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The North-South Commuter Railway and the Future of Regional Development in the Philippines: Insights from a Spatial Computable General Equilibrium Model

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The North-South Commuter Railway and the Future of Regional Development in the Philippines: Insights from a Spatial Computable General Equilibrium Model

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Abstract

The North-South Commuter Rail (NSCR) is a major railway project that will dramatically alter the transport network for the most economically vibrant regions in the Philippines. This paper develops a spatial computable general equilibrium to consider how this new infrastructure will change the economic opportunities in the rail catchment area – a location spanning *10,000* km^2. Calibrated on the state of the economy in the year 2020, results suggest that by itself, the NSCR has limited economic impact compared to the baseline by 2040. The NSCR's substantial potential to spur regional growth can only be realized when accompanied by reforms in land markets to accommodate urban development even as environmentally-sensitive areas remain protected. This would increase the area's gross value-added by 3.7% relative to the baseline. Coupling land market reforms with policies to reduce business costs in strategic locations ensures that the rail has the greatest impact, however the marginal benefit of each industrial cluster is influenced by the strength of agglomeration economies operative in the area.

Keywords: Spatial equilibrium model, economic geography, transport infrastructure

JEL codes: O2, R1, R3

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1. Introduction

The North-South Commuter Rail (NSCR) is a 163-kilometer rail infrastructure that will link Metro Manila, the Philippines' economic and political center, to special economic zones in the north and the manufacturing hubs to its south. This paper uses a spatial computable general equilibrium (SCGE) model to analyze the potential economic impacts of this investment.

Lower transport costs from the rail are expected to open up several channels of growth for the 119 cities and municipalities within the rail catchment area. First, gains from trade could be realized from the effectively enlarged market of each location which can now reach more locations at lower costs. This, in turn, enhances the scope for trade and productivity gains from specialization (Bernard et al. 2019; Charnoz et al. 2018). Second, the reduction of physical and economic distance leads to productivity gains from agglomeration economies – improved input and output market matching, knowledge diffusion, and scale economies in soft and hard infrastructure provision (Combes and Gobillon 2015; Zárate, 2022). Further agglomeration economies can also be realized when households and firms relocate near each other to take advantage of positive externalities that could not otherwise be realized by a handful of households and firms (Coşar and Fajgelbaum 2016; Donaldson and Hornbeck 2016; Redding and Rossi-Hansberg 2017). Finally, market access gains and agglomeration effects can be capitalized into land values, increasing the incomes of landowners (Donaldson and Hornbeck 2016; Mohammad et al. 2013).

However, while trade cost reduction is beneficial on the aggregate, the distribution of benefits and costs can be uneven within affected areas and across economic sectors. The location-specific characteristic of rail, or any transport infrastructure for that matter, means that it changes the relative distances of locations with each other. It is therefore possible for locations with good access to the rail network to grow at the expense of locations that are near direct access locations, while leaving faraway locations unaffected (Bogart et al. 2022; Fujita et al. 1999; Hodgson 2018).

The interplay of trade costs, technology, and resource endowment has generally shown new transport infrastructure to favor locations that are already better developed relative to the less developed regions. The latter could experience reduction in fixed asset investments, declines in industrial output, and outflow of skilled labor when introduced into competition with more attractive locations by lower trade costs (Diao, Leonard, and Sing 2017; Jin et al. 2020; Ke et al. 2017; Li, Wu, and Zhao 2020; Qin 2016; Yu et al. 2019). Effects could also differ across sectors. The stylized predictions from the economic geography literature is that lower trade costs accentuate spatial concentration in sectors where increasing returns to scale is strong, while dispersing industries that operate more strongly on the basis of comparative advantage (Pflüger and Tabuchi 2019). This appears consistent with evidence from studies of rail inter-city connections in China, Japan, the US, and most of today's developed economies. Broadly speaking, decentralization tends to be observed in the manufacturing sector, while concentration in the skill-intensive services where increasing returns to scale plays an important role (Chang and Zheng 2022; Chang et al. 2021; Li and Xu 2018; Zhou and Zhang 2021; Zou et al. 2021). These, in turn, translate to relatively larger gains for workers in technologically sophisticated and service sectors (Dong 2018; Hanley et al. 2022; Kuang et al. 2021; Sun et al. 2023).

The losses in some locations and sectors could be eased and compensated by larger overall gains if the cost of human interactions can decline faster relative to trade costs (Ahlfeldt and Feddersen 2018; Dong et al. 2021; Faber 2014; Liang et al. 2020). In practice, this implies enabling high worker mobility through foundational investments in human capital regardless of location.

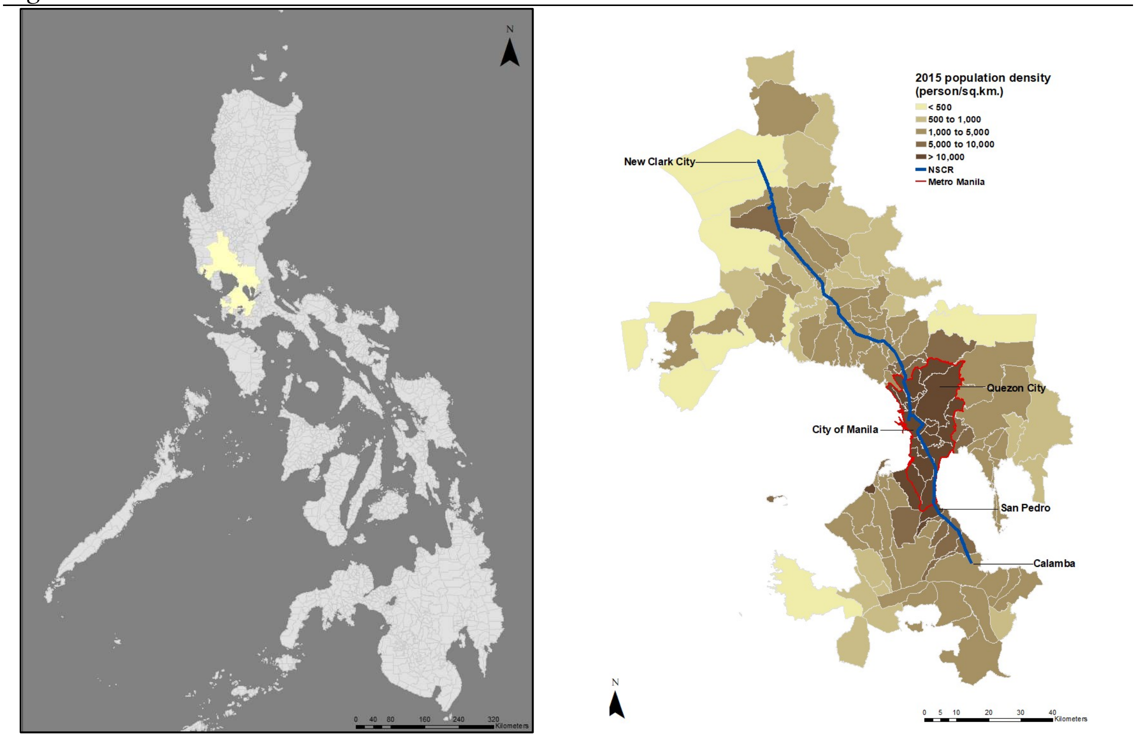
An infrastructure the size and scope of the NSCR is anticipated to be a gamechanger in the economic and spatial development of Metro Manila and the surrounding regions. With a catchment area of around 10 thousand km^2 involving 119 cities and municipalities, the spatial and sectoral distributions of benefit and cost will be heterogenous, and understanding these can help local governments put in place soft and hard infrastructure investments to maximize the benefit from the infrastructure and mitigate any negative effects. The SCGE model is well-suited to this objective. SCGE takes into account the full effects of the rail project for each unit in the catchment area – direct, indirect, and induced impacts. This recognizes that aside from the direct productivity benefits of reduced travel time, indirect gains could also come from the way each sector affects demand in other subsectors and locations. Importantly, the model allows for the changes in travel costs from the NSCR to change the location choices of households and firms, and thereby stimulate further productivity gains. Finally, the SCGE accommodates analyses of how the impacts of the NSCR could change when combined with other policy experiments such as additional infrastructure investments.

The results suggest that by itself, the NSCR has limited economic impact compared to the projected baseline gross value added (GVA) in 2040. The aggregate effects of implementing additional transport infrastructure to complement the NSCR likewise do not contribute larger gains in GVA, although the geographic and sectoral distributions of gains are more equitable compared to the NSCR-only scenario. These large infrastructure projects have modest impacts because under a situation of limited land supply, the economic opportunities generated by the infrastructure investments quickly translate to higher land prices. As such, the NSCR's substantial potential to spur regional growth only becomes perceptible when accompanied by reforms in land markets to accommodate urban development, increasing the catchment area's GVA by 3.7% relative to the baseline. Coupling land market reforms with policies to reduce business costs in strategic locations can ensure that the rail has the greatest impact. However, the marginal benefit of each industrial cluster is influenced by the strength of agglomeration economies operative in the area.

The North-South Commuter Rail and the catchment area

The NSCR is one of the most ambitious transport infrastructure investments in the Philippines. The project is estimated to cost nearly US$16 billion, equivalent to 4% of the country's GDP in 2019. The 163-kilometer rail infrastructure will link the highly dense Metro Manila, the Philippines' economic and political center, to special economic zones in the north and the manufacturing hubs to its south as illustrated in Figure 1.

Figure 1. The North South Commuter Rail Catchment Area



Source: Authors based on *2015 Philippine Census of Population and Housing and municipal land area (PSA 2020).*

Policy makers look to the infrastructure as a gamechanger to the region's beleaguered transport network. Roads in Metro Manila are among the most congested in Asia, with peak-time travel durations taking 50% longer than non-peak hours – substantially higher than the 24% average in large cities of neighboring countries (ADB 2019). Traffic congestion in Metro Manila and neighboring provinces is estimated to cost the economy US$ 50 to US$ 60 million a day (JICA 2019), equivalent to 6% of GDP in 2019.

The NSCR construction is divided into three phases, and the placements of the stations are configured to enhance the existing rail network and connect with other urban rail lines that are under construction. The 37.6-km middle segment will have ten stations connecting the City of Malolos, Bulacan, and the City of Manila, and is anticipated to be operational by 2027. It is expected to cut travel time between the two cities from 1.5 hours to 35 minutes. The northmost connection with six stations, totaling around 53 km in length, starts in New Clark City and terminates in the City of Malolos with operations expected to begin in 2028. Finally, the 56-km southern segment mainly follows the existing line of the Philippine National Railways, which runs from Tutuban to Calamba City. The full operation for the entire NSCR is foreseen to be in 2031 and will halve the travel time between Clark International Airport and Calamba from more than four hours to around two hours with a ridership of 0.6 to 0.76 million per day (ADB 2022; JICA 2019).

The NSCR only directly passes through 28 cities and municipalities, but the scale of the infrastructure is anticipated to affect as many as 119 local jurisdictions (see A1. Data Appendix

Table A1-1 for the complete list). The NSCR's extent of influence was determined based on the contiguous nighttime light area coverage of the 28 station-endowed cities. This is in keeping with the concept of a natural city which relies on an area's functional urban area, emphasizing city size by economic activity rather than administrative boundaries (Egger et al. 2017).

Figure 1 shows that the highest concentration of people in the catchment area is in Metro Manila, the economic and political capital, and then diminishes farther from the metropolitan boundary. Cities and municipalities south of Metro Manila are generally denser and more prosperous compared to areas in the north, reflecting the gradual migration of the manufacturing industries to the south of Metro Manila in the 1990s (World Bank 2017). Majority of the working population in the catchment area have at least completed high school education and are considered skilled. Low-skill workers account for only about one-fourth of the workforce and are concentrated along the edges of the catchment area. Non-tradeable services account for 56% of total employment and is the largest employment sector in most cities and municipalities. Business services is the next largest employer with a share of 28% with Metro Manila as its center. Manufacturing employment is highest in the peripheries of Metro Manila, especially towards the south.

The broad regional differences within the catchment area — a more greenfield and less developed north against a more brownfield and prosperous south — will be one of the driving forces for the nuanced interactions of each location with the NSCR.

2. Methodology: The SCGE Model

The SCGE model developed in this paper takes into account the full effects of the rail project for the 119 geographical units in the catchment area, each of which have residential and productive activities, and are linked by transport networks with each other.

The impacts of the NSCR are modeled as being mediated through three sets of channels. First, there are direct productivity benefits from reduced travel time. Second, indirect impacts come from the way each sector affects demand in other subsectors and locations. Finally, the most defining feature of an SGCE is its explicit modeling of how economic opportunities from the NSCR will induce the spatial reallocation of people and economic activities over time. The combination of these three channels determines the outcomes for each of the locations in the catchment area.

The SCGE model developed for this study is outlined in this section and shares large similarities with the model developed by Bird and Venables (2019). A full specification of the model is available in the appendix.

2.1 Agents in the model

There are two types of households, differentiated by skill level. They supply labor, and demand housing, and goods and services. Their choices include where to live, where to work, what type of housing to occupy (modern versus traditional), and amount of goods and services to consume. Thus, each household's choice of place of residence and place of work is endogenous, meaning it depends on prices (that of housing in particular) and commuting costs. Households have the following utility function:

$$U_{ij}^{lh} = \left(\prod_s x_{ij}^{slh}\right)^{\beta^{slh}} {h_{ij}^{lh}}^{\beta^{lh}} b_i^{lh} t_{ij}^{l} \qquad (1)$$

U_{ij}^{lh} is the utility of a household that lives in location i, works in location j, is of labor type l and lives in housing type h. x_i^s is household demand for good x in location i of sector s; q_i^h is the price per unit of floorspace; h_i^h is household demand for housing in location i and housing type h; b_i^{lh} is the amenity value to households living in location i, of labor type l and housing type h; and t_{ij}^l is the commuting costs of the household living in location i and working in location j of labor type l. This is maximized subject to the budget constrained in Eq (2).

$$w_j^l + m_{ij}^l = q_i^h h_{ij}^{lh} + \sum_s P_i^s x_{ij}^{slh} \qquad (2)$$

Where m_{ij}^l is the household income from land transfers for those living in location i, working in location j of labor type l.

The production side of the economy is represented by firms that use labor, land, and intermediate goods and services in production. Firms are grouped into three sectors: manufacturing, business services, and local services. Each of these is monopolistically competitive, and differ according to skill requirements, use of land and intermediate inputs, and costs of transporting their outputs. The largest sector is local services or services that are non-tradeable. Outputs of the other two sectors are tradeable, which means that they are bought and sold both within the catchment area and also exported.[1]

The three sectors differ in terms of their inputs. Manufacturing is the most land-intensive of the sectors, business services are more intensive in skilled labor, and local services are intensive in low-skill labor. All sectors have Cobb-Douglas technologies using labor of two skill levels, land, and intermediate goods and services, some of which are imported from outside.[2] The remainder of the inputs are composites of goods produced in the catchment area. Firms in each sector choose how much to produce and where to locate, depending on land rents, access to consumers, workers and suppliers of intermediate inputs.

$$Y_{is} = a_{is} \prod_k X_{ks}^{\alpha_{ks}} - F_{is} \qquad (3)$$

[1] Local services can also potentially be exported, but in insignificant quantities.

