ORIGINAL PAPER

Socio-economic drivers of increasing number of slums in Chile

Francisco Vergara-Perucich [1] ✉

[1] Centro Producción del Espacio, Universidad de Las Américas, Chile
✉ *jvergara@udla.cl*

Abstract

Between 2017 and 2020 the number of households living in slums in Chile has increased by 73.52%, which has led the state to urgently develop housing solutions to reorient public policy in this area. This article contributes to this discussion through an exploratory statistical analysis to identify the socio-economic drivers that best help to explain the formation of slums in Chilean cities. The resulting predictive model is tested in Greater Santiago, the nation's capital, with good results, validating its usefulness for the design of housing policies. Among the results, low household income and the presence of international immigrants explain an increase in the probability of housing precariousness, while the presence of renters and heads of household with postgraduate degrees decreases this possibility. In addition to the specific scope for the Chilean case, the article shares a methodological strategy that can be replicated in other countries and cities to develop similar diagnoses.

Highlights for public administration, management and planning:

- A predictive model is developed using census data to identify the areas of the city where vulnerability of housing measured by socioeconomic factors may reflect precariousness of housing.

- Areas of the city with high rate of international immigrants and/or low-income households tend to predict precariousness of housing.

- Areas of the city where households' heads have postgraduate degrees and/or are tenants tend to have less probability of developing precarious housing.

1 Introduction

The right to housing is part of the Universal Charter of Human Rights in its article 25. However, different phenomena obstruct important groups of society from gaining access to safe, habitable, and affordable housing, as stated by UN-Habitat (2021), for which the least favoured groups are households living in slums. Slums are understood as pockets of poverty within urban areas with little or no access to public services, no security of tenure, and precarious material construction (Brueckner et al. 2019). In Chile, there has been a considerable increase in the number of people living in precarious housing in recent years, marked by a considerable increase in the number of households living in slums. Between 2019 and 2020 alone there was an increase of 73.52% of households living in slums ((TECHO 2021). A survey conducted by the Ministry of Housing and Urbanism indicated that over 50% of families made the decision to live in slums for economic reasons.

The assessment of the housing problem in Chile is usually based on the inequalities of the market, the main provider of housing solutions either through private supply or through projects subsidised by the state. Although Chile during the 20th century had a housing production model organised by the state, with the national urban development policy of 1979 and the neoliberalization process of the housing market, the economy took on a predominant role in access to housing (Bohoslavsky et al. 2021; Daher 1991; Trivelli 1981; Gobierno de Chile 2014)[1]. With these changes, housing prices in Chile increased steadily from 1980 onwards (Vergara-Perucich 2018; Arriagada Luco & Simioni 2001) and in the face of the shortcomings discovered by an accelerated housing production without urbanism (Sugranyes & Rodriguez 2005), the process of social housing construction slowed

down and the mercantile production of the city became the major supplier of housing, thus changing the patterns of urban development in large cities (Cattaneo Pineda 2011). For decades the housing provision model has relied on a subsidiary model and the real estate market, however, this model does not have instruments to monitor the socially useful effectiveness of the resources employed, which between 1998 and 2017 increased by 665% even though in the same period the equivalent of 19.3 billion dollars at current value were invested (Vergara-Perucich 2021). There is a diagnostic problem with the housing solutions applied in Chile, given that by implementing public policies whose design ignores the socio-economic problems that tend to reproduce the housing deficit, the subsidised mechanism ends up injecting resources into the market (Razmilic 2010) rather than resolving the reproduction of the existing deficit.

This article seeks to provide descriptive evidence on the socio-economic conditions that could help to explain some critical aspects that influence the decision of a family to move to a slum or to live in precarious housing in the case of Chile. To elaborate this analysis, two complementary stages are carried out: in the first, the CASEN -socioeconomic characterisation surveys- of 2015 and 2020 are used, with more than 290 thousand responses to the survey divided among 316 communes nationwide, in the first stage as a study by ordinary least squares to identify the variables with the greatest influence on the increase in the precariousness of the housing of the households studied. A second stage of evaluation, based on the results of the first analysis, uses census data at the block level to identify the spaces with the highest risk of housing precariousness for these households for the case of Greater Santiago. This second stage was possible because the results of the first stage generated significant variables that had a representation in the 2017 CENSUS, which offers more detailed geospatial representations than the CASEN survey, which allowed us to elaborate a LISA analysis of spatial autocorrelation and their respective cartographies in Chile's capital city. Although these results are descriptive, they offer valuable information for the design and effective targeting of housing policy resources, seeking to identify urban areas where different socio-economic factors could be informing the development of housing depreciation that urgently needs to be addressed. This analysis can also be useful for the design of a methodology to monitor public investment, and a more in-depth analysis of these results can help design a public policy evaluation instrument for the Ministry of Housing and Urbanism, expanding the matrix of factors to be used in the analysis.

