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Reconstructing the Question of School Choice: Towards a Geographical Agent-Based Model for Chile

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Abstract*— The aim of this paper is to reformulate the question of school choice in a voucher system, by moving towards a perspective, assessing competition between schools and the choice of students using Geographic Information Systems (GIS) and Agent-Based Modeling (ABM). How spatial structure affects competition among schools? How do socio-geographic structuration and social interaction affect this process? We show a preview of the proposed model and main social mechanisms of school choice: Quality, Distance, Cost, Expectations, Homophily and Mimesis for students and their families, and Selection, Supply and Local Competition for schools.

I. Introduction

THIS paper aims reformulate the question of school choice within the Chilean educational system, moving towards assessing the levels of competition among schools and the freedom of choice of students and families using Geographic Information Systems (GIS) and Agent Based Modeling (ABM). The school choice voucher system that operates in Chile is one of the most studied research topics in Chilean education. It was created to maximize competition between schools in favor of increasing the quality and coverage of education in Chile. Evidence about the success of the system to fulfill its objectives is inconclusive, and studies including geographical factors are scarce. Most of the researches are based on variations of regression models trying to link school choice to educational quality. There have been no attempts to approach this issue though ABM, nor from complex geographic methodologies nor from the perspective of analytical sociology. Using the available databases for the city of Santiago, it is possible to geo-reference families' position in relation to the; position of the schools to assess the distance between them and by using GIS, it is possible to identify other socio-spatial conditions that affect school choice processes. ABM can be developed to simulate the behavior of families and schools, and the distance effects on variables of educational interest. It is relevant that future researches address the study of the effects of the spatial structure on the level of competition among schools, and how this structure affects the quality of education. The ABM may be calibrated with empirical geographic, socioeconomic and educational data, to simulate the manner in which families and educational institutions behave in relation to the conditions of their spatial environment. This could allow the generation of simulations of future behavior of the educational system if current conditions are maintained and could help social scientists and policy-makers to project counterfactual policy scenarios by the way of simulation, in order to compare different alternatives for the current system. Then, by reconstructing the question of school choice in Chile, new questions emerge, as the following: How does the spatial structuring affects competition between schools? Do agents make choices in constrained or full freedoms and rationality? Are agents pushed or pulled by the educational offer and socio-geographic structure? To what extent this spatial structuring as a context of operation of a voucher system is efficient and improves quality, in comparison with alternative systems? What would be the effects of changes in public policy regarding school choice? To what extent the existence of a school choice system and a voucher financing system favors improvement or decline quality of education in Chile? Future research with ABM and GIS offer an innovative alternative to assess theoretical, methodological and practical questions on school choice in Chile and in other choice based systems around the world. We show a preview of the proposed model and main social mechanisms of school choice: Quality, Distance, Cost, Expectations, Homophily and Mimesis for students and their families, and Selection, Supply and Local Competition for schools.

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II. Towards a Geographical Agent-Based Model of School Choice in Chile

The choice process in the field of education is complex and multidimensional. It has attracted the interest of sociologists, psychologists and economists, who have approached the subject from different points of view [1]. In addition, there are several school attendance policy models operating in different countries and contexts, and one of them is the model of free choice −Enforced regulatory zoning model (France, Germany); unforced regulatory zoning model (Finland, Norway, Scotland); restricted choice model (Spain, Italy or Sweden) and choice model (Belgium, the Netherlands and, to a lesser extent, England and Wales), according [2] − The current Chilean system –since the massive implementation of the demand subsidy mechanism through school vouchers in primary and secondary education– constitutes a unique scenario in the global context to assess the school choice process. It follows strong abstract assumptions and criteria: by means of maximizing of the freedom of choice of the families, the system would supposedly lead to increased competition within schools to capture as many students as they can [3]. Competition among schools will finally derive in increasing quality, as lower performance schools would tend to disappear. From this point of view, competition among schools would occur by increasing the quality of the education provided [4]), which can be distinguished by student's families.

This educational funding model based on demand subsidies (vouchers) offers a privileged observation context of the school choice process, motivating national and international research based on the Chilean case [5] Due to the social relevance of the matter, most researches combine the academic discussion of choice processes with public policy recommendations [6] Some authors, in favor of a voucher system, argue that it increases efficiency, competiveness and quality of education, while providing greater educational opportunities to disadvantaged students [7], [8], [9]. Critics of the voucher system claim that the school choice based in vouchers increases inequality, segregation and educational stratification. Others argue that the optimal competition conditions that the model intends cannot be met because of market flaws [10] The sociological problem beneath these questions is related to freedom of choice, and how it can be complete, limited or even possible, in diverse social contexts [11] It is also related to Diego Gambetta's question: "*Were they pushed or did they jump?*" [12] structural constrains and incentives may be exerting influence on school choices.

On one hand, neoliberal economic theory –focused in the freedom of choice of the individual– assumes the generation of optimal market competition conditions by means of aggregated individual rational decisions intended to maximize benefits. On the other hand, classic sociological theories highlight the importance of structural factors that motivate, alter, distort, orient or inhibit behavior on individuals, while the individuals can modify their own position within the structure or even have influence over the structure [13], [14], [15], [16]. The analytical sociology perspective of this paper assumes that although the individual has some freedom to choose, this choices always take place in empirically situated contexts, where several structural factors and the interaction with others may limit choice in its pure and exclusively rational form. The process of choice will be addressed from the perspective of what has been termed "real freedom" [17] which supposes that individuals make decisions based on limited relevant or identifiable options within his or her context.

Empirical data on reasons for school choice put into perspective the theoretical arguments in which voucher systems are based. Table 1 shows that the reason most mentioned establishment choice criterion by parents is not the academic quality results (only 31%), measured by the standardized tests, SIMCE for primary and secondary education and PSU for college entry, but the proximity to the family home (52%).

In addition, the mention of the shortest distance as the reason of choice is more common (65%) in the first two income quintiles, corresponding to the poorest 40% of the population. By contrast, the academic quality is mentioned as a reason for choosing more frequently in the richest families in the country (41% and 49% in quintiles IV and V).

