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Can Pakistan have Creative Cities? An Agent Based Modeling Approach with Preliminary Application to Karachi

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THE PAKISTAN STRATEGY SUPPORT PROGRAM (PSSP) WOKRING PAPERS

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ABSTRACT

Scholars and urban planners have suggested that the key characteristic of leading world cities is that they attract the best and brightest minds. As home to the creative classes, which consist of professionals working in knowledge-based industries, they are the bedrocks of prosperity and drivers of innovation. They not only provide unrivaled educational and professional opportunities, but also the best entertainment facilities such as art galleries, theaters and restaurants. Both through hard and soft infrastructure, residents of these cities enjoy seamless connectivity which fosters human creativity. When combined with population density, socio-economic diversity and societal tolerance, the elevated interaction intensity diffuses creativity and boosts economic productivity. However, rapidly urbanizing cities in the developing world are struggling to maintain adequate service delivery standards. The form and function of many cities are increasingly marred by congestion, sprawl and socioeconomic segregation, preventing them from experiencing expected productivity gains associated with urbanization. We operationalize these insights by creating a stylized agent-based model of a theoretical city, inspired by social complexity theory and the new urban literature. A virtual environment is designed where heterogeneous and independent decision-making agents interact under various policy scenarios, such as greater urban transportation investments and altered land-use regulations. By creating typical urban conditions, we conclude that the combination of mixed land-use, improved access to urban mobility and high societal tolerance levels foster creativity led urban economic growth.

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INTRODUCTION

Throughout the world many urban centers are the hubs of creativity and innovation as they attract the best and brightest minds, fostering creative thinking and expression (Landry, 2000). Not only is more than half the world population now residing in urban areas, but by 2030 all regions of the world including Africa and Asia will see the majority of its people living in cities. While the economic opportunities from this momentous transformation are truly unprecedented, cities must provide enabling policy environments for "enhanced productivity" that would turn urban centers into "poverty fighters" in the developing world (UN-Habitat, 2010). As home to what Florida (2002) terms "the creative class" cities are the primary drivers of sustained economic progress. But creative urban clusters can only thrive in cities that offer enabling environments that are conducive to the free flow of ideas, and provide the necessary facilities for transforming them into innovative products.

Leading cities around the world, the likes of Paris, London and New York, consistently attract the best human talent, thus becoming the hubs of creativity and innovation that in turn produce prosperity. They not only offer the best professional and educational opportunities, but boast the highest quality of recreational facilities and public services (Glaeser, 2011). In other words, they are the best places for both work and play. Through hard transportation infrastructure such as mass transit and well-designed public spaces like parks, art galleries and museums, they provide opportunities for human connectivity. They are inclusive, both in economic and social terms, providing comparable opportunities to all residents by avoiding policies that encourage exclusionary development and rent-seeking. But in many rapidly urbanizing developing countries including Pakistan, melting pots for thinkers and creative innovators to thrive are lacking (Planning Commission of Pakistan, 2011).

Contrary to leading world cities that are increasing embracing smart growth through mixed land-use, walkability and greater density, many developing country cities are moving towards low-density sprawl, gated communities and generally poor public transportation coverage (Henderson, 2002). In the case of Pakistan, the wealthy elites of Lahore and Karachi are increasingly residing in gated communities such as Defense Housing Authorities and Bahria Towns. Instead of walkability, they are encouraging increased reliance on automobiles. Instead of mixed land-use, they are embracing old-fashioned segregated zoning. Not surprisingly therefore, Pakistani cities are currently engulfed by a 'flyover frenzy' that achieves little in the way of solving the fundamental problems of urban development discussed later. While these housing schemes provide world class lifestyles to the lucky few, this model of urban development contradicts Jacob's (1961) widely respected view that cities are essentially "people systems" and hence should not be planned as mere networks of brick and mortar. Recent contributions in urban development literature offer stylized facts detailing the relationship between the spatio-temporal structure of cities and economic performance. For example, it is widely argued that greater population density, diversity and societal tolerance can drive creativity diffusion and thus economic productivity (Florida, 2002; Glaeser, 2011; Landry, 2000).

The purpose of this paper is to operationalize recent theoretical contributions in urban development through social simulation by focusing on the dynamic processes that produce urban clusters of creativity. Given their ability to abstract real-world social systems through simple individual level behavioral rules, agent-based models (ABMs) offer a rigorous alternative to conventional urban and regional modeling tools (Batty, 2007; Torrens, 2002). By creating a stylized virtual abstraction of a theoretical developing country city, we offer insights into the dynamic processes underlying creativity led urban development.

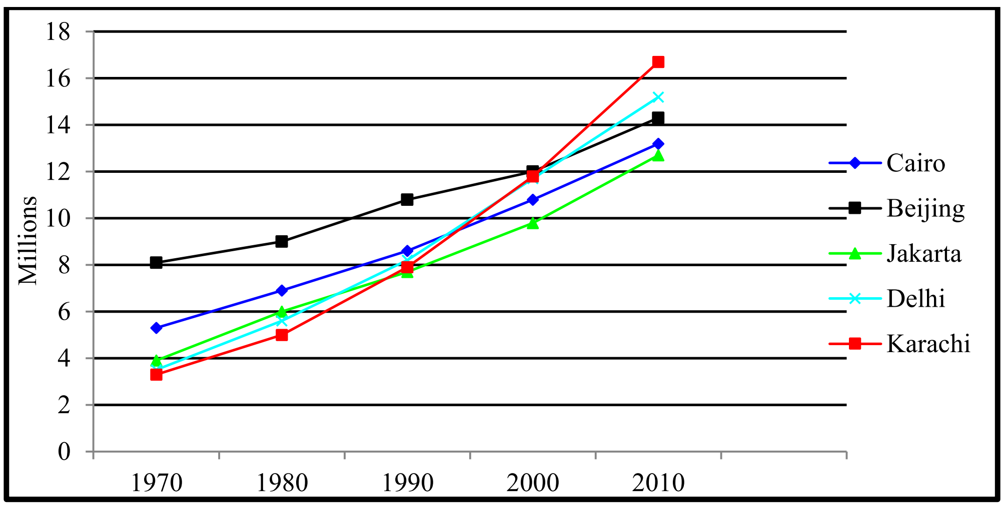
Through this model, we explore the following research questions: What are the key underlying factors inhibiting creativity led urban development in may cites around the world? And, what public policy options are available that can foster the emergence of creative clusters? Specifically, we will simulate the impact of introducing mixed land-use regulations (Glaeser, 2011), improving urban transportation services (Lucas and Rossi-Hansberg, 2002) and altering societal tolerance levels (Florida, 2002) on urban development parameters from the creative city perspective. Through heterogeneous and independent decision-making agents, parsimonious rules of interaction from existing literature, and attributes that abstract real-world urbanites, we create an artificial environment to ask "what-if" type questions and test hypothetical policy scenarios.

Following this introduction, Section 2 offers context to Pakistan's overall urban landscape with special emphasis on the state of affairs in Karachi. Section 3 will provide the background and discuss the role that ABMs can play in enhancing our understanding of the dynamic socio-economic processes within cities. In Section 4, we will introduce the Creative City Model, providing details about agents, the modeling landscape and rules of agent interactions. Thereafter, Section 5 analyzes results through a sensitivity analysis and a discussion of model verification before presenting scenarios under different parameter combinations. Finally, the paper concludes in Section 6 by linking key model outputs with real-world policy options available to planners in the developing world along with an overview of future research plans for furthering this project.

PAKISTAN'S STATE OF URBAN AFFAIRS: THE CASE OF KARACHI

Karachi is widely regarded as a microcosm of Pakistan with representation of all ethnic, religious and economic groups. It is not only Pakistan's largest city, but also its only functional seaport which served as the first national capital following independence in 1947. As of early 2012, Karachi's official population topped 11 million, making it the 11th largest city in the world. Other estimates from demographers put the number at over 18 million, based on the latest (1998) census failing to take into account 2 million aliens born outside Pakistan. This is because, in the last census conducted in 1998 the Pakistan Bureau of Statistics reported that they had not included 2 million residents of the city who were 'aliens' born outside of Pakistan. Demographers including Mehtab Karim of George Mason University and the University of Karachi have extrapolated this initial report to conclude that Karachi today hosts as many as 7 million 'aliens' who are not included in official population estimates. Irrespective of this disagreement, as evident in Figure 1, the city has experienced phenomenal growth since the late 1940s during which time the population has grown by 36 times. According to Karachi City Government (2007), the city's population is expected to reach 27.5 million by 2020. Such is Karachi's recent population growth momentum that Forbes magazine has termed it the "world's fastest growing megacity" with 80 percent growth between 2000 and 2010 to touch 20.9 million (Kotkin and Cox, 2013).

Figure 1: Developing Country Megacity Population Comparison



Source: Malik and Karim (2012).

To put these estimates in context, Figure 1 compares the population growth trajectories of five comparable megacities in the developing world. In the four decades preceding 2010, Karachi has galloped from being the smallest of the group to its leader, with the population more than doubling since the early 1990s. This extraordinary growth momentum, however, has been accompanied by severe pressures on public service delivery systems and deterioration in the security situation. Karachi has gained the reputation of being a largely lawless and violent city, with Foreign Policy magazine recently terming it the "world's most dangerous megacity" (Khan, 2013). Irrespective, the city continues to be the vital heart of Pakistan's struggling economic system.

Today, one out of every ten Pakistanis resides in Karachi. It is the financial and commercial capital of Pakistan, hosts the largest stock exchange and headquarters of all leading multinational and local corporations. It hosts 40 percent of Pakistan's financial activity and more than half of its bank deposits (Karachi City Government, 2007). Karachi is also home to Pakistan's largest television production houses, media and newspaper groups, professional organizations and military cantonments. The most crucial part of Karachi's domination lies in the economic realm. According to the Asian Development Bank (2005), the city produces 20 percent of Pakistan's GDP and generates more than 25 percent of national revenue. Furthermore, the Karachi seaport handles 95 percent of Pakistan's total foreign trade volume, both by providing freight handling and transportation services. It not only serves the rest of Pakistan but also its landlocked northwest neighbors including Afghanistan and Central Asian countries. Karachi's employment generation capacity can be judged by the fact that 45 percent of Pakistan's large-scale manufacturing jobs are located within the city. In addition, Karachi's primary economic advantage lies in the abundant and inexpensive supply of labor. It is hardly surprising therefore that the city has consistently been a magnet for economically distressed Pakistanis from throughout the country (Karachi City Government, 2007).

Pressing Problems and Misplaced Priorities

Notwithstanding the stark contrast between Karachi's importance for the Pakistan economy and its deteriorating socioeconomic situation, we will now provide an overview of the city's problems and current public policy priorities. In terms of spatial structure, the city is divided into vast swaths of low-density exclusively residential zones inhibited by high-income households and extremely congested towns with high levels of ethnic segregation. Since most jobs are in the central business district area around Saddar town, the highly inefficient and inconvenient transportation system incentivizes car usage, thus exacerbating the gap between the rich and the poor (Imran, 2009). Contrary to the pre-independence era when most workers in Karachi routinely would walk or bike to their workplaces each day, the current spatial structure has made the city extremely car dependent (Inskeep, 2012).

Ostensibly to improve the congestion problem, public investment has been pouring into the urban road network, featuring expressways for improving car-based connectivity between the suburbs and downtown areas. In fact all large cities in Pakistan are gripped by the politically rewarding 'flyover frenzies' which are essentially supply-side infrastructure policies (Noorani, 2012). However, as shown in relevant academic literature (Carli and Andersson, 2007), such policies only reinforce the perverse incentives sustaining urban sprawl. Moreover, there is ample evidence that additional road length in cities is associated with proportional increases in car usage, thus failing to alleviate the traffic congestion problem (Duranton and Turner, 2009).

In Karachi today, there are several missing elements which are preventing human creativity from fostering urban economic growth. The society of Karachi has low tolerance for new ideas; the illegal housing market is thriving; both urban sprawl and congestion are worsening; violence is on the rise; public transportation is inefficient and public spaces are non-existent (Planning Commission of Pakistan, 2011; Imran, 2010). Not surprisingly under such conditions, spatial segregation has worsened, with both ethnic groups and economic classes clearly separating themselves in their respective zones. For example, areas such as Orangi, Korangi and North Karachi dominantly host Urdu speaking household whereas Pushto speakers are concentrated in SITE and Kemari regions. This pattern of segregation emerged soon after the creation of Pakistan when Urdu speaking migrants arriving from India settled in newly developed areas whereas the original inhabitants (Sindhis) remained in their traditional zones.