2 Methods

This is an exploratory study with a quantitative approach whose objective is to obtain descriptive results by applying the econometric technique of ordinary least squares analysis for different socio-economic observations that arise from the survey of national socio-economic characterisation of Chile (CASEN) between 2015 to 2020. This analysis technique allows to review the linear relationship and degrees of influence of these socioeconomic observations with the number of precarious housings in the Chilean districts under study. Due to the massiveness and richness of the data, depending on the results of the statistical adjustment of the model, explanatory relationships between variables could be identified (Moreno Sarmiento 2013), which in this case are mainly derived from the slum survey developed by the Ministry of Housing and Urban Development in 2019, in which the main causes that promote the creation of precarious households forced to live in slums could be identified. From the specific analysis of observations to the question What reasons did you have to come to live in a slum?, twelve variables from the CASEN survey were identified that could be used to carry out a first test of ordinary least squares analysis. The details of these variables can be seen in Table 1. In general, some of the arguments of people living in slums could be classified as migratory reasons, low educational level, age, relationship between rent prices in the commune and income, unemployment, female heads of household, overcrowding, more than one family nucleus in the dwelling, reduced income, homeowners, and poor sanitary quality of the dwelling. On the other hand, to define the group of families in precarious housing, we use the question v1 of the CASEN 2015 and 2020 surveys: What is the type of housing in which you live? Among the options for this answer, the following are considered precarious housing:

- Piece in old house, in tenement, in shed or subdivided space,

- Shelter, improvement, or emergency housing,

- Ranch or hut,

- Precarious housing made of reused materials (cans, plastics, cartons, etc.).

From this selection, a sample of 291,360 households considered precarious with presence in 316 communes of the country is obtained and the variation between 2015 and 2020 is measured to configure the dependent variable. Regarding the econometric technique applied, this is the general formula of linear regression to obtain ordinary least squares:

$$y_n = \alpha + \beta_1 x_1 + \beta_2 x_2 \cdots \beta_i x_i + \epsilon_i \qquad (1)$$

Where y_n is the dependent variable (precarious housing), then α is the constant of the dependent variable that intercepts the regression curve, ϵ_i represents the random error, while β_i are the estimated coefficients for each dependent variable x_i, which are listed below in Table 1 .

Table 1 Independent variables for the analysis (x_i).

Variables	Obs.	Range	Min.	Max.	Mean
Three or more household per house	324	0.05	-	0.05	0.00
Immigrants	324	0.50	-	0.50	0.03
Mother living abroad	324	0.50	-	0.50	0.03
Postgraduate studies	324	0.47	-	0.47	0.07
Tenants	324	0.67	-	0.67	0.15
Price to income ratio	324	0.57	0.13	0.70	0.32
Low income	324	0.78	0.08	0.85	0.53
Woman as household head	324	0.26	0.43	0.69	0.53
Mother living in same district	324	0.74	0.18	0.91	0.59
Owners	324	0.91	0.09	1.00	0.68
Unemployed	324	0.34	0.66	1.00	0.87
Average age per district	324	20.96	36.99	57.95	48.13

Source: authors based on CASEN 2015 and CASEN 2020

A multi-co-linearity analysis is applied for the dependent variables of the study to define the statistical model to be presented. Regression models with variance inflation greater than 5 were discarded. The models were ensured to have a good statistical fit for selection both at the r^2 level and in their statistical significance measured by a p-value of less than 0.05.

