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Modeling Settlements Development in the Philippines

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ABSTRACT

A settlements model is formulated to identify the drivers of urban growth in the Philippines and to predict suitable growth areas outside Metro Manila. Historical population changes and spatial distribution in the country between 1960 and 2015 are analyzed, and trends in settlements development are reviewed. Based on established literature, 18 predictor variables are included in the model. Nine variables are found to be significant determinants of urban growth, of which the top four are related to economic activity. Stochastic Frontier Analysis is conducted to model the relationship between the growth drivers and settlements expansion, which subsequently allows the identification of suitable growth areas. Predicting where growth will occur next enables planners and decision-makers to refine strategies and foster balanced regional development in the Philippines. In response to the persistent issues of urbanward migration and crowding in cities, the model offers tools to direct population movements and to plan cities that are resilient, especially against health shocks like pandemics.

Keywords:
settlements development
urbanization
drivers of growth
spatio-temporal stochastic frontier model
growth modeling
balanced regional development

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INTRODUCTION

Studying the growth of settlements calls for an evaluation of how urban areas expand. This process is inevitably specific to a country, because there is no universal definition of urbanization and urban areas. What constitutes ‘urban’ varies between countries, and the threshold might be based on the number of inhabitants, infrastructure, and non-agricultural land uses and activities. The Philippines uses the population metric, with 2500 inhabitants being the minimum population

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threshold of an urban area (United Nations World Urbanization Prospects 2019). Urban areas are also defined using physical infrastructure density, such as kilometers of developed roads per square kilometer and structures per hectare. The availability of electricity, water, and communications utilities are considered, along with public transportation systems and social services like schools and health care.

Urbanization in the Philippines may be viewed as a process that expands an existing urban area by transforming or converting adjacent agricultural lands to non-agricultural uses (Chaves et al. 2020). An initial step in the analysis of urban growth is examining the inventory of alienable lands and identifying lands that are part of the public domain, which have been classified as alienable and disposable (A&D) (Commonwealth Act 141 of 1936). As these have not been categorized as forests, national parks, and mineral lands, A&D lands are within the commerce of men, and are further classified into various land uses, such as residential and commercial uses. In Philippine urban areas, we observe the development of residential subdivisions in the periphery of town centers (Atienza 2020). We note as well that the preponderance of non-agricultural activities along provincial and national roads connecting cities has spurred land use conversion along or near thoroughfares.

Runaway urban growth is expected to happen not in Metropolitan Manila but in small and intermediate cities (UN Habitat 2015). In 2015, the proportion of the population residing in urban areas in the Philippines was recorded at 51.2 percent, which means that some 51.73 million Filipinos lived in barangays classified as urban at that time (Philippine Statistics Authority 2015). By 2050, urbanization is expected to increase to 65 percent of the population (World Bank 2017).

Urbanization can be a driving force for growth and poverty reduction, as over 80 percent of global economic activity is concentrated in cities (World Bank 2017). If well planned and managed, cities can be engines of growth, opening opportunities for poverty reduction (World Bank 2017).

However, the Philippines has missed out on urbanization gains, even with its expanding economy. Unplanned urbanization, worsened by a fragmented approach to issues, constrains the national goal of achieving sustainable urban development. UN Habitat (2015) points to stumbling blocks such as deficient capacity of cities for inclusive urban planning and design; outdated and disjointed urban development policies, particularly on land management, public spaces, and private sector participation; sub-optimal financial management of local government units; and vulnerability of cities to climate change (UN Habitat 2015).

Consequently, ill-planned urbanization has swelled the urban poor stratum (Llanto 2007). Housing and land markets have fallen behind urban growth, creating an enormous demand for housing, social services, and secure land tenure (Llanto 2007).

Over time, the gap between housing demand and supply in the Philippines has widened. Ballesteros (2001) believes that the root of the housing shortage lies in the unaffordability of both housing and land for most households. The high price of land, especially urban land, contributes to the prohibitive cost of housing in the Philippines (Ballesteros 2001). Data from our model corroborate this finding, 20 years later. We note further a mismatch in housing supply and demand, especially in resettlement housing, as indicated by the phenomenon of displaced beneficiary families trooping back to their places of origin; distant, unsuitable, incomplete, and substandard settlement projects; and unoccupied housing units in government resettlement sites.

The absence of an integrated model for simulating the development of settlements in the country has brought about unplanned growth and urban sprawl. While there are planning tools for estimating future demand for land, infrastructure, and services based on population trends (see for instance the processes in the CLUP Guidebook 2014), these fail to consider the drivers of urban growth. Local Shelter Plans make use of population projections (DHSUD 2016), but shelter planning ignores growth factors.

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The settlements development model presented in the current study provides an analysis of the determinants of urban growth. The model adds a spatial dimension to the population projections by identifying growth areas. When planners have a tool for predicting new settlement areas based on identified drivers of urban growth, cities have a greater chance of being planned sustainably.

We ask the following questions:

- How do settlements develop in new growth areas in the Philippines?
- What drives urbanization?
- Where will growth occur next?
- How can new growth areas be integrated in the local planning process?

Trends in urban and settlements growth in the Philippines from 1960 to 2015 are reviewed to identify the prevailing drivers of urban growth, such as economic zones and major road and airport infrastructure projects. Following an analysis of these growth factors, potential growth areas for the period 2020–2035 are identified. The model is validated in an urbanizing pilot province, where land requirements are projected and suitable locations for settlements are identified.

The model offers local government units a tool they can use to recognize particular development drivers in their towns. It is hoped that planners are subsequently able to identify new growth areas and to simulate future urban expansion. The study offers program managers and local executives an integrated approach to balance the supply and demand for land by identifying suitable growth areas to meet such spatial demand. In the long term, the strategies are intended to induce balanced regional development, starting with the decongestion of Metro Manila.

Human settlements suitability

In their study "The Evolving Pattern of Philippine Human Settlements," Paderanga and Paraguya (2015) review the interaction of forces that led to the present configuration of population and economic activity in the Philippines. The characteristics that influence human settlements suitability are categorized into five themes: population, natural resource endowments, infrastructure investments and facilities, economic and demographic activities, and climate change and natural disasters.

