# 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 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. Estimated earnings profiles suggest that the lifetime difference is even larger: 22 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. We therefore interpret the return as a rent due to the restricted supply of doctors in the Netherlands. The returns do not vary with gender or ability, and appear to shift the entire earnings distribution.

JEL-codes: J44; I18; I23; C36

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

*This version: May 2013. We gratefully acknowledge valuable comments from Maarten Lindeboom, Sarah Turner, Dinand Webbink, and seminar participants in Amsterdam, Bern, Bonn, Bristol, Lausanne, Munich, New York, 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

This paper exploits admission lotteries for medical school in the Netherlands to estimate the earnings return to completion of medical school. Like in many other countries, the supply of doctors in the Netherlands is restricted through limiting the number of places in medical school (Simoens and Hurst, 2006). Our approach produces credible estimates of the rents that doctors earn in such a regulated labor market.

Regulating the supply of doctors can be motivated on the grounds of (i) ensuring the quality of the study program, (ii) the high costs of medical studies which would be wasted for students who do not find employment as a doctor, and (iii) avoiding supplier induced demand. Knowledge about the size of the rents that doctors earn, allows governments to take informed decisions about the tightness of the supply restriction, the level of tuition fees, and regulations regarding doctors' earnings levels.

Previous studies that looked at the monopoly rent of doctors were unable to address selectivity issues or examined rather 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 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. 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 monthly earnings that are on average 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.

We use administrative data from the 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 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.

The admission lotteries that we exploit in this paper allow us to deal with selectivity issues caused by, for example, high ability students self-selecting into medical school. 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 instrumental variable for completing medical school. The first stage effect is substantial and highly significant.

Even in the absence of a 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, 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 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. We also do not find differential returns by ability, where high-school GPA measures ability. Using the approach developed by Imbens and Rubin (1997), we analyze 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. There are fewer people with zero earnings and the whole earnings distribution is shifted to the right.

The large earnings differences cannot 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 annually around 300 hours more. After this first period this difference decreases to around 100 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.

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 main results, while Section 6 assesses the heterogeneity of treatment effects along three dimensions: gender, ability and position in the earnings distribution. Section 7 concludes.

## 2 Background and institutional context

### *2.1 Medical schools in the Netherlands*

In the Netherlands a high school diploma makes people eligible for university studies in all fields and institutions.[1] Students choose their field as soon as they enter university, unlike, for example, in the US where students specialize later. For most 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. 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 (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

[1] 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.

**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

(Hurley, 2000): educating more doctors could increase the number of medical treatments.

The minister of education officially sets the size of the quota. Until 1993 the annual quota was fixed at 1458 students, after which it was gradually expanded to 1815 students in 1995. In the years relevant for our paper 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 available for the 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.[2] Rejected applicants are allowed to reapply in the next year, and until 1999 they could do this as often as they wanted.[3] We observe that 69 percent of the rejected first-time applicants reapply a second time.[4]

The lottery is weighted such that students with a higher GPA on the secondary school exams have a higher probability of being admitted.[5] High school exams are nationwide and

[2]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.

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

[4]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.

[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 and should have passed these subjects.

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 final column indicates the 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.[6]

Figure 1 shows the admission rates per year by lottery category.[7] 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.[8]

The admission lottery is centrally executed. Applicants are allowed to list their first 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 the same for all study programs. 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 on-the-job training are

[6]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.

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

[8]In 1999 a reform was implemented which implied that 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 an exceptional GPA of 9.6 but lost the lottery three times in a row. The weights for the other categories remained the same.

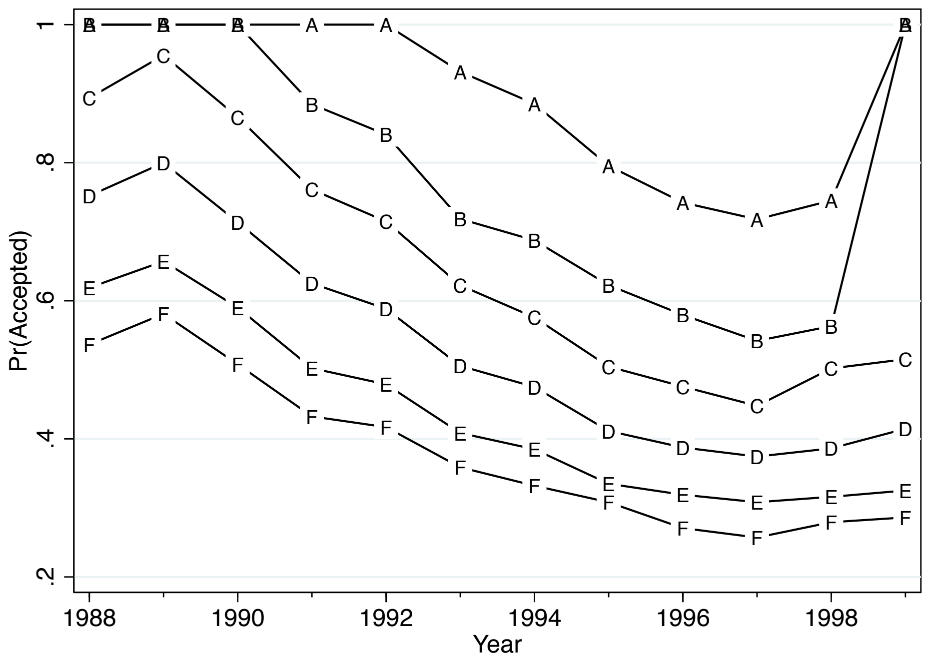



**Figure 1.** Probability of being admitted by year of application

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 1000 euro (at that time). After 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 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 study can take between six and 15 years.

### *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.[9] General practitioners constitute around 30 percent of the physician population.

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

The remainder pursues a career as a social doctor (10 percent)[10] 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 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 a specialist (52 versus 39 percent) and less likely to become general practitioner (25 versus 31 percent), social doctor (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 (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. During our observation period (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 service, in order to introduce incentives for providing services.

The number of practicing doctors in the Netherlands is 2.9 per 1000 inhabitants; close to the OECD average of 3.1.[11] 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 regular employees 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 four.

