Cutting the Queue to the Dentist: Waiting Time, Public-Private Interaction and Consumer Surplus

Tuomas Markkula*

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Abstract

In industries where private and public production coexist, public production can incentivize private competition and address distributional concerns. Using a structural model that incorporates affordable but capacity-constrained public health care producers into a framework with price-setting private producers and consumer demand, I examine how increasing public production's capacity affects waiting times, private practices' prices, and the distribution of consumer surplus. I estimate the model using consumer-level visit data on the Finnish dental care industry. In the counterfactual simulation, I increase the number of dentists in public practices by 20%. This reduces waiting times at public practices on average by 5%, or 1.5 days, but does not affect private practice prices as consumers do not switch from private to public practices. Low-income consumers benefit the most in relative terms, but the least in absolute terms.

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1 Introduction

In many industries such as education, housing, and health care, goods and services are produced by both private and public producers. However, the roles of private and public producers differ. Competition between private producers promotes efficiency and innovation (Bloom et al., 2015; Backus, 2020), and privatization of public production has been found to improve production efficiency (Chen et al., 2021). On the other hand, when competition is lacking private producers can raise prices, and incentives for innovation are dampened (Igami and Uetake, 2020; Asker and Nocke, 2021). Moreover, private producers can price out the most vulnerable consumer groups, which is especially worrisome for basic necessities like education, housing, and health care. Public production is a way to address these shortcomings of private production (Stiglitz, 1988).[1] The existence of public production can increase competitive pressure on private producers in markets where competition might otherwise be lacking. Moreover, direct government provision can ensure universal access to basic necessities. However, how these mechanisms play out in practice is not well understood.

I study a typical health care setting where affordable but congested public producers coexist with expensive private producers that allow consumers to bypass the queue. Using a structural model that incorporates capacity-constrained public producers into a framework with price-setting private producers and consumer demand, I examine how increasing public production's capacity affects market outcomes, and the distribution of consumer surplus. I estimate the model using consumer-level visit data on the Finnish dental care industry. Using the model, I show that increasing the production capacity of public practices reduces waiting times but fails to exert competitive pressure on private producers. Low-income consumers benefit the most relatively, but the least in absolute terms.

To study how increasing public practices' capacity affects public practices' waiting times, private practices' prices, and the distribution of consumer surplus, I need to model consumers' dental practice choices, equilibrium waiting times, and private practices' price-setting. In the model, heterogeneous consumers make discrete choices between public dental practices, private dental practices or not visiting a practice at all. Consumers' choices between public and private practices depend on how consumers weigh waiting against higher prices, and I allow consumers' preferences for waiting times and prices to depend on income. In addition, my model takes into account how consumers' income and age influence their decision not to visit a dental practice.

[1] Alternatively, the government could contract out the production of services to private firms, and negotiate a contract that would address the flaws of private production. However, it might be difficult to specify the characteristics of the service and to monitor that the contracted level of quality is maintained(Stiglitz, 1988). Additionally, in the presence of only a few suitable private producers contracting out might be expensive.

Public and private dental practices are differentiated by their prices, locations, and waiting times. Public practices are nonstrategic and have an exogenous production capacity that depends on the number of dentists at the practice. The waiting times are determined in the equilibrium as they depend on endogenous demand and demand depends on waiting times. High demand leads to longer waiting times, which in turn reduces demand, subsequently shortening waiting times, and so on. I obtain a steady state expression for average waiting times from queuing theory and use it as a reduced form equation. In the reduced form equation equilibrium waiting times depend on the demand for practice and the exogenous number of dentists at the practice. Private practices choose prices to maximize profits and take into account congestion externality: private practices' pricing decisions affect public practices' waiting times through demand. As a private practice increases prices, some consumers switch to public practices. As demand for public practices increases, waiting times increase. An increase in waiting time decreases the substitution to public practices, and as a result, the own-price elasticity of private practices is lower than it would otherwise be. This can result in higher prices for private practices.

The Finnish dental care industry is an ideal setting for studying the questions at hand. Affordable but congested public dental practices and expensive private dental practices share the market with comparable market shares. There is a large number of markets with varying market structures and a natural measure of capacity: the number of dentists working at the practice. Finally, I have individual-level data on dental care visits to both sectors for many years including visit-level prices and waiting times and I can link the visits to consumers' demographics, allowing me to study the distribution of consumer surplus. Finally, dental care is an "important and common type of primary care" (Buchmueller et al., 2016).

In my counterfactual, I increase the capacity of public practices by increasing the number of full-time equivalent dentists at public practices by 20%. This corresponds to an increase of 226 full-time equivalent dentists in total in the markets in my sample. If the policy change were implemented in the whole of Finland a 20% increase would require 450 additional full-time equivalent dentists. The counterfactual corresponds to a policy that would increase evening and weekend work done by either the current public practice dentists or private practice dentists outside their regular private practice hours. The number of private practice dentists is kept constant.

The increase in capacity decreases waiting times at public practices on average by 5% or 1.5 days, which is a small decrease relative to the 20% increase in the number of full-time equivalent dentists, and likely a result of the rather high practice-level own-waiting time elasticity of -2.74. The increase in capacity decreases the waiting times at first but as waiting times decrease, demand increases. Because of the substantial elasticity, waiting times decrease only by 5%, even though the market share of a public practice increases on average by 13%.

The increase in capacity does not affect the prices of private practices. Even though the average market share of public practices increases by 13% the average private practice market share decreases only by 2.8%. Most of the increase in public practices' market shares comes from consumers who have switched from not visiting a dentist to going to a public practice. Demand estimates reveal that high-income consumers are more responsive to waiting times and less responsive to prices, and vice versa for low-income consumers. Thus, it seems that the market is relatively segmented so that low-income consumers visit public practices and higher-income consumers are more likely to visit private practices, which allows private practices to keep their prices constant in the face of public practice capacity increase. Additionally, as waiting times decrease by only a small amount, the difference between public and private practices remains large in terms of waiting times. This contributes to the segmentation.

Low-income consumers benefit the most from the capacity increase in relative terms, but the least in absolute terms. High-income consumers benefit the most in absolute terms, which is because the probability of visiting a public practice is approximately the same across consumers with different incomes, but marginal disutility from waiting intensifies in income and at an increasing rate. Thus, larger income implies a more intense dislike for waiting, which in turn leads to a larger increase in consumer surplus from reduction in waiting times. I also show that the capacity increase might be welfare improving if public practices are able to hire personnel to do the capacity-increasing evening and weekend work at regular wages.

The capacity increase had only a limited effect on waiting times. The main reason for the small change in waiting times is that there appear to be relatively many consumers on the extensive margin that entered the market when waiting times decreased by a small amount. Siciliani et al. (2014) mentions how it might be difficult to decrease waiting times purely by increasing supply as the demand will immediately react to a decrease in waiting times. Instead, supply increases should be accompanied by demand restrictions, for example allowing consumers to access non-emergency dental care at public practices only every two or three years. This would reduce the substitution from not visiting to public practice and would lead to larger decreases in waiting times.

My results highlight the challenges of exerting competitive pressure on private producers through an increase in public production when public production is congested. They also show how increasing the capacity of public production impacts the distribution of consumer surplus when public production is congested. Private prices do not react, as at the current levels of waiting times the consumers preferring private producers do not view public practices as a close substitute to the private practices. Public producers' prices are usually low to allow access to care for everyone and waiting times function to target the public service to low-income consumers, as providing the service to everyone would be too expensive. The downside of this is that consumers who least prefer public production are the ones who dislike waiting the most. These are also usually the consumers with the lowest opportunity cost of money, so offering uncongested services to them at high prices is usually a profitable mode of operating for private alternatives. However, because these services cater to different consumer populations with different preferences for prices and waiting times, it is difficult for public production to apply competitive pressure on private producers.

Increasing public practices' capacity benefits low-income consumers, but high-income consumers benefit even more. A key reason for this is that while low-income consumers dislike waiting, they dislike waiting less than consumers with higher incomes. Instead, low-income consumers have the highest price elasticity of demand. Thus, reducing public practice prices might be a policy change that would benefit low-income consumers the most in a setting with congested public production.

Related Literature My work is mainly related to two strands of literature. First, I contribute to the literature on markets with both public and private production, particularly on the effects that an increase in public production has on market outcomes. My main contribution to this literature is studying how an increase in public production affects market outcomes when public production is rationed through waiting in addition to prices. Second, I contribute to the literature that builds and estimates structural models where congestion is determined in the equilibrium as a function of demand and producer capacity. My contribution is the development of a framework that features two types of producers: one that experiences endogenous congestion and cannot set prices, and another that operates without congestion and sets prices strategically. Furthermore, I contribute to the literature estimating waiting time elasticities in health care, where I estimate waiting time elasticities for a common primary care service. Finally, I also contribute to a large theoretical literature on markets with both public and private producers, by constructing a structural model and taking it to the data.

In the literature on markets with both public and private production, to my knowledge closest to my work is Dinerstein and Smith (2021), who show that an increase in public school funding, which increases the public schools' capacity, can result in some private schools exiting the market. A major difference between me and Dinerstein and Smith (2021) is that in the education context, all children must attend school, and thus there is no outside option. Thus the increased capacity in public schools resulted in a substantial substitution away from private schools. While my results show that increased capacity led consumers not using the service to start using public dental care, with minimal switching from private providers. My study highlights how the effects of an increase in public production's capacity on private producers depend on consumers' substitution patterns. This is especially true with waiting times, as substitution from not using a service to using publicly produced services dampens the reduction in waiting times that increased capacity can achieve.

My result that private practices' prices are not affected by the capacity increase is similar to the findings of Atal et al. (2024). They study how introduction of public pharmacies affected the prices of private pharmacies, and find that private pharmacies increased their prices instead of incentivizing competition. Atal et al. (2024) explain the finding by arguing that even though the public pharmacies were more affordable, they were also of lower quality and the entry allowed private pharmacies to segment the market. Price-sensitive consumers switched to public pharmacies and thus, private pharmacies' marginal consumers became less price-elastic. My findings provide more direct evidence of how market segmentation can insulate private producers from competition by public producers.

In addition, the empirical literature on public-private interaction contains studies that analyze how introducing a public production to a market with private producers affects prices, demand, and consumer welfare in markets like milk, and insurance (Jimenez-Hernandez and Seira, 2022; Saltzman, 2023). I contribute to this body of work by highlighting how public-private interaction is different when public production is allocated with waiting times and prices instead of only prices, and how market power disciplining and redistributive goals of public production play out in this setting.

The second strand of literature my study contributes to is the body of work building structural models with congestion as an equilibrium outcome. Russo (2024) quantifies the trade-off between redistribution and efficiency when rationing access to care with waiting times rather than with prices for physician office visits of the US veterans. She also draws on insights from the queuing literature, but her model, while allowing for capacity constraint and waiting times, does not allow her to change the congested practices' capacity, which is my main interest.

Brancaccio et al. (2024) and Elliott et al. (2024) study how a change in production capacity affects congestion and other outcomes, in addition to treating congestion as an equilibrium outcome. Brancaccio et al. (2024) study congested ports and ask how investments in port capacity would affect welfare through changes in trade volume and speed at which goods move from one country to another. They model congestion with a full dynamic queuing model with a production function for the time a ship spends at a port. However, their framework does not feature strategic price-setting competitors that could react to changes in congested producers' capacity. Elliott et al. (2024) build and estimate a model of mobile network operators where network operators invest in infrastructure and set prices. In their model, the quality of the operator's network depends on how fast the download speed is, which in turn depends on how congested the network is in the equilibrium. However, in their paper operators only differed in their prices and download speeds, there is no uncongested alternative, and firms can influence how congested their network is by varying prices. I contribute to this literature by studying and modeling a setting with two different types of producers: congested public practices with exogenous prices and uncongested price-setting private practices.