The case where the results will be tested is the metropolitan area of Santiago. The case to test and illustrate the results of the analysis is the metropolitan area of Santiago, a city that consists of 40% of the national population and 79% of the housing market. This city of more than 8 million inhabitants is made up of 32 autonomous administrative units known as communes, each with a mayor's office and a council that oversees the initiatives of the local mayors. This city has

no authority, such as a major mayor, to coordinate the rest of the mayors. In its functional configuration, there are few communes with a high diversity of functions, mainly the communes of Santiago, Providencia and Las Condes, but they are mostly residential communes. The political-administrative division of the territory of Santiago and the definitions of the limits of each commune configure a high level of residential segregation when measured by income. The location of high-income communes in the western sector of the city and low-income communes in the southern sector is very marked. This is due to a historical process and because the most aggressive urban expansion occurred from 1980 to 2010, when a deregulated real estate market prevailed without an active role of the state in land use planning. This has begun to change, but the effects of these changes have not been fully visible in the urban space. The results of the study are presented below.

3   Results and discussion

In a first approximation, an exploratory analysis of the Pearson correlation between the dependent variable, precarious housing, and the explanatory variables is carried out presented in Table 2.

Table 2 Pearson correlation between dependent variables and independent variables

Variables (X_i)	Precarious housing (Y)	Sig.	Obs.
Low-income	0.459	0.000	324
Price-to-income ratio	0.289	0.000	324
Postgraduate studies	-0.440	0.000	324
Tenants	-0.305	0.000	324
Mother who lives in the same district	0.185	0.001	324
Owners	0.132	0.017	324
Unemployed	-0.099	0.075	324
Average age per district	0.087	0.118	324
Woman as household head	-0.063	0.262	324
Immigrants	0.039	0.479	324
Mother living abroad	0.039	0.479	324
Three or more household per house	-0.002	0.977	324

The variables with appropriate statistical significance and the highest correlation were low-income households, the relationship between income and rent prices, and households where

the head of household lives in the same commune as his mother. In indirect correlation, the variables of the heads of households with postgraduate studies and the households that rent their homes appear with statistical significance. This aggregate analysis at the national level does not necessarily define explanatory relationships between variables, but it does indicate that there is a certain linear relationship between the variables that is of significant strength. This first result, on the one hand, shows that some of the variables included in this analysis are appropriate, while at the same time indicating that for the stepwise regression analysis it will be important to generate a co-linearity test to avoid those two variables are explaining the same variance about the dependent variable.

Multiple linear regression (Table 3) is applied using the stepwise strategy, which allows for an iterative review of the statistical significance of the independent variables, thus filtering which variables should be incorporated into the final predictive model. For each iteration new variables are added to identify which are the most appropriate in order to generate an explanatory model for the dependent variable.

Table 3 Regression summary and its coefficients to precarious housing as Y

Variables (X_i)	B	SE	Beta (Std.)	p-value	VIF	r^2
(Constant)	0.421	0.062		0.0000		0.321
Low income	0.396	0.089	0.298	0.0000	2.14	
Immigrants	1.235	0.195	0.385	0.0000	1.739	
Tenants	-0.514	0.137	-0.268	0.0000	2.419	
Postgraduate studies	-0.608	0.19	-0.208	0.0020	2.015	

The regression model indicates that the main explanatory variables report 32.1% of the variance of the dependent variable. This result is valuable, considering the statistical robustness of the model based on information from Chile's socio-economic characterisation survey, the main socio-demographic profiling instrument for the design of public policies in Chile. Co-linearity coefficients of less than 3 are observed, so variance inflation indicates that each variable included in the model is explaining a different aspect of the dependent variable. In the first order, the most directly influential variable is low-income households, in a direct relationship with the dependent variable, together with households composed of immigrants. On the other hand, the variables in inverse relationship are the presence of renter households and households whose heads have postgraduate studies. In summary, the study indicates that there is a higher probability that housing precariousness is occurring in low-income and immigrant households, while this probability decreases in renter households and in households where heads of household have completed postgraduate studies. One of the limitations of the CASEN survey is that it does not offer spatial units of analysis within the districts studied. The most detailed spatial unit for this survey is the commune. However, the regression results allow for a proxy with census data, whose most detailed spatial unit of information is at the block scale. The 2017 CENSUS asked questions that allow to generate a proxy dataset for each of the significant variables indicated by the regression model. Table 4 indicates the criteria that allowed to generate a detailed cartographic interpretation of the regression results for each variable.