Location is a significant factor affecting the safety and sustainability of human settlements (Paderanga and Paraguya 2015). The authors highlight the importance of ample, sustainable opportunities for livelihood without compromising the integrity of ecosystems and natural resources.

Urbanized areas and the economic activity they generate are spurred by the public investments in physical infrastructure, and subsequently attract migration (Paderanga and Paraguya 2015). Urbanward migration emerges as a determinant of population outcomes, particularly population size, age-sex structure, and spatial distribution (Paderanga and Paraguya 2015).

The authors point out, however, that infrastructure investments have been reactionary to prior build-up by private developers. This means that investments have lagged behind, rather than led to, economic and demographic growth. As a result, there has been a shortfall of economic and housing infrastructure, as well as the inappropriate location of population and business, increasing the cost of construction and maintenance of facilities (Paderanga and Paraguya 2015).

The development of Philippine human settlements has largely been the result of 'spontaneous evolution' engendered by unregulated developments by the private sector (Paderanga and Paraguya 2015). The authors suggest revisiting the planning of land, resources, economic activity, and population to navigate future development in a way that improves rather than leaves the human condition to chance.

Models for urban growth forecasting

Multiple studies have been developed to understand the drivers of urban growth and land use changes, as well as to forecast growth in different regions and countries. This section summarizes the different approaches in analyzing the spatial-temporal growth of settlements in urban spaces.

The use of models to simulate the potential conversion of agricultural lands to built-up areas in the Philippines was explored by Quintal et al. (2018). Their work centered on the Land Transformation Model, which integrated geographic information systems (GIS) and an artificial neural network. The model identified the drivers of urbanization and forecast three possible scenarios in the Seven Lakes Area in San Pablo City, Laguna. The distance to roads, distance to trails, distance to the Seven Lakes, slope elevation, and population density per barangay were found to bring about the conversion of agricultural lands to built-up areas. However, the forecast maps did not indicate where built-up development should be allocated or what could be done to mitigate adverse environmental impacts. The Quintal model recommends differentiating sub-types of built-up areas, such as residential, commercial, and industrial categories, for a better assessment of growth and its possible impacts. While the Quintal study is an excellent application of a land transformation tool, we find that it omits a discussion of infrastructure development as a factor affecting the mobility of people, accessibility of an area, and population inflows.

A Land Transformation Model was employed by Pijanowski et al. (2002) in the Grand Traverse Bay Watershed in Michigan, USA. The model illustrated how roads, highways, residential streets, rivers, Great Lakes coastlines, recreational facilities, inland lakes, agricultural density, and quality of views shaped urbanization patterns. Different spatial scales were assessed. The individual contribution of each predictor variable was examined and shown to vary across spatial scales. The model predictability increased substantially when results were aggregated by larger window sizes, with predictability being accurate 65 percent of the time (Pijanowski et al. 2002).

In the Philippines, Paderanga and Paraguya (2015) applied the Suitability Model for Human Settlements, which was implemented and automated in a GIS platform. The analysis identified areas suitable for human settlement based on a set of site characteristics. The authors considered suitability factors such as topography, slope, land cover, proximity to fault lines, roads, and streams, available natural resources, climate hazards, physical infrastructure, and demographic characteristics. Two levels of modeling were explored. The first tier generated an initial suitability model based on the inherent capacity of the area to sustain a society not frequently affected by climate hazards. The second level integrated this initial iteration with the infrastructure and demographic components to depict structures that were already in place and the current local population. Suitable areas for future housing and infrastructure development were subsequently highlighted.

SLEUTH models have been widely employed to explore urban growth and land use changes in different cities and continents (see for example Manca and Clarke 2012; Wu et al. 2010; Rafiee et al. 2009; Al-Shalabi et al. 2012). SLEUTH models are calibrated with historical data derived from satellite images to identify the predictors of local urban growth. The development of areas is simulated under 'business as usual' conditions plus alternative scenarios to evaluate the effect and extent of urbanization. The results are approximations that compare the consequences of different scenarios. SLEUTH, however, excludes components of urbanization such as population increase and socioeconomic variables.

MATERIALS AND METHODS

Theoretical framework

The Growth Pole strategy was initially related only to abstract economic space (Mercado 2002). Growth poles were first defined as "…centers (poles or foci) from which centrifugal forces emanate and to which centripetal forces are attracted. Each center being a center of attraction and repulsion has its proper field, which is set in the field of all other centers" (Darwent 1979, as cited in Mercado 2002).

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The concept of growth centers was later developed, in comparison to growth poles, referring to locations in geographic space. Economic and social development is initiated and transmitted to an area around the growth center (Mercado 2002). The concept has implications on the normative questions of regional economic development, especially on regional fiscal allocation. It posits that investment is best concentrated in growth centers rather than scattered around in some vague quest for 'balance' or 'equity' (Mercado 2002). Much of the work on growth centers has been based on the work of Boudeville (1966, as cited in Mercado 2002), especially in his notion of the three types of regions: homogenous, polarized, and planning regions.

In time, the growth center concept was refined to refer to the development of an urban center that triggers economic activities through infrastructure and direct incentives. Economic growth generates spread effects in the peripheral region in the form of increased employment and higher incomes (Mercado 2002). The pattern of regional development is expected to follow the growth of the urban hierarchy, and thus, regional gaps can be reduced by changing the structure of urban growth (Mercado 2002).

Where industrial expansion and primary production in the same geographic area can be planned together, the theory holds that the opportunities for creating symbiotic feedback relations between urban and regional areas should be maximized (Mercado 2002). Mercado (2002) observes that a metropolitan area may no longer perform the function of the growth pole of the peripheral region as the leading sectors of its economy become human resource-based rather than natural resource-based. Thus, its 'spread effects' may not be felt in its peripheral region. Moreover, its growth is no longer in response to growth in its peripheral regions but to the entire urban hierarchy, or in the case of big metropolises, megacities, megalopolis, or global cities, to the world economy (Mercado 2002).