My study is also related to studies estimating waiting time elasticities in health care. To my knowledge, the only other study estimating waiting time elasticity for primary care is Russo (2024) who estimates the elasticity for physician office visits of the US veterans. There is a larger number of studies estimating waiting time elasticities for inpatient care such as Martin et al. (2007); Sivey (2012); Riganti et al. (2017) and Bruni et al. (2021). Strobel (2024) estimates waiting time elasticity for emergency care. However, these services are quite different from primary care services and also from dental care services, so it is likely that the waiting time elasticity would differ between these services. There is also a large theoretical literature on public-private interaction and waiting times including Hoel and Sæther (2003); Marchand and Schroyen (2005); Brekke and Sørgard (2007) and surveyed by Barros and Siciliani (2011). I contribute to this literature by taking a model with public-private interaction and waiting times to data.

2 Institutional Setting

The Finnish dental care industry is worth €1 billion in expenditures according to the Finnish Institute for Health and Welfare (2019). The industry consists of both public and private dental care providers, with comparable market shares at the national level[2]. All permanent residents of Finland have access to public dental care but can choose to use private dental care. Public dental care's out-of-pocket prices are one-third of the private practices' out-of-pocket prices, but waiting times for the public providers can be long. Anecdotal evidence suggests that the waiting times are negligible at the private practices[3].

[2]Expenditure on public dental care was €377.6 million and expenditure on private dental care was €542.3 million in 2014. The remaining expenditure classes are university students' and Finnish Defence Forces' dental care with €13.8 million and dental prosthetics with €82.6 million.

[3]There are multiple available times for dental examination for the next day (Saturday) in the three of the four largest dental care chains in Helsinki as checked in the afternoon of Friday 28.6.2024. All the chains offer multiple times for dental examinations for the next Monday. The same holds in Turku for two of the large chains and all offer multiple times for the Monday and in Tampere all chains offer multiple times for

2.1 Public and Private Dental Care Providers

Public and private dental practices provide dental care services that aim to preserve and restore the oral health of the patient. In both types of practices, dental care is performed during a treatment episode, which consists of several visits during which the patient's condition is treated. The treatment episode begins with a diagnostic visit, during which a dentist performs a dental examination and X-rays. Based on the findings of the examination, the dentist makes a diagnosis and determines what dental treatments a patient needs. The treatments, most commonly fillings, teeth removals, root canal treatments, and periodontal treatments, are then performed during one or several follow-up visits.

Public dental care is organized by municipalities, which are required by law to provide dental care to their residents. Municipalities can also form a joint municipality authority to provide the services together. The central government regulates public providers' prices and the waiting times to obtain non-urgent care. The public providers' prices are capped at the dental procedure level, and most of the municipalities set prices at the cap. In general, non-urgent dental care should be provided within three months of the assessment of the need for treatment, but the three-month limit can be extended by an additional three months if the patient's health is not compromised. Violating the waiting time limit is a reputational concern and can lead to fines if the issue is not addressed sufficiently. Public dental care also provides urgent dental care. In the case of an urgent visit, a consumer's need is deemed urgent enough so that treatment should begin within a day. Public dental care does not provide aesthetic treatments or dental implants.

Private dental care is provided by firms, either national chains or independent practices owned by dentists. Private practices' pricing is not regulated, and private practices' services are covered by the National Health Insurance. The insurance covers all permanent residents of Finland and reimburses a fixed amount per procedure. According to Blomgren et al. (2017) the reimbursement paid for 31% of the expenses at the private providers in 2014, but the reimbursements were cut in 2015 and 2016, and as a result, the reimbursement covered only 15.7% of consumers' expenses in 2016. Private dental practices might provide higher quality care than public dental practices, as they might use more expensive materials and spend more time to perform the treatments.

2.2 Dentists

Dentists are the most important factor of production in dental care. The law states that they are the only dental care professionals who are allowed to diagnose oral diseases. A dentist

the Monday.

treats different inflammations and infections of the mouth area and plans and performs dental treatments like fillings, root canal treatments, and surgical treatments like teeth removal. There are on average 3915 working dentists per year between 2011 and 2019, and approximately 60% of dentists work in the public sector. A dental hygienist is the closest substitute to a dentist, but rather than examining, diagnosing, and treating oral disease like dentists, they focus on promoting oral health, performing dental check-ups without making a diagnosis, and performing assessments of the need for treatments. Dental hygienists often perform periodontal treatments, like tartar removal. Finally, dental nurses mainly assist dentists, perform limited dental check-ups without making a diagnosis and perform assessments of the need for treatments.

3 Data

I use comprehensive consumer-level data on dental care visits for all Finnish residents for 2014–2017 allows me to link visits to public and private dental practices to consumer characteristics. Moreover, I observe if a consumer does not visit a dental practice in a given year. I observe prices at the public and private practices, and individual-level waiting times at the public practices and I can link dentists to the practices where they work. Finally, I observe both practices' locations and consumers' residence locations.

Data on visits to private practices is administrative data from Kela, the Social Insurance Institution of Finland. The data contains all procedures performed at the private dental practices, that were reimbursed by the National Health Insurance[4] for 2014-2017. For each procedure, I observe the patient, the day of the visit, the daily price of the procedure, the treating dentist, and the dental practice. In addition, I observe what is the reimbursement level for the procedure and whether a higher reimbursement level applies due to the use of a specialized dentist's services or due to an unusual visit time[5]. Finally, I observe if a practice belongs to a chain, in which chain the practice belongs to, and the location of the practice in Statistics Finland's 250m×250m grid.

Data on visits to public practices is administrative data from the Finnish Institute for Health and Welfare. The data contains all visits to public dental practices for the years 2014–2017. For each visit, I observe the patient, the date on which the visit was booked and the day of the visit, what procedures were performed during the visit, and the location

[4]The procedures that fall outside the scope of the insurance are prosthetic and aesthetic procedures, so I do not observe these procedures. Additionally, from 2015 onward dental examination is only reimbursed every other year.

[5]A higher reimbursement level applies if the dentist performing the procedure provided treatment as a specialized dentist or if the treatment was performed outside regular hours.

of the practice in Statistics Finland's 250m×250m grid. Moreover, I observe whether the visit is an urgent visit or not. I calculate waiting time as a difference between the date of the first visit of the treatment episode and the date when the first visit was booked as done by the previous literature (Yee et al., 2022; Chartock, 2023; Russo, 2024). Unfortunately, the data on visits to public practices does not include prices. Therefore, I use data on the government-set procedure-specific price caps on public practice prices collected by Haaga (2019) instead, and assume that all municipalities set the prices at the caps.

Data on consumer characteristics is administrative data from Statistics Finland. These data contain consumer characteristics like age, sex, socioeconomic status, education, and disposable income as well as consumer's location of residence in 250m×250m grid for all permanent residents at the end of the year for years 2014-2017. As I observe the universe of permanent residents and can link consumers to their dental care visits, I observe if a consumer does not visit a dental practice in a given year.

Data on dentists comes from The National Supervisory Authority for Health and Welfare Valvira and Statistics Finland. I observe the age and specialization of dentists working at private practices in Valvira data. In addition, as I can link a dentist and a private sector visit using the private practice visit data from Kela, I observe how many patients the dentist treats, what treatments the dentist performs on a given patient, and in which private practice the dentist works at. For dentists working in the public sector, I observe the municipality where the dentist works and various characteristics like earnings, age, and sex in Statistics Finland data.

3.1 Constructing Treatment Episodes and Expected Prices

I model demand for dental care as a discrete choice between public and private practices and not visiting a practice, and thus I need to define a discrete unit of dental care. A natural choice for a unit of dental care is a treatment episode as it contains all the services that the consumer pays for, from diagnostics to treatments. The downside of using treatment episodes is that I need to group the individual dental care visits into treatment episodes myself. I start by defining a dental care visit. The public sector data contains a variable that indicates to which visit the treatments belong, while in the private sector data, I define a single visit as a unique combination of a patient, a practice, the date of the visit, and whether the person providing the treatment is a dentist or a dental hygienist.

In the public sector data, I construct the episodes from individual visits in the following way. If for two visits the interval between the booking date and the visit date overlap, I assume the visits belong to the same episode. Moreover, if the booking for one or more visits was done on a previous visit date, then the booked visits also belong to the same episode as the visit. Finally, if a visit was booked within 90 days of the previous visit, then the booked visit belongs to the same treatment episode as the previous visit. This is in accordance with the legislation stating that the waiting time for non-urgent care should be at most 90 days. In the private practice visit data, I assume that visits belong to the same treatment episodes if they are within 90 days of each other.

An additional issue is that consumers do not know what treatments their treatment episode contains before a diagnostic visit to a dentist. As the price of the treatment episode depends on how many and which treatments the dentist prescribes to the consumer, I need to take a stand on the consumers' expectations about their treatment bundle. As the focus of this paper is not on imperfect information, I make a simplifying assumption that all consumers expect to get the same sector-year-specific average bundle of treatments. I allow the average bundle to vary across sectors and years to allow for different treatment practices between private and public practices, as well as across years.

I construct the average bundles as follows. I take the 50 most common procedures performed on the study population. I then calculate weights for the procedures by dividing the number of procedures by the number of treatment episodes separately for each sector-year combination. The average bundle is then the weighted sum of the 50 most common procedures. I construct practice-specific prices by summing over the practice's prices for the 50 most common procedures while weighting the procedure-specific prices according to the procedure weights. Thus, the price that consumers consider when choosing between public and private practices and not visiting is the price of the average sector-year-specific bundle in a given practice. Even though the treatments do not vary across practices, private practices' prices for treatments vary and thus the price of the average bundle also varies across private practices. Public practice prices are the same within a year, but the price caps were increased in 2016, and thus also prices increased.

The average bundle assumption simplifies the analysis and allows me to model private practices as setting only one price. The one price can be thought of as a menu of prices for different procedures. For example with ten different bundle types, each private practice would need to set ten different prices that would correspond to the menu of prices as well as a bundle-type specific set of services. The downside of the assumption is that it can lead to biased price elasticity estimates, if consumers have rational expectations about their bundle of treatments and consumers' choices depend on the bundle they expect to get. However, this seems unlikely to me.

3.2 Market, Practice and Consumer Samples

I define a market as a combination of a geographic area and a year. To simplify the analysis I focus on isolated local markets, where the consumers residing in the market almost exclusively visit the dental practices located within the market. I assume that the geographical area is a municipality[6], and if many municipalities produce public dental care together, I assume that the municipality cooperation area is the geographical market. This definition produces sensible local markets for more rural areas but does not work for larger urban areas. Thus, I exclude the ten most populous municipalities from the sample, as well as their neighboring municipalities.

Table 1 presents summary statistics for 322 markets in my sample. I have an unbalanced panel of markets as some of the 101 geographic areas are in the sample for only a subset of 2014–2017. In a market, there are on average 2.46 public practices and 3.24 private practices. There is also significant variation in the number of practices across markets with a standard deviation of 1.87 for the number of public practices and a standard deviation of 2.75 for the private practices. Chains' role in these markets is limited. A 5% of the practices belong to a chain and only 2.5% of the practices have two practices by the same chain present. An important feature of the markets is that only 73.9% of the markets have a private practice present. This allows me to compare markets with and without public-private interaction. 90.1% of the markets have a public practice present. Finally, 46.9% of the markets are rural, 31.4% are semi-urban 31.4% and 21.7% are urban.