From this information, a set of cartographies is generated for Greater Santiago, indicating those urban spaces most vulnerable to the possibility of falling into a situation of probability housing. The formula for calculating the weight of each census tract on the variables is made by applying the regression results, as indicated below:

$$\check{I} = \alpha + \beta_{1'}x_{1'} + \beta_{2'}x_{2'} + \beta_{3'}x_{3'} \qquad (2)$$

Where α is the regression constant, $\beta_{1'}$ are the coefficients resulting from the regression and $x_{i'}$ are the specific census factors for each census tract, thus identifying the specific weight of each variable in the total $\check{I}$. To do this representation, it was important to consider the socio-economic configuration of the city of Santiago, using data from the Observatorio de Ciudades of the Pontificia Universidad Católica de Chile, available on their analytical mapping website (OCUC-UC 2021) In Fig. 1, the lower the socio-economic level by income of each spatial unit, the darker the colour. The purpose of including this map is to illustrate to people who do not know this city how socio-economic groups are distributed in the urban space, before identifying the spatialities of those households most likely to fall into situations of housing precariousness.

Being a result that is represented in Fig. 2, in the eastern sector of the city, there is a lower risk that these households fall into a situation of housing precariousness, a situation that is accentuated towards the extreme southern and western areas of the city. At the district level, Quilicura, Renca, Cerro Navia, Quinta Normal, Cerrillos, La Pintana and Puente Alto are communes that present a high

