Where Will Patients Go? A Network Simulation of General Practitioner Closures and Patient Displacement in Czechia

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Abstract

Background: Primary care in Czechia is largely provided by aging general practitioners (GPs), with an average age of 55—one of the highest in Europe. Coupled with low interest to enter general practice from younger doctors, this raises concerns about the healthcare system's ability to adapt to workforce decline, in face of the rising healthcare demands associated with an aging population.

Objective: To identify how patients in Czechia adapt to the shrinking GP workforce, highlight regions at risk of being unable to provide local primary healthcare, and identify GPs who benefit the system by absorbing displaced patient cohorts.

Method and Data: Using full-population data from the Czech health registries we build a network of GPs linked by their shared patients. The strength of the link between two GPs is given by the proportion of a GPs patients that visit both GPs during 2022-2023. We simulate GP closures and analyze how effectively their patients can be absorbed by the remaining GPs, based on patient-flow patterns and local provider capacity.

Results: The patients of two-thirds of GPs could immediately be absorbed by directly connected GPs with additional capacity. However, some regions, especially border areas like Domažlice, Tachov, Jeseník, and Chomutov, show weaker resilience to GP closures, with patients searching longer for GPs with capacity. The GPs who absorb patients are found not only in cities but also in suburban regions like Most, Teplice, and Kladno.

Conclusion: Our results indicate that patient flows could play a critical role in assessing the impact of changes in GP supply, as they introduce to the system a notable degree of flexibility. Therefore, evaluating the effects of changing GP availability requires considering not only the local supply but also the capacity of surrounding areas.

Keywords

Patient-sharing network; primary health care; healthcare supply; Czechia

Word count: 4,571

Introduction

General practitioners (GPs) have the potential to improve and maintain the health of the population, increase health literacy, ensure care for vulnerable groups, guarantee equal access to healthcare, and through their work, make the healthcare system more sustainable and efficient [1, 2]. Countries with a strong primary care section show better health outcomes in the population, smaller socioeconomic inequalities in self-assessed health, and lower rates of unnecessary hospitalizations [3]. However, many countries are facing various challenges in providing accessible and sustainable primary health care [4, 5] — and Czechia is no exception.

Firstly, Czechia is experiencing aging of its GPs, with more than 20% aged 65 or older [6]. The average age of GPs is 55, placing Czechia among countries with the oldest medical workforce in Europe [6, 7]. Moreover, the age distribution of Czech GPs is heavily skewed towards older ages, suggesting that most of them will soon reach the statutory retirement age of 65 [8, 9].

Secondly, Czechia exhibits deeply rooted regional disparities in providing sustainable and equally high-quality care in both urban and rural areas [10]. Although the geographical accessibility of primary health care is not a barrier [11], previous research has shown that the composition of both patients and GPs in urban and rural regions differs notably [9]. This is reflected, e.g., in the range and volume of services provided [9], with some sources even suggesting the existence of a distinct *rural way of working* of GPs [10].

Finally, primary care remains a relatively unattractive career choice for young physicians, which limits the number of new entrants into the specialization [12]. Although policymakers are taking steps to incentivize young GPs through various benefits [1], there are doubts about whether the current system can effectively address both the aging workforce and the urban-rural imbalance [8, 10].

Previous research on the geo-demographic aspects of primary health care provision in Czechia has primarily focused on identifying challenges stemming from the specific demographic composition of the GP population, which may contribute to a decline in GP workforce [13]. Šídlo et al. [13] identified the eastern and northeastern regions of the country—specifically the districts of Domažlice, Cheb, Chomutov, and Most—as well as areas surrounding Prague, Brno, and Ostrava, as potentially at risk of limited supply to primary care. However, the latter areas also exhibit high levels of mobility in healthcare-seeking behavior. Building on this, Maláková et al. [14] and Šídlo et al. [9] highlighted several rural areas that may face a future decline in GPs availability, as the adjusted patient-to-GP ratio has increased over time in these regions—for instance, Roudnice nad Labem, Lovosice, Kadaň, Bruntál, and Valašské Klobouky, thereby increasing the issue of decreasing supply of GP services.

