compared to the next-best alternative. The admission lotteries allow us to deal with selectivity issues. We present separate estimates for each year since the first application thereby constructing synthetic experience-earnings profiles.

The main complications in the empirical analysis is that losers of admission lotteries are allowed to reapply the next year, and that not all lottery winners actually complete medical school. To address this, we use the outcome of an individual's first lottery as instrumental variable for completion of medical school. Winning the first lottery increases the probability to complete medical school among applicants by around 36 percentage points, and this effect is highly significant.[1]

Even in the absence of the supply restriction, earnings as a doctor may differ from earnings in the next-best occupation. Two reasons are often mentioned. First, the investments in human capital differ. Becoming a doctor requires, on average, more years of education than necessary to enter other occupations. Because we observe the entire earnings profile since first applying to medical school and tuition fees are known, we can address these differences. Second, job characteristics differ between professions, most importantly, it is often claimed that doctors work long hours. We examine this possible explanation for the earnings differential by separately analyzing differences in working hours.

We find substantial earnings increases of working as a doctor instead of in the next-best occupation. There is no single year after graduation in which the return is less than 20 percent. The earnings profiles indicate that the return increases with experience. Twenty-one years after the first lottery doctors have, on average, more than 60 percent higher

[1]In the empirical analysis we will use "completion of medical school" as the endogenous variable of interest. It should be noted, however, that the first stage relation is very similar when this variable is replaced by "attending medical school" or "being licensed as a doctor".

earnings. The returns are very similar for men and women, although in absolute terms men earn more than women. We also do not find differential returns by ability, where ability is measured by high-school GPA. Using the framework developed by Imbens and Rubin (1997), we analyze the marginal distribution of earnings under different treatments. This reveals that the large earnings gains that we find are not only driven by high gains in the top end of the distribution. Among the doctors there are fewer people who have zero earnings and the whole distribution of earnings is shifted to the right.

The large earnings differences can not be attributed to differences in working hours. While doctors work longer hours than non-doctors, this difference is modest. In the first four years of their careers doctors work around 300 hours more on an annual basis. After this first period this difference shrinks to around 100 hours per year. There is also no evidence that doctors are more restricted in their private lives. Doctors are more likely to be married and to have children.

The instrumental variable approach implies that we identify average treatment effects for so-called compliers (Imbens and Angrist, 1994). These are applicants who enter the medical profession if they win the first lottery, and who do not enter the medical profession if they lose the first lottery. Not entering the medical profession after losing the first lottery can result from not reapplying or from losing subsequent lotteries. Since we also have information about participation in and outcomes of subsequent lotteries, we can further characterize the compliers. In particular, we can identify separately the earnings gain for compliers who do not reapply when they lose the first lottery, and for compliers who reapply when they lose the first lottery but also lose subsequent lotteries. The empirical results show that the earnings returns are largest for the first type of compliers. If we view the number of potential reapplications as a signal of motivation, this implies that the returns are highest for the least motivated. This is due to the least motivated having worse outcomes in their next-best occupations.

A possible confounding factor in the instrumental variable strategy is that disappointment of losing the first lottery may have a direct effect on earnings in the next-best occupation. To assess this possible channel, we report results from admission lotteries for two other university studies, one of which does not give access to a regulated labor market. We find no earnings difference between winners and losers of the first lottery for that study. This suggests that the disappointment of losing an admission lottery does not reduce future earnings.

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 3 describes the data used in this paper. Section 4 discusses the empirical model and the identification. Section 5 presents the estimation results. Section 6 discusses the interpretation of our results in terms of characterizing different types of compliers. Section 7 concludes.

2 Background and institutional context

2.1 Medical schools in the Netherlands

In the Netherlands students choose their field as soon as they enter university, unlike, for example, the US where students specialize later. Graduates from the pre-university track in high school can enroll in all fields at all universities.[2] Universities have to accept all applicants. However, some fields have a quota, implying that only a fixed number of students is admitted.

The quota for medical schools was introduced in 1976. Initially, the argument for 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 (RVZ, 2010). First, since university education is largely publicly funded and medical school is much more expensive than the average study, it is considered a waste of resources to educate doctors for whom there is no employment as a doctor. Second, the teaching capacity of medical schools is limited. Finally, there may be supplier induced demand (Hurley, 2000), implying that educating more doctors will increase the number of medical treatments.

The minister of education decides about the size of the quota. Until 1993 the annual

[2] In the Netherlands 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.

Table 1. Lottery categories

Category	GPA	Share	Weight
A	$GPA \geq 8.5$	0.02	2.00
B	$8.0 \leq GPA < 8.5$	0.07	1.50
C	$7.5 \leq GPA < 8.0$	0.10	1.25
D	$7.0 \leq GPA < 7.5$	0.23	1.00
E	$6.5 \leq GPA < 7.0$	0.25	0.80
F	$GPA < 6.5$	0.33	0.67

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.

quota was fixed at 1458 students. From 1993 to 1995 it was gradually expanded to 1815 students in 1995. In the years relevant for this study it remained at this level. The size of the quota is based on the number of places in specialization tracks, which is determined by the associations of specialists. For example, the association of neurologists decides how many places there are for specialization tracks in neurology.

If the number of applicants for medical schools exceeds the quota (which has always been the case), a lottery determines who is admitted.[3] Rejected applicants are allowed to reapply in the next year, and until 1999 they could do this as often as they wanted.[4] We observe that 69 percent of the rejected first-time applicants in our sample reapply a second time.

The lottery is weighted such that students with a higher GPA on secondary school exams have a higher probability of being admitted.[5] 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 which lottery groups - labelled A to F -, together with the shares of applicants in each category.[6] The final column indicates the

[3]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.

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

[5]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 among these subjects and should have passed these subjects.

[6]Additionally, there are categories G and H for students who did not participate in the nationwide high school exams, such as foreign students. These categories, which contain less than 10 percent of the applicants, are excluded from the analysis.

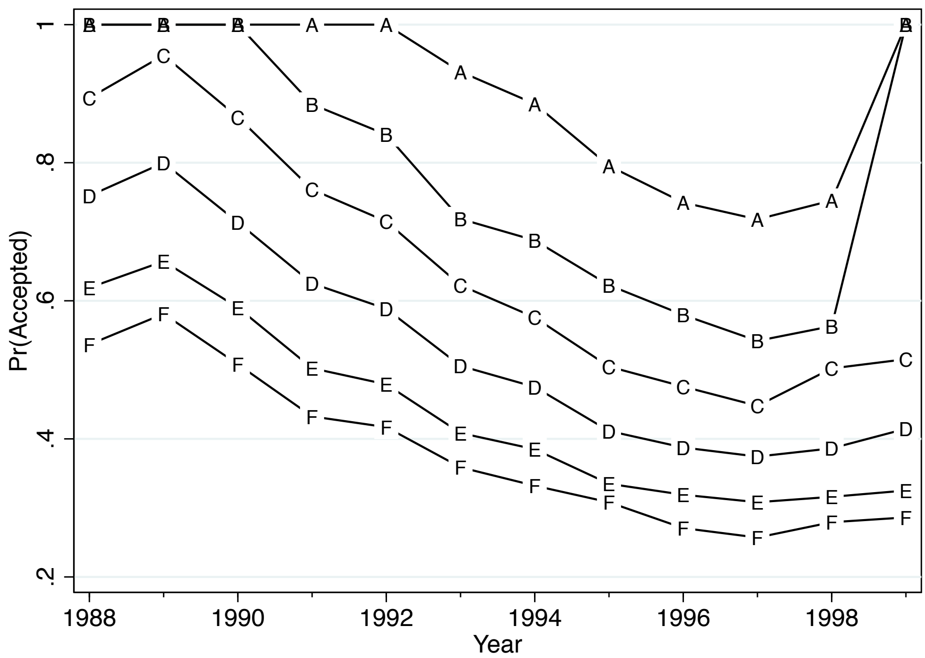


Figure 1. Probability of being admitted by year of application

weights in the lottery. This weight determines the ratio of places assigned to a category over the number of applicants in this category relative to category D. Hence, someone in category A has a twice as high probability of being admitted than someone in category D.[7]

Figure 1 shows the admission rates by lottery category.[8] In most years applicants in category A are almost certainly admitted but, as Table 1 shows, this category contain only 2 percent of all applicants. The majority of applicants are in categories C to F, for which the admittance rates ranges 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.[9]

The admission lottery is centrally executed. Applicants are allowed to list their first

[7]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. 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.

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

[9]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. This reform was implemented as a response to a large public discussion about a girl that finished high school with a GPA of 9.6 but lost the lottery three times in a row. The weights for the other categories remained the same.

three preferred medical schools. After the result from the lottery is known, admitted students are divided over the medical schools taking account of their preferences where possible. 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 fixed by the government. There are no private institutes offering the same education.

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 practical training are required. After that, students can choose to specialize. The specialization 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 get a place in one of the medical specializations it is common to first get a PhD degree. In total, the complete medical study can take between six and 15 years.

During the 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 1000 euro (at that time). During the PhD or specialization track students are not charged a tuition fee. Instead, they have a formal employment contract and receive a salary.

2.2 The labor market for doctors in the Netherlands

On average 45 percent of all licensed doctors in the Netherlands are registered as a specialist.[10] General practitioners constitute around 30 percent of the physician population. The remainder pursues a career as a social doctor (10 percent)[11] or does not specialize at all (15 percent). The latter group can either be non-specialized doctors that work as a so-called "basisarts" or those that completed a medical degree, registered as a healthcare 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 a specialist (52%

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

[11] The category social doctor includes among others insurance doctors, doctors for mentally disabled, community doctors etc.

versus 39%) and less likely to become general practitioner (25% versus 31%), social doctor (8% versus 10%), or to never specialize (15% versus 20%).

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%) are organized in such partnerships (Schafer 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 of medical specialists. In the time that we study (1999-2009) 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 unit of provided service, in order to introduce incentives for extra services.

The number of practicing doctors in the Netherlands is 2.9 per 1000 inhabitants, close to the OECD average is 3.1.[12] Also the division amongst 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 salaried or self-employed. Self-employed GP's in the UK, 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 also in several other countries (including Australia, Austria, Canada, Ireland and Germany) this ratio exceeds 4.

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

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

the Dutch government is not allowed to demand a language requirement, but employers can. In practice, many employers ask a candidate to pass the same language test as the 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.

3 Data

3.1 Data sources and sample

The data used in this paper come from two sources. The first source are the administrative records from the agency (DUO) that registers enrollment of all Dutch students in higher education and that conducts the lottery. So, we observe all applicants for medical school together with their lottery category and the outcomes of the lotteries. Furthermore, we know the actual study choices of all lottery applicants, winners and losers. Information on study progress is also available as the agency registers when and whether students successfully complete certain stages.

