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Do physicians locate as spatial competition models predict? Evidence from Alberta

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This article analyses how physicians choose locations of practice in response to spatial competition forces and considers the implications of such choices for public policy to alleviate shortages of practitioners in rural areas. The predicted geographic distribution of physicians, as determined through spatial competition modelling, was compared with the actual distribution of physicians in 1990 among Alberta's 19 census divisions. Physicians were found to respond to spatial competition forces in choosing where to practise, with the qualification that 1 urban patient had a demand weight equal to 2.32 rural patients. A policy to attract more physicians to rural areas by means of income subsidies is technically feasible but expensive. The high cost means that alternative policies such as a bigger and more effective ambulance network to transport patients to medical centres should become the focus of public policies to improve health care in rural areas.

L'auteur analyse la façon dont les médecins choisissent où ils vont exercer, en réponse aux forces de la concurrence spatiale; il étudie les répercussions de ces choix sur la politique publique dont l'objectif est de réduire les pénuries de praticiens en milieu rural. La répartition géographique prévue de médecins, telle que déterminée par la modélisation de la concurrence spatiale, a été comparée à la répartition réelle des médecins, en 1990, dans 19 divisions albertaines de recensement. L'auteur a constaté que les médecins réagissent aux forces de la concurrence spatiale dans le choix du lieu où ils vont exercer, avec la réserve suivante : un patient urbain possède une pondération de demande égale à 2,32 patients ruraux. Ainsi, il serait techniquement réalisable, mais coûteux, d'élaborer une politique afin d'attirer davantage de médecins dans les régions rurales au moyen de subventions au revenu. Le coût élevé signifie que les diverses politiques possibles, par exemple des réseaux ambulanciers plus vastes et plus efficaces pour transporter les patients vers les centres médicaux, seraient les solutions que devraient privilégier les politiques publiques afin d'améliorer les soins de santé dans les régions rurales.

A general hypothesis emerging from models of competitive markets is that suppliers of a good, to maximize profit, spread themselves geographically according to their buyers.[1] In empiric analysis this spreading is considered to be evidence that markets are competitive and functioning efficiently. In this context there has been considerable interest in the geographic distribution of physicians, particularly between rural and urban areas.

A question of public policy interest is whether the increase in the availability of physicians has lessened the "rural shortage" problem. However, there is considerable disagreement on the definition of rural shortage, especially whether it should be based on patient needs or consumer demands.[2,3] This issue is not tackled directly in this paper. Rather, a definition of rural shortage that is consistent with spatial competition modelling is accepted. For empiric analysis, rural shortage is defined as the difference between the number of practitioners who actu-

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ally locate in a rural area and the number who are predicted to locate there in response to spatial competition forces.

The spatial distributions predicted from competitive forces represent not only market results but also, under certain circumstances, efficient and equitable physician allocations and thus suggest an optimum distribution of health care practitioners. Although spatial modelling cannot give complete insights, it *is* more definitive on what can be expected from market-based policies designed to affect the spatial distribution of physicians.

US researchers have studied physician distribution primarily through spatial modelling and in general have concluded that an increasing availability of physicians helps to alleviate rural shortages.[4-6] Canadian studies[7,8] have been more equivocal, in part because Canadian analysts have been more enamoured of the theory of physician-induced demand, which implies that physicians do not have to locate in areas where the population:physician ratios are highest in order to maximize income. Although the demand-inducement hypothesis may be empirically valid its predictions of the spatial distribution of physicians have rarely been statistically evaluated. The analysis in this paper partially compensates for this oversight.

Spatial competition models

Spatial competition models vary in complexity. However, in the context of a physician market their most salient features can be ascertained through a relatively simple model, which assumes that (a) physicians locate where they expect to maximize income, (b) each person in the population represents the same demand for a physician's services and (c) each physician has the same production capacity, measured in patient load. Under these assumptions, spatial competition modelling implies that the population:physician ratio for the market as a whole defines the population a particular geographic segment of the market must have in order to attract one practitioner.

Table 1 uses these assumptions in the context of a market separated spatially into three centres. Initially, the population is assumed to have 12 physicians, for an overall population:physician ratio of 11 458. Ten physicians would locate in centre A, two in B and none in C, each practitioner having a patient load of 11 000.