[2] Food enters the model as an 'imported' input to retail, which is part of local services.

Where Y_{is} is the firm output in location i in sector s, a_{is} is the total factor productivity, α_{ks} is the share parameter of input k with the sum of share parameters summing to one across the factors of production, X_{ks} is the factor of production input, and F_{is} is the fixed costs of production.

Provided that $a_{is} \prod_k X_{ks}^{\alpha_{ks}} > F_{is}$, then $Y_{is} > 0$. Fixed costs are part of the production function because production requires a minimum number of factor inputs. For example, a factory may need a minimum threshold of machinery and labor before it can produce any output.

Assuming non-zero production, a firm minimizes the costs for each level of production:

$$\min \sum_k v_{ks} X_{ks} \qquad s.t. \;\; Y_{is} + F_{is} = a_{is} \prod_k X_{ks}^{\alpha_{ks}} \tag{4}$$

Where v_k is the price of factor of production k.

Housing is supplied by developers assuming two building technologies. The 'modern' technology can achieve density by building tall. This technology implies increasing marginal cost, but does not reduce the quality of accommodation. Meanwhile, 'traditional' technology, uses materials with poor load-bearing properties and achieves density by crowding. More floor-space per unit of land area can be produced at constant marginal cost, but its value goes down as amenity declines with crowding. Finally, firms utilize land directly in their production activities.

Developers choose the floorspace per unit of land area, g_i^h that maximize rents, where i is the location of the construction firm and h is the type of housing provided. For modern housing $(h = 1)$, developers choose floorspace per unit of land area, g_i^h. The price of floorspace per unit of quality is q_i^h. κ^h and γ^h are parameters that determine the shape of the cost function, where $\kappa^h > 0$, $\gamma^h \geq 1$. The maximization problem is:

$$\max_{g_i^h} r_i^h = q_i^h g_i^h - \kappa_i^h \left(g_i^h\right)^{\gamma^h} \tag{5}$$

Traditional housing $(h = 2)$ has constant marginal costs but increases density by reducing the quality of construction. The fall in quality reduces the price that households are willing to pay for traditional housing. The price for this type of development is a fraction of the price of a development with unit quality, q_i^h. This fraction is a function of the floorspace per unit area, which reflects the extent to which quality deteriorates and is represented in the objective function below by $\left(g_i^h\right)^{\frac{1-\lambda}{\lambda}}$.

$$\max_{g_i^h} r_i^h = g_i^h q_i^h \left(g_i^h\right)^{\frac{1-\lambda}{\lambda}} - \kappa_i^h g_i^h \tag{6}$$

2.2 Spatial connectivity

Spatial connectivity enters the model in two distinct ways. First, workers travel between place of residence and place of work, this is more costly (destroying more utility) the further the journey. Transport costs also depend on transport mode – public or private – the choice of which depends on skill level.[3] Public and private modes of transport have different commute times for each origin-destination pair with private transport having lower pairwise commuting costs than public in the individual's utility function.

Second, goods and services must be delivered from firms to customers. Transport costs t_{ij}, are incurred in 'iceberg' form as lost units of output, which varies across sectors according to the tradability of their output within and outside the catchment area.[4] These costs apply to goods used for final consumption and to intermediate goods. The structure of intermediate goods linkages between firms and transport costs creates a force for clustering of activity (Fujita et al. 1999).

$$t_{ij} = \exp\left(t_s \times dist_{s,ij}\right) \tag{7}$$

$dist_{s,ij}$ is the travel time between two cells i and j (normalized to 1 being the maximum travel time between two cells within the city), so $dist_{s,ij} \leq 1$, Meanwhile, . t_s differs based on the sector ranging from 0.8 for households to 1.3 for firms that produce local services.

In a variant of the model where potential 'agglomeration' is included, spatial connectivity enters the model through an additional path. Spatial clustering in all production sectors lead to localization economies, i.e. positive productivity spillovers between firms in the same sector, the strength of which depends on their proximity to each other. Formally, productivity in all sectors is an iso-elastic function of the sum of employment in firms in the sector, weighted by negative exponential distance between firms. The distance weights take the form of an exponential spatial decay such that, for example, employment entailing 15 minutes of commute has 0.74 times the impact of employment in same location; employment half an hour away has 0.55 times the impact, and employment at the farthest ends of the catchment area has just 0.01 times the impact of employment in the same location. The elasticity of productivity with respect to this weighted mass of employment remains constant across sectors. In the base case, the elasticity takes value 0 (entailing no change to productivity with density), which rises to 0.06 for scenarios with agglomeration (i.e. a 100% increase in weighted employment mass increases productivity by 6%).[5]

2.3 Market clearing

Firms, households, and developers interact through the markets for goods and services, land, labor, and housing (Figure 2). Each market operates in every spatial unit in the catchment area, so prices and wages are location specific. A location's productivity determines the output of firms in that unit

[3] Only skilled workers are assumed to have access to private transport.

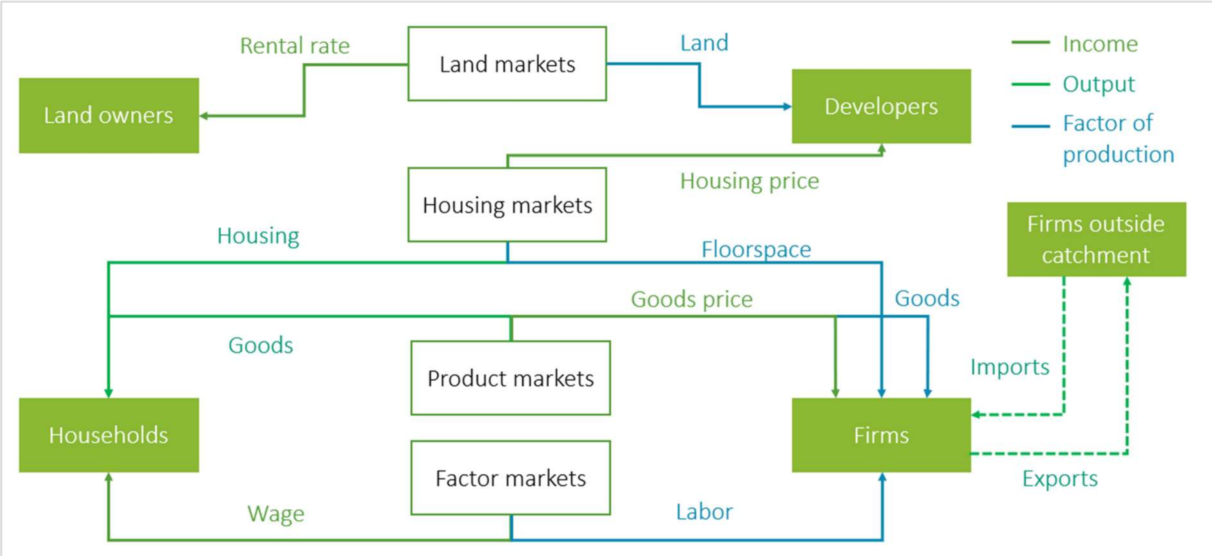
[4] Iceberg trade cost is a common assumption in the empirical trade literature. The idea is that only a proportion of the products reaches the final destination, and the losses increase with the distance travelled.

[5] The elasticity value for NSCR catchment area assumes a value that is roughly the median of the range of estimate in the literature. Since some components of agglomeration are already captured by the model, these two values can be considered as extremes of the likely range.

such that firms are willing to pay higher wages to locate in higher productivity locations. Meanwhile, locations with higher amenity are more attractive to households.[6]

Price differences in goods and services within the catchment area is small (bounded by transport costs), as it is for labor (bounded by commuting costs). However, large differences are observed for land and hence housing prices with large center to edge variation in land rents. This means that rents in the center are substantially higher than rents in peripheral areas. Together, these create a setting where the spatial variation in rents is much greater those in prices and wages.

Figure 2. Interactions in the SCGE Model



Notes: Goods travelling between firms within the catchment area and those outside it could be either final output consumed by households directly via distributor firms, or used as intermediate inputs of production. This is the same for trade within the catchment area, whereas firms outside are not modelled in the analysis. In the latter, demand and supply are functions of a fixed price.

Units in the catchment area also trade goods and services with the outside world, and the equilibrium solves for prices such that supply equals demand in each of these markets, and in each unit. Within this structure, the supply of land is exogenous, although its use (commercial by sector and residential by type, modern or traditional) is solved within the model. The allocation of land between competing uses is determined by bid-rents capturing the demand from different sectors of production and types of residential use. The economic use of land can change either at the intensive margin – increasing in density over the same space; or in the extensive margin – new developed areas. Within the catchment area, the intensity of land-use can change by building taller or crowding.

The model solves the equilibrium set of prices that determine land use, location of residence and employment, and consumption and production levels given existing technologies embodied by the production capabilities of firms; preferences based on the objective function of each agent; the connectivity structure in transport networks; and endowments in labor type and land in each location.

[6] Households do not have a direct workplace preference parameter, and do not care about workplace locations apart from the differences in wages. Household utility is positively impacted by higher wage such that workplace preference is only indirectly influenced by the productivity parameter (as productivity determines the wage).

The model is calibrated by finding the productivity and amenity values for each productive sector and household type in each location, such that the model solution exactly fits the base data.

Changes in policy scenarios enter the model exogenously to simulate its impact. For example, the travel time reduction from the NSCR is modeled as a shorter commuting time and cheaper transportation costs between locations of the catchment area, while technology, preferences, geography, endowments, productivity, and amenity values remain as given.

3. Data sources

3.1. Transport network

The existing transport network in the NSCR catchment area are taken from the shapefiles of the Department of Public Works and Highways as of June 2020, supplemented with Google OpenStreetMap (OSM) as of 6 January 2021. Information on the rail network including travel speeds were obtained from the Light Rail Transit Authority and the Philippine National Railways.

Peak hour travel times by private and public road transit between random locations within Metro Manila and neighboring units are taken from Google API between 18 February to 11 March 2020, and averaged to arrive at travel times for municipal pairs.[7] This is supplemented with open road transit data and a direct network analysis to arrive at travel time information for all municipal pairs in the catchment area. In cases where travel time information is not available in the Google API sample, travel duration for municipal pairs that go through Metro Manila were derived by identifying twenty-eight key access and entry points to Metro Manila using OSM.

The 2040 baseline pairwise travel time between units in the catchment area incorporates anticipated travel time changes from the ongoing transport projects listed in

[7] Peak hours correspond to 5 to 9 am in the morning and 5 to 9pm in the evening.

Table A1-2, which came from the Transportation Masterplan (JICA 2019) together with the government's priority infrastructure projects as of May 2021. To keep the model tractable, projects included in the model were selected based on a set of criteria: (i) broad geographical reach spanning multiple local government jurisdictions; (ii) completion around the same time as the NSCR; (iii) certainty of construction or projects that have started construction as of August 2021.

Other transport projects from the Master Plan that have yet to start construction or are still awaiting official budget allocations make up the list of complementary infrastructure (Table A1-3), which were used as one of the policy scenarios.

3.2. Socioeconomic data by city and municipality

The model is calibrated on the levels and distribution of social and economic activities in each of the 119 cities and municipalities that make up the catchment area, which are then projected forward to the year 2040 to form the baseline or business as usual scenario (BAU).

The catchment area's constant GVA is derived from the population-weighted regional output accounts from the PSA (2020), and assumed to grow at 5.5% per annum until 2040 based on projections of the Asian Development Bank.

Information on population and number of households, including information for their projections to 2040 are from the 2015 Philippine Census of Population and Housing (PCPH) (PSA 2017). The origin-destination flow of working populations between each pair of municipalities, by sector, and years of education are available from Form 3 of the PCPH 2010.

There are four productive sectors in the PCPH corresponding to agriculture (not included in the model), manufacturing, local services, and business services. The local services sector refers to locally consumed services such as personal services, food and accommodation; while the business services cover activities such as banking and finance, professional services, etc.

The share of modern and traditional housing in each municipality was derived using information on household characteristics in the PCPH. A dwelling is considered traditional if it meets one of the following criteria: (i) roof or wall materials are made from makeshift materials or unreported; (ii) rent-free house or lot with owner consent; (iii) rent-free house or lot without owner consent.

The spatial distribution of firms by sector and employment size for each municipality came from the 2018 Updated List of Establishments from the PSA (PSA 2022). The share of income spent on housing and transportation services, and labor force characteristics such as participation, employment, and wage by sector are sample-weighted average municipality values from the 2015 Family Income and Expenditure Survey and the 2015 Labor Force Survey respectively.

3.3. Other city and municipality characteristics

The PCPH has information on available amenities in each village such as schools, hospitals, markets, and establishments. This formed the basis for calculating the shares of villages in each municipality with access to different amenities.

The production relationship among sectors is represented by the 2017 30x30 Input Output Tables for 2017 from the ADB and is assumed to apply across all municipalities in the catchment area.

Finally, the authors built a land use category for each of the 119 units using a variety of sources: the most updated comprehensive land use plans; provincial development and physical framework plans; flood hazard maps from the Phil-LiDAR programs; and strategic agriculture and fisheries development zones from the Department of Agriculture. The categories from the various sources were then harmonized into three broad classifications: (i) non-developable areas or protected areas (47%); (ii) built-up areas (31%); and (iii) available expansion areas (22% or 2,300 km^2).