Doctors with a non-Dutch diploma can practice in the Netherlands if the Dutch reg-

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

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

istration authority recognizes their diploma. 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 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 six 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*

Our data come from three 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 admission lotteries. Hence, 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 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 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.[12] 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. Finally, applicants in lottery category A are excluded since almost all of them are eventually admitted to medical school. This leaves us with 25,551 individuals.

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.

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.

### *3.2 Descriptive statistics*

Table 2 presents descriptive statistics separately for winners and losers of their first lottery.[13] The upper part of the table provides information on personal characteristics. About 60 percent of the applicants is female and the percentage of women is similar

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

[13] 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.** Descriptive statistics by admission status of the first lottery application

| | Lottery winners | Lottery losers |
|---|---|---|
| *Personal characteristics* | | |
| Female | 58% | 58% |
| Age at first application | 18.3 | 18.3 |
| Non-western immigrant | 8% | 8% |
| GPA high school exams (0-10) | 7.06 | 6.79 |
| *Study enrollment and completion* | | |
| Enrolled in medical school | 94% | 45% |
| Completed medical school (by 2010) | 83% | 41% |
| Licensed as doctor (by 2008) | 80% | 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) | 39,149 | 28,268 |
| Annual working hours (2006-2010) | 1756 | 1693 |
| Hourly earnings (2006-2010) | 31.5 | 24.1 |
| *Household composition* | | |
| Married in 2010 | 51% | 45% |
| Children in 2010 | 60% | 51% |
| Number of individuals | 11,819 | 13,672 |

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

among winners and losers. The average age at the first application is 18.3. The mean GPA of lottery winners is higher than of lottery losers, which reflects that GPA determines the weight in the lottery.

Next, the table presents summary statistics on study enrollment and completion. 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; six 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 83 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 afterwards registered as a doctor in the Netherlands.

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.[14] Only five 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 (ten percent), Economics (nine percent) and Law (six percent).

Lottery losers are seven 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 GPA: Applicants in lottery category F are seven percentage points less likely to obtain a diploma than applicants in lottery category B.

The lower part of Table 2 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.[15] All amounts are corrected for the average wage development of university graduates over the observation period and converted to 2010 euros. Table 2 shows that earnings are, on average, around 38 percent higher for winners than for losers.

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

[15] The fraction of people that live abroad increases over time and is five percent in 2008; this fraction is the same for winners and 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 (1872 hours per year).[16] Average working hours are close to 1700, but winners work approximately four percent more 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.

## 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 $\tau$ ($Y_{it\tau}$) and having completed medical school ($D_i$):

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

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. $\alpha_t$ 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

[16] 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) * 1872 hours.

result (0/1) of the first lottery ($LR_{1i}$) in which individual $i$ participated. We estimate a first-stage equation of the form:

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

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.[17] 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.

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

# 5 Main results

The presentation of the main results is divided into three parts. We first present and discuss estimates of the effect of medical school on (log) earnings. We then continue with estimates of the effect of medical school on working hours, (log) earnings per hour and employment. Finally, we look at the impact of medical school on family outcomes: being

[17]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 $\lambda$.

married and having children.

*Earnings*

We perform our regressions separately for year after the first lottery ($t-\tau$), which implies that each regression uses different subsamples. Table 3 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), also the estimates in the first row are 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 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 3 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

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

| $t - \tau$ (1) | N (2) | 1st stage (3) | Earnings (x€1000) (4) | log(Earnings) (5) |
|---|---|---|---|---|
| 0 | 2,159 | 0.36 (0.02)*** | -1.2 (0.3)*** | -0.36 (0.15)** |
| 1 | 4,607 | 0.36 (0.01)*** | -2.5 (0.3)*** | -0.67 (0.12)*** |
| 2 | 7,167 | 0.37 (0.01)*** | -0.7 (0.3)*** | -0.02 (0.08) |
| 3 | 9,885 | 0.38 (0.01)*** | 0.1 (0.3) | 0.07 (0.06) |
| 4 | 12,438 | 0.39 (0.01)*** | -1.3 (0.3)*** | -0.18 (0.06)*** |
| 5 | 14,952 | 0.39 (0.01)*** | -7.1 (0.4)*** | -1.35 (0.07)*** |
| 6 | 17,154 | 0.39 (0.01)*** | -11.0 (0.4)*** | -1.31 (0.07)*** |
| 7 | 18,945 | 0.38 (0.01)*** | 11.3 (0.8)*** | 0.76 (0.06)*** |
| 8 | 20,705 | 0.38 (0.01)*** | 20.3 (0.9)*** | 0.85 (0.04)*** |
| 9 | 22,183 | 0.38 (0.01)*** | 13.8 (0.7)*** | 0.51 (0.03)*** |
| 10 | 23,484 | 0.38 (0.01)*** | 9.8 (0.7)*** | 0.34 (0.03)*** |
| 11 | 24,849 | 0.38 (0.01)*** | 7.6 (0.7)*** | 0.21 (0.02)*** |
| 12 | 22,608 | 0.38 (0.01)*** | 7.7 (0.8)*** | 0.23 (0.02)*** |
| 13 | 20,117 | 0.39 (0.01)*** | 9.3 (0.9)*** | 0.24 (0.02)*** |
| 14 | 17,568 | 0.39 (0.01)*** | 11.3 (1.3)*** | 0.25 (0.03)*** |
| 15 | 14,894 | 0.39 (0.01)*** | 16.2 (1.7)*** | 0.31 (0.03)*** |
| 16 | 12,410 | 0.38 (0.01)*** | 25.2 (2.2)*** | 0.34 (0.03)*** |
| 17 | 9,949 | 0.39 (0.01)*** | 29.4 (2.7)*** | 0.40 (0.04)*** |
| 18 | 7,808 | 0.39 (0.01)*** | 30.6 (3.6)*** | 0.39 (0.05)*** |
| 19 | 6,056 | 0.40 (0.01)*** | 42.4 (4.2)*** | 0.54 (0.06)*** |
| 20 | 4,306 | 0.41 (0.02)*** | 41.8 (5.3)*** | 0.49 (0.07)*** |
| 21 | 2,784 | 0.41 (0.02)*** | 42.3 (6.9)*** | 0.45 (0.08)*** |
| 22 | 1,430 | 0.45 (0.03)*** | 39.4 (7.3)*** | 0.48 (0.12)*** |

*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.