Table 2 presents the summary statistics for the practices in the included markets that sum up to 1484 practice-year observations for 2014–2017. My four-year panel of dental practices is unbalanced. There are 218 unique public practices, 713 public practice-year observations, 256 unique private practices, and 771 private practice-year observations. The average treatment episode costs out-of-pocket €119 in an average public practice and €180 in an average private practice, a difference of €61s. The price of the treatment episode varies a lot in the private sector as the standard deviation is €47. The variation in public practice prices comes only from the across-year variation in the price caps. Affordable public practices are congested, and the average first-visit waiting time is approximately 32 days, with a substantial standard deviation of 16 days. Within-episode waiting times are longer, on average 40 days. Moreover, public practices are on average larger than private practices. A public practice has on average a market share of 30%, while a private practice has on average a market share of 14%. In addition, an average public practice has 50% more visits

[6] An alternative to this would be to use the locations of consumers and practices to construct catchment area-based markets. This would likely produce overlapping markets, which would complicate empirical analysis.

per year, treats more unique patients per year, performs more dental procedures per year and completes more treatment episodes per year than an average private practice. Finally, 12.5% of private practice-year observations are by practices that belong to chains.

I restrict my consumer sample to 25–80 years old consumers residing in the included markets. The restriction is necessary as university students in Finland have their own dental care, which I do not have data on[7]. I drop all consumers younger than 25 years, as dropping only university students would result in a selected sample. The upper bound restricts the sample to consumers who are in the market for dental care. I take a 40% random sample of my consumer sample that I use in the empirical analysis.

Table 3 presents summary statistics for my unbalanced panel of two million consumer-year observations by a half million unique consumers. The table's last three columns divide the unique consumers into three categories based on which dental practices they have visited between 2014–2017. Half of the consumers have visited a public practice, 35% have visited a private practice, and 27% have not visited a dental practice between 2014–2017. If a consumer has visited both a public and a private practice, then they are included in both public and private practice visit columns. The share of not visiting is slightly inflated due to the unbalancedness of the consumer panel. For example, some consumers are in the data only in 2017 because they turned 25 in 2017, and they are included in the "No visit" column if they did not visit a dental practice in 2017. The table shows that consumers who have visited a private practice are on average oldest and have the highest income, while consumers who have visited a public practice are younger and have lower income. Consumers who have not visited have the lowest income on average and are slightly younger on average than consumers with a private visit. The average number of episodes per year is 0.5, meaning that on average a consumer goes through a treatment episode every other year. Consumers with a public visit a dental practice more often, on average once every 1.7 years, and consumers with a private visit visit a dental practice on average almost every year.

Figure 1 displays how consumers' choices between public and private practice, and not visiting vary by yearly disposable income. The figure shows that all income groups use public dental care, but private dental care is more common for high-income consumers. As income increases from €27 thousand the share of consumers choosing a private practice increases, while the share of consumers visiting a public practice decreases. Additionally, the share not visiting a dental practice decreases as we move from lowest yearly incomes to incomes over €27 000 and levels off afterward.

[7]University studies in Finland usually take at least five years, three years for the undergraduate degree and two years for the master's degree, and the typical age to begin studies is between 19 and 21 years.)

4 Model

I am interested in what would happen to public practice waiting times, private practice prices, and distribution of consumer surplus if public practices would employ more dentists. To this end, I build a structural model of the industry that endogenizes consumer demand, prices, and waiting times. Heterogenous consumers choose whether to purchase dental care services and from which practice. Private practices choose their prices to maximize profits and public practice waiting times are determined in the equilibrium by consumers' choices and an exogenous number of dentists. Private and public dental practices are differentiated by their location. All choices are simultaneous. I model the demand for non-urgent dental care, and I am taking as given the number of dentists in the local market, as well as the number of dental practices and their locations. In addition, I am not modeling public sector wages.

4.1 Consumer Demand

A consumer can choose to visit one of the private dental practices or one of the public dental practices in the market or decide not to visit a dental practice. A market is a municipality or a municipality cooperation area-year combination. Outside good is not visiting a dental practice in a given year and using income on other things. Market size, M_t, is the number of individuals in the consumer sample residing in the market. The indirect utility for consumer $i \in I_t$ from purchasing a dental care treatment episode from practice $j \in J^{pri} \cup J^{pub}$, where $j = 0$ denotes outside good, in market $t \in T$, is

$$u_{ijt} = \delta_{jt} + \mu_{ijt} + \epsilon_{ijt} \tag{1}$$

$$\delta_{jt} = x_{jt}^{\intercal}\beta + \lambda_y + \xi_{jt} \tag{2}$$

$$\mu_{ijt} = (x_{jt} \otimes z_{1it})^{\intercal}\theta_2 + \theta_3 h_{ijt} \tag{3}$$

$$u_{i0t} = z_{2it}^{\intercal}\theta_1 + \epsilon_{i0t}, \tag{4}$$

where $\otimes$ denotes a Kronecker product. ϵ_{ijt} is i.i.d. and follows the type-I extreme value distribution and is consumer i's idiosyncratic preference shock for practice j. δ_{jt} captures consumers' mean utility from choosing the practice j. It is a linear function of practice characteristics, x_{jt}, including the price of the average treatment bundle and a yearly average of individual consumers' waiting times for practice j. Waiting times are zero for private practices. λ_y is a year fixed effect for year y. ξ_{jt} is the unobservable component of the mean utility and contains the unobservable practice-specific quality as well as the average waiting time for private practice j if the private practice has positive waiting times. Thus, the demand model captures these important unobservable practice characteristics and they are kept constant in the counterfactuals. ξ_{jt} is correlated with prices and waiting times and hence, private practice prices and public practice waiting times are endogenous. Public practice prices are set at the national price cap and are thus exogenous.

Access to consumer-level data with consumer characteristics allows me to model how observable consumer characteristics affect consumers' choices. μ_{ijt} captures flexibly how consumers' preferences for the practice j's characteristics depend on the consumers' observable characteristics, z_{1it}. z_{1it} contains consumer i's disposable income, and its 2nd power.[8] Income and its 2nd power is interacted with price and waiting times. For example, the model allows consumers with higher incomes to have a lower price elasticity and a higher waiting time elasticity. The interactions allow me to study how the distribution of consumer surplus changes when public practices' capacity is increased (Griffith et al., 2018). This is because the interactions between prices and waiting times and consumer characteristics allow observationally different consumers to have different preferences for prices and waiting times as well as different elasticities and substitution patterns. Absent interactions, increasing the public practice capacity would affect all consumers the same. Additionally, interacting product characteristics with a nonlinear function of consumer's income ensures that the demand model does not restrict the range of pass-through the model can produce (Griffith et al., 2018; Miravete et al., 2024).[9]

The availability of consumer-level data with consumer and practice locations allows me to include consumer i's distance to practice j, h_{ijt} into the model. Thus, the consumer's indirect utility for practice j depends on the distance from the consumer's residence of locations to the practice in a granular 250m$\times$250m grid. I also allow consumers' preferences for the outside good of not visiting practice to depend on consumers' characteristics. For example, I expect older and higher-income consumers to visit a dental practice more often. Formally, consumer is' indirect utility for not visiting a practice, u_{i0t}, depends on consumer's characteristics z_{2it}, containing consumers age and income as well as their second powers.

Consumer i chooses a practice to maximize her indirect utility. Together with the assumptions on ϵ_{ijt}, this leads to the following expression for the probability that consumer i

[8] I choose the quadratic function instead of income bins, as Miravete et al. (2024) recommends against using bins as they result in discrete consumer types which strongly restricts the possible combinations of elasticity and pass-through that the model can accommodate.

[9] As shown by Miravete et al. (2024), see also Griffith et al. (2018), a logit demand without preference heterogeneity restricts pass-through to be below one.

chooses practice j in market t

$$\mathcal{P}_{ijt} = \frac{\exp(\delta_{jt} + \mu_{ijt})}{1 + \sum_{k=1}^{J} \exp(\delta_{kt} + \mu_{hkt})}. \tag{5}$$

Integrating over consumer characteristics z_{it} gives the market share of practice j in market t

$$s_{jt} = \frac{1}{I_t} \sum_{i \in I_t} \mathcal{P}_{ijt}(z_{it}). \tag{6}$$

4.2 Public Practice Waiting Times

I model public practices' waiting times as equilibrium objects that depend on how many consumers book an appointment at the practice, how many dentists work at the practice, and how productive the practice is. An expression for the average waiting time within a year that depends on these variables can be derived from a simple queuing theory model,[10] see Bhat (2008). Using the steady-state average waiting times that arise from the model as a reduced-form equation, I get the following parameterized expression for the average waiting time in days for a consumer booking an appointment at a public practice j in market t

$$b_{jt} = \psi_1 \frac{q_{jt}}{d_{jt}} + \tau_y + \omega_{jt}, \;\; j \in J^{pub}. \tag{7}$$

The right-hand side of the equation consists of how many consumers seek care at the practice during a year, per the number of dentists working at the practice, q_{jt}/d_{jt}. The number of consumers is divided by the number of dentists working at the practice, which corresponds to how many consumers can be treated simultaneously. Dividing the length of the queue by the number of dentists gives the number of patients a single dentist must treat before it is consumer i's turn. ψ_1 is service time: how large share of a day does it take to treat a consumer with an average treatment bundle. ω_{jt} allows some practices to be more productive, in the sense that with the same consumers per dentists ratio, practices can have different waiting times. Finally, I allow for different productivity levels across years shared by all public practices with year-fixed effects, τ_y.

Waiting times depend on the private practices' prices as well as consumers' choices in the equilibrium, as these choices affect the demand for the public practice's services q_{jt}. Thus, demand and waiting times are determined simultaneously in the equilibrium, and thus

[10] The expression arises as a steady state of the M/M/K queuing model, where consumers' arrivals to a dental practice follow a Poisson distribution (M), how long does it take to serve a consumer follows an exponential distribution (M) and there are (K) dentists treating the consumers. Brancaccio et al. (2024) use this kind of model to study congestion at ports.

demand is endogenous in Equation 7. I assume that the waiting time cannot be negative $b_{jt} \geq 0$. Waiting times for the private practices are included in the demand model and are not allowed to change in the counterfactuals. Instead, private practices can change prices.

4.3 Private Practices

Private practices choose the price of the average treatment bundle to maximize profits. I model private practices as single-practice firms as there are only a few markets where the same chain has two practices in the market.[11] Moreover, chains do not have uniform prices across markets. Private practice j's pricing problem in market t is

$$\text{arg max}_{p_{jt} \in J_t^{pri}} \sum_{j \in J_t^{pri}} \Big(p_{jt} - mc_{jt}\Big) q_{jt}(p_t, b_t(q_t^{pub})). \tag{8}$$

p_{jt} is the price of the average service bundle for practice j, $q_{jt}(p_t, b_t(q_t^{pub}))$ is the number of patients treated, $q_{jt}(p_t, b_t(q_t^{pub})) = s_{jt}(p_t, b_t(q_t^{pub}))M_t$, M_t is the number of consumers in the local market and $b_t(q_t^{pub})$ contains public practices' average waiting times. mc_{jt} is practice j's marginal cost function, which I assume to be constant.

The standard first-order condition of the private practice's problem is

$$p_{jt} = mc_{jt} + q_{jt}(p_t, b_t(p_t)) \left[- \frac{\partial q_{jt}(p_t, b_t(p_t))}{\partial p_{jt}} \right]^{-1} \tag{9}$$

We can see that a less elastic demand for practice j implies higher prices for practice j. The price-setting problem accounts for the fact that private practices' prices affect public practices' waiting times, and the waiting times affect private practices' prices. Private practices' prices impose a congestion externality on public practices, as an increase in the private practices' prices increases demand for the public practice. Thus, waiting times at the public practice increase. The congestion externality results in higher private practice prices, as the congestion externality shifts consumers' price elasticity of demand towards zero. The intuition is following. If all private practices set high prices, then many consumers prefer to visit a public practice. However, because of the limited capacity of the public practice, the increase in demand will increase waiting times at the public practice. As consumers dislike waiting, with large enough waiting times some consumers will prefer to visit one of the private practices even with high prices. This will result in a lower price elasticity of demand for private practices.