Between 1987 and 2004, almost 50,000 persons applied at least once to medical school. Because we are interested in the full history of lottery participation, we exclude from the data 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. The 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 start of the application history. To further minimize the number of mistakes, we exclude applicants that are older than 20 at the time that we observe their first application.[13] Since 2000, Dutch medical schools can admit at most 50 percent of their students using

[13]In the Netherlands children finish high school at the age of 18, so if they applied in 1985, skipped the 1986 and 1987 lotteries and applied again in 1988 they will be older than 20 when we observe their application.

their own criteria. Therefore, we exclude all applicants that applied for the first time after 1999. Finally, applicants in category A are excluded since almost all of them are eventually admitted to medical school. This leaves us with 25,551 observations.

Using social security numbers, the information from DUO is merged to the individual records of all Dutch citizens kept by Statistics Netherlands. We lose 60 observations, who do not have a valid social security number and cannot be matched. These individuals 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 and contain detailed information on earnings from various sources and on 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 2009, with exception of the variable hours worked which is only available for the years 2006-2009. Finally we have records from the BIG-register, that registers all healthcare professionals in the Netherlands. This register provides information regarding the care provider's qualifications and entitlement to practice. From this register we know whether someone is licensed as a doctor.

3.2 Descriptive statistics

Table 2 presents descriptive statistics separately for winners and losers of their first lottery.[14] The first part of the table provides information on personal characteristics. The majority of the applicants is female and the percentage of women is similar among winners and losers. The average age at the first application is 18.3, which indicates that most applicants apply directly after finishing high school. In the Netherlands the nominal age at the end of high school is 18. The mean GPA of lottery winners is higher than of lottery losers, which reflects that GPA is used to determine the weight in the lottery.

Next, the table presents summary statistics on study enrollment and completion. The

[14] When there can be no confusion we sometimes refer to winners and losers of the first lottery in which they participated as "lottery winner" and "lottery loser".

Table 2. Descriptive statistics of first time lottery applicants by admission status (means)

	Admitted	Rejected
Personal characteristics		
Female	0.58	0.58
Age at date of first application	18.3	18.3
Non-western immigrant	0.08	0.08
GPA high school exams	7.06	6.79
Study enrollment and completion		
Enrolled in medical school	0.94	0.45
Completed medical school	0.83	0.41
Licensed as a doctor	0.80	0.42
Enrolled in study program in NL	0.99	0.95
Completed study program in NL	0.96	0.89
Labor market outcomes		
Mean earnings per year 1999-2009	38,050	27,506
Mean hours worked 2006-2009	1,755	1,685
Mean hourly earnings 2006-2009	30.3	23.5
Ever collected benefits	0.27	0.28
Household composition		
Married in 2010	0.51	0.45
Children in 2010	0.60	0.51
Number of observations	13,672	11,819

outcome of the first lottery is associated with a 50 percentage point increase in enrollment into medical school. Not everyone who wins the first lottery actually enrolls in medical school; 6 percent of the winners of the first lottery do not. Of the losers of the first lottery 45 percent enroll in medical school (after winning a subsequent lottery). Of the winners who enroll, 83 percent completes medical school, and for the losers 91 percent do so. Finally, almost all who complete medical school also register as a doctor and are therefore licensed as a doctor. The small difference between completion and registration rates for lottery winners may be caused by the fact that completion data run to 2009 while the register of licensed doctors only runs to 2008. For lottery losers we see that 42 percent is registered as a doctor while only 41 percent completed medical school in the Netherlands. For these individuals it is possible that they completed a medical degree abroad and afterwards registered as a doctor in the Netherlands.[15]

For the interpretation of the estimated returns to medical school it is important to know which alternatives the lottery losers opted for. The majority of the lottery losers attends a study program in the Netherlands. 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 studies abroad. Of the lottery participants that do not enroll in medical school but do enroll for Dutch higher education 32% enrolls in a health related field. Other regularly chosen fields include Science (15%), Social and Behavioral Sciences (15%), Engineering (10%) and Economics (9%) 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). Also the fact that lottery losers have, on average, lower ability (GPA), may explain their lower graduation rate. This explanation is supported by results from a regression of having a diploma on GPA: Applicants in category F are 7 percentage points less likely to obtain a diploma than applicants in category B.

[15] The Netherlands shares its southern border with Belgium, which does not have a quota for medical schools. Instead, applicants have to pass an entry exam.

We focus on the following labor market outcomes: earnings, working hours, earnings per hour and collecting benefits. 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 per year. All amounts are corrected for the average wage development of university graduates over the observations years and converted to 2010 euros. Earnings are set equal to zero for people who live in the Netherlands and have no income from labor.[16] This includes students who have no earnings from a side-job. Table 2 shows that mean earnings are around 38 percent higher for winners than for losers.

Information on the number of hours worked is only available for 2006 to 2009 and only for employed workers. For the self-employed we assume a full-time job (1872 hours per year).[17] Average working hours are close to 1700, but winners work approximately 4 percent more hours than losers. This difference is not sufficient to equalize earnings per hour; these are about 29 percent higher for the winners. Among both the winners and the losers, about 27 percent ever received any kind of social insurance benefits (welfare, unemployment and disability insurance) in the period 1999-2009.

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

4 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:

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

where $t - \tau$ indicates the number of years elapsed between the year of the first lottery

[16]The share of people that live abroad increases over time and is 5 percent in 2008, this share is the same for winners and losers.

[17]In case a person has income both from employment and from self-employment we take: hours worked= hours from employment + (income from self-employment/total income) * 1872 hours.

and the year in which the outcome is observed. D_i is a dummy variable which is equal to one if individual i completed medical school, zero otherwise. 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 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 number of years since the first lottery $(t - \tau)$.

Even with admission lotteries, completing medical school is potentially endogenous. Not all admitted students actually complete medical school, and some lottery losers may reapply in subsequent years. Therefore, we instrument D_i with the result (0/1) of the first lottery (LR_{1i}) in which someone participated. We estimate a first-stage equation of the form:

$$D_i = \kappa + \lambda LR_{1i} + X_i\theta + LC_{i\tau} + V_i \tag{2}$$

The identifying assumption for $\delta_{t-\tau}$ to be the causal effect of completing medical school on labor market outcome Y is that conditional on X and LC the result in the first lottery is mean independent of U: $E(LR_1 \cdot U|X, LC) = 0$. Recall that in each year within each lottery category all individuals have the same probability of being admitted. This conditional random assignment guarantees that the mean conditional independence assumption holds.

In equation (2) the parameter λ reflects the difference in the completion rates between winners and losers of the first lottery. It will not equal one for three reasons. First, some winners of the first lottery decide not to enroll in medical school. Second, a share of those who win and enroll do not complete medical school. And third, people who lost the first lottery can still obtain a medical degree if they win one of the later lotteries. An interpretation of λ is that it describes the share of compliers in the data. Compliers are applicants for whom registration as a doctor is determined by the result of the first lottery. In Section 6 we elaborate further on the definition of the compliers and the interpretation of the estimates from this model.

By estimating equation (1) separately for each year following the first lottery, we obtain a picture of the evolvement of the earnings differential during the first 21 years after the first lottery. This period also captures the longer study duration in medical schools compared to alternative studies, and thereby an estimate of the opportunity costs of the longer investment in human capital.

5 Results

5.1 First stage

The first stage that we estimate, is the effect of winning the first lottery on the probability to complete medical school. We estimate the first stage by year after the first lottery ($t-\tau$), which implies that we estimate the effect for differentiated subsamples. Table 3 reports these results in more detail. The second column reports the number of observations in each regression and shows how this number varies across rows. The final row of column (1) is only based on 2009-earnings information of people who first applied in 1988. The penultimate row is based on 2009-earnings information of people who first applied in 1989 and on 2008-earnings information of people who first applied in 1988, and so on. Because the admission data end in the same year in which the earnings data start (1999), also the estimates in the first row are based on just a single cohort. The third column reports first stage estimates. The first stage estimates are highly significant (the F-statistic is never below 285) and are all close to 0.36

5.2 Main findings

The fourth column of Table 3 presents the instrumental variable estimates of the effect of medical school on annual earnings (in thousands of euros). The estimates are also plotted in panel (a) of Figure 2. During the first six years after the first lottery, the effect is negative or close to zero. In the first four years the reduction is modest and due to two reasons: students who are not in medical school more often have a small job while studying and some people that are not admitted to medical school will decide to work

Table 3. Instrumental variable estimates of the effects of completing medical school on labor market outcomes $t - \tau$ years after first applying

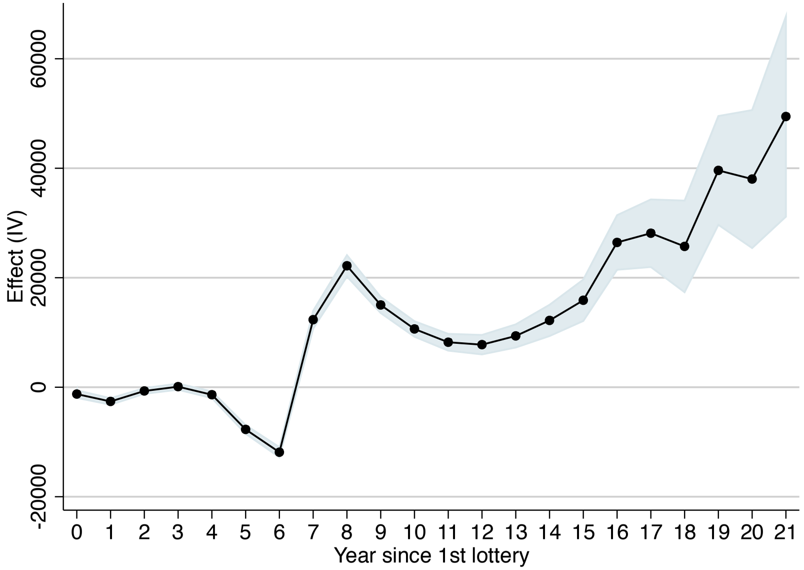
$t - \tau$ (1)	N (2)	1st stage (3)	Earnings (4)	I[Earnings>Subsistence] (5)	log(Earnings) (6)	Hours (7)	log(Earnings/Hrs) (8)
0	2159	0.35 (0.02)***	-1.3 (0.4)***	-0.04 (0.02)*	-0.37 (0.16)**		
1	4607	0.34 (0.01)***	-2.6 (0.3)***	-0.17 (0.02)***	-0.71 (0.12)***		
2	7167	0.36 (0.01)***	-0.7 (0.3)***	-0.08 (0.02)***	-0.03 (0.08)		
3	9885	0.36 (0.01)***	0.1 (0.3)	0.02 (0.02)	0.08 (0.07)		
4	12438	0.36 (0.01)***	-1.4 (0.3)***	-0.02 (0.02)	-0.19 (0.06)***		
5	14952	0.36 (0.01)***	-7.7 (0.4)***	-0.35 (0.02)***	-1.42 (0.08)***		
6	17154	0.35 (0.01)***	-11.9 (0.5)***	-0.36 (0.02)***	-1.37 (0.08)***		
7	18946	0.35 (0.01)***	12.3 (0.8)***	0.28 (0.02)***	0.80 (0.06)***	228 (99)**	0.27 (0.05)***
8	20705	0.35 (0.01)***	22.2 (1.0)***	0.33 (0.02)***	0.90 (0.05)***	484 (62)***	0.22 (0.03)***
9	22185	0.35 (0.01)***	15.0 (0.8)***	0.21 (0.01)***	0.55 (0.03)***	290 (39)***	0.19 (0.02)***
10	23485	0.35 (0.01)***	10.6 (0.7)***	0.12 (0.01)***	0.36 (0.03)***	262 (30)***	0.13 (0.02)***
11	22762	0.36 (0.01)***	8.2 (0.8)***	0.09 (0.01)***	0.23 (0.02)***	120 (27)***	0.11 (0.02)***
12	20244	0.36 (0.01)***	7.8 (0.9)***	0.07 (0.01)***	0.25 (0.02)***	147 (26)***	0.13 (0.02)***
13	17681	0.35 (0.01)***	9.4 (1.1)***	0.08 (0.01)***	0.26 (0.02)***	14 (27)***	0.15 (0.02)***
14	14980	0.35 (0.01)***	12.2 (1.5)***	0.07 (0.01)***	0.27 (0.03)***	161 (28)***	0.18 (0.03)***
15	12494	0.35 (0.01)***	15.9 (1.9)***	0.06 (0.01)***	0.31 (0.03)***	125 (30)***	0.23 (0.03)***
16	10012	0.36 (0.01)***	26.4 (2.5)***	0.08 (0.01)***	0.35 (0.04)***	60 (32)*	0.33 (0.04)***
17	7866	0.36 (0.01)***	28.1 (3.1)***	0.06 (0.02)***	0.43 (0.05)***	90 (36)**	0.36 (0.04)***
18	6100	0.37 (0.01)***	25.7 (4.3)***	0.02 (0.02)	0.39 (0.06)***	60 (34)*	0.36 (0.04)***
19	4329	0.38 (0.02)***	39.6 (5.1)***	0.03 (0.02)	0.57 (0.07)***	106 (37)***	0.47 (0.05)***
20	2805	0.40 (0.02)***	38.0 (6.4)***	0.01 (0.03)	0.51 (0.08)***	63 (46)	0.45 (0.06)***
21	1436	0.44 (0.03)***	49.4 (9.3)***	0.03 (0.04)	0.62 (0.11)***	28 (56)	0.57 (0.08)***

