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ABSTRACT: Saudi Arabia rapidly urbanized during the late 20th century, transforming its primordial Bedouin society into a sedentary nation state. This raised numerous major socio-economic and demographic challenges, including urban growth and regional disparities. This paper assesses these issues using a mixed model of urban economics and economic geography to investigate the impacts of regional transportation policies on urban growth and welfare. With the introduction of urban costs, the numerical simulations derived two main results: (i) public transport policies can be used as a strategic instrument for regional planning; and (ii) contrary to Tabuchi (1998), the dispersion equilibrium is better than the concentration equilibrium from a welfare point of view.

Key words: KSA; Urban Growth; Transportation; Public Policies; Welfare

I- Introduction
The Kingdom of Saudi Arabia (KSA) was transformed from a timeless desert realm of Bedouins into a modern urbanized state due to the oil boom from the mid-20th century, with the vast majority of the population becoming sedentary and living in major metropolitan areas (MAs) such as Riyadh, Jeddah, Dammam, Makkah and Medina. Such urbanization and development has created some serious challenges, such as atmospheric pollution, urban sprawl and regional disparities. In recent years, the Saudi government has prioritized transportation infrastructure projects at the core of their development plans, including Vision 2030, which are essential to realize regional integration among big, medium and small cities by developing the rural zones.

In many countries public transport policies are deployed as strategic instruments of regional planning to encourage the relocation of some economic activities to non-metropolitan zones and cities (Cavailhès et al., 2007). The concentration of economic and demographic activities in metropolitan cities is contingent on the endogenous characteristics of cities and transportation networks, thus it is necessary to
develop essential infrastructure and services in non-metropolitan areas as part of regional planning, including transport (Bertolini et al., 1998). This paper introduces two kinds of transportation models to investigate the impacts of both intraregional and interregional public transportation policy on urban growth and household welfare in KSA.

Different theoretical models studied the relationship between transportation costs and industrial location, notably those devised by Helpman and Krugman (1985) and Krugman (1991). According to Behrens et al. (2009), those models had two points in common: (i) they showed that any decrease in the interregional transport cost leads to more concentration of activities in fewer regional centers, thereby inducing more regional inequalities; and (ii) they ignored the existence of intraregional transportation costs inside major cities due to urban costs (e.g. land rents, pollution, commuting costs, poor quality of transportation networks etc.).

In order to investigate how public spending on transportation infrastructure affects the location and welfare, Martin and Rogers (1995) introduced two types of infrastructures: domestic and international infrastructure. They found that it is important to improve the quality of domestic infrastructure in developing countries in order to attract foreign direct investment (FDI) firms and their resources. They also showed that the expenditure effect for regional and national economies can be positive if the increase in demand of manufacturing products exceeds the decrease in demand due to tax increase.

Intra-urban costs comprise another crucial issue discussed in the literature to show how urban costs (e.g. land rents, commuting costs, pollution, poor quality of local transportation infrastructure, etc.) affect the industrial location and household welfare. For instance, Tabuchi (1998) used a unified model of economic geography (Krugman, 1991) and urban economics (Alonso, 1964) to reveal the causes of dispersion and concentration in economic activities (workers and firms) between regions. He showed that the agglomeration equilibrium is better than the dispersion equilibrium from a welfare point of view. Using quasi-linear utility function, Ottaviano et al. (2002) developed a system of two cities (including an agricultural sector and fixed housing consumption) to analyse the variations in transport cost and travel, supposing exogenous commuting cost, finding a possibility of asymmetric agglomeration with different commuting cost levels between cities.

In spite of the studies which highlighted the advantages of agglomeration (Duranton and Puga, 2004; Duranton and Turner, 2012), many researchers also found a negative influence of urban costs on the location of firms within large cities (Brakman et al., 1996; Krugman and Elizondo, 1996; Tabuchi, 1998; Duranton and Puga, 2001; Cavailhès et al., 2007; Goryunov and Kokuvin, 2014; Jedwab et al., 2017). This induces firms to leave central urban areas, forming secondary employment centers or clusters (Henderson and Mitra, 1996; Lucas and Rossi-Hansberg, 2002), as a consequence of which workers may profit from less localization cost by choosing to live in suburban or rural areas (Glaeser and Kahn, 2004; Holmes and Steven, 2004; Zhang, 2016). Urban costs may slow down (intensify) rural-to-urban (urban-to-rural) migration, thereby decreasing urban growth in the long-run (Jedwab et al., 2017). The formation of small clusters or cities within a wider metropolitan area is becoming well-known in the literature as a polycentric city, which appears to be a natural response to increasing urban costs (Cavailhès et al., 2007).
This work uses a unified model of urban economics and economic geography to investigate the effects of regional transportation policies on urban growth and welfare. Based on Duranton et al. (2014) and Mayer and Trevien (2017), we suppose that Saudi spending on transportation infrastructure should ameliorate the productivity of workers inside urban zones once the quality of domestic transportation networks is getting better. Both intra-urban and interurban infrastructures are considered in this article.