TABLE I – PERCENTAGE OF PARENTS WHO MENTIONED THE FOLLOWING REASONS FOR SCHOOL CHOICE AMONG THE TOP THREE CHOICES. SOURCE: SIMCE SURVEY 2009.

Reasons for school choice	Total	I	II	III	IV	V
Because it is close the family home	**52%**	65%	65%	62%	59%	50%
Because it offers high quality of education (SIMCE and PSU)	**31%**	25%	31%	37%	41%	49%
Because of their values and orientation	**29%**	23%	28%	32%	38%	47%
Because of its infrastructure	**23%**	18%	22%	26%	31%	36%
Because brothers attend this school	**2%**	29%	29%	26%	23%	21%
Because it was the cheapest one	**21%**	34%	32%	27%	21%	12%
Because friends attend this school	**10%**	12%	12%	12%	11%	10%
Because it was bilingual	**5%**	2%	3%	3%	4%	10%
Because it was the only one on the district	**4%**	7%	6%	4%	4%	3%
Because it offered the vocational course that looked for	**3%**	4%	4%	3%	3%	2%
Because my son/daughter was not accepted in other school	**2%**	2%	2%	2%	2%	1%
Other Reason	**26%**	25%	29%	31%	33%	33%

There is evidence that the process of choice, therefore, is configured socioeconomically; [18], [19], [20]. In this regard, the study conducted in [21] stands out, as it recognizes three types of parents regarding their ability to operate in the "education market": parents that are "competent", with high cultural capital and information to choose school depending on the quality; parents that are "semi-competent" to choose using the reputation of the school as reference to opt; and finally, "disconnected" parents, who choose according to the closeness. In Chile, according to the SIMCE 2009 survey results, "disconnected" parents seem to predominate, especially in the poorest (Table 1).

Methodologically, the effects of the voucher system have been addressed from two perspectives: the perspective of verbalization or declaration (by means of qualitative or quantitative research) of reasons for choice which is generally limited to the description, and another perspective of ex post facto analysis of school choices. From the latter perspective, economic studies using statistical methods and econometric models have been conducted to assess effects of the system in quality [22], [23], [24]. To the date, no conclusive results have been brought up regarding the impact of the school choice process on quality. Such investigations tend to emphasize the effects of the voucher system in academic results, regardless of the spatio-temporal structure that relates to the position, distance and other conditions affecting elections of families in socio-geographic contexts. Contrarily, national [25] and international [26] evidence have been gathered supporting the hypothesis that school choice policies tend to affect negatively the equality of education. The OECD alerts about the risks: “School choice has increased across OECD countries. Yet, it can result in segregating students by ability, income and ethnic background and in greater inequities across education systems. School choice schemes should include mechanisms that mitigate the negative effects on equity” [27].

Only few authors have proceeded through geo-referencing methodology, GIS and distance analysis to observe school choice processes and to assess the role of quality in this choice, both internationally [28], [29] and nationally [30], [31], [32]. However, these researches do not consider the interaction among educational stakeholders –between students/families and schools and among schools– in different conditions, according to specific geographical contexts and distribution of educational agents. Therefore, they cannot conclusively determine the validity of the assumption of choice and competition in the system, as social and spatial interaction has not been considered.

The great amount of individuals and groups involved, the complex interaction networks and different levels of aggregation in the educational sphere have led some authors to describe the field of education as a complex system [33], [34], to the extent that it is recursive, self-referential, self-regulates its operation and from which emergent properties arise from the interaction of agents and their different relation between them [35]. In this kind of systems, it is not possible to predict with absolute precision the evolution and changes they will experience, as complex networks of interaction aggregate to shape its conditions [36], [37], [38], [39]. Therefore, the authors who are observing the systems from the complexity perspective note that there are specific tools to address them, which have been called the “complexity algorithms” [40]. In particular, the ABM seem best suited to observe social systems as complex local interactions networks [41], [42], [43]. ABM has been recently used to assess educational choice in France and Italy [44]. This work offers an ABM of educational choice, in which agents make decisions regarding going up another year of education. Another paper [45] is highly relevant, as offers a revisiting of Schelling’s model applied to school dynamics. The main mechanisms presented in that paper is the preference for shorter distance and the preference for

similar ethnicity; however, although highly relevant, this works do not offer data calibration for their models.

Finally, the voucher system has been challenged from different theoretical, methodological and policy perspectives, evaluating their effectiveness, usefulness and validity of basal assumptions through diverse methods. Therefore, the theoretical question of how social conditions and the spatial setting affect the choice process emerges. It is also relevant from a policy-maker perspective to ask what effect this school choice policy (vouchers) has on the overall quality of the educational system. On the other hand, it is methodologically relevant to address the question of how to approach the social phenomenon of school choice in this context, as it seems necessary to move forward in applying innovative methodologies to allow a more comprehensive view of the process of choosing schools.

III. National Context: Vouchers and School Choice in Chile

In Chile, since the educational reform of 1981, the school education funding scheme operates through a demand-based subsidy mechanism, commonly referred to as voucher or coupon, which means that the State pays monthly to the school private owners or public responsible institutions or individuals, conditional to effective attendance of students averaged over the last three months prior to payment. This mechanism is intended to provide greater choice for families, promote competition for the attraction and retention of pupils amongst schools, resulting in improved levels of educational quality. The amount of the school subsidy was established by law, which have been slightly modified applying some minor changes during the last three decades, as the subsidy amount has increased and it now differs by education level and modality of education, and there are bonuses for the subsidy if the school is in a rural area, if it is in a geographically isolated area, amongst other bonuses (DFL N º 2, Ministry of Education, 1996, called "Subsidies Act").