If a 13th physician were added he or she would locate in centre A and expect a patient load of 10 577. Centre A is preferred to B (where the expected load for a third physician would be 7333) or C (where the load for the first physician would be 5500).

Additional physicians would continue to locate in centre A until the 17th and 18th physicians, who would locate in A and B (the particular order being indeterminate). Physicians 19 through 22 would locate in A, and 23 through 25 would locate in A through C (the order again being indeterminate).

An important characteristic of the spatial competition model is its prediction that increases in physician numbers will be distributed proportionately to original personnel stocks, at least for areas that already have practitioners. If the economy in Table 1 has 24 physicians rather than 12, there is a doubling of physicians in both centre A (from 10 to 20) and B (from 2 to 4). Of course, whenever centre C attracts its first practitioner this represents an infinite increase in supply.

Although in the model in Table 1 each person is

Table 1: Hypothetical model of the competitive spatial distribution of physicians among three centres and expected number of patients per physician

Total population (n = 137 500)		Centre A (n = 110 000)		Centre B (n = 22 000)		Centre C (n = 5 500)	
No. of physicians	No. of patients per physician	No. of physicians	No. of patients per physician	No. of physicians	No. of patients per physician	No. of physicians	No. of patients per physician
12	11 458	10	11 000	2	11 000	0	–
13	10 577	11	10 000	2	11 000	0	–
14	9 821	12	9 167	2	11 000	0	–
15	9 167	13	8 462	2	11 000	0	–
16	8 594	14	7 857	2	11 000	0	–
17	8 088	15	7 333	2	11 000	0	–
18	7 639	15	7 333	3	7 333	0	–
19	7 237	16	6 875	3	7 333	0	–
20	6 875	17	6 471	3	7 333	0	–
21	6 548	18	6 111	3	7 333	0	–
22	6 250	19	5 789	3	7 333	0	–
23	5 978	20	5 500	3	7 333	0	–
24	5 729	20	5 500	4	5 500	0	–
25	5 500	20	5 500	4	5 500	1	5 500

assumed to represent the same demand for physician services, changing the assumption to reflect known demographic determinants of demand modifies the hypotheses generated by the model relatively little. Suppose, for example, each person in a rural area demands half the health care of an urban counterpart. In the model this could be handled if town sizes were measured in terms of demand units rather than populations. In this context, centre C (the rural area, by assumption) would have a size of 2750 rather than 5500, whereas centres A and B would still have respective sizes of 110 000 and 22 000. The number of physicians in the model would have to be increased to 50 before centre C would attract 1, and the equilibrium population:physician ratio would be twice as high in C as in A or B. But increases in physician numbers would still be distributed spatially in proportion to original personnel stocks.

Departures from the assumption that physicians are income maximizers, like departures from the assumption that all individuals represent the same demand for health care, are easily incorporated into a spatial competition model. It is theoretically appealing to assume that physicians maximize utility rather than profit and that job satisfaction is related to not only generating income but also doing a good clinical job, having a substantial amount of professional discretion, working in a pleasant neighbourhood and meeting other personal and professional goals. However, the more appealing assumption does not qualitatively modify the prediction drawn from the simple spatial competition model: physicians continue to migrate to a given geographic area if they expect higher incomes there.

This point is illustrated by modifying the model in Table 1. Suppose that physicians are interested in maximizing income, subject to the condition that because centre C is viewed as an unpleasant place to live $1.50 earned there has the same utility as $1 earned in centre A or B. Town sizes can be converted into utility-adjusted demand units, centre C having an adjusted population of 3667, as compared with 110 000 in A and 22 000 in B. The physician distribution analysis then proceeds exactly as in Table 1, the total number of physicians having to be 38 before centre C attracts 1.