The congestion externality enters the private practice's pricing problem through price

[11] I will use the multiproduct formula for these chain practices in future versions of this paper.

derivatives of demand, which differ from the usual price derivative of demand obtained from a logit demand. This is because in the equilibrium the public practices' waiting times depend on the private practices' prices and the private practices' prices depend on the waiting times. The derivative of the private practice j's quantity with respect to the p_{jt} is

$$\frac{\partial q_{jt}}{\partial p_{jt}} = M_t \frac{1}{I_t} \sum_{i \in I_t} \frac{\partial \mathcal{P}_{ijt}}{\partial p_{jt}} \tag{10}$$

$$= M_t \frac{1}{I_t} \sum_{i \in I_t} \left(\frac{\partial u_{ijt}}{\partial p_{jt}} \mathcal{P}_{ijt}(1 - \mathcal{P}_{ijt}) - \sum_{k \in J_t^{pub}} \left[\frac{\partial u_{ikt}}{\partial b_{kt}} \frac{\partial b_{kt}}{\partial s_{kt}} \frac{\partial s_{kt}}{\partial p_{jt}} \mathcal{P}_{ijt} \mathcal{P}_{ikt} \right] \right) \tag{11}$$

The first term of Equation 11 is negative as it is a standard logit own-price derivative telling how the demand for practice j changes when practice j changes its price. The second term expresses how the waiting times of the public practices change when practice j changes its price. The second term is positive under sensible conditions: consumers dislike waiting, an increase in public practice demand increases waiting time, and public practices' demand increases in private practices' prices. Thus, a larger increase in the waiting times of public practices after a change in p_{jt} results in a less price elastic demand for practice j.

The extent to which the congestion externality reduces consumers' price sensitivity to private practices' prices depends on how much consumers dislike waiting, how much waiting times change when public practices' demand changes, and how much public practice demand changes when private practice changes their price, $\partial q_{ijt}^{pub} / \partial p_{jt}$. The first two components I get straightforwardly from the demand model and from the waiting time model, but the third component requires more work.

The expression for the market share of public practice is a fixed point relation, where on the left-hand side I have the demand for public practice j, and on the right-hand side, I have a function that depends on the demand for public practice through the waiting times.

$$q_{jt} = M_t \frac{1}{I_t} \sum_{i \in I_t} \mathcal{P}_{it}(b_{jt}(q_{jt})), \text{ for } j \in J_t^{pub} \implies s_{jt} = \frac{1}{I_t} \sum_{i \in I_t} \mathcal{P}_{it}(b_{jt}(s_{jt} M_t)), \text{ for } j \in J_t^{pub} \tag{12}$$

I differentiate this equation using implicit differentiation. I get for the public practice j's cross-price derivative with respect to private practice k's price in a market with only one public practice

$$\frac{\partial s_{jt}}{\partial p_{kt}} = \frac{- \sum_{i \in I_t} \left[\frac{\partial u_{ikt}}{\partial p_{kt}} \mathcal{P}_{ikt} \mathcal{P}_{ijt} \right]}{\sum_{i \in I_t} \left[1 - \left(\frac{\partial u_{ijt}}{\partial b_{jt}} \frac{\partial b_{jt}}{\partial s_{jt}} \right) \mathcal{P}_{ijt}(1 - \mathcal{P}_{ij}) \right]}, \text{ for } j \in J_t^{pub}, k \in J_t^{pri} \tag{13}$$

which is positive assuming consumers dislike higher prices and longer waiting times. This expression for the cross-price derivative of a public practice is intuitive. The numerator is the standard logit cross-price derivative, which is then scaled up or down by the denominator. The denominator is one minus the own-waiting time derivative of a public practice. If consumers dislike waiting, then the denominator is larger than one and the cross-price derivative is scaled down. An increase in a private practice price increases demand for a public practice less than without waiting times. Moreover, the congestion externality is larger, the larger the own-waiting time derivative of the public practice. If there is more than one public practice in a market the $\frac{\partial s_{jt}}{\partial p_{kt}}$ depends also on other public practices' cross-price derivative. In that case, I turn each public practice-specific expression of Equation 13 into a linear system of equations and solve it numerically. See appendix A.1 for the derivations of cross-price derivatives of public practices and own-price derivatives of private practices.

5 Estimation and Results

I estimate the parameters of consumer demand using maximum likelihood and two-stage least squares, marginal costs using the first-order conditions of the private practices problem, and parameters of the waiting time model using two-stage least squares.

5.1 Estimating Demand

My consumer-level visit data allows me to estimate demand using a simple two-step procedure.[12] In the first-step I estimate the mean utilities δ_{jt}s as fixed effects and the preference heterogeneity parameters θ in

$$\mathcal{P}_{ijt} = \frac{\exp(\delta_{jt} + \mu_{ijt}(x_{jt}, z_{it}, h_{ijt}; \theta))}{1 + \sum_{k=1}^{J} \exp(\delta_{kt} + \mu_{ikt}(x_{kt}, z_{it}, h_{ikt}; \theta))}, \tag{14}$$

using maximum likelihood.[13] As prices and waiting times as well as the unobservable quality and unobservable private practice waiting times are kept constant in this step as they are in δ_{jt}, there is no endogeneity problem even though the $\mu_{ijt}(x_{jt}, z_{it}, h_{ijt}; \theta)$ contains interactions between prices and waiting times and consumer characteristics.

In the second step, I estimate the mean effects of the product characteristics, prices and

[12] Compared to a Berry et al. (1995) style demand estimation with market-level data, I do not need to recover δ_{jt} using BLP inversion that requires a standard error correction (Grieco et al., 2023). Moreover, I do not need to use nonlinear IV estimators which are vulnerable to a weak instrument problem (Gandhi and Houde, 2023).

[13] This is a conditional logit model with around 1500 δ_{jt}s that I estimate with Stata's asclogit command.

waiting times, using 2SLS and the estimates for the practice-market-specific mean utility, $\widehat{\delta_{jt}}$, obtained in the first step.

$$\widehat{\delta}_{jt} = x_{jt}^{\intercal}\beta + \xi_{jt} \tag{15}$$

where x_{jt} contains prices and waiting times. As almost all variation in prices comes from private practices and all variation in waiting times comes from public practices, I estimate the price parameter using private practices and the waiting time parameter using public practices.

For private practices prices are endogenous. In addition to prices being determined in the equilibrium, any correlation between unobservable quality and prices leads to an endogeneity problem. I instrument for prices with the number of dentists working at the public practices in the same municipality where the practice is located. This instrument is a combination of a BLP instrument and a cost-shifter. The number of public practice dentists is a measure of the capacity in the public sector, and the larger the capacity larger the competitive pressure on the private practices in the market is. Additionally, the more there are public practice dentists, the easier it is for the private practice to hire dentists, and thus private practices' marginal costs should be lower when there are many public practice dentists.

BLP instruments are widely used in the industrial organization literature to instrument for prices and for demand (Berry and Haile, 2021; Gandhi and Houde, 2023). They affect prices, as practices can set higher prices for equally desirable products that are more isolated in the product characteristics space. BLP instruments satisfy the exclusion restriction because the number of competitors and other practices' characteristics do not enter the consumer's indirect utility for practice j. Finally, other product characteristics than prices are commonly assumed to be exogenous, in the sense that practice is not choosing them in the short term. Cost shifters are instrumental variables that affect prices through practices' marginal costs and need to be mean independent of unobservable quality, ξ_{jt}. I can also introduce fixed effects to control for unobserved quality and time-varying demand shocks. However, I need to consider the trade-off between the fixed effects and variation left in the instrumental variables after controlling for the fixed effects. Introducing too many fixed effects can lead to a weak instrument problem.

For public practices waiting times are endogenous as they are determined in the equilibrium together with demand and prices. Moreover, endogeneity could also arise from any unobserved changes in quality, like improvements in premises that would affect demand. I instrument for the waiting times with the number of private practice dentists working in the same municipality where the practice is located. Again, the instrument is a combination of a

BLP instrument and a cost-shifter. I assume that public practice prices are exogenous, as I am using the price caps set by the government. Instead of including the public practice prices in the model, I include year fixed-effects that absorb the prices as there is only across-year variation in public practice prices.

5.1.1 Demand Estimation Results

Table 4 presents the estimates on how prices and waiting times affect the mean utility. The estimates are in utilities, so magnitudes are not interpretable, but the estimates' signs are. All estimates are statistically significant at the conventional levels. The first two columns of the table show OLS and 2SLS estimates for price. The OLS estimate is negative but small, and the 2SLS estimate is negative and larger in absolute value. This is what we would expect if the endogeneity problem arises from a positive correlation between unobservable quality and prices. The last two columns show the estimates for waiting times. OLS estimate of the waiting time is negative and the 2SLS estimate of the waiting time is more negative than the OLS estimate. Again, this is as expected because we should expect a positive correlation between waiting times and unobservable quality.

Table 5 displays preference heterogeneity estimates. The estimates are of the expected sign: consumers with higher income are less sensitive to price, but at a decreasing rate, while higher income consumers dislike waiting more and at an increasing rate. Moreover, higher income and older consumers are more likely to visit a dental practice but at a decreasing rate. All consumers dislike practices that are far, but the effect decreases in distance.

With demand estimates at hand, I can calculate elasticities with respect to prices and waiting times. Table 6 shows average aggregate and practice-level own-price and own-waiting time elasticities calculated by sector. The elasticities in the table do not account for the congestion externality and thus should be interpreted as lower bounds, as the congestion externality reduces the absolute value of the elasticity. The average aggregate price elasticity measures how consumers' decision to use any dental care depends on prices. I find an estimate of -0.84, so demand for dental care is inelastic and a one percent increase in dental care price decreases demand for dental care by 0.84%. This is a large estimate compared to the previous studies on health care markets, for example, a common benchmark for the price elasticity of the demand for medical care is -0.2 from the Rand Health Insurance Experiment (Aron-Dine et al., 2013). A major reason for the difference in the estimates is that in my setting there is no coinsurance[14] and no cap for the out-of-pocket expenditures, so consumers pay the price increase in full, which is reflected in the price elasticity. For example, Keeler and Rolph

[14] With coinsurance consumer pays a percentage share of their expenses, for example with coinsurance of 20% consumer pays 20% of expenses themselves.

(1988)'s analysis of Rand Health Insurance Experiment data results in elasticity estimates of -0.12 and -0.39 for medical spending on dental care with 0%–25% and 25%–95% coinsurance, respectively.[15] I find sector-specific aggregate price elasticities of -1.64 for the private sector and -1.30 for the public sector.

The average practice-level own-price elasticity is -4.68, meaning that a one percentage increase in price decreases the practice's demand by 4.68%. Private practices' elasticities are on average higher, with a mean of -5.83, while public practices' elasticities are lower, with a mean of -3.47. The private practices' own-price elasticity is comparable to Gowrisankaran et al. (2015)'s own-price elasticity of hospitals when consumers do not have health insurance. The elasticity is lower for public practices, as they have substantially lower out-of-pocket prices. Average cross-price elasticities are small and vary between 0.14 and 0.19 across within and cross-sector elasticities.

I can only calculate aggregate waiting time elasticity for public practices as private practices waiting time is zero. I find an aggregate waiting time elasticity of -1.01 for the public sector. There is only a small amount of work estimating aggregate waiting time elasticities. The literature on hospitals typically finds an elasticity in the range of -0.1 and -0.2, see for example (Martin et al., 2007; Sivey, 2012; Riganti et al., 2017). The difference in the estimates likely stems from a difference in the costs of waiting between care given in a hospital and dental care. Practice-level own-waiting time elasticity is -2.71, which is three times larger than a recent estimate for the US veterans choosing a physician's practice by Russo (2024). A reason for the difference is that Russo (2024)'s sample's consumers are on average 61 years old while my sample's consumers are on average 53 years old. My sample is thus likely to have fewer pensioners who have a lower opportunity cost of time. Moreover, it could be that waiting for a physician's visit is more costly than waiting for a dental care visit. Average cross-waiting time elasticities are small. The average within-sector cross-waiting time elasticity is 0.11 for public practices and across-sector cross-waiting time elasticity is 0.13.