The reform of the early '80s was based on the theoretical proposal of Milton Friedman [46] which held the convenience of installing a predominantly private system of educational provision based on market mechanisms, reducing the role of the State [47]. Although school choice in Chile has always been the student allocation policy, it is very important to note that the law that created the voucher system was passed during the military dictatorship and it was not subject of democratic discussion. After 1990, with the return of democracy, the demand-based scheme has been deepened, corrected and consolidated. The main changes of the system were that the government partially funds general education and requires a minimal curriculum, leaving the administration of schools in the hands of competing companies. The State delivers a payment to the schools that are selected by the families, assuming that it maximizes their capabilities of choice. The voucher was assumed as a system which would create a virtuous competition amongst schools.

Since the implementation of the voucher model, the Chilean education has significantly increased enrollment and coverage [48] and recently, performance has slightly improved in some international measurement results [49], although there is no evidence that the voucher system has been the one and only cause of this growth. However, gaps remain in the performance indicators of schools from different income levels [50], an issue that has given place to many studies which have tried to explain this phenomenon. Most of them have been looking at the effects of the demand-based subsidy model [51].

Supporters of the voucher system argue that maximized the choice of families, educational institutions will compete to attract students and increase enrollment. Gradually, this design would eliminate the schools that fail to attract students, while increasing the range of options, so that the system would enjoy the benefits of market competition. Supporters of this model tend to emphasize the benefits of competition in a context of free choice, which would lead to improved quality, while opponents point to the inequity of the system and the lack of evidence for the quality improvement. The voucher system has been subject of extensive discussion in academic, political and ideological spheres, being highly relevant to Chile. Recently, the 2011 student movement pointed-out the flaws and inequalities of Chilean education, in which the demand subsidy was highly criticized. From this perspective, it is very important to account for the effectiveness and usefulness of the voucher as funding model, which would allow scientists to establish technical criteria for the policy development of the educational system, better satisfying social demands for quality and equity in education.

IV. Empirical context: research on vouchers and school choice in Chile

Some authors have argued that the voucher system in a model of educational choice would lead to an improvement in the quality of education [52], [53] because the only way that a school have to attract students and increase and retain enrollment is quality of education.

The introduction of the voucher system has also raised a number of criticisms, as we have seen. [54] and [55] suggest that the demand subsidy mechanism necessarily generates inequality. Other authors argue that there are market failures that prevent the optimal results expected of competition [56]. Although some researchers claim that the voucher system improves the quality of education by maximizing the freedom of families [57] other authors discuss these results, arguing that there are profound socioeconomic and information differences, which lead to increasing inequality and segregation [58], [59], [60].

In the national and international literature, so far, there is no consensus about the effectiveness of the system of subsidizing demand and school choice mechanisms, mainly because there is no conclusive research on the actual conditions of freedom of choice ("real choice"). For example, [61], [62] argue that introducing the income level and parental education as control variables, no significant differences between the quality of public and subsidized can be observed. Previous research have not yet found a clear answer regarding the usefulness or not of vouchers on improving quality, as suggested by [63], [64] and [65] among others. These studies apply statistical controls to the process of self-selection of families when they choose school. However, these studies do not include the distance amongst the factors that influence choice, even though it appears to be an extremely relevant variable as it was shown in Table 1.

Regarding the inclusion of distance in the selection process, in the international literature the work of Hastings, [66] stands out: They find that the distance and school performance on standardized tests are increasingly important for parents and families with higher income level and students with stronger cognitive abilities. [67] conclude that the differences in information levels are highly relevant in the process of choosing school.

In Chile there have been few studies in which students' homes are geo-referenced or that include geographical variables regarding students and their schools. [68] and also [69] provide some examples. They attempt to approach the matter of the distance between the households and the schools that students attend, calculating travel distances for each student. A more recent study [70], geo-referenced the students who took the PSU (College Entry Test) in 2009, in order to evaluate the school selection process that took place. The authors postulate that households make different decision processes, including a first choice among schools (distinguishing excellent performance schools from others), and then choose between schools closer to home. In addition, the authors found that families are willing to set aside 7 PSU points, to travel one less kilometer.

However, the agents in the system do not make educational choices in a homogeneous or neutral environment. Considering the geographical and demographical distribution of the educational suppliers and demanders, different conditions of choice can be found, involving diverse competition schemes between schools. Some authors have termed this situation as “quasi-markets” in education [71]. These conditions can generate a scenario of what we can call a "geo-competitive isolation" of certain schools, due to the differentiated social, economic, cultural conditions of their environment. These geo-isolated schools do not have the same incentives to improve that other schools, because they are under different competitiveness conditions. This situation may contradict the principles of perfect competition in which the voucher and school choice systems are based. It is for this reason that the methodology of geo-referencing to approach school choice [72] must become more complex to allow the approach of transportation phenomena or differentiated urban spaces that generate changes in agents' decisions. This implies to go beyond the measurement of travel distances, and address connectivity, security, levels of trust, social cohesion, availability of options to choose, and several other variables that can be affected by geographic location.

Similarly, the mere application of statistical correlations to geographic phenomena does not solve the problem of local interaction nor allows social scientists to simulate alternative scenarios to test hypotheses. That is innovative methodologies are required to account for the complexity of the school choice process in this voucher scheme of educational choice. The complex social systems perspective offers several tools for its analysis [73], as cellular automata [74], [75] and agent-based modeling and social simulation [76], [77], [78]. These modeling techniques are theoretically related with the analytical sociology perspective [79], [80], [81], etc.).

We have developed this subject for the last 4 years in the Institute of Philosophy and Complexity Sciences (IFICC), getting involved on methodologies of agent-based modeling [82]. Currently, it is relevant to explore the possibility of using agent-based models and GIS to assess school choice [83], [84], [85]. The models can be calibrated with real data available, which indicate academic performance, socioeconomic conditions, demographic data, location of facilities, etc., provided by the Chilean Ministry of Education. Therefore, from the perspective of geo-referenced modeling of local interaction of agents which understands education as a complex system, it is relevant to try to respond about the influence of social and geographical heterogeneity in school choice processes, particularly in the current educational voucher system in Chile. Agent-based modeling techniques calibrated with geo-referenced data can aid in generating predictions and project simulated counterfactual scenarios [86], [87].