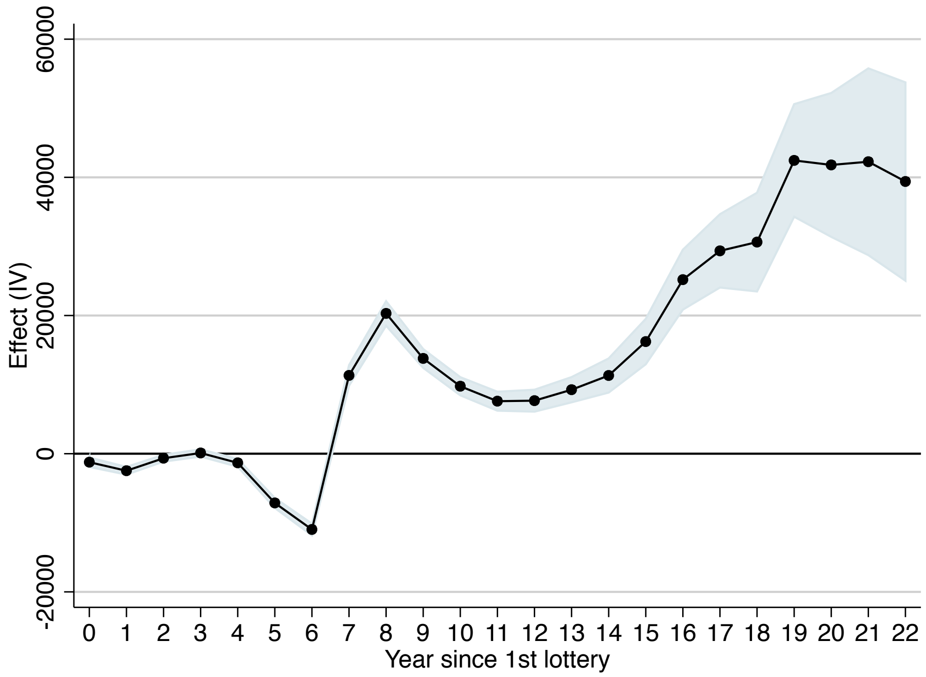



**Figure 2.** Instrumental variable estimates of the effects of completing medical school on earnings $t - \tau$ years after first applying (colored areas are 95 percent confidence intervals).

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 years onwards 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 20,000 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 onwards, 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.

The final column of Table 3 shows results for the effect of medical school on the

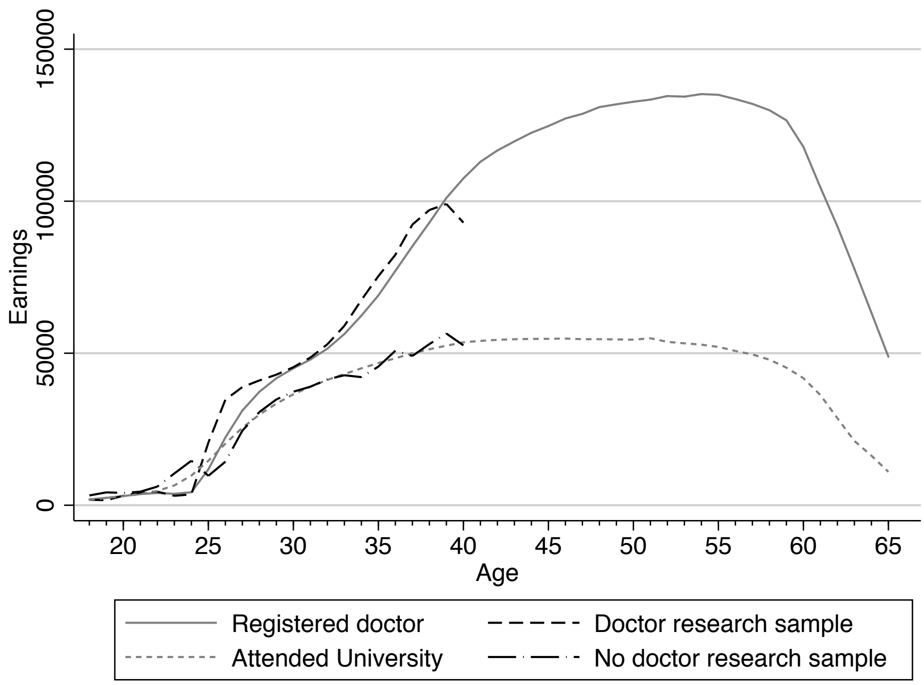



**Figure 3.** Predicted levels for earnings

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 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.

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

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

where $\bar{X}$ and $\bar{LC}$ are the observed sample means. 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 attenders, where the latter serves as reference group for the "non-doctors".[18] We regressed 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 non-doctors. 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 year the estimated differences from Table 3 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 (1,154,629), while at a discount rate of 0.05 the net present value is still almost half a million euros (495,315). The internal rate of return equals 33%.

*Hours and employment*

It is often argued that doctors make longer working hours, which could explain (part of) the earnings return. Column (3) of Table 4 and panel (a) of Figure 4 report estimates

[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 earnings while being active on the labor market.

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 four years doctors work a total of 1,200 hours more than non-doctors. The average number of working hours during these four years together is around 6,400 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 six percent difference. Differences in working hours can therefore not explain the large earnings gain to medical school.[19] This is confirmed by the results in column (4) of Table 4 (and panel (b) of Figure 4) 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 increases to 0.43.[20]

The final column in Table 4 (and panel (c) of Figure 2) 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 struggle more finding stable employment. From year ten onwards medical school graduates are around six percentage points more likely to have earnings above the level of welfare benefits than other students, relative to a base of 0.89.

