Do Dutch dentists extract monopoly rents?

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Abstract

We exploit lottery-determined admission to dental school to estimate the payoffs to the study of dentistry in the Netherlands. Using data from up to 22 years after the lottery, we find that in most years after graduation dentists earn around 50,000 Euros more than they would earn in their next-best profession. The payoff is larger for men than for women but does not vary with high school GPA. The large payoffs cannot be attributed to longer working hours, larger investments while studying (opportunity costs and direct costs), or unpleasant aspects of working as a dentist. A plausible explanation is that dentists earn a monopoly rent. Results from regressions of dentists' earnings on dentists density are consistent with this, as are the facts that the supply of dentists in the Netherlands is low and that the payoff does not vary with high school GPA.

JEL-codes: J44; I11; I18; C36

Keywords: Dentists; medical labor markets; occupational licensing; monopoly rents; admission lotteries

1 Introduction

Governments in many countries limit the number of people working in the medical sector. This is often achieved by restricting access to medical training places. Arguments to restrict supply are that training people for medical professions is costly and that additional supply may create its own demand.[1] To avoid that reduced supply translates into excessive

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[1] Gottschalk et al. (2018) document a recent example of supplier-induced demand among 180 dentists in Switzerland, of whom 28 percent recommend treatment to a patient who does not need treatment.

rents for medical professionals, many governments regulate the prices that can be charged for medical services. It is, however, hard to assess whether the resulting earnings for medical professionals are "correct". One way to assess the correctness of earnings of medical professionals is to compare their earnings with what the same workers would have earned in alternative professions. This is for example the question that researchers try to answer when calculating the public-private wage gap (e.g. Bradley et al., 2017; Hartog and Oosterbeek, 1993).

In this study we focus on dentists in the Netherlands and try to answer the question how much more dentists earn compared to what the same people could have earned in another profession. To do so, we take advantage of the fact that in the years 1991 to 1999, there were always more applicants for dental schools in the Netherlands than available places and that a lottery determined which applicants were admitted. In this design, losers of the admission lotteries serve as comparison group. This creates an arguably more convincing comparison group than is usually the case when earnings are compared across different occupations or sectors. In those cases identification is typically based on a conditional independence assumption.

Combining data on results of the admission lotteries with data on later earnings allows us to estimate the causal effect of studying dentistry on earnings. In addition to earnings outcomes, we also examine whether studying dentistry instead of the next-best field, affects working hours, human capital investments and private-life outcomes.

We are not the first to relate the earnings of dentists to limited supply and contribute to a broader literature on occupational licensing (f.e. Kleiner, 2000) and one on dentistry in particular. In an early study, Shepard (1978) compares prices for dental services and mean dentists' income between thirty-five states in the US that restricted licensing of out-of-state dentists and fifteen states having reciprocity agreements recognizing each other's licenses. He finds that prices and incomes are 12 to 15 percent higher in the non-reciprocity states (p.200). Using a more refined measure of states' strictness in licensing, Kleiner and Kudrle (2000) confirm Shepard's results with respect to prices of dental services and mean dentists' income. In addition, they find no evidence that stricter licensing influences the quality of dental services.[2,3]

Our paper also contributes to the recently emerging literature that examines payoffs to specific fields of study (e.g. Hastings et al., 2013; Grosz, 2016; Ketel et al., 2016 and Kirkebøen et al., 2016; see also: Altonji et al., 2012, 2016). Most related is our previous

[2]The estimates reported by Shepard (1978) and Kleiner and Kudrle (2000) can best be interpreted as associations rather than as causal effects. Neither paper points to an exogenous source of variation in states' strictness in licensing, nor do they use a difference-in-differences approach.

[3]Grytten and Sørensen (2000) analyze the dental market in Norway – a country where the supply of dentists is almost twice as large as in the Netherlands – and find no support for Norwegian dentists earning monopoly rents.

paper (Ketel et al., 2016) where we use admission lotteries to estimate the financial payoffs to completing medical school in the Netherlands. There we find that in every year after graduation doctors earn at least 20 percent more than similar applicants who end up in their next-best profession.[4]

Almost immediately after graduation the annual gross income of people who studied dentistry is on average 50,000 Euros higher than what they would have earned in their next-best field of study. This amounts to a premium of 63 percent. We have information up to 22 years after students' first application to study dentistry and find that the annual gain is fairly stable over this period and is driven by income generated from self employment. We do not find that dentists work longer hours, incur larger investments during their studies in terms of forgone earnings and direct expenses, or make larger sacrifices in private-life outcomes. Given that there are about twice as many applicants than available places also speaks against the explanation that the high payoffs compensate for other unattractive features of the work as such a compensation should only make the marginal dentist indifferent.

One plausible explanation for the high payoffs for dentists is that they earn a monopoly rent due to the limited supply. To investigate this further we regressed earnings of dentists on the relative supply of dentists in local labor markets controlling for region and year fixed effects. Consistent with the monopoly rent explanation we find that dentist's earnings decrease with dentist density. Also the fact that the supply of dentists in the Netherlands is lower than in most other countries, and that payoffs are equally high for low-GPA dentists as for high-GPA dentists are consistent with rents explaining the high returns. Other potential explanations for the high payoffs are supplier-induced demand due to asymmetric information between dentists and patients, and comparative advantage where dentists possess a unique bundle of skills that makes them very productive as dentists but not very productive elsewhere. Our research design does not allow us to disentangle between the supplier-induced demand, the comparative advantage and the monopoly-rent explanations.

The remainder of this paper is organized as follows. The next section provides further details about the institutional context and the admission lottery to the study of dentistry. 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 between men and women and by high school GPA. In that section, we also compare the payoffs of completing dentistry to the payoffs of completing medical school. Section 7 discusses possible reasons for the large earnings premium. We consider working hours, costs of studying, compensating differentials,

[4] We compare the findings from the previous study and the current one in detail in Section 6.

comparative advantage and monopoly rents. Section 8 concludes and discusses the implications of our findings.

2 Background and institutional context

2.1 Studying dentistry in the Netherlands

High school graduates in the Netherlands who complete the academic track are eligible for university studies in all fields of study and institutions.[5] Students choose their field of study as soon as they enter university, unlike, for example, in the US where students specialize later. For the large majority of fields, universities have to accept all applicants but some fields have quotas that limit the number of students that are admitted. Dentistry is one of the studies with a quota.[6]

Following the rapid expansion of university enrollment in the 1970s, the Dutch Minister of Education has since 1972 the possibility to limit the number of students admitted to specific university studies through quotas. A quota can be based on capacity constraints of the universities and on labor market considerations. An important input for the determination of the quota for dentistry are negotiations between the Ministry of Health and the professional association of dentists. This association may protect the labor market position of the current dentists, which can result in conservative forecasts of the future demand for dentists. For the cohorts of applicants that we consider in this paper (1991-1999), the annual quota increased from 142 in 1991 to 216 in 1999, and was on average 180 students.

Until the year 2000, students who applied to a study with a quota were admitted on the basis of the results from a (nationwide) centralized lottery.[7] Admission lotteries to dental schools (and other oversubscribed studies) were originally introduced to promote equality of opportunity in higher education. It was thought that this would not be achieved to the same degree by admission on high school GPA when able students from less-advantaged backgrounds have fewer resources to prepare for exams. Rejected applicants are allowed to reapply in the next year, and until 1999 they could do this as often as they wanted.[8] We

[5]Dutch schoolchildren are tracked into different levels around the age 12 when they enter secondary school. The academic track is the highest track. Around 20 percent of all students complete this track.

[6]Other university studies that have quotas are medical school, veterinary medicine and (in some years) international business studies. In Ketel et al. (2016) we exploit the quota for medical school.

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

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

Table 1. Lottery categories

Category	High School GPA	Share	Weight
A	$GPA \geq 8.5$	0.003	2.00
B	$8.0 \leq GPA < 8.5$	0.019	1.50
C	$7.5 \leq GPA < 8.0$	0.035	1.25
D	$7.0 \leq GPA < 7.5$	0.138	1.00
E	$6.5 \leq GPA < 7.0$	0.217	0.80
F	$GPA < 6.5$	0.400	0.67
Other	-	0.187	1.00

Note: 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 1991-1999. 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.

observe that 65 percent of the rejected first-time applicants reapply at least once.[9]

The nationwide admission lottery is weighted such that students with a higher GPA on their high-school exam have a higher probability to be admitted.[10] High-school exams are nationwide and externally graded on a scale from one to ten, where six and above indicates a pass. Table 1 shows which GPA intervals are assigned to the different lottery categories – labeled A to F – together with the shares of applicants in each category. The category "Other" refers to students who did not attend high school in the Netherlands and therefore did not participate in the high-school exams, such as foreign students. The final column indicates the weights of the different categories in the lottery. The total number of available places are divided over categories A to F such that for the number of available places divided by the number of applicants in a category, the weights as in Table 1 hold.[11]

Figure 1 shows the admission rates per year by lottery category.[12] In the early years all applicants are admitted. From 1991 onwards the number of applicants exceeds the quota, although in 1991 and 1992 the number of lottery losers is small. The majority of applicants are in categories C to F, for which admission rates decline to only 31 percent in 1998. Since applicants can participate in multiple lotteries, almost 73 percent of all