V. THEORETICAL CONTEXT: INDIVIDUAL CHOICE WITHIN SOCIAL STRUCTURES

The concept of education as a competitive market is the basis of the theory of Milton Friedman [88], who proposed a model of educational provision based on freedom of choice for families, in which the state subsidizes the attendance of children of the schools of their choice through a voucher. As schools compete for students in this market, the individual incentive of schools is on improving the quality, which enables an overall system optimization. In a related line of thought, but with a more theoretically complex approach, authors like Coleman [89] Hedström [90] and Elster [91] analyze the relationship between freedom of choice and individual rational choice. The seminal work of Boudon [92]

[93], [94] shed lights in the link between social structure and school choice, opening the door for limited rationality or different rational approach in diverse socioeconomic contexts, with his concept of "primary" and "secondary" effects of culture and class, respectively. Boudon's work is also very interesting as he proposed changes to the educational system in order to reduce segregation, which is crucial in the approach of the Chilean voucher system of school public funding.

From the more structural sociological theory (not structuralism as [95] warned), individual rational choice is put into perspective within an analysis of the structure-agent relationship, meaning that the organization of social space and time is understood as dynamic relationship of interdependence between agent and structure. In this line of thought, the social structure determines into a certain extent the action of the agents so they would not act in a fully "rational" manner, while the projects and actions of the agents may also lead to structural changes [96], [97], [98]. The choice of educational establishment, in this sense, can be understood as a dynamic process in which combine structural and individual actions to shape social reality. In this regard, this research assumes the theoretical question the extent in which agent and structure determines each other. In the matter of school choice, it intends to reveal if they "were pushed" into selecting certain school or if they "jumped" by themselves to enroll in it, or if it is a little bit of both mechanisms [99].

One of the most interesting approaches to the problem of this research is the Theory of Real Freedom. In general, we refer to the concept of educational opportunities to all those possibilities that are available for opting in education, which together with not being prohibited are feasible to afford in terms of resources. In this sense, the notion of increasing educational opportunities relates to the concept of real freedom provided by the Belgian philosopher Philippe Van Parijs [100]. Under this concept, real freedom conjuncts in one instances the negative dimension of the concept of freedom ("no one can stop me from exerting my will") with the positive idea of having the resources and capabilities to do it. In this sense, the concept of "real freedom" of Van Parijs is more demanding than that of negative freedom, as it interrogates for the effective availability of resources (of various kinds) to execute the will of the individual [101]).

Due to the above, in the context of this research, the question addresses the real possibilities beyond the merely virtual ones, from which people may choose. In this case, it is relevant to assess the possibilities of action of parents, in regard of the selection of the educational institution where their children will attend. This means asking for the educational opportunities, involving the combination of no prohibition with effective resource allocation to do so. This notion of opportunity applied to education, is clearly connected with the notion of opportunity presented in the DBO model (Desires, Beliefs & Opportunities) proposed by [102]). Under this model, although opportunities may exist independently of the actor, they must be known, so that they can affect the actor's behavior through their beliefs. This phenomenon adds an additional element, subtle but important for the present analysis: it calls into question that if those educational opportunities are not prohibited and are affordable in terms of resources, the actors should be fully aware of their real feasibility.

In referring to the DBO model, it must also be considered that the action of an actor affects the opportunities of other actors, too. This shows the importance of the interaction between agents in a complex system of relationships, which determines the conditions of real freedom of the agents of the system: A desire or belief of an agent can affect its perception of opportunity, and an observing agent may shift his desires or beliefs because of this action, allowing new opportunities to emerge for that agent. Agent-based modeling seems to be one of the few formal tools for coping with this issue [103]. Under these conditions, a reformulation of the sociological research question in rather manner is required, as conditions of real freedom for educational choice must now be addressed in socio-spatially located contexts.

VI. Proposed School Choice Mechanisms for a Voucher-Based Educational System

The results of background research and statistical analysis of socio-economical, educational conditions and geographical information, a restructuration of the question regarding school choice –in order to construct a model– requires the identification of some fundamental elements: a) Environmental conditions; b) Agent characteristics; c) Rules of behavior. But previous to define those model-related issues, a sociological analysis should identify the mechanisms behind the model's operational conditions.

Regarding the environmental conditions, we have constructed a quantitative taxonomy of districts in the city of Santiago, using several socioeconomic, local, cultural, developmental and educational variables. We resumed the information of the 33 districts of the Chilean Capital City into 7 different groups of districts in which conditions for school choice vary. Methodologically, the taxonomy of districts comes from a factor analysis of principal components, with varimax rotation (on appendix).

From over 200 social and educational indicators from several governmental datasets, from which 20 relevant index were constructed. Six factor explain 63% of total variance, and helped us to construct groups of districts. Details in the factor and cluster analysis may be found in [104].

The factors were denominated according to the kind of phenomena that variables were related to: (1) "Distrital local

development" (including security, public school conditions, local entrepreneurship, health services quality and municipal finances). (2) "Economic and cultural capital" (ownership of means of transportation, socioeconomic level, quality of dwellings, educational level). (3) "Secondary socialization an integration" (including access to information, school life). (4) "Power" (including labor scale position and daily need to travel). (5) "Health and growth of housing" (including growth of housing and municipal health) and (6) "Local uprooting" (including housing mobility, civic culture and ethnicity).

Then, we applied a cluster analysis, which grouped districts according to the factors. Interpreting the dendrogram (on appendix), seven types of districts emerged, with differentiated conditions for school choice. Great environmental differences –that may be affecting school choice conditions– emerge with the analysis, showing great geographic diversity in terms of opportunities for families. More and better choice conditions concentrate in the wealthy eastern zone of Santiago. Great and new residential districts with high growth in the last years (in red) configure a reality of its own. Concentric distribution of school choice conditions, from the central Santiago district to the more peripheral districts. An interesting relation occurs regarding the concentration of better social conditions with availability of the subway and the encirclement highway (with involves all orange districts).

We resumed the information of the 33 districts of the Chilean Capital City into 7 different groups of districts in which conditions for school choice vary:

Agents, therefore, will have diverse contexts for choosing school depending on their location in the city, which offer a differentiated structure of opportunities for choice.