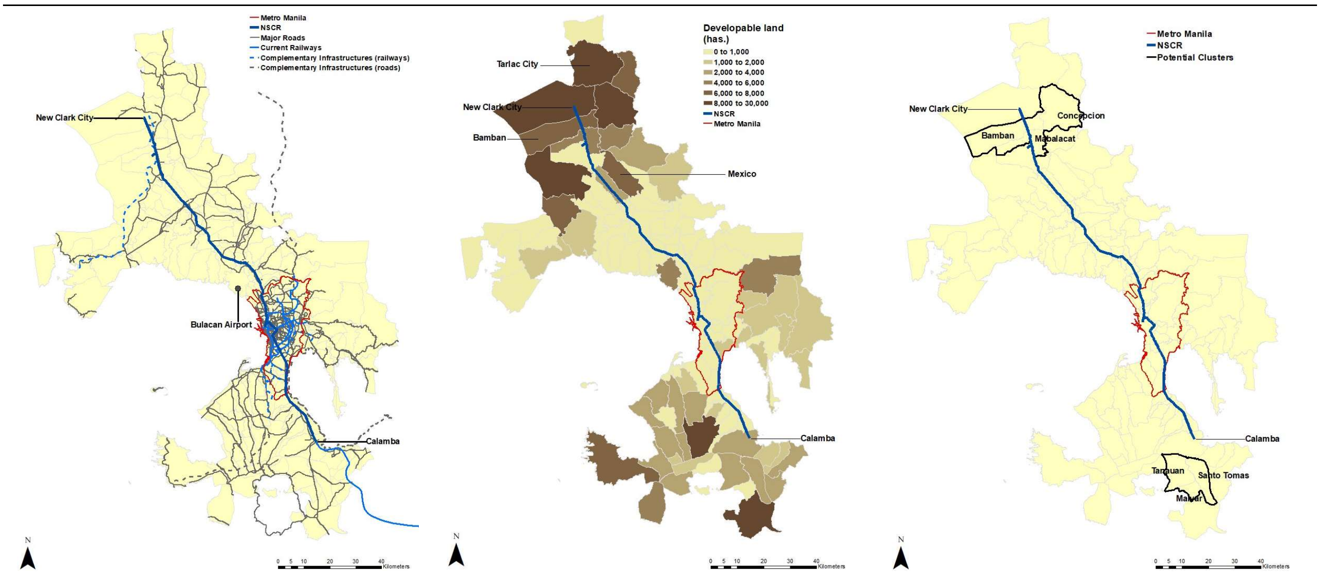
4. Policy scenarios

The BAU considers a 2040 where none of the NSCR segments are constructed, but incorporates transport projects that are already being built prior to the NSCR's construction. Scenario A corresponds to the core experiment when the NSCR becomes fully operational, while the next four scenarios recognize that interactions with other infrastructure and policies could alter the magnitude as well as the spatial and sectoral distribution of the NSCR's impacts.

In Scenario B, the NSCR's effect on transport costs unfolds in the context of other transport infrastructure projects that have been planned but have not yet been approved and funded. This set of infrastructure includes four trans-provincial highways, and six rail lines illustrated in Figure . This recognizes that the extensiveness and quality of adjoining transport infrastructure will influence the reach of the NSCR's effects.

Figure 3. NSCR under alternative scenarios

1. *Scenario B*	2. *Scenario C*	3. *Scenario D and E*



Sources: Authors based on: (1) DPWH and NEDA inventory of approved projects (2021); (2) various land use plan sources

Scenario C considers a policy that relaxes land use to allow the development of about 2.3 thousand km^2 of land in the catchment area to meet demand for urban development while leaving protected areas intact (Figure 3.2). Land use regulations govern how areas can be developed— zoning, lot sizes, densities, urban growth boundaries, and building height restrictions. The interaction between land markets and transport networks are key determinants of how limited land resources are allocated for competing social and economic uses through their influence on land value (Bird and Venables 2020; Chen et al. 2023; Lall et al. 2021; Miyauchi et al. 2021; Rappaport 2008; Robson et al. 2018). Existing regulations in the Philippines put primacy on land suitability in determining land use plans. While the supply-side approach is useful for identifying protection areas such as environmentally sensitive zones, prime agricultural lands, and rights-of-ways, the one-sided emphasis tends to translate into an urban curtailment policy and has been associated with illegal encroachment and urban sprawl (Corpuz 2013).

Finally, scenarios D and E consider a 10% reduction in business costs in one and two hypothetical industrial clusters respectively (Figure 3.3). To place this policy experiment in context, the Philippines has been ranked 171 out of 190 economies in the 2020 Doing Business Report for starting a business, well below its regional peers (World Bank 2020). Furthermore, the survey indicates that procedures vary across multiple national and local governments involved in the approval and regulatory chain. The lack of standardized regulations for procedures and land use raises uncertainty and the costs for businesses to relocate where they make the most economic sense.

Industrial clusters could be a way to manage this problem, albeit on a limited scale. In this experiment, the cluster in the north is made-up of Bamban, Concepcion, and Mabalacat City, which envelope the Clark Freeport Zone. In the south, Malvar, Santo Tomas, and Tanauan in the south forms another cluster. These likely up-and-coming economic clusters were chosen based on (i) availability of land for development; and (ii) proximity to highly urbanized areas.

5. Results

The projection of 2020 socioeconomic landscape to 2040 shows that the catchment area's population in 2040 will increase by around 1.8 million households (21%) while GVA doubles from 2020 levels reaching over US$ 460 billion. Despite this growth, the level falls short of the vision of *AmBisyon 2040* to increase national per capita income by threefold between 2015 to 2040 to reach upper middle income status (NEDA 2016), a level that entails a catchment area GVA that is at least 30% higher than the BAU.

The BAU and the results from subsequent scenario experiments are summarized in Table 1.

5.1. Scenario A: The NSCR construction

The Scenario A column in Table 1 shows that constructing the NSCR has limited impact on total GVA, wages, and total land rents by 2040. GVA rises only by a modest US$ 1.6 billion (0.4%) relative to BAU 2040.

Spatially, the completion of the NSCR makes the areas along the route relatively more attractive to households and businesses. This leads to rising rents along the NSCR while rents further away become depressed (Figure 4). The area east of Metro Manila, especially Antipolo City also experiences an increase in populations and rent. While not directly on the NSCR route, these areas benefit from the completion of ongoing light rail systems that are designed to be linked with the NSCR.

Figure 4. Scenario A: Population and Area Rents, % Change Relative to Baseline

Population	Total Rent

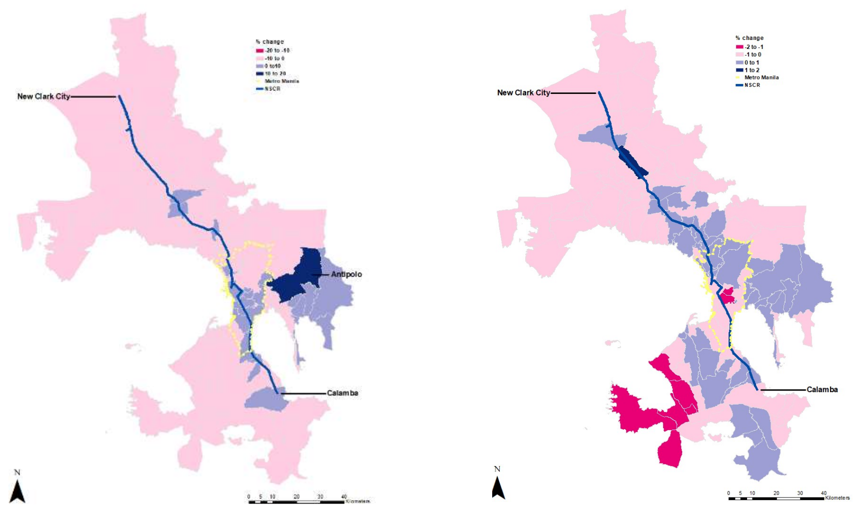


Table 1. Results of the NSCR Scenario Experiments

Economic outcomes		2040 Baseline	Scenario A	Scenario B	Scenario C	Scenario D	Scenario D*	Scenario E	Scenario E*
			NSCR	NSCR and Complementary Infrastructure	NSCR and Land Use Policy Changes	NSCR and Reduced Business Costs in Cluster A	NSCR and Reduced Business Costs in Cluster A and agglomeration	NSCR and Reduced Business Costs in both Cluster A & B	NSCR and Reduced Business Costs in both Cluster A & B, and agglomeration
			% change from baseline 2040						
Population (*workers*)	**Modern housing**	8.8 million	-0.1%	-0.1%	-8.6%	-9.0%	-8.7%	-9.2%	-8.9%
	Traditional housing	1.5 million	0.6%	0.5%	49.1%	51.5%	49.9%	52.6%	51.0%
Total wage	**Total**	355.1 bn US$	0.5%	0.5%	3.5%	5.1%	10.1%	6.2%	9.7%
	Skilled	297.2	0.6%	0.6%	3.9%	5.3%	9.0%	6.4%	8.5%
	Low-Skill	57.9	-0.5%	-0.4%	1.7%	4.0%	15.9%	5.3%	15.7%
Land Rent	**Total**	109 bn US$	0.0%	0.0%	4.3%	6.3%	12.8%	7.5%	12.4%
	Per km2	33.3 mn US$	0.0%	0.0%	-38.0%	-36.8%	-33.0%	-36.1%	-33.2%
GVA	**Total**	463 bn US$	0.4%	0.3%	3.7%	5.4%	10.7%	6.5%	10.3%
	Business Services	112.0	5.7%	5.6%	17.6%	15.4%	-0.5%	16.7%	-1.5%
	Local Services	54.0	-0.2%	0.1%	6.2%	9.2%	38.9%	11.8%	39.8%
	Manufacturing	235.4	-2.1%	-2.1%	-4.3%	-1.2%	8.6%	-0.5%	8.2%
Utility	**Skilled**	100 (indexed)	0.3%	0.4%	7.4%	9.0%	14.4%	9.7%	14.5%
	Low Skill	100 (indexed)	-0.3%	0.1%	7.9%	10.8%	22.8%	11.3%	23.2%

Business and local services firms are generally drawn to areas where concentrations of people have grown, even as manufacturing activities disperse to areas with lower rent. The latter's GVA contribution shrinks by 2.1%. Business services emerge as the sector responsible for the aggregate GVA increase, with contributions rising by over US$ 6 billion or 5.7% from baseline such that increases in wages largely accrue to the skilled workers.

Notwithstanding the limited incremental contributions of the NSCR to the GVA by 2040, back-of-the-envelope calculations suggest that the investment is worth making from a cost-benefit analyses perspective. The GVA contributions of the NSCR is estimated to exceed the capital and operation costs by close to US$ 3 billion by 2060. This estimate is based on assumptions of a project cost of US$16 billion, operating and maintenance cost of US$ 430 million per year, and a discount rate of 6%. Accounting for other benefits such as vehicle costs savings, CO_2 emission reductions, and road safety benefits brings potential benefits to over US$ 300 billion, such that benefits are almost three times as large as the capital and operating costs.

5.2. Scenario B: NSCR and complementary infrastructure

The completion of the NSCR together with the line-up of complementary infrastructure projects in the Transport Masterplan (Scenario B) has almost no additional aggregate economic impact compared to Scenario A.

Nonetheless, the headline similarities mask differences in impacts across space and between social groups. Compared to Scenario A, there is more movement of households along the route of the NSCR as transport connections with the peripheral areas improve with additional transport projects. Skilled workers in modern housing still concentrate around Metro Manila, but there are limited movements to traditional housing vacated by low-skill households in the periphery of the NSCR's path as rents in these areas decrease.[8] While wages of low-skill workers still fall, the improved accessibility for the entire catchment area combined with practically no movement in average rents results to a small increase in the utility of the low-skill, and hence wage inequality is less severe compared to Scenario A.

Local services employment increases the most in areas along the NSCR route in keeping with the sector's greater reliance on low-skill workers. However, business services employment only increases along the southern segment of the NSCR and east of Metro Manila. Finally, manufacturing employment rise in many areas but generally avoids locations that experience increase in per km^2 near the rail route.

[8] This behavior comes from the Fréchet parameter in preferences for location pairs, which ensures that at least some people from all groups want to live in all locations. This is imposed in the model to prevent corner solutions and locations with zero inhabitants.

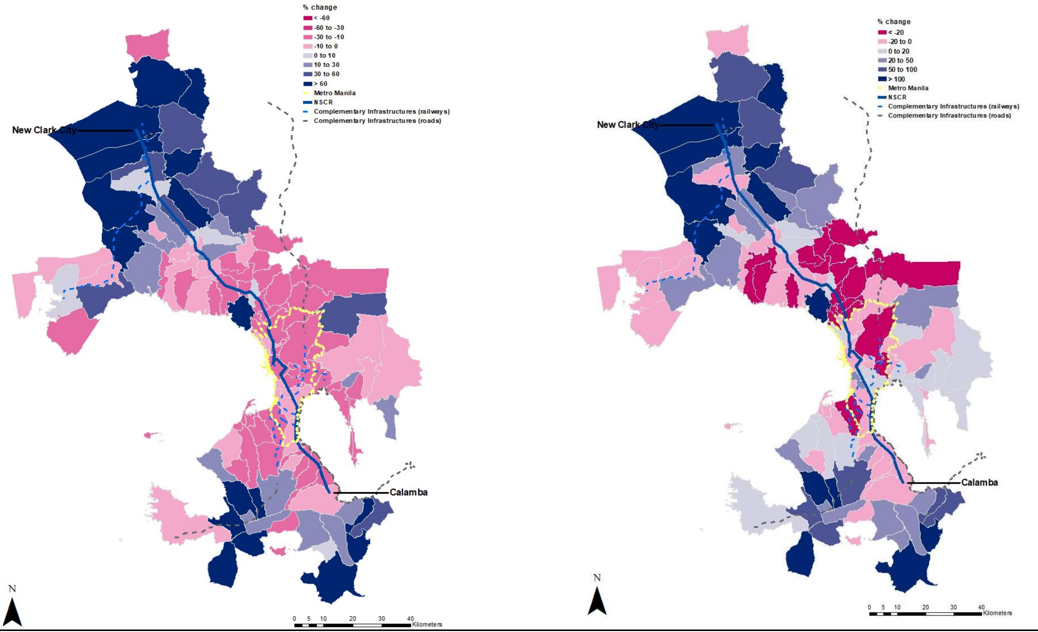
5.3. Scenario C: NSCR with changes in land use policies

Results from Scenario C demonstrate that reforms in land use regulations to facilitate urban development is key to unlocking the economic potentials of the NSCR. The large increase in the supply of developable land unsurprisingly drives down rents per km^2 across the catchment area. However, on the aggregate, limited land availability for development in the most appealing areas means that the rise in commercial activity and residential development offsets the per km^2 fall in rents such that total rents nonetheless rise by around 4.3%.