The other side of the coin—how patients might respond to a potential reduction in GP capacity—remains largely unexplored. Yet, the patient's perception is equally important when shaping future primary care policies [9, 15], as previous research has demonstrated that patient-centered systems yield better performance [16].

In this paper, we aim to bridge the gap between (i) identifying regions at risk of insufficient primary care supply and (ii) understanding how patients respond to reductions in healthcare availability. We propose to use a network analysis approach, novel to this literature, to infer the healthcare seeking behavior of patients, based on historical GP utilization. We assume that if a patient's GP were to close their practice, the patient would seek care from

GPs they had previously visited during periods when their regular GP was temporarily unavailable. The assumption that historical patient flows can inform future behavior is supported by data: among patients whose GP left the system in 2022, up to 92% subsequently registered with a GP they had previously visited (Authors' calculation using data from the National Registry of Reimbursed Health Services).

The tendency of displaced patients to gravitate toward GPs they have previously visited is also supported by several theoretical frameworks, including path dependence theory [17], bounded rationality theory [18], and the theory of planned behavior [19]. According to path dependence theory, what has happened at an earlier point in time will affect the possible outcomes of a sequence of events occurring at a later point in time [20]. Bounded rationality theory emphasizes that decisions are often not made to achieve the best possible outcome, but rather a satisfactory one, frequently relying on limited information or personal experience [21]. The theory of planned behavior highlights the importance of an individual's subjective perception of task difficulty in the decision-making process [22]. Once a patient has visited a potential substitute GP, this prior experience can strengthen their intention to return to the same provider in the future, as it might represent the minimal-effort option.

We estimate the patient-sharing network using registered patient flows from Czech administrative healthcare data. In this context, “patient sharing” does not imply dual registration with multiple GPs — which is prohibited under Czech law — but rather refers to instances where GPs act as substitutes for one another, leading to patients receiving care from different providers over time. To simulate disturbances within this network, we remove individual GPs and observe how patients reallocate based on existing provider connections. This approach allows us to identify regions and districts that may be vulnerable to shifts in the GP workforce, as well as areas with the capacity to absorb displaced patients.

This paper addresses two research questions:

(i) Which regions might be unable to supply primary care provision locally when faced with the loss of GPs?

(ii) Which localities, and which GPs within them, demonstrate the greatest capacity to absorb displaced patients within the GP network, due to their central role in taking over patients following the GP closure?

The innovative aspect of this study lies in its approach to identifying vulnerable regions. Rather than emphasizing geographical distance as the main factor in decision-making when seeking a new GP—which research has shown is not the primary barrier in European countries [11, 23, 24]—we focus on observed historical patterns of patient behavior. We thereby shift the traditional focus on 'capacity' as an indicator of a well-managed healthcare system to the concept of provider 'replaceability'. In many respects, replaceability provides a more accurate lens, as the relevance of 'insufficient capacity' depends on how easily a shortage can be compensated.

Data

This paper uses full-population administrative data from the National Registry of Reimbursed Health Services database (NRRHS) in Czechia. The NRRHS, managed by Institute of Health Information and Statistics of the

Czech Republic (IHIS), records each interaction between a patient and a healthcare provider covered by health insurance. Since health insurance is mandatory for all residents in Czechia, the NRRHS offers comprehensive medical data on the entire population. The government schemes and compulsory health care financing schemes are 85% in Czechia, placing it among the highest in Europe [25].

The data for the IHIS registers are gathered by insurance companies or directly from medical facilities. For our analysis, we use the data provided by insurance companies, that are found in the NRRHS. As documented previously [26, 27] these data are suitable for analyzing both population health and the healthcare system in Czechia, after data has been verified by IHIS. In the NRRHS, we work with the data table “treatments”, which contains information about the patients’ age and visits to GPs as well as details about the GP who administered the treatment (provider ID, type of provider, date of treatment, address of the provider). More detailed information about the structure of NRRHS database can be found in Appendix 1.