The existence of widespread violence since the 1980s has exacerbated this segregation, as safety considerations force new immigrants to locate in neighborhoods dominated by their ethnic groups (Ahmad, 1993). Due to the lack of productive avenues and inclusive public spaces, diversity has in fact fueled ethnic violence. Unlike Western metropolitans, ethnic identities in Pakistan continue to trump individual and professional affiliations, which contributes to ethnicity based spatial segregation. Unless this unfavorable spatial structure is reformed, Karachi will continue to suffer from low creativity which will in turn hamper long-term and inclusive economic progress. The combination of poverty, unemployment and illiteracy will continue to fuel intolerance and extremism, thus completing the self-reinforcing vicious cycle of low human capital, great economic deprivation, unprecedented intolerance and political violence.

The challenge for the government in Pakistan is how to reverse these trends and improve economic growth prospects. The traditional supply-side policies of increasing infrastructure through foreign aid and domestic investment are not creating an ethos of creativity led urban and regional development. The key questions that policymakers must grapple with are as follows. What can be done to invigorate creativity in urban spaces? Is the perverse existing urban form and function the main problem? If yes, then how can public policy be altered to promote creative entrepreneurship in Pakistan's cities? As emphasized by the Planning Commission of Pakistan (2011), fundamental reforms will require the promotion of an alternative narrative, thus forcing rent-seeking elites to give up privileges by unlocking expensive swaths of State-owned land for public use. By way of economic incentives, private investments in creativity enhancing projects should be promoted simply by reducing the government's footprint on the economy (Auerswald *et al.*, 2011).

MODEL BACKGROUND

Before introducing the Creative City Model, this section situates relevant urban development policy literature in the broader context of economic growth and its sociocultural determinants. In addition, we explain why informing our simulation by viewing cities as complex adaptive systems helps gain unique new perspectives on urban development policy. The paper attempts to make a theoretical contribution in understanding the complicated relationship between human creativity, spatial structure of cities and economic development.

The Role of Creativity in Urban and Economic Growth

Economic growth theory was significantly influenced by Romer's (1990) theory of endogenous growth. Romer argued for moving beyond land, physical capital and labor as the chief determinants of economic progress. His contributions have since propelled human capital to the forefront of this long-standing debate. Economists including Barro (2001) and Cohen and Soto (2007) have empirically established the relationship between long-term productivity and human capital indicators, in particular educational attainment. Likewise, Krugman's (1991) work on the spatial structures of economics brought agglomeration effects into the limelight, and became the starting point for the literature on new economic geography. These ideas influenced leading multilateral agencies, notably the World Bank (2009) and the Organization for Economic Cooperation and Development (2006), to begin emphasizing the need to understand territoriality in the economic growth debate. In terms of policy advice, this implied advocacy for the need to maximize the benefits of agglomeration by reducing the inefficiencies caused by congestion. In other words, as cities and regions experience agglomeration effects and firms begin to cluster, urban services come under pressure to maintain quality (Hendersen, 2002).

Looking at the U.S. case, the main cause of traffic congestion in American cities is sprawl, caused by the socio-cultural preference for suburban lifestyle and enabling government policies. Suburban households enjoy larger landholdings with subsidized mortgage rates, vast networks of highways, affordable fuel prices and higher quality public schools (Glaeser, 2011). The cost of these luxuries however, is the need to commute long distances between suburban homes and workplaces, causing traffic congestion. These trends have spurred the "new urbanism" movement, which argues in favor of car-free urban living through walkable neighborhood designs (Duany *et al.*, 2010). Building on Mumford's (1962) arguments that urban sprawl had broken the relationship between people and their living spaces, the anti-sprawl movement has promoted "smart growth" as the alternative (Porter, 2002). Through transit-oriented development and walkability, it is believed this paradigm of urban growth fosters greater human interaction which is the key function of cities (Jacobs, 1961).

The productivity of these interactions however depends on the quality of human capital, which can be conceptualized as reflecting the level of human creativity, or vice versa. Andersson (1985) emphasized that human creativity is "generic not genetic" hence the creative potential in cities must be tapped for achieving prosperity. The "theory of the creative class" situates the creativity and urban development debate into the context of global economic transformations (Florida, 2002). With the diminishing relevance of the traditional land, labor and capital paradigm, human ingenuity has become the central force behind economic progress in the 21st century. Florida (2002, 2012) empirically demonstrates the link between economic prosperity and the proportion of the urban population whose primary professions require continuous application of their inherent creativity. Hence he argues that the key source of success in modern cities is their ability to attract and retain the most creative talent. And amongst them, places which provide high quality urban services will likely emerge as the centers of innovation and job creation. These perspectives however, have been criticized for glossing over concerns regarding deepening income inequality and social disparity (Peck, 2005). In addition, Marcuse (2003) and others have argued that the underlying research methodology supporting theory development naively equates correlation with causality. In other words, whether creative classes produce economic value or the other way around remains largely untested in modern metropolitans.

In the history of urban civilizations however, socio-ethnic and religious tolerance has been the hallmarks of great cities which fostered scientific and economic advancements through free interactions between diverse groups of individuals (Mumford, 1962). In emphasizing the need for creating unique brand identities of cities, Landry (2000) suggests that socio-economic diversity is essential for cities to remain "widely creative" with residents finding the "mix of imaginations required for the emerging complexities or urban life." Being inherently social creatures, humans thrive under conditions that facilitate their desire for social interaction. By allowing greater population density through vertical growth and mixed land-use, cities achieve the requisite scale for delivering high quality and largely affordable public services. In the United States, public investments in world class education alone can turn the best educated cities into "loci of development" (Glaeser, 2011). In addition, greater socio-ethnic and religious diversity as well as societal tolerance dramatically improve the productivity of human interactions by enabling the emergence of talent complementarities amongst creative individuals (Hagel et al., 2010).

The Creative City Model presented below operationalizes three key policy parameters from the urban development literature discussed above which are believed to foster creativity led economic growth: mixed land-use, greater public transportation access, and improved societal tolerance. Given the criticism on the methodological and causal dimensions of the "theory of creative class" (Peck, 2005; Marcuse, 2003) this model contributes to the debate by offering scenarios analysis through a virtual laboratory based on social complexity theory.

Cities as Complex Adaptive Systems

By viewing cities as complex adaptive systems, much like natural systems, we gain unique perspectives into their inner-workings through social simulation. Complex systems are defined by Simon (1962) as:

> *"…one made up of a large number of parts that interact in a non-simple way. In such systems, the whole is more than the sum of the parts, not in an ultimate, metaphysical sense, but in the important pragmatic sense that, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole."* (pp. 468)

The key definitional idea in complex systems is to observe global phenomena through local-level interactions (Crooks and Happenstall, 2012) as the richness of such systems depends on agent adaptions following interactions amongst them (Holland, 1995). The idea of viewing cities as complex systems originates from Jacobs' (1961) following observation:

> *"Cities happen to be problems in organized complexity, like the life sciences. They present situations in which half a dozen or several dozen quantities are all varying simultaneously and in subtly interconnected ways… The variables are many but they are not helter-skelter; they are interrelated into an organic whole."* (pp. 432 - 433)

At the time, these radical views triggered an intellectual movement against traditional, top-down urban planning approaches. Gradually, the idea that cities are organically growing systems gained ground, propelled by Alexander's (1964) argument that top-down planning processes were merely an artifact of post industrial revolution economic development. He further demonstrated that prior to the industrial revolution; cities were always planned from the bottom up. In essence, cities are hierarchical and non-linear systems where millions of residents depend on hundreds of simultaneously operating subsystems to sustain their daily routines. Like complex systems in nature, elements within urban systems cannot be explained by linear mathematical models as they exhibit emergence. In other words, cities as a whole are greater than the sums of their constituent parts which can only be explained by the underlying dynamism of their socioeconomic environments. They are layers upon layers of change without any holistic spatial form, thus urban systems often remain at "the edge of chaos" and system stability depends on feedback loops from their constituent subsystems (Batty, 1976).

Even before the concept of "networked infrastructure" became popular (Graham and Marvin, 2001) systems dynamics thinkers argued that whatever happens in one component of any social system had tremendous impact elsewhere (Root, 2013; Bonabeau, 2002). For example, the land-use and transportation systems are highly intertwined with the housing and social hierarchical subsystems within cities. The poor quality of public transportation profoundly impacts housing prices and thus land-use patterns through the crucial aspect of accessibility. By analyzing these interconnections, planners can gain novel perspectives into the dynamics underlying socioeconomic processes within cities.

Why Use Agent-Based Models in Urban Studies?

The operationalization of complexity theory is made possible by agent-based models (ABMs), which simulate social systems from the bottom up, thus allowing the emergence of previously unexpected macroscopic phenomenon from individual level interactions (Torrens, 2002). Recent strides in computing power have allowed urban modeling to evolve from a system-level focus towards individual-level interaction, thus vastly improving their explanatory power. While neighborhoods and land patches are the physical building blocks of cities, individual agents are the components of their human-societal structure (Batty, 2007). In criticizing large data-intensive urban models for their high resource demands, Lee (1973) argued in favor of models based on simple rules of interaction. Later, this demand provided the impetus for the widespread popularity of dynamic urban modeling (Wegener, 1994).

In recent years, ABMs have been applied to study a variety of urban issues, including land-use policy (Filatova et al., 2009), slum formation (Patel et al., 2012), pedestrian movement (Torrens, 2012), social segregation (Fosset and Warren, 2005), car traffic movement (Bjornskau, 2005), evolutionary urban growth (Bretagnolle and Pumain, 2010) and the landscapes of cities (Batty, 2001). ABMs have the distinct advantage of contributing towards "theory building" and "hypothesis generation" (Barros, 2012). Their explanatory power goes beyond correlations and causations, enabling the identification of specific factors dictating seemingly inexplicable agent behaviors (Epstein, 2006). When compared to econometric models, they typically feature a vast number of individual-level parameters affecting the decision-making of each heterogeneous agent. ABMs have the unique ability to handle numerous parameters simultaneously (Gilbert and Troitzsch, 2005). While mathematical models are mostly based on simplistic assumptions limiting their explanatory power, Miller and Page (2007) argue that ABMs have the crucial ability to offer constraint-free environments that produce unexpected outcomes.

However, little attention has focused on modeling the relationship between human creativity and urban growth. An exception is two recent contributions focusing on the economic geography and complexity science dimensions. Through a simulation of the creativity diffusion process using social network analysis, Spencer (2012) confirms that human diversity in large physical areas fosters the diffusion of creativity through production of novel ideas. He operationalizes several stylized facts from "the social psychology, network analysis and economic geography literature" to understand the dynamic interaction between physical locations, social networks and its economic implications. In addition, Liu and Silva (2013) model the market dynamics between firms attempting to locate closer to potential workers, and households searching for affordable dwellings to occupy. While claiming to apply their planning model to the city of Nanjing in China, they do not discuss any specific ways in which their model findings can inform real-world policymaking. Therefore, the Creative City Model presented below is designed not only to theoretically operationalize stylized facts from popular urban development literature, but crucially to evaluate concrete policy options available to city and regional governments.

THE CREATIVE CITY MODEL

In the interest of operationalizing the aforementioned stylized facts from the literature for theory building, at its current stage of development the Creative City Model is largely theoretical, albeit spatially explicit. Therefore, key features of the model environment are based on typical developing country cities having inadequate public transportation services, infrastructure shortfalls, informality in the housing market and increasingly, sprawling high-end residential areas (World Bank, 2009). From the development policy perspective, the model allows us to run "thought experiments" (Epstein and Axtell, 1996) for developing a more profound understanding of the processes leading to the formation of urban creative clusters. The first step involved designing a theoretical model to unravel the relationship between human creativity and urban development. After gaining sufficient confidence in the validity of its inner workings, we attempt to answer the following policy questions through scenario analysis: What impact will relaxing urban zoning laws have on economic output? How will greater urban mobility or lower transportation costs alter the form and function of cities? And, to what extent can greater societal tolerance or urban amenities stimulate the creative economy?