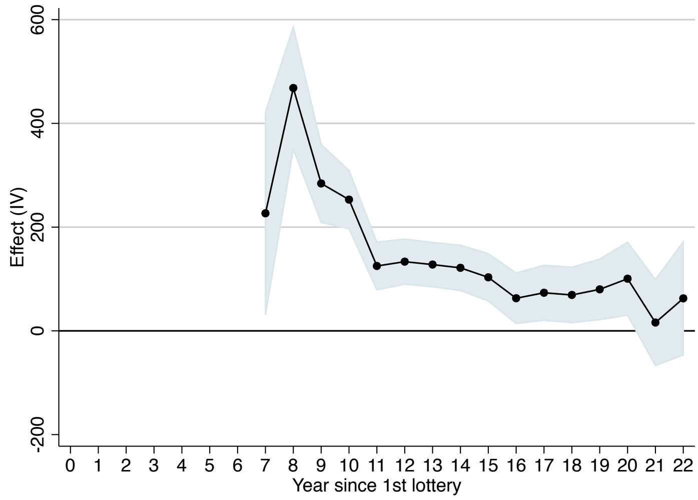
[19] The estimated effect on hours is downward biased if self-employed doctors work more hours than the 1872 hours that we imputed for them. This is unlikely to be the case. Leuven et al. (2013) conducted a survey among around 60 percent of the people that applied to medical school in the period 1988-1993. 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).

[20] Calculation of predicted hours for an average individual with and without medical school reveals that the large effect in years 7 to 9 are mainly driven by the fact that doctors more often have a full-time job.

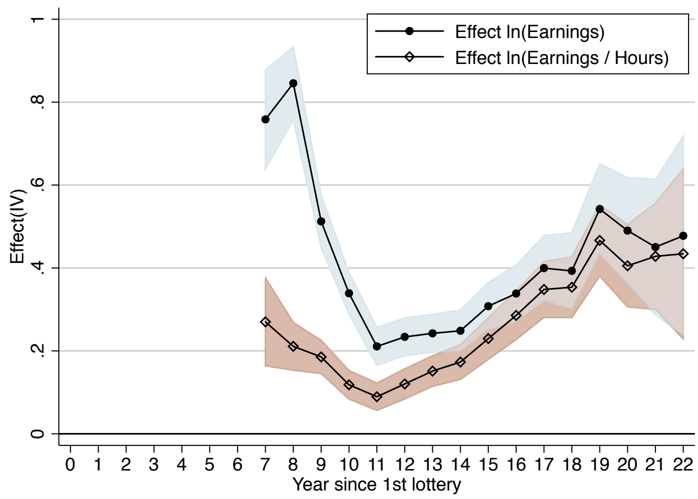
**Table 4.** Instrumental variable estimates of the effects of completing medical school on labor market outcomes $t-\tau$ years after first applying

| $t-\tau$ (1) | N (2) | Hours (3) | log(Earnings/Hrs) (4) | I[Earnings>Welfare] (5) |
|---|---|---|---|---|
| 0 | 2159 | | | -0.04 (0.02)* |
| 1 | 4607 | | | -0.16 (0.02)*** |
| 2 | 7167 | | | -0.08 (0.02)*** |
| 3 | 9885 | | | 0.02 (0.02) |
| 4 | 12,438 | | | -0.02 (0.02) |
| 5 | 14,952 | | | -0.32 (0.02)*** |
| 6 | 17,154 | | | -0.34 (0.02)*** |
| 7 | 18,945 | 227 (100)** | 0.27 (0.05)*** | 0.25 (0.02)*** |
| 8 | 20,705 | 468 (60)*** | 0.21 (0.03)*** | 0.30 (0.02)*** |
| 9 | 22,183 | 284 (38)*** | 0.19 (0.02)*** | 0.19 (0.01)*** |
| 10 | 23,484 | 253 (29)*** | 0.12 (0.02)*** | 0.11 (0.01)*** |
| 11 | 24,849 | 125 (23)*** | 0.09 (0.02)*** | 0.08 (0.01)*** |
| 12 | 22,608 | 133 (22)*** | 0.12 (0.02)*** | 0.06 (0.01)*** |
| 13 | 20,117 | 128 (22)*** | 0.15 (0.02)*** | 0.06 (0.01)*** |
| 14 | 17,568 | 121 (22)*** | 0.17 (0.02)*** | 0.05 (0.01)*** |
| 15 | 14,894 | 103 (23)*** | 0.23 (0.03)*** | 0.05 (0.01)*** |
| 16 | 12,410 | 63 (25)** | 0.29 (0.03)*** | 0.06 (0.01)*** |
| 17 | 9949 | 73 (27)*** | 0.35 (0.03)*** | 0.05 (0.01)*** |
| 18 | 7808 | 69 (27)** | 0.35 (0.04)*** | 0.03 (0.02)* |
| 19 | 6056 | 80 (30)*** | 0.47 (0.04)*** | 0.04 (0.02)** |
| 20 | 4306 | 100 (36)*** | 0.41 (0.05)*** | 0.00 (0.02) |
| 21 | 2784 | 16 (42) | 0.43 (0.07)*** | 0.02 (0.03) |
| 22 | 1430 | 63 (56) | 0.43 (0.10)*** | 0.05 (0.04) |

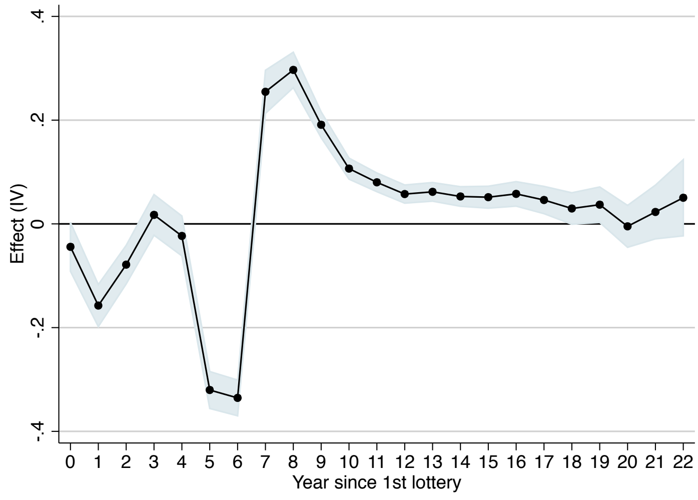
*Notes*: Standard errors in parentheses. Total number of individuals is 25,491. * $p < 0.10$ , ** $p < 0.05$ , *** $p < 0.01$ . Every cell in this table represents a separate regression, which include controls for gender, ethnicity, age in the first lottery year, lottery category, year of first lottery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




**(a)** Hours




**(b)** ln(Hourly Earnings)




**(c)** I[Earnings>Subsistence Level]

**Figure 4.** Instrumental variable estimates of the effects of completing medical school on labor market outcomes $t - \tau$ years after first applying (colored areas are 95 percent confidence intervals).