This paper is divided into five sections. The second introduces an overview about the phenomena of rapid urbanization in KSA. Section 3 develops the mixed model of economic geography and urban economics and derives the short-run equilibrium conditions. Section 4 investigates the impacts of regional public policies on urban growth, and the analysis of spatial equilibrium and stability. Section 5 shows some policy implications on welfare. The final section concludes the paper and notes some implications for Saudi policy makers.

2 An overview on the rapid urbanization in KSA

The Ninth Development Plan (Ministry of Economy and Planning, 2010-2014) provides a benchmark to understand the rapid urbanization process in KSA over the last two decades. The plan suggests a balanced regional development, in the form of more convergences in development levels among different regions, as well as more decentralization, to enable municipalities to invest in some productive projects, create employment opportunities, and enhance their collaboration with the private sector in implementing development projects.

In alignment with our research subject, the Plan includes two relevant objectives:

i) To improve the role of local, regional and national development centers, taking into account the development of the least developed economic and social centers;

ii) To achieve the regional integration among large, medium and small cities by supporting the development of rural zones and providing an appropriate investment climate inside these zones.

Interestingly, despite the significant impact of better access to transport networks on the economic development of KSA, to our knowledge no previous study investigated the real effects of transportation development projects in terms of urban growth and household welfare at both the regional and national level, which is highlighted later in this paper. However, it is necessary from the outset to comprehend the very rapid urbanization process in KSA over the last two decades.

According to the UN (2014) report entitled “World Urbanization Prospects, 2014” urbanization in KSA was very rapid and complex during the last five decades, and it was proportionally more intense than more populous Arab countries such as Egypt, Syria and Iraq (Abou-Korin and Al-Shihri, 2015). Based on the UN (2014) report, the percentage of the urban population in KSA has jumped from about 20% in 1950 to 80% in 2000 and is expected to reach 90% in 2050 (see Fig. 1). The urban population doubled 36 times, from just 665,000 in 1950 to 24.8 million by 2015, and it is expected to reach 35.8 million inhabitants by 2050, which means that urban costs are expected to increase dramatically in the coming two decades.
Table 1 highlights the historical and projected population growth for the years 1950-2025 for five major Saudi metropolitan areas: Riyadh, Jeddah, Makkah, Medina and Taif. It is clear that these cities have witnessed rapid population growth in the last three decades, with the most rapid proliferation in Riyadh and Jeddah (Choguill, 2008). Obviously this was contemporaneous with the oil boom period from 1975 to the mid-1990s, which precipitated continuous urban-rural migration as well as endogenous urban population growth (i.e. through birth rates and reduced mortality). Prior to 1965 the ratio of the urban population was very low and up to 1975 the national capital of KSA had a population of only one million inhabitants. Riyadh quadrupled its population between 1980 and 2005, going from just 1 million to over 4 million, and cities like Makkah, Medina and Jeddah crossed the 1 million threshold. With a population of almost 5 million, the metropolitan area of Jeddah is the second largest population area in KSA after Riyadh, attributed mainly to its proximity to the holy city of Makkah and accessibility to the second most important airport in the country.