To build the proposed model it is necessary to identify the main social mechanisms of school choice. Statistical and theoretical research led the team to reduce the complexity of school choice to six different mechanisms for students and their families: Preference for quality, Preference for shorter distance, Preference for lower costs, Differences in expectations for different agents, Homophily in terms of socioeconomic similarity and Mimesis of neighbors behavior. Preliminary evidence on Chile suggest that distance, quality and price are the most relevant determinants of school choice [105].

We also preliminary present three main mechanisms to explain school behavior: Selection, Supply and Local Competition.

- Preference for higher quality is a relevant concept both theoretically and empirically, as parents tend to choose schools that show better performance. Choice system's advocates defend the importance of quality as a signal for the choosing families, as an ideal school system will lead most families to choose better schools and the rest would simply disappear (although this have been contested by evidence). Still quality is frequently used as a choice mechanism, but the relative importance that different kinds of actors give to quality to make decisions vary greatly among socioeconomic

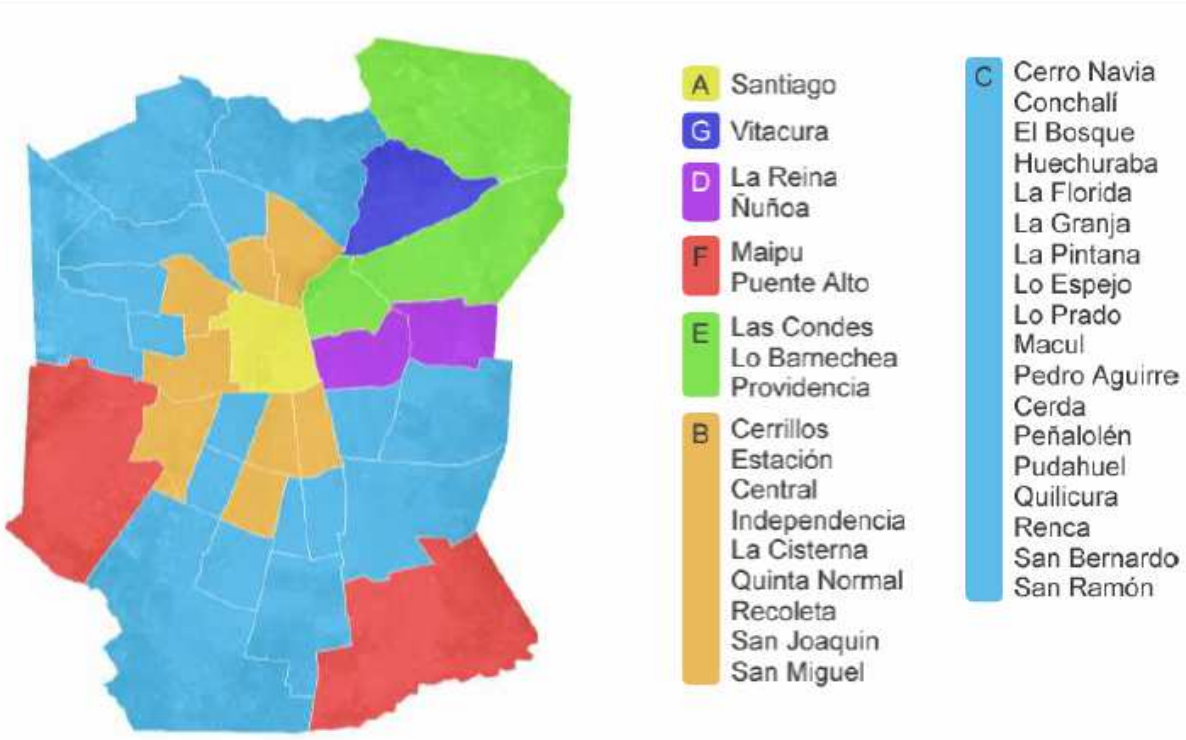


Figure 1– Typology of districts of Santiago, Chile, varying school choice conditions. Source: authors' own elaboration.

and educational backgrounds. The social mechanism expressed in its more general way is the following: "Parents prefer higher quality schools". Although the "level of quality of a school" is still a social construction, there is multiple evidence that parents tend to prefer schools that they view as higher quality schools for their children [106].

• Preference for shorter distance is the most general geographic condition affecting school choice. Although usually neglected, distance has been included solely as Euclidian distance, thus not considering other issues as connectivity, geographical obstacles and availability of transportation, which varies in different socioeconomic, cultural and educational contexts. In this preliminary research, the social mechanism of distance may be expressed as: "Parents prefer schools which are close to their homes", and the strength of that preference is diverse according to the context and agents' conditions. Preference for shorter distance appears frequently in the literature, both for Chile [107] and internationally [108], so it is reasonable to use this mechanism in our model.

• Preference for lower price is the third mechanism. The financial aspect in a voucher system with the possibility of complementing the schooling cost beyond of what is covered by the voucher implies a form of segregation by payment capacities. Poorer parents will not be able to access to some schools, in which tuitions cost are higher. There is abundant evidence that in poorer backgrounds the preference for low cost is overwhelmingly high and even at some levels, paid schools are simply out of the choice set [109]. On the other hand, for richer parents, a more expensive school may signal quality or separation from other social groups, so tuition levels may act attracting high income families. This cost effect varies among different socioeconomic levels. Therefore, the social mechanisms can be simplified to the following: "Parents tend to choose schools with lower tuition costs", but the intense of the preference varies as some parents may afford higher tuition fees and may interpret them as quality indicators. This calls for a deeper discussion that will not be address here, but we acknowledge it, for it to be included in further versions of the model, once a first version is concluded.

• Expectations play a major role in school choice, as higher expected results may lead to higher investments from parents, while the need for an immediate income may lead poorer families to prefer a vocational, work-oriented and shorter educational track. This implies that the rule should be "Parents with lower expectations of educational continuity may select vocational tracks, while parents with higher educational perspectives tend to choose scientific and humanistic tracks", which intensities' varies across social groups. Expectations are included in [110] and [111].