Using this data, we consider all treatments provided by each of the 4,253 registered independent GP practices during 2022-2023. GPs working in health centers and hospitals (~10% of the GP population) are excluded from our analyses as these physicians offer non-comparable services. We include only GPs who provide adult care, as in Czechia, primary care for children is typically delivered by different providers. To create an equal grounds comparison across GP practices, we scale the activities by the full-time equivalent of GPs in a practice, effectively accounting for part-time employment and the number of GPs working in the practice.

We link GPs’ addresses to geographical data and analyze the impact of GP closures on the sustainability of primary care provision at different geographical levels, including municipal, district, and regional. Details on the geographical hierarchies are provided in Appendix 2.

Methods

We aim to create a national model to measure how patients change GPs when their GP practice closes. To achieve this, we build on existing literature [28] and apply network analysis to effectively capture patient behavior. Similarly to Lo Sardo et al. [28], we construct the network based on transition probabilities between GPs. However, our methodology does not aim to analyze the network's capacity to withstand stress before losing the ability to provide care. Instead, we focus on the final destinations of displaced patients as an indicator of how effectively they can find a substitute GP locally. Additionally, we apply our analysis within the Czech context, which has a different healthcare data structure compared to Austria, the focus of Lo Sardo et al. [28].

We construct a network in which nodes represent GP practices, and edges represent patient flows between practices, emerging when patients have previously visited both GPs. Edge weights are equal to the proportion of patient-sharing between two GPs, allowing us to assess the importance of each connection. For GP *i*, this proportion is calculated as the ratio of shared patients between GPs *i* and *j* to the size of the patient population of GP *i*. This implies that the network is directed, meaning that the direction of the edge points from the 'major GP', *i*, to the 'substitute GP', *j* (arrows in Figure 1, Panel *a*). The major GP is the one with whom patients are registered, which is captured by capitation payments in the IHIS database, i.e. regular payments from the insurance company to the GP. At the same time, the major GP provides most treatments to the patient during the observed period (see Appendix 3). Patients visit the substitute GP if, e.g., the major GP is on temporal leave due to vacation, illness, maternity leaves etc.

Within this network, we simulate patient movements initiated by the removal of a single GP. We assume that the direction of these movements is determined by the historical patterns of patient sharing between GPs. This assumption is supported by the NRRHS data: 92% of patients, who consulted multiple GPs in 2022, then switched to a GP they had previously visited. Consequently, if a GP practice closes, displaced patients are most likely to seek care with a GP they previously visited, as measured by the edges. This step is illustrated in Figure 1, Panel *b*: when the GP labeled α closes their practice, their patients attempt to seek care from providers β, γ, and δ in proportions of 0.3, 0.2, and 0.5, respectively.