Notes: Standard errors in parentheses. Total number of individuals is 25,491. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. 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.

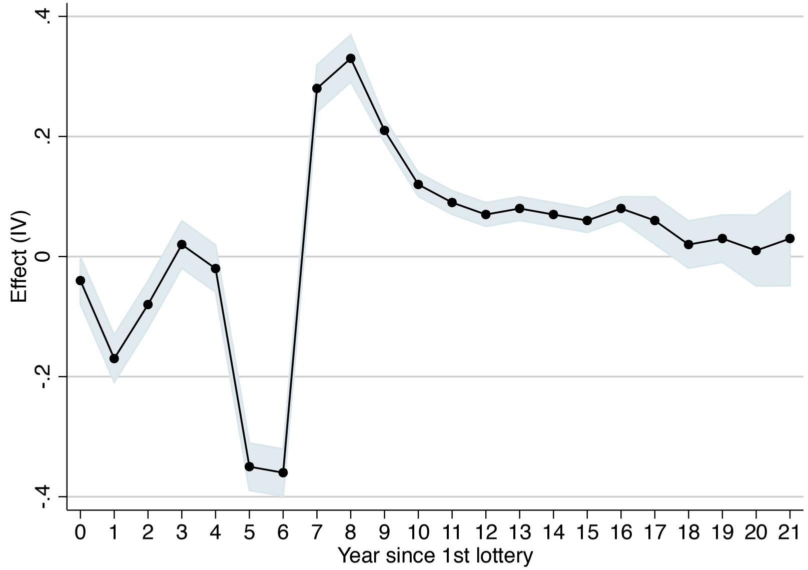
rather than to study. In the fifth and the sixth year after first applying the reduction in earnings is substantial. This reflects that most alternative studies have a shorter duration than the six years required for medical school. Individuals who do not attend medical school enter the labor market earlier and start receiving income earlier than individuals attending medical school. These negative earnings effects in the fifth and sixth years express the larger investment in human capital of people who complete medical school.

The picture reverses from the seventh years onwards. This is the moment that students from medical school have graduated and start earning, either in the labor market or while working 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 22,000 euro per year difference in the eighth year reduces to less than half of that in the twelfth year. This is probably due to the large share of students from medical school that is in a specialization track in these years. Starting wages in specialization tracks are relatively high but hardly rise over the remaining years. From the twelfth year onwards, students from medical school will finish their specialization track and start working as a (self-employed) specialist or GP. The earnings difference increases again and eventually amounts to almost 50,000 euro per year in the twenty-first year.

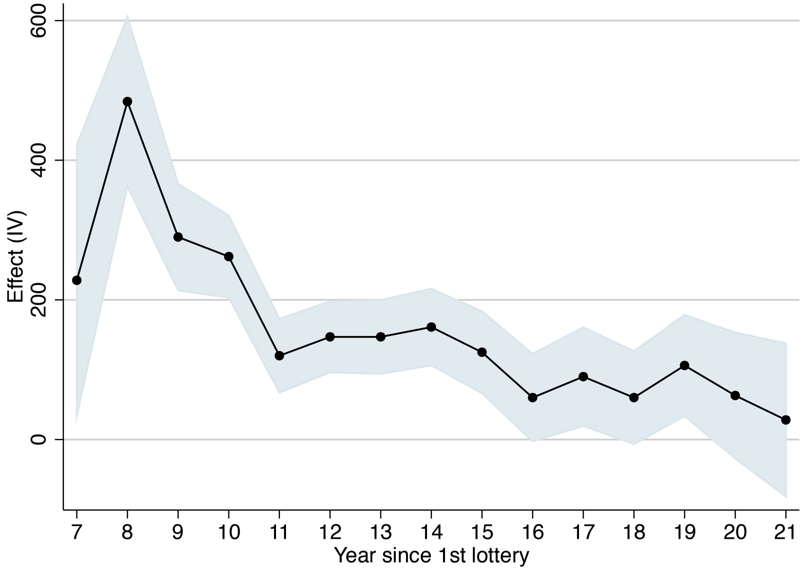
An explanation for the huge jump in the seventh and eighth year can be seen in the fifth column and in panel (b) of Figure 2. Here the dependent variable is a dummy for earning above the level of welfare benefits. In the fifth and sixth year after the first lottery, students in medical school are less likely to earn above the level of welfare benefits than those not in medical school, which is consistent with the fact that they have not yet entered the labor market. But just as with the level of earnings, the sign reverses in the seventh year after the first lottery. The effect is particularly large seven to nine years after the first lottery, which suggests that a large share of the students from medical school find (full-time) work immediately after graduating. From year ten onwards medical school graduates are around seven percentage points more likely to have earnings above the level of welfare benefits than other students, relative to a base of 0.90.



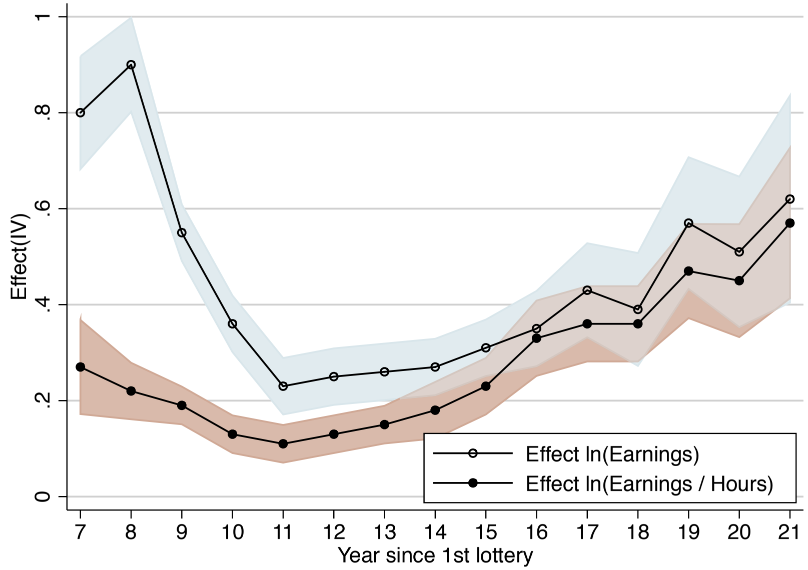
(a) Earnings



(b) I[Earnings>Subsistence Level]



(c) Hours



(d) ln(Hourly Earnings)

Figure 2. Instrumental variable estimates of the effects of completing medical school on labor market outcomes $t - \tau$ years after first applying

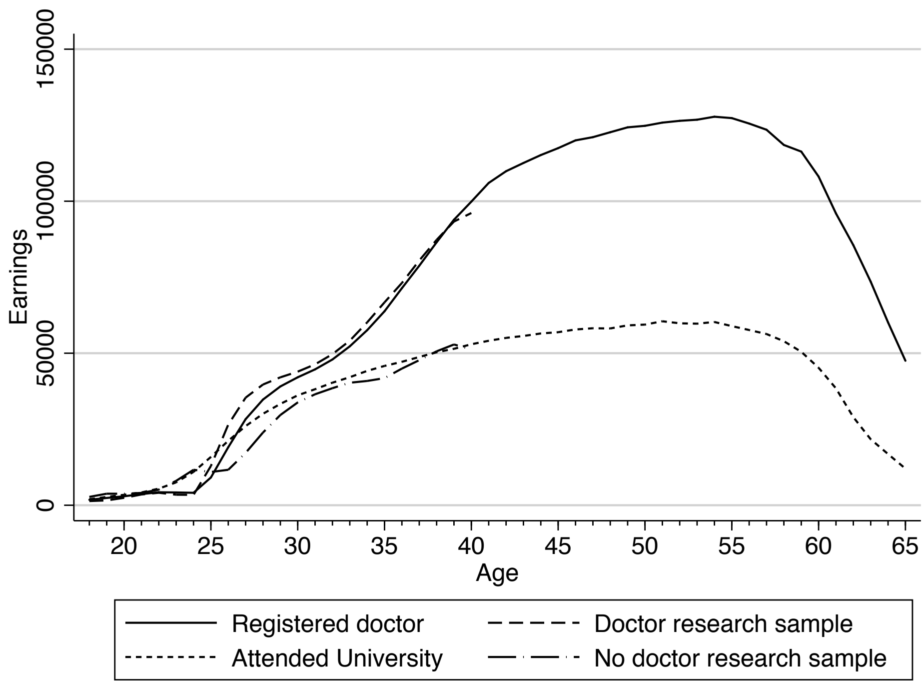


Figure 3. Predicted levels for earnings

In Figure 3 we use the estimated model to show the predicted earnings profiles for an average individual with and without completion of medical school. This implies that for both $D = 0$ and $D = 1$, we compute the expected earnings according to

$$\hat{Y}_{t-\tau} = \hat{\alpha}_t + \hat{\gamma}_{t-\tau} + \hat{\delta}_{t-\tau} D + \bar{X}\hat{\beta} + \bar{LC}$$

where $\bar{X}$ and $\bar{LC}$ are the sample means within our sample. To get an idea how these earnings profiles evolve until retirement, rescaled average wage profiles of medical school graduates and other university attenders are also plotted, where the latter serves as a reference group for the "non-doctors".[18] We regressed the observed average wage profile 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 non-doctors. The wage profiles show that while being in medical school, students earn less than if they would have attended another study. At the age of 24, after they have

[18] 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 income earned while being active on the labor market.