Akin to the growth center strategy, the Central Place theory examines the location and spatial arrangements of settlements. Introduced by Walter Christaller in 1933, the theory states that the primary purpose of a settlement is the provision of goods and services to the surrounding market area (Keeble 1969). Such towns are centrally located and therefore may be called central places. Settlements that provide more goods and services than other areas are called higher-order central places, fewer in number but more widely distributed than lower-order central places. Lower-order locations have small market areas and provide goods and services that are purchased more frequently. Thus, central places offer more functions, and lower-order places fewer.

For Christaller, what matters is the centrality of a place, i.e., the facilities it provides as a center for services and the population it serves, which may not be proportionate to the resident population of that particular place. Nevertheless, he notes a connection between centrality and resident population. He used the number of telephones in a place to derive the degree of centrality, indicating the number of services the place performs apart from those relating to the needs of its inhabitants (Keeble 1969)

Location theory (see for instance Isard and Schooler 1959) posits that firms and households decide to locate in areas where their costs are minimized, compared to central place theory which establishes that settlements develop in areas containing infrastructure that generate business and employment, such as commercial centers and public markets (King 1985). Urban areas are differentiated from rural areas according to the land use and economic activities in these locations.

Distribution and size of settlements

Keeble (1969) explains that human settlements are not arbitrarily scattered but rather form a pattern, even if a highly irregular one. This pattern represents a simple distribution of settlements,

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largely based on food gathering among primitive societies. With the introduction of animal husbandry and crop cultivation, settlements were established near fertile land with a reliable supply of water. The population of any particular community was limited by the number that could be fed from the produce of the area (Keeble 1969).

The improvement of communication routes, introduction of wheeled transport, and centralization of administration resulted in a more complicated settlements pattern, although still based on the original distribution of communities. Keeble cites locations in England to illustrate the classification of settlements: (i) the national capital, (ii) provincial capitals, (iii) local capitals, (iv) fully-fledged towns, (v) urban villages or major rural centers, (vi) villages or minor rural centers, (vii) hamlets, and (viii) isolated farmhouses and agricultural workers' cottages (Keeble 1969). These places exhibit various degrees of centrality or nodality, perform different functions, and have different population sizes, visual characteristics, and intervals of occurrence (Keeble 1969).

Keeble notes, however, that there are a few sharp breaks in the continuity of size and spacing of centers, which gives the classifications some arbitrariness. The interventions that increase accessibility or self-sufficiency tend to change the function of places, diminishing the usefulness of the hierarchy of places. The manufacturing industry, geographic obstacles, varying land fertility, and irregular spacing of traffic routes are distorting factors that push and pull the pattern of settlements out of place (Keeble 1969).

As for the town size, R. E. Dickenson refers to Christaller's figure of 7 to 9 kilometers (4.5 to 6.0 miles) as the average distance between places in closely settled areas (Keeble 1969). Dickenson points out that this spacing provides a local service area that takes about one hour to traverse from circumference to center (2.5 to 3.0 miles) (Keeble 1969). Eva Taylor, on the other hand, puts the average distance of market towns at 10 to 12 miles in fertile lowland areas, an interval which makes possible the carrying of produce or driving of stock to a morning market (Keeble 1969). Finally, Dudley Stamp and S. H. Beaver consider 7 to 10 miles the normal distance between market towns in medieval England (Keeble 1969). As a result of the introduction of railways and the improvement of roads in the 19th century, fewer towns were required, and thus approximately every other one decayed (Keeble 1969).

Factors influencing land development

Chapin (1965) presents a recursive model of the land development process showing decisions by all actors involved, from policymakers to developers to households. Chapin models a sequence of decisions, the first being the developer's decision to prepare land for residential use; the second the builder's decision on dwelling unit types; finally, the third being the decision of the household to buy or rent a dwelling unit (Chapin 1965).

It is understood that each cycle of decisions modifies the market situation for the next cycle, and these are taken into account in the next decision sequence, being a recursive model. Chapin (1965) observes that households, firms, and other activities interact frequently, and need to be in proximity to one another, shaping location decisions.

Stochastic frontier analysis

The stochastic frontier model was first proposed by Aigner et al. (1977, as cited in Wang 2008) and Meeusen and van den Broeck (1977, as cited in Wang 2008) in the context of a production function estimation to account for the effect of technical inefficiency. It starts from the principle that a production function gives the maximum possible output with a given set of inputs. However, the use of technology in the production process may vary among producers and fully efficient producers may realize the full potential of the technology and obtain the maximum possible output for given inputs, while less efficient producers see their output fall short of the maximum possible level. Therefore, the underlying technology defines a frontier of production as deviations, which can be

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interpreted as inefficiency (Wang 2008).

Although the stochastic frontier model is often applied to the estimation of production and cost functions, an increasing body of research has adopted the methodology to other fields of study, such as labor market search models (Hofler and Murphy 1992 as cited in Wang 2008), financing constraints on investment (Wang 2003 as cited in Wang 2008), and economic growth of countries (Kumbhakar and Wang 2005 as cited in Wang 2008). A review of the existing models in the stochastic frontier literature is given in the work of Kumbhakar and Lovell (2000 as cited in Wang 2008).

Following the concepts and theories presented, the conceptual framework of the Settlements Development Model is shown in Figure 1.

Settlements development modeling framework

The first step in modeling settlements development is an analysis of the historical population growth and spatial distribution in the Philippines from 1960 to 2015.

Subsequently, the factors affecting urban growth and urbanization are identified. The model uses the province as the unit of analysis because some longitudinal and spatial data are unavailable at the city or municipal level. Data on the predictor variables in all 81 provinces in the Philippines are collected and included in the regression.

Correlation analysis and trend-pattern recognition are conducted to determine the prospective variables to be included in the model. All identified variables that are postulated to influence settlements development individually show a significant correlation to urban growth. To determine which are confounding factors, several frontier models that account for the spatial and temporal effects are created to ultimately determine the drivers of urban growth. The results are used to identify the new growth areas.