*Family outcomes*

Above we already established that the higher earnings of doctors cannot be attributed to much longer working hours. Here we assess whether doctors sacrifice in other dimensions. In particular, 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.[21] Our 2SLS estimates 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).

## 6 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 is 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 2 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 5a shows the estimates of the earnings returns separately for men and women.[22] Until the sixth year both men and women experience an earnings loss from studying in

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

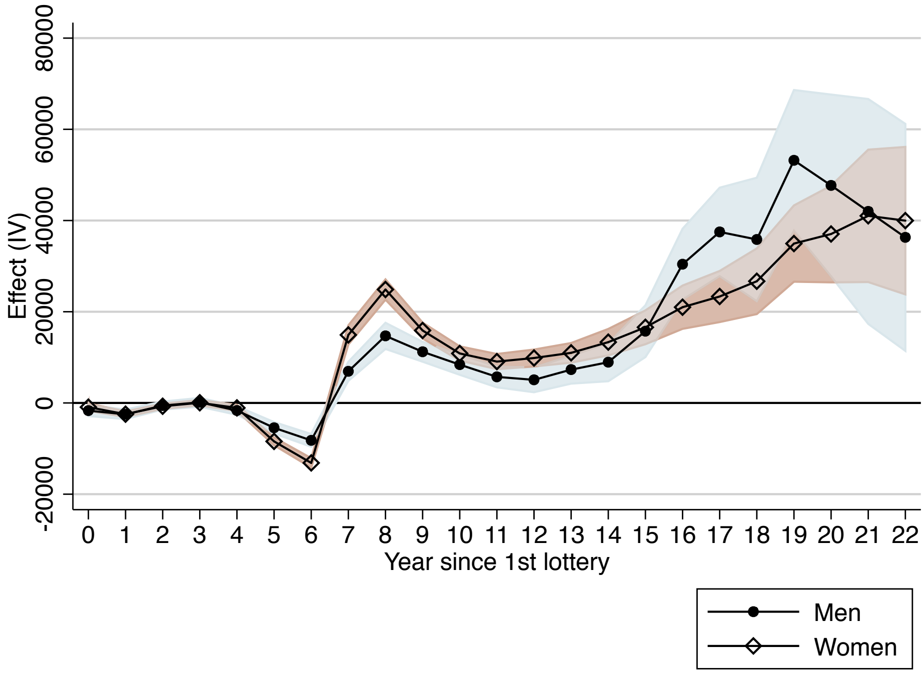
[22]Table A2 in the appendix reports the results.

medical school. This loss is very similar across genders. In years seven to 14, the returns are much larger for women than for men, but from year 15 onwards men catch up and in the final years the returns to medical school are slightly larger for men than for women. 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 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 a bit further in their career male doctors even work fewer hours than male non-doctors.

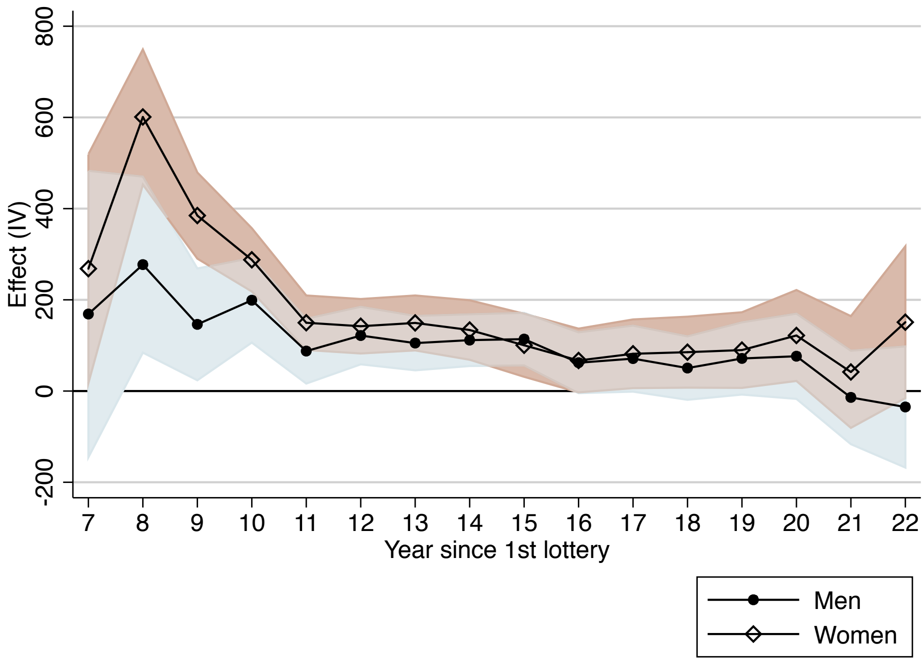
Figure 6 repeats Figure 3, but now for men and women separately. These graphs reveal two important facts. First, while the estimated returns to medical school for men and women are very similar, earnings levels are much higher for men than for women. Female doctors earn more or less the same as male non-doctors. 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 0.78 million euros for women. At a discount rate of 0.05 these amounts are 0.56 and 0.36 million euros. The internal rates of return are 31% for men and 35% for women.

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 this is a significant 9 percentage points (s.e. 2 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).