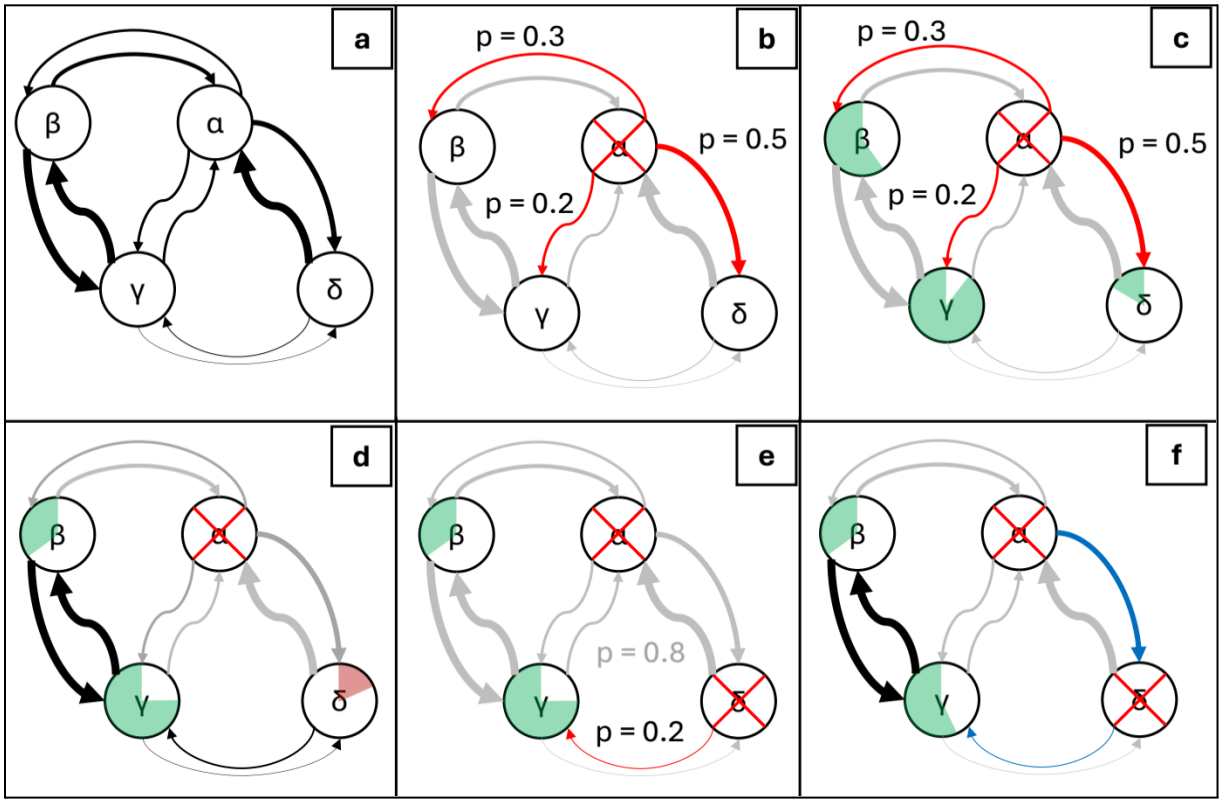
Whether connected GPs can accommodate displaced patients depends on their capacity—both actual and hypothetical maximum (illustrated by the pie charts in Figure 1, Panel *c*). Actual capacity is defined as the total number of patients for whom the GP served as the major provider in 2022–2023. We define maximum capacity as the c-th percentile of the distribution of patients per full-time GP, which is approximately normally distributed (see Appendices 3 and 4). Consequently, the available capacity of a practice is the difference between the maximum number of patients and the actual number of patients, multiplied by the number of full-time equivalent physicians employed in the practice. For our main results, we use the 75th percentile—equal to 1,809 patients per full-time GP—as it closely aligns with list sizes for most GPs across Europe [29].

The available capacity of GPs sets a limit on how many displaced patients they can absorb. If the arrival of displaced patients exceeds the maximum capacity of a neighboring GP, the excess patients would continue to move further through the network. This time, the direction of their movement is determined by the edges of the provider with no more capacity. This is illustrated in Figure 1, Panels *d*, *e* and *f*. If provider δ were to absorb all the patients referred from α, their capacity would be exceeded (Figure 1, Panel *d*). Therefore, patients of α must continue searching for a substitute. This time, they are referred to provider γ, as δ had previously shared patients only with γ (Figure 1, Panel *e*). Provider γ has sufficient capacity to accommodate all patients, so the process ends at this point (Figure 1, Panel *f*).

To simulate the effect of a practice closure, we remove one GP from the estimated network and simulate the transitions of their patients as previously described. This hypothetical practice closure assigns two characteristics to each GP. The first is cascade length, which represents the number of iterations required for all patients to find a new GP. In Figure 1, Panel *f*, the cascade of length two is illustrated for provider α by the blue edges. If the cascade length of a removed GP is one, all their patients find a new GP among the GPs directly connected to the provider being removed. In such cases, the GP's network connections are sufficient to ensure a direct replacement. A cascade length of 2 suggests that some displaced patients were rejected once during their search for a new provider and required an additional iteration to find a new GP. In general, a cascade length of n implies $n - 1$ unsuccessful attempts to find a new GP.