Table 4 Interpretative proxies of census variables for regression results

| Variables in the model	CENSUS variables	Calculation rationale for proxies
Low income	Schooling Age	Weighted value between schooling years and age. The lower the schooling with higher age lowers the income.
Immigrants	Country where household head were born	CENSUS direct question.
Tenants	Tenancy situation	CENSUS direct question.
Postgraduate studies	Schooling	CENSUS direct question.
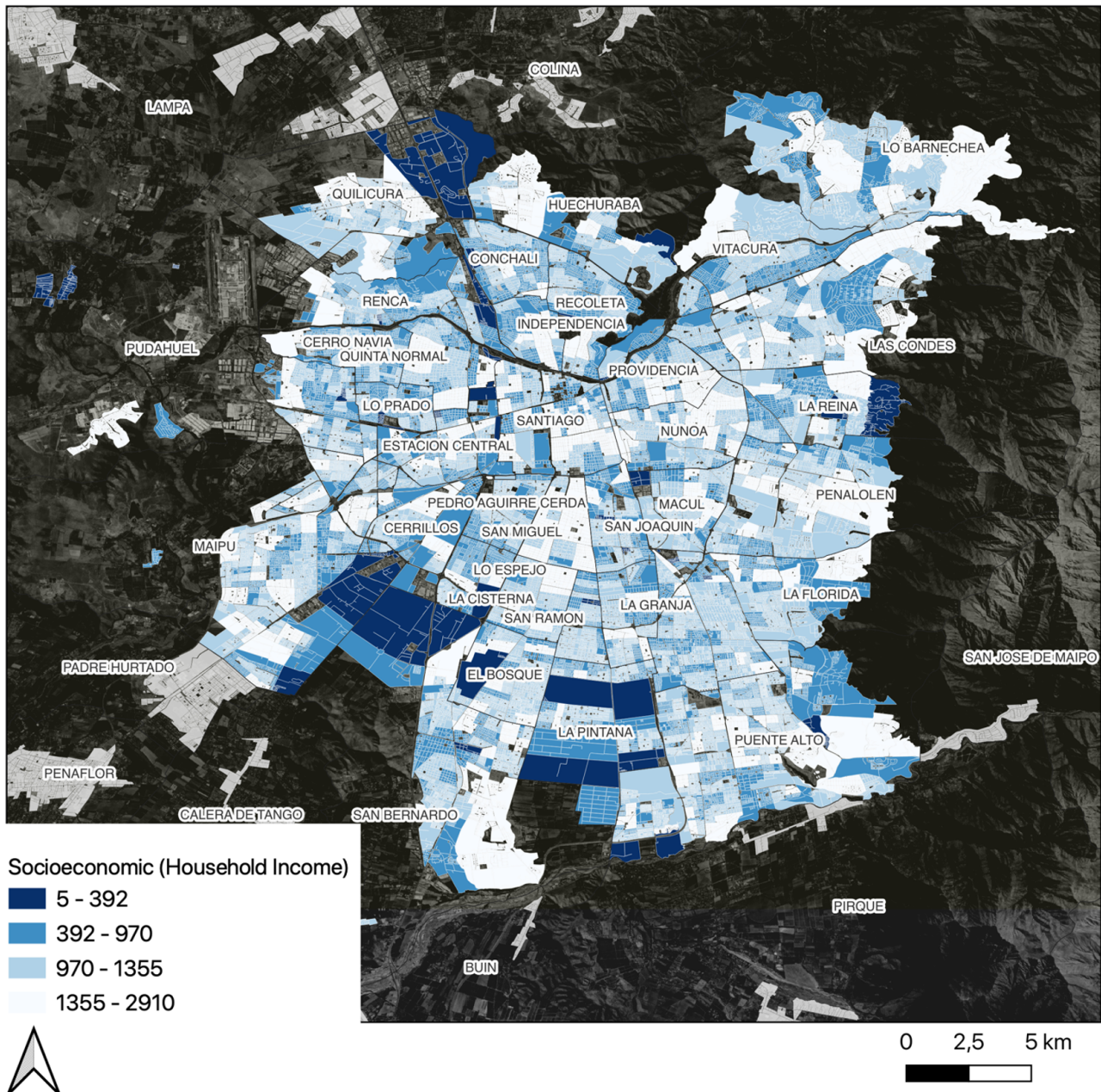
Fig. 1 Socio-economic category of households by income level in Greater Santiago
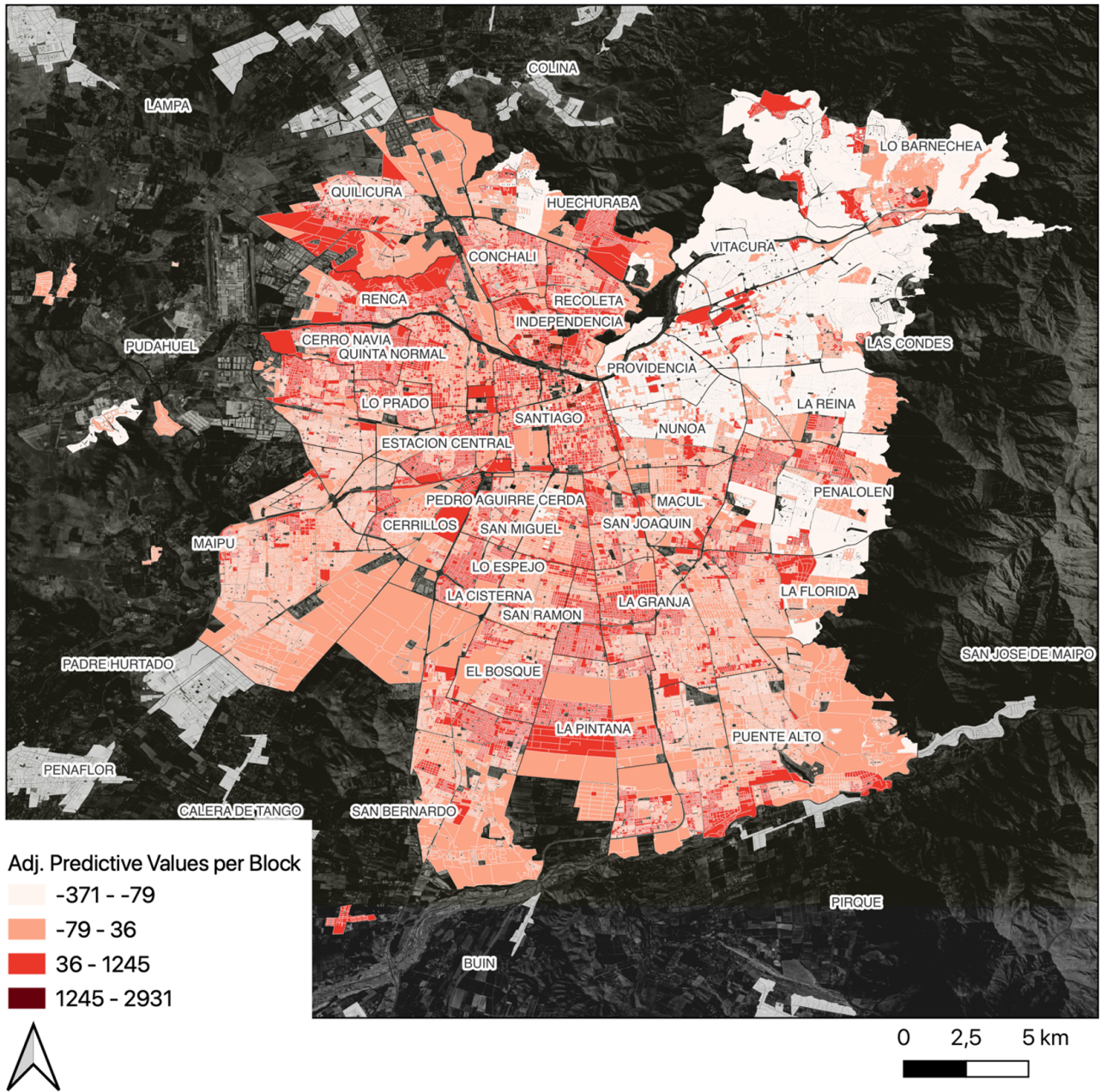