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

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

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

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

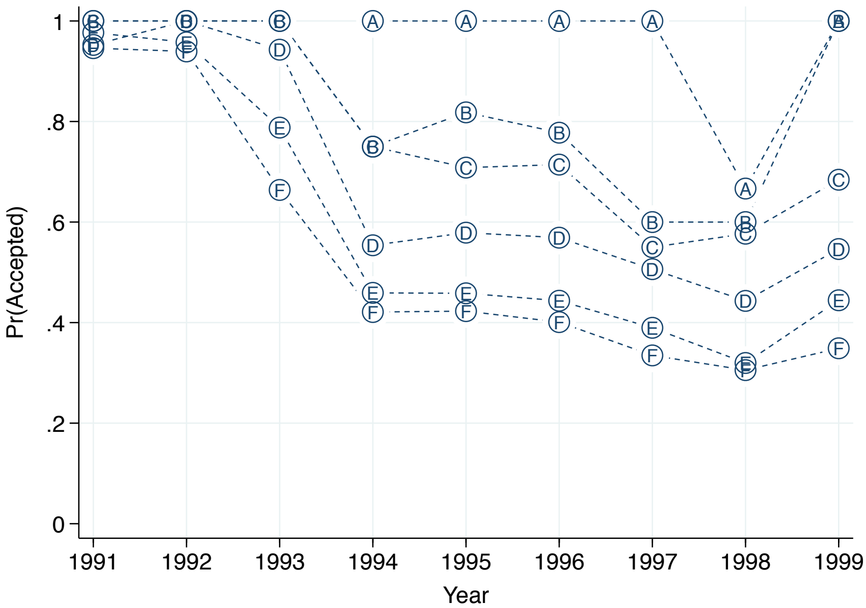

Figure 1. Probability of being admitted by year of application

persons that applied between 1991 and 1999 are eventually admitted.[13]

The admission lottery is centrally administered and executed. Participants in the admission lotteries can list their preferred schools. Applicants' ranking of schools does not affect the outcome of the lottery. Once the result from the lottery is known, the admitted students are assigned to the schools while taking their preferences into account where possible. For the lottery years 1991-1999, 84 percent of the lottery winners got a place at their first-ranked university. In the Netherlands, dentistry is offered by four universities: two in Amsterdam, one in Groningen and one in Nijmegen. The study programs for dentistry at these universities are similar in content and quality. One reason why quality differences are small is that all Dutch universities are publicly funded and that tuition fees are low and the same for all universities (and fields of study). Consistent with the similarity of the dentistry program at different universities, there are only small differences in the GPA of the students that list different schools as their most preferred school.

Until 2007, the study of dentistry in the Netherlands had a nominal duration of five years and after finishing, graduates can start practicing as a dentist. A small share (8.8 percent in our data) of the graduates from the study of dentistry specialize as oral surgeon or orthodontist.

[13]In 1999 a reform was implemented which implied that applicants with a GPA above eight (category A and B) are automatically admitted. The weights for the other categories remained the same.

2.2 *The market for dental services in the Netherlands*

There are around 8,000 practicing dentists in the Netherlands.[14] All of them are university-educated dentists who are registered by the government.

Dental practices in the Netherlands are private; there are no state practices. The typical practice is small, with one dentist and one assistant. In the larger cities some practices are larger, consisting of several dentists, assistants and dental hygienists. Oral surgeons are mostly affiliated with a hospital and orthodontists mostly run a private practice. Patients are referred to these specialists by their regular dentists. A growing number of Dutch dentists employ the services of a dental hygienist, and in the larger cities particularly, there are also separate dental hygienist practices.

Many Dutch inhabitants attend their dentists once or twice a year for regular check-ups. Patients are responsible for the payment of their treatment costs. For children under age 18, dental care costs are covered by the basic health insurance which is compulsory for all citizens. Adults can insure for dental care by supplementary insurance packages. These packages can cover up to 75 percent of costs, but they are subject to caps which limit the amount that is covered by the insurance. Only 45 percent of people in the Netherlands buy supplementary dental insurance. Godfried et al. (2001) report evidence of adverse selection into supplementary dental insurance in the Netherlands.

On behalf of the government, the Dutch Health Care Authority sets maximum rates for all dental treatments, where treatments are described in uniform codes. All Dutch dentists must adhere to these codes. The maximum rates result from negotiations between the Health Care Authority and the professional association of dentists.

3 Data

3.1 *Data sources and sample*

Our data come from several sources. The first source is the administrative registry of the agency (DUO) that conducts the admission lotteries and also registers enrollment and study progress of all Dutch students in higher education. These data contain all applicants for the study of dentistry, their lottery category (but not their exact GPA) and the outcomes of the lotteries. Furthermore, from the enrollment registry we obtain the actual study choices of both winning and losing lottery applicants. Information on study progress is available as the agency registers when and whether students successfully complete certain stages of their studies.[15]

[14] Information in this subsection is partly based on Rietrae (2016).

[15] Information on lottery participation is available from 1987-2004. The availability of the years 1987-1990 allows us to establish first lottery participation in 1991. The study enrollment registry runs from 1987

We exclude all applicants who applied for the first time after 1999 because from the year 2000 onwards dental schools can admit up to 50 percent of their students using their own criteria. We also exclude applicants in lottery category/lottery year combinations for which the probability of winning the lottery is equal to one.[16] This leaves us with a sample of 2,309 persons.

Using social security numbers, the lottery and enrollment information from DUO is merged to individual administrative records of all Dutch citizens kept by Statistics Netherlands (we lose 9 observations without a valid social security number, reducing the final sample to 2,300 observations). The data of Statistics Netherlands include information from municipalities, tax authorities and social insurance administrations. This includes detailed information on earnings from various sources, labor supply and individual characteristics such as age, gender, ethnicity and marital status. All inhabitants of the Netherlands are registered at a municipality, which means 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 2015. Statistics Netherlands also has records from the so–called BIG-register which includes all health-care professionals in the Netherlands, which can be linked. This register provides information regarding individual qualifications and entitlement to practice. From this register we know whether someone is licensed as a dentist.

For self-employed workers, the administrative records from Statistics Netherlands contain no information on working hours. Since the majority of the dentists are self-employed, we cannot compare working hours and hourly wages between winners and losers of the first lottery. To examine whether the large income payoff to the study of dentistry we find below, is due to long working hours, we use information from the research project "Study & Work" which is based on an annual survey among people who recently finished their studies and entered the labor market. The data have been collected by SEO Amsterdam Economics for each year from 1997 to 2015. The survey asks which field of study someone completed and also whether someone ever participated in an admission lottery and if so, for which field of study. A disadvantage of the survey is that the answers cannot be linked to the other administrative data, but the survey has the advantage that it contains information about working hours, both for employees and for self-employed workers.

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to 2004, and is augmented using information on attended/completed education from Statistics Netherlands (containing information up to 2016).

[16]This applies to category A for all years, and to category B/C/D for some lottery years, see Table A1.

Table 2. Balancing of personal characteristics by admission status of the first lottery application

	Lottery winners	Lottery losers	p-value
Female	0.49	0.49	0.50
Age at first application	18.9	18.8	0.68
Non-western immigrant	0.09	0.11	0.51
Number of individuals	1,180	1,120	

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

3.2 Descriptive statistics

Table 2 presents the balancing of the available pre-treatment characteristics between winners and losers of their first lottery.[17] We show the sample means of the individual characteristics and report the p-value for equality obtained from regressing this characteristic on a dummy for winning the lottery and the full interaction of year of lottery fixed effects and lottery category fixed effects. Each p-value comes from a separate regression. About 49 percent of the applicants are female, the average age at the first application is 18.8, and around 10 percent of the sample are from non-western origin. The p-values raise no concern about the randomness of the admission lotteries. This is consistent with the fact there has never been a case where someone questioned the fairness of the admission lottery for dental school or any other study with admission lotteries in the Netherlands.

Table 3 presents summary statistics on study achievement and labor market outcomes by result of the first lottery. Lottery losers have, on average, a lower GPA on the secondary school exams, which follows mechanically from the GPA-weighted lottery. Therefore, the results in Table3 are weighted to allow for a comparison between the lottery winners and losers.[18] The result of the first lottery is associated with an almost 50 percentage points increase in enrollment into dentistry. Not everyone who wins the first lottery actually enrolls in dentistry; nine percent do not. Among the losers of the first lottery, almost 42 percent end up enrolling for dentistry (after winning a subsequent lottery). Of the winners 77 percent complete the study of dentistry, compared to 39 percent for the losers. Finally, almost all individuals who complete dentistry also register as a dentist, and are therefore licensed. The small difference between completion and registration rates may be caused

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

[18] Specifically, we have used the inverse of the probability of winning the lottery for each lottery category/lottery year combination as weights. This corrects for the fact that among the lottery winners (losers) applicants in de higher lottery categories are overrepresented (underrepresented).

Table 3. Descriptive statistics by admission status of the first lottery application

	Lottery winners	Lottery losers
Study enrollment and completion		
Enrolled in dentistry	0.91	0.42
Completed dentistry	0.77	0.39
Licensed as dentist	0.77	0.41
Enrolled in study program in the Netherlands	0.99	0.96
Completed study program in the Netherlands	0.98	0.97
Labor market outcomes		
Annual real (2014) taxable earnings (1999-2015)	65,759	48,664
Self-employed	0.61	0.40
Family outcomes		
Married	0.57	0.56
Partner	0.83	0.80
Children (Yes/No)	0.74	0.71
Number of children	1.59	1.49
Number of individuals	1,180	1,120

Note: Since the lottery is weighted we have weighted observations by the inverse probability of winning the lottery for each lottery category/lottery year combination to allow for a causal interpretation of the differences between the columns. For the outcomes self-employed, married and children we take the outcome in the last year that we observe the individual in the registry (for 94 percent of the individuals this is the year 2015). At this point in time the individuals are on average 39 years old.

by the fact that registration by definition can only be done after graduation. Additionally, for lottery losers it might be that some individuals obtained a dental degree abroad and afterwards registered as a dentist in the Netherlands. In the analyses these individuals are treated as non-completers of the study of dentistry. This is likely to bias the estimates of the payoffs to dentistry slightly downwards.