Table 1. Past and projected populations in main Saudi MAs (in thousands)

<table>
<thead>
<tr>
<th>Year</th>
<th>Riyadh</th>
<th>Jeddah</th>
<th>Makkah</th>
<th>Medina</th>
<th>Taif</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>111</td>
<td>119</td>
<td>148</td>
<td>44</td>
<td>30</td>
</tr>
<tr>
<td>1960</td>
<td>156</td>
<td>141</td>
<td>215</td>
<td>82</td>
<td>66</td>
</tr>
<tr>
<td>1970</td>
<td>408</td>
<td>348</td>
<td>313</td>
<td>112</td>
<td>147</td>
</tr>
<tr>
<td>1980</td>
<td>1055</td>
<td>594</td>
<td>383</td>
<td>284</td>
<td>257</td>
</tr>
<tr>
<td>1990</td>
<td>2325</td>
<td>1742</td>
<td>856</td>
<td>529</td>
<td>381</td>
</tr>
<tr>
<td>2000</td>
<td>4519</td>
<td>3171</td>
<td>1326</td>
<td>885</td>
<td>482</td>
</tr>
<tr>
<td>2010</td>
<td>6413</td>
<td>4406</td>
<td>1749</td>
<td>1206</td>
<td>582</td>
</tr>
<tr>
<td>2015</td>
<td>7155</td>
<td>4921</td>
<td>1959</td>
<td>1356</td>
<td>631</td>
</tr>
<tr>
<td>2025</td>
<td>7617</td>
<td>4770</td>
<td>2039</td>
<td>1488</td>
<td>701</td>
</tr>
</tbody>
</table>

Source: UN- World urbanization prospects: the 2014 revision
3 The Model

Most recent economic geography models were based on those of Krugman (1991) and Krugman and Elizondo (1996), which were premised on the dichotomous dynamics between agglomeration and dispersion spatial forces. Agglomeration forces include market size effects, forward and backward linkages and good quality transportation infrastructure, while dispersion forces include external diseconomies such as poor quality transportation networks, commuting costs and higher land rents inside major urban areas.

3.1 Assumptions

This model includes only the centripetal forces that arise from the interaction among economics of scale, intraregional and inter-TC market size (i.e. backward and forward linkages). The only dispersion force that we take into account is commuting cost/land rent. Despite the fact that there are some other external diseconomies in real urban areas, this choice is adopted in order to keep this model as simple as possible.

Consider an economy with two symmetrical regions, 1 and 2, which are the same size at baseline (i.e. all economic activities are equally distributed between regions without any spatial discrimination). At equilibrium, two possible spatial configurations (symmetric and asymmetric equilibrium) can be discussed in the Saudi context. In each region there are two zones, one urban and one rural. There are two factors of production, labor and land. Labor is perfectly mobile between these zones, but impossible between regions. The total population $L$ is presented below, while $L_1$ and $L_2$ represent respectively the total population in region 1 and region 2.

$$L = L_1 + L_2$$

(1)

In each region, there is a share of workers $\lambda_k$ working and living in the urban zone, employed exclusively in the industrial sector. The other share $1-\lambda_k$ lives and works in the rural zone, employed exclusively in the agricultural sector. We assume that each urban worker needs a fixed living space, one unit of land. The size of the urban zone is $\lambda_kL_k$; with a linear city, the maximum distance to the city center is:

$$x = \lambda_kL_k/2$$

(2)

Regarding the rural zone, the wage is normalized to the unity and the land, as abundant and having an opportunity cost equal to zero. The total net income that is necessary for the consumption of homogenous and differentiated industrial goods is:

$$E_{k,0} = (1-g)(1+F_k/L_k)$$

(3)

where $F_k$ is the land rent in the urban zone $k$, and $g$ is a proportional tax on the regional income.

In the urban zone, the net income for a worker localized at the distance $x$ from the city center is given by the following expression, where $\left(1-\gamma_kx\right)w_k$ is the net wage of both commuting cost and land rent for all workers.

$$E_k(x) = (1-g)((1-\gamma_kx)w_k + F_k/L_k) - F_k(x)$$

(4)
It means that workers who live outside the city center will not pay any land rent, but receive a net wage due to the time spent in commuting. Workers who live in urban zone will receive more money, but should pay for the land rent.