The elasticities also vary by income. Figure 2 shows average own-price elasticity by five income bins. We can see from the figure that the own-price elasticity decreases from -5.21 to -4.81 as we move from the lowest bin to the highest. Own-waiting time elasticity increases from -2.62 to -3.18 between the lowest and highest bins. Thus, the heterogeneity in own-elasticity is more pronounced for the waiting times than for the prices, a likely outcome given the difference between how disutility for price and waiting times change as income increases as can be seen from the preference heterogeneity estimates in Table 5. Disutility for waiting times increases at an increasing rate as a function of income as is evident from Figure 2,

[15]More on the difficulties of obtaining price elasticities from the Rand Health Insurance Experiment see (Aron-Dine et al., 2013).

while the disutility for price decreases at a decreasing rate as a function of income. Finally, we should expect this pattern of heterogeneity as we might expect high-income consumers to have a low opportunity cost of money and high opportunity cost of time, while low-income consumers are more likely to have a high opportunity cost of money and low opportunity cost of time.

Finally, with demand estimates at hand, I can also calculate how likely consumers with different incomes are to visit a public practice, a private practice or not visit a practice. Figure 3 presents the average probabilities for visiting a public practice, a private practice and not visiting any practice in a given year for different income bins. As we move from the lowest income bin towards the highest income bin, the probability of not visiting a dental practice decreases from 71.1% to 63.1%, and the probability of visiting a private practice increases from 12.9% to 19.3%. Consumers from all income bins are roughly equally likely to visit a public practice, with probabilities ranging from 20.2% to 22.6%.

5.2 Backing Out Marginal Costs

I follow a common practice and use private practices' first-order conditions to back out the marginal costs.

$$mc_{jt} = p_{jt} - q_{jt}(p_t, b_t(p_t))\left[-\frac{\partial q_{jt}(p_t, b_t(p_t))}{\partial p_{jt}}\right]^{-1} \tag{16}$$

As everything on the right-hand side of the equation is either data or estimated, I know the left-hand side of the equation. I assume that marginal costs are constant, which is a common simplifying assumption in the industrial organization literature. Table 8 shows summary statistics on backed-out marginal costs and compares them to prices. The average marginal cost is €203.27 and as the average price is €233.73, the average markup is €30.5 and the average markup percentage is 13%. The markups are on average quite low, indicating that the competition is relatively fierce. For example, my estimates are lower than markups for for-profit (26%) and not-for-profit (20%) hospitals by Gaynor and Vogt (2003). The competitiveness of the industry is at least partly explained by the lack of coinsurance and out-of-pocket cost maximum.

5.3 Estimating Public Practice Waiting Time Equation

I estimate the waiting time equation using 2SLS.

$$b_{jt} = \psi_1 \frac{q_{jt}}{d_{jt}} + \tau_y + \omega_{jt}, \quad j \in J^{pub}. \tag{17}$$

The challenges in estimating this equation are that consumer demand, the numerator of demand per dentists $\frac{q_{jt}}{d_{jt}}$, is endogenous and determined simultaneously with demand in the equilibrium. Moreover, the measure for the number of dentists, the number of public sector dentists working in the municipality, is a noisy measure of dentist capacity at the public practices. I solve the endogeneity of demand by using a BLP instrument: the difference to the nearest practice from practice j. Instrumenting for the $\frac{q_{jt}}{d_{jt}}$ also solves the measurement error problem.

I expect that the average waiting time should increase when the demand for the practice relative to the number of dentists at the practice increases. The number of patients a dentist can treat is assumed to be constant, and thus an increase in demand should result in higher waiting times. Table 9 presents the estimates of the queuing model. Using OLS, I find that increasing treatment episodes per dentist at a public practice reduces waiting times. This is the likely direction of the bias as a positive waiting time shock increases waiting times, and as consumers dislike waiting, consumer demand and positive waiting time shock are negatively correlated. Thus, the OLS estimate is biased downwards. When I turn to the instrumental variable specification I obtain a statistically significant positive estimate of 0.0692. Now increasing the treatment episodes per dentist by one increases a practice's average waiting time by 0.07 days. As I add year-fixed effects to the specification, standard errors increase, but the estimate is unchanged. I the instrumental variables specification with year-fixed effects in the counterfactuals.

6 Counterfactual Analysis

I am interested in how capacity increase in public practice affects public practices' waiting times, private practices' prices, and the distribution of consumer surplus. Moreover, I ask what the marginal cost of the public practices needs to be so that the increase in capacity would increase total welfare. In the counterfactuals, I increase the capacity of the public practices by increasing the amount of full-time equivalent dentists at the public practices by 20%.[16] This is equal to an increase of 226 full-time equivalent dentists in total in the markets

[16] I multiply the number of dentists in the public practices by 1.2.

in my sample for 2015. If the policy was implemented in the whole of Finland, it would mean an increase of approximately 500 full-time equivalent dentists. To put these numbers in context, 182 dentists graduated from Finnish dental schools in 2020. The counterfactual corresponds to a policy that would increase evening and weekend work. The additional work could be performed either by public practice dentists or by private practice dentists outside their private practice hours.[17] Counterfactuals are calculated for the year 2015, with corresponding public practice prices and National Health Insurance reimbursement levels.[18]

When calculating the counterfactual equilibrium I need to calculate three objects: market shares, waiting times, and prices. A complication is that public practice market shares are an implicit function as they depend on waiting times and waiting times depend on market shares. So for every new set of equilibrium prices, I need to solve for the public practice market shares as a fixed point. This raises the issue of the existence and uniqueness of equilibria of the public practice market shares. Fortunately, Bayer and Timmins (2005) prove the existence and uniqueness of equilibrium for logit models in the presence of congestion effects, which in my context requires that consumers dislike waiting. Thus, there exists a unique equilibrium in public practice market shares.

6.1 Market Outcomes, Consumer Surplus, and Profits

Figure 4 shows the percentage change in the mean waiting time and mean private practice prices when public practice capacity is increased by 20%. The average waiting time decreases by 5% or by 1.5 days against the baseline mean of 29.45 days, while the average price stays practically constant. Figure 5a shows that while public practices' market share increased on average by 13.2% the market share of private practices decreased by only 2.7% and the share of not visiting a dentist decreased by 3.1%. These changes in percentage points are shown in Figure 5b. The market share of the public practices increases on average by 2.6 percentage points while the private practice market share decreases by 0.4 percentage points and not visiting share decreases by 2.2 percentage points. Most of the new public practice patients were not visiting a dentist before the capacity change, and thus the change in capacity does not threaten private practices' market share, explaining the lack of change in private practices' prices.

The total consumer surplus increases by 7.8% and total profits go down by 3.0% as seen

[17]In the United Kingdom, the Labor Party has suggested creating 2 million additional National Health Service appointments by extra evening and weekend work (BBC News, 2024). An alternative policy would be to lengthen the mandatory six-month practical training that is a part of the dental school curriculum in Finland and increase dental school intake.

[18]The public practice treatment bundle costs €105 and the National Health Insurance reimbursement is €60 for the private sector treatment bundle.

from Figure 6a. Consumer surplus increase is driven by the shorter waiting times, while profits decrease because private practices lose market share to public practices. Figure 6b shows that the euro increase in total consumer surplus is almost nineteen times the euro decrease in private practices' profits. Total consumer surplus increases by €2.85 million while private practices' profits decrease by €0.16 million. The increase in public practice capacity moves surplus from private practices to consumers. On the face of the quite small decrease in the waiting times, the increase in consumer surplus is large.

Figure 7a shows that the capacity increase benefits low-income consumers the most in relative terms. Consumer surplus increases by 8.8% for the lowest income bin, while the increase for the highest income bin is just 6.8%. However, Figure 7b shows that low-income consumers benefit the least in absolute terms and high-income consumers benefit the most. The total consumer surplus for the lowest income bin increases by €508 thousand, while the consumers in the highest income bin benefit in total by €595 thousand, €87 thousand more. The lowest-income consumers start at a lower level of consumer surplus, and thus their relative increase is the largest, even though the absolute change is the smallest.

Figures 8a and 8b show how the probability of visiting a public and a private practice and not visiting a dental practice change between the baseline and the counterfactual in terms of percentages and percentage points for different income bins. The probability of choosing a private practice or not visiting a dental practice decreases for consumers in all income groups by approximately 3%, while the probability of visiting a public practice increases for the three lowest income bins by 11.6% while the probability increases more for the highest and the second highest income bins, 12.8% and 12.0%, respectively. In percentage point terms the probability of visiting a public practice increases by 2.5 percentage points across all income bins. The probability of visiting a private practice decreases more for high-income consumers, whose probability of not visiting a dental practice decreases the least.

6.2 Is the Capacity Increase Likely to be Welfare Improving?

Even though I am not able to calculate the change in the total welfare as I do not have an estimate of public practices' marginal costs, I can evaluate whether the increase in the public practice capacity is likely to be welfare increasing. I assume that the 20% increase in public practice dentists-work years is implemented with additional evening and weekend work by either the current public practice dentists or by private practice dentists outside their regular private practice hours. The expression for the change in total welfare after the capacity increase is then,

$$\Delta\pi + \Delta\text{CS} - \Delta Q^{Pri} r_y + \Delta Q^{pub} \times (p^{pub} - mc^{pub}) > 0. \tag{18}$$

The first term, $\Delta\pi$, is the change in the private practice profits, and the second term, ΔCS is the change in consumer surplus. $\Delta Q^{Pri} r_y$ represents how the payments of National Health Insurance reimbursements change as the demand for private practices changes. Finally, there is an increase in the number of consumers treated by public practices, times the out-of-pocket price minus the unknown public practice marginal costs of the additional evening and weekend work. I assume that the public practices are making a net loss, $p^{pub} - mc^{pub} < 0$, on the evening and weekend work. Using this equation, I get an expression for the upper bound of the public practice marginal costs of the additional evening and weekend work such that the change in total welfare is positive

$$\frac{\Delta\pi + \Delta\text{CS} - \Delta Q^{Pri} r_y}{\Delta Q^{pub}} + p^{pub} > mc^{pub}. \tag{19}$$

The first term on the left-hand side of the equation is the change in the total surplus divided by the increase in the public production, and thus it gives the additional surplus generated per one additional consumer treated at the public practices on average. The larger it and the out-of-pocket price at public practices are, the higher the upper bound for the marginal cost of the evening and weekend work that would result in the capacity increase being welfare improving.

When I plug in the numbers, I find that the public practice's marginal cost must be less than €210.37 for the capacity increase to be welfare improving. The first term on the left-hand side of Equation 20 states that the increase in total consumer surplus and reimbursement savings outweigh the private practices' loss of profits by €105.37 per new consumer treated at the public practices.

$$€105.37 + €105 > mc^{pub} \tag{20}$$

I can compare this condition to my estimates of the marginal costs of private practices. The 25th percentile of private practices' marginal costs is €174.88, which is €38.49 less than the upper bound for the public practice marginal cost €210.37. This suggests that the increase in capacity might be welfare improving. However, if all of the additional capacity comes from the existing personnel working overtime at public practices, then the mc^{pub} should be interpreted as marginal cost when dentists and dental nurses are working overtime. Public sector dentists collective agreement states that for the five first overtime hours, the pay is

50% higher and after five hours 100% higher (Tehy ry, 2022). The €210.37 is a reasonable upper limit for public practices' marginal costs, but if interpreted as overtime marginal costs, it is likely too small. For example, assuming that labor costs are 70% of the marginal costs and assuming that the 50% overtime increase in wages applies, the €210.37 marginal cost with overtime labor indicates a non-overtime marginal cost of €161.28. This is at the margin of being unreasonably low, as the 25th percentile of private practices' marginal costs is €174.88. However, if the additional capacity can be obtained at the current wage rates or at slightly higher wages, for example 10% higher wages, the counterfactual might be welfare improving.