• Homophily is a long identifiable social mechanism for several kinds of choice. In this proposal, homophily is regarded as the tendency to choose schools in which student with similar characteristics attend. Therefore, the mechanism in this case is "Parents choose schools in which students that are similar to them attend", which relative importance is different depending on other variables. Homophily is a traditionally used variable to explain social behavior [112], and there is evidence of homophilic behavior in educational contexts [113], [114]. Much of the literature in this regard approaches the issue of race and ethnicity, which is not relevant to Chile. Therefore, the socioeconomic background may operate in the same way that racial variable does, as reported in US schools.

• The final concept is mimesis, theoretically and empirically proved mechanism for decision making and behavior in social conditions. Imitating other people behavior is probably the most basic behavior scheme in social contexts, and no difference is expected in educational choice situations. The rule can be formalized as "Parents choose schools that other parents of their local neighborhood do". Imitative behavior is also a widely used mechanism to explain social phenomena. Reference [115] reports that imitative behavior may foster a growing tendency to inequality, which may be applied to educational choice. Reference [116] includes the variable of social interaction between members of different groups, which may allow some kind of inter-group mimesis.

School behavior, although much more limited (as school play a mostly passive role trying to attract students), still is important to model school choice. Therefore, we had identified three main mechanisms that we can summarize on:

• If possible, Schools will select student with better initial conditions, as education costs an efforts will be smaller if children and teenagers already have higher social and cultural capital. Selection has two versions: a) Academic version: "Schools tend to select higher performing students" and b) Economic version: "Schools tend to select higher income students". These mechanism present variations across diverse social groups and varies by levels of demand for educational services.

• Preference for limited relative educational supply: Where School is located will define much of it ability to attract and capture student enrollment. They choose according to several variables: "Schools tend to prefer locations in search of increased profit, increased enrollment, and lower investment", varying by school type.

• Schools will reduce levels of effort in improving education in contexts of lower local competition: This relates directly to geocompetitive isolation, market share and market power. This mechanism implies an increase on the levels of freedom for school with less competition around.

Although several other mechanisms may be identified, this research shows the basic geographical contextual structural factors and the main social mechanisms for choice, as well as the reasons for them to vary across groups. This approach will serve as theoretical and empirical background for the construction and programming of a school choice model for simulating the evolution and effects of diverse choice conditions, first in Chile, but then in other contexts in which voucher policies and school choice mechanisms are relevant configurators of the educational system.

VII. Towards a "zero" model of school choice for Santiago, Chile

Although this is a preliminary work, some light can be shed on how a model could be constructed, with the available variables and data.

As stated before, the model feeds on real data regarding the position of each school in Santiago. In the first set of images, we present the distribution of schools in Santiago, according to their dependence: (1) District (municipal) public schools; (2) Private subsidized school and (3) private schools. It is evident how public schools are evenly distributed in the city, as are the private subsidized schools. To these kinds of schools mostly poor and lower middle class attends. In the third image, private schools tend to be on the eastern part of the city.

The blue curves represent levels of density of schools, and the closer they are, the more density they indicate. To these schools student go daily, travelling nearly 1 km to their school, as showed in the following distribution of travel distances to school:

Based on these georeferenced data, the preliminary model include two kind of agents: families and schools. The operation rules with which agents act depend on three mechanisms: the evaluation of distance, the evaluation of quality and the evaluation of price (for all of which data and other evidence suggest that are relevant variables for school choice process). As this is a preliminary attempt, other mechanisms that may be relevant were excluded for the moment, in hope of including them in more sophisticated versions of the model.

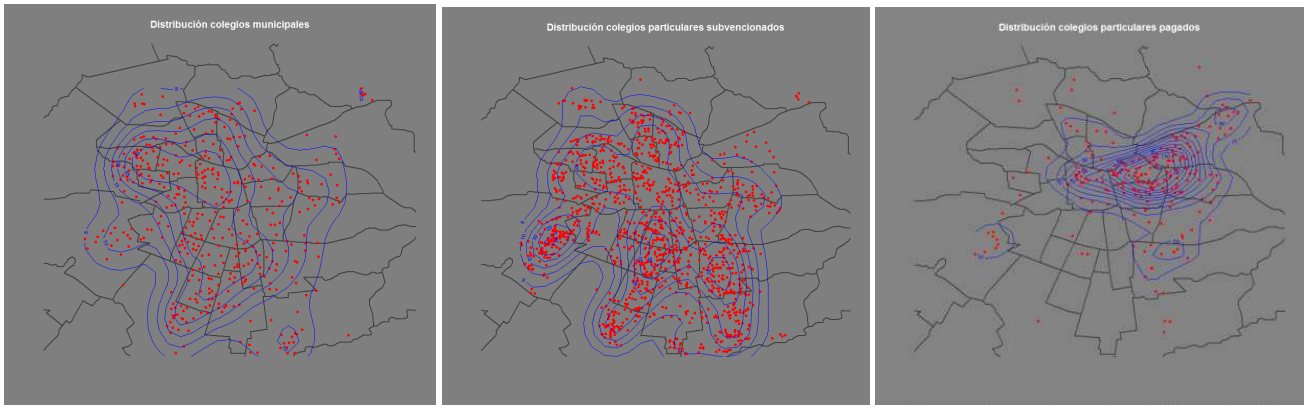
Each variable is calculated from each family regarding all schools of the city. After the decision-making process, the output of the agent-family is –as a behavior– the selection of a given school among all included in the choice set. In the simplest model, the choice set is comprised of all schools in the city.

For agent-schools, behavior rules depend of two kind of variables: the number of families that chose the school and the student's academic performance. The output of the agent-school performance as a behavior is a change of price and school quality (standardized test performance). The positions of families and schools are real positions reported in the geographical coordinated of the databases, included in the GIS. Each iteration of the model represent one academic year.

VIII. Pseudo-coding of the zero model

Agent-Family Rules of Behavior

a. A random family is selected randomly among the georeferenced ones (Ai). If the family has already chose a school for their children, another family is selected randomly.