The land rent \( F_k(0) \) is trivially a decreasing function of \( x \), minimum for \( x = \lambda_k L_k / 2 \). Land being allocated to the highest bidder, this minimum is equal to the opportunity cost of land, which is equal to zero, \( F(\lambda_k L_k / 2) = 0 \). From this, we can deduce the final expression for the industrial wage.

\[
W_k = \frac{2}{2 - \gamma_k \lambda_k L_k}
\]  

(5)

The urban land rent is given by the following expression.

\[
F_k = 2 \int_0^{\lambda_k / 2} F_k(x) dx = (1-g) \gamma_k W_k \left( \frac{\lambda_k L_k}{2} \right)^2
\]  

(6)

After some substitutions and simplifications, the expression of the net income for urban workers is given by the following equation:

\[
E_k(x) = E_{k,0} = \left( 1 - g \right) \left( 1 + \frac{\gamma_k \lambda_k L_k}{2(2 - \gamma_k \lambda_k L_k)} \right)
\]  

(7)

Like most economic geography models (Krugman, 1991; Krugman and Elizondo, 1996; Puga, 1998), we consider an economy with two regions and two private sectors: an agricultural sector with constant returns to scale (tied to the land); and a manufacturing sector with increasing returns to scale. The latter is imperfectly competitive and produces differentiated manufactures. There are two production factors, each of which is assumed to be specific to one sector. Consumers have a preference for manufacturing varieties, and manufactured goods can be exported from one region to the other one with an “iceberg” transportation cost: for each unit of goods shipped from one region to the other, only a fraction arrives. \( \tau \) is an inverse index of transportation cost. In this model, we introduce a public sector which produces public infrastructure, and is paid by a proportional tax on regional incomes. The government exogenously allocates public investments among the two symmetric regions.

The easiest way to do this is with the Dixit-Stiglitz monopolistic competition model (Dixit and Stiglitz, 1977). This current model takes into consideration a large number of symmetric products. Each producer acts as a profit-maximizing monopolist, but free-entry drives profits to zero. Consumers have the same preferences in both regions. They have a Cobb-Douglas preference function over homogenous product and a CES aggregate of the \( N \) manufactured goods.

\[
U = \frac{1}{\mu(1-\mu)^{\frac{1}{\sigma}}} M^{\mu} A^{1-\mu} \quad \text{with} \quad M = \left[ \sum_{i=1}^{N} q_i^{\sigma} \right]^{\frac{1}{\sigma}} \quad 0 < \mu < 1 \text{ and } \sigma > 1
\]  

(8)

where \( A \) is the quantity of homogenous product consumed, \( M \) is the global quantity of manufactured goods consumed, \( q_i \) is the quantity of each manufactured good consumed, \( \mu \) is the substitution elasticity between manufactured goods and the product tied to the land, and \( \sigma \) is the elasticity of
substitution between different manufactured goods.

\[ A = (1-\mu)E \]
\[ M = \mu E / I \]
\[ q_i = \mu E p_i^1 p_i^\sigma \] with \[ I = \sum p_i^{1-\sigma} \]

In the agricultural sector, one unit of labor produces one unit of product, and wages are equal in both regions. Therefore, the price of homogeneous product provided by this sector is also equal to one.

\[ P_k^A = V_k^A = 1 \] (10)

The production of a quantity \( Q \) of any variety \( i \) requires a fixed and a variable quantity of a specific labor input. The cost function in the manufactured sector is:

\[ l_i = \alpha + \beta Q \] (11)

\( l_i \) is the quantity of labor necessary to produce \( Q \) units of product \( i \). \( \alpha \) and \( \beta \) are respectively the fixed and the variable cost in each region.

3.2 The short-run equilibrium conditions

Each producer faces an elasticity of demand equal to the elasticity of substitution and therefore will charge a price that is a constant markup over marginal cost.

\[ p_k = \frac{\sigma}{(\sigma-1)} \beta \] (12)

\( E \) is the income, \( p_i \) is the price of the variety \( i \), the price of the homogenous product tied to land equal to one. Consumers maximize their utility under income constraints:

\[ \sum p_i^{1-\sigma} = (1-\sigma) \]

Given the assumption that free entry will drive profit to zero, there is a unique zero-profit for each product.

\[ Q = \frac{\alpha}{\beta} (\sigma - 1) \] (13)

The Dixit-Stiglitz index price is:

\[ I_k = n_k p_k^{1-\sigma} + \frac{\mu E_{k,0}}{n_k} \]

and the quantities consumed for each good produced in \( k \) are:

\[ q_{k,i} = \frac{\mu E_{k,0} p_k^{1-\sigma}}{n_k p_k^{1-\sigma} + \frac{\mu E_{k,0}}{n_k} q_i^{\sigma}} \] (15)

and for the good produced in region \( l \),

\[ q_{k,l} = \frac{\mu E_{k,0} q_i^{\sigma}}{n_k p_k^{1-\sigma} + \frac{\mu E_{k,0}}{n_k} q_i^{\sigma}} \] (16)