The greater availability of land encourages both skilled and low-skill workers to move to areas where newly developed lands are most abundant. Cities and municipalities north of Metro Manila on average expand the number of households by 40%, the south by 27%, while Metro Manila de-densifies (Figure 1). However, this outward expansion is also driven by traditional housing, with 735,000 more households in traditional housing than in the BAU.[9]

Figure 1. Scenario C: Population and Area Rents, % Change Relative to Baseline

Population | Total Rent



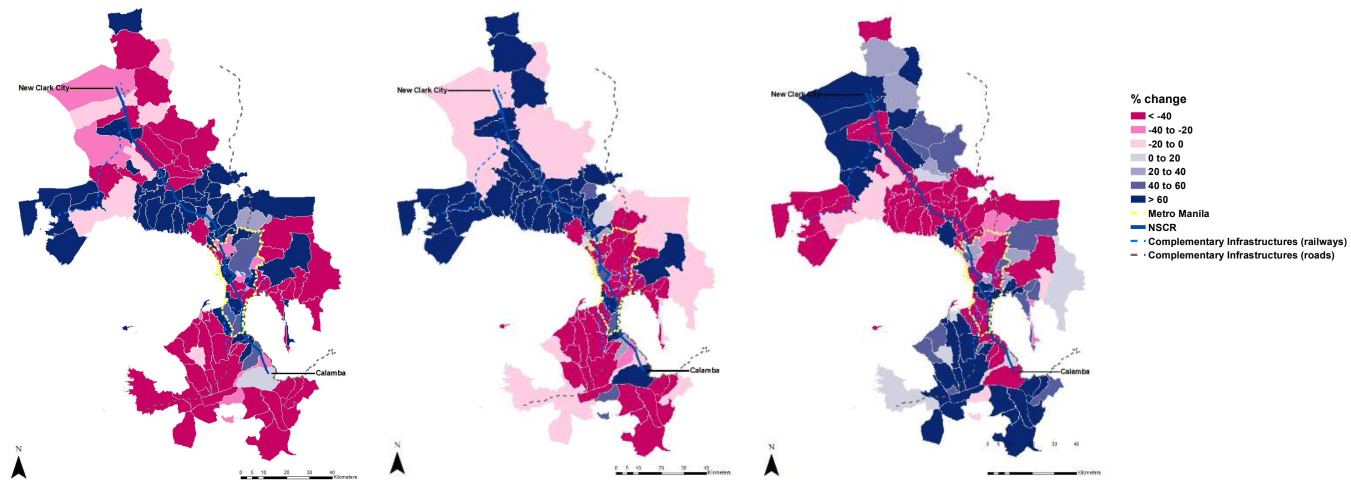
Local services, attracted by dense populations, congregate in areas around the NSCR route, especially in the north. Growth in Scenario C is predominantly driven by a US$ 20 billion increase (17.6%) in business services GVA, most of which shift towards the northern belt of Metro Manilla. Manufacturing relocates to the areas with the largest falls in rent per km^2

[9] The scale of this shift should be seen in context and is partly model-driven. The assumed constraints on development between 2020 and the baseline 2040 scenario, combined with 20% population growth implies a substantial fall in households living in traditional housing (both in absolute numbers and as a share). Availability of land for development in this scenario partly reverses this trend. In 2020, 19.1% of households live in traditional accommodation, which falls substantially to 14.8% under the BAU, and then rises to 22.2% in this scenario. From this perspective, this is only a 3.1 percentage point rise compared to 2020.

corresponding to the places that have seen the largest expansion in available land. Nonetheless, the sector's GVA still falls by U$ 10 billion (4.3%) relative to the BAU.

Figure 6. Scenario C: Sectoral Employment, % Change Relative to Baseline

Business services | Local services | Manufacturing



Under scenario C, GVA rises by US$ 17 billion or 3.7% from the BAU. Wages for the skilled rise by nearly US$ 11.6 billion (3.9%), and almost US$ 1 billion (1.7%) for low-skill workers. Combined with falls in area rents and increased regional connectivity from the NSCR, welfare for both skill levels are 7 to 8 index points higher than in the BAU.

5.4. Scenario D: NSCR with change in land use policy and reduced business cost in the northern cluster

The 10% reduction of business cost in the northern cluster of Bamban-Concepcion-Mabalacat in Scenario D increases productivity, further augmenting the economic impact of the NSCR on GVA, wages and rents.

Patterns of relocation in Scenario D are broadly similar to Scenario C, except that households move out of the northern cluster because of higher per km^2 rent and instead move to municipalities near the cluster. Per km^2 rents rise in the cluster, but fall elsewhere such that average per km^2 rents are 36.8% lower than the BAU. Nonetheless, this still results in total rents being 6.3% larger across the catchment area because of the overall increase in available land and economic activities.

Business services move along the path of the NSCR, especially in the northern segment and strongly to cities and municipalities north of Metro Manila, registering a growth of 15.4% in GVA contributions compared to the BAU. While manufacturing activities are generally split between the far north and south, they exit the cluster in Scenario D because of higher rent, and double their employment levels in the south (Figure 7A). Manufacturing GVA remains smaller by 1.2% compared to the baseline, but this fall is much less than the 4.3% fall in Scenario C. Even as local services are drawn to high population areas, the effects ripple out throughout the economy as richer households and firms demand more goods and services from other businesses leading to local services GVA contribution to grow by 9.2% from the baseline.

Under Scenario D, GVA increases by US$ 25 billion, representing a 5.4% increase from the BAU. Wages rise by almost $18 billion (5.1%), with both skilled and low-skill workers reaping substantial gains. However, per km^2 rents fall less than in Scenario C. This means that the ratio between welfare gain to wages is lower in Scenario D because a portion of the gains goes directly to rent payments.

Assuming stronger agglomeration effects (Scenario D* in Table 1) leads to firms experiencing positive productivity spillovers from locating near one another. This encourages greater concentration and multiplies the impact of the NSCR. GVA rises by almost US$ 50 billion (10.7%) and wages by close to US$ 36 billion (10.1%) from the BAU, representing at least five-percentage point increases in both GVA and wages compared to a low agglomeration context.

Low-skill workers gain substantially, with wages rising by over US$ 9 billion (15.9%), and are almost 23% better-off than at baseline, with skilled workers not far behind (14%). Per km^2 land rents are 33% cheaper even as total rent expands by a further US$ 14 billion (12.8%).

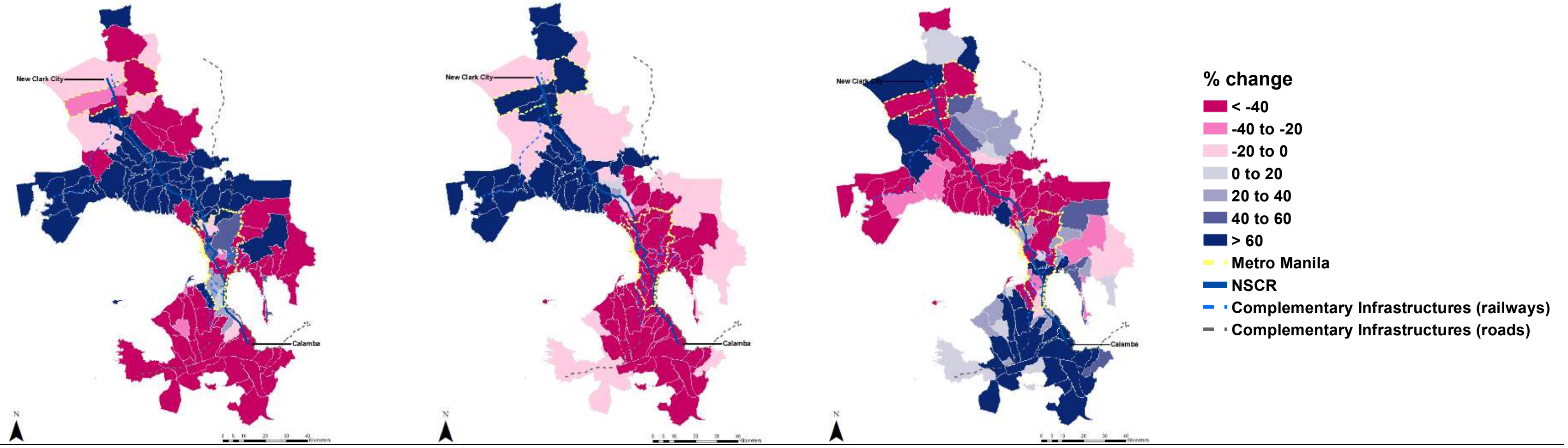
Strong agglomeration forces encourage more pronounced specialization of economic activities - with local services in the north cluster, business services in the northern catchment area, and manufacturing in the south (Figure 7B エラー! 参照元が見つかりません。). Agglomeration forces magnify the patterns seen in Scenario D. The GVA contribution of local services grows further by US$ 21 billion (38.9%) from the BAU. Manufacturing GVA rises by US$ 20 billion (8.6%) in stark contrast to this sector's GVA fall in other scenarios. Meanwhile, GVA contribution of business services fall slightly by -0.5% because the expansion of the sector in many places dilute productivity gains that come from spatial concentration.

Household relocation patterns under strong agglomeration are broadly similar when agglomeration forces are weak, but exhibit greater spatial concentration in areas close to the northern segment of the NSCR. Per km^2 rents increase more intensely in the northern cluster.

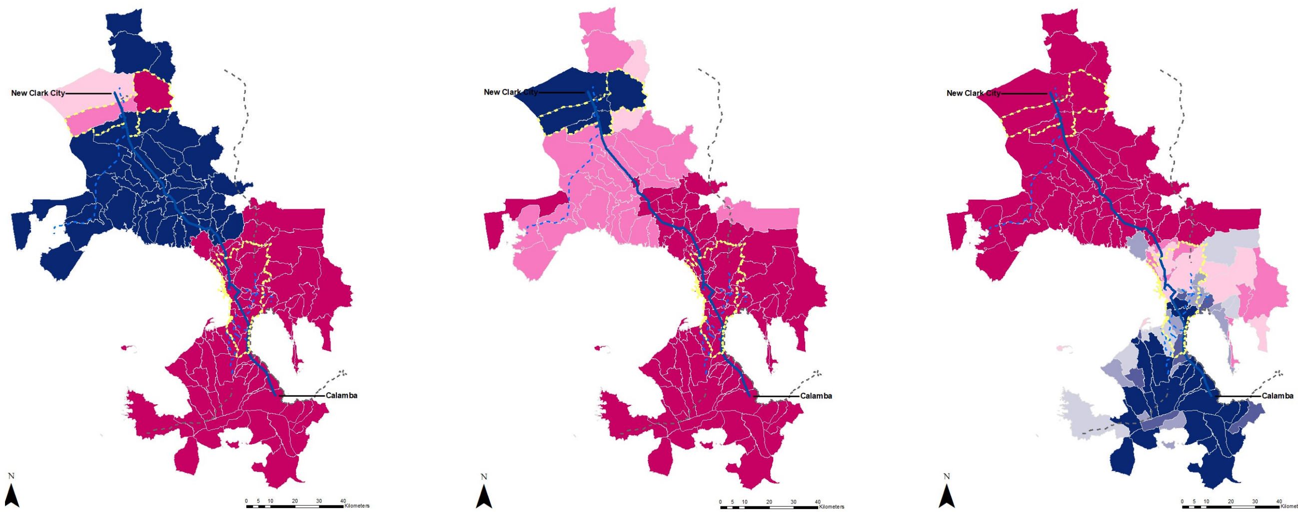
Figure 7. Scenario D: Sectoral Employment, % Change Relative to Baseline

A. Weak agglomeration

Business services | *Local services* | *Manufacturing*



B. Strong agglomeration



Notes: The areas indicated by border markers correspond to the Bamban-Concepcion-Mabalacat cluster in the north, and Metro Manila in the center.

5.5. Scenario E: NSCR with land reform and reduced business cost in two clusters

Scenario E considers an additional cluster in the south that experiences a 10% reduction in business costs.[10] This increases the GVA by 6.5% from the BAU, but only adds a mere 1.1 percentage point increase than Scenario D.

Diminishing returns come into play since most of the economic gains have already been captured when the northern cluster was introduced. Without additional inputs of labor, capital or land investments, additional clusters will each have marginally smaller contributions.

The overall household relocation patterns are very similar to Scenario D – spread around the clusters, although generally avoiding the clusters themselves because of the increase in per km^2 rents. Both clusters attract local services, which benefit from higher productivity. Employment in the local services sector more than double in the clusters but are drastically reduced in other areas plummeting by more than 80% in Metro Manila and surrounding areas. Business services shift towards the path of the NSCR while avoiding the clusters, with largest increase in areas just north of Metro Manila. The sector adds US$ 18.7 billion to GVA and continues as the major driver of GVA growth. As in Scenario D, manufacturing activities move south, but is now slightly more spatially concentrated. The manufacturing GVA contribution shrinks the least under Scenario E.

Introducing agglomeration forces in the context of two clusters (Scenario E* in Table 1) dilutes the productivity spillovers from spatial clustering. Having two clusters without agglomeration has positive, even if smaller marginal economic impacts compared to Scenario D. However, with agglomeration forces, GVA increase is 0.4 percentage point less than Scenario D*. The two clusters end up competing for economic activities, splitting firms between them, reducing the valuable spillovers in each cluster and dampening the total economic impact.

The spatial distribution of the changes in sector employment between Scenarios D* and E* are very similar, but there are important differences in magnitudes. The northern cluster and surrounding jurisdictions still experience substantial gains in business services employment, but less so than they otherwise would in D* such that the reduction to GVA contribution from baseline is also greater (-0.5% in D* versus -1.5% in E*). The southern cluster gains manufacturing employment in Scenario E*, but the aggregate effect on GVA while positive is 0.4 percentage point less than in Scenario D*. Finally, the mild reshuffling of employment in

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[10] The sequence with which the hypothetical clusters are introduced in the can alter the results. Location decisions tend to be path dependent and their consequences are enduring. In the model, the northern cluster was introduced first given it has larger land available and that the northern section of the NSCR will be completed earlier.

local services within the northern cluster increases its GVA contribution by a percentage point compared to Scenario D*.

Ultimately, the rate at which diminishing returns set in with additional clusters depends heavily on the strength of the agglomeration effects in the catchment area. The assumed elasticity of productivity of 0.06 with respect to weighted mass of employment can be considered an upper bound since some components of agglomeration are accounted for in the model through commuting and trade costs. Although not considered in this work for the sake of computational tractability, agglomeration effects could also vary by industry, depending on how specialized and tradeable are the inputs to production (Overman and Puga 2010).

6. Policy implications and conclusions

The NSCR is a large transport infrastructure project that can significantly alter the economic geography of Metro Manila and its surrounding regions, an area of around 10 thousand km^2 spanning 119 cities and municipalities.

This paper studies the effects of the NSCR on the rail catchment area using a SCGE model to capture the multi-layered and complex interactions of locations and factors of production including their potential relocation in response to the NSCR.

Results of the modeling exercise show that the construction of the NSCR alone (Scenario A) results to a modest increase in GVA by 0.4% compared to the baseline, with most of the growth driven by business services such that benefits accrue mostly to the skilled workers. The construction of additional infrastructure together with the NSCR (Scenario B) do not improve aggregate outcomes. Nonetheless, the benefits are more equitably distributed among skill profile and across space.

It is only when available lands in the catchment area are freed-up for urban use (Scenario C) that substantial gains from the baseline could be realized. Without this, constraints on land supply limits the spatial expansion of economic activities and quickly leads to increasing rents. Greater land availability leads to an expanded GVA of 3.7% from the BAU, matched by 3.5% growth in wages. GVA contributions of both business and local services grow and welfare of both skilled and low-skill workers increase by at least 7%.

The impact of the NSCR can be further enhanced through the reduction of business costs in some clusters (Scenarios D and E). However, the size of the benefits is greatly influenced by the strength of agglomeration economies. In the presence of strong agglomeration, additional clusters compete and dilute the productivity spillovers thus reducing the overall impact. These tradeoffs mean that policymakers cannot pick every locality to be a winner and close coordination across stakeholders is key to maximizing efficient investment in the region.

Finally, even the best combination of infrastructure and policies (scenario D with strong agglomeration) fall short of meeting Philippine government's aspiration of reaching middle income status by 2040. This points to other areas of critical policy reforms such as investments in human capital which are essential to improving social mobility and expanding the scope for the creation of high-value jobs and businesses in the region.