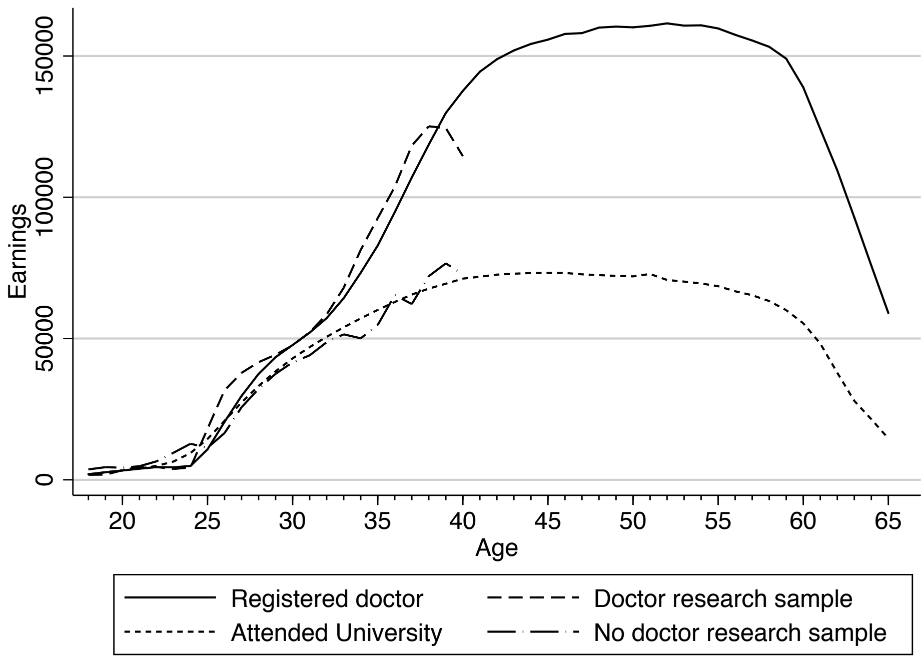



**(a)** Earnings

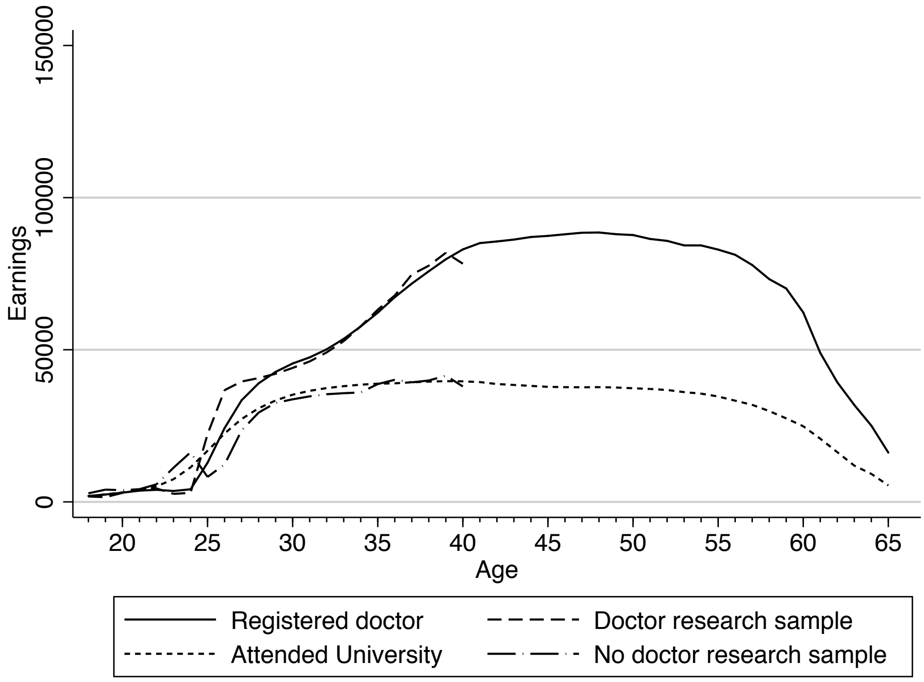



**(b)** Hours

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




**(a)** Men




**(b)** Women

**Figure 6.** Predicted earnings by gender

*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 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.[23] Figure 7 reports the results.[24] 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 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 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 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' GPAs do not respond to changes in 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 faster than students with a low GPA.

[23] Recall that category A is omitted since there are too few losers in this category.
[24] The results can also be found in Table A3 in the appendix.