This total demand should equal the total supply given by equation (13).
\[
\frac{\mu k E_{k,0}e^{\sigma}}{n_k e^{-\sigma} + n_k (\tau p_k)^{e^{-\sigma}}} + \frac{\mu l E_{l,0}(\tau p_k)^{e^{-\sigma}}}{n_k (\tau p_k)^{e^{-\sigma}} + n_k (\tau p_k)^{e^{-\sigma}}} = \alpha (\sigma - 1)
\]  

(17)

\(\gamma_k\) is the intraregional transportation cost (or the commuting cost) in the urban zone \(k\) (i.e. any change in these two costs will represent a change in the quality of transportation infrastructure). For example, if the Saudi government decides to decrease the interregional transportation cost between the MA of Jeddah and the MA of Riyadh, then the value of \(\tau\) is expected to be reduced significantly. Also, the extension of the King Abdulaziz International Airport (Jeddah), or the creation of a new harbor in King Abdullah Economic City represents an improvement in the quality of interregional transportation infrastructure.

New transportation projects can be funded by a regional income tax (Barro, 1990), particularly if such projects are supplied exclusively by the public authority (Martin and Rogers, 1995). Thus the total budget is equal to \(G\):

\[
g = g(R_1 + R_2)
\]  

(21)

where \(g\) indicates the tax rate applied by the Saudi government, and \(R_1, R_2\) are the total incomes in regions 1 and 2 (respectively).

This budget will serve to finance the interregional transportation infrastructure \(g_{tr}\), the intraregional transportation infrastructure \(g_{t1}\) in region 1, and the intraregional transportation infrastructure \(g_{t2}\) in region 2. The repartition function of expenditure is given by the following equation:

\[
G = g_{tr} + g_{t1} + g_{t2}
\]  

(22)
The public authority is supposed to use the labor factor to provide both transportation infrastructures. The intraregional infrastructure is supposed to be provided by residents of the urban zone, while the interregional infrastructure is supposed to be provided by residents of rural zone. As the agricultural wage is normalized to one in the rural zone, the quantity of labor necessary for the provision of interregional infrastructure will be equal to \( g_r \).

\[ \tau = \frac{\partial g_r}{\partial \tau} \quad \gamma_k = \frac{g_k}{W_k} \] \[ \text{with} \quad \frac{\partial \tau}{\partial g_r} < 0 \quad \text{and} \quad \frac{\partial \gamma_k}{\partial g_r} < 0 \]

(23)

4.2 The equilibrium location of firms

The objective is to study the impacts of public expenditure on the spatial repartition of firms and workers and thus on urban growth. Even though all necessary equations are well defined at the short-run equilibrium, this model does not have an analytical solution. Therefore, some numerical simulations are provided using the software Maple 9.5. Two spatial equilibrium configurations are considered in this section; the asymmetric equilibrium (Jeddah/Taif) and the symmetric equilibrium (Makkah/Medina). This study will also determine the long-run stability conditions for both dispersion and concentration equilibriums. For example, the relocation of manufacturing firms from the MA of Jeddah to the MA of Taif is described as unstable if the profitability exceeds the unity. Otherwise, it is qualified as stable (see Fig. 14-15 and Appendix 1 for calculations).

4.2.1 The concentration equilibrium

Here we select the MAs of Jeddah and Taif because of the fact that the former is the second-largest MA (after Riyadh) with almost 5 million inhabitants in 2015, and it has a very dense urban area (mainly due to its high attractiveness for both workers and firms). Without any public regulation, this equilibrium configuration should intensify regional disparities, leading to less convergence in development levels among the two regions.
In this case, all the manufacturing activities ($\hat{\lambda}_1$) are supposed to be concentrated in the MA of Jeddah, indexed by 1. In other words, both manufacturing and agricultural sectors exist in Jeddah, while the MA of Taif includes only the agricultural sector.

\[ \lambda_2 = 0, F_2 = 0 \]  \hspace{1cm} (24)

By substituting equation (24) in the short-run equilibrium equations, then we have the following system of equations:

\[
\begin{align*}
\mu(1-g)[\tau(I_t+\psi)+L_2] &= \tau \left( \lambda_t \left[ 4 - \gamma \lambda_t L_t + 2 g_{\gamma t} - g \gamma \right] - \frac{4}{4} \frac{2}{2-\gamma} \right) \\
g_t + g_{\gamma t} &= g(L_t + L_2 + \psi)
\end{align*}
\]  \hspace{1cm} (25)

The first equation describes the goods market equilibrium, while the second defines the public budget equilibrium.