Table 4. Discounted lifetime rents

Discount rate	All	Men	Women
0.02	1,061,117	1,172,977	716,195
0.05	455,757	501,007	330,856
0.10	134,995	144,976	109,907

Notes: The entries represent discounted earnings at the time of participating in the first lottery. The estimated lifetime rents are for a representative individual.

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 of the effect of completing medical school up to 21 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.

Using the results from Table 3 we can calculate the lifetime benefits of completing medical school. For the first 21 year the estimated differences are used so this takes account of the longer education period for doctors and of the two years of unpaid residencies. We assume that in addition to the 21 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. Net present values of the lifetime rent are calculated for discount rates equal to 2%, 5% and 10% and earnings are discounted at the time of participating in the first lottery. Table 4 presents the results. We see that even for a high discount rate of 10% the present value of the net earnings gain for doctors exceeds 100,000 euro. At a more moderate discount rate of 5%, the gain is already more than 450,000 euro. At a low discount rate of 2% the gain even exceeds one million euro.

The sixth column of Table 3 shows results for the effect of medical school on log earnings, conditional on having positive earnings. The observed pattern is very similar to the pattern for the level of earnings (which includes zeros) in column (4). During the first six years after the lottery, medical school graduates have lower log earnings than not admitted students and this reverses in the seventh year. Until the tenth year the pattern is a bit erratic, but from the eleventh year onwards, the gain for winners steadily increases, up to 0.61 in the last year covered by the data.

Part of the large earnings gain for doctors may be attributable to longer working hours. Column (7) and panel c) report IV estimates where the number of working hours per year is the dependent variable. Information about hours is only available for the years 2006 until 2009, and therefore only for the seventh to twenty-first year after the first lottery. The results reveal that doctors especially work more hours per year during the first four years after finishing the initial phase of their study. During these four years doctors work a total of 1200 hours more than non-doctors. The average number of working hours during these four years together is around 5,750 hours, so that doctors work around 20 percent more than those that did not complete medical school. After these first four years doctors work about 100 hours more per year than non-doctors. Compared to a baseline of 1,600 hours this is a 6 percent difference. Differences in working hours can therefore not explain the large earnings gain to medical school. This is confirmed by the results in the final column and panel d) where log earnings per hour is the dependent variable. The effect on log earnings per hour is only marginally smaller than the effect on log earnings. From the eleventh year onwards the gain in the log of per hour earnings steadily increases to 0.56.

Figure 4 plots predicted levels of hours for an average individual with and without medical school. Based on a 36 hour workweek the amount of yearly hours worked is 1,872. We see that from the seventh to the ninth year the non-doctors work only around 1,200 hours per year. The large effect that we find on hours in these years is thus mainly driven by the fact that doctors more often have a (full-time) job. After the tenth year the number of hours stabilizes for both groups. In these years the doctors work only marginally more hours than the non-doctors.

Other outcomes Table 3 shows that with the exception of the first few years of their career, doctors do not work much longer hours than others. We now inquire whether the high earnings of doctors come at the cost of other outcomes. In Table 5 we look at the impact of medical school completion on having children, being married and ever receiving state benefits (unemployment benefits or welfare benefits). The first column pertains to

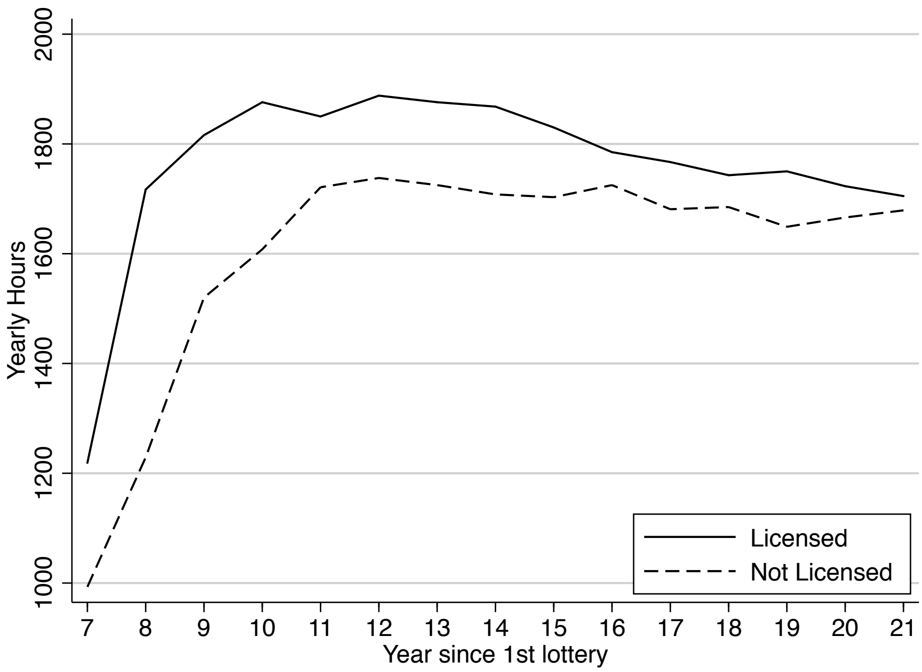


Figure 4. Predicted levels for yearly hours worked

Table 5. Other outcomes

	All	Men	Women
Children in 2010	0.09 (0.02)***	0.13 (0.03)***	0.06 (0.02)**
Married in 2010	0.05 (0.02)***	0.10 (0.03)***	0.02 (0.03)
Ever state benefits	-0.05 (0.02)***	-0.11 (0.02)***	0.01 (0.02)

Notes: Robust standard errors in parentheses. Total number of individuals is 25,491. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Every cell in this column represents a separate regression, which include controls for gender (in the first column), 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

the whole sample, while the second and third columns report results separately for men and women.[19] The results show that doctors never do worse in terms of these outcomes; they do not have fewer children, they are more likely to be married and they are less likely to have ever received state benefits. Results by gender show that male doctors score significantly different on all these variables compared to male non-doctors, while for women only the likelihood to have children is higher for doctors. In short, doctors' household situation does not suffer from their occupation.

[19] In the next subsection we report effects on labor market outcomes by gender.

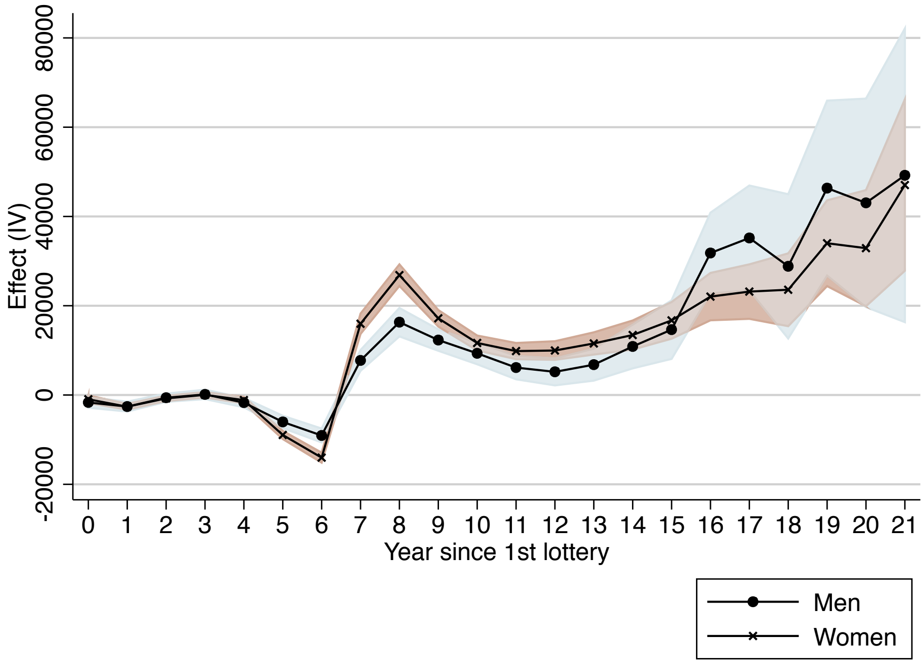
5.3 Heterogenous treatment effects

We now turn to the heterogeneity of treatment effects. We first examine whether treatment effects differ between men and women. As Table 2 reveals, a majority of the applicants for medical school is female. While of all university students in the Netherlands less than half is female during the period 1988-1999, this is 58 percent in medical schools. This justifies the question whether women have a comparative advantage in medical school. Next we investigate whether treatment effects differ by ability. As described in Section 2 the admission lottery uses weights based on applicants' GPA on secondary school exams. Applicants with a higher GPA have a higher chance to be admitted. This system of a weighted admission lottery warrants the question whether this allocates the available places efficiently. Finally, we inquire variation in treatment effects along the earnings distribution. This is motivated by the concern often expressed by policy-makers, that some medical specializations pay very high earnings.

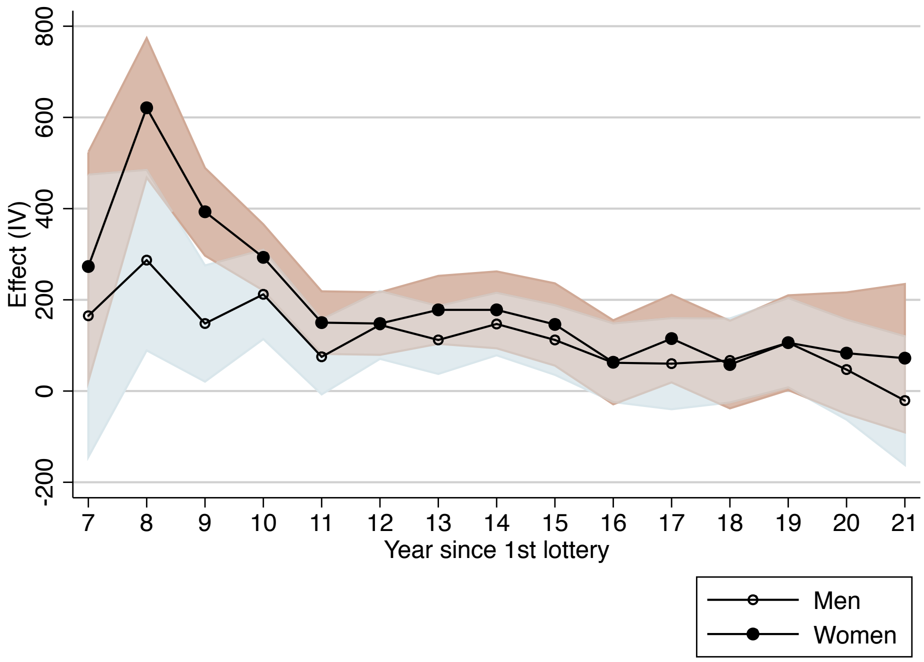
By gender Figure 5a shows the estimates of the earnings gain separately for men and women.[20] Until the sixth year both men and women experience an earnings loss from having opted for medical school. This loss is very similar across the sexes. In years 7 to 14, the gain is much larger for women than for men, but from year 15 onwards men seem to catch up and in the last year the gain of medical school is even slightly larger for men than for women. This suggests that male doctors more often choose for long specialization tracks than female doctors. Figure 6 shows gender-specific predicted earnings profiles with and without medical school. This reveals that female doctors earn more or less the same as male non-doctors, and that doctors earn more than non-doctors of the same sex.