6.3 Discussion

The counterfactual aims to evaluate how the capacity increase in public practice affects public practices' waiting times, private practices' prices, and the distribution of consumer surplus. I find that a sizable 20% increase in the public practices' dentists reduces waiting times by only 5% or 1.5 days. Most, of the capacity increase seems to be reflected in the market share of the public practices, which increases by 13%. The root source of the modest decrease in waiting times is that the demand that an individual public practice faces is quite elastic to waiting times, with an average of -2.71. Thus, as waiting times initially decrease due to the capacity increase, the demand increases a lot, which brings the waiting times back up with only a modest reduction in the average waiting times. Thus, it is difficult to reduce waiting times with capacity increases when the demand is elastic to waiting times. Previous work, for example Siciliani et al. (2014), has noted that waiting time reductions with supply-side policies might fail if the policy is not accompanied by a way to keep demand under control.

The small decrease in waiting times together with consumer substitution patterns explains why private practices do not lower their prices more. Private practices' optimal price response to the increase in the public practice capacity depends on the preferences of high-income consumers, as high-income consumers are more likely to choose a private practice. Marginal disutility for price becomes less intensive for higher incomes, and at a decreasing rate, while marginal disutility for waiting time intensifies in income and at an increasing rate. Due to these preferences, consumers choosing private practices are not very likely to switch to public practices and thus private practices do not need to decrease their prices more. The segmentation of markets to low-income consumers visiting public practices and high-income consumers who visit private practices helps to isolate private practices from competition by public practices.

It is worthwhile to compare my results to Dinerstein and Smith (2021), who find that an increase in funding for public schools resulted in some private schools exiting the market. In their paper, all children have to be enrolled in either public or private school, and thus the increase in public school funding leads to switching from private to public schools. However, in my case, a large share of consumers is not using dental care services in a given year. Thus, consumers will substitute public practices for both private practices and not visiting a dentist. Moreover, as public practices are congested, the switching from not using the service to public practices dampened the decrease in waiting time that the capacity increase brought about. This further makes private practices more insulated from public practices' capacity increase compared to private schools in Dinerstein and Smith (2021), and partly explains why public practices' capacity increase fails to increase competition among private dental practices in my setting.

My results indicate that the increase in capacity benefits low-income consumers, even though higher-income consumers benefit from the capacity increase more in absolute terms. The reason why low-income consumers benefit the least in absolute terms is that the probability of visiting a public practice is almost constant across different income bins while the disutility from waiting time increases in income. Thus, low-income consumers benefit less from the decrease in waiting times than consumers with higher incomes. My findings indicate that relatively high public practice out-of-pocket prices might be a larger issue for low-income consumers than the waiting times. This is because low-income consumers are the most price-sensitive consumers. Thus, instead of decreasing waiting times by increasing public practice capacity, it might be more beneficial for low-income consumers to reduce public practice prices. Improving the desirability of the public option could improve the consumer surplus more for low-income consumers, but to achieve this the improvement should be one that low-income consumers would appreciate the most.

Finally, I find that the capacity increase improves total welfare if the 20% increase in public practice dentists can be achieved without too large increases in wages. This in turn depends on how much free capacity there is in the private practices and how willing private sector dentists are to do additional evening and weekend work. Moreover, the 20% increase in capacity could also be achieved with the current number of dentists if the productivity of these dentists could be increased. This could be done for example by investigating what treatments could be performed by dental hygienists instead of dentists.

7 Conclusion

Public and private production coexist in many industries, like education, housing, and health care. The rationale for introducing public production alongside private production is that public production can increase competition if the incentives at the market are otherwise lacking and public production can address distributional concerns. As typical industries with both public and private producers produce important services it is important to know how they work. I build a structural model of the Finnish dental care industry that represents a typical health care setting with public and private producers: public production is affordable but congested, and private production is expensive and allows consumers to cut the queue. Consumer demand, waiting times, and private practices' prices are endogenous in the model. To gain insight on how public practices' capacity affects waiting times, and how capacity increases and the change in waiting times affects private practices prices and the distribution of consumer surplus, I perform a counterfactual exercise where I increase the public practices' capacity by 20%. I find that waiting times decrease on average by 5% or 1.5 days and private practices' prices do not change. Consumer surplus increases the most for low-income consumers in relative terms, but in absolute terms low-income consumers benefit the least. My findings highlight the complex interactions between public and private production that can produce unexpected outcomes, especially in markets where public production is congested. This is particularly important to keep in mind when considering government policies in these markets.

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Tables and Figures

Table 1: Summary Statistics: Markets

	Mean (SD)
Characteristic	N = 322
Population (thousands)	21.00 (18.75)
Number of public practices	2.46 (1.87)
Number of private practices	3.24 (2.75)
Share practices belonging to a chain	0.05 (0.11)
Has a private practice	73.9%
Has a public practice	90.1%
Has two practices by the same chain	2.5%
Urban municipalities	21.7%
Semi-urban municipalities	31.4%
Rural municipalities	46.9%
Unique geographic areas	101

Note: Calculated for the included markets and for years 2014–2017. An observation is a market and a market is a combination of municipality or municipality cooperation area and a year. A unique geographic area is the geographic part of the market definition, so either a municipality or municipality cooperation area.

Table 2: Summary Statistics: Practices

Characteristic	Public practices N = 713	Private practices N = 771
Market share excluding outside good	0.30 (0.31)	0.14 (0.15)
Total visits	4,349.84 (3,944.04)	2,857.16 (1,964.11)
Mean out-of-pocket price (€)	119.37 (13.57)	180.11 (47.21)
Mean first visit waiting time (days)	31.71 (15.77)	0.00 (0.00)
Mean within-episode waiting time (days)	39.67 (16.06)	0.00 (0.00)
Total yearly consumers	1,297.44 (1,081.71)	1,073.91 (727.09)
Total yearly episodes	1,433.61 (1,202.43)	1,304.45 (901.14)
Total yearly procedures	9,289.84 (8,887.41)	4,589.74 (3,199.63)
Mean episode complexity	14.35 (2.98)	10.48 (2.28)
Belongs to a chain	0.0%	12.5%
Unique practices	218	256

Note: Standard deviation in parenthesis. Calculated for the included markets and for years 2014–2017. One observation is a dental practice in a market, where the market is a combination of a municipality or a municipality cooperation area and a year. Episode complexity refers to how time-consuming a given treatment episode is. It takes into account the number of procedures and how long performing each procedure takes. Procedure-specific complexity (Vaativuus in Finnish) is defined in Saarela et al. (2024).

Table 3: Summary Statistics: Consumers

Characteristic	All	Has a public visit	Has a private visit	No visits
Age	52.46 (15.74)	50.63 (15.491)	54.28 (14.425)	53.71 (17.14)
Yearly net income (€1000s)	28.48 (15.64)	27.75 (13.718)	32.50 (18.321)	25.02 (13.72)
Episodes per year	0.51 (0.68)	0.63 (0.695)	0.88 (0.746)	0.00 (0.00)
More than one episode per year	8.7%	10.0%	18.2%	0.0%
Unique consumers	524,769	253,667	185,143	141,906

Note: Standard deviation in parenthesis. Calculated for a 40% random sample of 25–80 years old consumers residing in included markets and for years 2014–2017. One observation is a consumer-year combination. ”Has a public visit” means that a consumer has visited a public practice between 2014–2017. Similarly ”Has a private visit” means that a consumer has visited a private practice between 2014–2017. If a consumer has visited both public and private practice between 2014–2017, then they are included in both columns. ”No visits” means that a consumer has not visited either a public or a private practice between 2014–2017.

Table 4: Results: Mean Utility

Dependent Variable:	$\widehat{\delta}_{jt}$					
Sample:	Private Practices			Public Practices		
Estimator:	OLS	OLS	IV	OLS	OLS	IV
Constant	-4.613***			-3.501***		
	(0.1266)			(0.0734)		
Price	-0.0041***	-0.0047***	-0.0378***			
	(0.0007)	(0.0006)	(0.0006)			
Waiting Time (days)				-0.0138***	-0.0141**	-0.0876***
				(0.0021)	(0.0037)	(0.0066)
N	771	771	771	713	713	713
Year FE	No	Yes	Yes	No	Yes	Yes
F-test (1st stage)			97.099			124.39

Notes: Significance thresholds for stars are: *** for 0.01, ** for 0.05 and * for 0.1.

Table 5: Results: Preference Heterogeneity

Variable	Estimate	Standard Errors
Price × Income (Thousands)	1.160e-04	5.690e-06
Price × Income^2	-4.140e-07	5.140e-08
Waiting Time × Income	-1.749e-04	1.520e-05
Waiting Time × Income^2	-1.260e-06	1.640e-07
Outside Good × Income	-6.628e-03	1.095e-03
Outside Good × Income^2	8.030e-05	1.030e-05
Outside Good × Age	-8.272e-02	7.880e-04
Outside Good × Age^2	6.948e-04	7.490e-06
Distance	-9.641e-02	3.615e-04
Distance^2	3.756e-04	8.170e-06

Note: 16.4 million consumer-alternative observations. The estimates are from a conditional logit model with 1,484 alternative specific constants or δ_{jt}s.

Table 6: Results: Aggregate Elasticities and Practice-level Own-elasticities

Elasticity	Variable	Sector	Mean elasticity	SD
Aggregate elasticity	Price	Both	-0.84	
Aggregate elasticity	Price	Private	-1.64	
Aggregate elasticity	Price	Public	-1.30	
Aggregate elasticity	Waiting time	Public	-1.01	
Practice-level elasticity	Price	Both	-4.68	1.60
Practice-level elasticity	Price	Private	-5.83	1.48
Practice-level elasticity	Price	Public	-3.47	0.31
Practice-level elasticity	Waiting time	Public	-2.74	1.31

Note: Aggregate elasticity corresponds to how the extensive margin of visiting a dental practice varies as price or waiting time changes, and is calculated as $\sum_j^{J_t} \frac{\partial s_j}{\partial p_j} \frac{p_j}{s_j} \frac{s_j}{s^{pri}+s^{pub}}$, where s^{pri} is the total market share of private practices in a given market.

Table 7: Results: Practice-level Cross-elasticities

Variable	Sector	Within sector	SD	Across sector	SD
Price	Private	0.17	0.15		
Price	Public	0.14	0.14		
Price	Public			0.16	0.18
Price	Private			0.19	0.16
Waiting time	Public	0.11	0.13		
Waiting time	Public			0.13	0.17

Note: Cross-elasticities correspond to how the demand for practice changes when a characteristic of another practice changes.

Table 8: MCs and Prices

Variable	Mean	SE	25th percentile	Median	75th percentile
MC	203.27	3.36	174.88	200.82	234.16
Price	233.73	3.37	204.70	231.61	265.32

Note: Marginal costs are obtained from the private practices' first-order conditions. Price includes the National Health Insurance reimbursement, and is thus higher than the out-of-pocket price.

Table 9: Results: Queuing Model

Dependent Variables:	Yearly Average Waiting Time		
Estimator:	OLS	IV	IV
Constant	32.92***	0.4706	
	(0.9824)	(8.693)	
Demand Per Dentists	-0.0023	0.0692***	0.0692*
	(0.0018)	(0.0191)	(0.0268)
N	713	713	713
Year FE	No	No	Yes
IV: Distance to the Nearest Competitor			
F-test (1st stage)		20.634	21.117

Notes: Significance thresholds for stars are: *** for 0.01, ** for 0.05 and * for 0.1.