Fig. 2 Predicted results with resulting regression function by block according to higher risk of precarious households

risk in relation to the vulnerability of their households. The probability of the emergence of new forms of housing precariousness in these communes is high and requires special attention from their local authorities and the Regional Government, considering that the data used for this study are from 2017 and the reality of the pandemic could have increased the risks for the most vulnerable households, a situation that has not yet been fully investigated.

To improve this interpretation of the results at the level of territories, the variables are evaluated under a spatial autocorrelation analysis by Luc Anselin's LISA method (Anselin 2010), in order to see the degrees of agglomeration of households that, due to their vulnerability, deserve attention from local authorities. For this case, the Moran strategy has been used, which can be written as follows:

$$I_j = \frac{z_i}{m_2} \sum_j w_{ij} \; ; \; m_2 = \frac{\sum_i z_i^2}{n} \tag{3}$$
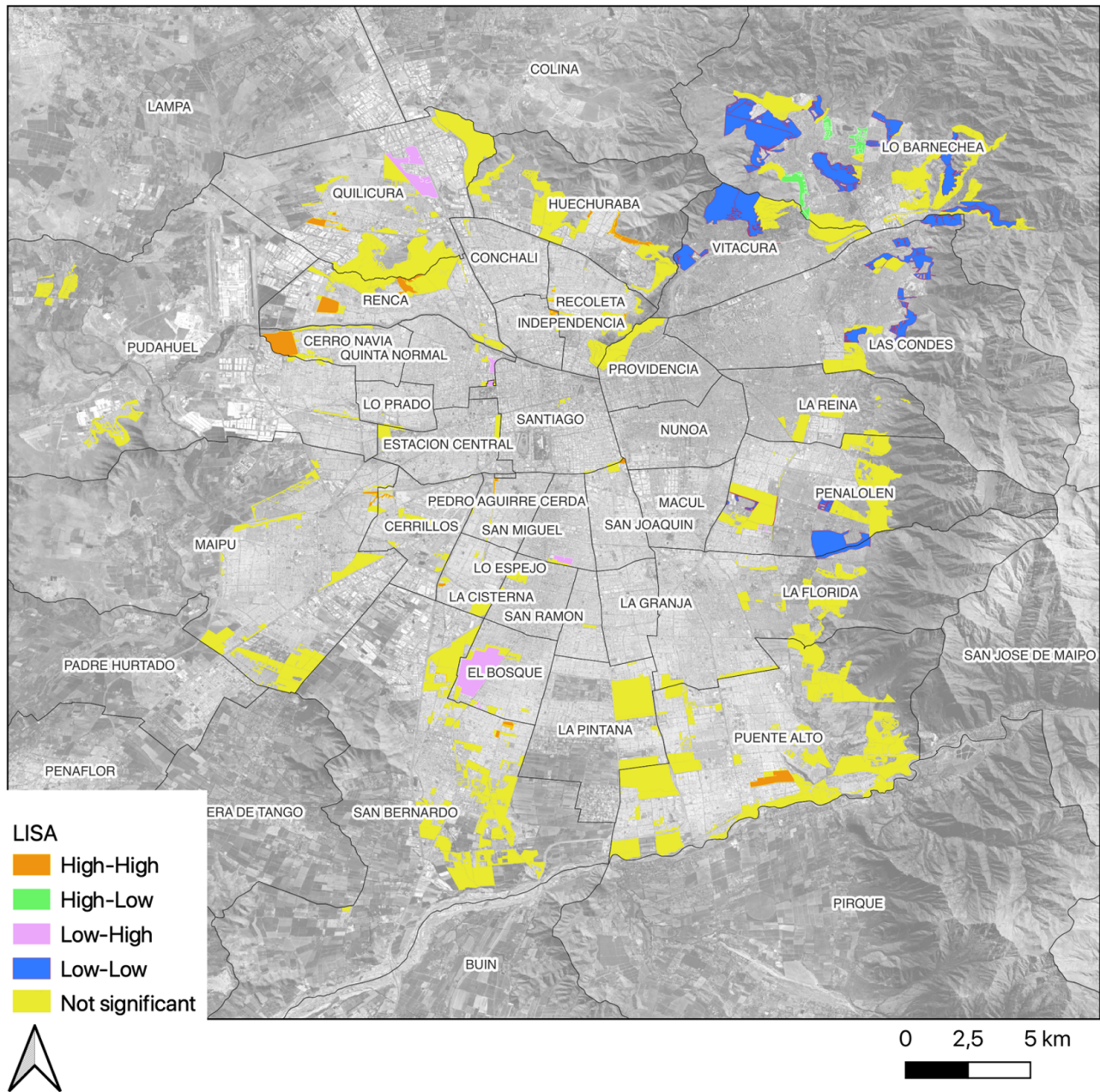
Fig. 3 Spatial autocorrelation map for LISA coefficients