Panel b) of Figure 5b shows that from the seventh to the tenth year after the first lottery, doctors work longer hours than non-doctors of the same sex. 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 a bit further in their career male doctors even work fewer hours than male non-doctors.

[20] Table A2 also reports these results.



(a) Earnings



(b) Hours

Figure 5. IV estimates of effects of medical school completion on earnings and hours, by year since first lottery and gender

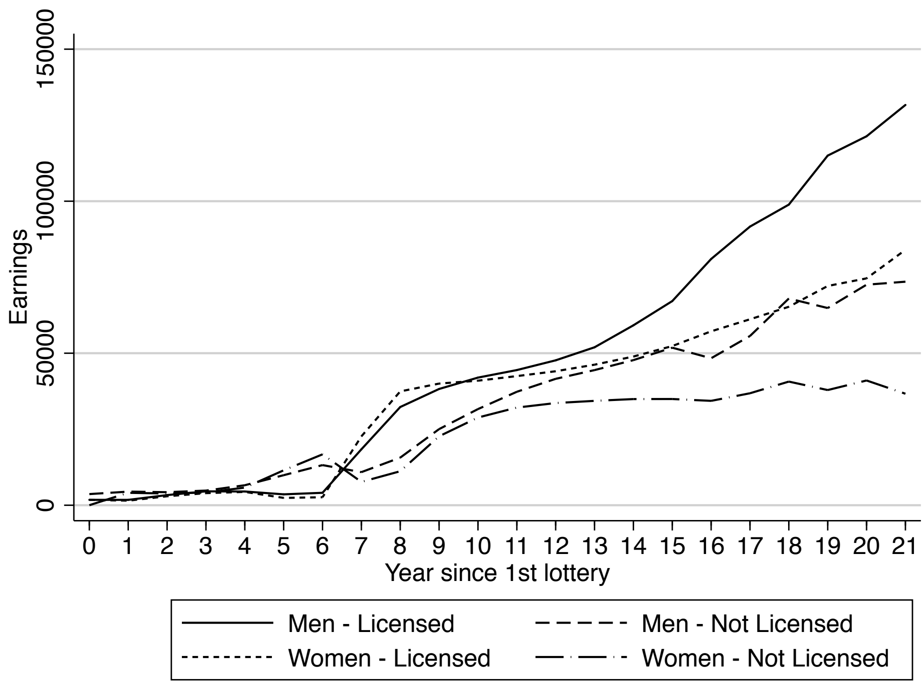


Figure 6. Predicted earnings, gender differences

By ability The lottery gives higher chances to be admitted to applicants with higher GPA on their secondary school exams. This warrants the question whether there is a difference in earnings gain between people with different GPA's. To examine this, we estimated earnings gains by year after first lottery separately for lottery categories B to F.[21] Figure 7 reports the results.[22] 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 a higher GPA. This is probably mainly 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 becomes a specialist increases with GPA. Conditional on completion of medical school,

[21]Category A is omitted since there are too few losers from this category.

[22]The results can also be found in table A3

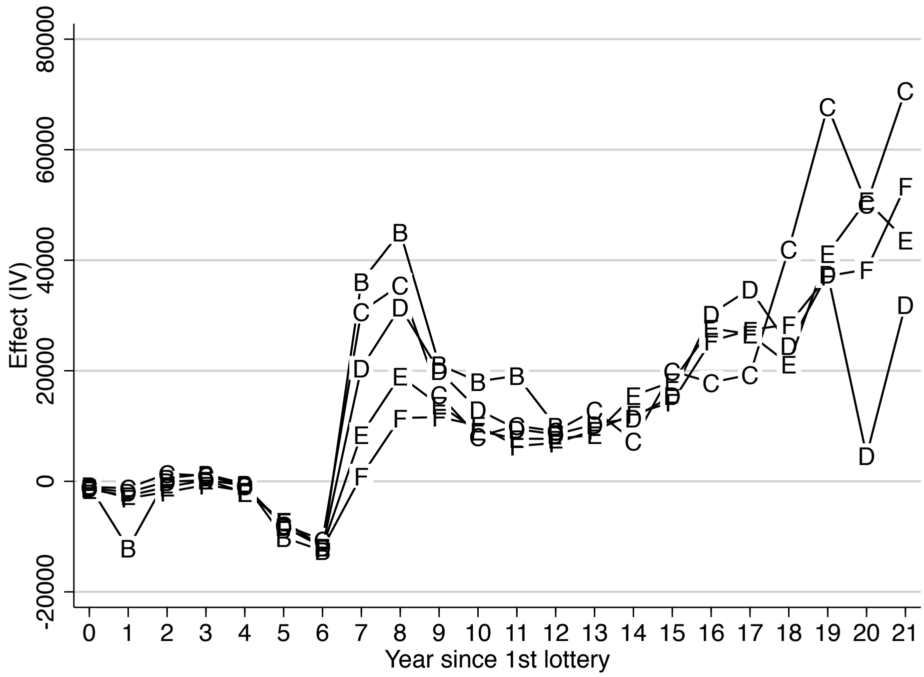


Figure 7. IV estimates of effects of medical school completion on earnings, by year since first lottery and lottery category

the percentage of specialists decreases monotonically from 59 percent in category B to 42 percent in category F. That we still do not find differences in the returns for the different lottery categories follows from the worse outside opportunities that applicants in the lower lottery categories have. Conditional on winning the first lottery, applicants in category F have a 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' GPA's do not respond to changes in the chances to be admitted, this implies that there is no clear support for a system in which only students with the highest GPA are selected.

Effects along the distribution of earnings 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 GP's and specialists reported in Section 2, 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).[23]

Figure 8 plots the estimated earnings distributions for winning and losing compliers 12 and 18 years after the first lottery. We see that both 12 and 18 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 18 years most winning compliers will have finished their specialization track. The earnings of winning compliers are then more dispersed and the right tail of the winning compliers is much fatter, which implies that there are more top earners among the winning compliers. Both figures show that the earnings gains from medical school that we found in Section 5.2 are not only driven by high gains in the top end of the distribution. Among the winning compliers there are less people who have zero earnings and the distribution of winning compliers is to the right of the distribution of losing compliers.

6 Interpretation

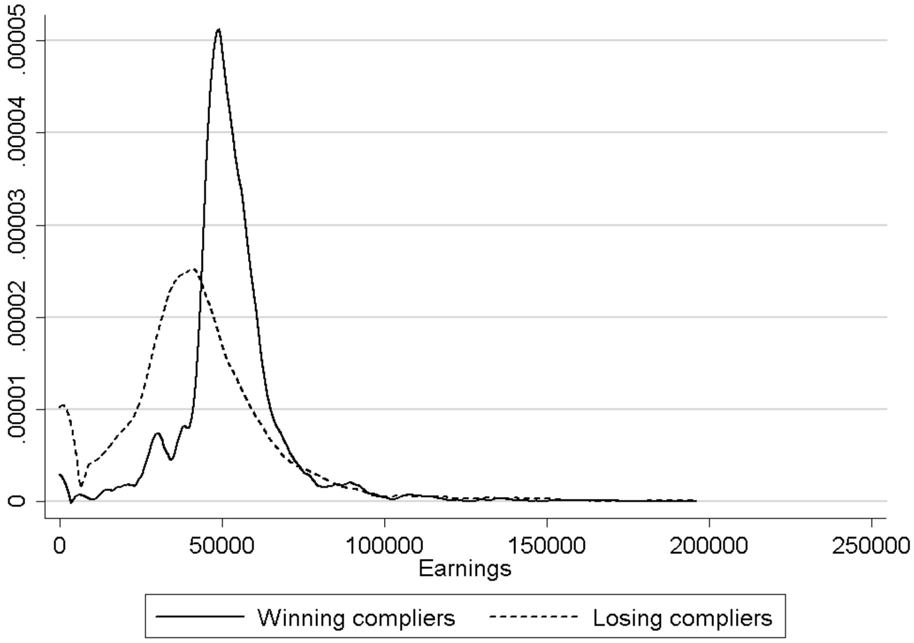
6.1 Degrees of compliance

In this section we provide some interpretation to the estimated returns to medical school. As we already stressed before, using the instrumental variable approach identifies the average treatment effect of medical school for applicants who comply with the result of the first lottery. Below we characterize these compliers in more detail. Following Imbens and Angrist (1994), the Wald estimator can be expressed in terms of potential outcomes as:

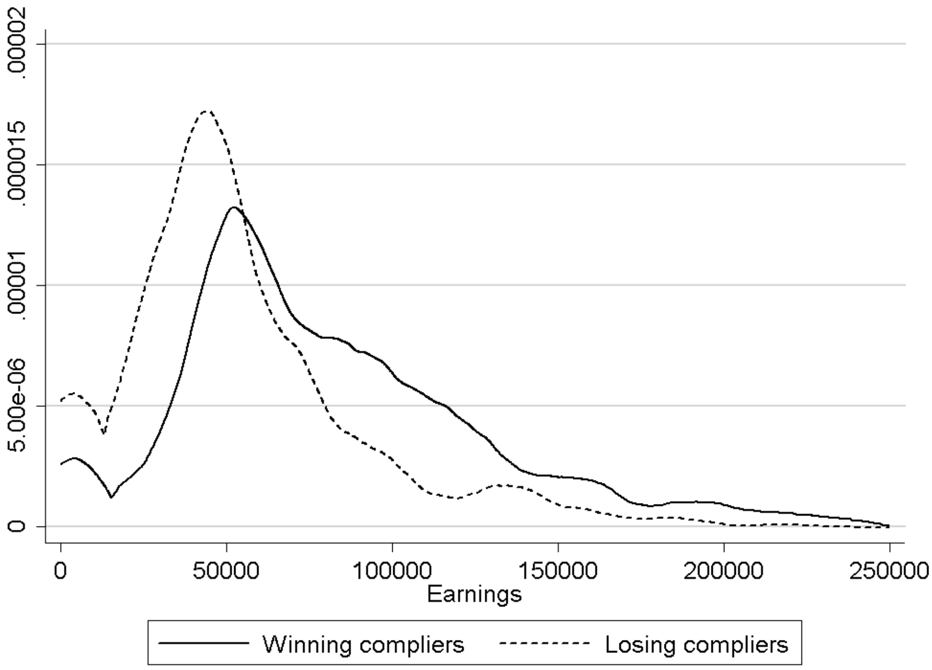
$$\frac{E[Y|LR_1 = 1] - E[Y|LR_1 = 0]}{P(D = 1|LR_1 = 1) - P(D = 1|LR_1 = 0)} = E[Y(1) - Y(0)|D(LR_1 = 1) - D(LR_1 = 0) = 1] \quad (3)$$

where $Y(1)$ and $Y(0)$ are potential outcomes with and without medical school, respec-

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



(a) 12 year after the first lottery



(b) 18 years after the first lottery

Figure 8. Earnings distribution of winning and losing compliers

tively, and $D()$ is an indicator for completing medical school if the expression in parentheses holds.