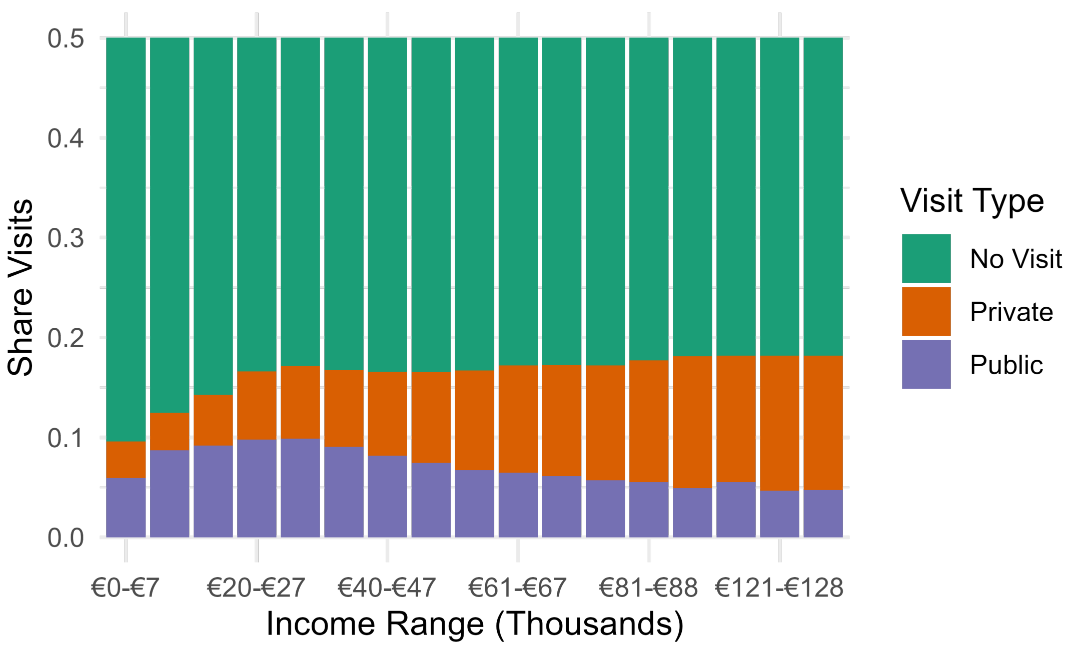


Figure 1: Consumers' Practice Choices by Income Range

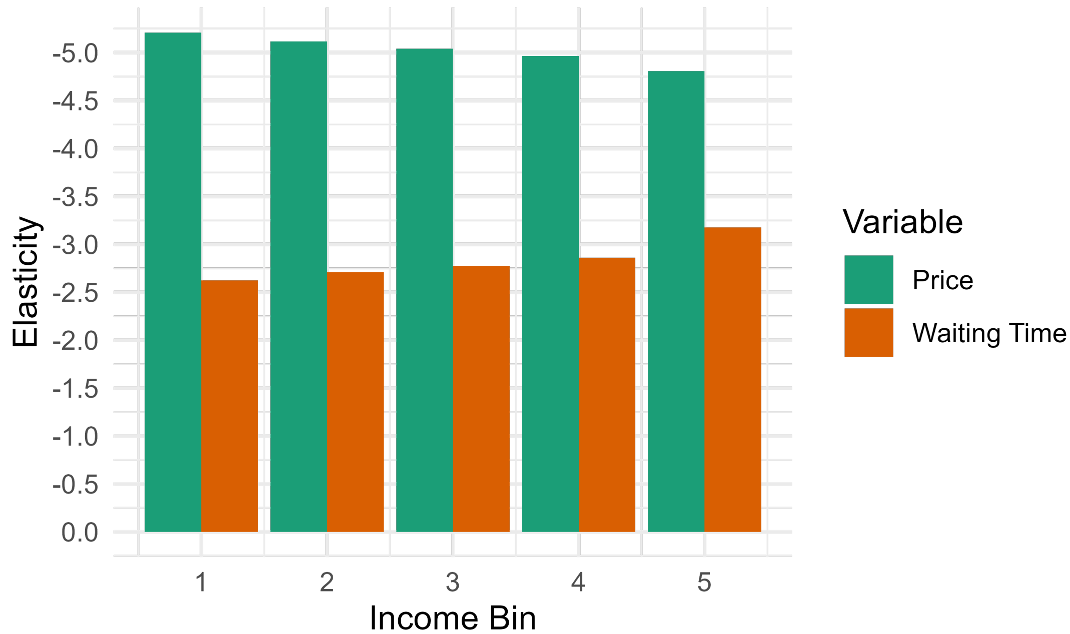


Figure 2: Consumers' Average Own-elasticities by Income Bins

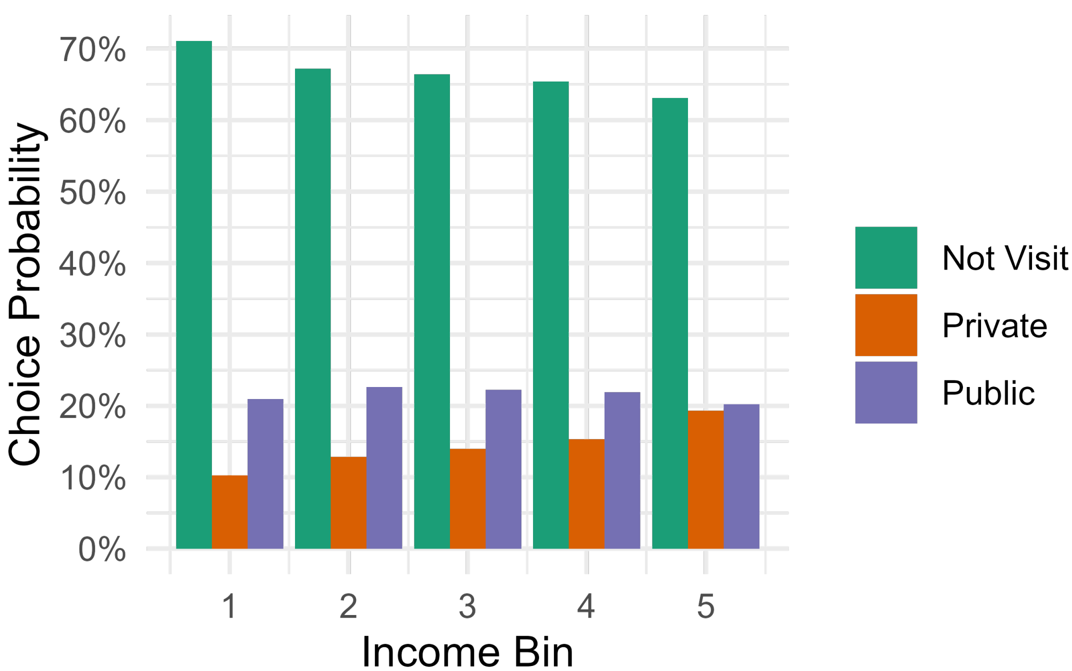


Figure 3: Average Sector-Specific Choice Probabilities by Income Bins

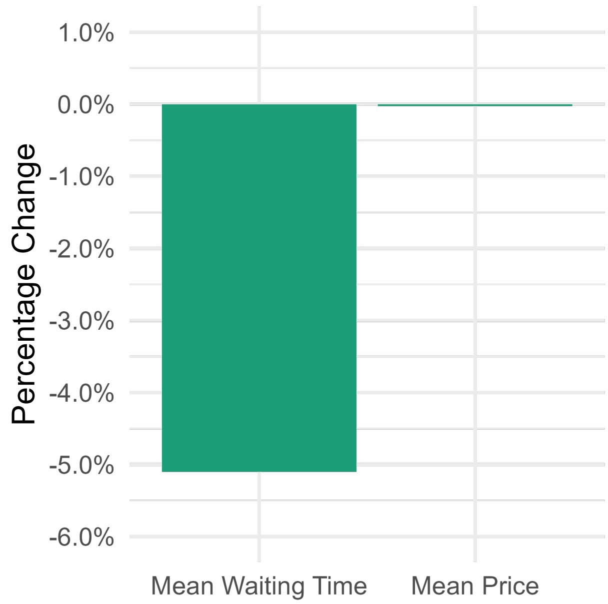
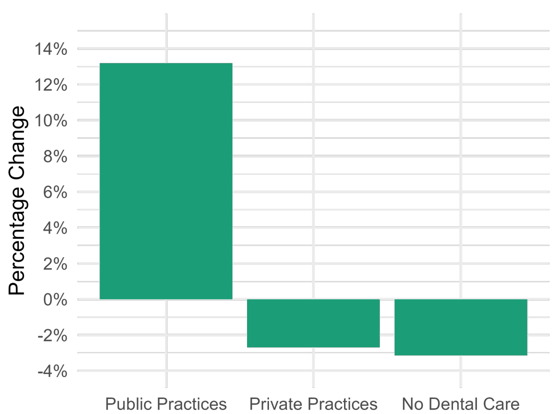
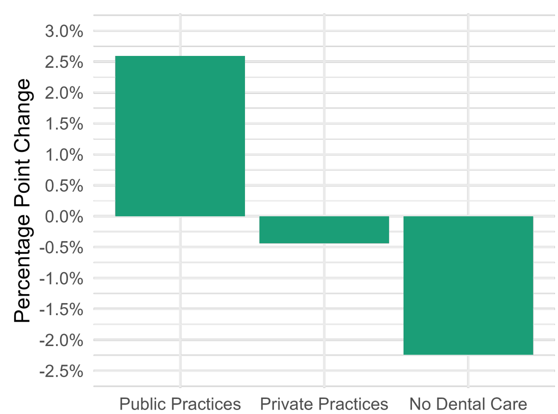