For the interpretation of the estimated payoffs to dental school it is important to know which alternatives the lottery losers choose. Most lottery losers attend a study program in the Netherlands.[19] Only four 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 dentistry but do enroll in Dutch higher education 33 percent enroll in a health-related field (eight percent in medical school). Other fields that are frequently chosen are Economics and Law (28 percent), Science and Engineering (19 percent) and Social Sciences, Humanities and Education (16 percent). Almost all lottery participants complete a study program in the

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

Netherlands.

Table 3 also shows the means of 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. All amounts are corrected for the average wage development of university graduates over the observation period and expressed to constant 2015 Euros. Table 3 shows that earnings are, on average, around 35 percent higher for winners than for losers. Of the winners, 61 percent are self-employed compared to 40 percent for lottery losers.

Finally, the bottom part of the table shows descriptive statistics for family outcomes in the last year that an individual is observed (2015 for 94 percent of the sample). Winners of the lottery are more likely to be married or have a partner and to have children.

4 Empirical approach

To estimate the payoff to dentistry we apply the same empirical approach as in Ketel et al. (2016). We assume a linear relationship between the labor market outcome of individual i in year t who applied for the first time to study dentistry in year τ ($Y_{it\tau}$) and having completed dentistry (D_i):

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

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. α_t and $\gamma_{t-\tau}$ are fixed effects for the year in which the outcome is observed and the number of years since the first application. $U_{it\tau}$ is the error term. The parameters of interest are $\delta_{t-\tau}$ which describe the payoffs to completing dentistry $t - \tau$ years after first applying. We estimate equation (1) separately for 0 to 22 years since the first lottery participation.

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

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

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 who are in the same year in the same lottery category, have the same probability to be admitted. This conditional random assignment guarantees that the conditional mean independence assumption holds.

In equation (2) the parameter $\lambda_{t-\tau}$ reflects the difference in completion rates between winners and losers of the first lottery.[20] An interpretation of $\lambda_{t-\tau}$ is that it describes the fraction of compliers in the data, which are applicants for whom completion of the study of dentistry is determined by the result of the first lottery.[21] By estimating equation (1) separately for each number of years after the first lottery, we estimate how the earnings payoff develops during the first 22 years after the first lottery. This period captures the potentially longer study duration of dentistry compared to alternative studies, and thereby provides an estimate of the opportunity costs of the longer investment in schooling.

In the above we framed the analysis in terms of the effects of completion of dental school. Alternatively, it is possible to consider enrollment in dental school (or being licensed as dentist) as the endogenous variable of interest. The instrumental variable estimates for completion and enrollment are quite similar because the first-stage estimates are not too different. The first-stage estimate of the effect of winning the first lottery on completion dental school equals around 0.41 while the first-stage estimate of the effect of winning the first lottery on enrolling in dental school is around 0.51. Replacing completion by enrollment as endogenous variable of interest will therefore lower the IV estimates by around 20 percent ($1 - \frac{0.41}{0.51}$).

The choice of enrollment or completion as the endogenous variable has implications for the exclusion restriction needed for a causal interpretation. Altonji et al. (2016) discuss the difference between the two exclusion restrictions in case a substantial share of those who enroll do not complete. With enrollment as the endogenous variable, these applicants contribute to the estimates of winning compliers, whereas with completion as the endogenous variable, these applicants end up in the group of never takers. If dropouts from dental school are disappointed and therefore have worse labor market outcomes, the result of the first lottery (the instrument) has an impact on earnings independent of completion (but not of enrollment). Given that the share of dropouts from dental school is not substantial (see Table 3) we prefer to discuss our results in terms of completion because it is the more interesting endogenous variable from the perspective of labor markets of

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

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

medical professionals.

5 The payoff to completion of dentistry

Table 4 reports estimates of the effect of completing dentistry on (log) annual earnings.[22] Performing our regressions separately by number of years after the first lottery ($t - \tau$) implies that each regression uses different subsamples. The second column reports the number of observations in each regression and shows how this varies across rows. The first row ($t - \tau = 0$) is based on 1999-earnings information of people who first applied in 1999. The second row is based on 2000-earnings information of people who first applied in 1999 and on 1999-earnings information of people who first applied in 1998, and so on.[23]

The first-stage regressions describe the effect of winning the first lottery on the probability to complete dentistry. The first-stage estimates in column (3) are highly significant, with the F-statistics ranging from 28 to 391, and are all close to 0.40; winning the first lottery increases the probability to complete dentistry with around 40 percentage points.[24]

The fourth column of Table 4 presents the instrumental variable estimates of the effect of completing dentistry on the level of annual earnings (in thousands of Euros). These estimates are also plotted in Figure 2. During the first five years after the first lottery, the payoff to completing the study of dentistry is significantly negative. During their studies, those who will complete dentistry earn 2000 to 3000 Euros less per year than they would have earned in their next-best alternative. This is due to some of the lottery losers working full time instead of immediately enrolling in an alternative study, and to some lottery losers who enrolled in an alternative study having higher earnings from side jobs. The negative payoff during the first five years captures the foregone earnings of studying dentistry instead of the next-best alternative. Six years after the first lottery a substantial share of those studying dentistry complete their studies and enter the labor market. One year later almost all of those studying dentistry completed their studies. From then on, the gross annual earning of dentists are on average around 50,000 Euros higher than the gross annual earnings in the next-best alternative. This amount stays fairly constant during the subsequent 15 years.[25]

[22]In an online appendix to this paper we present tables and figures using enrollment as the treatment variable.

[23]In principle it is possible to extend the analysis to 23 and 24 years after the first lottery since we observe lottery losers from 1991 onwards. For these years the sample sizes get, however, too small.

[24]Because the share of lottery winners varies across years (see Figure 1) and because the shares of (re)applicants varies somewhat from year to year, the first-stage estimates vary somewhat between the different rows.

[25]There are strong fluctuations in earnings payoffs 20 years after the first lottery. In that period also confidence intervals widen substantially. The reason is that these payoffs are estimated on only few obser-

Table 4. Instrumental variable estimates of the effects of completing dentistry on earnings $t-\tau$ years after first applying

$t-\tau$ (1)	N (2)	First stage (3)	Earnings (x€1000) (4)	log(Earnings) (5)	I[Earnings=0] (6)
0	288	0.31 (0.06)***	-1.9 (0.9)**	-0.60 (0.51)	0.23 (0.16)
1	601	0.38 (0.04)***	-3.5 (0.8)***	-1.22 (0.30)***	0.19 (0.10)*
2	949	0.40 (0.03)***	-1.8 (0.6)***	-0.21 (0.22)	0.16 (0.07)**
3	1216	0.41 (0.03)***	-2.3 (0.6)***	-0.68 (0.18)***	0.01 (0.06)
4	1502	0.40 (0.02)***	-2.4 (0.8)***	-0.56 (0.18)***	0.00 (0.05)
5	1817	0.41 (0.02)***	-3.0 (1.1)***	-0.17 (0.17)	0.14 (0.05)***
6	2020	0.41 (0.02)***	25.0 (3.0)***	1.08 (0.18)***	-0.07 (0.04)
7	2152	0.41 (0.02)***	48.3 (4.3)***	1.43 (0.16)***	-0.07 (0.04)**
8	2267	0.41 (0.02)***	50.2 (4.5)***	1.35 (0.14)***	0.02 (0.03)
9	2253	0.40 (0.02)***	48.5 (5.1)***	0.89 (0.11)***	-0.03 (0.03)
10	2241	0.40 (0.02)***	47.6 (5.3)***	0.75 (0.09)***	-0.03 (0.02)
11	2232	0.40 (0.02)***	51.4 (6.0)***	0.67 (0.09)***	-0.04 (0.02)*
12	2221	0.40 (0.02)***	51.6 (6.0)***	0.67 (0.08)***	-0.01 (0.02)
13	2210	0.40 (0.02)***	47.9 (6.2)***	0.57 (0.09)***	-0.02 (0.02)
14	2197	0.40 (0.02)***	54.3 (6.5)***	0.55 (0.09)***	-0.03 (0.02)
15	2197	0.40 (0.02)***	57.3 (7.2)***	0.58 (0.08)***	-0.04 (0.02)**
16	2190	0.40 (0.02)***	50.2 (6.7)***	0.44 (0.08)***	-0.04 (0.02)**
17	1914	0.42 (0.02)***	54.8 (7.1)***	0.58 (0.08)***	-0.03 (0.02)
18	1619	0.41 (0.03)***	51.0 (8.6)***	0.52 (0.09)***	-0.01 (0.03)
19	1284	0.41 (0.03)***	46.6 (9.7)***	0.41 (0.11)***	-0.04 (0.03)
20	1022	0.40 (0.03)***	27.8 (11.8)**	0.34 (0.13)***	-0.06 (0.04)
21	746	0.42 (0.04)***	27.0 (15.1)*	0.40 (0.17)**	-0.05 (0.05)
22	451	0.39 (0.07)***	45.1 (25.9)*	0.49 (0.24)**	-0.13 (0.09)

Notes: Robust standard errors in parentheses. Total number of individuals is 2,300. * $p<0.10$, ** $p<0.05$, *** $p<0.01$. 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.