Compliers complete medical school when being admitted in the first lottery, and do not complete medical school when not being admitted in the first lottery. The latter implies that an applicant either does not reapply after losing the first lottery, reapplied one or more times and always lost, or won but did not complete medical school. The first group, whom we refer to as "first degree" compliers seems to meet the concept of compliance closer than re-applicants who only comply with the result of the first lottery because they loose subsequent lotteries. Depending on the number of lotteries in which applicants participate, we refer to them as "second degree" compliers, "third degree" compliers, and so on. The more often someone reapplies, the closer he or she is to an always-taker. Since we have information about subsequent lotteries, we can separately identify the earnings effects for different groups of compliers.

We simplify the analysis to five types of applicants: first, second, third degree compliers, never takers and always takers. Always-takers are people who participate in at least four lotteries. It is straightforward to extend the analysis to more groups of compliers, and as will become clear below defining always takers as people who intend to participate in four or more lotteries does not affect the average returns for the other groups of compliers. Never takers are people who do not complete medical school irrespective of the result of the lotteries. Defiers are excluded. We first want to identify the shares of the five groups from our data. Let L_k be a dummy variable indicating whether a person applies for the k^{th} lottery; 1 if yes, otherwise 0. LR_k is a dummy variable indicating whether a person won the k^{th} lottery (conditional on participating); 1 if yes, otherwise 0.

Let C_N be a stochastic variable indicating whether the person is a never taker. A never taker is an applicant, who will not complete medical school when being admitted:

$$\Pr(C_N = 1) = \Pr(D = 0 | LR_1 = 1)$$

Next, let C_k be a stochastic variable describing whether the person is a k^{th} degree complier. A first-degree complier does not reapply after losing the first lottery, and complete medical school when being admitted in the first lottery:

$$\Pr(C_1 = 1) = \Pr(L_2 = 0|LR_1 = 0)(1 - \Pr(C_N = 1))$$

Similarly, we consider the second-degree and third-degree compliers:

$$\Pr(C_2 = 1) = \Pr(L_3 = 0|LR_2 = 0, L_2 = 1)(1 - \Pr(C_N = 1)) \Pr(L_2 = 1|LR_1 = 0),$$

and,

$$\Pr(C_3 = 1) = \Pr(L_4 = 0|LR_3 = 0, L_3 = 1)(1 - \Pr(C_N = 1)) \\ \Pr(L_3 = 1|LR_1 = 0, LR_2 = 0) \Pr(L_2 = 1|LR_1 = 0).$$

Finally, let C_A be a stochastic variable indicating whether the person is an always taker. Given that we already characterized the four other groups, the probability of being an always taker is:

$$\Pr(C_A = 1) = 1 - \Pr(C_3 = 1) - \Pr(C_2 = 1) - \Pr(C_1 = 1) - \Pr(C_N = 1)$$

For tractability we impose that the probability of being a never taker is the same in every lottery, which is consistent with our data. In each lottery the fraction of admitted students that does not complete medical school is very similar.[24]

Next, we consider the probability of being a complier in our empirical analyses, which are individuals for which the outcome of the first lottery determines whether or not to complete medical school. This holds for first-degree compliers, and second-degree and third-degree complier who loose all subsequent lotteries after the first lottery (or win

[24]In the first lottery the proportion of never-takers is 0.195. For the second and third lottery these proportions are respectively 0.197 and 0.181.

subsequent lotteries but do not complete):

$$\Pr[D(LR_1 = 1) - D(LR_1 = 0) = 1] =$$
$$P(C_1 = 1) + P(C_2 = 1)P(LR_2 = 0) + P(C_3 = 1)P(LR_2 = 0)P(LR_3 = 0)$$

Using this characterization of the compliers in our estimations, we can then rewrite the right hand-side of equation (3) as a weighted average of the potential outcomes for the different groups of compliers:

$$\frac{E[Y|LR_1 = 1] - E[Y|LR_1 = 0]}{P(D = 1|LR_1 = 1) - P(D = 1|LR_1 = 0)} =$$
$$\begin{gathered}(E[Y(1) - Y(0)|C_1 = 1]P[C_1 = 1] \\ + E[Y(1) - Y(0)|C_2 = 1]P[C_2 = 1]P[LR_2 = 0] \\ + E[Y(1) - Y(0)|C_3 = 1]P[C_3 = 1]P[LR_2 = 0]P[LR_3 = 0])/ \\ (P[C_1 = 1] + P[C_2 = 1]P[LR_2 = 0] + P[C_3 = 1]P[LR_2 = 0]P[LR_3 = 0])\end{gathered} \quad (4)$$

We now restrict the sample to people who lost the first lottery and applied for the second lottery. For this group of individuals, the result of the second lottery is random (conditional of the lottery category). Again using instrumental variables estimation, we can estimate for the compliers to the result of the second lottery the average treatment effect of medical school. This group of compliers to the result of the second lottery consists of second and third-degree compliers. Recall that first-degree compliers never get to the second lottery.

The Wald estimate using applicants to the second lottery can be expressed as a

Table 6. Estimates of effects of medical school completion on earnings for different lotteries and degrees of compliers, by year since first lottery

	Lottery 1		Lottery 2		Lottery 3		1st degree	2nd degree
$t - \tau$	N	IV	N	IV	N	IV	compliers	compliers
0	2159	−1.3 (0.4)***	879	0.1 (0.5)	280	0.3 (1.1)	-2.3	0.0
1	4607	−2.6 (0.3)***	1966	−1.0 (0.4)**	674	−0.1 (0.8)	-3.9	-1.3
2	7167	−0.7 (0.3)***	3161	−1.5 (0.4)***	1152	−1.3 (0.7)*	-0.1	-1.6
3	9885	0.1 (0.3)	4484	−0.6 (0.4)*	1736	−2.1 (0.6)***	0.7	-0.1
4	12438	−1.4 (0.3)***	5687	−0.3 (0.4)	2247	0.3 (0.6)	-2.3	-0.5
5	14952	−7.7 (0.4)***	6777	−3.9 (0.6)***	2693	−1.4 (1.2)	-10.8	-4.9
6	17154	−11.9 (0.5)***	7730	−11.5 (0.6)***	3056	−6.1 (1.0)***	-12.2	-13.6
7	18946	12.3 (0.8)***	8357	−15.8 (0.7)***	3282	−14.9 (1.1)***	35.1	-16.1
8	20705	22.2 (1.0)***	8898	9.8 (1.7)***	3429	−17.6 (1.5)***	32.2	20.4
9	22185	15.0 (0.8)***	9196	16.9 (1.2)***	3482	0.3 (2.0)	13.5	23.2
10	23485	10.6 (0.7)***	9398	10.0 (1.1)***	3501	9.9 (2.2)***	11.2	10.0
11	22762	8.2 (0.8)***	8760	4.4 (1.1)***	3258	6.0 (2.2)***	11.3	3.8
12	20244	7.8 (0.9)***	7649	3.7 (1.3)***	2843	1.1 (2.3)	11.1	4.7
13	17681	9.4 (1.1)***	6449	3.0 (1.6)*	2363	1.4 (2.6)	14.5	3.6
14	14980	12.2 (1.5)***	5137	6.6 (2.3)***	1783	−4.6 (3.7)	16.7	10.9
15	12494	15.9 (1.9)***	3987	7.9 (3.2)**	1293	−2.6 (5.8)	22.4	11.9
16	10012	26.4 (2.5)***	2932	12.6 (4.0)***	865	15.2 (7.4)**	37.7	11.6
17	7866	28.1 (3.1)***	2004	20.9 (5.4)***	519	11.4 (10.7)	34.0	24.5
18	6100	25.7 (4.3)***	1386	23.4 (8.0)***	300	14.9 (17.2)	27.6	26.7
19	4329	39.6 (5.1)***	838	12.1 (13.5)	150	−79.6 (51.9)	61.9	47.4
20	2805	38.0 (6.4)***	502	12.6 (16.1)	80	−22.0 (60.4)	58.7	25.9
21	1436	49.4 (9.3)***	255	17.9 (24.2)				

Notes: Standard errors in parentheses. Total number of individuals is 25,491. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Every cell in this table represents a separate regression, which include controls for gender, ethnicity, age in the first lottery year, and for each lottery the lottery category in that lottery , year of lottery and interaction terms of the year of lottery and lottery category.

weighted average potential outcomes of second and third degree compliers as follows:

$$\frac{E[Y|LR_2 = 1] - E[Y|LR_2 = 0]}{P(D = 1|LR_2 = 1) - P(D = 1|LR_2 = 0)} =$$
$$(E[Y(1) - Y(0)|C_2 = 1]P[C_2 = 1]$$
$$+ E[Y(1) - Y(0)|C_3 = 1]P[C_3 = 1]P[LR_3 = 0])/$$
$$(P[C_2 = 1] + P[C_3 = 1]P[LR_3 = 0]) \quad (5)$$

Repeating the instrumental variables estimation for applicants to the third lottery gives the average treatment effect for compliers to the result of the third lottery. This group only consists of third degree compliers, which gives the following expression:

$$\frac{E[Y|LR_3 = 1] - E[Y|LR_3 = 0]}{P(D = 1|LR_3 = 1) - P(D = 1|LR_3 = 0)} = E[Y(1) - Y(0)|C_3 = 1] \quad (6)$$

With the estimate of the average treatment effect for third degree compliers in equation (6) and estimates of the shares of second and third degree compliers, we can back out the average treatment effect for second degree compliers from equation (5). Likewise, with estimates of the average treatment effects of third and second degree compliers and of the shares of first, second and third degree compliers, we recover the average treatment effect for first degree compliers from equation (4).