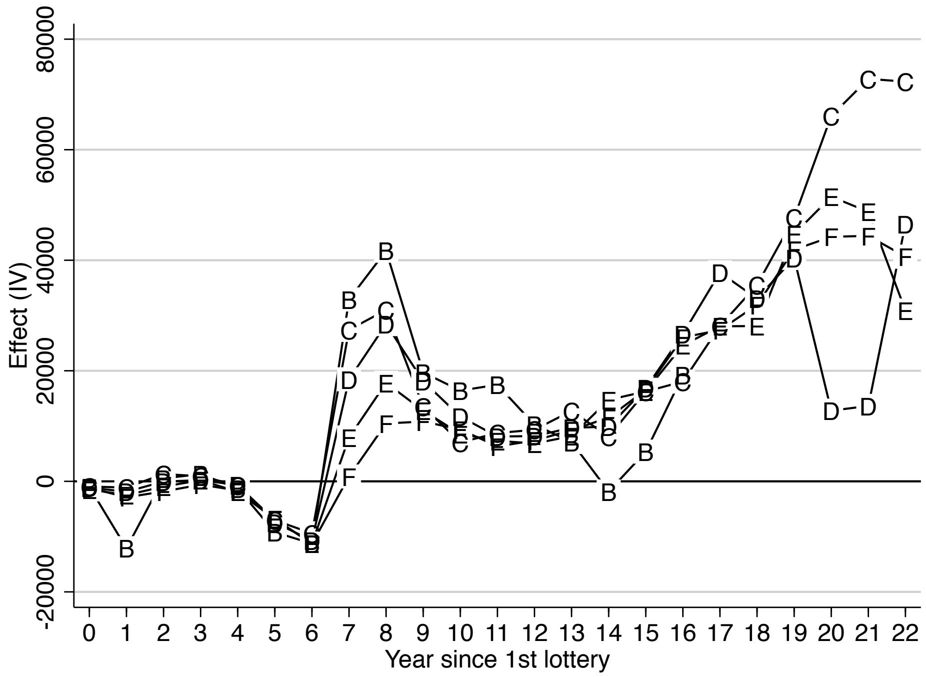


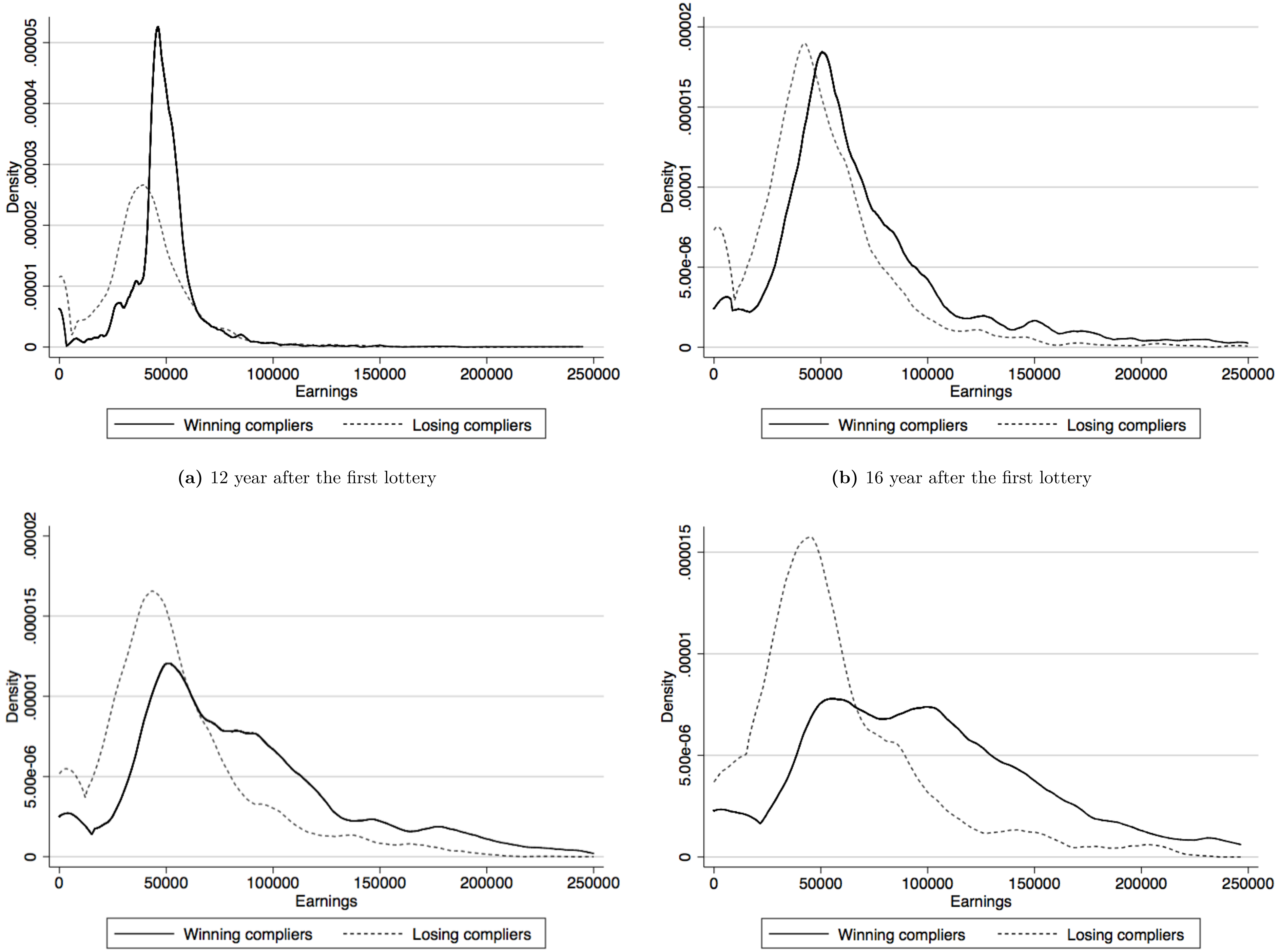

**Figure 7.** IV estimates of effects of medical school completion on earnings, by year since first lottery and lottery category

*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 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).[25]

Figure 8 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

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




**(a)** 12 year after the first lottery

**(b)** 16 year after the first lottery

**(c)** 18 year after the first lottery

**(d)** 20 years after the first lottery

**Figure 8.** Earnings distribution of winning and losing compliers

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 5 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.

## 7 Conclusion

Our empirical results provide evidence for 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. If we interpret the remainder of the earnings returns as monopoly rent, this also explains why the number of applicants is substantially higher than the number of available slots in medical schools.

Releasing the quota might reduce the monopoly 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.[26] Releasing the quota is costly in a situation in which the government 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).[27] Students pay only a tuition fee of around 1000 euros per year, which is not differentiated across studies.

[26]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.

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

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.[28]

Releasing the quota may not only increase public expenditures on university education, but it is often argued that due to supplier-induced demand also health-care costs may increase. However, one might question whether the coexistence of high private returns and high public investment is desirable. Policy makers can either consider maximizing earnings for individuals in the medical profession or shift part of the study costs to students. Our results suggest that there is sufficient scope for medical school students to pay a larger share of their study costs. This might also 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. *Quarterly Review of Economics and Finance*, 40(4):485–502.

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.

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


[28]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.

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 Rubin, D. B. (1997). Estimating outcome distributions for compliers in instrumental variables models. *Review of Economic Studies*, 64(4):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.

Leuven, E., Oosterbeek, H., and De Wolf, I. (2013). The effects of medical school on health outcomes: Evidence from admission lotteries. *Journal of Health Economics*, 32:698–707.

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

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.