Models are used in public policy analysis for overcoming the "bounded rationality" of the human mind, thus moving towards more scientifically rigorous ways of exploring social systems (Simon, 1962). Depending on their level of abstraction, Axtell and Epstein (1994) classify ABMs from "level 0" types that broadly caricature real-world agent behavior to "level 3" where they are in quantitative agreement with both the macro- and micro-structures of the target system. At the current stage of development, the Creative City Model falls in the "level 1" category for being only in qualitative agreement with the emergent macro-structures of urban development. It is designed to offer broad theoretical insights rather than specific predictions about the form and function of real-world cities. The model consists of individual agents differentiated by attributes such as income and education levels, and an environment featuring different types of land-use and creativity stock. The movement and interactions of agents is purposeful, determined by behavioral rules and real-time feedback loops from constantly updating agent and environmental attributes. Therefore, the model simulates the emergence of creative clusters under specific conditions of agent and environmental behavior, allowing researchers to understand agent level decisions and their connections with emergent macrostructures.

The Agents

Individual heterogeneous agents are the most significant component of this model. Their location decisions and rule-based interactions determine the shape and size of creative clusters. Despite the innate creativity of each individual, the extent to which they apply it in professional settings varies. In the absence of any objective metrics for human creativity (Torrance, 1988), we classify agents as having low, medium or high levels of creativity. This classification merely highlights the extent to which agents apply creativity for problem-solving in their workplace. To further minimize pre-supposed subjectivity, we allow users to set the percentage of highly creative individuals in the model. The model then equally divides the remaining agents between the medium and low categories. As the simulation progress through time and thus agents interact, these creativity levels become crucial determinants of residential clustering and associated economic outcomes.

Table 1: Summary of Agent Attributes

Attributes	Range
Creativity	Low, Medium or High
Literacy	Literate or Illiterate
Income	1,000 – 350,000
Tolerance	1 – 99 percent

As shown in Table 1, each agent possesses several socioeconomic attributes including literacy and annual income levels. The user-specified education level randomly assigns each agent as either educated or uneducated, without differentiating them by level or type of education. Upon model setup, an income distribution (user-defined, either bimodal or gamma) is created around the user-specified average and top ten percent income levels, thus allowing users to control both absolute and relative prosperity. Every agent is therefore allocated a starting income level at the onset, which is subject to change during the course of model runs. Besides individual attributes however, agent behavior is impacted by several user-defined inputs such as agent population growth rate, societal tolerance level, rate of brain drain, restrictions on agent mobility and new construction.

Environment

Given the model's theoretical focus, we design an urban landscape that broadly replicates real-world urban land-use patterns. Since urban land-use is regulated by local government primary through zoning laws, we classify constituent urban land patches as follows: residential (60 percent), commercial (10 percent), green area (10 percent), water way (10 percent) and infrastructure (10 percent). Notwithstanding the unique land-use mix of each city, we estimate these values from Karachi, Pakistan. In the absence of government issued land-use maps, we undertook visual inspection using Google Earth imagery to determine the approximate land-use structure through a 40 x 40 grid representing roughly 1,600 square kilometers of the Karachi region. At the time of model initialization, these land-use categories are randomly applied onto constituent patches. The presence of high or medium creative agents on any residential parcel boosts the creative value of land patches and the user-specified creative density level serves as the threshold to classify land parcels as being creative or otherwise. Being creative often becomes the starting point for the emergence of creative clusters. However, while agents are free to move across the environment, they can only settle in residential areas. As clusters grow, neighboring commercial zones and public spaces get absorbed into them as well.

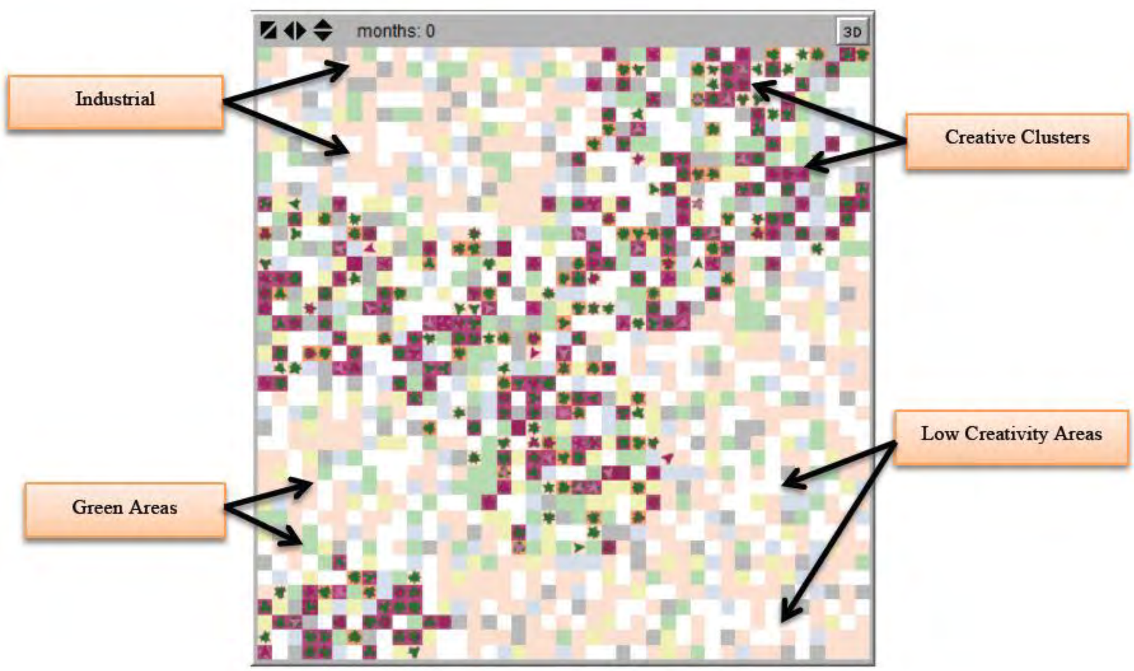
Table 2: Summary of Environment Cell Attributes

Attributes	Range	Details
Creative Value	1 – ∞	Determined by Creative Values
Land Use Type	1 – 7	Commercial, Residential, Mixed land-use, Public Space, Infrastructure, Waterways and Green Areas
Population	0 – 2,100	Number of agents residing
Rental Rate	1 – 150,000	Monthly rent, Pakistani Rupees

In line with standard ABM practice, land units essentially act as interactive agents albeit without spatial mobility capability. Their basic attributes however, including rental price and creativity level, dictate the behavior of agents operating within them. Average annual rents are user-specified, but vary across patches in the environment and depend on their population density and creative value (defined as number of high or medium creative) population density. As the model progresses through time, the spillovers from highly dense land units diffuse into the surrounding von Neumann neighborhood of 4 adjoining patches, boosting their creativity and population density (Neumann, 1966). As these surrounding patches are frequented by agents with medium and high creativity, they gain creative value, thus resulting in the emergence of clusters of creativity. The key attributes of each constituent cell of the model landscape are summarized in Table 2.

As shown in Figure 2, the color intensity of land patches indicates the density of creative population, with darker shades representing greater creativity and consequently, higher rents. Similarly, the triangular-looking agents are color coded accordingly to creativity endowments with green, pink and magenta representing low, medium and high levels respectively. The model initializes with agents located to start out on patches that are residential, but it allows them to move around within these patches or move to other patches to find more affordable living. Some of the patches may be visited but cannot be inhabited as they represent land-use types that are typically off limits to residential settlements; specifically in the model commercial zones, green areas, waterways and infrastructure. The user however has the option of allowing development into some of these areas. In order to capture spatial segregation of real-world cities, the environment constitutes seven randomly assigned neighborhoods (inspired by the number of Karachi's constituent zones) with some overlap. Users can view the environment by toggling between color-coded land-use types (shown below), the neighborhood boundary configurations, rents, and creative value.

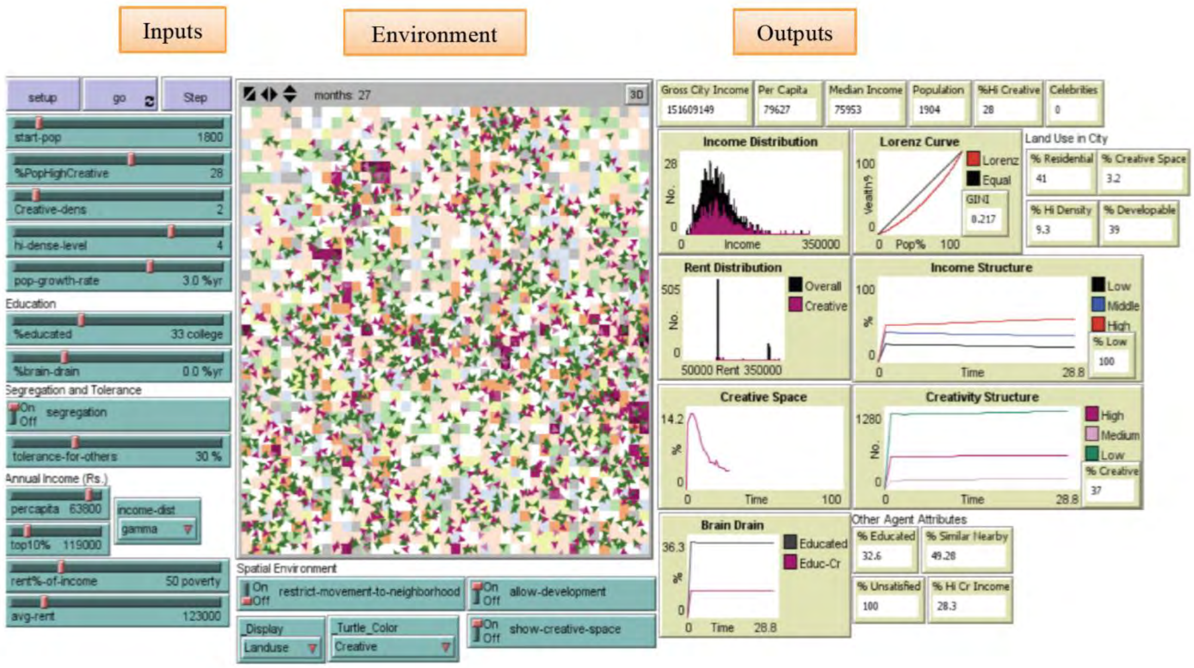
Figure 2: Creative City Model Environment



Model Interface

The model was created using NetLogo 5.0, a simple yet powerful modeling platform along with a user-friendly interface. As shown in Figure 3, the model's input parameters, spatial environment and outputs are arranged from the left to right of the screen. Input parameters are arranged topically by education, segregation and the income-rent related. The spatial environment related user controls, including movement and new residential construction restrictions, are placed below the model environment. Moreover, interested readers can interact with the Creative City Model by visiting: http://css.gmu.edu/CreativeCity/.

Figure 3: Creative City Model User Interface[1]



Users can run their simulations using various input parameter combinations and observe their impact on the constantly updating environment. In addition to spatial insights visible through observation in the environment, several output charts and monitors provide constantly updating simulation data related to income, urban land-use and human creativity. These include distributions of income and rent, the Lorenz curve, GINI coefficient, and gross city income. In addition, the real-time per capita and median income levels are viewable as well. Urban land-use patterns can be examined by the 'Land Use in City' section under outputs through indicators for the proportion of land labeled residential, high-density and developable land. Moreover, the population's creativity is captured by the proportion of high, medium and low creativity individuals, literacy levels, and the proportion of creative spaces shown on the output side. Apart from the creativity structure chart, users can view the several agent attributes including the proportion of those labeled highly creative and percentage of those who are unsatisfied with their neighborhoods and thus looking to move. The model's environment constitutes a 2-dimensional 40 x 40 grid, with each of the 1,600 patches representing 1 square kilometer squares in the real-world urban context.

Behavioral Rules

The interactions among agents and the environment dependent on simple behavioral rules, derived in the form of stylized facts from urban development literature discussed earlier. These rules are summarized in Table 3 below before being expressed in mathematical terms.