Spatial-Temporal Stochastic Frontier Model

Panel data contains information on both the temporal dependencies and the relationship among units at a specific point in time. However, if units are selected at one point in time using a probability sampling procedure, the induced sampling distribution often characterizes the basic independence of the observations. These are the most common models usually postulated for panel data.

At a specific time point, dependencies among units can be generated not only by the sampling distribution induced by the selection procedure but also by those influenced by other units within a specific neighborhood. Several measures of spatial distance have been proposed in the literature of spatial statistics. Depending on the complexity of the model and the problem, simple or complicated measures of spatial distance are needed.

In stochastic frontier modeling, several models are proposed, given the panel data. Assuming constant factor coefficients over time, Battese and Coelli (1992) postulate a time-decaying inefficiency (improving learning curve) as

$$y_{it} = f(x_{it};\beta)\exp(v_{it})\exp(-u_{it}) \quad (1)$$

$$u_{it} = \exp\{-\gamma(t-T)\}u_i \quad (2)$$

Eventually, the producers realize their failure to adopt efficient technologies and correct them, after which a more efficient production process is applied. Battese and Coelli (1995) further postulate that inefficiencies are a function of some exogenous variables and use the maximum likelihood technique in parameter estimation.

Many stochastic frontier models for panel data fail to simultaneously account for temporal dependencies, the improving learning curve of producers, spatial externalities, or the adoption of efficiency-enhancing technologies among the producers in a spatial neighborhood. Ignoring this aspect of the information contained in the panel data results in inadequate differentiation of the

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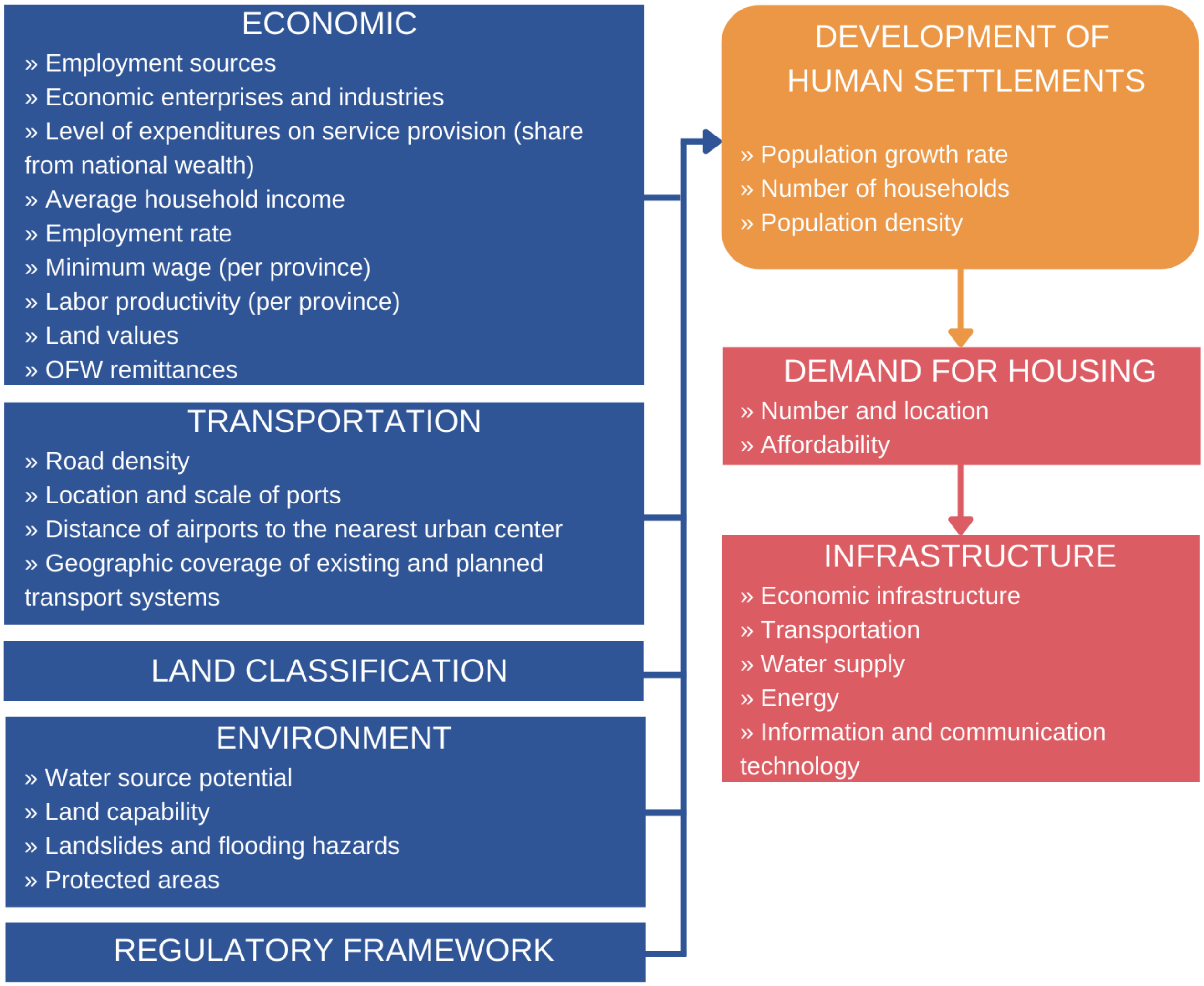

Figure 1. Framework of the Settlements Model

producer's efficiency-inducing potentials. Hence, it may result in inferior estimates of technical efficiency coefficients. Chudik et al. (2011) and Pesaran and Tosetti (2011) believe that the spatial model can only accommodate the weak form of cross-sectional dependence (CSD); thus the spatial-based approaches are potentially subject to biases in cases of strong CSD. Mastromarco et al. (2016) propose a way to accommodate both weak and strong CSD in modeling technical efficiency by combining the exogenously driven factor-based approach and an endogenous threshold efficiency regime selection mechanism. This makes use of unobserved time-varying factors to account for time-varying technical inefficiency.