Previous studies

The question of whether health care practitioners gravitate to geographic areas according to expected patient loads has been studied fairly extensively. In the United States the Rand Corporation's analysis of health care demand tested two hypotheses: that the minimum town size needed to attract a specialist depends on the national supply and that the growth in specialist numbers in areas already possessing practitioners is proportional to initial physician stocks.[4-6]

Concerning the first hypothesis the standard technique has been to compare the proportions of US communities with different populations predicted by the model to have at least one practitioner with the actual proportions. For example, as of 1979 the US national population:physician ratio for urology was 28 148, which led to a prediction that all towns with 19 999 or fewer people would have no urologists, 19% of towns with 20 000 to 29 999 people would have one urologist, and all towns with 30 000 or more people would have at least one urologist. The actual proportions were 2% of towns with 2500 to 4999 people, 10% of those with 5000 to 9999 people, 47% of those with 10 000 to 19 999 people, 89% of those with 20 000 to 29 999 people and 100% of those with 30 000 or more people.[9] These statistics were considered to represent empiric confirmation that 20 000 to 29 999 was the minimum town size needed to attract a urologist, with the recognition that some smaller towns attract urologists because town size often underestimates the available market and because some urologists are prepared to practise part-time or in areas outside of their specialty. The Rand studies generated similar results for 17 specialty groups for the years 1960, 1970, 1977 and 1979.[4-6]

In one main respect the method is biased toward accepting the hypothesis that physicians locate according to spatial competition forces; the prediction that towns many times larger than the threshold size will attract at least one practitioner is hardly a robust confirmation of the spatial physician distribution hypothesis. In the Rand studies the bias is partly offset by evidence that in towns already having specialists the growth in availability tends to be proportional to initial stocks.

Outside of the United States empiric studies on the spatial physician distribution hypothesis have been less focused, in part because of a lack of confidence by non-US analysts that the hypothesis has conceptual merit and in part because of a lack of data. An Australian study confirmed the Rand results in that growth rates in physician supply by geographic area tended to be equiproportional.[10] One Canadian study found that until the 1970s provincial licensing regulations had induced a large number of immigrant physicians to locate in the Atlantic and Prairie provinces, helping alleviate physician shortages in less urban provinces.[7] Another concluded that the growth in the number of physicians in the 1970s did not, in general, alleviate inequalities in the distribution of practitioners among provinces or between rural and urban communities.[8] However, these two studies were designed to test not the spatial physician distribution hypothesis but, rather, the hypothesis that physicians were optimally distributed to provide "needed" health care.

In the 1980s a major Canadian study of the spatial physician distribution hypothesis analysed the geographic distribution of general practitioners and specialists in Quebec.[11] Although the study confirmed the US results — the probability of a physician locating in an area increases with population size — it identified other determinants for choosing a location, such as average income in the area, presence of high-quality restaurants and proximity to a large urban centre.

Alberta evidence

Alberta has relatively few urban centres — two cities (population between 700 000 and 850 000), eight towns (between 10 000 and 70 000) and 23 small communities (between 5000 and 10 000). The number of centres is not large enough to generate statistically reliable results from Rand-style tests.

The best way to analyse the Alberta data is in terms of its 19 census divisions. Table 2 shows the distribution of practitioners among large urban districts, small urban districts, and small towns and rural districts in Alberta in 1990. Large urban districts accounted for 65.36% of the provincial population and 78.14% of the physicians; the respective proportions for the small urban districts were 12.07% and 10.20% and for the small towns and rural districts 22.57% and 11.66% (10 of the small census districts had no town larger than 10 000). The aggregate distributions in Table 2 represent how many physicians would be in each census division if all of them were allocated in proportion to the divisions' populations.

However, the aggregate distribution in Table 2 has significant limitations as a prediction of what would happen under perfect spatial competition. It does not adjust for different specialties requiring population catchment areas of different sizes to be economically feasible. To account for this the "specialty-adjusted" distribution in Table 2 was determined as follows. First, for each specialty the census divisions large enough to attract at least one practitioner were identified. This condition is assumed to be met if a division's population is larger than 75% of a specialty's population:physician ratio for the province as a whole. Next, census divisions large

Table 2: Actual and spatially predicted distributions of physicians among 19 census divisions in Alberta, 1990[12]