[1] The input values indicated in Figure 3 are for illustration only, thus not reflective of any particular real-world city.

Table 3: Rules of Behavior Summary

Role	Behavioral Rules
Agent Movement	Stop when satisfied (based on environment) and content (based on nearby agents)
Agent Interaction	Partnering may lead to increased creativity level
Environment Values (Density, Rent, Occupancy, Creative Value)	Based on density/frequency of agent visit
User interaction	Modify values, change display of environment and agents based on attributes, query agents

Depending on agent attributes and changing microscopic environmental conditions, these rules create outcomes at the macroscopic level. While behavioral rules remain fixed throughout the simulations, users can change input values to obtain varying results at any time during a model run. The key behavioral rules are described below.

AGENT MOBILITY

The seemingly random movement of agents in the model is dictated by their desire to acquire satisfaction, without which they continue their movements. The first component of satisfaction is rent affordability, measured by their ability to afford housing within the user-defined rent percentage of income threshold, as defined by the following condition:

$$R_{im} \leq \alpha \, \rho_{im} \qquad (1)$$

Where R_m is the monthly market rent in any given neighborhood, α represents the user-specified rent percentage of income threshold and ρ_m is the level of monthly income any given agent. The second determinant of satisfaction relates to socio-ethnic segregation, and requires each agent to reside exclusively in neighborhoods with similar-agent majorities. To determine similarity, each agent accesses whether the majority of agents on the eight surrounding patches are within 25 percentage points of their own tolerance level, which is assigned through user-specification. The satisfaction condition is defined as follows:

$$-1.125\,(T_j) \leq \tau_i \leq +1.125\,(T_j) \qquad (2)$$

Where T_j is the tolerance level for any given eight-patch local neighborhood and τ_i represents the individual tolerance levels of specific agents. Together, the satisfaction of these two conditions allows agents to reside on a given cell, if these conditions are not met the agent will continue moving in search for satisfactory conditions.

DIFFUSION OF CREATIVITY

Although every interaction between agents will not produce economic value, the likelihood of increasing income may occur when two highly creative agents interact in a high creative value neighborhood. This captures perhaps the fundamental insight from Glaeser (2011) and Florida (2002, 2012) who believe that urban neighborhoods endowed with mixed land-use, walkability, transit accessibility and great public spaces etc. cultivate a culture of entrepreneurship and innovation. These areas are therefore endowed with creative potential, and as medium and high creative agents interact in this space, it raises the creative value of the location.

Given the theoretical nature of this model and our desire for generalizability, we have created a proxy for measuring urban amenity endowments of neighborhoods, i.e. the creative value. In essence, it is a summation of the creative values of agents which can be expressed as follows:

$$\sum_{i=1}^{n} CV = \sum_{i=1}^{n1} 10\ (ch_n) + \sum_{i=1}^{n2} 5\ (cm_n) + \sum_{i=1}^{n3}\ 1\ (cl_n) \qquad (3)$$

Where CV stands for the total creative value of each patch while ch_n, cm_n and cl_n represent the number of highly creative, medium creative and lowly creative agents respectively. Moreover, the total number of agents is merely a summation of the three categories of agents as follows: $n = n1 + n2 + n3$. Given that creativity is an inherent human characteristic (Simonton, 2012), we allocate one creative value point to low creativity agents, five points to medium creative, and 10 points to high creative agents. In the absence of any empirical standards for defining or quantifying human creativity, these values are mainly notional and intended to conceptualize the underlying idea that the agglomeration of creative agents has benefits to specific patches in the model's landscape. However, patches will lose creative value when it does not continually attract creative agents and as such it may decay back to zero. The resulting pattern is that some creative clusters may emerge and exist for a short time span; that is not all of those that start to emerge will persist through model runs stretching over several years.

INCOME AND THE RENTAL MARKET

Real-world urban income data based on multiple countries reveals that per-capita income mostly follows a two-peak distribution, one each for lower- and upper-income stratums of society (Quah, 1997). Therefore, the income of agents in the model is distributed either by gamma (Salem and Mount, 1974) or bi-modal distribution (Newhouse, 1969), depending on user preference. At the initial setup, each agent is allocated an annual income level which updates throughout model runs in several ways. First, agents who improve their creativity state, from low to medium or high (this occurs after interacting with a higher creativity agent) receive a five and two percent income increase respectively. This is a reflection of the real-world reality that creative class agents enjoy higher per-capita income levels (Florida, 2012). In recognition of the real-world phenomenon of demand-supply dictating rental prices, the model assumes that high creative value neighborhoods are more desirable. Thus greater demand and static supply results in increases of rents. At each model cycle, neighborhood rents increase automatically as shown in Table 4.

Table 4: Creative Values and Rents

Neighborhood Creative Value Range	Rent Increase (%)
1 – 50	0
50 – 100	5
100 – 300	10
300 – 500	50
500+	100

POPULATION GROWTH AND BRAIN DRAIN

The user-defined population growth rate, representing both natural growth and inward migration, impacts all agents irrespective of their creativity level. However, brain drain is by definition the loss of creative and educated professionals from the workforce hence it does not impact lowly creative agents in the population (Stark, 2004). The following equation explains this as follows:

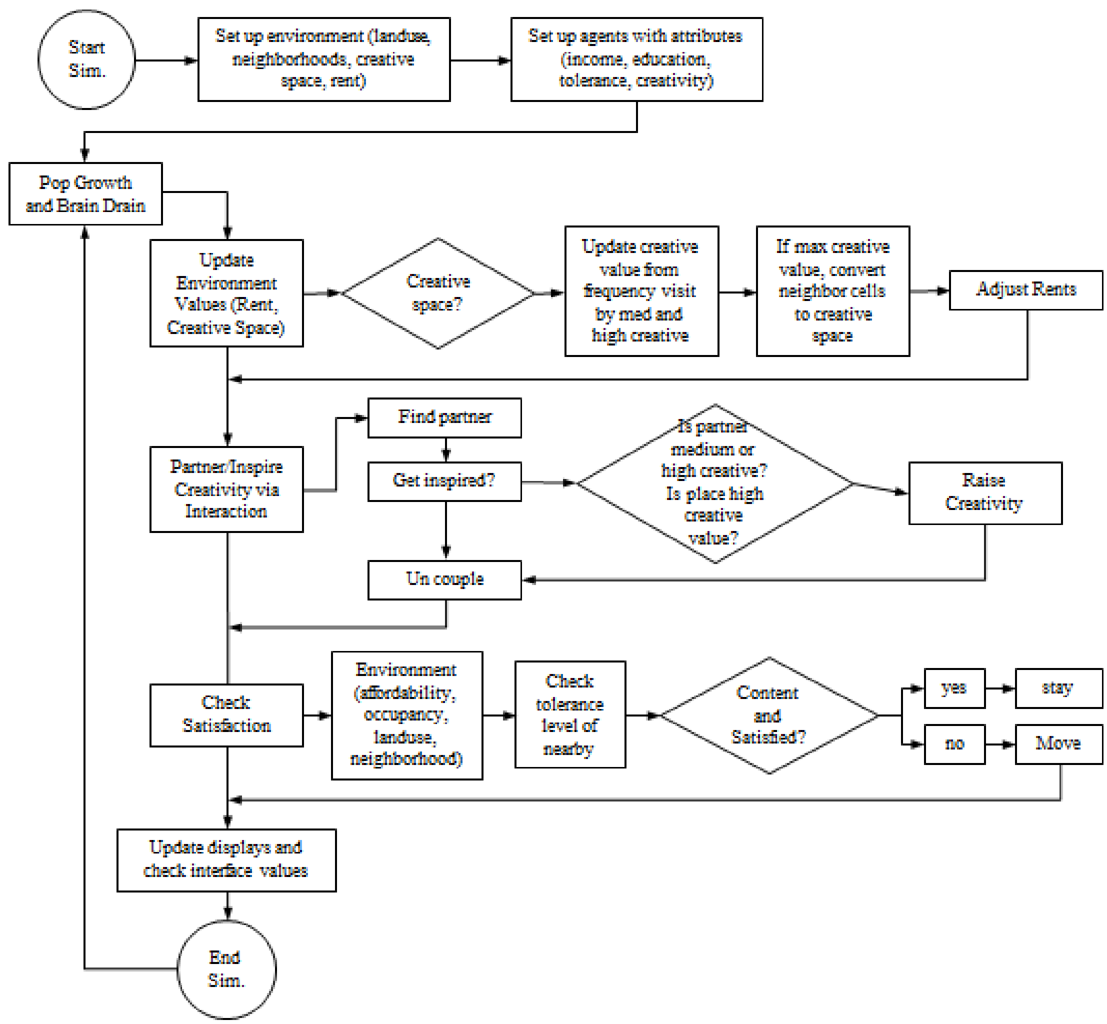
$$P_t = [(p_{t-1}^{c}\ \Delta P) - \Delta\beta] + (p_{t-1}^{nc}\ \Delta P) \qquad (4)$$

Where $P_t$is the total agent population in the current time period, and $p^c$and p^{nc} represent current populations of creative and non-creative agents respectively. In addition, ΔP is the user-defined annualized population growth rate and $\Delta\beta$ is the rate of brain drain, the later applying only to highly creative and medium creative agents. In many developing countries, the continual loss of highest quality talent to foreign country poses significant challenges for economic development (Haque, 2007).

Model Logic Flow

At every time increment, which for this model is notionally defined as a single month, a series of pre-defined steps are executed. The purpose of Figure 4 is to present the model's logic structure, i.e. key reasons behind how the model progresses and the overall decision sequence. The model when initialized will take the user-specified values from the interface and set up the environment and creates the agent population. After applying population growth rate and brain drain values to agent population in real-time, it begins computing changes in creative spaces based on frequency of visits by different types of agents. Thereafter, agent movements cause serendipitous encounters which result in partnerships between them. In line with the literature discussion in Section 3, creativity diffusion in the model occurs when partnered agents gain inspiration from their highly creative counterparts, thus improving their own creativity level. Subsequently, the model assesses satisfaction for each agent, determining whether they should continue moving or settle down. Finally, all displays and interface values are updated and reported.

Figure 4: Creative City Model Logic Flow



MODEL OUTPUTS

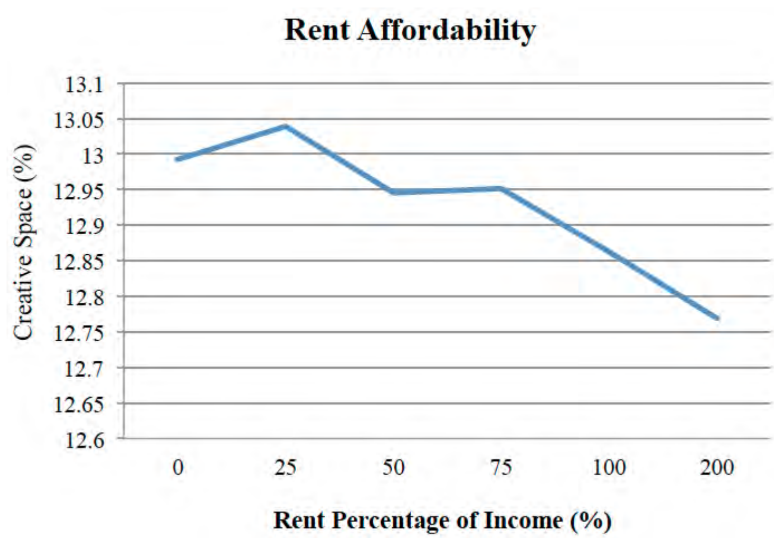
The key output from the model is the emergence of creative clusters depending on various input configurations from the interactions of individual agents. Therefore, the percentage of land parcels classified as creative (termed creative spaces) and their clustering offer the most useful insights. As consequences of these agglomerations, problems of income inequality and thus socioeconomic disparity also emerge (Peck, 2005). These problems are captured by the model's constantly updating output side displays including the Lorenz curve, income distribution and per capita income. As discussed below, housing affordability is central to the evolution of simulated social interactions in our model, hence the distribution of rents indicator offers insights on the interplay of rent levels with the overall spatial structure of the city.