Figure 4: Counterfactuals: Changes in Prices and Waiting Times

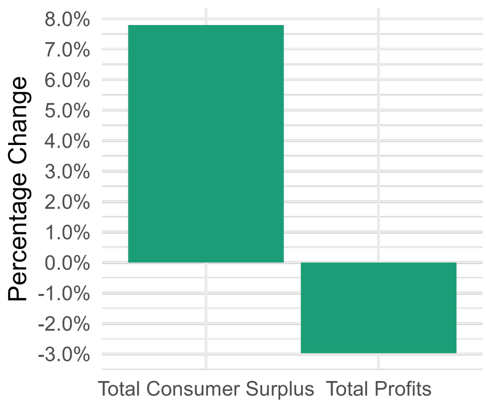


(a) Percentage Changes in Market Share

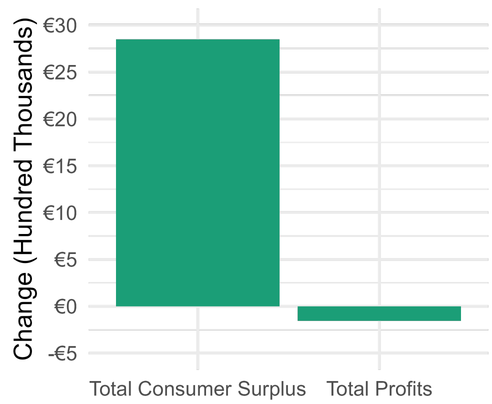


(b) Percentage Point Changes in Market Shares

Figure 5: Counterfactuals: Changes in Average Market Shares

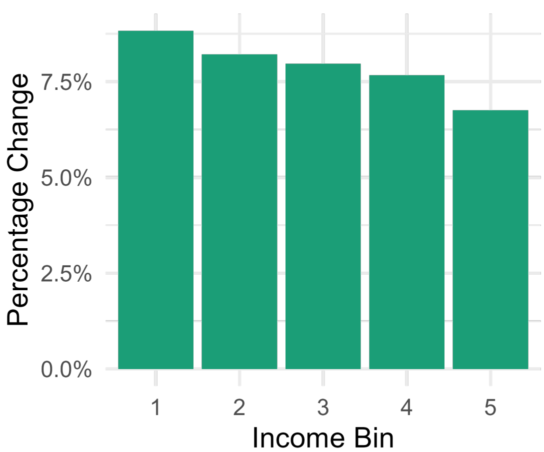


(a) Percentage Changes

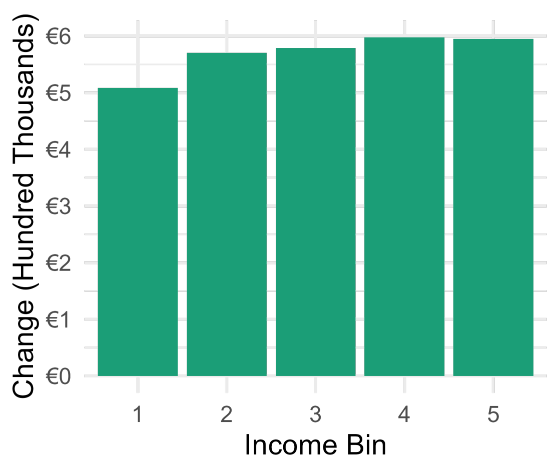


(b) Absolute Changes

Figure 6: Counterfactuals: Total Consumer Surplus and Profits

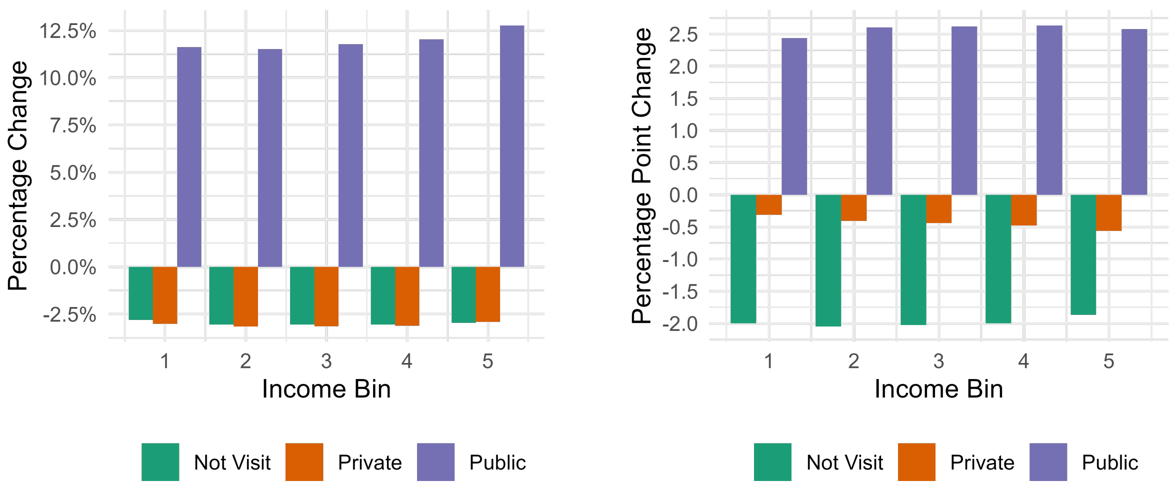


(a) Percentage change in CS



(b) Absolute change in CS (€)

Figure 7: Counterfactuals: Change in Consumer Surplus by Income Bins



(a) Percentage Change

(b) Percentage Point Change

Figure 8: Counterfactuals: Change in Average Sector-Specific Choice Probabilities by Income Bins

Appendices

A.1 Derivatives

Derivatives of the logit model with respect to prices and waiting times are more complicated than usually, because the expression for the market share of a public practice is an implicit function that depends on the public practice market share through the waiting time equation. To solve for the own-price derivatives of private practices that I need for private practice's first-order condition, I first solve for cross-price derivatives of public practices and use those to solve for the own-price derivatives of private practices. I also solve for own-price derivatives of public practices.

A.1.1 Cross-Price Derivatives for Public Practices

In a given market the market share for the public practice k is an implicit function.

$$s_{kt} = \frac{1}{I_t}\sum_i^I \mathcal{P}_{ik} = \frac{1}{I_t}\sum_i^I \frac{\exp(\delta_{kt}(s_{kt}) + \mu_{ijt})}{1 + \sum_{h=1}^{J^{pri}} \exp(\delta_{ht} + \mu_{iht}) + \sum_{c=1}^{J^{pub}} \exp(\delta_{ct}(s_{ct}) + \mu_{ict})}$$

The first step of implicitly differentiating these equations, taking a derivative with respect to the p_{jt} and solving for the derivative, which gives the following.

$$\frac{\partial s_{kt}^{pub}}{\partial p_{jt}} = \frac{-\sum_i^I [P_{ik}(\frac{\partial u_{ijt}}{\partial p_{jt}} P_{ij} + \sum_{o \neq k}^O \frac{\partial u_{iot}}{\partial b_{ot}} \frac{\partial b_{ot}}{\partial s_{ot}} \frac{\partial s_o}{\partial p_j} P_{io})]}{\sum_i^I \left[-\frac{\partial u_{ikt}}{\partial b_{kt}} \frac{\partial b_{kt}}{\partial s_{kt}} P_{ik}(1 - P_{ik}) + 1\right]}$$

This can be manipulated into a linear equation in the derivative of market share with respect to the price. First, multiply the equation by the denominator on the right-hand side.

$$\frac{\partial s_{kt}^{pub}}{\partial p_{jt}} \left(\sum_i^I \left[-\frac{\partial u_{ikt}}{\partial b_{kt}} \frac{\partial b_{kt}}{\partial s_{kt}} P_{ik}(k - P_{ik}) + 1 \right] \right) = -\sum_i^I \left[P_{ik} \left(\frac{\partial u_{ijt}}{\partial p_{jt}} P_{ij} + \sum_{o \in J^{pub}, o \neq k} \frac{\partial u_{iot}}{\partial b_{ot}} \frac{\partial b_{ot}}{\partial s_{ot}} \frac{\partial s_o}{\partial p_j} P_{io} \right) \right]$$

Rearrange

$$\begin{aligned}\sum_i^I P_{ik} \left(\frac{\partial u_{ijt}}{\partial p_{jt}} P_{ij} \right) = &-\frac{\partial s_{kt}^{pub}}{\partial p_{jt}} \left(\sum_i^I \left[-\frac{\partial u_{ikt}}{\partial b_{kt}} \frac{\partial b_{kt}}{\partial s_{kt}} P_{ik}(1 - P_{ik}) + 1 \right] \right) \\ &-\sum_i^I \left[P_{ik} \left(\sum_{o \in J^{pub}, o \neq k} \frac{\partial u_{iot}}{\partial b_{ot}} \frac{\partial b_{ot}}{\partial s_{ot}} \frac{\partial s_o}{\partial p_j} P_{io} \right) \right]\end{aligned}$$

Notice that we know the left-hand side, as it is just data and a function of demand estimates. On the right-hand side, the equation is linear in all derivatives of all public practice market shares in market t with respect to price p_j. I can stack these equations for all public practices and solve the resulting system of equations numerically to obtain the cross-price derivatives for the public practices.

A.1.2 Own-Price Derivatives for Public Practices

Own-price derivatives can be obtained using implicit differentiation and the expression for public practices market shares. First, differentiate with respect to p_{jt}.

$$\frac{\partial s_{jt}}{\partial p_{jt}} = M_t \frac{1}{I_t} \sum_{i \in I_t} \left(\frac{\partial u_{ijt}(b_{jt}(s_{jt}))}{\partial p_{jt}} \mathcal{P}_{ijt}(1 - \mathcal{P}_{ijt}) - \sum_{k \in J_t^{pub} \setminus j} \left[\frac{\partial u_{ikt}}{\partial s_{kt}} \frac{\partial s_{kt}}{\partial p_{jt}} \mathcal{P}_{ijt} \mathcal{P}_{ikt} \right] \right)$$

Then solve for $\frac{\partial s_{jt}}{\partial p_{jt}}$. Note that $\frac{\partial u_{ijt}(b_{jt}(s_{jt}))}{\partial p_{jt}}$ is a function of $\frac{\partial s_{jt}}{\partial p_{jt}}$ because of the waiting times.

$$\frac{\partial s_{jt}}{\partial p_{jt}} = - \frac{\sum_i^I \left[\frac{\partial u_{ijt}(p_{jt})}{\partial p_{jt}} (1 - P_{ijt}) P_{ijt} - \sum_{k \in J_t^{pub} \setminus j} \frac{\partial u_{ikt}}{\partial b_{jt}} \frac{\partial b_{kt}}{\partial s_{kt}} \frac{\partial s_{kt}}{\partial p_{jt}} P_{ikt} P_{ijt} \right]}{\sum_i^I \left[\frac{\partial u_{ijt}}{\partial b_{jt}} \frac{\partial b_{jt}}{\partial s_{jt}} (1 - P_{ijt}) P_{ijt} + 1 \right]}$$

Rearrange.

$$\begin{aligned} \sum_i^I \left[\frac{\partial u_{ijt}(p_{jt})}{\partial p_{jt}} (1 - P_{ijt}) P_{ijt} \right] = & - \frac{\partial s_{jt}}{\partial p_{jt}} \sum_i^I \left[\frac{\partial u_{ijt}}{\partial b_{jt}} \frac{\partial b_{jt}}{\partial s_{jt}} (1 - P_{ijt}) P_{ijt} + 1 \right] \\ & + \sum_{k \in J_t^{pub} \setminus j} \left[\sum_i^I \frac{\partial u_{ikt}}{\partial b_{jt}} \frac{\partial b_{kt}}{\partial s_{kt}} \frac{\partial s_{kt}}{\partial p_{jt}} P_{ikt} P_{ijt} \right] \end{aligned}$$

Then we can form a linear system of equations consisting of the following for the public practices $j \in J^{pub}$.

$$\begin{aligned} \sum_i^I \left[\frac{\partial u_{ijt}(p_{jt})}{\partial p_{jt}} (1 - P_{ijt}) P_{ijt} \right] = & - \frac{\partial s_{jt}}{\partial p_{jt}} \sum_i^I \left[\frac{\partial u_{ijt}}{\partial b_{jt}} \frac{\partial b_{jt}}{\partial s_{jt}} (1 - P_{ijt}) P_{ijt} + 1 \right] \\ & + \sum_{k \in J_t^{pub} \setminus j} \left[\sum_i^I \frac{\partial u_{ikt}}{\partial b_{jt}} \frac{\partial b_{kt}}{\partial s_{kt}} \frac{\partial s_{kt}}{\partial p_{jt}} P_{ikt} P_{ijt} \right] \end{aligned}$$

As we know the cross-price derivatives of public practices, the only unknowns are the own-price derivatives and we can solve them numerically.

A.1.3 Own-Price Derivatives for Private Practices

Similarly, as for the public practices, I can derive the expression for the own-price derivative of private practice j.

$$\sum_i^I \left[\frac{\partial u_{ijt}(p_{jt})}{\partial p_{jt}} (1 - P_{ijt}) P_{ijt} \right] = -\frac{\partial s_{jt}}{\partial p_{jt}} + \sum_{k \in J_t^{pub} \setminus j} \left[\sum_i^I \frac{\partial u_{ikt}}{\partial b_{jt}} \frac{\partial b_{kt}}{\partial s_{kt}} \frac{\partial s_{kt}}{\partial p_{jt}} P_{ikt} P_{ijt} \right]$$

By stacking these equations for all private practices in a market, I can solve for the own-price derivatives from the resulting linear system of equations numerically, as I know the cross-price derivatives of public practices.