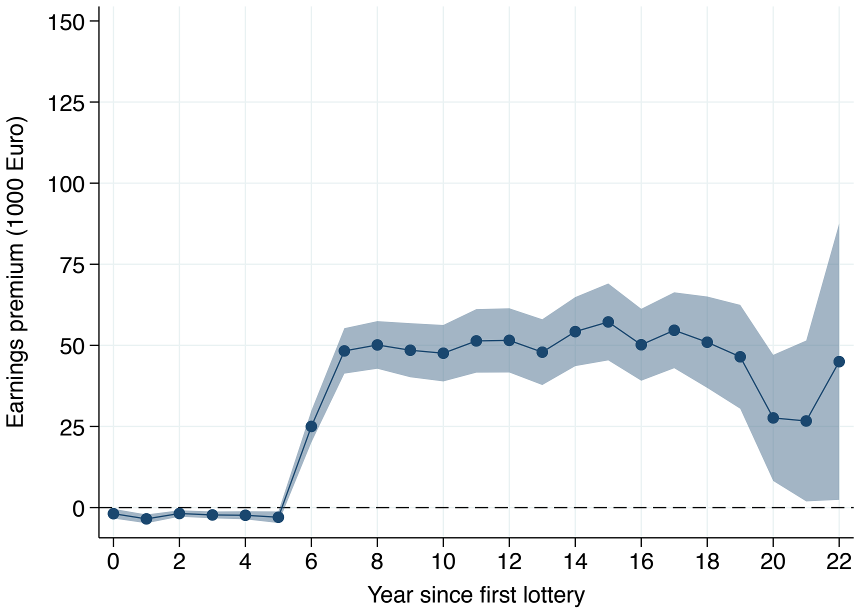

Figure 2. Instrumental variable estimates of the effects of completing dentistry on earnings $t-\tau$ years after first applying (colored area is 90 percent confidence interval)

The fifth column of Table 4 shows results for the effect of completion of dentistry on the logarithm of earnings, conditional on having positive earnings. The observed pattern is very similar to the pattern for the level of earnings (which includes zeros). During the first six years after the lottery, dentistry students have lower log earnings than they would have had in their next-best alternative. This reverses in the sixth year. Because the amount of the earnings gap stays relatively stable while the level of earnings in the next-best alternative increases over time, the log earnings payoff decreases over time from 1.43 after seven years to 0.49 after 22 years. A log earnings differential of 0.49 implies that earnings as a dentist are 63 percent above earnings in the next-best alternative.

The final column shows the effect of dental school on the probability of having no earnings, the extensive margin employment effect. This confirms that future dentists are more likely to have zero earnings while studying than would be the case in their next-best alternative. From six years after the first lottery onwards all point estimates in the final column are negative, and some significantly, indicating that dentists are more likely to have positive earnings than would be the case in their alternative profession.

In Figure 3 we show the predicted earnings profiles for an average individual with and

vations, i.e. only the cohorts of individuals who first participated in the lottery in the first few years of our observation period. In that period only few individuals lost the lottery and never became dentist. A straight line through the estimates between 19 and 22 years after the first lottery falls in the 90 percent confidence interval.

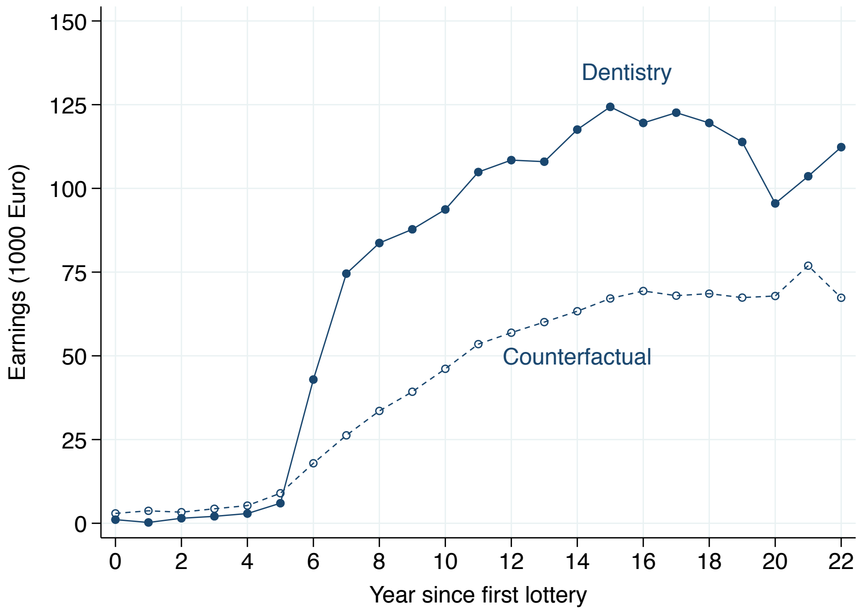

Figure 3. Predicted counterfactual earnings levels

without completion of dentistry. We estimate expected earnings using

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

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

where both D_i on the right-hand side of equation (3) and $1 - D_i$ on the right-hand side of equation (4) are instrumented using the result of the first lottery (LR_i). The IV estimate of the effect of D on $Y \cdot D$ gives the average potential outcome with treatment (Y^1) for compliers, and the IV estimate of the effect of $1 - D$ on $Y \cdot (1 - D)$ gives the average potential outcome without treatment (Y^0) for compliers.[26] The coefficient $\delta_{1,t-\tau}$ ($\delta_{0,t-\tau}$) is the estimate of the average potential outcomes for compliers with (without) completion of dentistry. Figure 3 shows that annual earnings with and without completion of dentistry increase with the number of years after the first lottery. The difference between the two profiles is fairly constant over time.

6 Heterogeneous treatment effects

We now turn to heterogeneity in the payoffs to dentistry. We first examine differences between men and women. Next, we investigate differences by ability as measured by students' GPA categories. Finally, we compare the earnings payoffs of dentists with the

[26] This follows Abadie (2003). In Appendix C we derive these expressions.

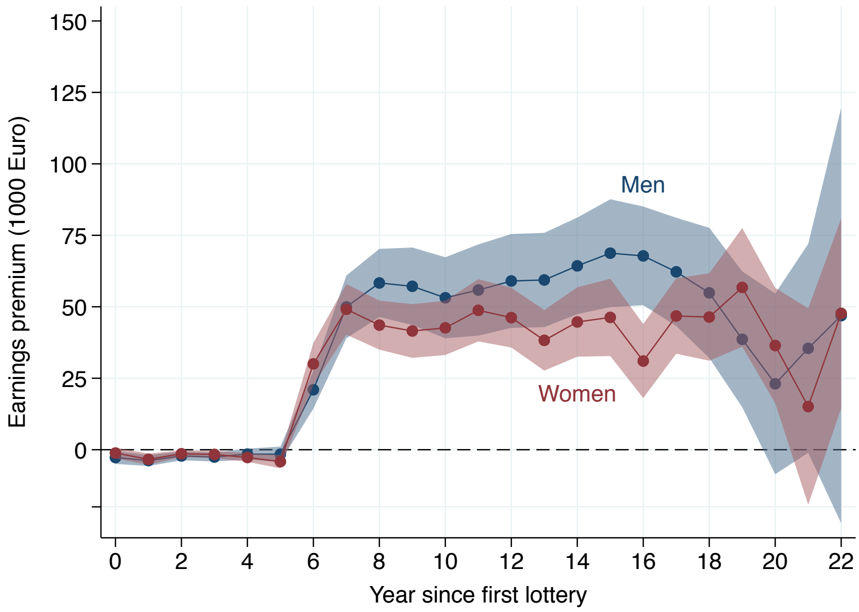

Figure 4. IV estimates of effects of dentistry completion on earnings, by year since first lottery and gender (colored areas are 90 percent confidence intervals).

earnings payoffs to completion of medical school in the Netherlands, which we studied in Ketel et al. (2016).

Gender

Figure 4 shows the estimated earnings payoffs separately for men and women.[27] During the study period the payoff profiles for men and women coincide. In the sixth year after the first lottery the payoff is larger for women than for men, reflecting that women usually complete their study faster than men. Between eight and 18 years after the first lottery the payoffs are higher for men than for women, and this difference is quite substantial between 12 and 17 years.[28] Over the entire period the undiscounted sum of the payoffs for men is 164,000 Euros higher than the undiscounted sum of the payoffs for women; at a discount rate of 5% the difference in favor of male dentists amounts to 81,000 Euros.

Figure 5 repeats Figure 3 by showing predicted earnings profiles, but now for men and women, separately. This shows that for women – dentists and non-dentists – the earnings profiles are relatively flat from 10 years after the first lottery onwards. For men — dentists and non-dentists alike – earnings profiles are increasing during a much longer period. The increase is steeper for male dentists than for male non-dentists.

[27]Table A2 in the appendix reports the estimates.

[28]If we estimate the IV regressions interacting the dental school dummy with gender, the difference between men and women is only significantly different from zero in four out of 22 years.

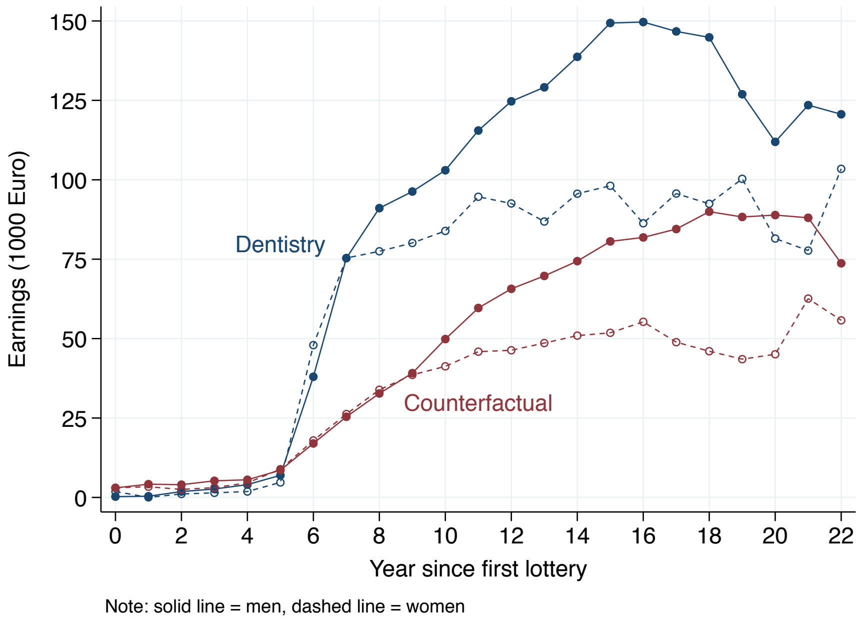

Figure 5. Predicted counterfactual earnings levels by gender

Ten percent of the male dentists specialize as orthodontist or oral surgeon, for female dentists this share is 7 percent. This difference is too small to explain why payoffs for men are higher than for women.