Verification and Sensitivity Analysis

Before interpreting any results from experimentation, we undertook extensive verification and sensitivity analysis to gain confidence in the inner-workings of the model. The purpose of this exercise was to ensure that the model results broadly followed theoretical expectations discussed above. For instance, does greater population density and lower social segregation levels in the model result in greater prosperity through diffusion of creativity? Similarly, is greater education levels associated with better economic outcomes through greater creative interactions? While some of these might appear to be obvious outcomes of the model design, the validity of theoretical ABMs can only be established by systematically testing each of its parameters, albeit with simple illustrations of correlations (Railsback et al., 2006).

Given the centrality of having creative urban spaces endowed with amenities (parks, restaurants, walkability etc.) and populated with highly creative individuals, we tested the sensitivity of the single most crucial output, i.e. percentage of creative urban spaces. As shown in the figures that follow, these one-on-one correlations also validate the inner-workings of the model by ensuring that they follow expectations established in the stylized facts discussed earlier. Each of the results discussed in this section represent averages of 100 model runs of 10 years, thus ensuring that model stochasticity did not bias the findings. With all other parameters kept near-zero levels, we altered a single parameter at a time to ensure the complete isolation of their impact from other factors. The effect of each sensitivity analysis can therefore be attributed solely to changes in the parameter of interest under each scenario.

Figure 5: Creative Spaces and Rent as Percentage of Income[2]



In Figure 5, the rent percentage of income refers to the amount of income individuals have to spend on rent in any given month. As the level increases along the horizontal axis, people have to spend a larger part of their total income on housing. Therefore, the negative slope indicates that as the percentage of income spent on rent increases, the number of people who can afford higher rents prevailing in creative clusters will decrease. Leading critics of Florida's (2002) theory of the creative class have long argued that mixed land-use in downtown neighborhoods are prohibitively expensive for even middle-class professionals, let alone low-income families (Peck, 2005; Malanga, 2004). While these arguments gain credence from the aforementioned results, Glaeser (2011) argues that greater rent affordability (either through larger incomes or cheaper rents) in fact mixes-up these classes, thus improving socioeconomic diversity and propelling economic activity. In model resulsts however, we witness that after rising with percentage of income spent on rent till the 25 percent mark, creative space tips over and continuing falling till the 50 percent mark. The U.S. government benchmarks housing affordability at 30 percent, with households being

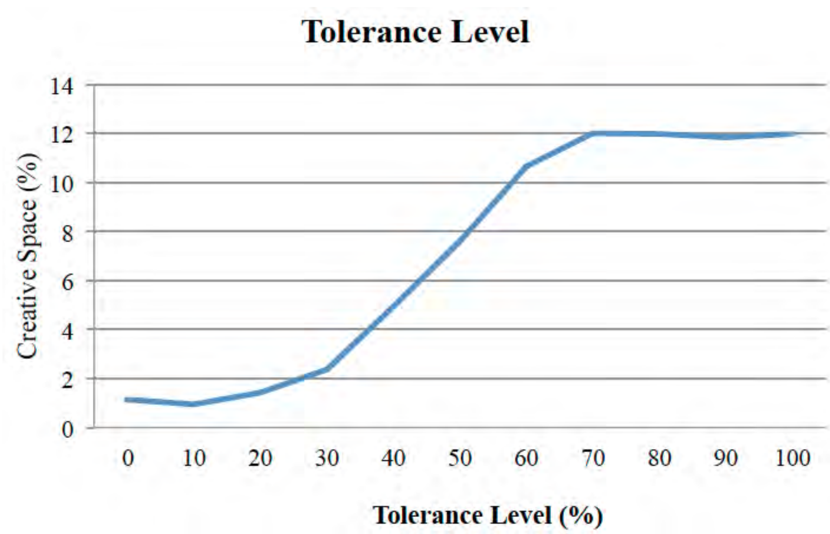
[2] Although in real life rent affordability of 100 or 200 percent is unrealistic, we test these parameters at the validation stage to ensure the model adheres to logical expectations.

forced to spend any more on rent considered poor (Cohen *et al.*, 2010). The model's tipping point remains in the same ballpark, lending some weight to its theoretical validity.

The idea of incorporating societal tolerance in the model is inspired from Thomas Schelling's (1971) segregation model which demonstrated that seemingly innocuous preferences of residing alongside neighbors of the same ethnicity results in complete segregation. This "herding behavior" is marked by tipping points, the identification of which can offer tremendous insights to policymakers dealing with social phenomenon like cities (Gladwell, 2006). In addition, as discussed above, the urban society's tolerance towards religious minorities, immigrant groups and new ideas has been the hallmark of great cities. Hence in today's world, diverse and tolerance cities, the likes of New York and London, are most likely to produce clusters of creativity. In the model therefore, we expect societal tolerance to be positively correlated with creative spaces.

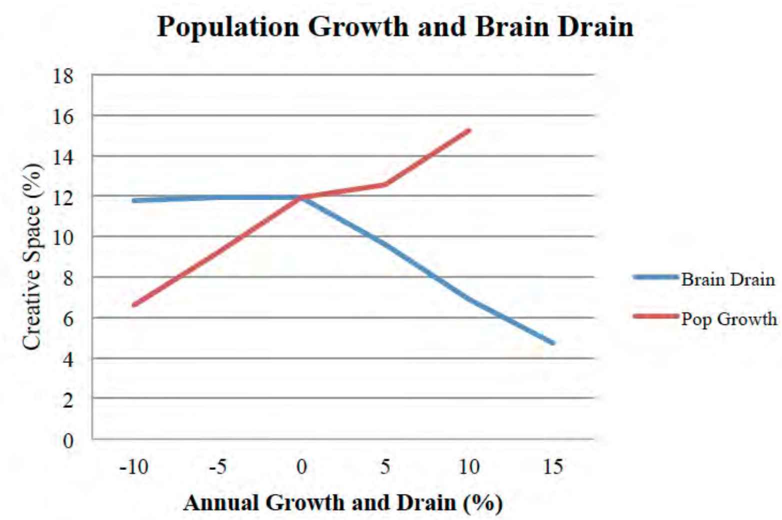
Each agent is embedded with a tolerance value, assigned through normal distribution around the user-specified mean value, ranging from 0 to 100 percent. In searching for suitable housing units, agents are programmed to reside only in neighborhoods where the majority of the population falls into a 25 percent tolerance range. Therefore, agents with lower tolerance values have much smaller tolerance acceptability ranges as compared to their more tolerant counterparts. For example, an agent with tolerance level of 10 percent will only accept neighborhoods where the majority falls into the 8 – 11 percent range; whereas at 80 percent the acceptability range will be much larger, i.e. 70 – 90 percent.

Figure 6: Creative Spaces and Societal Tolerance Level



The results shown in Figure 6 confirm that as the individual tolerance levels of agents increase, the proportion of creative urban spaces improves. At low tolerance levels of under 10 percent, creative urban spaces shrink but show modest improvement from here on till the 30 percent mark. Similar to Schelling's (1971) tipping point of 25 percent mark, we witness the relationship between tolerance and creative space undergone a sharp positive take-off at around 30 percent. This finding improves model validity and further reaffirms our hypothesis that societal tolerance is a crucial determinant of creativity led urban development. However, the impact of tolerance improvement begins to dwindle at 60 percent before flattening out at 70 percent and beyond. As discussed in this section later, this merely proves that tolerance alone cannot continue increasing creative spaces indefinitely.

Figure 7: Creative Spaces with Population Growth and Brain Drain Rate



In Figure 7, the urban population growth rate is associated with higher density levels, which in turn increases interactions amongst agents. This leads to the potential for sprouting of greater number of entrepreneurial ventures through partnerships among agents, creating economic value added. Despite the highly positive overall relationship, creative spaces remain largely unchanged in the 0 to 5 percent population growth rate range. Since most real-world cities grow within this range, this flattening of the graph suggests that citrus paribus, population growth alone does not result in the emergence of creative clusters. Not all the world's fastest growing cities therefore, in particular the likes of Lagos and Karachi, boast any significant creative space endowments.

The problem of brain drain, however, the phenomenon where educated or highly skilled professionals begin leaving their home country amass, poses significant challenges for most developing countries (Haque, 2007). The presence of highly educated professionals is necessary for creative industries to prosper and societies to remain tolerant; hence the rate of brain drain is negatively correlated with creative spaces. On the opposite side however, the results above indicate that negative brain drain, essentially the growth of the population of highly educated professionals, leads to higher percentage of creative space which does not continue growing indefinitely. In the Creative City Model, both population growth and brain drain rates have a highly sensitive relationship with creative spaces, thus confirming that the intensity of interactions amongst individuals is crucial determinants of cluster formation.

Experimentation

Having discussed model verification in the previous section, we will now undertake "what-if" scenario analysis to test policy reform ideas presented in literature. Three key policy options faced by governments were tested: altering urban zoning (Glaeser, 2011), improving transportation (Lucas and Rossi-Hansberg, 2002), and improving societal tolerance levels (Florida, 2002). In the Creative City Model, each of these is tested with ON/OFF type controls on the user-interface as follows. First, allowing Development (*'Dev'* in figures below) converts previously unused land to developable status and existing residential areas can grow vertically, both of which increases population density and vice versa. This control captures the policy option of greater mixed land-use. Second, allowing movement (*'Mov'* in figures below) enables agents to move beyond their neighborhoods (consisting on average of 225 random patches) in search for affordable housing units and likeminded partners. The real-world policy option of investing in transportation networks is evaluated in this manner. Third, permitting segregation (*'Seg'* in figures below) includes tolerance levels of agents into their location decision. This ensures that they only reside in neighborhoods where the majority of agents have similar creativity levels. The issue of socio-ethnic segregation in metropolitans is explored through this experiment.

Given that these aspects of urban form and function are highly intertwined, e.g. land-use affects mobility which in turn impacts segregation (Bjornskau, 2005) we experimented with eight different scenarios using all possible combinations of these three options. For this analysis however, the focus is on key outputs including percent creative spaces, proportion of creative individuals, income per capita and rent affordability. Together they capture the diffusion of human creativity in the urban context, covering both their positive (prosperity, creative clusters etc.) and negative (inequality, segregation etc.) aspects. For each experiment, ex-ante expectations based on stylized facts from literature are compared and contrasted with model outputs, thus offering explanations for variations. Given the conceptual nature of this model, output values are interpreted mainly in notional terms, with the relative magnitudes being most crucial. The results discussed throughout this section again represent averages of 100 model runs, calculated using the final outcomes after running the model for 10 years in the future. Moreover, every tick in the model is designed to represent a single month, allowing agents adequate time to readjust their locations based on their individual worldwide. The 10 year time period allows 121 ticks, providing adequate time for the model to stabilize and represent long-term impacts of policy interventions. Before discussing experiment results however, we will introduce the basic input parameters for capturing real-world urban form and function.

KARACHI INPUT PARAMETERS

In order to provide realistic results from experiments, we move beyond baseline values of theoretical cities to utilize survey data from the city of Karachi, Pakistan based on a 1,000 sample size survey of youth (Malik and Karim, 2012). The survey provided estimates for levels of educational attainment, brain drain, high levels of creativity, income distribution and tolerance levels of the 18-34 year age cohort of the city. Moreover, the model's starting agent population was based on recent estimates that the city's population has crossed 21 million after experiencing rapid population growth during the last decade (Kotkin and Cox, 2013). Hence each agent in our simulation represents approximately 10,000 real-world urbanites and annual population growth rate is set at eight percent. The values shown in Table 5 provide an estimate of input parameter combinations based on Karachi, which is used as the base case for representing developing country megacities more generally.