The first three columns in Table 6 report IV estimates of the effect of medical school on earnings by year since first lottery using the result of the first, second and third lotteries as instrument. The results in the first column repeat those from column (4) in Table 3, the results in the second column are obtained when restricting the sample to people who lost the first lottery and apply to the second. Likewise the results in the third column are obtained when restricting the sample to people who lost the first and second lotteries and apply to the third. The results in the third column pertain to third degree compliers. Using the procedure outlined above, the final two columns present estimates of the earnings gains for first and second degree compliers.[25] For some years after the first

[25]The shares of the different groups are: 0.224 for first degree compliers, 0.225 for second degree compliers, 0.151 for third degree compliers, 0.205 for always-takers, and 0.195 for never-takers. The

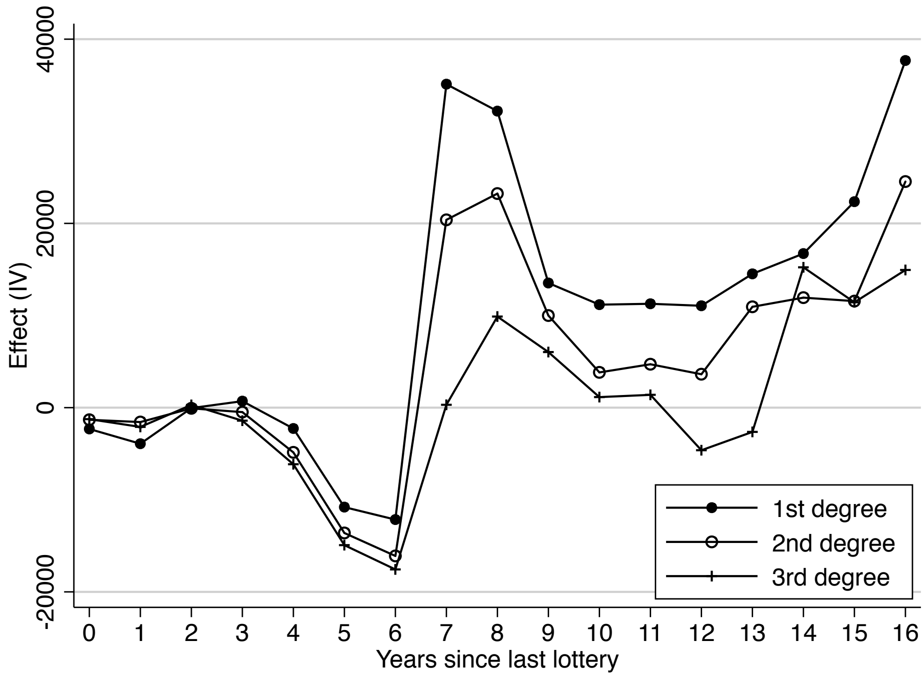


Figure 9. Estimates of effects of medical school completion on earnings for different lotteries and degrees of compliers, by year since first lottery

lottery, the numbers of observations are rather small and the estimates imprecise, but for the years with enough observations the pattern, seems clear. The earnings gain for first degree compliers is larger than for second degree compliers, which in turn is larger than that of third degree compliers. In Figure 9 we plot the returns for the different degrees of compliers. In order to correct for the fact that second and third degree compliers study longer we now have years since last lottery on the X-axis.

We expected that effects would be larger for higher degree compliers, as larger returns for this group could explain why they engage in multiple costly lotteries. The results show the opposite pattern, returns are larger for lower degree compliers. Figure 10 plots the predicted levels of earnings for different degrees of compliers. Earnings as a doctor are very similar for the different groups of winning compliers, so the effect we find is mainly driven by the difference in earnings between groups of losing compliers: Losing third degree compliers earn more than losing first degree compliers. A tentative conclusion could be that first degree compliers are less motivated, both when it comes to reapplying for

probability to lose the first lottery ($\Pr(LR_1 = 0)$) equals 0.536. For the second and third lotteries these probabilities are 0.582 and 0.574, respectively.

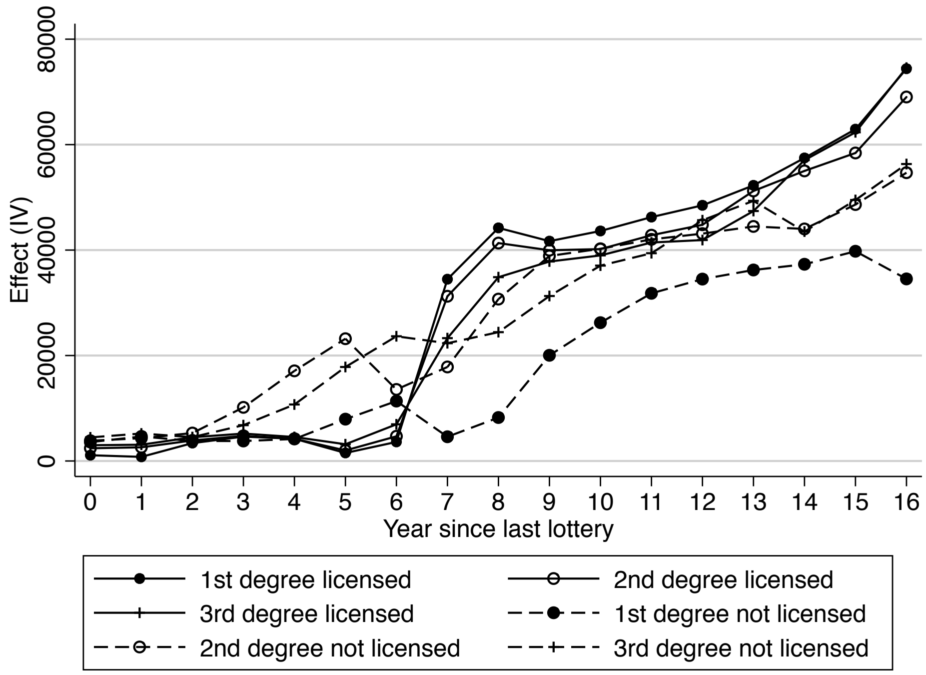


Figure 10. Predicted earnings for different degree compliers

medical school as to their performance in their second best option. Third degree compliers on the other hand, try harder to get in to medical school and are more motivated to make the best out of their second best option when they do not manage to get in to medical school.

6.2 Validity of the instrument

We use the result of the first lottery as instrumental variable to estimate the returns to medical school. In Table 3 we have shown already that this instrument has a strong impact on the endogenous variable. Above we argued that the exclusion restriction holds by virtue of the randomization of the lottery. The exclusion restriction does not hold, however, when lottery losers are disappointed and therefore do worse, or that people are less motivated if they can not follow the study of their first choice. This may lead to an overestimation of the monopoly rent of doctors. To assess the importance of this mechanism, we analyze admission data from two other studies that have or had a quota and a centrally executed admission lottery: dentistry and international business studies. Just like medicine, the diploma of dentistry provides access to a regulated occupation.

Completing dentistry might therefore also give access to monopoly rents. A diploma in international business studies does not provide access to a regulated labor market. We consequently assume that admission to this study does not generate a monopoly rent. If we still find an earnings difference between winning and losing compliers for this study, this could be the result of losers being disappointed and/or being less motivated for the study of their second choice.

Estimates of the earnings gain to dentistry and international business diplomas are presented in Figure 11.[26] For dentistry the effect on earnings is positive and substantial from the fifth year since the first lottery onwards.[27] The effect is around 50,000 euro per year from the seventh to the thirteenth year and increases to 70,000 euro in the sixteenth year. These returns are higher than the returns to medical school in the same years, and show that also in the market for dentists substantial rents are present. The effect of completing international business studies (using the result of the first lottery as an instrument) on earnings is only significantly different from zero in one of the fourteen observation years. While we acknowledge that the level of disappointment from losing the lottery for medical school may differ from the level of disappointment from losing the lottery for international business studies, the estimates are still informative. They show that at least for business studies there is no independent effect of losing the lottery on future earnings.

7 Conclusion

The results of this paper provide evidence for the existence of a substantial monopoly rent for doctors. This calls the desirability of a quota in combination with low tuition fees into question. According to the results, at least 20 percent of doctors' earnings consist of a rent. This rent is defined relative to the next-best option that applicants for medical school have; without completing medical school the same people would have earned at

[26]The lottery for dentistry started later than the lottery for medicine, so we can only estimate the effect on earnings up to the sixteenth year after the first lottery. The lottery for international business studies was abolished in 1992 so for international business we can only estimate the effect from the seventh year on.

[27]In the years relevant for this paper the nominal duration of the dentistry study was five years.

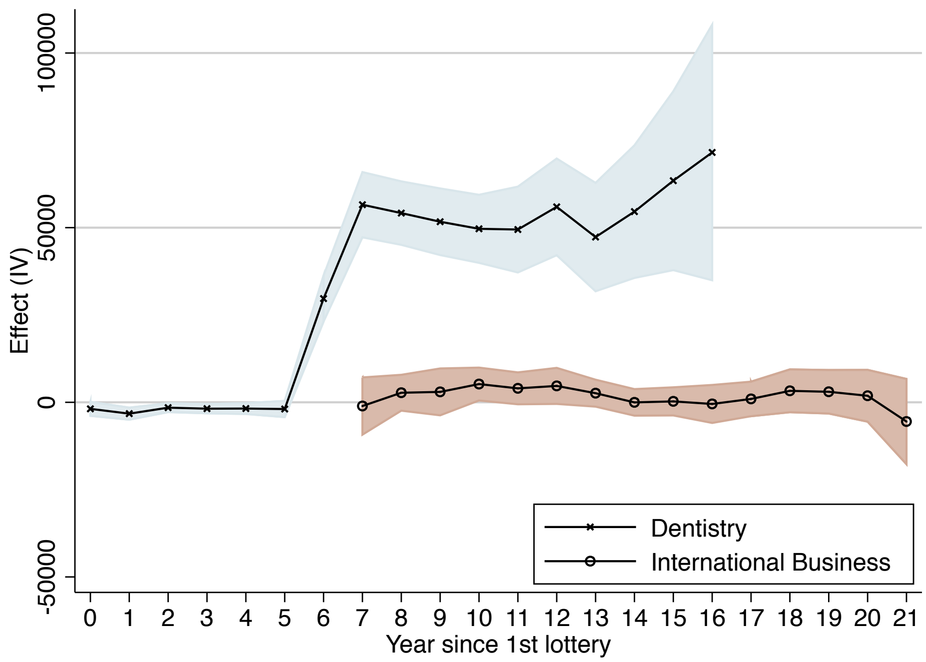


Figure 11. Instrumental variable estimates of the effects of completing dentistry and international business on earnings t $-$ τ years after first applying

least 20 percent less. The estimated wage profiles suggest that the gain is much higher in the long run: twenty-one years after participating in the first lottery the earnings difference has increased up to 60 percent. Only a small part of this earnings difference can be attributed to differences in working hours or a longer investment in human capital. Releasing the quota might reduce the rents of doctors. If we assume that wages 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.[28]

Releasing the quota is costly in a situation in which the government heavily subsidizes tuition fees, as is currently the case in the Netherlands. The costs of a medicine study are much higher than the costs of other study programs. Over the course of the whole study the costs of a medicine student are estimated to be at least 167,000 euros compared to an average amount of 55,000 euros for a study program of a comparable level (Houkes-Hommes, 2009).[29] Students pay only a tuition fee of around 1000 euros per year, which

[28]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 medicine 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.

[29]Part of the difference in costs reflects the fact that the study of medicine takes longer than the

is not differentiated across studies. Furthermore, the majority of the medical students starts a specialization track after finishing medical school. The costs of a specialization track are completely born by the government and range from 40,000-145,000 euro.[30]

The coexistence of high private benefits and high social costs raise the question whether a larger part of the costs should be shifted to the students. We see that even under the conservative assumptions underlying Table 4, there is sufficient scope for medical school students to pay a larger share of their education costs. This would allow the government to increase the number of available places without increasing public expenditures. At the same time higher costs 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.