Ability

The lottery assigns applicants with a higher GPA on their high-school exams a higher probability to be admitted. This raises the question of whether there is a difference in earnings gain between people with different GPA's. To examine this, we estimated earnings payoffs by year after first lottery separately for lottery categories C to F.[29] Figure 6 reports the results. For categories C and D the estimates in the first years and last years are not very precise due to small sample sizes.

For most years after finishing the study of dentistry, the annual payoffs are not significantly different for applicants from categories C, D, E and F. [30] If anything, the payoffs tend to be somewhat higher for the lower GPA-categories (E and F) than for the higher categories (C and D). Weighted by their sample shares, the sum of undiscounted payoffs for applicants from categories C and D is 69,000 Euros lower than the undiscounted payoffs for applicants from categories E and F. At a discount rate of 5% the difference

[29]Category A is omitted since there are so few lottery losers in this category. Category B has so few applicants that power is lacking to run the analysis separately for this category. All estimated coefficients are in Table A3 in the appendix.

[30]This follows from an IV regression which interacts the dental school dummy with the dummies for the lottery categories.

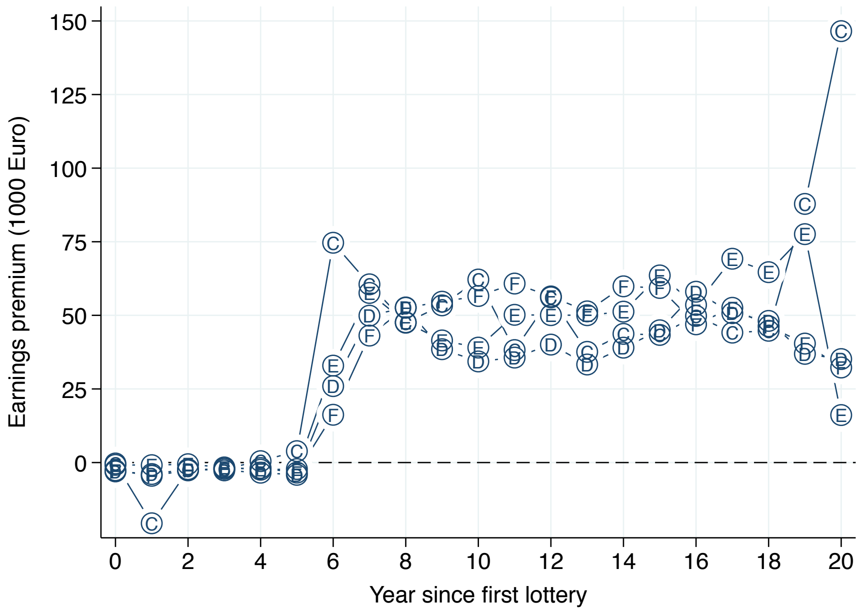

Figure 6. IV estimates of effects of dentistry completion on earnings, by year since first lottery and lottery category

in favor of dentists from lower GPA categories amounts to 39,000 Euros. Figure B1 in the Appendix indicates that the difference in favor of low-GPA applicants results from a combination of low-GPA applicants having higher earnings as dentist than high-GPA applicants (upper graph), and high-GPA applicants (especially from category D) having higher counterfactual earnings than low-GPA applicants (bottom graph). These results give no ground for an admission policy that favors applicants with higher GPA.

Comparison with medical school applicants

In Ketel et al. (2016) we used admission lotteries to estimate the earnings payoff to completion of medical school in the Netherlands. In this subsection we compare the results for applicants for dentistry with the results for medical school applicants. Table 5 compares characteristics of the two samples of applicants. Among applicants for dentistry the share of women is almost 10 percentage points lower than among applicants for the female-majority medical study. The mean of GPA is also lower for prospective dentists than for prospective doctors and applicants for dentistry are on average five months older than applicants for medical school. Finally, the share of non-western immigrants is somewhat higher among dentistry applicants than among medical school applicants.

Applicants for dentistry and for medical school also differ somewhat in the next-best field that rejected compliers choose. Twenty-eight percent of the rejected compliers for dental school study economics or law, while this share is only 15 percent for the rejected

Table 5. Characteristics of applicants and graduates of medical school versus dentistry

	Applicants			Graduates		
	Dentistry	Medical school	*p*-value	Dentistry	Medical school	*p*-value
Female (%)	49.1	58.4	0.00	50.8	60.4	0.00
GPA high school exam	6.7	6.9	0.00	6.7	7.0	0.00
Age at first application	18.8	18.3	0.00	18.7	18.2	0.00
Non-western immigrant (%)	9.6	7.5	0.00	8.2	6.9	0.10
Number of individuals	2,300	25,393		1,372	15,372	

Notes: *p*-values based on t-test for unequal variances. Mean GPA of high school exam is calculated using the midpoints of the GPA categories.

compliers for medical school. Nineteen percent of the rejected compliers for dental school study science or engineering. This share is 25 percent for the rejected compliers for medical school. Rejected compliers from the two pools of applicants are equally likely to opt for another health-related field and to study social and behavioral sciences.

Figure 7 shows in a single graph the payoffs to medical school (in red) and to the study of dentistry (in blue). The payoffs profile for doctors is very different from that of dentists. The first phase of the medical study takes one year more than the (entire) study of dentistry. After six year of medical school, doctors specialize for another six to nine years. During the specialization phase doctors earn a salary, which is higher than what they would have earned in their next-best profession. Because the salary during the specialization is constant, the payoff for doctors declines between years 8 to 12. After 12 years medical school students start to finish their specialization and their payoffs are increasing. Nineteen years after the first lottery doctors catch up with dentists, and both groups earn an annual payoff of around 50,000 Euros. Dentists can enter self-employment directly after graduating. Doctors first need to specialize, and their total payoffs only catch up with those of dentists once a larger share of their income comes from self-employment. This explanation is confirmed by Figure B2 in the Appendix, that splits total earnings into profits (for self-employed dentists/doctors) and wage earnings.

Figure B3 in the Appendix shows that the higher payoffs for dentists than for doctors are not due to dentists having worse counterfactual earnings. On the contrary, the counterfactual earnings for dentists are higher than the counterfactual earnings for doctors. This suggests that the two studies attract different types of applicants.

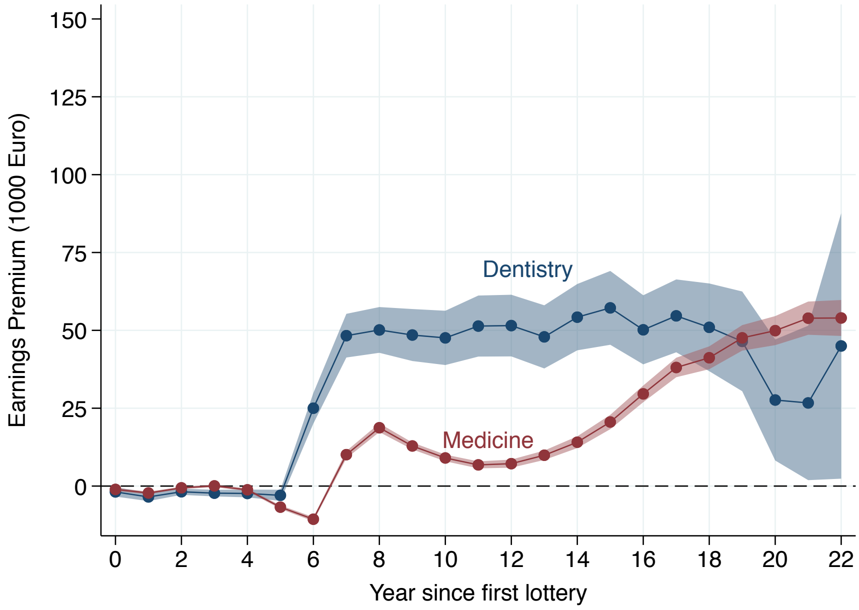

Figure 7. IV estimates of effects of dentistry versus medical school completion on earnings, by year since first lottery

7 Mechanisms

In this section we discuss possible mechanisms for the high payoffs to the study of dentistry. The mechanisms that we consider are working hours, investments in schooling, compensating differentials, monopoly rents, supplier-induced demand and comparative advantage.

Hours

One reason why dentists earn such high incomes may be that they work long hours. The data from Statistics Netherlands do not contain information on working hours for people who are self employed. Because a majority of dentists is self employed we can not address this issue using the merged register and admission lottery data. Fortunately, the research project "Study & Work" conducted by SEO Amsterdam Economics, gives relevant information.