A spatial-temporal stochastic frontier model is postulated as

$$\ln y_{it} = \ln f(x_{it};\beta) + v_{it} - u_{it} \quad (3)$$

$$v_{it} = \rho v_{it-1} + \psi_{it} \quad (4)$$

$$u_{it} = \frac{1}{1+\exp[-(w_{it}\gamma + z_{it}\phi)]} + \varepsilon_{it} \quad (5)$$

where, the subscript i refers to the producer and t the time period, hence, y_{it} is the output of producers i at time t, x_{it} are the factors of production, v_{it} is the autocorrelated pure error, u_{it} are measures of inefficiency, w_{it} are measures

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of spatial distance, z_{it} are other determinants of inefficiency, $\mathcal{E}_{it}$ and Ψ_{it} are white noise terms, β, γ, Φ, ρ and are the corresponding parameters. The production structure is assumed to be constant over time, hence reflected in time-independence of β. In a reasonably sized panel, the production structure is not expected to change because changes may have been brought by significant technological innovations that can be detected only in a much longer panel. The temporal dependence measured by ρ also assumes homogeneity across producers. The short-term dependency in efficiency indexed by ρ is not expected to exhibit structural changes within a short panel. Unlike Battese and Coelli (1995) who specified a non-negative-valued distribution for error terms, and hence, a more complicated likelihood function, the logit specification in equation (5) will ensure non-negative predicted values of u_{it} resulting in estimates of technical efficiency bounded above by 1.

A dynamic production parameter in equation (5) may account for the spatial externalities accounted for by the spatial indicator but will require a more complicated estimation procedure. Equation (4) can also be generalized to the higher-order AR process but the time-adjustment process of inefficiency reduction might be contaminated for much longer autoregressions given a short panel.

The additivity of the models presented in equations (3) to (5) will make estimation via the hybrid backfitting algorithm feasible. The estimation algorithm follows:

1. Equations (3) and (4) are combined and ignored $-u_{it}$ to estimate β and ρ simultaneously using generalized least squares. Compute the residuals $\hat{u}_{it} = \ln y_{it} - \ln f(x_{it};\hat{\beta}) - \hat{\rho} e_{it-1}$, this contains information on γ, Φ; e_{it-1} is the lagged value of the residuals from the fitted model.
2. Given $\hat{u}_{it}$, fit equation (5) as a general linear model to estimate γ and Φ.
3. The estimate of technical efficiency is
4. $$\mathrm{TE}_{it} = \exp - \left[\frac{1}{1 + \exp\left[-\left(w_{it}\hat{\gamma} + z_{it}\hat{\phi} \right) \right]} \right] \quad (6)$$

The simultaneous estimation of β and ρ yields optimality over individual estimation in pure backfitting of an additive model. Following the argument of Landagan and Barrios (2006), this will not necessitate further iteration of the algorithm.

The inclusion of autoregression in the error of the production function accounts for the producers' learning curve while also accounting for the possible cumulative effect of production errors. The spatial externalities that can vary over time and across neighborhoods help characterize efficiency and inefficiency differences among the producers.

Variable selection

Backward and Forward selection are variable selection techniques (Agresti 2013). Variable selection is a method of picking which variables to include in the model. It is a special case of model selection. Stepwise variable selection is a family of methods for including variables in a model sequentially.

Forward stepwise regression begins with a small model, taking into consideration all one-variable expansions of the small model, and proceeding to add the variable which is optimal, depending on some criterion. This criterion could be of the lowest p-value, highest adjusted R2, lowest Mallow's Cp, and lowest AIC. Variables are added one at a time until the criterion stops improving or has reached its optimal value. Meanwhile, backward stepwise regression starts with the largest model the team is willing to use and continues eliminating covariates until the criterion no longer improves.

Description of variables

Outcome variable

The outcome variable, or the variable of interest, is the main focus of the study which the researchers aim to explain or describe. In this analysis, the growth in the number of households in a province is the outcome or dependent variable. The development of a settlement is measured in terms of the projected number of (additional) households in a particular local government unit. The projections are made using the spatio-temporal stochastic model, which considers population growth as a production function, taking into account the efficiencies and the spatial dependency of the provinces. The advantage of using the number of households as the outcome variable is twofold. First, it is derived by dividing the population by the average household size of the province, thus accounting for different mean household sizes among the provinces. Second, the projected number of households equates to the number of housing units as a measure of housing need.

Predictor variables

The predictor or independent variables are the observable quantities that explain or describe the dependent variable. The predictor variables include economic factors such as employment sources, economic enterprises and industries, level of expenditures on service provision, average household income, employment rate, labor productivity, and migrant worker remittances. In the environment sector, the variables are water source potential, land capability, proportion of land with high flooding and landslide hazards, and proportion of land that is classified protected area. Factors related to access and transportation such as road density, location and scale of ports, the distance of airports to the nearest urban center, and geographic coverage of existing and planned transport systems are also considered determinants of urban growth.

The final outcome and predictor variables used in this study are shown in Table 1. These are variables for which official data is available for the study period 1960-2015 and in all 81 provinces in the Philippines.

Table 1. Variables used in the study

Type of Variable	Description of Variable
Outcome variable	Number of households per province
Predictor variables	Internal Revenue Allotment of the province (in millions of pesos)
	Total expenditure of the province (in millions of pesos)
	Total area of the province (in hectares) that has high to very high level of hazard to flooding
	Presence of ecozone - 1 if the province has at least one ecozone, 0 otherwise.
	Absolute distance of the center of the province to the nearest airport (in kilometers)
	Groundwater allocation
	Road density - total road length of the province (in km) divided by the total land area of the province (in km^2); km of road per km^2 of land area of a province
	Percent of the total land area of the province that is declared a protected area

RESULTS AND DISCUSSION

Population growth is viewed as a production function in which the provinces have varying efficiencies in terms of their output. This means that even if two provinces have the same values for the specified factors of urban growth, they can still have a different increase in the number of households due to their in/efficiency.

The spatial dependency of the provinces is also accounted for because the growth of each province is likely affected by its neighboring provinces. Thus, the use of a spatial stochastic frontier model can be viewed as the usual regression model but which additionally takes into account the efficiency and spatial dependency of the provinces.