The second GP characteristic is a shock absorption indicator, defined for each provider as the proportion of displaced patients they are able to accommodate. We consider GPs with high shock absorption as contributing the most to the overall resilience of the GP healthcare sector.

Fig. 1 Schematic representation of the work-flow of the proposed methodology for building, simulating, and analyzing the patient-sharing network of general practitioners in Czechia



Source: Authors

Notes:

The α, β, γ, δ represent GPs and arrows between them represent weighted edges.

The provider α was removed and patients were displaced during the simulation.

p = probability of patient sharing

… = share of remaining free capacity

= share of exceeded capacity

The longest cascade (length = 2) is highlighted in blue color on panel *f*

Results

In 2022–2023, around 7 million individuals visited a GP at least once, which is 75% of the Czech population aged 18 or over. In total, 66% of GPs have between 1,000 and 1,800 patients in total per full-time employee. Assuming a standard patient load of 1,809 per GP, the estimated total capacity of GPs in Czechia is approximately 9 million patients (see Appendix 4). The available free capacity per provider shows substantial variation across districts, ranging from around 30% extra capacity in the districts of Olomouc, Jičín, and Benešov, to as low as 13% in the districts of Louny, Teplice and Děčín and the lowest capacity was in the district of Chomutov – only 5.8%. A map showing the geographical locations of the Czech districts is provided in the Appendix 2.

The patient-sharing network of Czech GPs includes a total of around 4,200 practices, connected by nearly 280,000 edges representing patient flows. Simulating practice closures, 62% of all GPs have a cascade length of 1, meaning that all their patients could be absorbed by neighboring providers. Patients of the remaining 38% of providers would experience at least one rejection in their search for a new GP. Specifically, 34% of GPs have a cascade length of 2, and another 4% have a cascade length of 3. Only a negligible share—0.3% (13 providers)—have a cascade length of 4 or more. Displaced patients of these 13 providers were rejected by three additional facilities before eventually finding a GP with available capacity. Hence, most patients find a replacement GP at fairly low search lengths since available capacity is high.