This project is based on an annual survey among people who recently finished their studies and entered the labor market. Data have been collected for each year from 1997 to 2015. The survey asks which field of study someone completed. This identifies the respondents who completed the study of dentistry. The survey also asks whether someone ever participated in an admission lottery and if so, for which field of study. This identifies the respondents who lost the lottery for dentistry. With regard to working hours, the

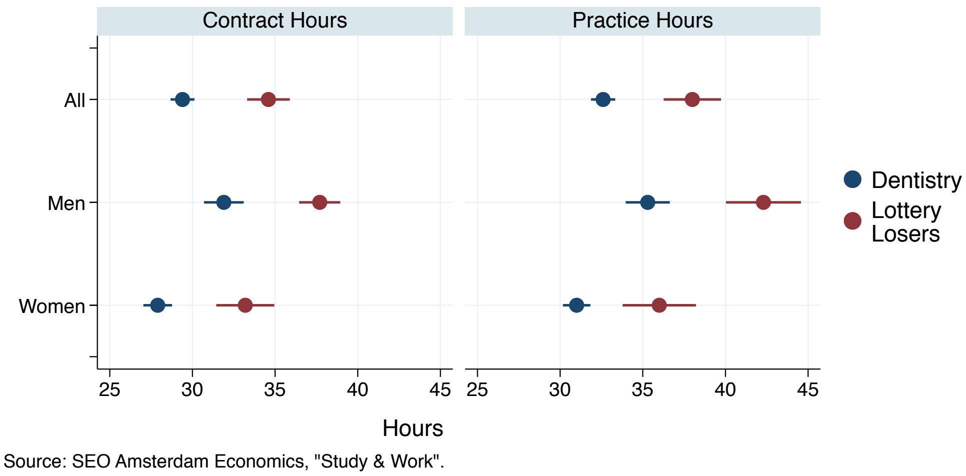

Figure 8. Working hours per week

survey asks about contract hours (both for employees and for self employed) and about practice (actual) hours. Table 8 reports the mean numbers of hours for dentists and for losers of the lottery for dentistry together with their standard deviations and the numbers of observations.[31] This is based on pooled data from all waves. Results are presented for men and women together and separately for men and women.

The results in the table show that dentists work significantly fewer hour than respondents who lost the lottery for dentistry (and didn't become a dentist). In contract hours the difference is 5.2 hours per week, and for practice hours 5.5 hours per week. These differences are very similar for men and for women. The table also shows that male dentists work around 4 (around 14%) more hours per week than female dentists. This partly explains why male dentists earn more than female dentists, and may also partly explain why male dentists have a higher payoff (measured in Euros) to dentistry than female dentists.[32]

We conclude that differences in working hours cannot explain the earnings payoff to completing the study of dentistry. If anything, dentists work fewer hours than comparable others. This is consistent with leisure being a normal good.

[31] We gratefully acknowledge the help of Paul Bisschop from SEO Amsterdam Economics for supplying this information.

[32] The Wage Indicator Survey which is annually collected by the Amsterdam Institute for Labor Studies (AIAS) also contains information about level of education, occupation and actual working hours per week. The number of dentists in the pooled sample that report their working hours is in this dataset only 54. In this data it is not possible to identify who lost the lottery for dentistry. When we compare dentists with all others in this dataset who attained a university degree, we find that dentists work on average 1.5 hours less per week than the comparison group ($p = 0.068$).

Opportunity cost

After completion of the study of dentistry, winning compliers possess a different set of knowledge and skills than compliers who lost the lottery. It is not possible to assess what share of the payoff to dentistry should be attributed to the specific knowledge and skills bundle without detailed information on people's human capital. We do, however, have information about the opportunity costs of the human capital acquisition of dentists. Because we have estimated effects of studying dentistry on annual earnings starting in the year of the first lottery, the estimates cover the period that applicants are enrolled in (dentistry) school.

Inspection of Table 4 and Figure 2 reveals that winning compliers have lower annual incomes than losing compliers until five years after the first lottery, but the differences are modest and completely wiped out by the substantially higher incomes of winning compliers in later years. The internal rate of return of completion of dental school equals 62% and the internal rate of return of enrolling in dental school equals 64%.

Because tuition fees for university in the Netherlands are the same for all universities and for all fields of study, the payoffs to dental school cannot be justified by a larger direct investment. The uniform tuition fees across fields of study imply rather different tuition subsidies across fields of study. Dental school is among the fields with a high tuition subsidy.

Compensating differentials

Incomes of dentists will exceed incomes in second-best occupations if dentists are compensated for some unattractive feature of their work. Compensation may be required for dentistry being more unpleasant, having less social prestige, or requiring larger sacrifices in personal life compared to second-best occupations.

The compensation for the unpleasantness of the work should be so high that it makes the marginal worker with the largest distaste for unpleasant work indifferent between being a dentist and her second-best occupation. The fact that the number of applicants for dental schools is about double the number of available training places suggests that the actual earnings differential exceeds the amount that is necessary to make the marginal dentist indifferent.

In the top 100 of most prestigious occupations in the Netherlands, Korsten (2017) ranks dentists at position 17. This is below some of the medical specialists, surgeon (position 1), internist (4), general practitioner (9) and radiologist (11), but above other status professions including pharmacist (18), veterinarian (19), Colonel in the army (20) and company doctor (39). Some compensation for a lower status than other medical

Table 6. Family outcomes

	All	Men	Women
Married/Partner	0.04 (0.04)	0.12 (0.06)**	-0.02 (0.06)
Has Children	0.09 (0.05)*	0.14 (0.07)**	0.03 (0.07)
Number of children	0.28 (0.13)**	0.31 (0.18)*	0.22 (0.18)

Notes: Robust standard errors in parentheses. Total number of individuals is 2300 (1171 men and 1129 women). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. 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

professions may therefore be required. The ranking of dentists is, however, not so low that it can explain more than a small part of the observed earnings differential.

To assess whether the high incomes of dentists are a compensating differential for large sacrifices in their personal life, we estimated the impact of completing dentistry on the probabilities of being married or having a partner and on having children. Being less likely to be married or having a partner and having no or fewer children may signal restrictions in the possibility to build a family life.[33] Table 6 reports the results.

The effect of studying dentistry on family outcomes are more favorable for men than for women. For women there is no significant effect on being married or having a partner, while for men there is a significant 12 percentage points (s.e. 6 percentage points) increase. Completion of dentistry raises the probability to have children for men by 14 percentage points. For women the effect is small and insignificant. Completion of dentistry has a positive effect on the number of children for men, but not for women. Differences in family outcomes can thus not explain the earnings payoff to completion of the study of dentistry.

Taken together, we conclude that compensating differentials can at most explain a small part of the payoffs of completing dental school in the Netherlands. This is supported by information from the 2018 ranking of USNews of best-paying jobs and best careers. Dentist occupies the ninth position in the best-paying job ranking and the second position in the best careers ranking.[34] This suggests that other features of working as a dentist, such as lack of stress, room for advancement and a satisfying work-life balance, are sufficiently attractive relative to earnings that it boosts the position of dentists from ninth to second.

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

[34] See: https://money.usnews.com/careers/best-jobs/rankings

Monopoly rents

The previous subsections argue that the high payoffs to completing the study of dentistry cannot be attributed to long working hours, larger investments while studying (opportunity costs and direct costs) or for unpleasant aspects of working as a dentist.

The obvious remaining explanation is that Dutch dentists are extracting a monopoly rent. The supply of dentists in the Netherlands is low due to the quota that the Dutch government sets on the inflow into dental schools. Regulations and language barriers restrain the supply of foreign doctors. Whether the supply restrictions results in a monopoly rent depends on the elasticity of the demand for dentists and on what the equilibrium number of dentists would have been. The demand for health care services is considered to be rather inelastic, with price elasticities around -0.2 (e.g. Liu and Chollet, 2006), while the estimates in the final column of Table 2 indicate that an oversupply of dentists is unlikely. Two necessary conditions for supply restrictions to lead to monopoly rents are therefore satisfied.

For tentative support for the presence of monopoly rents, we can exploit (local and time) variation of dentist density within the Netherlands. To this end we construct a variable "dentist density" which is the number of dentists per 1,000 inhabitants per labor market region/year.[35] Under the assumption that dentists work in the same region as where they live (we do not have information on where they hold practice) we can explore whether dentists' earnings are higher in regions with lower dentist density. Table 7 shows that this is the case. The results are robust to including fixed effects for the labor market region (in case wages are generally higher in the most urban west of the Netherlands). The results are consistent with the explanation that the level of competition affects dentists' income. These results should, however, be interpreted with care because we do not model dentists' decisions where to locate.

Overall, while we have no direct proof of rent extraction, these results, the low density of dentists in the Netherlands compared to other countries and the fact that the payoffs are large for all GPA categories (see Figure 6) are all in line with the presence of monopoly rents in the Dutch labor market for dentists.

Supplier-induced demand

As the study by Gottschalk et al. (2018) indicates, dentists have an information advantage over their patients which they may exploit to deliver otherwise unwanted treatments. A

[35]For this analysis we look at *all* registered dentists in the Netherlands (in the labor market age), taken from the registry of health care professionals. There are 40 labor market regions, and we have earnings information for the dentists for the years 1999-2015. There are on average 0.52 dentists (s.d. 0.27) per 1000 inhabitants in a labor market region; the values range from 0.26 to 1.66.

Table 7. Dentist density and dentists' earnings

	Dependent variable: yearly dentists' earnings (x1000€)		
	(1)	(2)	3
Dentists per capita (x1000)	-44.4 (1.4)***	-21.6 (1.3)***	-20.5 (3.3)***
Observation year fixed effects	x	x	x
Individual controls		x	x
Local labor market fixed effects			x

Notes: The independent variable is number of dentists per 1,000 inhabitants by labor market region (COROP area). A labor market region is defined as a regional center and the catchment area surrounding it. Standard errors are clustered by individual. Sample size: 162,693 observations (11,727 individuals). Individual controls include gender, nine dummies for age and a dummy for non-western origin.

part of the rent extracted by dentists can therefore be due to supplier-induced demand resulting from asymmetric information. The negative association between dentist density and incomes reported in Table 7 suggests that dentists cannot raise demand in high density areas enough to fully offset the effect of more competition. However, dentists in high density areas may still exploit their information advantage to partially undo the effect of more competition. This means that at the national level, we cannot exclude that an increase of the supply of dentists could lead to an increase in supplier-induced demand.