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

# A Appendix 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 (x€1000) | | Hours | |
|---|---|---|---|---|
| $t-\tau$ | Men | Women | Men | Women |
| 0 | −1.7 (0.6)*** | −0.9 (0.4)** | | |
| 1 | −2.5 (0.5)*** | −2.5 (0.3)*** | | |
| 2 | −0.6 (0.4) | −0.7 (0.3)** | | |
| 3 | 0.1 (0.5) | 0.0 (0.3) | | |
| 4 | −1.7 (0.5)*** | −1.1 (0.3)*** | | |
| 5 | −5.4 (0.6)*** | −8.4 (0.4)*** | | |
| 6 | −8.2 (0.7)*** | −13.2 (0.5)*** | | |
| 7 | 6.9 (1.1)*** | 14.9 (1.1)*** | 169 (160) | 268 (128)** |
| 8 | 14.7 (1.5)*** | 24.9 (1.1)*** | 277 (98)*** | 601 (76)*** |
| 9 | 11.2 (1.1)*** | 15.9 (0.9)*** | 146 (63)** | 385 (48)*** |
| 10 | 8.4 (1.1)*** | 10.9 (0.8)*** | 199 (47)*** | 288 (35)*** |
| 11 | 5.7 (1.2)*** | 9.1 (0.9)*** | 88 (36)** | 150 (31)*** |
| 12 | 5.1 (1.4)*** | 9.9 (0.9)*** | 122 (32)*** | 142 (30)*** |
| 13 | 7.3 (1.6)*** | 11.0 (1.1)*** | 105 (30)*** | 149 (31)*** |
| 14 | 8.9 (2.1)*** | 13.3 (1.5)*** | 112 (29)*** | 134 (33)*** |
| 15 | 15.7 (2.9)*** | 16.6 (1.9)*** | 114 (29)*** | 100 (35)*** |
| 16 | 30.4 (4.0)*** | 21.0 (2.4)*** | 62 (34)* | 67 (36)* |
| 17 | 37.5 (5.0)*** | 23.3 (2.9)*** | 71 (37)* | 82 (38)** |
| 18 | 35.8 (6.9)*** | 26.7 (3.7)*** | 50 (36) | 85 (40)** |
| 19 | 53.2 (7.9)*** | 34.9 (4.3)*** | 71 (40)* | 90 (42)** |
| 20 | 47.7 (10.2)*** | 37.0 (5.4)*** | 76 (48) | 122 (51)** |
| 21 | 42.0 (12.6)*** | 41.0 (7.4)*** | −14 (52) | 42 (62) |
| 22 | 36.3 (12.7)*** | 40.0 (8.2)*** | −35 (68) | 151 (85)* |

*Notes*: Standard errors in parentheses. Total number of individuals is 25,491, of which 10,661 are men and 14,880 are women. * $p < 0.10$ , ** $p < 0.05$ , *** $p < 0.01$ . 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 (x€1000), by year since first lottery and lottery category

| $t-\tau$ | *B* | *C* | *D* | *E* | *F* |
|---|---|---|---|---|---|
| 0 | −1.0 (1.7) | −0.9 (1.0) | −1.1 (0.6)** | −1.5 (0.6)*** | −1.2 (0.8) |
| 1 | −12.1 (6.5)* | −1.1 (0.8) | −1.9 (0.5)*** | −2.5 (0.5)*** | −2.9 (0.5)*** |
| 2 | 0.5 (1.3) | 1.3 (0.7)* | 0.0 (0.5) | −0.9 (0.5)** | −1.8 (0.5)*** |
| 3 | 1.3 (1.7) | 0.9 (0.7) | 0.2 (0.5) | 0.2 (0.4) | −0.6 (0.6) |
| 4 | −1.3 (1.2) | −0.7 (0.8) | −0.7 (0.5) | −1.9 (0.5)*** | −1.6 (0.6)*** |
| 5 | −9.2 (1.9)*** | −7 (1.1)*** | −7.4 (0.8)*** | −6.8 (0.7)*** | −6.8 (0.7)*** |
| 6 | −11.3 (2.2)*** | −9.4 (1.4)*** | −10.7 (0.9)*** | −11.3 (0.8)*** | −11.3 (0.8)*** |
| 7 | 32.9 (5.5)*** | 27.4 (3.3)*** | 18.4 (1.6)*** | 7.9 (1.3)*** | 0.9 (1.2) |
| 8 | 41.7 (5.9)*** | 31.0 (3.2)*** | 28.4 (1.7)*** | 17.8 (2.0)*** | 10.5 (1.4)*** |
| 9 | 19.7 (4.3)*** | 13.5 (2.3)*** | 18.1 (1.4)*** | 12.8 (1.3)*** | 10.8 (1.2)*** |
| 10 | 16.4 (4.2)*** | 7.0 (2.1)*** | 11.7 (1.3)*** | 8.6 (1.2)*** | 9.4 (1.2)*** |
| 11 | 17.5 (4.6)*** | 8.7 (2.4)*** | 8.1 (1.4)*** | 7.3 (1.4)*** | 6.3 (1.1)*** |
| 12 | 10.2 (5.4)* | 9.3 (2.9)*** | 8.2 (1.6)*** | 6.9 (1.5)*** | 7.4 (1.3)*** |
| 13 | 7.1 (6.9) | 12.7 (3.5)*** | 9.7 (2.0)*** | 8.2 (1.6)*** | 9.3 (1.5)*** |
| 14 | −1.8 (10.7) | 8.1 (4.6)* | 9.9 (2.7)*** | 14.7 (2.3)*** | 11.5 (1.9)*** |
| 15 | 5.4 (14.7) | 16.2 (7.2)** | 16.8 (3.7)*** | 16.3 (3.0)*** | 16.6 (2.5)*** |
| 16 | 19.2 (17.6) | 18.0 (10.7)* | 26.6 (4.9)*** | 24.6 (3.8)*** | 26 (3.4)*** |
| 17 | 2.2 (31.7) | 28.1 (11.0)*** | 37.8 (7.0)*** | 28.1 (4.7)*** | 27.4 (3.9)*** |
| 18 | −125.3 (230.4) | 35.5 (14.7)** | 33.0 (9.2)*** | 28.1 (7.0)*** | 31.9 (4.8)*** |
| 19 | 74.3 (1937.3) | 47.7 (14.0)*** | 40.4 (11.9)*** | 44.7 (7.2)*** | 41.9 (5.6)*** |
| 20 | 136.1 (40.2)*** | 66.1 (18.8)*** | 12.8 (18.2) | 51.5 (8.7)*** | 44.2 (6.8)*** |
| 21 | 137.7 (57.2)** | 72.8 (35.8)** | 13.6 (26.2) | 48.8 (11.0)*** | 44.4 (8.3)*** |
| 22 | 124.5 (56.9)** | 72.3 (60.0) | 46.5 (21.8)** | 30.9 (13.4)** | 40.6 (9.1)*** |

*Notes*: Standard errors in parentheses. Total number of individuals in categories B, C, D, E and F are respectively 1808, 2724, 6083, 6435 and 8441. * $p < 0.10$ , ** $p < 0.05$ , *** $p < 0.01$ . 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

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 $\phi_c, \phi_a$ and $\phi_n$ 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 $g_n(y) = f_{10}(y)$. 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,

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