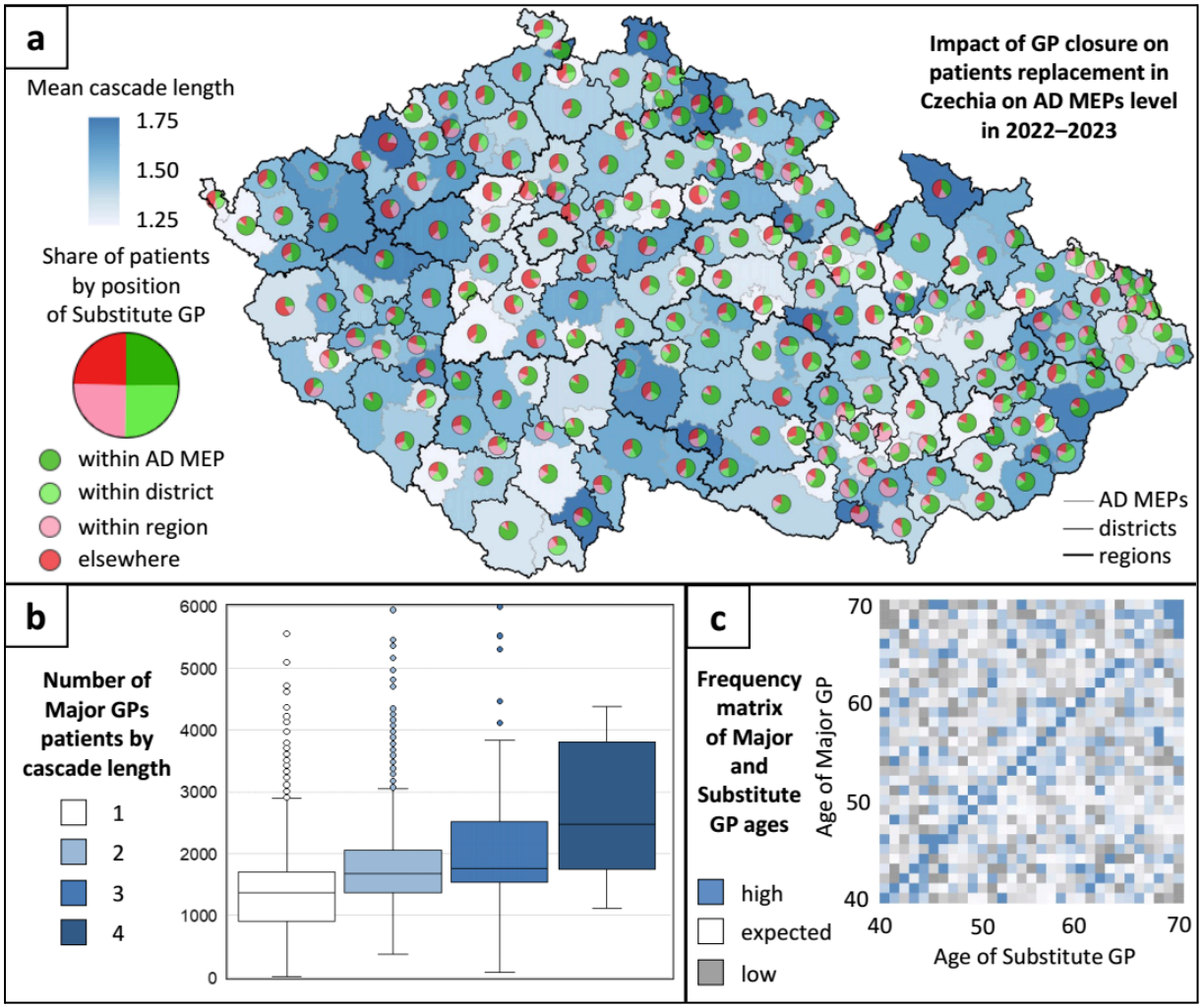
Figure 2, Panel *a* shows the average cascade length at the level of administrative district of municipalities with extended powers (AD MEP) in blue-scale color and illustrates the distance to absorbing GPs in a red-green pie chart. This distribution expresses the proportion of patients who were accommodated within their own AD MEP, district, region, or had to travel outside their region to find a substitute GP. In large cities such as Prague, Brno, and many regional or district centers, most patients find a substitute provider within the same AD MEP. In AD MEPs surrounding urban centers—such as those around Brno, Ostrava, and Plzeň—displaced patients typically find a new provider within the region, but outside their own AD MEP. This is because the GP network tends to direct patients to an adjacent city, rather than within their district.

In several areas of Czechia, a large proportion of patients are not accommodated within their own region. This is particularly common in the northwest of the country on the borders of the Ústí nad Labem, Central Bohemia, Plzeň and Karlovy Vary regions. The relatively long cascade lengths observed in these regions, along with the high share of patients who ultimately find a substitute GP outside their region, suggest that displaced patients initially seek care within their AD MEPs or district, but face insufficient capacity, forcing them to move further through the GP network in search of available providers. The longer cascades are also found in some periphery areas (Frýdlant, Jeseník), as well as in some AD MEPs in the Liberec, Zlín, or Vysočina region. However, patients from these AD MEPs find a new GP mostly in their district, or even AD MEP, indicating that patients from these areas tend to 'wander' within their AD MEP or district—prolonging the cascade—but eventually manage to find a new GP with available capacity locally. Compared to northwest Czechia, such patient behavior is rare and occurs primarily in the Karlovy Vary district.