A spatio-temporal model is used to look for the set of independent variables that greatly explains the variability in the number of households and removes all the multi-collinear explanatory variables. The model is given as:

$$\log(y_i) = \log[f(x_i;\beta)] + v_i - u_i$$

- x_i are the values of the factors for the ith province and β is the corresponding coefficient;
- $v_i \sim N(0,\sigma_v^2)$
- $u_i \sim N^+(0,(1-\rho\Sigma_i\omega_i)\sigma_u^2)$
- u_i and v_i are independently distributed of each other and of the regressors
- ω_i is a standardized row of the spatial weights matrix
- ρ is the spatial lag parameter ($\rho \epsilon[0,1]$)

The final model uses nine predictor variables: log of internal revenue allotment, log of average family income, log of total expenditure of a province, log of the area that has high hazard to flooding, presence of ecozones, distance of the nearest airport, groundwater allocation, road density, and percent of land in the province which is declared as a protected area. These variables are shown in Table 2, with the corresponding coefficients and significance values.

Table 2. Predictor variables with corresponding coefficients and significance values

Variable	Coefficient	Standard Error	Z Stat. (standard score)	P-value
log of IRA	1.163947	0.054284	21.44	<0.000
log of average family income in the province	0.668051	0.038624	17.3	<0.000
log of total expenditure of a province	0.055568	0.011599	4.79	<0.000
log of the area that has high hazard to flooding	0.013072	0.001903	6.87	<0.000
presence of ecozones	0.007063	0.001499	4.71	<0.000
distance to the nearest airport	0.000632	8.95E-05	7.06	<0.000
groundwater allocation	7.32E-06	8.46E-06	0.86	0.038
road density	0.0059941	0.00064	9.37	<0.000
percent of land in the province which is declared as a protected area	-0.0046631	0.0085923	-0.254	0.042

Using the model, the predicted number of households for each province in 2020 is computed by plugging in the 2015 values of the identified factors of growth. The predicted number of households for each of the provinces is ranked, resulting in the top 20 growth provinces:

1. Cebu
2. Cavite
3. Bulacan
4. Negros Occidental
5. Laguna
6. Pangasinan
7. Rizal
8. Davao Del Sur
9. Batangas
10. Pampanga
11. Iloilo

12. Nueva Ecija
13. Quezon
14. Leyte
15. Zamboanga Del Sur
16. Camarines Sur
17. Isabela
18. South Cotabato
19. Misamis Oriental
20. Negros Oriental

Thereafter, empirical sensitivity analysis is conducted by verifying if the top 10 and bottom 10 provinces in terms of growth that the model has identified are the same as the top 10 and bottom 10 in the actual 2015 Philippine census of population. The sensitivity analysis shows that the settlements model is robust.

Of the nine identified drivers of settlements growth, four are economic factors: internal revenue allotment (now called national tax allotment), average family income, government expenditure, and presence of economic zones. This result demonstrates the importance of economic development in inducing the growth of settlements. As well, it supports the notion that the economic capability of local governments, in terms of the national tax allotment and public expenditure, accelerates investments and creates economic opportunities, subsequently drawing migrants.

The settlements model predicts that the availability of support infrastructure such as road networks, ports and airports, and groundwater supply contribute to the attractiveness of a place.

The environmental factors 'area exposed to flooding hazard' and 'percent of protected areas' are understood as constraints to settlements growth. These variables are inputs to the suitability analysis of an area, that is, these criteria determine whether certain sites should be off-limits to urban expansion.

The top 20 growth provinces by 2020 -- the list holds even by 2030-- are distributed across the three major groups of islands of the Philippines: Luzon, Visayas, and Mindanao. However, none of them are in the National Capital Region or Metro Manila. It was decided to exclude the 17 cities and municipalities that comprise Metro Manila from this analysis on the assumption that the metropolis could no longer sustain settlements growth. The model provides policy recommendations that support the goal of the Philippine government to decongest the National Capital Region and generate a more balanced regional development in the country. The authors believe, nonetheless, that a separate study on Metro Manila settlements development would be worth pursuing to unmask the reasons for its continuing attraction to migrants and transient workers.

Forecasting and planning components

The settlements model has two components: Forecasting and Planning, as shown in Figure 3. The Forecasting component allows the identification of the nine main drivers of population growth; the projection of additional households; and the subsequent housing supply and housing demand balancing. This calculation, in turn, yields an estimation of the number of housing units, number of hectares, and costs required to accommodate the future population. The drivers of population growth and the projected number of hectares required for the additional housing units are used as inputs to land use simulation. Land use simulation depicts urban expansion and identifies the suitable location of settlements.

When the model methodology and results were presented to planners and policymakers for the first time, in January 2020, their immediate request was for the team to include a component that would enable its use in development planning. Thus, the planning component was added to integrate the model in the local development process.

Users are shown how the model can be integrated, first, through an analysis of the characteristics of the