Table 5: Input Parameters for Experiments

Input Parameters	Experiment Values[3]
Starting Population	2,100
Annual Population Growth Rate	8 percent
Literacy Rate	50 percent
Annual Rate of Brain Drain	3 percent
Proportion of Highly Creative Agents	15 percent
Average Societal Tolerance Level – Segregation	30 percent
Monthly Income: per capita / top 10 percent	Rupees 30,000 / 100,000
Average Monthly Rent	Rupees 12,000
Rent Percentage of Income Affordability Threshold	30 percent

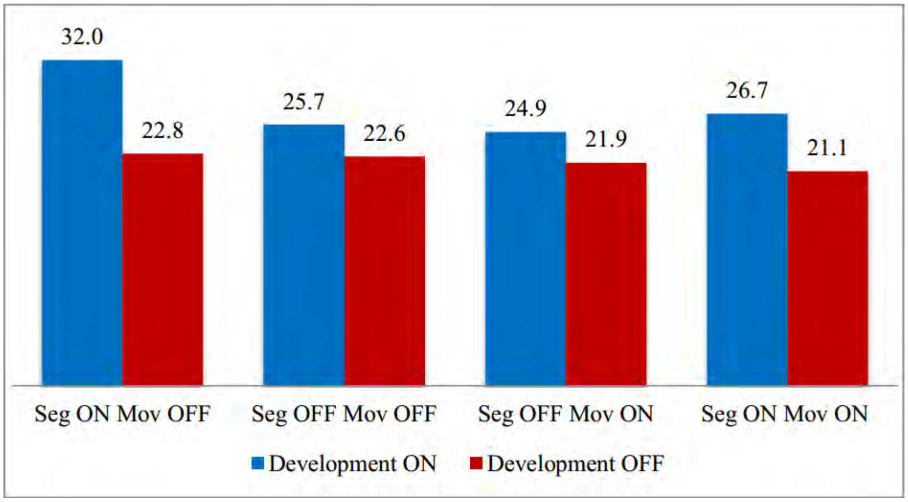
URBAN ZONING AND LAND-USE REGULATION

The supply of residential and commercial real estate largely depends on urban zoning and land-use regulations imposed by municipal governments, which in many cases are overly restrictive (Rose, 1989). Therefore, the easing of typically strict urban land development and building construction regulations will likely reduce prices. Our model allows users to control whether additional real-estate development is allowed or otherwise, exploring impacts on macroscopic urban form through changes in the supply of housing units. Allowing development enables the construction of residential units in previously industrial or commercial zones, both through mixed land-use and vertical growth. In simple terms however, allowing additional urban development within the model amounts to an increase in building supply which is likely to reduce rents. Hence we expect the "allow-development" control to

[3] The following variables are estimated from the Karachi youth survey: literacy rate, rate of brain drain, proportion of highly creative agents, societal tolerance level; population growth rate. Starting population are from Kotkin and Cox (2013); income distribution from Pakistan census data; rental rates use the real-estate website Zameen.com; and the rent affordability threshold is from U.S. government standards.

show significant sensitivity to the proportion of creative spaces, thus demonstrating the wisdom of relaxing urban land-use regulations for improved economic conditions.

Figure 8: Percent Creative Spaces with Development



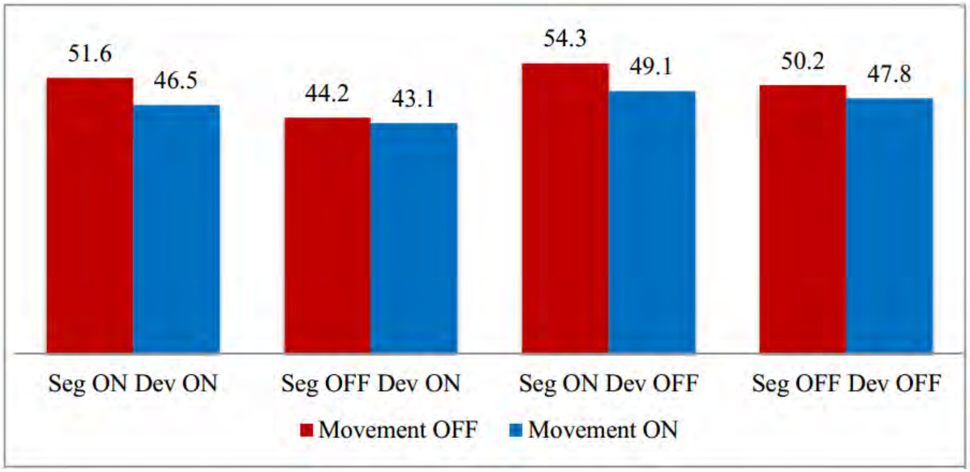
Both the development control and the percent creative space parameter relate to land-use attributes are inherently spatial. Hence Figure 8 focuses on the relationship between the development control and its impact on creative spaces. From among the eight unique combinations involving three controls with two options each, *ceteris paribus*, we expect development to have the greatest impact on creative spaces through agent-agent and agent-environment interactions. First, the experiment reveals significant sensitivity in the relationship between development and creative spaces, averaging 5.2 percentage points. This is consistent with ex-ante expectations as additional development boosts urban floor space and thus population density, both of which augment clustering of likeminded and highly creative agents. In real-world cities, reforms in land-use regulation towards mixed land-use (and transport infrastructure investments) in places like Arlington, Virginia have created clustering of professionals working in the creative sector.

Furthermore, we observe that creative spaces are greater whenever development is allowed irrespective of whether segregation and movement are allowed or otherwise. This finding is consistent with perspectives in the literature, which associate greater density with the clustering of creativity. In addition, the highest percentage of creative spaces emerges when development and segregation are allowed and movement is restricted. This shows that the intensity of interactions due to physical containment, especially when around similar agents, fosters somewhat greater creativity. In other words, when highly creative agents are contained in neighborhoods with poor mobility services, they are likely to generate novel ideas. In Figure 8, scenarios where segregation is allowed results in more creative spaces due to the same reason. To some extent this finding negates the view that greater mobility and diversity are pre-conditions for creativity led economic development due to enhanced opportunities for serendipitous encounters.

TRANSPORTATION AND MOBILITY

In leading metropolitan centers, seamless connectivity is available to residents through extensive public transportation systems that are largely affordable. Access to transportation and thus urban mobility are vital pre-conditions for interactions among urbanites, which in turn boosts economic outputs (Lucas and Rossi-Hansberg, 2002). In the model therefore, agent movements can be restricted to within neighborhoods of residence by applying the Restrict Movement parameter. When the restriction is not applied however, agents are free to move throughout the city with the assumption that better public transportation access allows them to do so. The underlying desire of agents to continue movements in search for affordable housing units remains consistent under both circumstances. However, given that the literature posits that greater human interactions accelerate the diffusion of creativity, we focus on the relationship between the movement control and percentage of creative agents.

Figure 9: Percent Creative Agents with Movement



In Figure 9, we observe that each scenario where movement is restricted results in greater percentage of creative agents in the model. The highest report values are observed when segregation is enforced, with disallowing development producing higher values. This augments the intensity of interaction argument made earlier as the combination of movement restriction, enforced segregation and disallowance of development creates the most interaction intensity. Conversely, the lowest percentages of creative agents are observed when development is allowed in the absence of segregation, which negates arguments in literature equating greater tolerance and mixed land-use with the diffusion of creativity. If the model results were consistent with those observations, the combination of no segregation along with allowance for movement and development would have produced the greatest population of creative agents. In terms of sensitivity, changes to the movement control produces an average impact of 3.45 percentage points, relatively lower than the relationship between development and creative spaces discussed earlier. In fact, creative agent percentage shows the greatest sensitivity to segregation as it directly impacts free human interaction, with the existence of segregation being associated with greater diffusion of creativity within the model's environment.

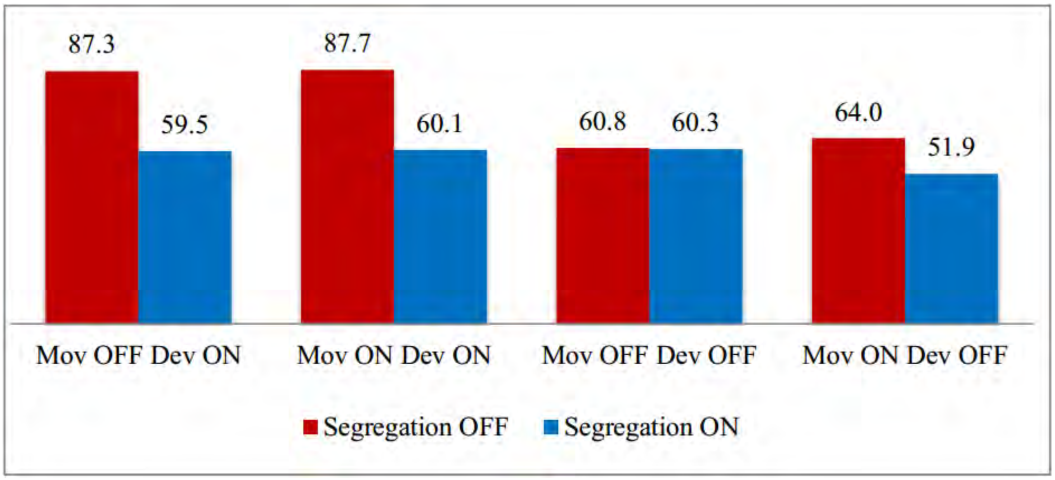
The overall results thus far demonstrate a consistency whereby any combination of the three controls resulting in greater intensity of creative agent interactions fosters creativity. This further implies that social and economic segregation in cities, resulting in highly creative agents residing in close proximity, is most likely to produce prosperity. However, whether this translates into greater socially equitable outcomes remains unanswered and will be dealt with in the following subsection. Both the two key findings and the concern highlighted here are consistent with the arguments for and against the theory of the creative class. Having discussed creativity related aspects of the project, we will now analyze results from the segregation experiment, as related to both inequality and prosperity.

SEGREGATION, INEQUALITY AND PROSPERITY

Taking inspiration from Schelling's (1971) path-breaking work on socio-ethnic segregation in urban neighborhoods, we hypothesize that cities with greater societal tolerance are more likely to be prosperous. Some of the world's greatest cities are magnets of immigrants and offer incredibly assimilating societies due to extremely high tolerance for divergent socioeconomic, religious and racial groups. Moreover, recent contributions in urban simulation literature has demonstrated how seemingly innocuous preferences for residing in neighborhoods where the majority belongs to one's own ethnic group leads to suboptimal outcomes for society (Eckerd *et al.,* 2012*;* Kim *et al.,* 2013). Therefore, when segregation is turned on in the Creative City Model, individual preference for similar neighbors (determined by tolerance level) becomes part of the residential location decision. Each agent is programmed to consider the tolerance range of agents in its neighborhood, strictly preferring staying with the 10 percentage point range of their own creativity level. When the segregation is turned off however, these considerations do not apply towards the location decisions of agents.

A chief criticism of new urban literature has been that it results in social and economic inequalities (Marcuse, 2003; Peck, 2005), thus crowding out low- or middle-income classes from the so-called clusters of creativity. Despite mixed land-use resulting in greater housing supply, public investments in transit and high demand in emerging neighborhoods drive rentals up beyond the reach of highly talented professionals. Hence the purpose of this experiment is to understand the relationship between segregation and rent affordability, measured as the percentage of the population spending less than 30 percent of income on rents. Since rising rental prices crowd out agents from the housing market, this relationship offers insights into social inequality resulting from combinations of the three controls.

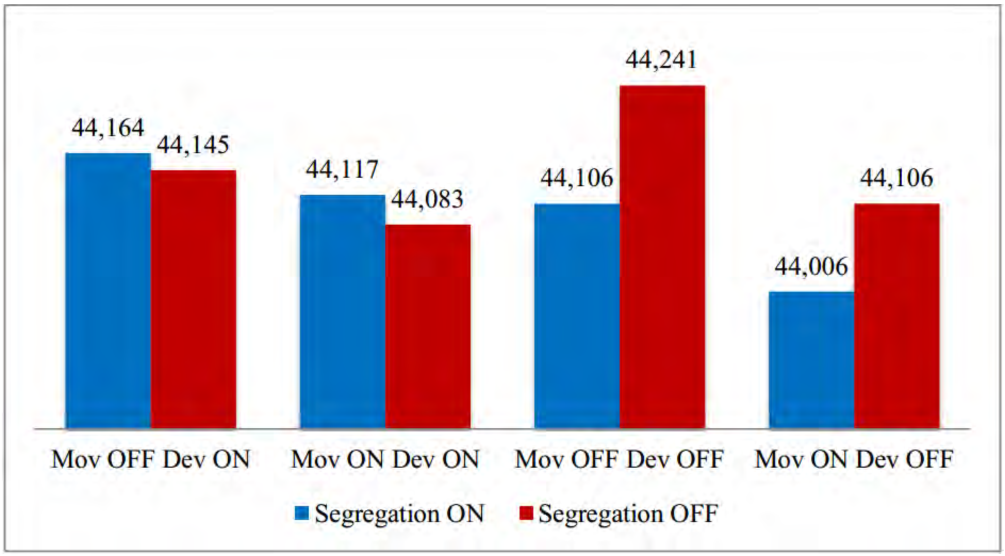
Figure 10: Percent Affording Rent with Segregation



As shown in Figure 10, turning segregation off always improves rent affordability albeit with varying magnitudes, with allowance for development (with segregation not enforced) resulting in major improvements in social welfare. In the contexts of non-allowance for development, particularly with movement restriction, rent affordability decreases as expected as both variables negatively impact the supply of rental floor space in the housing market. When comparing the differences between scenarios with segregation enforced or otherwise, development appears to be driving affordability due to the supply-demand dynamics of the housing market. However, results indicate relatively lower sensitivity to both the movement and development controls, particularly when segregation is enforced.