Comparative advantage

A final explanation for the high payoffs of dentists is that people who want to be a dentist are very skilled as dentist relative of how good they are in other fields. This is a case of comparative advantage which occurs if being a dentists requires a specific combination of skills that is not so useful elsewhere. Key competencies of dentists are fine motor skills, good communication skills, patience and working independently. While the same combination of skills seems also useful in other well-paid medical occupations such as surgeon, anesthesiologist and gynecologist, it may be that dentists lack other skills that these occupations require.

8 Conclusion

This paper documents a large earnings payoff to completion of the study of dentistry in the Netherlands. Applicants who won the first admission lottery and studied dentistry earn from the first year that they enter the labor market onwards, 50,000 Euros per year more than what they would earn had they lost the first admission lottery and ended up in their second-best profession.

This large earnings differential cannot be explained by dentists working longer hours. On the contrary, dentists work around 14 percent hours per week less than people who participated in the lottery for dental school and lost. We also find no support that the earnings differentials compensates for larger investments while studying (opportunity costs and direct costs), or for unpleasant aspects of working as a dentist.

Our preferred explanation is that Dutch dentists are extracting a monopoly rent. This explanation is supported by the finding that dentist earnings are lower in local labor markets where the supply of dentists is larger. The monopoly-rent explanation is also consistent with the fact that low-GPA dentists gain as least as much as high-GPA dentists. Alternatively, the high earnings of dentists can reflect supplier-induced demand resulting from asymmetric information or a comparative advantage where dentists have a rather specific bundle of skills that can only be put to productive use when working as a dentist. In either case, our results imply that earnings of dentists in the Netherlands are well above what is required to attract a sufficient number of qualified dentists.

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A Appendix tables

Table A1. Fraction p admitted and number of applicants N by year and lottery category (A–F)

	A		B		C		D		E		F		Total	
Year	p	N	p	N	p	N	p	N	p	N	p	N	p	N
1991			1.00	3	1.00	7	0.95	21	0.98	43	0.95	74	0.96	148
1992			1.00	3	1.00	3	1.00	28	0.96	47	0.94	99	0.96	180
1993			1.00	5	1.00	8	0.94	35	0.79	66	0.66	119	0.76	233
1994	1.00	2	0.75	8	0.75	12	0.55	65	0.46	98	0.42	171	0.48	356
1995	1.00	1	0.82	11	0.71	24	0.58	76	0.46	96	0.42	201	0.49	409
1996	1.00	3	0.78	18	0.71	21	0.57	58	0.44	124	0.40	197	0.47	421
1997	1.00	1	0.60	10	0.55	20	0.51	79	0.39	136	0.34	233	0.39	479
1998	0.67	3	0.60	5	0.58	26	0.44	88	0.32	122	0.31	252	0.35	496
1999	1.00	2	1.00	12	0.68	19	0.55	97	0.44	126	0.35	235	0.44	491
Total	0.92	12	0.81	75	0.70	140	0.60	547	0.50	858	0.45	1581	0.51	3213

Notes: 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 the effects of completing dentistry on earnings, by year since first lottery and gender

	Earnings (x€1000)	
$t-\tau$	Men	Women
0	-2.7 (1.4)**	-1.2 (1.2)
1	-3.8 (1.2)***	-3.3 (1.2)***
2	-2.2 (0.9)**	-1.4 (0.7)**
3	-2.6 (0.9)***	-1.7 (0.8)**
4	-1.5 (1.2)	-2.7 (0.9)***
5	-1.6 (1.6)	-4.2 (1.4)***
6	21.0 (4.0)***	30.0 (4.5)***
7	50.0 (6.7)***	49.1 (5.4)***
8	58.4 (7.2)***	43.6 (5.2)***
9	57.2 (8.3)***	41.5 (5.7)***
10	53.1 (8.6)***	42.6 (5.8)***
11	55.9 (9.7)***	48.8 (6.6)***
12	59.0 (10.0)***	46.2 (6.4)***
13	59.4 (10.0)***	38.3 (6.4)***
14	64.3 (10.3)***	44.7 (7.4)***
15	68.8 (11.5)***	46.3 (8.2)***
16	67.8 (10.5)***	31.0 (7.9)***
17	62.2 (11.5)***	46.8 (8.0)***
18	54.9 (13.8)***	46.5 (9.3)***
19	38.6 (14.5)***	57.0 (12.6)***
20	22.8 (19.3)	36.7 (12.3)***
21	35.5 (22.3)	16.0 (21.0)
22	47.0 (44.2)	47.8 (20.2)**

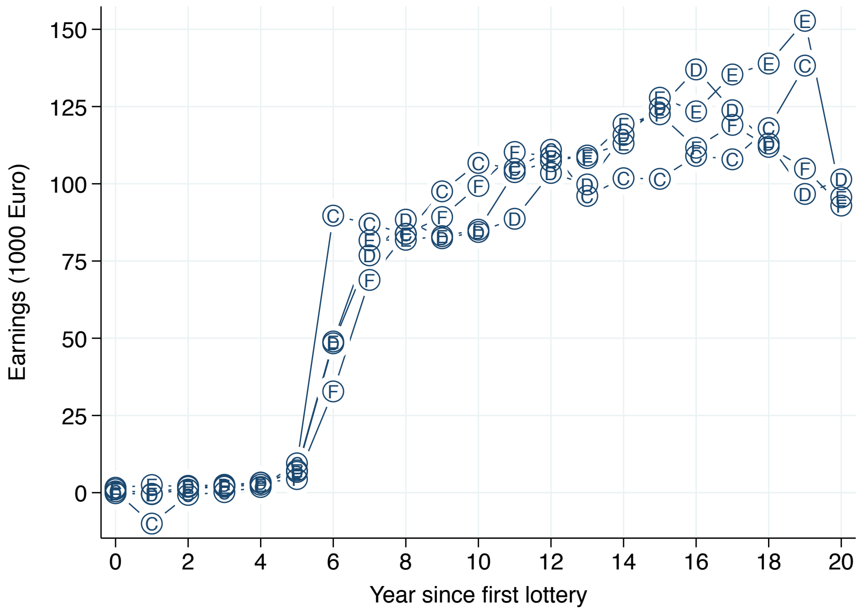
Notes: Robust standard errors in parentheses. * $p < 0.10$. ** $p < 0.05$. *** $p < 0.01$. Every cell in this table represents a separate regression, which include controls for ethnicity, age in the first lottery year, lottery category, year of first lottery and interaction terms of the year of first lottery and lottery category.

Table A3. IV estimates of the effects of completing dentistry on earnings (x€1000) by year since first lottery and lottery category

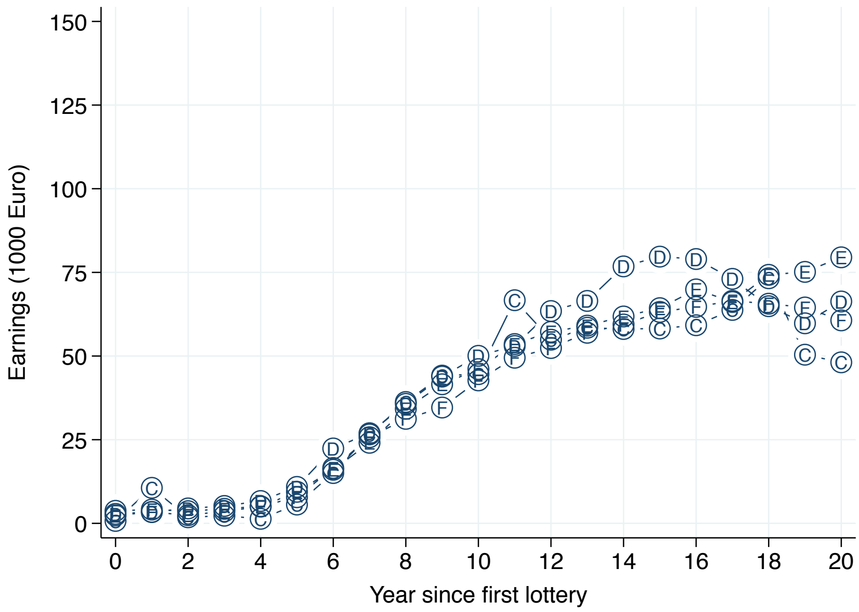
$t-\tau$	C	D	E	F
0	-0.3 (2.3)	-3.0 (1.5)**	-0.8 (1.9)	-2.6 (1.5)*
1	-20.6 (23.8)	-3.9 (1.2)***	-0.9 (2.0)	-4.5 (1.3)***
2	-2.5 (3.3)	-2.3 (1.3)*	-0.6 (1.0)	-2.6 (1.0)**
3	-2.1 (2.2)	-2.6 (1.5)*	-1.7 (1.1)	-2.1 (1.0)**
4	0.5 (1.9)	-3.4 (1.8)*	-2.4 (1.2)**	-1.9 (1.2)
5	3.9 (4.0)	-4.2 (2.3)*	-2.2 (2.2)	-3.4 (1.6)**
6	74.0 (21.1)***	26.0 (7.3)***	32.9 (5.9)***	16.2 (4.0)***
7	59.7 (22.4)***	50.1 (8.5)***	57.6 (8.9)***	43.1 (6.1)***
8	48.7 (21.8)**	53.1 (8.7)***	47.6 (9.4)***	52.6 (6.5)***
9	53.4 (22.5)**	38.6 (10.4)***	41.5 (9.1)***	54.6 (7.9)***
10	62.0 (27.8)**	34.3 (12.3)***	39.0 (9.5)***	56.6 (7.8)***
11	38.8 (39.0)	35.2 (12.0)***	50.2 (11.0)***	60.8 (8.8)***
12	55.8 (22.3)**	40.1 (16.5)**	50.1 (11.1)***	56.4 (8.5)***
13	36.8 (23.1)	33.7 (16.3)**	50.1 (10.8)***	51.4 (9.0)***
14	42.5 (20.4)**	38.6 (17.7)**	51.3 (11.7)***	59.9 (9.2)***
15	43.8 (20.2)**	45.1 (20.5)**	63.6 (13.1)***	59.3 (9.9)***
16	50.6 (24.7)**	57.6 (19.1)***	53.5 (12.8)***	47.0 (9.2)***
17	46.7 (24.3)*	49.9 (19.0)***	69.2 (13.7)***	52.6 (10.0)***
18	45.9 (33.9)	49.6 (28.0)*	64.7 (15.9)***	46.3 (10.9)***
19	87.4 (39.9)**	39.6 (21.9)*	77.6 (24.3)***	40.4 (11.6)***
20	165.2 (81.3)**	38.3 (21.0)*	16.1 (23.6)	32.3 (17.2)*