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A1. Data Appendix

Table A1-1. Cities and Municipalities in the NSCR Catchment Area

Province	City/Municipality	Province	City/Municipality	Province	City/Municipality
Bataan	Dinalupihan	Pampanga	San Fernando	Laguna	Alaminos
Bataan	Hermosa	Pampanga	San Luis	Laguna	Bay
Bataan	Morong	Pampanga	San Simon	Laguna	Binan
Zambales	Olongapo City	Pampanga	Santa Ana	Laguna	Cabuyao
Zambales	Subic	Pampanga	Santa Rita	Laguna	Calamba City
Bulacan	Balagtas	Pampanga	Santo Tomas	Laguna	Calauan
Bulacan	Baliuag	Pampanga	Sasmuan	Laguna	Los Baños
Bulacan	Bocaue	Tarlac	Bamban	Laguna	San Pedro City
Bulacan	Bulacan	Tarlac	Capas	Laguna	Santa Rosa City
Bulacan	Bustos	Tarlac	Concepcion	Rizal	Angono
Bulacan	Calumpit	Tarlac	Gerona	Rizal	Antipolo
Bulacan	Guiguinto	Tarlac	La Paz	Rizal	Baras
Bulacan	Hagonoy	Tarlac	Tarlac City	Rizal	Binangonan
Bulacan	Malolos City	Batangas	Calaca	Rizal	Cainta
Bulacan	Marilao	Batangas	Laurel	Rizal	Cardona
Bulacan	Meycauayan City	Batangas	Lipa	Rizal	Rodriguez
Bulacan	Norzagaray	Batangas	Malvar	Rizal	Morong
Bulacan	Obando	Batangas	Nasugbu	Rizal	Pililla
Bulacan	Pandi	Batangas	Santo Tomas	Rizal	San Mateo
Bulacan	Paombong	Batangas	Talisay	Rizal	Tanay
Bulacan	Plaridel	Batangas	Tanauan	Rizal	Taytay
Bulacan	Pulilan	Cavite	Alfonso	Rizal	Teresa
Bulacan	San Jose Del Monte	Cavite	Amadeo	Metro Manila	Manila
Bulacan	San Rafael	Cavite	Bacoor City	Metro Manila	Mandaluyong
Bulacan	Santa Maria	Cavite	Carmona	Metro Manila	Marikina
Pampanga	Angeles City	Cavite	Cavite City	Metro Manila	Pasig
Pampanga	Apalit	Cavite	Dasmarinas City	Metro Manila	Quezon City
Pampanga	Arayat	Cavite	General Trias	Metro Manila	San Juan
Pampanga	Bacolor	Cavite	Imus	Metro Manila	Caloocan City
Pampanga	Candaba	Cavite	Indang	Metro Manila	Malabon City
Pampanga	Floridablanca	Cavite	Kawit	Metro Manila	Navotas City
Pampanga	Guagua	Cavite	Mendez	Metro Manila	Valenzuela
Pampanga	Lubao	Cavite	Naic	Metro Manila	Las Pinas
Pampanga	Mabalacat City	Cavite	Noveleta	Metro Manila	Makati City
Pampanga	Macabebe	Cavite	Rosario	Metro Manila	Muntinlupa
Pampanga	Magalang	Cavite	Silang	Metro Manila	Parañaque City
Pampanga	Masantol	Cavite	Tagaytay City	Metro Manila	Pasay City
Pampanga	Mexico	Cavite	Tanza	Metro Manila	Pateros
Pampanga	Minalin	Cavite	Trece Marteres	Metro Manila	Taguig City
Pampanga	Porac	Cavite	Gen. Ma. Alvarez		

Source: Authors

Table A1-2. Ongoing Transport Infrastructure

Project	Description
Roads	
NLEX-SLEX Connector Road	An 8 km all elevated highway extending the NLEX southward from end of Segment 10 in C3 Road Caloocan City to PUP , Sta. Mesa, Manila and connect to common Point of Skyway Stage 3 traversing mostly along the PNR rail track.
Subic Bypass Road Extension (Naugsol - Tipo - Dinalupihan)	The 2-lane road with a total length of 18.90km will serve as an alternate route bypassing Subic, Zambales and Olongapo City.
Cavite-Laguna Expressway	The project is a closed-system rolled expressway connecting CAVITEX in Kawit, Cavite and end at the SLEX-Mamplasan Interchange in Biñan, Laguna
Bacoor Diversion Road	This 6-lane road was proposed in anticipation of the traffic volume that will be generated once the proposed LRTA Line 1 South Extension Project becomes fully operational and other future expansion of the LRT.
Binangonan-Angono-Taytay Lakeview Diversion Road	A four-lane totaling 15-km and providing 7 arterial roads. The project will ease traffic flow traversed by the Manila East Road.
Taal Lake Circumferential Road, Batangas	Construction of access roads leading to declared tourism destinations. The circumferential road will have a length of 53.19 Km (legal easement), 21.00 Km (national roads), and 7.43 Km (unclassified road). The 102.923-Km project will connect the 10 municipalities and 2 cities along the Taal Lake.
Metro Manila BRT Line 1 (Quezon Ave.)	A BRT line from Manila City Hall to Quezon City Hall. The system includes 16 stations with 280 buses in operation.
Metro Manila BRT-Line 2 (EDSA BRT)	A 48.6-km BRT running along the entire EDSA corridor with 63 BRT stations, catering to 1.6 million passengers daily.
Metro Manila Skyway Stage 3	18.83 kms elevated expressway that will connect Skyway Stage 1 in Buendia, Makati City to the North Luzon Expressway in Balintawak, Quezon City.
NLEX Harbor Link, Segment 10	A 5.58-km, 6-lane elevated expressway connecting McArthur Highway and C-3.
NLEX Harbor Link, R-10 Exit Ramp	A 2.6-km road with 4-lane elevated ramp extending the NLEX Harbor Link Segment 10 exit to Radial Road 10 (R-10), using C-3 Road as its route
NLEX Harbor Link, SEGMENT 8.2	A 8.35-km road with 4-lanes from Mindanao Avenue to Republic Avenue turning right to Luzon Avenue up to Commonwealth Avenue in Quezon City.
Manila Cavite Toll Expressway, C-5 South Link Expressway	A 7.70-km expressway, with 6 lanes stretching from R-1 Expressway to SLEX/C5
Southeast Metro Manila Expressway, C-6 (Phase I)	A combination of elevated and at grade expressway, mostly 6 lanes, from Skyway/FTI, Taguig City to Batasan Complex in Quezon City, 32.66 kms and it consists of 6 sections
Rail	
LRT Line 1 Cavite Extension	A 11.7 km extension of the existing LRT Line 1, which will run from Baclaran to Niog in Bacoor, Cavite. The rail is predicted to cut travel time from Manila to Cavite from 70 to 25 minutes, carrying 300,000 to 500,000 passengers daily.
Metro Manila Subway Project (MMSP)	A 34-kilonter subway that will connect the city's business districts and is projected to serve an initial 365,000 passengers daily.
Metro Rail Transit Line 7	A 23-kilometer railway system connecting Quezon City to San Jose Del Monte City, Bulacan that can accommodate 300,000 – 800,000 passengers daily.

Table A1-3. Complementary Infrastructure

Project	Description
Roads	
Laguna Lakeshore Road Network Project	The 44-km expressway dike will provide a safer, convenient and faster travel time to motorist coming from north to south of the project area to various tourist destinations in Laguna, Rizal, Quezon and Batangas.
North Luzon Expressway East, Phase I and II	The project is a 91.20 km, four-lane expressway starting from the end point of La Mesa Parkway and/or jct. of C-6 in San Jose del Monte via Norzagaray, Angat, San Ildefonso, San Miguel, Gapan and Sta. Rosa.
MacArthur Highway to New Clark City via Kalangitan Road, Capas, Tarlac	Construction/Improvement of Access Road to improve access and connectivity to tourism gateways, service centers and tourism sites
Cavite-Tagaytay-Batangas Expressway	A 50.42-kilometer expressway that will link the Cavite–Laguna Expressway in Silang, Cavite to Nasugbu, Batangas
Rail	
C5 MRT 10 Project	The 22.5-km LRT system consisting of 16 stations along circumferential road C5, connecting NAIA Terminal 3 to Quezon City at Commonwealth Avenue with possible interchange at Tandang Sora Station and LRT Line 2 at Aurora Station.
MRT Line 4 Project	An elevated 15.56-kilometer monorail system with eleven (11) stations connecting from N. Domingo Station in Quezon City to Taytay Station in Rizal.
Fort Bonifacio – Makati Skytrain	A 1.873-km public transit system between the vicinity of the Line 3 Guadalupe Station and Fort Bonifacio. It generally follows the existing roads within the vicinity i.e., J.P. Rizal Avenue, Lawton Avenue, 8th Avenue, and 38th Street, operating at a maximum speed of 40 to 50 km/h.
LRT-2 West Extension (Recto-Pier 4)	The project involves the design and construction of the 3.02-km Western extension of the existing Line 2 from Recto Station to Pier 4 in Manila City. The total length of LRT Line 2 will be approximately 20.593 km upon completion of the project and East Extension.
LRT Cavite Line 6 A, Phases 1 and 2	A 23.5-kilometer Light Rail Transit System, consisting of nine stations that will extend the LRT-1 Extension Project from Niog in Bacoor to Governor's Drive in Dasmarinas traversing Bacoor, Imus and Dasmarinas Cities.
Subic-Clark Railway	The 71.13-km railway is a component of the PNR Luzon System Development Framework providing initial freight service between the Subic Bay Freeport Zone and the Clark Freeport and Special Economic Zone, linking Subic Port with Clark International Airport and New Clark City.

Sources: DPWH (2021), DOTr (2021), JICA (2019), NEDA (2021)

Table A1-4. Description of Land Use Categories

Land classification	Land use
1. Non-developable	Mangrove, wetlands, watershed, forests, coastal; ecotourism; production forest, forest land, protected agriculture and aquaculture; hazard prone areas; water bodies; parks and recreation
2.Developable: brownfield 2.1 Residential 2.2. Industrial 2.3. Commercial 2.4. Mixed use	Developable land (including reclamation and PUD); industrial estates, urban/residential use, commercial, mixed use, production land, others - cemeteries, dumpsites, idle lands, reclamation, planned unit developments; built-up; mining & quarrying; institutional
3.A.Developable expansion - greenfield	Non-prime agriculture and aquaculture land, Special land use (VOA Concepcion Tarlac)
3.B. Developable expansion - brownfield	Institutional and utilities; utilities; infrastructure; open areas (shrubs, grasslands); tourism and recreation; lahar/river wash areas

Source: Authors based on city and municipality CLUPs, PDPFPs, SAFDZ

A2: Model Appendix

SCGE Production and Expenditure Parameters

Parameter	Group			Source
Firm expenditure shares (α)	Business services	Local services	Manuf.	
Business services	0.064	0.103	0.054	*IO table*
Local services	0.035	0.056	0.029	*IO table*
Manufacturing	0.201	0.327	0.171	*IO table*
Land	0.05	0.05	0.1	*Assumption*
Primary Goods	0	0.014	0.046	*Assumption*
Skilled labor	0.6	0.3	0.5	*Assumption*
Low-skill labor	0.05	0.15	0.1	*Assumption*
Household expenditure shares (β)	Skilled	Low-skill		
Business services	0.1	0.1		*Assumption*
Local services	0.35	0.35		*Assumption*
Manufacturing	0.3	0.3		*Assumption*
Housing	0.25	0.25		*Assumption*
Construction	Modern	Traditional		
Height (γ)	2	1		*Henderson et al. (2021)*
Crowdedness (λ)	1	4		*Henderson et al. (2021)*
Elasticity of substitution (σ)	0.8			*From literature*
Fréchet (ς)	25			*From literature*

A3: Technical Appendix

A3.1 Model Derivation

There are 119 internal locations in the SCGE model each representing a city or municipality in the NSCR catchment area and 1 external location representing the outside world. Each location is represented by i.

There are three sectors in the model: manufacturing, local services, and business services. Firms in the manufacturing, local services and business services sectors buy production inputs from other firms. They sell their outputs to households, firms, and the outside world. The agricultural sector does not sell their goods directly to households but does so through the three sectors in the model.

There are three actors in the model: households, firms, and developers.

A3.1.1 Goods and services

The economic actors in each location (households, firms, and construction) can demand goods and services from any of the other locations in the model. There are two requirements to determining the value of demand for goods and services in a location:

(i). The demand function for goods and services in a single location

(ii). The total value of expenditure on goods and services across all locations

This section derives the first requirement which is the demand function for goods for a *given* level of expenditure. The derivation for the second requirement is contained in later sub-sections that focus specifically on the firm, household, and construction decisions.

For simplicity, the derivation starts with simple Armington demand for a variety of a good in a single location before expanding to multiple locations. This derivation applies to households, firms, and construction.

Let preferences be defined as follows:

$$U = {X_s}^{\gamma} {X_n}^{1-\gamma}$$

Where X_s and X_n are composite goods, and $\gamma \in [0,1]$. Composite goods X_s and X_n comprise different varieties of goods and defined by a constant-elasticity-of-substitution function:

$$X_s = \left[\int_0^n x_s(v)^{\frac{1}{1-\sigma}} di\right]^{1-\sigma}$$

$$X_n = \left[\int_0^n x_n(q)^{\frac{1}{1-\sigma}} di\right]^{1-\sigma}$$

Where σ is the elasticity of substitution between any two varieties, n is the range of the varieties produced, $x_s(v)$ is the demand for variety v from sector s and $x_n(q)$ is the demand for variety q from sector n. For convenience, the remainder of the derivation focuses on the demand for varieties in sector s. However, it is possible to derive the demand for varieties in sector n by symmetry.

Step 1: Compensated demand functions

To begin with, it is necessary to maximize utility subject to the budget constraint. The method follows the two-step approach in (Fujita et al. 1999) to derive the demand for a variety of sector s goods based on cost minimization.