References

Anderson, G. M., Halcoussis, D., Johnston, L., and Lowenberg, A. D. (2000). Regulatory barriers to entry in the healthcare industry: The case of alternative medicine. *The Quarterly Review of Economics and Finance*, 40(4):485–502.

Baltagi, B. H., Bratberg, E., and Holma, T. H. (2005). A panel data study of physiciansÕ labor supply: the case of Norway. *Health Economics*, 14:1035–1045.

Burstein, P. L. and Cromwell, J. (1985). Relative incomes and rates of return for U.S. physicians. *Journal of Health Economics*, 4(1):63 – 78.

Friedman, M. and Kuznets, S. (1954). *Income from Independent Professional Practice*. NBER Books. National Bureau of Economic Research, Inc.

Herfs, P. (2009). International medical graduates in the Netherlands. Phd-dissertation, Utrecht University.

alternative study programs.

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

Houkes-Hommes, A. (2009). De kosten van verruimen of loslaten van de numerus fixus. Report, SEO.

Hurley, J. (2000). An overview of the normative economics of the health sector. In Culyer, A. J. and Newhouse, J. P., editors, *Handbook of Health Economics*, volume 1A. Elsevier.

Imbens, G. W. and Angrist, J. D. (1994). Identification and estimation of local average treatment effects. *Econometrica*, 62(2):467–475.

Imbens, G. W. and Rubin, D. B. (1997). Estimating outcome distributions for compliers in instrumental variables models. *The Review of Economic Studies*, 64(4):pp. 555–574.

Kugler, A. D. and Sauer, R. M. (2005). Doctors without borders? Relicensing requirements and negative selection in the market for physicians. *Journal of Labor Economics*, 23(3):437–466.

Noether, M. (1986). The growing supply of physicians: has the market become more competitive? *Journal of Labor Economics*, 4:503–537.

OECD (2010). *Health at a glance 2010*. OECD, Paris.

Rizzo, J. and Blumenthal, D. (1994). Physician labor supply: Do income effects matter? *Journal of Health Economics*, 13:433–453.

RVZ (2010). Numerus fixus geneeskunde: Loslaten of vasthouden. Report, Raad van Gezondheid (RVZ).

Schafer, W., Kroneman, M., Boerma, W., van den Berg, M., Wester, G., Deville, W., and van Ginneken, E. (2010). The netherlands: Health system review. *Health Systems in Transition*, 12(1):1–229.

Showalter, M. and Thurston, N. (1997). Taxes and labor supply of high-income physicians. *Journal of Public Economics*, 66:73–97.

Simoens, S. and Hurst, J. (2006). The supply of physician services in OECD countries. OECD Health Working Papers 21, OECD Publishing.

Sloan, F. (1975). Physician supply behavior in the short run. *Industrial and Labor Relations Review*, 28:549–569.

A Results Tables

Table A1. Fraction p admitted and number of applicants N by year and lottery category

	A		B		C		D		E		F		Total	
Year	p	N	p	N	p	N	p	N	p	N	p	N	p	N
1988	1.00	29	1.00	96	0.89	179	0.75	495	0.62	537	0.54	749	0.67	2085
1989	1.00	30	1.00	84	0.96	158	0.80	429	0.66	531	0.58	697	0.71	1929
1990	1.00	36	1.00	111	0.87	194	0.71	468	0.59	571	0.51	746	0.64	2126
1991	1.00	41	0.89	130	0.76	201	0.63	547	0.50	649	0.43	881	0.56	2449
1992	1.00	51	0.84	113	0.72	235	0.59	600	0.48	689	0.42	1036	0.53	2724
1993	0.93	44	0.72	167	0.62	241	0.51	702	0.41	847	0.36	1299	0.45	3300
1994	0.89	61	0.69	208	0.58	389	0.48	905	0.39	1034	0.33	1331	0.43	3928
1995	0.80	88	0.62	265	0.51	430	0.41	982	0.34	1024	0.31	1402	0.39	4191
1996	0.74	97	0.58	283	0.48	494	0.39	1084	0.32	1119	0.27	1496	0.36	4573
1997	0.72	117	0.54	310	0.45	498	0.37	1114	0.31	1129	0.26	1486	0.35	4654
1998	0.75	106	0.56	332	0.50	492	0.39	1121	0.32	1041	0.28	1325	0.37	4417
1999	1.00[a]	87	1.00[a]	341	0.52	421	0.42	1025	0.33	898	0.29	1146	0.43	3918
Total	0.86	787	0.73	2440	0.59	3932	0.49	9472	0.41	10,069	0.36	13,594	0.46	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. IV estimates of effects of medical school completion on earnings and hours, by year since first lottery and gender

	Earnings		Hours	
$t-\tau$	Men	Women	Men	Women
0	−1.7 (0.6)***	−1.0 (.4)***		
1	−2.6 (0.6)***	−2.6 (.3)***		
2	−0.6 (0.5)	−.8 (.3)***		
3	0.1 (0.5)	0.0 (.3)		
4	−1.7 (0.5)***	−1.1 (.4)***		
5	−6.0 (0.7)***	−9.0 (.5)***		
6	−9.1 (0.8)***	−14.0 (.6)***		
7	7.7 (1.2)***	16.0 (1.2)***	165 (158)	273 (128)**
8	16.3 (1.6)***	26.9 (1.2)***	287 (101)***	621 (78)***
9	12.3 (1.2)***	17.2 (.9)***	148 (65)**	393 (49)***
10	9.3 (1.2)***	11.7 (.8)***	212 (50)***	293 (37)***
11	6.1 (1.3)***	9.8 (.9)***	75 (42)*	150 (35)***
12	5.2 (1.5)***	10.0 (1.1)***	145 (38)***	148 (35)***
13	6.8 (1.8)***	11.6 (1.3)***	112 (38)***	178 (38)***
14	10.9 (2.5)***	13.4 (1.7)***	147 (35)***	178 (43)***
15	14.7 (3.3)***	16.7 (2.1)***	112 (39)***	146 (46)***
16	31.8 (4.6)***	22.0 (2.7)***	62 (44)	63 (47)
17	35.2 (6.0)***	23.2 (3.1)***	60 (51)	115 (49)**
18	28.8 (8.2)***	23.6 (4.2)***	67 (47)	58 (49)
19	46.3 (10.0)***	34.0 (4.9)***	106 (50)**	106 (53)**
20	43.0 (11.9)***	32.9 (6.6)***	47 (56)	83 (68)
21	49.2 (16.8)***	47.0 (9.8)***	−21 (72)	72 (83)

Notes: Standard errors in parentheses. Total number of individuals is 25,491. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Every cell in this table represents a separate regression, which include 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.

Table A3. IV estimates of effects of medical school completion on earnings and hours, by year since first lottery and lottery category

$t-\tau$	B	C	D	E	F
0	−.8 (1.5)	−1.0 (1.1)	−1.2 (0.6)**	−1.5 (0.6)***	−1.1 (0.8)
1	−12.1 (6.5)*	−1.2 (0.9)	−2.0 (0.5)***	−2.6 (0.5)***	−3.0 (0.6)***
2	.6 (1.3)	1.4 (0.8)*	−0.0 (0.5)	−1.0 (0.5)***	−1.9 (0.5)***
3	1.3 (1.7)	1.0 (0.7)	0.2 (0.5)	0.2 (0.5)	−0.7 (0.6)
4	−.5 (1.5)	−0.8 (0.9)	−0.7 (0.6)	−2.0 (0.5)***	−1.7 (0.6)***
5	−10.2 (2.1)***	−7.9 (1.2)***	−8.2 (0.8)***	−7.2 (0.7)***	−7.3 (0.7)***
6	−12.6 (2.5)***	−10.6 (1.6)***	−11.9 (1.0)***	−11.9 (0.8)***	−12.1 (0.8)***
7	36.1 (6.3)***	30.7 (3.8)***	20.5 (1.8)***	8.5 (1.4)***	1.0 (1.3)
8	45.1 (6.5)***	35.5 (3.8)***	31.5 (1.9)***	19.1 (2.1)***	11.5 (1.5)***
9	21.1 (4.6)***	15.7 (2.6)***	20.0 (1.5)***	13.8 (1.3)***	11.6 (1.3)***
10	18.1 (4.4)***	8.1 (2.4)***	13.0 (1.4)***	9.1 (1.3)***	10.1 (1.3)***
11	19.1 (4.9)***	10.1 (2.8)***	9.5 (1.6)***	7.7 (1.5)***	6.4 (1.2)***
12	10.0 (5.8)*	9.1 (3.4)***	8.5 (1.9)***	7.7 (1.7)***	6.9 (1.4)***
13	5.7 (8.8)	12.9 (4.3)***	10.3 (2.5)***	8.4 (1.8)***	9.2 (1.7)***
14	−5.6 (15.1)	7.3 (6.5)	11.5 (3.4)***	15.5 (2.6)***	12.2 (2.1)***
15	5.9 (20.2)	20.0 (10.3)*	15.5 (4.6)***	18.0 (3.5)***	14.4 (2.6)***
16	14.8 (27.1)	17.9 (14.4)	30.3 (6.4)***	27.7 (4.3)***	25.4 (3.6)***
17	7.2 (70.9)	19.3 (14.7)	34.8 (8.3)***	26.6 (5.5)***	27.4 (4.3)***
18		42.0 (18.7)**	24.6 (10.9)**	21.2 (9.0)**	28.4 (5.1)***
19		67.8 (18.1)***	37.5 (17.2)**	41.2 (8.6)***	37.1 (6.4)***
20		50.2 (34.2)	4.7 (24.8)	50.8 (11.3)***	38.3 (7.6)***
21		70.7 (55.8)	32.0 (41.8)	43.6 (13.0)***	53.4 (11.3)***

Notes: Standard errors in parentheses. Total number of individuals is 25,491. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Every cell in this table represents a separate regression, which include controls for gender, ethnicity, age in the first lottery year and year of first lottery.

B Estimation of outcome distributions for compliers

To explain this method we introduce some extra notation. $Y_i(1)$ and $Y_i(0)$ denote the potential earnings with and without medical school respectively. For each observation we observe the triple (LR_{1i}, D_i, Y_i). We cannot directly identify the compliers from the data, but we can identify some of the never-takers (for whom $LR_{1i} = 1$ and $D_i = 0$) and some of the 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 will be denoted $g_a(y)$ and $g_n(y)$. Furthermore we will also know the population proportions ϕ_c, ϕ_a and ϕ_n of respectively compliers, always-takers and never-takers.

The distributions that we are after 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 directly observed 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 $D_i = 1$) we will observe 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 $g_n(y) = f_{10}(y)$. Imbens and Rubin (1997) show that the distributions for the winning and losing compliers can be expressed in terms of the directly estimable distributions in the following way:

$$g_{c0}(y) = \frac{\phi_n + \phi_c}{\phi_c} f_{00}(y) - \frac{\phi_n}{\phi_c} f_{10}(y), \tag{A1}$$

and,

$$g_{c0}(y) = \frac{\phi_a + \phi_c}{\phi_c} f_{11}(y) - \frac{\phi_a}{\phi_c} f_{01}(y). \tag{A2}$$