Cascade length is associated with the number of displaced patients. Figure 2, Panel *b* presents the distribution of patient numbers per GP by cascade length. For GPs with a cascade length of 1, the average number of patients is slightly lower (~1,500) compared to those involved in longer cascades. In particular, for cascades of length 4, the average number of displaced patients reaches 2,500.

When GP closures happen due to retirement, it is important to understand to whom displaced patients are referred – if patients enroll with a young GP or they end up with GPs who are themselves nearing retirement. We focused on the relationship between the age of the departing GP and the ages of the absorbing GP. Figure 2, Panel *c* reveals that this association is rather weak, yet GPs are noticeably more likely to share patients with other GPs of the nearly same age as illustrated by the blue diagonal elements. Hence, patients from older GPs are increasingly likely to take up practice with another older GP who might retire in a few years.

Fig. 2 Average length of cascade, replacement patterns, and GPs age from a network simulation of GP's closure



Source: Authors

Note: Technical details for standardization (Panel *c*) are provided in Appendix 5

Note: On Panel b, the interquartile range (IQR) is presented as a box, and "whiskers" that extend to the smallest and largest values within 1.5 × IQR from the quartiles. Points outside this range are plotted as outliers. The horizontal line in the box denotes mean of the distribution.

Figure 2 highlights regions where patients may be most disadvantaged if their GP closes their practice. Figure 3 illustrates which GPs provide the greatest benefit to the care sector, as measured by their capacity to absorb displaced patients. Each GP is represented by a dot, with larger and darker dots indicating practices that absorb more patients. GPs are connected by lines (edges), where the color of each line reflects the number of displaced patients transferred, and the line thickness represents the proportion of those patients. To maintain clarity in the figure, we include only GPs with more than 1,300 patients and connections (edges) that account for more than 10% of the displaced patient flow.

Providers with the greatest capacity to absorb patients (benefits) are not only found in urban areas, but also in districts such as Karlovy Vary (Karlovy Vary region), Most, Teplice and Ústí and Labem (Ústí nad Labem

region), as well as several districts surrounding Prague, including Kladno or Benešov. Northeastern Bohemia also has large absorbers, particularly in districts such as Pardubice and Žďár nad Sázavou. In these cities, GPs who are most capable of absorbing systemic shocks are found. The Vysočina region is particularly lacking in GPs with such characteristics.

Figure 3 shows several very long edges spanning the entire country. These should be interpreted as examples of suboptimal scenarios rather than likely pathways for patients seeking new GPs as Figure 3 represents the final reallocation of displaced patients, the longest edges likely reflect patients with long referral cascades or limited connections within their local regions. In other words, these cross-country edges reveal systemic weaknesses resulting from insufficient interconnectedness among GPs at the local level. Naturally, such edges may also arise from 'noise' in the network, caused by rare transitions that reflect very specific types of patient's behavior, including migration.

Fig. 3 Final directions of displacements and total benefit of GPs

Source: Authors

Note: The size and color of the nodes are proportional to the total number of displaced patients each provider absorbs (dark and large nodes represent providers with a high benefit to the system). The width of the edges is proportional to the share of the displaced cohort transitioning to the substitute GP, while the color of the edges indicates the total number of displaced patients who successfully find a new provider.

Discussion

Czech GPs are aging rapidly [9], raising concerns about future gaps in primary care provision due to retirements. Our simulation results suggest that the GP network exhibits notable resilience to individual practice closures. If patients substitute to a GP they previously visited when their usual provider becomes unavailable, approximately two-thirds of GPs could be immediately replaced by peers within the system.

Even under this relatively optimistic patient displacement scenario, we found that closures can severely restrict access to local care in certain regions. Areas such as Domažlice, Tachov, Jeseník, Chomutov, and the border zone between the Vysočina and South Bohemian regions show particularly long referral cascades and high rates of patient displacement beyond their home areas. Additional vulnerable zones include northwestern districts (Louny, Rakovník, Karlovy Vary, Plzeň-Sever), southern districts (Pelhřimov, Telč), and northern regions (Jilemnice, Semily, Vrchlabí). While closures in these regions do not always force patients out of their administrative districts, patients face an above-average number of rejections in their search for new providers.