Census division	Actual distribution: Population	Actual distribution: No. of physicians	Spatially predicted distribution, no. of physicians: Aggregate*	Spatially predicted distribution, no. of physicians: Adjusted for specialty†
Large urban districts	1 615 300	3 386	2 832	2 917
Calgary	770 200	1 514	1 350	1 390
Edmonton	845 100	1 872	1 482	1 527
Small urban districts	298 200	442	523	517
Medicine Hat	57 200	79	101	95
Lethbridge	117 000	175	205	206
Red Deer	124 000	188	217	216
Small towns and rural districts	557 900	505	978	899
Pincher Creek	36 600	40	64	59
Hanna	12 000	12	21	17
Drumheller	39 200	31	69	61
Stettler	39 200	30	69	61
Rocky Mountain House	16 300	10	29	22
Camrose	76 600	69	134	131
Bonneville	44 900	46	79	72
Whitecourt	56 200	41	99	93
Hinton	25 700	25	45	42
Banff	26 000	39	46	40
Fort McMurray	47 800	42	84	78
High Level	50 100	32	88	80
Grande Cache	13 900	9	24	19
Grande Prairie	73 400	79	129	124
Total	2 471 400	4 333	4 333	4 333

*Numbers predicted from the notion that each census division should have the provincial average of one physician for each 570 people.
†Numbers predicted from the notion that all physicians, including family practitioners, locate according to the provincial practitioner:population ratio for their specialty.

enough to attract at least one practitioner were allocated practitioners prorated according to the divisions' populations (with allocations rounded to the nearest whole numbers). Finally, estimates of practitioner numbers for individual specialties were added to get the numbers in the last column of Table 2.

This procedure leads to the result that practitioners in 16 specialties are predicted to locate only in Calgary and Edmonton, practitioners in 12 specialties mainly in the five largest urban areas and practitioners in 14 specialties (including primary practice) in most of the census divisions. The 16 specialties with a provincial population:physician ratio of more than 170 000 were clinical immunology, endocrinology, geriatrics, hematologic pathology, hematology, infectious diseases, medical biochemistry, medical microbiology, medical oncology, nephrology, neuropathology, nuclear medicine, pediatric neurology and vascular surgery. The 12 specialties with a provincial population:physician ratio between 170 000 and 60 000 were cardiovascular and thoracic surgery, community medicine, dermatology, emergency medicine, gastroenterology, otolaryngology, physical medicine and rehabilitation, plastic surgery, radiation oncology, respiratory medicine, rheumatology and urology. The 14 specialties with a ratio of less than 60 000 were primary practice, anesthesia, diagnostic radiology, general surgery, internal medicine, pediatrics, psychiatry, anatomic pathology, cardiology, general pathology, neurology, obstetrics and gynecology, ophthalmology and orthopedic surgery. Of the last 14 specialties 7 had a ratio of less than 20 000, and under the spatial competition model these practitioners are predicted to locate in every census division. It is significant that the 14 specialties predicted to disperse most widely accounted for 95% of Alberta's physicians. Therefore, the effect of specialty on practitioner distribution is not as great as it appears.

Table 2 suggests that the two large urban districts had 554 more physicians than their populations warranted and that 85 of the "apparent surplus" were attributed to specialty mix. At the other end of the spectrum the 14 rural districts had 473 fewer physicians than their populations suggested, and 79 of the "apparent shortage" were because of an absence of specialists who would not locate there in any event. As a rough generalization the "specialty effect" accounts for about 15% of the deviation between population and physician distribution in Alberta, defined either as "urban surplus" or "rural shortage."

After the effect of specialty was adjusted for, Banff was the only rural census division that did not have an apparent shortage of physicians. In 1990 Banff had 39 health care practitioners; its specialty-adjusted predicted number was 40. This result is attributable to Banff's being a major tourist area, with substantially more amenities than are found in the average rural district.

Not only were there substantial variations between the population:physician ratios in Alberta, but these variations were highly stable over time. Table 3 indicates that the rural population:physician ratio as a proportion of its urban counterpart was 2.30 in 1963, 2.17 in 1972, 2.30 in 1987 and 2.32 in 1990.