Where m_2 is the variance of the distribution of the variables for the set $z_i = y_i - y$; w_{ij} is the spatial weight assigned to the observations of the variables ii together with ji, and n is the number of observations. This geostatistical technique identifies the areas with the highest level of weighting of the results that deserve the most attention (high-high) and also to review where the isolated areas (high-low) break with apparently less vulnerable neighbourhoods (low-low).

In Fig. 3, these results are observed in the Greater Santiago. This analysis in specific relation to High-

High relations, points out the districts of Cerro Navia, Renca, Quilicura, Huechuraba, Puente Alto and San Bernardo where there is a greater probability of housing precariousness based on the model, with a marked location in the periphery of the city. On the other hand, some clusters appear in the peri-centre of the city, specifically in Pedro Aguirre Cerda, Cerrillos, Independencia, San Joaquín and La Cisterna.

To check the effectiveness of this study, based on the results of smooth analysis, with data from 2017, a distance matrix between the centroids

of these units is carried out with relevant levels of statistical significance on the potential development of precarious housing against the 2019 cadastre of slums for the city of Santiago of the Ministry of Housing and Urban Development, published in 2021. In this cadastre for Greater Santiago, 97 slums are indicated. Based on a distance matrix, it was assessed as a successful prediction that slum formations in the city would be located at an average distance of 1200 metres from the centroids resulting from the LISA analysis. As a result of this complementary analysis, the model had an accuracy of 22% for indicating where slums would be in Greater Santiago. As indicated in Table 5, accuracy was highest in the communes of Quinta Normal, Maipú, Huechuraba, Pedro Aguirre Cerda, Puente Alto, Santiago and Cerrillos.

Table 5 Distance matrix between centroids of LISA areas with statistical significance and actual location of slums in Santiago based on 2019 data.