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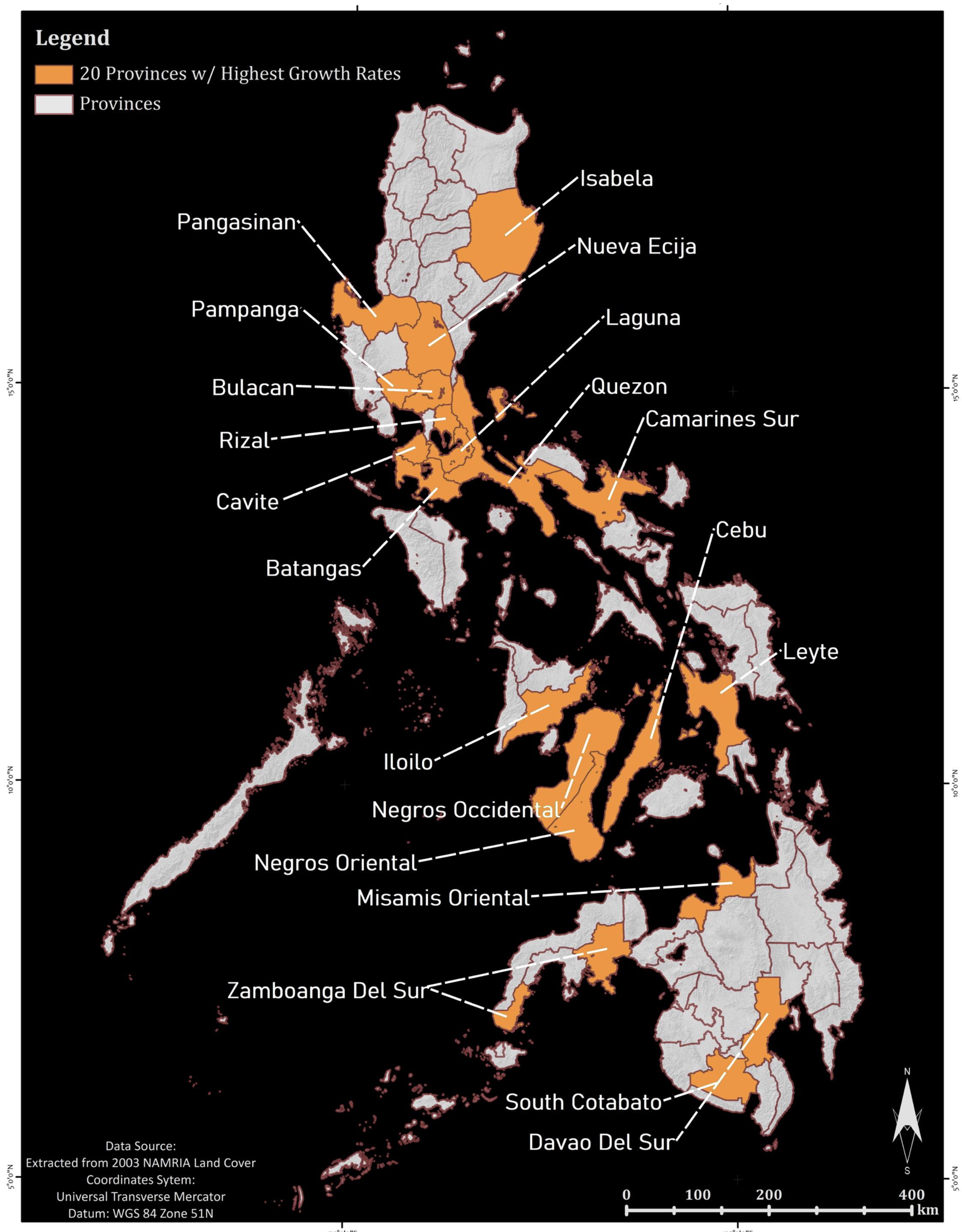

Figure 2. Top 20 Growth Provinces in the Philippines

local government unit, as well as its development vision. Second, the nine factors shaping settlements growth are used to direct spatial and development strategies at the local level. For example, economic zones have been shown to attract populations; so do airports and ports, as well as accessibility to the road network. Heightened government spending and Internal Revenue Allotment are important 'pull variables' for migration. Planning strategies are drawn using these established relationships.