Fig. 3 shows that when the interregional transport cost is null ($\tau=1$), with the presence of a lower intra transport cost ($\gamma=0.1$) and a higher manufacturing share ($\mu=0.6$), then the exported goods from the MA of Jeddah to the MA of Taif become less expensive, inducing a lower regional price index and a higher demand for home manufacturing goods. Moreover, with a higher manufacturing share, residents can benefit from a decrease in the price index, leading to an increase in the demand of manufacturing goods. Similarly, firms locating in the MA of Jeddah will profit from a larger market size. These economic effects lead to a full concentration of manufacturing activity, leading to an excessive increase in urban growth. As shown in Fig. 5, the full agglomeration of activities is possible with the presence of a higher intraregional transport cost.
($\gamma = 0.6$) and a lower interregional transport cost if the manufacturing share is sufficiently high ($\mu = 0.6$).

In Fig. 6, when the interregional cost is sufficiently low, then it is cheaper for Taif to import manufacturing goods from the MA of Jeddah, inducing a lower regional price index and a higher demand for home goods. Also, with a higher intra transport cost in the MA of Jeddah ($\gamma = 0.6$), the local firms bear higher production costs due to higher wages paid to workers in order to compensate their commuting cost. In addition, with the presence of a lower manufacturing share ($\mu = 0.3$), the demand for manufacturing goods in the MA of Jeddah is decreased. These interactive effects induce more dispersion of manufacturing activities, leading to a decrease in urban growth. This is consistent with the scenario shown in Fig. 4, where the presence of lower intraregional transport cost ($\gamma = 0.3$) and manufacturing sharing ($\mu = 0.3$), lead to a dispersion in the manufacturing activities and to a decrease in the urban growth.
Table 2. Parameter values for the concentration equilibrium

<table>
<thead>
<tr>
<th>Parameters</th>
<th>$L_1$</th>
<th>$L_2$</th>
<th>$g_\tau$</th>
<th>$g_{\gamma_1}$</th>
<th>$\gamma_1$</th>
<th>$\mu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig. 3</td>
<td>1</td>
<td>1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Fig. 4</td>
<td>1</td>
<td>1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Fig. 5</td>
<td>1</td>
<td>1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Fig. 6</td>
<td>1</td>
<td>1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.6</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Source: Compiled by authors

The simulation results in Fig. 7-8 show that relocating firms from the MA of Jeddah to the MA of Taif is possible because the agglomeration equilibrium is unstable in both cases. In other words, with the presence of lower (or higher) intraregional transportation cost, manufacturing firms are able to realize long-term profit in the MA of Taif due to the higher urbanization rate in the MA of Jeddah ($\lambda_1=0.8$). The same results are obtained when the Saudi government does not apply any taxes ($g=0$) on regional incomes (see Fig. 14-15, Appendix 2). However, it becomes stable with intermediate values of interregional transportation costs, where the commuting cost $\gamma_1$ is null and the elasticity of substitution $\sigma$ is close to one.

Table 3. Parameter values for the asymmetric stability

<table>
<thead>
<tr>
<th>Parameters</th>
<th>$L_1$</th>
<th>$L_2$</th>
<th>$g$</th>
<th>$\gamma_1$</th>
<th>$\sigma$</th>
<th>$\lambda_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig. 7</td>
<td>1</td>
<td>1</td>
<td>0.1</td>
<td>0.3</td>
<td>4</td>
<td>0.82</td>
</tr>
<tr>
<td>Fig. 8</td>
<td>1</td>
<td>1</td>
<td>0.1</td>
<td>0.01</td>
<td>4</td>
<td>0.82</td>
</tr>
</tbody>
</table>

Source: Compiled by authors

4.2.2 The dispersion equilibrium

In this spatial configuration, the choice of MAs of Makkah and Medina is related to their similarities in terms of population and economic activities, with both having direct access to the interregional transport networks via airports and highways. Additionally, they
face the same challenges related to the existence of urban costs inside their urban areas. A general description of this spatial configuration is given by the Fig. 9 below.