A novel contribution of this study is the identification of "shock absorbers"—GPs who take in a high number of displaced patients. Notably, such providers are not limited to large urban areas but are also found in medium-sized towns like Most, Teplice, Kladno, Benešov, and Kolín. In contrast, they are almost entirely absent in the already vulnerable Vysočina–South Bohemian corridor. We also discovered a systemic weakness in the structure of patient-sharing networks: younger GPs tend to be less connected than older ones. This generational imbalance could reduce the future flexibility and adaptability of the system, especially as older, more central providers retire.

From a methodological standpoint, this study makes several important contributions. To our knowledge, this is the first application of patient-sharing network simulation in the Czech context; prior research has focused mainly on Austria [28]. Given differences in healthcare-seeking behavior and systemic structure—especially following the Czechia's post-socialist transition—these findings offer insights that are not easily transferable from other countries. Furthermore, our focus on the final destinations of displaced patients reveals structural weaknesses in the system that have not previously been explored.

We also advance the conceptual framework by adding "replaceability" to traditional measures of capacity. A region may have sufficient nominal capacity but still lack effective provider substitutes, making it more vulnerable in practice. Conversely, highly replaceable GPs contribute disproportionately to the system's overall resilience, suggesting a new way to identify both risks and strategic points for policy intervention.

Despite these contributions, several limitations must be acknowledged. First, our estimates rely on assumptions about patient behavior following a GP's closure. Although we observed that 92% of patients tend to seek care from a previously visited GP, this number may be inaccurate. With an observation period of two years, we cannot observe if patients visited a GP prior to our observation period or inaccurate reports of registered GPs in our data. Additionally, our data cannot distinguish between genuine care-seeking behavior and one-off visits due to temporary factors like travel or vacation, meaning some connections in the network may not reflect true substitution options although such visits offer some connection to a potential substitution GP.

Second, our estimates of GP capacity depend on administrative reporting of staffing levels, which may contain inaccuracies. However, the financial incentive for GPs to report working hours correctly partially mitigates this concern. Third, while we conducted robustness checks by adjusting for age composition across regions, the lack of individual-level patient data limits our ability to fully account for healthcare demand differences. Future research should aim to incorporate more of patients' differing needs, such as their health status, which should be taken into account especially in capacity calculations.

A further limitation is our focus on single GP closures. In practice, concurrent retirements or closures may lead to larger displaced patient cohorts and place greater strain on the system, for which we found some evidence: when larger patient cohorts were displaced, cascade length increased (Figure 2, Panel *b*). Future research could address this by modeling concurrent closures and identifying "breaking points" in the network where access collapses. Additionally, this methodology could be extended to include other medical specialties (e.g., cardiology, dentistry, gynecology), which also face workforce shortages.

Finally, while our approach deliberately shifts focus away from geographic distance, this abstraction may obscure certain local realities. For example, the percentage of patients receiving care outside their region may carry different implications in remote border districts compared to centrally located areas. Future work could integrate distance measures more explicitly into the network model.

Conclusion

This study uses simulation methods in patient-sharing networks to assess the resilience of primary care in Czechia in the face of GP closures. We identified not only practices that are difficult to replace, but also key providers who serve as shock absorbers by accommodating displaced patients. Our results show that, under certain assumptions, most patients would be able to find a new GP without encountering full-capacity providers—though regional vulnerabilities remain.

Importantly, we highlight how both structural characteristics of the network and provider-level traits (such as age and connectivity) influence the system's ability to withstand workforce shocks. The study offers new tools for identifying regions at risk and for targeting interventions to support the sustainability of primary care.

As Czech primary care undergoes dynamic transformation, our findings provide actionable insights for policymakers seeking to ensure equitable, accessible, and resilient healthcare provision. By advancing both conceptual understanding and practical tools, this research supports informed decision-making in a sector critical to population health.

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