District	Average distance (m)
Quinta Normal	224
Maipú	531
Huechuraba	563
Pedro Aguirre Cerda	708
Puente Alto	988
Santiago	1085
Cerrillos	1146
Renca	1595
Lo Espejo	1708
Cerro Navia	1767
Peñalolén	1836
La Florida	2116
San Bernardo	2118
El Bosque	2300
Quilicura	2532
Independencia	2822
Recoleta	2953
Las Condes	3154
San Joaquín	3284
San Miguel	4045
Lo Barnechea	4185
Vitacura	4315

Source: authors with Housing and Urbanism Ministry

The results indicate that there is an association between socio-economic factors and processes of housing precariousness, in which the authorities' action is highly relevant. Currently, the housing deficit in Chile is like that of 1998, despite a high level of investment in the provision of social housing. The subsidiary strategies in housing policy seem to be insufficient to meet these urgent needs.

In addition, there has been an important recent migratory flow from other Latin American countries and the socio-economic effects of the pandemic, which in the last two years could have aggravated the housing problem. The exploration of different housing solution strategies seems to be an unavoidable way forward in the coming years to prevent vulnerable households from having to move into precarious housing for socio-economic reasons.

4   Conclusions

Rodrigo Hidalgo coined the concept of precariópolis, referring to deteriorated urban spaces where state and market housing solutions fail to break the reproduction of a process of housing precariousness (Hidalgo 2018; Hidalgo et al. 2008). The results of this analysis are indicative that the concern for the formation of these precariopolises has a latent spatial representation that deserves further attention to seek appropriate solutions to avoid their reproduction, responding to Hidalgo's approach to this urban problem. Subsidiarity and the free market are insufficient to address the housing problem in Chile.

The multiple linear regression model at the national level identified four socio-economic drivers that with an acceptable level of statistical representativeness can contribute to predict those sectors of Chilean cities where there is greater vulnerability to the development of informal housing. Testing these results geographically for Greater Santiago, it can be observed that the model can predict the formation of new slums in urban areas, which, with different adjustments, can be useful for the design of targeted housing policies to avoid housing precariousness processes.

One of the limitations of the study is that in Chile there was a failed census in 2012 that triggered the development of an abbreviated census in 2017 whose data records did not provide the levels of information required for this type of instrument. Therefore, the incorporation of explanatory variables into the spatial analysis model was limited by the availability of reliable data for the analysis. A new population census will be conducted in 2022, so this study could be re-run to see how the results vary. In this sense, a key aspect is to increase the number of variables with statistical representation on the block scale. Thus, in 2023 Chile should publish the databases of a new population census. The new data will allow testing whether this model can be made more accurate. Another possibility for generating new approaches

to the research question is to work with time series techniques to identify causal factors for the increase of slums. Again, the current problem with such studies in Chile is that there are serial data at the national level and at most at the regional level, so the geographic precision of the results would not be optimal although it would allow one to contrast these results. Finally, the model applied to the city of Santiago could be applied to other cities in Chile to see if the statistical results are still significant.

Although this analysis has been carried out for the case of Chile, it is possible that the methodology and rationale of the study process could be replicated in other countries in order to identify similar patterns. It is important to mention that although in Chile there is good access to data in relation to the reality of Latin America, developed nations in Europe, Asia, or North America, where the volume and quality of data is higher, it could generate results with greater precision than those presented here and with important implications for influencing decisions on territorial planning and housing policy.

Given the inadequacy of housing policy in its current state, the Ministry of Housing and Urban Development must begin the process of overcoming subsidiary mechanisms. To begin with, a public instrument for monitoring the effects, effectiveness and gaps in housing policy must be created. This does not currently exist, and it is urgent that a redesign of housing policy considers official results vis-à-vis the implementation so far of the subsidiary system. International experience can help to reorient housing policy. It is difficult to find housing policies that do not achieve some success without the active participation of the state in the development, provision, and management of housing, whether in the form of concession, public housing, or fair rent. In this sense, the integration of new housing units with social objectives cannot be isolated from the planning process of urban services and specific functions such as work, educational and recreational areas. In other words, it is ideal for new housing solutions to emerge from integrated urban plans, where housing is part of the services offered by new developments rather than the driving force behind them.

Footnotes

[1] The process of neoliberalisation of housing is based on the state abandoning the organisation of allocation, planning and delivery of housing in order to let the market perform this task in a profit driven scheme. In the case of Chile, this occurred specifically through the dismantling of the territorial planning apparatuses that depended on the Ministry of Housing and Urbanism by releasing of taxes to construction companies, the expansion of urban limits by consuming agricultural areas and the liquidation of public land for the development of private real estate projects.

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