![Diagram showing the dispersion equilibrium (Makkah/Medina)](image)

**Fig. 9. Description of the dispersion equilibrium (Makkah/Medina)**

In this symmetric equilibrium, all economic activities are distributed equally between the MAs of Makkah and Medina. More precisely, the agricultural and manufacturing sectors are present in each MA. The symmetric equilibrium is given by the following system of equations.

\[
\begin{align*}
(1-g)(2L(2-gL)+(1-g)gL)=\psi(\lambda(4-gL+2g_{r}g)-4g_{r}) \\
g_{r}+2g_{r}=2g \left(L+(1-g)\frac{g_{L}^{2}}{2(2-gL)}\right)
\end{align*}
\]

where:

\[
\psi = \frac{\tau^*+\tau}{\lambda(\tau^*+1)}
\]

Fig. 10-13 shows that when the interregional transport cost is sufficiently high it becomes more expensive to import manufacturing goods from one region to another, leading to a higher regional price index and thus to a lower demand for home goods. In addition, with the presence of higher commuting costs, firms bear a higher production cost due to the wages they pay to compensate workers for their commuting costs. These costs act as barriers to entry for new firms, leading to an increase in regional prices and a decrease in demand for manufacturing goods, which leads to a decrease in urban growth.
If the interregional transportation cost is intermediate (τ = 1.3), given the presence of higher commuting cost (γ = 0.6), the industrial location in each urban zone becomes less attractive. The congestion cost discourages the free entry of new firms, inducing higher prices and lower demand for manufacturing goods. Consequently, urban residents become more sensitive to higher levels of congestion, but less sensitive to the availability of manufacturing goods produced locally and imported at lower cost from the other MA. Thus, workers will be
interested in the consumption of more agricultural products and housing space by relocating in the rural zone, implying a dramatic decrease in the urban growth.

When the interregional transportation cost is sufficiently low \((1 \leq \lambda < 1.3)\), and independent from the level of commuting cost (Fig. 10-13), then firms tend to agglomerate in each urban zone, leading to an increase in the urban growth. In fact, workers become less sensitive to the higher levels of urban costs, but more sensitive to the availability of manufacturing goods at lower cost. It is important to note that the manufacturing share plays a significant role in the intensity of this urban growth.

In order to study the question of stability for the symmetric equilibrium (Appendix 3), we apply a method of linearizing a system of differential equations (profit and number of firms) to an equilibrium point. When differentiating \(\eta\) by taking into account the symmetric configuration and the free-entry condition, we find the following expressions:

\[
\frac{d q}{d n_1} = \frac{A_2 B_2 + A_1 B_2}{A_1 A_2 A_2} \quad \frac{d q}{d n_1} = \frac{A_2 B_2 + A_1 B_2}{A_1 A_2 A_2}
\]

Such that \(\beta_k q_k > 0\), \(d \pi_k / d n\) has the same sign as \(d q / d n\). To be stable, it follows that \(d q / d n < 0\) and \(d q / d n > 0\), then,

\[
\frac{A_2 B_2 + A_1 B_2}{A_1 A_2 A_2} < 0 \quad \text{and} \quad \frac{A_2 B_2 + A_1 B_2}{A_1 A_2 A_2} > 0
\]

Some numerical simulations are conducted to determine the equilibrium stability. When the interregional transportation cost takes an intermediate value, the symmetric equilibrium is considered stable. However, it becomes unstable when the interregional transport cost is sufficiently low. Two additional cases whereby symmetric equilibrium can be stable are: (i) when the intraregional transport cost is sufficiently low \((\gamma = 0)\); and (ii) when both intraregional and inter-TC are sufficiently high.

5 Spending on transport infrastructure and welfare implications

The main objective in this section is to determine the welfare implications of public spending on transportation infrastructure at the regional and interregional levels. We suppose that all manufacturing activities are concentrated in the MA of Jeddah. The welfare level can be derived using the indirect utility level and given by the following equation:

\[
V = (1-g) \left[1+\frac{\gamma^2}{2(2-\gamma)} \left(\frac{4-\gamma A}{4+\gamma A} \right) \left(1-\gamma A \right) \right]^{1-\sigma} \left[1+\frac{4\gamma^2}{(2-\gamma)(2+\gamma A)} \right]^{\sigma-1} \]

(29)
Equation (29) shows that in the case of asymmetric equilibrium (Jeddah/Taif), the welfare level depends on the geographic distribution of urban residents ($A$) as well as the public spending on domestic infrastructure ($G$) and the applied tax rate ($\tau$). It should be noted that only the agricultural sector continues to exist in Taif. Consequently, the household welfare level will not depend on the quality of interregional transportation infrastructure between Jeddah and Taif.