Notes: Robust standard errors in parentheses. * $p < 0.10$. ** $p < 0.05$. *** $p < 0.01$. 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 Appendix figures

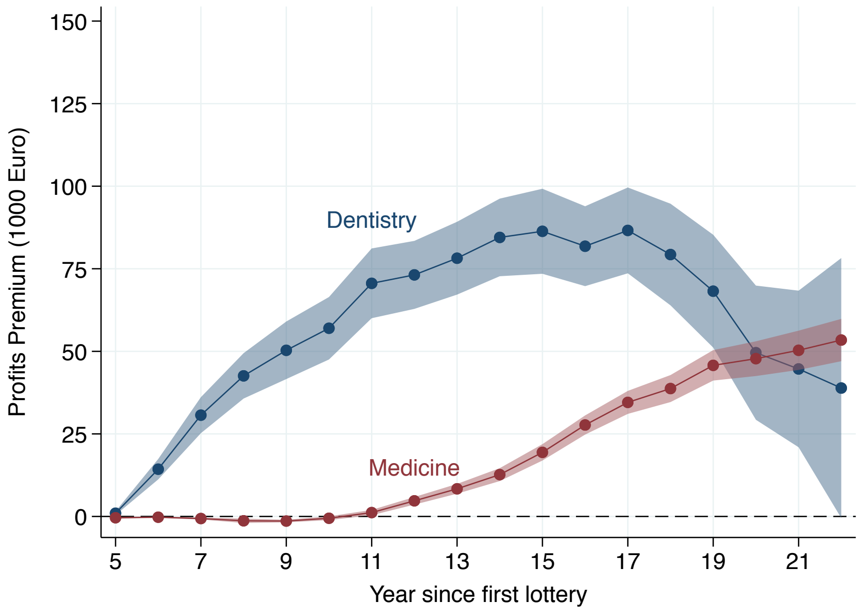


(a) Completed dentistry

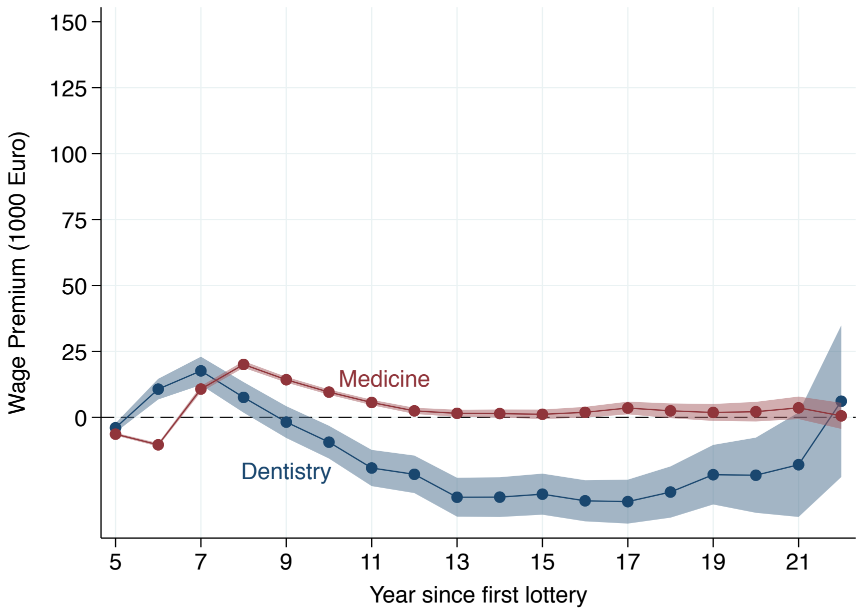


(b) Dentistry not completed

Figure B1. Predicted counterfactual earnings levels by lottery category



(a) Profits



(b) Wages

Figure B2. IV estimates of effects of dentistry versus medical school completion on profits and wages, by year since first lottery

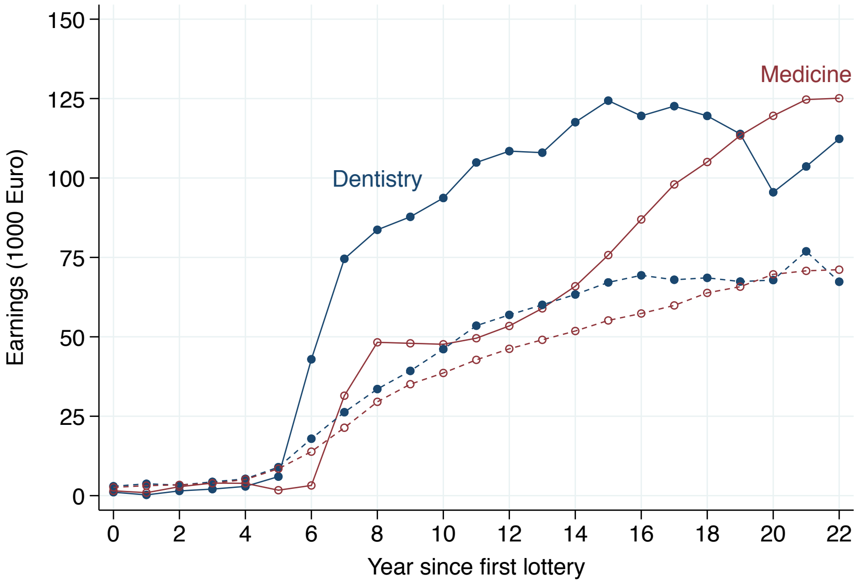


Figure B3. Predicted earnings levels of dentistry versus medical school completion, by year since first lottery

C Derivation of equations (3) and (4)

Using the law of total probability we can write the following expressions for $E[Y \cdot D|Z=1]$ and $E[Y \cdot D|Z=0]$:

$$\begin{aligned}
E[Y \cdot D|Z=1] &= E[Y|D=1,Z=1]P(D=1|Z=1) \\
&\quad + E[Y \cdot 0|D=0,Z=1]P(D=0|Z=1) \\
&= E[Y|D=1,Z=1]P(D=1|Z=1) \\
&= E[Y^1|D=1,Z=1]P(D=1|Z=1) \\
E[Y \cdot D|Z=0] &= E[Y \cdot 1|D=1,Z=0]P(D=1|Z=0) \\
&\quad + E[Y \cdot 0|D=0,Z=0]P(D=0|Z=0) \\
&= E[Y|D=1,Z=0]P(D=1|Z=0) \\
&= E[Y^1|D=1,Z=0]P(D=1|Z=0) \\
&= E[Y^1|D=1,Z=0]P(D=1|Z=0)
\end{aligned}$$

Note that individuals for whom $D=1, Z=1$ are always-takers (a) and compliers (c), while those with $D=1, Z=0$ are always-takers. This means that $P(D=1|Z=1) = P(a \text{ or } c) = P(a) + P(c)$ and $P(D=1|Z=0) = P(a)$. Using this, we obtain:

$$\begin{aligned}
E[Y \cdot D|Z=1] &= E[Y^1|D=1,Z=1]P(D=1|Z=1) \\
&= (E[Y|a]P(a|a \text{ or } c) + E[Y|c]P(c|a \text{ or } c))(P(a \text{ or } c)) \\
&= E[Y^1|a]P(a) + E[Y^1|c]P(c) \\
E[Y \cdot D|Z=0] &= E[Y^1|D=1,Z=0]P(D=1|Z=0) \\
&= E[Y^1|a]P(a)
\end{aligned}$$

From Imbens and Angrist (1994) we know that:

$$E[D|Z=1] - E[D|Z=1] = P(c)$$

which shows that the IV estimate of the effect of D on $Y \cdot D$ gives the average Y^1 for compliers:

$$\frac{E[Y \cdot D|Z=1] - E[Y \cdot D|Z=0]}{E[D|Z=1] - E[D|Z=1]} = \frac{E[Y^1|c]P(c)}{P(c)} = E[Y^1|c]$$

A similar argument shows that the IV estimate of the effect of $1-D$ on $Y \cdot (1-D)$ gives the average Y^0 for compliers:

$$\frac{E[Y\cdot(1-D)|Z=1]-E[Y\cdot(1-D)|Z=0]}{E[(1-D)|Z=1]-E[(1-D)|Z=1]}=\frac{E[Y^0|c]P(c)}{P(c)}=E[Y^0|c]$$

These are equations (3) and (4) in Abadie (2003).