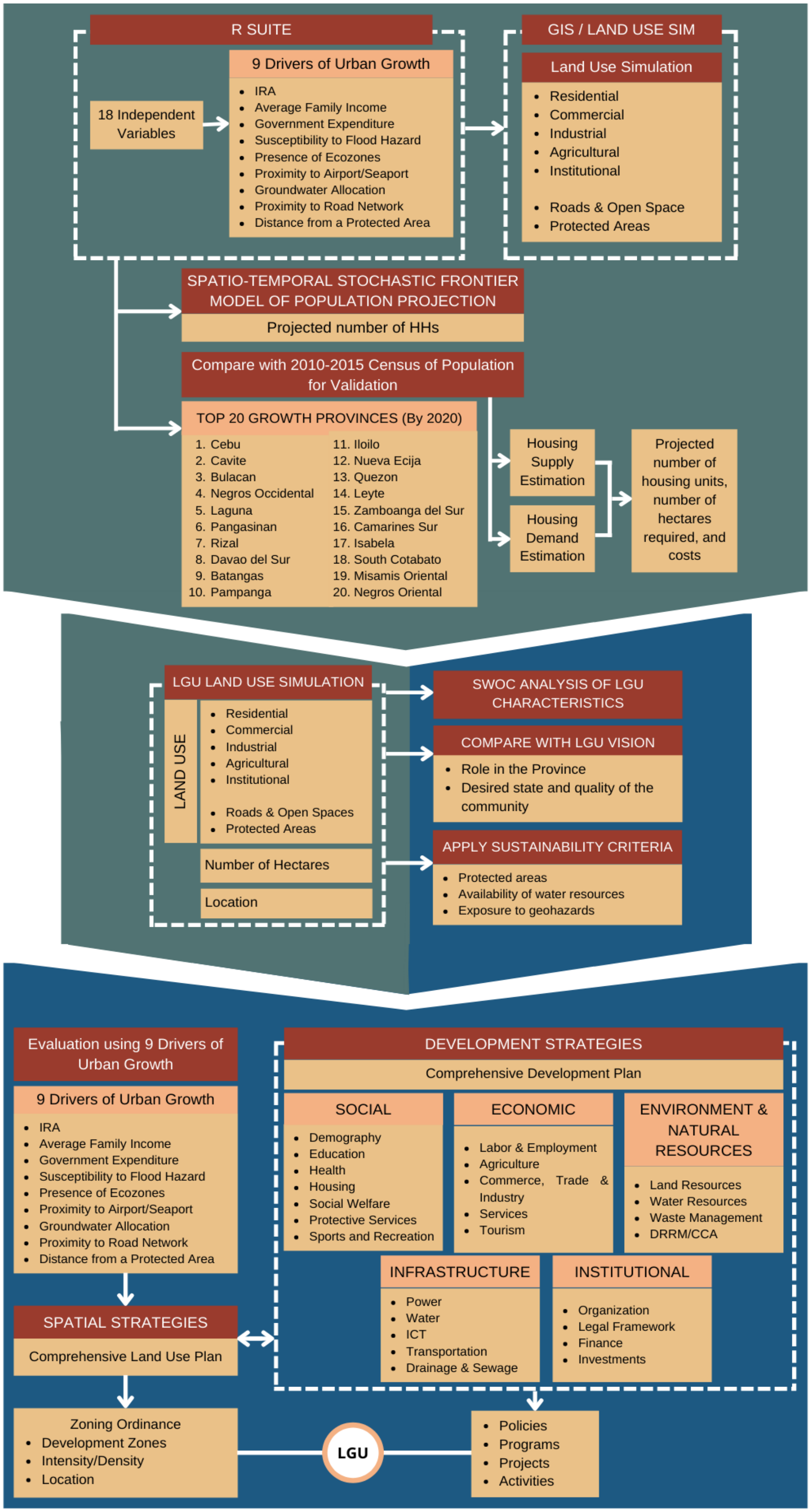

Figure 3. Model Structure

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Of practical interest is the tool to match the supply and demand of housing and land for the projected population. Finally, the model includes a discussion of planning the support sectors, notably economic, transportation, and infrastructure sectors, to sustain a settlement. The strategies are integrated in the Comprehensive Land Use Plan and Comprehensive Development Plan.

CONCLUSION

Use of the settlements model in planning

When the growth areas have been projected, the results are cross-checked with the contents of the Comprehensive Land Use Plan and the Comprehensive Development Plan, which local governments are mandated to update on a regular basis. If the projections are consistent or aligned, the roles of the fast-growing towns and the constituent municipalities in the planning area are identified. Subsequently, the growth nodes and their impact areas are validated.

It becomes essential to increase government spending in projects that develop and sustain these nodes and link them spatially and economically. This linkage will entail strengthening the connectivity and accessibility of growth areas through quality transport infrastructure, especially roads and air/seaports. City managers need to implement integrated land use and transport plans and increase the resiliency of new growth areas and their transport systems.

We find that sustaining local development entails engendering diverse economic opportunities using the livelihood assets or resource base of a growth area. This strategy applies even to non-central rural areas. Planners recognize the need to support suburban areas, where the population works in the agriculture sector but lives in urban barangays. When adequate services are provided in these suburban areas, the residents no longer need to go to the city.

The goal to attract migrants to the fast-growing provinces, cities, or municipalities by building upon their 'pull factors' is crucial. It is equally relevant to convince the migrants to stay in the selected site. The likelihood of staying increases with available economic opportunities in the area.

It is hoped that the model is practical enough for planners to manage the spatial distribution of population and to direct internal migration not just to promising cities, but also to less urbanized and less populated regions in the Philippines.

Correcting uneven development and the Balik Probinsya Program

The concentration of people and employment opportunities in the National Capital Region brings to the fore the longstanding issue of lopsided regional development and unequal distribution of economic activities. Dense concentrations of populations in Metro Manila contributed to the national capital being the epicenter of the COVID-19 pandemic in the Philippines, in addition to large cities such as Cebu, Cagayan de Oro, Iloilo, and Davao.

With that in mind, President Duterte issued Executive Order no. 114 on May 6, 2020, institutionalizing Balik Probinsya, Bagong Pag-asa. The program intends to boost countryside development and inclusive growth through the provision of adequate social services and support for full employment, industrialization, and improved quality of life in rural areas (Executive Order 114 2020). In the short term, the state encourages the voluntary movement of individuals and enterprises from Metro Manila to identified rural areas, a move implemented in the middle of the pandemic in 2020. Medium-term actions start with establishing special economic zones, especially in Visayas and Mindanao, followed by the development of micro, small, and medium-sized enterprises that are suitable in rural areas. Long-term strategies point to the proposed decentralization of powers and seat of governance, legislation on tax incentives for agricultural and tourism industries, and the creation of new urban centers outside the existing major ones (Executive Order 114 2020).

The DOST- PLANADES Settlements Model has been recognized as an important science-based tool to support the implementation of the Balik Probinsya program. Section 3.1.3 of the Implementing Guidelines of Executive Order no. 114 provides that government organizations consider using the DOST-PLANADES Model to calculate future housing supply and demand and to identify the suitable location of housing projects in emerging centers. The national government hopes that such an approach would result in a better allocation of returning residents to places that are complete and sustainable.

Crowding, rather than density, makes cities vulnerable

In the COVID-19 pandemic, the populations most at risk were those that depended heavily on the informal economy, occupied areas susceptible to shocks, had inadequate access to social services, political influence, and technology, and hence had limited capacities and opportunities to adapt (Boerwinkel 2020).

This raises the question of whether populous, dense cities are more vulnerable to pandemic risks. Studies (see for example Hamidi et al. 2020) find that COVID-19 infection rates are not significantly related to city density. Hamidi (2020) shows that higher density areas have, in fact, significantly lower virus-related mortality rates, possibly due to better health care. Hsu (2020) demonstrates that risk is associated with crowding (the number of people within an enclosed space, such as a vehicle or house) rather than density (the number of people per unit of land). Rader et al. (2020) observe that in China and Italy, larger and denser cities had larger and longer COVID-19 outbreaks, while smaller and less dense areas had shorter but more intense spikes.

High COVID-19 infection rates in large cities such as Chicago, New York, and Seattle reflect their global connection in travel, trade, tourism, and migration, more than their density (ITDP 2020). Infection exposure can increase with density, but other factors are more significant. Density is less a risk than factors such as global connections, public health programs, demographic structure, and lifestyle (Li et al. 2018). Richard Florida (2020) adds that the kind of density makes a difference in transmitting the virus, particularly when people are crammed together in multifamily, multi-generational households, or factories or frontline service work in close physical proximity to one another or the public (Florida 2020).

As for the Philippines, its large cities are both dense and crowded, making them ill-prepared for a health shock such as a pandemic. Urbanward migration persists and shows no sign of reversing. The country sorely needs to correct crowded urban conditions, starting with the decongestion of Metro Manila. At the same time, it makes sense to direct the unbridled migration to growth areas that are planned. Forecasting where growth occurs next empowers city planners to design settlements that are sustainable and resilient to shocks.

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