Notwithstanding the apprehensions from critics regarding social welfare, the key argument in favor of the policy prescription accompanying new urban literature is that they produce economic prosperity for urbanites. As discussed above, the clustering of highly talented individuals under conditions of population density increases collaboration amongst them, eventually resulting in economic value through new business activity. In line with model findings discussed earlier, this implies that segregating likeminded individuals within urban neighborhoods will in fact increase their creative outputs, thereby boosting economic output. Therefore, we utilize the most widely accepted indicator of prosperity, i.e. income per capita, which provides a snapshot of the absolute scale of prosperity in any given region. Without including inequality concerns in the discussion, we interpret results to understand how different social and policy scenarios result in varying levels of prosperity.

Figure 11: Annual per Capita Income (PKR) with Segregation



Unlike trends seen in other experiments, results in Figure 11 do not present a clear and consistent relationship between the control selections and main output parameter. Overall per capita incomes differences are small in percentage terms. In cases where development is disallowed we observe the absence of segregation resulting in greater per capita income levels, especially when movement is restricted. In other words, while the absence of segregation results in greater income per capita, the outcome changes to the opposite after development is allowed. Given that in Figure 8 we found that allowing development is associated with greater creative spaces, this appears to imply that the agglomeration of creative agents by itself does not produce prosperity. The finding is consistent with real-world examples of artsy districts in cities like Berlin and Paris, where relatively low income but highly creative artists reside. These conditions are sustained in situations marred by the absence of supporting institutions that could help translate raw talent into economic productivity. For example, the lack of efficient and institutionalized patent or business registration systems in many developing countries hampers the creation of economic prosperity.

DISCUSSION AND CONCLUSION

The Creative City Model has demonstrated the validity of many stylized facts obtained from new urban literature while providing contrary insights to others. For example, the model indicated a positive relationship between mixed land-use and the emergence of the clusters of creativity; while the same sensitivity was not observed in the case of greater urban mobility fostering the spread of creativity. In addition, we argue that notions regarding creativity led urban development apply to the context of developing country cities just as they do in Western contexts. The model further evaluated the expected results of three policy options available to urban planners in developing countries: relaxing land-use regulations, improving urban mobility and promoting societal tolerance. Through extensive scenario testing using various combinations of these options, we observe trends that provide new insights into the inner-workings of relevant academic literature on urban development policies.

We conclude that from a public policy perspective, there exists a tradeoff between the desire social equity, estimated via rent affordability, and the rapid diffusion of creativity. Throughout the experiments discussed earlier, we observe that rent affordability remains inversely related to the proportion of creative spaces and creative agents. Whether facilitating creativity will eventually drive the majority urban population towards higher paying professional jobs, or ends up trickling the economic benefits down, is an open question worthy of further investigation. As the proportions of creative agents in the population and spaces in the model environment are strongly correlated (comparing Figure 8 and 9), we confirm that human creativity has a natural tendency to cluster and thus benefit from agglomeration effects. In addition, this is the first known contribution in the literature introducing brain drain into the creative economy debate, thus demonstrated how the departure of educated and highly creative professional impacts the economic performance of developing cities (as shown in Figure 7).

Moreover, we find through multiple scenario analyses that the intensity of interactions amongst agents rigorously dictates the spread of creativity (measured by creative spaces and creative agents) irrespective of the underlying factors responsible for it. In the urban context, it is greatest when large populations are contained in given physical spaces. Whether this occurs due to lack of transportation services, preference to stay local, or segregation between income classes within densely populated cities, the result remains the same. In fact we witness that improvements in transportation access can counteract creativity diffusion by spreading out agents across the city. Likewise, the physical containment of agents in neighborhoods where the majority's tolerance levels are within a small range further fosters creativity. In other words, this shows that humans tend to prosper in familiar environments, either by way of socializing with likeminded individuals or by confidently expressing their inner creativity through a greater risk taking appetite.

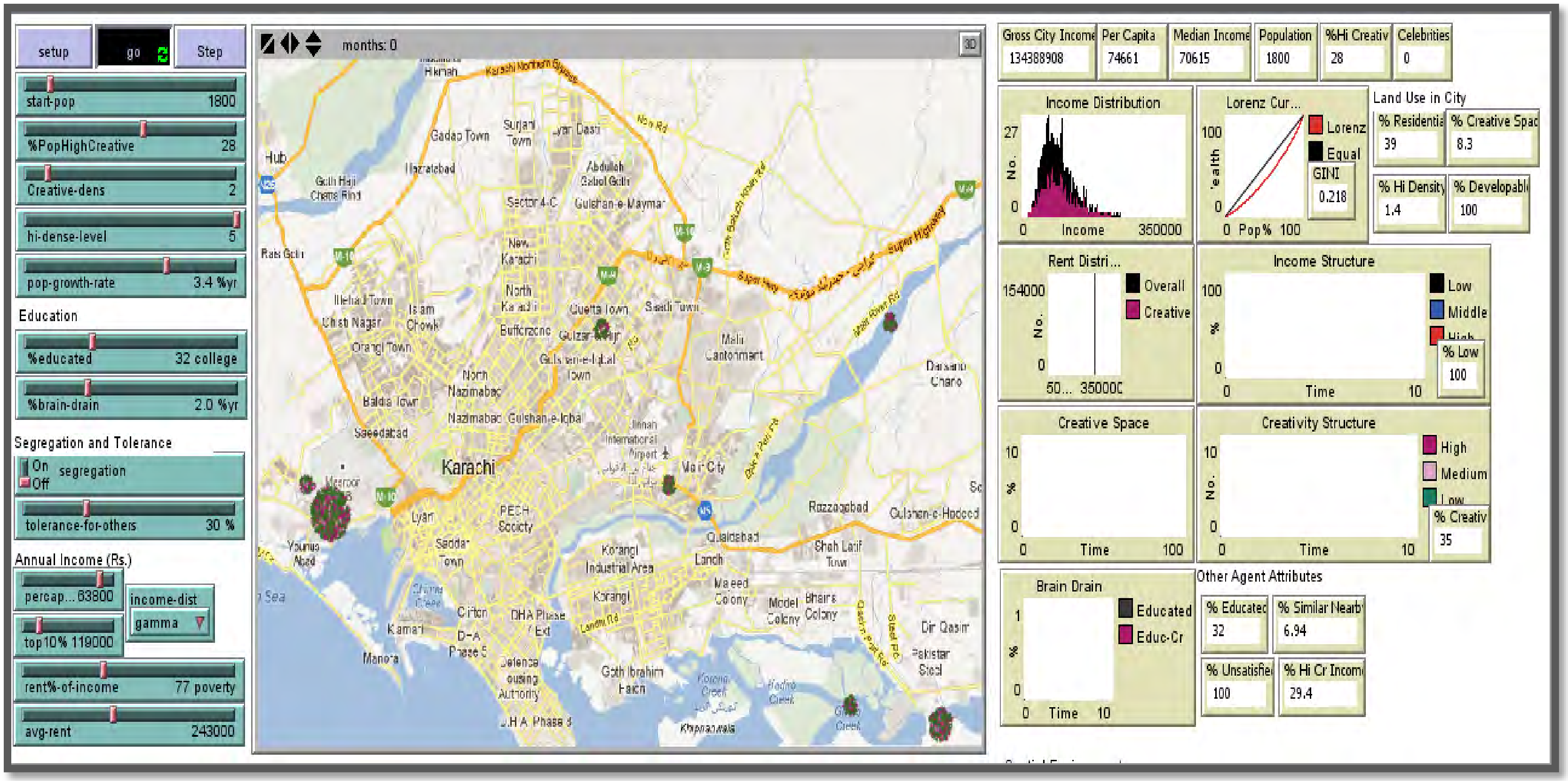
In terms of specific policy options, we found that relaxing urban zoning to favor mixed land-use leading to additional development (either horizontal or vertical) is associated with better rent affordability. Although this is desirable outcome from the social equity perspective, its relationship with creativity is found to be less rigorous than previously anticipated. While allowing greater urban development generally results in more creative agents and spaces, the magnitude of this relationship remains quite low. Likewise, improving urban mobility alone does not produce any significant improvements in any of the three main outcomes and thus remains largely dependent on other supporting policy initiatives, such as the relaxing of urban land-use regulations. Notwithstanding the long-standing belief that urban transportation is a crucial determinant of economic growth, we argue that public investments in hard infrastructure should be accompanied with development policy, i.e. changing mindsets away from 1960s style zoning towards mixed land-use. In addition, higher societal tolerance levels are found to be positively associated with the proportion of creative agents but negatively related to the proportion of creative spaces. The results confirm that openness towards new ideas and the propensity to interact with dissimilar individuals proactively fosters the hidden creative potential in humans.

Future Research Agenda

Having analyzed the inner-validity of the Creative City Model, we are well-positioned for its real-world application through calibration with socioeconomic data points from Pakistani cities. Moreover, the future development of this model will involve the integration of Geographical Information System (GIS) based approaches into the analytical framework. By introducing topographical features and additional spatial constraints, the model's application to actionable policy agenda items will be tested. At that stage, model users will be able to visually interact with simulations of real-world cities, altering spatial constraints to visually observe impact on urban form and function. Eventually the Creative City Model could be developed into a platform for testing various hypotheses emanating from stylized facts in urban studies literature, as well as their epistemological basis in the humanities.

In order to apply the Creative City Model to Karachi, as shown in Figure 12, base maps of the city will replace the currently theoretical environment to introduce real spatial constraints to the inner workings of the model. It will therefore provide additional insights into Karachi's urban form and function by allowing planners to test "what-if" type hypothetical policy scenarios within the city's specific context. For example, what impact will the revival of the Karachi circular railway have on the spatial structure of the city? Will windfall gains from rising land prices in rail accessible neighborhoods adversely impact the diffusion of human creativity? In order to answer these questions however, the research team will obtain additional spatial, demographic and socioeconomic data preferably at the sub-city level. These data points could be obtained from a variety of sources, including government of Pakistan's latest census data and household surveys to obtain relevant social and economic data to inform the simulation. For example, a household travel survey could be conducted to estimate vehicular traffic movement throughout an average week, thus providing insights into agent behavior.

Figure 12: Karachi Application Following GIS Integration in Netlogo



REFERENCES

Ahmad, N., 1993. 'Choice of Neighbourhoods by Mover Households in Karachi', *Urban Studies*, 30 (7), pp.1257–1270.

Alexander, C. (1964), *Notes on the Synthesis of Form,* Harvard University Press, Harvard, MA.

Andersson, A. (1985), 'Creativity and Regional Development', *Papers of the Regional Science Association,* 56(1): 5-20.

Asian Development Bank, 2005. *Karachi Mega Cities Preparation Project*, Manila: Asian Development Bank. Available at http://www2.adb.org/Documents/Produced-Under-TA/38405/38405-PAK-DPTA.pdf.

Auerswald, P., Shroff, S. & Bayrasli, E., 2010. *Creating a place for the future: toward a new development approach for the Islamic Republic of Pakistan*, Islamabad, Pakistan: Planning Commission of Pakistan.