(1) District (municipal) public schools; *(2) Private subsidized school* *(3) private schools*

Figure 2– Schools distribution by type

b. A school is selected among the georeferenced ones (Cj). If a school has completed their available vacancies, another school is randomly selected. School vacancies are calculated as the real enrolment plus 5%, as basal flexibility.
c. The distance between Ai y Cj (dij) is calculated and the quality value (qj) and price (cj) of the school are assigned using the database information. These values are normalized.
d. An utility function for each school is calculated for each family U(Ai,Cj) from the values calculated in (c). The utility function is equivalent to the sum of the partial utility function of each variable (which are considered independent by hypothesis) U(Ai,Cj)= U(dij)+U(qj)+U(cj). The utility function is logistic.
e. A probability of choice P(Ai,Cj) for Ai to choose Cj in a logit model []Benenson and Torrens 2004) in the form of P(Ai,Cj)= exp[βU(Ai,Cj)].
f. A random number between 0 and 1 is determined. If the value is the less or equal to $P(A_i,C_j)$ the family A_i chooses the C_j school and the model goes back to (a). If the value exceeds $P(A_i,C_j)$ the family A_i does not choose C_j school and the model goes back to (b).
g. This part of the model ends when all families have selected a school for their children.

Agent-School Rules of Behavior

h. Once the previous process is finished (all families chose schools). The changes of states of schools are calculated.
i. The price of school c_j is updated in the following year according to the following rule: if vacancies are not filled, the price of school updates as c_j-Δ_j, if vacancies are indeed filled, the price is updated as c_j+Δ_j, where Δ_j follows a normal distribution N(x,ε).
j. Quality q_j (in SIMCE standardized test results) is updated each year as the average SIMCE average of the students of the school.
k. The simulation ends when all schools have updated their states.
l. The process from (a) is repeated for a Y% of randomly selected students. As at least 25% of students a year change schools (Y% > 25%).

This pseudo-coding will be programmed in the R environment, using the GIS data of schools and families. Future versions of the model will include the taxonomy of districts as choice determinants and the other mechanisms that have been identified as relevant for social choice processes.

IX. The New Question of School Choice in Chile

Finally, the school choice process in the current educational voucher system in Chile, put against the contextual, empirical, conceptual and methodological background, must go beyond the question of the utility of the voucher system, but it must also encompass the question for the conditions of real freedom of educational choice for families,

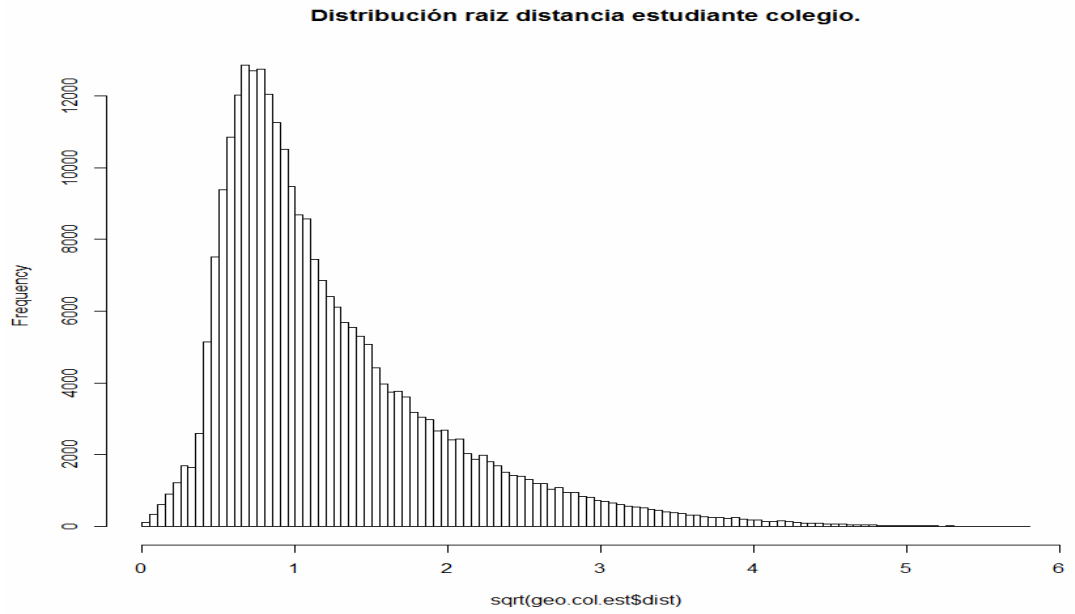


Figure 3–Distribution Square Distance Student from Schools.

understanding education as a complex system. It is necessary to rethink the approach to this research problem, introducing innovative methodologies that combine statistical elements, agent-based modeling and geographical information systems (GIS research should guarantee full confidentiality the personal data of individuals and families, according to the ethical principles of scientific research [117]). Therefore, to reformulate the research question, the following questions should be addressed: how socio-spatial structure affects the interaction between educational agents and, particularly, how it affects the competition between educational institutions? How they affect the real freedom of choice in socially interactive contexts? Due to the above, to what extent the spatial structure reduces the efficiency of the voucher system, in comparison to alternative systems? What would be the effects of changes in public policy, considering geographical condition and interaction networks? Therefore, future research should approach educational choice by means of agent-based modeling and simulation of the effect of the space-time structure on the choice of educational institutions by the families, in the context of a free choice system and State funding through vouchers.