Spatial distribution and public policy

These results may dismay policymakers who had hoped that increases in the availability of physicians would equalize rural and urban population:physician ratios. However, the expectations from spatial competition models never warranted such a hope. In fact, the stability of the indices in Table 3 over time reflects proportionate increases in physician numbers across geographic areas and, in this sense, is consistent with the spatial competition hypothesis.

Table 3: Population per physician in Alberta and population indices[8,12]

Variable	1963	1972	1987	1990
Population per physician	996	784	597	570
	Indices*			
Alberta	1.000	1.000	1.000	1.000
Large urban districts	0.847	0.880	0.827	0.836
Calgary	0.865	0.948	0.874	0.892
Edmonton	0.831	0.819	0.789	0.791
Small urban districts	1.217	1.272	1.253	1.183
Medicine Hat	1.199	1.352	1.377	1.269
Lethbridge	1.131	1.284	1.260	1.172
Red Deer	1.310	1.284	1.188	1.156
Small towns and rural districts	1.954	1.912	1.906	1.937

*Indices were calculated by dividing the population per physician for each area by the population per physician for Alberta.

The only modification that must be made to the simple spatial model in Table 1, to enable it to explain completely how Alberta physicians assess different areas in terms of their desirability for practice, is to give 1 urban patient a demand weight equal to 1.42 town patients and to 2.32 rural ones.

The presumption that competitive market forces (reflected in prices, advertising, spatial location or some other variable) lead to economically efficient results is based on a hypothesis that the basic objective of an economic system is to satisfy health care "wants" (reflected by market demands) and not "needs." For example, if 18 was the optimum number of physicians needed in the model in Table 1 to make the marginal social benefit from one additional practitioner equal to the marginal social cost of training and employing a practitioner, 15 of these physicians should locate in centre A, 3 in B and none in C in order to optimize social welfare in a "wants" context. No physicians in centre C can be defined as optimum because the fact that 5500 people go without care reflects nothing more than that these people are not prepared to pay enough to justify the cost of a physician.

Of course in public policy formulation a distinction is invariably made between "wants" and "needs." In the example in Table 1 one physician is presumed to be able to provide care for 11 000 people. If society adds a social objective — that each citizen receive "needed" health care — this objective would be most inexpensively met if there were 13 physicians (10 locating in centre A, 2 in B and 1 in C).

Unfortunately, the cost-effective way of meeting the social objective is not automatically through an unfettered physician market. However, assuming that the optimum number of physicians is achievable, it is technically easy to induce the right geographic distribution. All that needs to be done is to set up a subsidy arrangement to offer physicians locating in centre C fees twice as high as those given physicians in A or B. Under the assumptions in Table 1, practitioners in centre C would have incomes twice as large as practitioners in A and B, but the income result would be modified if each rural person constituted a different demand from an urban counterpart or if practitioners placed different utilities on incomes earned in different geographic areas. For policy this means that if a subsidy is offered in terms of a payment arrangement different from the one in centres A and B (where alternatives to fees might be salaries or per-capita payments) special care must be taken to get the subsidy accounts right.

The empiric evidence suggests that spatial competition forces do affect where Alberta health care practitioners locate, subject to the qualification that rural patients do not constitute as large a demand inducement as do urban patients. This in turn suggests that a policy of subsidizing rural health care practice is capable of modifying the rural–urban distribution of physicians. The remaining issue is the cost of such a policy. In Alberta, suppose that the public policy objective is to induce 394 physicians to migrate from urban districts to the 14 small town and rural census divisions (Table 2) and that 1 urban patient is equal to 2.32 rural patients. An effective subsidization policy would make each rural person's demand weight 2.32 times as large as it is in the unsubsidized situation. This would be roughly equivalent to increasing the province's "population" by 30% (i.e., a rural population of 557 900 multiplied by 2.32). The public sector cost of such a policy would be high, probably prohibitively so according to most policymakers.[13]

This explains in part why, when policymakers have attempted to get physicians to locate in rural areas by means of financial incentives, attempts were made to find ways cheaper than increasing relative fees (by 132% in the case of Alberta). The most common policy is to offer relatively small financial incentives to medical students in return for a commitment to work in underserviced areas for a prescribed period. Such a policy tends to be ineffective, because many students renege on their commitment (if this is an option) and when they do honour it they tend to displace freely migrating practitioners.[14] Even when such a policy works it usually represents only a temporary solution.