For any given X_s, economic actors will want to demand the combination of varieties that minimizes cost, and therefore face the following optimization problem:

$$\min \int_0^n p_s(i) x_s(v)\, di \qquad s.t. \left[\int_0^n x_s(v)^{\rho} di\right]^{1/\rho} = X_s$$

The Lagrangian and first-order condition is as follows:

$$\frac{x_s(v)^{\rho-1}}{x_s(u)^{\rho-1}} = \frac{p_s(v)}{p_s(u)}$$

Rearranging the above first-order conditions yields: $x_s(v) = x_s(u) \left(\frac{p_s(u)}{p_s(v)}\right)^{1/1-\rho}$

This expression can then be substituted into the budget constraint:

$$\left[\int_0^n \left(x_s(u)\left(\frac{p_s(u)}{p_s(v)}\right)^{1/1-\rho}\right)^{\rho} di\right]^{1/\rho} = X_s$$

Bringing out the common term $x_s(u)\, p_s(u)^{1/1-\rho}$ from the integral and rearranging derives:

$$x_s(u) = \frac{p_s(u)^{1/\rho-1}}{\left[\int_0^n p_s(v)^{\rho/\rho-1} dv\right]^{1/\rho}} * X_s$$

This is the demand function for $x_s(u)$ for a fixed level of sector s goods consumption, X_s, and therefore it is compensated. The compensated demand function for $x_s(u)$ simplifies as follows:

$$x_s(u) = \left(\frac{p_s(u)}{P_s}\right)^{-\sigma} X_s$$

$$P_s = \left[\int_0^n p_s(v)^{1-\sigma} di\right]^{1/1-\sigma}$$

Where P_s is the price index and $\sigma = \frac{1}{1-\rho}$

Step 2: Uncompensated demand functions

Following the derivation of the compensated demand function, it is necessary to now derive the uncompensated demand function. The uncompensated demand functions for X_s and X_n follow from maximizing the actor's utility subject to the budget constraint to yield:

$$X_s = \frac{\gamma E}{P_s}$$

$$X_n = \frac{(1-\gamma)E}{P_n}$$

Where E is the actor's expenditure on goods and services. Substituting the compensated demand function into the above compensated demand functions produces the following:

$$x_s(u) = \mu E \frac{p_s(u)^{-\sigma}}{P_s^{-(\sigma-1)}}$$

Multiple locations

The demand function for a given variety can be generalized across many locations to derive the inter-regional trade flows associated with the actors. Transportation costs determine the costs of shipping goods and services across locations and follow an iceberg model which assumes that a fraction of the good and service "melts" in transit to its destination. Therefore tx units of a good and service must be shipped to meet 1 unit of demand where $t \geq 1$.

Iceberg transport costs are modeled using exponential decay:

$$t_{ij} = \exp(t_s \times dist_{s,ij})$$

Where for goods and services, t_s, differs based on the sector and household:

$t_s = \log(0.8)$ for households: Households can lose up to 20% of their welfare by commuting across the full scope of the catchment area daily

$t_s = \log(1.05)$ for Business Services: Business services are highly tradable. People are willing to travel far to access services they use infrequently.

$t_s = \log(1.3)$ for Local Services. Local services are costly to ship around the catchment area. People experience great disutility in travelling to buy every day services.

$t_s = \log(1.1)$ for Manufacturing. Manufacturing is shipped around the catchment area, but has a cost associated with this due to bulkiness.

$dist_{s,ij}$ is the travel time between two cells i and j (normalized to 1 being the maximum travel time between two cells within the city), so $dist_{s,ij} \leq 1$.

Note that under these parameters, $t_{ij} \leq 1$ for households. For goods and services, any equations involving transportation will have t_{ij} raised to $-\sigma$ or $(1-\sigma)$, where $\sigma = 6$, and so the resulting $t_{ij}^{-\sigma}, t_{ij}^{(1-\sigma)} \leq 1$.

Recall the price index: $P_s = \left[\int_0^n p(i)^{1-\sigma} di\right]^{1/1-\sigma}$ which can be expanded to j locations:

$$P_{is} = \left[\sum_j \int_0^{n_j} p_{ijs}(i)^{1-\sigma} di\right]^{1/1-\sigma}$$

Where i and j are locations, with i being the home location. In addition, p_{ij} is the price in location i for goods produced in location j, and assumes that any variety produced in the same location has the same price (Fujita et al. 2001):

$$P_{is} = \left[\sum_j n_j p_{ijs}{}^{1-\sigma}\right]^{1/1-\sigma}$$

Note that $p_{ij} = p_j t_{ij}$ where t_{ij} are the iceberg transportation costs between locations i and j and must be ≤ 1.

$$P_{is} = \left[\sum_j n_j \left(p_{js} t_{ij}\right)^{1-\sigma}\right]^{1/1-\sigma}$$

This can be generalized so that the uncompensated demand function for variety u in sector s for goods produced in location i for multiple locations and sectors becomes:

$$x_{is}(u) = \sum_j \gamma_s E_j \frac{p_{jis}(u)^{-\sigma}}{P_{js}{}^{-(\sigma-1)}}$$

Substitute $p_{jis} = p_{js} t_{jis}$ into the above equation and simplify further:

$$x_{is}(u) = \sum_j \gamma_s E_j \left(p_{is} t_{ijs}\right)^{-\sigma} P_{js}{}^{(\sigma-1)}$$

The above equation denotes the uncompensated actor demand function summed across all locations for a variety u in sector s produced in location i.

Let $\gamma_s E_j = E_{js}$, therefore:

$$x_{is}(u) = \sum_j E_{js} \left(p_{is} t_{ijs}\right)^{-\sigma} P_{js}{}^{(\sigma-1)}$$

The above equation is a consumption function where part of the good will melt *en route* given the iceberg transportation costs. Therefore, to identify a demand function in terms of the realized sales of the goods and services in the location of purchase, the consumption demand function must be multiplied by the iceberg transportation costs, t_{ijs}. This gives the following:

$$x_{is}(u) = \sum_j E_{js} (p_{is})^{-\sigma} (t_{ijs})^{1-\sigma} P_{js}{}^{(\sigma-1)}$$

External Locations

The model allows for trade with external locations. Firms import goods from external locations and use these in their production and sell them on to households. Firms also export goods to external locations. There are three aspects of the model that incorporate external trade with other locations: (i) the price index, (ii) an export demand equation; and (iii) an import demand equation

(i) Price index

Previously, the price index has been derived as follows:

$$P_{is} = \left[\sum_j n_j \left(p_{js} t_{ij}\right)^{1-\sigma}\right]^{1/_{1-\sigma}}$$

In the presence of trade with external locations, the price index expands to the following:

$$P_{is} = \left[\sum_j n_j \left(p_{js} t_{ij}\right)^{1-\sigma} + n_0 (p_o)^{1-\sigma}\right]^{1/_{1-\sigma}}$$

The second term in the brackets relates to an external location where n_0 denotes the number of varieties in the external location 0 and p_o denotes the price of the good in the external location. Unlike trade with j locations within the catchment area, n_0 and p_o are exogenous and is not explicitly modelled. All locations can import goods and services.

(ii) Export demand

The access points for external trade in the model will be the main entry and exit points for goods and services to locations outside the catchment area. These points represent key roads out of the catchment area (see エラー! 参照元が見つかりません。) together with sea and air ports, with balance of payments ensuring exports equal imports at any given time. A simple export demand equation will determine the size of these flows:

$$X_{is} = \alpha_i n_{is} p_{is}{}^{-\sigma}$$

Where α_i is a parameter that measures the degree of connectivity of the location to the outside world and p_i is the price of goods in location i.

(iii) Import demand

All locations in the model are able to import goods and services from the external location. The import demand equation is derived and characterized the same way as if the location was purchasing goods from another location in the catchment area of the SCGE. Therefore, the total import demand across all locations in the catchment area for goods and services produced externally is as follows:

$$c_{0s}(u) = \sum_j \gamma_s E_j (p_0)^{-\sigma} P_{js}{}^{(\sigma-1)}$$

A3.1.2 Households

Households choose where to live and work, and what type of housing to consume. There are two types of households: skilled and low-skill, facing the following utility function:

$$U_{ij}^{lh} = \left(\prod_s x_{ij}^{slh}\right)^{\beta^{slh}} h_{ij}^{lh\,\beta^{lh}} b_i^{lh} t_{ij}^{l}$$

Where U_{ij}^{lh} is the utility of a household that lives in location i, works in location j, is of labor type l and lives in housing type h. x_i^s is household demand for good x in location i of sector s; q_i^h is the price per unit of floorspace; h_i^h is household demand for housing in location i and housing type h; b_i^{lh} is the amenity value to households living in location i, of labor type l and housing type h; and t_{ij}^l is the commuting costs of the household living in location i and working in location j of labor type l. The exponents β represent expenditure shares. Each household faces the following budget constraint:

$$w_j^l + m_{ij}^l = q_i^h h_{ij}^{lh} + \sum_s P_i^s x_{ij}^{slh}$$

Where m_{ij}^l is the household income from land transfers for those living in location i, working in location j of labor type l. Households therefore face the following optimization problem:

$$\max \left(\prod_s x_i^{slh}\right)^{\beta^{slh}} h_{ij}^{lh\,\beta^{lh}} b_i^{lh} t_{ij}^{l} \quad s.t. \;\; w_j^l + m_{ij}^l = q_i^h h_{ij}^{lh} + \sum_s P_i^s x_{ij}^{slh}$$

The optimization problem leads to the following first order conditions:

$$\frac{\partial \mathcal{L}}{\partial x_{ij}^{tlh}} = \beta^{tlh} \left(\prod_{s \neq t} x_{ij}^{slh}\right)^{\beta^{slh}} x_{ij}^{tlh\,\beta^{tlh}-1} h_{ij}^{lh\,\beta^{lh}} b_i^{lh} t_{ij}^{l} - \lambda P_i^t$$

$$\frac{\partial \mathcal{L}}{\partial x_{ij}^{ulh}} = \beta^{ulh} \left(\prod_{s \neq u} x_{ij}^{slh}\right)^{\beta^{slh}} x_{ij}^{u\,\beta^{ulh}-1} h_{ij}^{lh\,\beta^{lh}} b_i^{lh} t_{ij}^{l} - \lambda P_i^u$$

$$\frac{\partial \mathcal{L}}{\partial h_i^{lh}} = \beta^{lh} \left(\prod_s x_{ij}^{sl}\right)^{\beta^{slh}} h_{ij}^{lh\,\beta^{lh-1}} b_i^{lh} t_{ij}^{l} - \lambda q_i^h$$

Setting the first order conditions to zero and dividing them by one another yield expressions in terms of x_{ij}^{tlh}.

$$\frac{\beta^{tlh} x_{ij}^{tlh^{-1}}}{\beta^{ulh} x_{ij}^{ulh^{-1}}} = \frac{P_i^t}{P_i^u}$$

$$\frac{\beta^{tlh} x_{ij}^{tlh^{-1}}}{\beta^{ulh} h_{ij}^{lh^{-1}}} = \frac{P_i^t}{q_i^h}$$

Rearranging in terms of x_{ij}^{tl} and h_{ij}^{lh}:

$$x_{ij}^{ulh} = \frac{\beta^{ulh} P_i^t}{\beta^{tlh} P_i^u} x_{ij}^{tl}$$

$$h_{ij}^{lh} = \frac{\beta^{lh} P_i^t}{\beta^{tl} \; q_i^h} x_{ij}^{tl}$$

Recall the budget constraint:

$$w_j^l + m_{ij}^l = q_i^h h_{ij}^{lh} + \sum_s P_i^s x_{ij}^{slh}$$

Substitute the optimal expressions for x_i^t into the budget constraint:♠

$$w_j^l + m_{ij}^l = q_i^h \frac{\beta^{lh} P_i^t}{\beta^{tlh} q_i^h} x_{ij}^{tlh} + \sum_s P_i^s \frac{\beta^{slh} P_i^t}{\beta^{tlh} P_i^s} x_{ij}^{tlh}$$

This simplifies to the following:

$$w_j^l + m_{ij}^l = P_i^t x_{ij}^{tlh} \left(\frac{\beta^{lh}}{\beta^{tl}} + \sum_s \frac{\beta^{sl}}{\beta^{tl}} \right)$$

Rearranging for x_i^{tl} :

$$x_{ij}^{tlh*} = \frac{w_j^l + m_{ij}^l}{P_i^t \left(\frac{\beta^{lh}}{\beta^{tlh}} + \sum_s \frac{\beta^{slh}}{\beta^{tl}} \right)}$$

The sum of the shares of household expenditures on goods and housing is equal to 1, that is $\beta^{lh} + \sum_s \beta^{sl} = 1$. Therefore, x_{ij}^{tl} * simplifies to the following:

$$x_{ij}^{tlh*} = \frac{\beta^{tl} \; (w_j^l + m_{ij}^l)}{P_i^t}$$

By symmetry, this is the form of the optimal demand for all goods. Likewise, symmetry implies that the optimal demand for residential housing is the following:

$$h_{ij}^{lh*} = \frac{\beta^{lh} (w_j^l + m_{ij}^l)}{q_i^h}$$

Recall the utility function:

$$U_{ij}^{lh} = \left(\prod_s x_{ij}^{sl} \right)^{\beta^{slh}} {h_{ij}^{lh}}^{\beta^{lh}} b_i^{lh} t_{ij}^l$$

Substitute the optimal demands into the utility function to identify the indirect utility function based in terms of income and prices.

♠ s has replaced u in the optimal expression so that the budget constraint consistently uses s as the notation for the summation.

$$U_{ij}^{lh} = \left(\prod_s \frac{\beta^{slh}(w_j^l + m_{ij}^l)}{P_i^s}\right)^{\beta^{slh}} \left(\frac{\beta^{lh}(w_j^l + m_{ij}^l)}{q_i^h}\right)^{\beta^{lh}} b_i^{lh} t_{ij}^l$$

Recalling that the shares of expenditures on goods and housing sum to 1, the indirect utility function simplifies to the following:

$$U_{ij}^{lh} = \left(\prod_s \beta^{slh}\right)^{\beta^{slh}} \left(\beta^{lh}\right)^{\beta^{lh}} \left(\frac{w_j^l + m_{ij}^l}{q_i^{h\,\beta^{lh}} \prod_s P_i^{t\,\beta^{slh}}}\right) b_i^{lh} t_{ij}^l$$

The segment in the expression involving the shares of expenditure parameters, $\left(\prod_s \beta^{slh}\right)^{\beta^{slh}} \left(\beta^{lh}\right)^{\beta^{lh}}$, drops out if they are defined in a certain way. This leaves the final simplified form of the indirect utility function:

$$U_{ij}^{lh} = \left(\frac{w_j^l + m_{ij}^l}{q_i^{h\,\beta^{lh}} \prod_s P_i^{t\,\beta^{slh}}}\right) b_i^{lh} t_{ij}^l$$

The home location, work location, and housing type of households is not fixed. Instead, these are choices that the households make within the model. Each household has a specific amenity value that is assumed to follow a Fréchet distribution.

The household maximizes utility by simultaneously choosing where to live and where to work. This leads to the following definition of the probability of a household of labor type l, living in location i in housing type h, working in location j:

$$\pi_{ij}^{lh} = \frac{\left(u_{ij}^{lh}\right)^{\varsigma}}{\sum_h \sum_i \sum_j \left(u_{ij}^{lh}\right)^{\varsigma}}$$

Where ς is the Fréchet distribution parameter.