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X. APPENDIX

i. Factor analysis of principal components: eigenvalues and total variance explained to derive six factors

Total Variance Explained

Initial Eigenvalues			Extraction Sums of Squared Loadings	
Total	% of Variance	Cumulative %	Total	% of Variance
3,863	19,314	19,314	3,863	19,314
2,808	14,041	33,356	2,808	14,041
2,042	10,208	43,563	2,042	10,208
1,687	8,435	51,998	1,687	8,435
1,146	5,731	57,729	1,146	5,731
1,052	5,262	62,991	1,052	5,262
,937	4,686	67,677		
,921	4,604	72,281		
,870	4,348	76,630		
,683	3,413	80,042		
,649	3,243	83,285		
,594	2,969	86,254		
,491	2,456	88,710		
,477	2,383	91,092		
,448	2,242	93,334		
,383	1,914	95,249		
,295	1,477	96,725		
,254	1,269	97,995		
,227	1,133	99,128		
,174	,872	100,000		

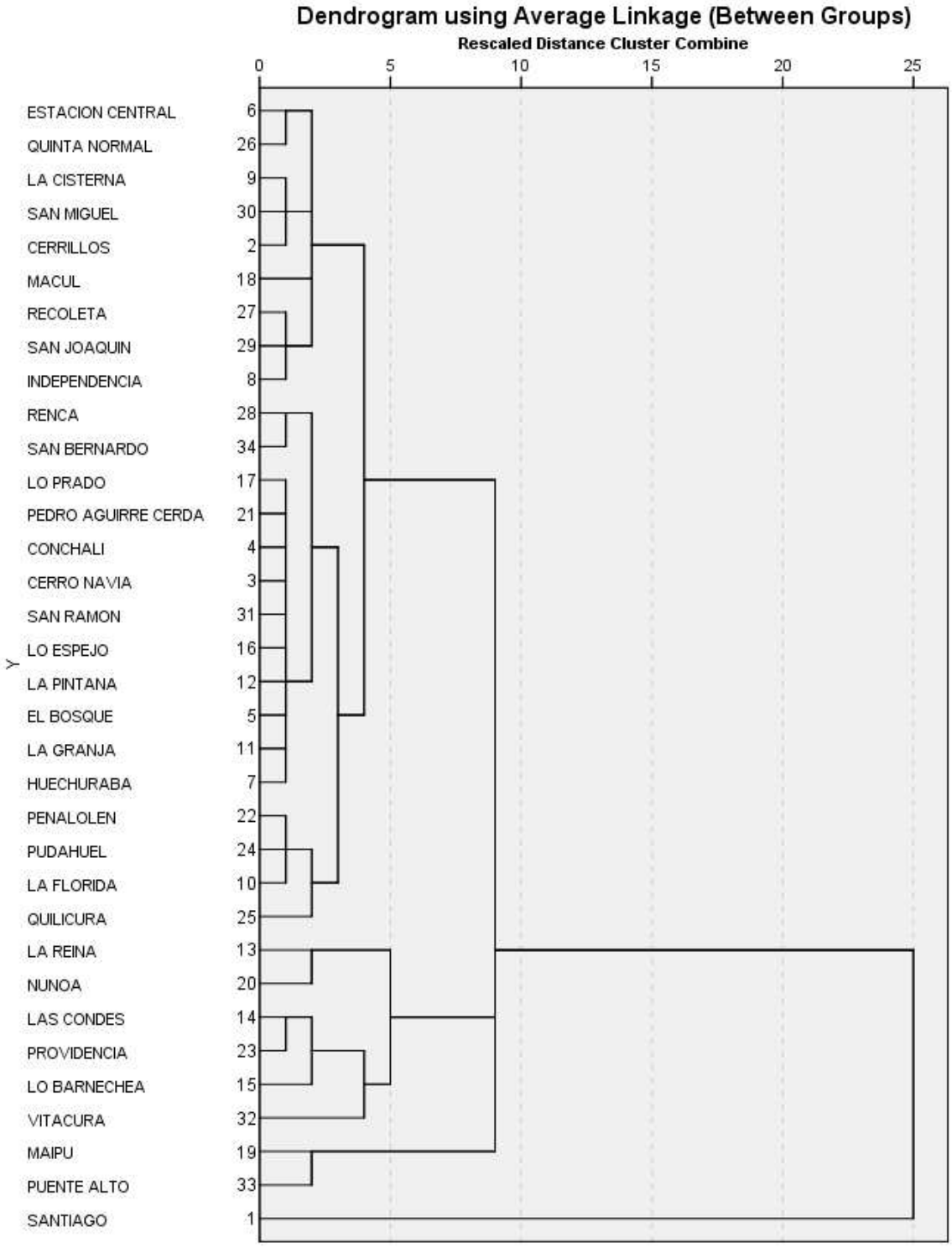
ii. Factor analysis of principal components: Rotated component matrix

Rotated Component Matrix[a]

	Component					
	Desarrollo comunal	Capital económico y cultural	Socialización secundaria	Poder	Servicios de salud y crecimiento habitacional	Desarraigo
Seguridad	-,752	-,020	,011	-,066	,257	,055
Condiciones Educacionales Municipales	,718	-,020	,488	,184	,017	-,090
Desarrollo empresarial	,633	,189	-,176	,251	,163	,097
Espacio	,541	,273	,238	,370	,302	,123
Calidad de Salud	-,510	,395	,088	,160	,393	,279
Finanzas Municipales	,483	-,104	,393	-,170	,206	-,078
Propiedad de transporte	,084	,800	,032	,252	,042	,115
NSE	,049	,766	,018	-,159	,018	-,054
Calidad de Vivienda y Hogar	-,179	,704	-,003	-,328	-,093	-,097
Nivel educativo	,283	,627	,063	,447	,133	,046
Acceso a informacion	,068	,108	,872	,052	,026	,014
Clima escolar	-,153	-,120	,791	-,021	-,196	-,059
Calidad de empleo	,193	,146	,674	,078	,120	,122
Posicion Ocupacional	,036	,070	,023	,749	-,061	,029
Inmovilidad diaria	,127	-,185	,061	,743	,243	-,151
Crecimiento de Vivienda	,089	-,013	,069	,085	,854	-,123
Salud municipal	,452	-,124	,421	,019	-,619	-,049
Movilidad habitacional	,014	,082	,028	,079	-,099	,771
Cultura civica	,131	,081	-,015	,342	-,095	-,412
Etnia	,010	-,369	-,017	-,109	-,050	,382

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 11 iterations.

iii Cluster analysis dendrogram



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