The high cost of effectively modifying the rural–urban mix of physicians suggests further consideration of whether such redistribution is really a defensible social policy. The policy is traditionally justified because in a developed and civilized society, needed health care should be available to everyone. But the acceptance of this proposition does not necessitate the acceptance of the corollary, that the providers of such care be located within a certain distance of all potential patients. Meeting need, even in an emergency, always reduces to the problem of effectively and quickly transporting patients to physicians. With current transportation technology for health care, physical distance is rarely a binding constraint.

Stated more generally, the cost–benefit profile of equalizing the availability of rural and urban health care practitioners makes the policy uneconomic. The costs are high, and on the benefit side there is little epidemiologic evidence suggesting that rural populations have shorter life expectancies or higher rates of disease because of practitioner shortages. Moreover, even if such evidence were to emerge, it likely would still be more cost effective to move patients closer to physicians in a time sense (by creating bigger and more effective ambulance networks) than to move physicians closer to patients in a physical sense.

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Conferences

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June 25-27, 1993: Lung Association 93rd Annual Meeting
Halifax
Lung Association, National Office, 508-1900 City Park Dr., Blair Business Park, Gloucester, ON K1J 1A3; tel (613) 747-6776, fax (613) 747-7430

June 26-27, 1993: Pediatric Advanced Life Support
Calgary
Shelley Gerelus, Cardio-Pulmonary Resuscitation Program, Mount Royal College, 4825 Richard Rd. SW, Calgary, AB T3E 6K6; tel (403) 240-6090, fax (403) 240-6729

June 26-30, 1993: Canadian Paediatric Society 70th Annual Meeting (preceded by Pediatric Emergency Therapeutics [PET] and Pediatric Advanced Life Support [PALS] course)
Vancouver
Canadian Paediatric Society, 401 Smyth Rd., Ottawa, ON K1H 8L1; tel (613) 737-2728, fax (613) 737-2794

June 27-30, 1993: Canadian Ophthalmological Society 56th Annual Meeting and Exhibition
Montreal
Hubert Drouin, executive director, or Kimberley Ross, office administrator, Canadian Ophthalmological Society, 610-1525 Carling Ave., Ottawa, ON K1Z 8R9; tel (613) 729-6779, fax (613) 729-7209

July 4-7, 1993: 84th Annual Conference — Sustaining Our Communities: Health for the Future
St. John's
Robert Burr, director of communications, Canadian Public Health Association, 400-1565 Carling Ave., Ottawa, ON K1Z 8R1; tel (613) 725-3769, fax (613) 725-9826

July 5-8, 1993: 84th Annual Conference of the Canadian Public Health Association (CPHA) (cosponsored by the Newfoundland Public Health Association)
St. John's
CPHA Conference Secretariat, 400-1565 Carling Ave., Ottawa, ON K1Z 8R1; tel (613) 725-3769, fax (613) 725-9826

July 19-21, 1993: Public Health Conference on Records and Statistics — Toward the Year 2000: Refining the Measures
Washington, DC
US Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Center for Health Statistics, 1100-6525 Belcrest Rd., Hyattsville, MD 20782

July 20-23, 1993: 4th International Symposium of the International Society for Brain Electromagnetic Topography (ISBET)
Havana, Cuba
Dr. Nibaldo Hernandez, president, ISBET '93 Organizing Committee, PO Box 6880, Ciudad Habana, Cuba; tel 011-53-7-21-7442 or 011-53-7-21-7390, fax 011-53-7-33-6321

Aug. 22-27, 1993: 7th World Congress on Pain
Paris, France
International Association for the Study of Pain, 306-909 NE 43rd St., Seattle, WA 98105; tel (206) 547-6409, fax (206) 547-1703

Aug. 23-27, 1993: 3rd International Congress on Amino Acids and Analogues
Crete, Greece
Dr. G. Lubec, Department of Paediatrics, University of Vienna, Währinger Gürtel 18, A 1090 Vienna, Austria; fax 011-43-1-40400-3238

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