Demand for goods and services

The value of household demand for sector s in location i for goods and services is the following:

$$\sum_l \sum_j \sum_h L^l\left(\pi_{ij}^{lh} P_i^s x_i^{tlh*}\right)$$

Where L^l is the total quantity of labor in the catchment area. Substituting in x_i^{tlh*} produces:

$$\sum_l \sum_j \sum_h L^l\left(\pi_{ij}^{lh} \beta^{tl}\ (w_j^l + m_{ij}^l)\right)$$

The value of household demand on housing type h in location i is the following:

$$\sum_l \sum_j L^l\left(\pi_{ij}^{lh} q_i^h h_i^{lh*}\right)$$

Substituting in h_i^{lh*} yields:

$$\sum_l \sum_j L^l \left(\pi_{ij}^{lh} \beta^{lh} (w_j^l + m_{ij}^l)\right)$$

Supply of labor

Households supply labor to firms in exchange for a wage. Each member of the labor force provides one whole unit of labor. The value of the supply of labor of type l in location j:

$$w_j^l L_j^l = w_j^l L^l \sum_i \sum_h (\pi_{ij}^{lh})$$

A3.1.3 Firms

Supply of goods and services

The manufacturing, local services, and business services sectors are monopolistically competitive, producing differentiated products as modelled by Dixit-Stiglitz. Agricultural production is not modelled. Instead, firms import agricultural goods from external locations.

Firms in each of the three modelled sectors produce goods and services according to a Cobb-Douglas (CD) production function as follows:

$$Y_{is} = a_{is} \prod_k X_{ks}^{\alpha_{ks}} - F_{is}$$

Where Y_{is} is the firm output in location i in sector s, a_{is} is the total factor productivity, α_{ks} is the share parameter of input k with the sum of share parameters summing to one across the factors of production, X_{ks} is the factor of production input, and F_{is} is the fixed costs of production. If the elasticity of substitution is η, then $\eta = \frac{1}{1-r}$.

Provided that $a_{is} \prod_k X_{ks}^{\alpha_{ks}} > F_{is}$, then $Y_{is} > 0$. Fixed costs are part of the production function because production requires a minimum number of factor inputs. For example, a factory may need a minimum threshold of machinery and labor before it can produce any output.

Assuming non-zero production, then a firm will minimize costs for each level of production. Firms will have the following optimization problem:

$$\min \sum_k v_{ks} X_{ks} \qquad s.t.\;\; Y_{is} + F_{is} = a_{is} \prod_k X_{ks}^{\alpha_{ks}}$$

Where v_k is the price of factor of production k.

The Lagrangian equations to solve the firm's minimization problem and derive an optimality condition based on factors of production k, l and λ are as follows:

$$\mathcal{L} = \sum_k v_{ks} X_{ks} - \lambda \left[a_{is} \prod_k X_{ks}^{\alpha_{ks}} - (Y_{is} + F_{is}) \right]$$

$$\frac{\partial \mathcal{L}}{\partial X_{ls}} = v_{is} - \lambda a_{is}\alpha_{ls}X_{ls}^{\alpha_{ls}-1}\prod\nolimits_{k\neq l} X_{ks}^{\alpha_{ks}}$$

$$\frac{\partial \mathcal{L}}{\partial X_{ks}} = v_{ks} - \lambda a_{is}\alpha_{ks}X_{ks}^{\alpha_{ks}-1}\prod\nolimits_{m\neq k} X_{ms}^{\alpha_{ms}}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = a_{is}\prod\nolimits_{k} X_{ks}^{\alpha_{ks}} - (Y_{is} + F_{is})$$

Dividing $\frac{\partial \mathcal{L}}{\partial X_{ls}}$ by $\frac{\partial \mathcal{L}}{\partial X_{ks}}$ and setting the optimality conditions to 0, yields:

$$\frac{v_{ls}}{v_{ks}} = \frac{\alpha_{ls}}{\alpha_{ks}}\frac{X_{ks}}{X_{ls}}$$

Once rearranged this becomes:

$$X_{ks} = \frac{\alpha_{ks}v_{ls}}{\alpha_{ls}v_{ks}}X_{ls}$$

The expression can be substituted into $\frac{\partial \mathcal{L}}{\partial \lambda}$ and set the optimality condition equal to 0.

$$Y_{is} + F_{is} = a_{is}\prod\nolimits_{k}\left(\frac{\alpha_{ks}v_{ls}}{\alpha_{ls}v_{ks}}X_{ls}\right)^{\alpha_{ks}}$$

Rearranging the terms for X_{ls}:

$$X_{ls} = \frac{Y_{is} + F_{is}}{a_{is}}\left(\frac{\alpha_{ls}}{v_{ls}}\prod\nolimits_{k}\left(\frac{v_{ks}}{\alpha_{ks}}\right)^{\alpha_{ks}}\right)$$

Plugging X_{ls} back into the cost function:

$$C_{is} = \sum_{l} v_{ls}\frac{Y_{is} + F_{is}}{a_{is}}\left(\frac{\alpha_{ls}}{v_{ls}}\prod\nolimits_{k}\left(\frac{v_{ks}}{\alpha_{ks}}\right)^{\alpha_{ks}}\right)$$

Bringing out terms out of the summation where possible:

$$C_{is} = \frac{Y_{is} + F_{is}}{a_{is}}\prod\nolimits_{k}\left(\frac{v_{ks}}{\alpha_{ks}}\right)^{\alpha_{ks}}\sum_{l}\alpha_{ls}$$

Where $\sum_{l}\alpha_{ls} = 1$, which allows simplification:

$$C_{is} = \frac{Y_{is} + F_{is}}{a_{is}}\prod\nolimits_{k}\left(\frac{v_{ks}}{\alpha_{ks}}\right)^{\alpha_{ks}}$$

This can further simplify to the following:

$$C_{is} = c_{is}(Y_{is} + F_{is})$$

Where c_{is} is the constant marginal cost and equal to $\frac{1}{a_{is}}\prod_{k}\left(\frac{v_{ks}}{\alpha_{ks}}\right)^{\alpha_{ks}}$

The firm's profit function can now be derived based on the result of the cost minimization. The profit function for a firm in location i and sector s is the following:

$$\pi_{is} = p_{is}Y_{is} - C_{is}$$

which can be decomposed as:

$$\pi_{is} = p_{is}Y_{is} - c_{is}(Y_{is} + F_{is})$$

Where c_{is} is the constant marginal cost and $c_{is}F$ is the fixed cost of production. Firms choose a price to maximize profits, which can be solved by differentiating the profit function with respect to price.

$$\frac{\partial \pi_{is}}{\partial p_{is}} = Y_{is} + p_{is}\frac{\partial Y_{is}}{\partial p_{is}} - c_{is}\frac{\partial Y_{is}}{\partial p_{is}}$$

The first two terms are determined using the product rule given both p_{is} and Y_{is} are functions of p_{is}. Y_{is} is a function of p_{is} given that consumer demand is affected by price. In the previous section the actor demand was derived as follows:

$$x_{is}(u) = \sum_{j} E_{js}(p_{is})^{-\sigma}(t_{ijs})^{1-\sigma}P_{js}{}^{(\sigma-1)}$$

Therefore, it follows that $\frac{\partial Y_{is}}{\partial p_{is}} = -\sigma\sum_j E_{js}(p_{is})^{-\sigma-1}(t_{ijs})^{-\sigma}P_{js}{}^{(\sigma-1)}$ where $\frac{\partial P_{js}}{\partial p_{is}} = 0$ since there is a continuum of firms. $\frac{\partial Y_{is}}{\partial p_{is}}$ can simplify further to the following:

$$\frac{\partial Y_{is}}{\partial p_{is}} = \frac{-\sigma Y_{is}}{p_{is}}$$

Plugging $\frac{\partial Y_{is}}{\partial p_{is}}$ back into the optimized profit function produces the following:

$$\frac{\partial \pi_{is}}{\partial p_{is}} = Y_{is} + p_{is}\left(\frac{-\sigma Y_{is}}{p_{is}}\right) - c_{is}\left(\frac{-\sigma Y_{is}}{p_{is}}\right)$$

Set $\frac{\partial \pi_{is}}{\partial p_{is}} = 0$.

$$\sigma = 1 - c_{is}\left(\frac{-\sigma}{p_{is}}\right)$$

This simplifies to the following to give the optimal price set by the firm:

$$p_{is} = \frac{c_{is}\sigma}{\sigma - 1}$$

The profit function can also be used to derive the fixed level of output that each firm supplies under 0 profits.

$$\pi_{is} = p_{is}Y_{is} - c_{is}(Y_{is} + F_{is})$$

$$0 = p_{is}Y_{is} - c_{is}(Y_{is} + F_{is})$$

$$(p_{is} - c_{is})Y_{is} = c_{is}F_{is}$$

Substituting in the optimal price yields the following:

$$\left(\frac{c_{is}\sigma}{\sigma-1}--c_{is}\right)Y_{is} = c_{is}F_{is}$$

The expression can be simplified to find the fixed level of output that each firm supplies under 0 profits.

$$\overline{Y_{is}} = F_{is}(\sigma-1)$$

Demand for factors of production

The value of factor demands for a single firm in location i and sector s is the following:

$$v_{ks}X_{ks} = v_{ks}\frac{\partial C_{is}}{\partial v_{ks}}$$

Where the $X_{ks} = \frac{\partial C_{is}}{\partial v_{ks}}$ due to Shepherd's lemma. This becomes the following based on the form of the cost function:

$$v_{ks}X_{ks} = v_{ks}(Y_{is}+F_{is})\frac{\partial c_{is}}{\partial v_{ks}}$$

The value of factor demands for all firms in location i and sector s is therefore:

$$n_{is}v_{ks}X_{ks} = n_{is}v_{ks}(Y_{is}+F_{is})\frac{\partial c_{is}}{\partial v_{ks}}$$

To identify $\frac{\partial c_{is}}{\partial v_{ks}}$, recall that c_{is} is the following:

$$c_{is} = \frac{1}{a_{is}}\prod\nolimits_k\left(\frac{v_{ks}}{\alpha_{ks}}\right)^{\alpha_{ks}}$$

Adding terms to both the numerator and denominator as part of the simplification process:

$$\frac{\partial c_{is}}{\partial v_{ks}} = \frac{1}{a_{is}}\frac{\alpha_{ks}}{\alpha_{ks}}\left(\frac{v_{ks}}{\alpha_{ks}}\right)^{\alpha_{ks}-1}\prod\nolimits_{l\neq k}\left(\frac{v_{ls}}{\alpha_{ls}}\right)^{\alpha_{ls}}$$

Using the original expression for the value of factor demands for all firms in location i and sector s, and substituting in $\frac{\partial c_{is}}{\partial v_{ks}}$:

$$n_{is}v_{ks}X_{ks} = n_{is}v_{ks}(Y_{is}+F_{is})\frac{1}{a_{is}}\frac{\alpha_{ks}}{\alpha_{ks}}\left(\frac{v_{ks}}{\alpha_{ks}}\right)^{\alpha_{ks}-1}\prod\nolimits_{l\neq k}\left(\frac{v_{ls}}{\alpha_{ls}}\right)^{\alpha_{ls}}$$

This can simplify to the following:

$$n_{is}v_{ks}X_{ks} = n_{is}v_{ks}\frac{\alpha_{ks}p_{is}Y_{is}}{v_{ks}}$$

Given $p_{is}Y_{is} = C_{is}$ due to the zero-profit condition.

A3.1.4 Construction

There are two subsectors in the construction sector: Modern residential, $h = 1$ and traditional residential, $h = 2$. Firms utilize land directly in their production.

The main decision variable for construction firms is how densely to build. In both subsectors, modern and traditional residential, the cost of building an additional unit of floorspace rises as the density of buildings increases. For modern buildings, a rise in density means an increase in the height of buildings with no changes to the quality of floorspace; marginal costs are increasing in height, but greater density means more space offered to households. For traditional buildings, a rise in density means a fall in the quality of buildings as houses are packed in horizontally.

Supply of housing

Firms choose the floorspace per unit of land area, g_i^h, where i is the location of the construction firm and h is the type of housing provided by the firm. In this case, modern or traditional residential.

For modern residential ($h = 1$), developers choose floorspace per unit of land area, g_i^h. The price of floorspace per unit of quality is q_i^h. κ^h and γ^h are parameters that determines the shape of the cost function, where $\kappa^h > 0$, $\gamma^h \geq 1$. The maximization problem is:

$$\max_{g_i^h} r_i^h = q_i^h g_i^h - \kappa_i^h \left(g_i^h\right)^{\gamma^h}$$

Deriving first order conditions and plugging g_i^{h*} back into the objective function yields the expression for optimal profits, r_i^{h*}:

$$r_i^{h*} = q_i^h \left(\frac{q_i^h}{\gamma^h \kappa_i^h}\right)^{\frac{1}{\gamma^h - 1}} - \kappa^h \left(\left(\frac{q_i^h}{\gamma^h \kappa_i^h}\right)^{\frac{1}{\gamma^h - 1}}\right)^{\gamma^h}$$

This simplifies to the following:

$$r_i^{h*} = \kappa_i^h (\gamma^h - 1) \left(\frac{q_i^h}{\gamma^h \kappa_i^h}\right)^{\frac{\gamma^h}{\gamma^h - 1}}$$

Given optimal conditions, construction firms for modern residential housing earn the following revenue per unit of land:

$$q^h g^{h*} = q^h \left(\frac{q_i^h}{\gamma^h \kappa_i^h}\right)^{\frac{1}{\gamma^h - 1}}$$

Manipulating the right-hand side of the above equation to substitute in optimal rents yields:

$$q^h g^{h*} = \frac{\gamma^h}{(\gamma^h - 1)} r_i^{h*}$$

The total value of supplied land for modern housing can be identified by multiplying the total land area demanded for development for each construction type:

$$q^h g^{h*} G_i^h = \frac{\gamma^h}{(\gamma^h - 1)} r_i^{h*} G_i^h$$

Based on g_i^{h*} and r_i^{h*} the total value of the costs per unit of land for modern housing is:

$$\kappa_i^h \left(g_i^h\right)^{\gamma^h} = \frac{r_i^h}{(\gamma^h - 1)}$$

Traditional residential ($h = 2$) has constant rather than increasing marginal costs but increases density by reducing the quality of construction. The fall in quality will reduce the price that households are willing to pay for traditional housing developments. The price for this type of development is a fraction of the price of a development with unit quality, q_i^h. This fraction is a function of the floorspace per unit area, which reflects the extent to which quality has reduced in the housing and is represented in the objective function below by $\left(g_i^h\right)^{\frac{1-\lambda}{\lambda}}$. Developers maximize their rents by choosing g_i^h.

$$\max_{g_i^h} r_i^h = g_i^h q_i^h \left(g_i^h\right)^{\frac{1-\lambda}{\lambda}} - \kappa_i^h g_i^h$$

Deriving first order conditions and plugging g_i^{h*} back into the objective function gives optimal profits, r_i^{h*}:

$$r_i^h = q_i^h g_i^h \left(g_i^h\right)^{\frac{1-\lambda}{\lambda}} - \kappa_i^h g_i^h$$

This simplifies to the following:

$$r_i^h = \kappa_i^h (\lambda - 1) \left(\frac{q_i^h}{\lambda \kappa_i^h}\right)^{\frac{\lambda}{\lambda - 1}}$$