Barro, R.J. (2001), 'Human Capital and Growth', *American Economic Review,* 91 (2): 12-17.

Barros, J. (2012), 'Exploring Urban Dynamics in Latin American Cities Using an Agent-Based Simulation Approach', in Heppenstall, A., Crooks, A.T., See, L.M. and Batty, M. (eds.), *Agent-based Models of Geographical Systems*, Springer, New York, NY, pp. 571-590.

Batty, M. (2001), 'Polynucleated Urban Landscapes', *Urban Studies,* 38(4): 635-655.

Batty, M., Desyllas, J. and Duxbury, E. (2003), 'Safety in Numbers? Modelling Crowds and Designing Control for the Notting Hill Carnival', *Urban Studies,* 40(8): 1573-1590.

Batty, M. (2005), *Cities and Complexity: Understanding Cities with Cellular Automata, Agent-Based Models, and Fractals,* The MIT Press, Cambridge, MA.

Bjornskau, T. (2005), 'Road Traffic Change: A Catalyst for Segregation?' *Urban Studies,* 42(1): 69-89.

Bretagnolle, A. and Pumain, D. (2010), 'Simulating Urban Networks Through Multiscalar Space-time Dynamics (Europe and United States, 17th -20th Centuries)',*Urban Studies,* 47(13): 2819-2839.

Bonabeau, E. (2002), 'Agent-Based Modelling: Methods and Techniques for Simulating Human Systems', *Proceedings of the National Academy of Sciences of the United States of America (PNAS),* 99(3): 7280-7287.

Carli, C. & Anderson, C., 2007. *Can we really build our way out of congestion'*, Melbourne, Australia. Available at http://www.abp.unimelb.edu.au/gamut/pdf/east-west-study.pdf.

Cohen, R., Wardip, K. and Williams, L. (2010), *Rental Housing Affordability: A Review of Current Research,* The Center for Housing Policy, Insights Housing Policy Research, Washington, DC, Available at http://www.nhc.org/media/files/RentalHousing.pdf.

Crooks, A.T. and Heppenstall, A. (2012), 'Introduction to Agent-Based Modelling', in Heppenstall, A., Crooks, A.T., See, L.M. and Batty, M. (eds.),*Agent-based Models of Geographical Systems*, Springer, New York, NY, pp. 85-108.

Duany, A., Plater-Zyberk, E. and Speck, J. (2001), *Suburban Nation: The Rise of Sprawl and the Decline of the American Dream,* Macmillan, New York, NY.

Duranton, G. & Turner, M., 2009. 'The Fundamental Law of Road Congestion: Evidence from US cities', *National Bureau of Economic Research Working Paper Series*, 15376 (EEE).

Eckerd, A., Campbell, H. & Kim, Y., '2012. Helping those like us or harming those unlike us: illuminating social processes leading to environmental injustice', *Environment and Planning B: Planning and Design*, 39(5), pp.945 – 964.

Epstein, J.M. (2007), *Generative Social Science,* Princeton University Press, Princeton, NJ.

Epstein, J.M. and Axtell, R. (1996), *Growing Artificial Societies: Social Science from the Bottom Up,* MIT Press, Cambridge, MA.

Filatova, T., Parker, D. and van der Veen, A. (2009), 'Agent-Based Urban Land Markets: Agent's Pricing Behavior, Land Prices and Urban Land Use Change', *Journal of Artificial Societies and Social Simulation,* 12(1), Available at http://jasss.soc.surrey.ac.uk/12/1/3.html.

Florida, R. (2002), *The Rise of the Creative Class: And How It's Transforming Work, Leisure, Community and Everyday Life,* Basic Books, New York, NY.

Florida, R. (2012), *The Rise of the Creative Class, Revisited - Updated and Revised Tenth Anniversary Edition,* Basic Books, New York, NY.

Fossett, M. and Waren, W. (2005), 'Overlooked Implications of Ethnic Preferences for Residential Segregation in Agent-Based Models', *Urban Studies,* 42(11): 1893-1917.

Gilbert, N. and Troitzsch, K.G. (2005), *Simulation for the Social Scientist (2nd Edition),* Open University Press, Milton Keynes, UK.

Gladwell, M. (2006), *The Tipping Point: How Little Things Can Make a Big Difference,* Hachette Digital, Inc, New York, NY.

Glaeser, E. (2011), *Triumph of the City: How Our Greatest Invention Makes us Richer, Smarter, Greener, Healthier and Happier,* Pan Macmillan, New York, NY.

Graham, S. and Marvin, S. (2001), *Splintering Urbanism: Networked Infrastructures, Technological Mobilities and the Urban Condition,* Routledge, New York, NY.

Granovetter, M. (1973), 'The Strength of Weak Ties', *American Journal of Sociology,* 78(6): 1360-1380.

Hagel, J., Brown, J.S. and Davison, L. (2012), *The Power of Pull: How Small Moves, Smartly Made, Can Set Big Things in Motion,* Basic Books, New York, NY.

Haque, N. (2007), *Brain Drain or Human Capital Flight.,* Pakistan Institute of Development Economics, Lectures in Development Economics, No. 11, Islamabad, Pakistan.

Henderson, V. (2002), 'Urbanization in Developing Countries', *The World Bank Research Observer,* 17(1): 89-112.

Holland, J.H. (1995), *Hidden Order: How Adaptation Builds Complexity,* Addison-Wesley, Reading, MA.

Imran, M., 2009. 'Public transport in Pakistan: a critical overview', *World Transit Research*. Available at http://www.worldtransitresearch.info/research/3506.

Imran, M., 2010. *Institutional Barriers to Sustainable Urban Transport in Pakistan*, Oxford University Press, USA.

Inskeep, S., 2012. *Instant City: Life and Death in Karachi* Reprint, Penguin Books.

Jacobs, J. (1961), *The Death and Life of Great American Cities,* Vintage Books, New York, NY.

Karachi City Government, 2007. *Karachi Strategic Development Plan 2020*, Karachi, Pakistan: City District Government Karachi.

Khan, T., 2013. 'Cooking in Karachi', *Foreign Policy*. Available at http://www.foreignpolicy.com/articles/2013/09/03/cooking_in_karachi_meth_pakistan [Accessed November 1, 2013].

Kim, Y., Campbell, H. & Eckerd, A., 2013. 'Residential Choice Constraints and Environmental Justice', *Social Science Quarterly (online)*.

Kotkin, J. and Cox, W. (2013), *The World's Fastest-Growing Megacities,* Forbes, Available at http://www.forbes.com/sites/joelkotkin/2013/04/08/the-worlds-fastest-growing-megacities/ [Accessed on August, 8th, 2013].

Krugman, P. (1991), 'Increasing Returns and Economic Geography', *Journal of Political Economy,* 99(3): 483-499.

Landry, C. (2000), *The Creative City: A Toolkit for Urban Innovators,* Earthscan, London, England.

Lee, D.B. (1973), 'Requiem for Large-Scale Models', *Journal of the American Institute of Planners,* 39: 163-178.

Liu, H. and Silva, E.A. (2013), 'Simulating the Dynamics Between the Development of Creative Industries and Urban Spatial Structure: An Agent-Based Model', in Geertman, S., Toppen, F. and Stillwell, J. (eds.), *Planning Support Systems for Sustainable Urban Development*, Springer Berlin, Berlin, Germany, pp. 51-72.

Lucas, R.E. and Rossi–Hansberg, E. (2002), 'On the Internal Structure of Cities', *Econometrica,* 70(4): 1445-1476.

Malanga, S.C.J.W. (2004), 'The Curse of the Creative Class', *City Journal,* 14(1): 36-45, Available at http://www.city-journal.org/html/14_1_the_curse.html.

Malik, A. and Karim, M. (2012), 'Karachi Youth Survey: Attitudes, Ambitions and Entrepreneurial Potential of Karachi's Youth', *USIP Conference*, Washington, DC.

Marcuse, P. (2003), 'Review of The Rise of the Creative Class by Richard Florida', *Urban Land,* 62(8): 40-41.

Miller, J.H. and Page, S.E. (2007), *Complex Adaptive Systems,* Princeton University Press, Princeton, NJ.

Mumford, L. (1961), *The City in History: Its Origins, Its Transformations, and Its Prospects,* Houghton Mifflin Harcourt, New York, NY.

Noorani, T., 'The flyover frenzy', *The News International, Pakistan*. Available at http://www.thenews.com.pk/Todays-News-9-73450-The-flyover-frenzy [Accessed May 1, 2012].

Organization for Economic Cooperation and Development (2006), *OECD Territorial Reviews: Competitive Cities in the Global Economy,* OECD Publishing, Paris, France.

Patel, A., Crooks, A.T. and Koizumi, N. (2012), 'Slumulation: an Agent-based Modeling Approach to Slum Formations', *Journal of Artificial Societies and Social Simulation,* 15(4), Available at http://jasss.soc.surrey.ac.uk/15/4/2.html.

Peck, J. (2005), 'Struggling with the Creative Class', *International Journal of Urban and Regional Research,* 29(4): 740-770.

Planning Commission of Pakistan (2011), *Pakistan: Framework for Economic Growth,* Planning Commission Government of Pakistan, Islamabad, Pakistan.

Porter, D.R. (2002), *Marking Smart Growth Work,* Urban Land Institute, Washington, DC.

Quah, D.T. (1997), 'Empirics for Growth and Distribution: Stratification, Polarization, and Convergence Clubs', *Journal of Economic Growth,* 2(1): 27-59.

Railsback, S.F., Lytinen, S.L. and Jackson, S.K. (2006), 'Agent-Based Simulation Platforms: Review and Development Recommendations', *Simulation,* 82(9): 609-623.

Romer, P. (1990), 'Endogenous Technological Change', *The Journal of Political Economy,* 98(5): 71-102.

Root, H.L. (2013), *Dynamics Among Nations: The Evolution of Legitimacy and Development in Modern States,* MIT Press, Cambridge, MA.

Rose, L.A. (1989), 'Urban Land Supply: Natural and Contrived Restrictions', *Journal of Urban Economics,* 25(3): 325-345.

Schelling, T.C. (1971), 'Dynamic Models of Segregation', *Journal of Mathematical Sociology,* 1(1): 143-186.

Simon, H.A. (1962), 'The Architecture of Complexity', *Proceedings of the American Philosophical Society,* 106(6): 467-482.

Simonton, D.K. (2011), 'Big-C Creativity in Big City', in Andersson, D.E., Andersson, Å.E. and Mellander, C. (eds.), *Handbook of Creative Cities*, Edward Elgar Publishing, Cheltenham, England.

Spencer, G.M. (2012), 'Creative Economies of Scale: An Agent-based Model of Creativity and Agglomeration', *Journal of Economic Geography,* 10(1): 247-271.

Stark, O. (2004), 'Rethinking the Brain Drain', *World Development,* 32(1): 15-22.

Torrance, E.P. (1988), 'The Nature of Creativity as Manifest in its Testing', in Sternberg, R.J. (ed.) *The Nature of Creativity: Contemporary Psychological Perspectives*, Cambridge University Press, New York, NY, pp. 43-75.

Torrens, P.M. (2002), 'Cellular Automata and Multi-agent Systems as Planning Support Tools', in Geertman, S. and Stillwell, J. (eds.), *Planning Support Systems in Practice*, Springer-Verlag, London, England, pp. 205-222.

Torrens, P.M. (2012), 'Moving agent-pedestrians through space and time', *Annals of the Association of American Geographers*, 102(1): 35-66 (DOI: 10.1080/00045608.2011.595658)

UN-HABITAT (2010), *State of the Cities 2010-11 - Cities for All: Bridging the Urban Divide,* UN-Habitat, Nairobi, Kenya, Available at http://www.unhabitat.org/content.asp?cid=8891&catid=643&typeid=46&subMenuId=0&AllContent=1.

von Neumann, J. (1966), *Theory of Self-reproducing Automata,* University of Illinois Press, Urbana-Champaign.

Wegener, M. (1994), 'Operational Urban Models: State of the Art', *Journal of the American Planning Association,* 60(1): 17-29.

World Bank (2009), *Reshaping Economic Geography* World Development Report No. SKU 17607, Washington, DC.

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