Given optimal conditions, construction firms for traditional housing will earn the following revenue per unit of land:

$$q_i^h \left(g_i^{h*}\right)^{\frac{1-\lambda}{\lambda}} g^{h*} = q_i^h \left(g_i^{h*}\right)^{\frac{1}{\lambda}}$$

Manipulating the right-hand side of the above equation to substitute in optimal rents yield the following expression:

$$q_i^h \left(g_i^{h*}\right)^{\frac{1}{\lambda}} = \frac{\lambda}{(\lambda - 1)} r_i^{h*}$$

The total value of land supplied for traditional housing can be identified by multiplying by the total land area demanded:

$$q^h\left(g_i^{h*}\right)^{\frac{1}{\lambda}}G_i^h = \frac{\lambda}{(\lambda-1)}r_i^{h*}G_i^h$$

Based on g_i^{h*} and r_i^{h*} the total value of the costs per unit of land for traditional housing floor area is the following:

$$\kappa_i^h\left(g_i^h\right)^{\gamma^h} = \frac{r_i^h}{(\lambda-1)}$$

Demand for goods and services for construction

The construction sector demands goods and services to produce buildings. κ_i^h characterizes the unit cost of construction which can be represented as follows:

$$\kappa_i^h = \phi_i^h \prod\nolimits_s (P_i^s)^{\mu^{sh}}$$

The cost function for modern residential ($h = 1$) is the following:

$$C_i^h = \kappa_i^h\left(g_i^h\right)^{\gamma^h}$$

Shepherd's lemma states that the partial derivation of the cost function with respect to the factor price is equal to the demand for the factor of production. As such, the demand for goods and services from location i on sector s from the construction sector per unit is equal to the partial derivative of the unit cost with respect to the price index:

$$x_i^{sh} = \left(g_i^h\right)^{\gamma^h}\frac{\partial\kappa_i^h}{\partial P_i^s}$$

where x_i^{sh} is the demand for goods and services from location i and construction type h on sector s when $h = 1$. This becomes:

$$x_i^{sh} = \mu^{sh}\left(g_i^h\right)^{\gamma^h}\phi_i^h \prod\nolimits_s (P_i^s)^{\mu^{sh}-1}$$

The value of this demand when $h = 1$ per unit of construction is as follows:

$$P_i^s x_i^{sh} = \mu^{sh}\left(g_i^h\right)^{\gamma^h}\phi_i^h \prod\nolimits_s (P_i^s)^{\mu^{sh}}$$

which simplifies to:

$$P_i^s x_i^{sh} = \mu^{sh}\left(g_i^h\right)^{\gamma^h}\kappa_i^h$$

Given that G_i^h is the total land area in location i for housing type h, the total value of demand from constructing housing type $h = 1$ and $h = 2$ in location i on goods and services in sector s is the following:

$$G_i^h P_i^s x_i^{sh} = G_i^h \mu^{sh} g_i^h \kappa_i^h$$

As previously derived $\kappa_i^h\left(g_i^h\right)^{\gamma^h} = \frac{r_i^h}{(\gamma^h-1)}$, therefore, the value of demand from $h = 1$ is:

$$G_i^h P_i^s x_i^{sh} = G_i^h \mu^{sh} \frac{r_i^h}{(\gamma^h - 1)}$$

By symmetry, the value of demand from constructing housing type $h = 2$ in location i on goods and services in sector s is the following:

$$G_i^h P_i^s x_i^{sh} = G_i^h \mu^{sh} \frac{r_i^h}{(\lambda - 1)}$$

A3.1.5 Market Clearing

Labor

Given there are two labor types there will be two labor market clearing conditions in each location in the catchment area.

The demand for labor comes from firms. The previously derived value of demand for factor k in location i and sector s is the following:

$$n_{is} v_{ks} X_{ks} = n_{is} v_{ks} \frac{\alpha_{ks} p_{is} Y_{is}}{v_{ks}}$$

Given this general expression for factor demand, the value of factor demand for labor of type l across all sectors is the following:

$$n_{is} w_{ls} X_{ls} = \sum_s n_{is} w_{ls} \frac{\alpha_{ls} p_{is} Y_{is}}{w_{ls}}$$

The supply of labor comes from households. As previously derived, the value of labor supply is the following:

$$w_j^l L_j^l = w_j^l L^l \sum_i \sum_h \left(\pi_{ij}^{lh}\right)$$

Based on the value of demand and supply of labor in each location i and labor type l, the market clearing condition is the following:

$$w_j^l L^l \sum_i \sum_h \left(\pi_{ij}^{lh}\right) = \sum_s n_{is} w_{ls} \frac{\alpha_{ls} p_{is} Y_{is}}{w_{ls}}$$

Where the left-hand side (LHS) of the market clearing condition represents the supply of labor and the right-hand side (RHS) represents the demand for labor.

Goods and Services

The demand for goods and services comes from households, firms, the construction sector, and external locations via exports.

As derived previously, the demand for goods and services produced in location i and sector s from households, firms, and the construction sector in the catchment area is the following:

$$x_{is}(u) = \sum_{j} E_{js}(p_{is})^{-\sigma}(t_{ijs})^{1-\sigma} P_{js}{}^{(\sigma-1)}$$

E_{js} is the expenditure on goods and services in sector s in location j and is equal to the following:

$$E_{js} = \sum_{l}\sum_{j}\sum_{h} L^{l}\left(\pi_{ij}^{lh}\beta^{slh}\left(w_{j}^{l} + m_{ij}^{l}\right)\right) + \sum_{t} n_{it}P_{is}\frac{\alpha_{ts}p_{it}Y_{it}}{P_{is}} + G_{i}^{1}\mu^{s1}\frac{r_{i}^{1}}{(\gamma^{1}-1)} + G_{i}^{2}\mu^{s2}\frac{r_{i}^{2}}{(\gamma^{2}-1)}$$

The first term on the RHS is the value of household expenditure on goods and services in sector s for those who live in location i; the second term is the value of firm expenditure on sector s for firms based in location i across all sectors t; the third term is the value of derived demand for goods and services in sector s for units in modern residential construction while the fourth term is the analogous term for the traditional residential sector.

Further to the demand for goods and services produced in the catchment area that comes from other locations in the catchment area, there is also demand from external locations. As derived previously, the value of the export demand function can be specified as follows:

$$X_{is} = \alpha_{i} n_{is} p_{is}{}^{-\sigma}$$

The supply of goods and services comes from firms in each of the three sectors. The production function is a Cobb-Douglas function as follows:

$$Y_{is} = a_{is}\prod_{k} X_{ks}^{\alpha_{ks}} - F_{is}$$

There are three market clearing conditions in each location i, with one condition for each of the three sectors. The market clearing condition for sector s is as follows:

$$n_{is}p_{is}Y_{is} = p_{is}\sum_{j} n_{is}E_{js}(p_{is})^{-\sigma}\left(t_{ijs}\right)^{1-\sigma}P_{js}{}^{(\sigma-1)} + \alpha_{i}n_{is}p_{is}{}^{1-\sigma}$$

Land

Given two types of construction subsectors, each location requires two market clearing conditions for the construction sector.

The demand for floor area comes from households while firms demand land. As previously derived, the value of household demand for housing type h in location i across both labor types l is the following:

$$\sum_{l}\sum_{j} L^{l}\left(\pi_{ij}^{lh}\beta^{lh}(w_{j}^{l} + m_{ij}^{l})\right)$$

The supply of floor area comes from construction firms. The value of floor area is the following:

$$q^h g^{h*} G_i^h = \frac{\gamma^h}{(\gamma^h - 1)} r_i^{h*} G_i^h$$

There are two separate market clearing conditions for the construction sector. The supply of floor area is on the LHS and the demand for floor area is on the RHS in each of the two market clearing conditions below.

For modern residential, $h = 1$:

$$\frac{\gamma^1}{(\gamma^1 - 1)} r_i^{1*} G_i^1 = \sum_l \sum_j L^l \left(\pi_{ij}^{l1} \beta^{l1} (w_j^l + m_{ij}^l) \right)$$

For traditional residential, $h = 2$:

$$\frac{\gamma^2}{(\gamma^2 - 1)} r_i^{2*} G_i^2 = \sum_l \sum_j L^l \left(\pi_{ij}^{l2} \beta^{l2} (w_j^l + m_{ij}^l) \right)$$

In addition to the market clearing conditions, further constraints required on available land area for development and the rental rates to ensure that the value of demand and supply of floor area are equalized.

In the case of land area available for development, the market clearing condition in each location i is the following:

$$\overline{G_\iota} = G_i^1 + G_i^2 + G_i^3$$

Where $\overline{G_\iota}$ is the total area of land available for development in location i. G_i^3 is the demand for land from firms.

Rental rates must equalize across all construction types in each location i. Otherwise, landowners could profitably build a different construction type, and hence the sector will not be in equilibrium. The following two market clearing conditions are required:

$$r_1 = r_2$$

$$r_3 = r_2$$

A third market clearing condition $r_1 = r_3$ is not required as this is already implied by the first two conditions.

A3.2 System of Equations

A3.2.1 Households

Income

$$i\_h_{ij}^{lh} = L_{ij}^{lh} (w_j^l + m_{ij}^l)$$

Demand for goods and services:

$$x_{ij}^{tl\ *} = \frac{\beta^{tl}\ (i\_h_{ij}^{lh})}{P_i^t}$$

Demand for housing♣:

$$h_{ij}^{lh*} = \frac{\beta^{lh}(i\_h_{ij}^{lh})}{q_i^h}$$

Value of demand for goods and services:

$$e\_hgs_i^s = \sum_j \sum_l \sum_h P_i^s x_{ij}^{slh*}$$

Value of demand for housing:

$$e\_hh_i^h = \sum_j \sum_l q_i^h h_i^{lh*}$$

Value of supply:

$$s\_l_j^l = \sum_i \sum_h L_{ij}^{lh} w_{jl}$$

Indirect utility:

$$U_{ij}^{lh} = \left(\frac{w_j^l + m_{ij}^l}{q_i^{h\,\beta^{lh}} \prod_s P_i^{t\,\beta^{slh}}} \right) b_i^{lh} t_{ij}^l$$

A3.2.2 Firms

Optimal price for goods and services:

$$p_{is} = \frac{c_{is}\sigma}{\sigma - 1}$$

Marginal cost of production:

$$c_{is} = \frac{1}{a_{is}} \prod_k \left(\frac{v_{ks}}{\alpha_{ks}} \right)^{\alpha_{ks}}$$

Supply of goods and services:

$$\overline{Y_{is}} = F_{is}(\sigma - 1)$$

Value of supply of goods and services:

$$s\_gs_{is} = n_{is} p_{is} Y_{is}$$

Value of demand for intermediate goods and services:

♣ $\lambda = 1$ for formal residential and commercial construction given there is no reduction in the quality of floorspace as density increases.

$$e\_fgs_i^t = \sum_s n_{is} P_{it} \frac{\alpha_{st} p_{is} Y_{is}}{P_{it}}$$

Value of demand for labor:

$$e\_fl_i^l = \sum_s n_{is} w_{il} \frac{\alpha_{sl} p_{is} Y_{is}}{w_{il}}$$

Value of demand for land:

$$e\_fc_i = \sum_s n_{is} p\_land_i \frac{\alpha_{sz} p_{is} Y_{is}}{p\_land}$$

A3.2.3 Construction

Marginal cost of production:

$$\kappa_i^h = \phi_i^h \prod_s (P_i^s)^{\mu^{sh}}$$

Modern Residential

Floorspace density:

$$g_i^{1*} = \left(\frac{q_i^1}{\gamma^1 \kappa_i^1}\right)^{\frac{1}{\gamma^1 - 1}}$$

Rental rate:

$$r_i^{1*} = \kappa_i^1 (\gamma^1 - 1) \left(\frac{q_i^1}{\gamma^1 \kappa_i^1}\right)^{\frac{\gamma^1}{\gamma^1 - 1}}$$

Value of supply:

$$s\_cf_i = \frac{\gamma^1}{(\gamma^1 - 1)} r_i^{1*} G_i^1$$

Value of demand:

$$e\_cfgs_i^{s1} = G_i^1 \mu^{s1} \frac{r_i^1}{(\gamma^1 - 1)}$$

Traditional Residential

Floorspace density:

$$g_i^{2*} = \left(\frac{q_i^2}{\gamma^2 \kappa_i^2}\right)^{\frac{1}{\gamma^2-1}}$$

Rental rate:

$$r_i^{2*} = \kappa_i^2(\gamma^2 - 1)\left(\frac{q_i^2}{\gamma^2 \kappa_i^2}\right)^{\frac{\gamma^2}{\gamma^2-1}}$$

Value of supply:

$$s\_cc_i = \frac{\gamma^2}{(\gamma^2 - 1)} r_i^{2*} G_i^2$$

Value of demand:

$$e\_ccgs_i^{s2} = G_i^2 \mu^{s2} \frac{r_i^2}{(\gamma^2 - 1)}$$

A3.2.4 Location Decisions

Labor location:

$$L_{ij}^{lh} = L^l \pi_{ij}^{lh}$$

Probability function:

$$\pi\_live_i^{lh} = \frac{\left(u_{ij}^{lh}\right)^{\varsigma}}{\sum_h \sum_i \left(u_{ij}^{lh}\right)^{\varsigma}}$$

$$\pi\_comm_{ij}^{lh} = \frac{\left(u_{ij}^{lh}\right)^{\varsigma}}{\sum_j \left(u_{ij}^{lh}\right)^{\varsigma}}$$

Price index:

$$P_{is} = \left[\sum_j n_j \left(p_{js} t_{ij}\right)^{1-\sigma} + n_0 (p_o)^{1-\sigma}\right]^{1/_{1-\sigma}}$$

Imports and exports

Import demand:

$$i\_gs_{kis} = imp_s E_{is} (p_{ks})^{-\sigma} (t_{kis})^{1-\sigma} P_{is}{}^{(\sigma-1)}$$

Export demand:

$$e\_egs_{is} = \alpha_i n_{is} p_{is}{}^{-\sigma}$$

A3.2.5 Market Clearing

Labor

$$s\_l_i^l = e\_fl_i^l$$

Goods and Services

$$s\_gs_{is} + i\_gs_{kis} = p_{is} \sum_j n_{is} E_{js} (p_{is})^{-\sigma} (t_{ijs})^{1-\sigma} P_{js}{}^{(\sigma-1)} + \alpha_i n_{is} p_{is}{}^{1-\sigma}$$

Where $E_{js} = e\_hgs_j^s + e\_fgs_j^s + e\_cgs_j^{s1} + e\_cgs_j^{s2}$

Construction

Modern:

$$s\_cf_i = e\_hh_i^1$$

Traditional:

$$s\_ci_i = e\_hh_i^2$$

Land clearing:

$$\overline{G_\iota} = G_i^1 + G_i^2 + G_i^3$$

Rental rate equalization:

$$r_1 = r_2$$

$$r_3 = r_2$$