When the Saudi regional policy is focused to improve the domestic quality of transportation infrastructure in Jeddah, which consists of decreasing commuting costs, the welfare level in this region will decrease. This result can be attributed to the lower wages that manufacturing firms will pay due to the significant decrease in this commuting cost, and to the tax rate that workers must pay to finance this public expenditure, leading to a significant decrease in their incomes. Indeed, these two effects will reduce the indirect utility of workers. In the light of this result, it will be socially inefficient for the Saudi government to apply a tax rate on regional incomes to finance the provision of domestic infrastructure in Saudi MAs. However, the Saudi government can choose other options like Public-Private Partnership (PPP) to enhance the quality of domestic infrastructure in Jeddah.

In the symmetric equilibrium, all the economic activities are distributed equally between the MAs of Makkah and Medina that have almost the same socioeconomic characteristics; in other words, we suppose that both sectors still exist in both regions. The indirect utility level is given by the following equation:

$$V=(1-g)(1+\frac{\gamma^2}{2(2-2\gamma)})(\frac{\lambda(4-\gamma+2\rho \gamma)-4g}{4\sigma})(\frac{2\beta \sigma}{(\sigma-1)(2-\gamma)})^{-\sigma}(1+\tau^{-\sigma})^{-\mu(1-\sigma)}$$

If public expenditure invests more to enhance the interregional transportation infrastructure between Makkah and Medina, mainly to improve the quality of transportation networks devoted to freight (e.g. railroads, highways and airports), then the direct effect will be positive on the household welfare regardless the tax rate. In fact, this result can be explained by two opposite effects. Firstly, every change in the quality of interregional transportation infrastructure is able to decrease the prices of manufacturing goods traded between both regions, leading to an increase in the real wage rate of workers and therefore in the demand of goods. Secondly, workers will face higher tax on their wages, consequently leading to decreased final demand for goods. Despite the negative effect of applying a tax rate on
regional incomes, it appears that the net effect of this public policy is positive on household welfare. This result is very important for policy makers and the Saudi government, because it can justify any interregional public policy consisting to improve the quality of transportation infrastructure between these MAs. From a welfare point of view, there is no problem to apply a tax rate on the regional incomes to finance this public expenditure. Contrary to Tabuchi (1998), the dispersion equilibrium (Makkah/Medina) is better than the concentration equilibrium (Jeddah/Taif) from a welfare point of view.

6 Conclusions and recommendations

This paper used a mixed general equilibrium model of new economic geography and urban economics in order to investigate the impacts of public spending on transport infrastructure on urban growth and household welfare, considering the existence of two kinds of transportation costs: intraregional and interregional. The first type of transport cost is directly related to the urban costs (e.g. commuting cost and land rents), while the second is related to the trade of manufacturing goods between different regions. In the context of KSA, two pairs of MAs were chosen: Makkah and Medina for the dispersion equilibrium, and Jeddah and Taif for the concentration equilibrium.

In the short-run equilibrium, results showed that the full concentration of economic activities in the MA of Jeddah occurs when both interregional and intraregional costs become sufficiently low. Consequently, the MA of Taif can lose all manufacturing activities in favor of the MA of Jeddah, thereby leading to a higher urban growth and more spatial inequalities. However, in the long-run equilibrium, there is an interesting opportunity to see some manufacturing activities relocating from the MA of Jeddah to the MA of Taif due to higher intraregional transportation costs in the former. For more balanced regions, the Saudi government may invest more in the quality of domestic transportation infrastructure inside the MA of Taif. In fact, any investment on the only interregional transport infrastructure between Jeddah and Taif without any improvement of the quality of infrastructure in Taif will increase the interregional disparities.

From a welfare point of view, the main finding was related to the fact that the household welfare will be higher in the dispersion state (Makkah/Medina) than in the agglomeration state (Jeddah/Taif) when the regional public policy is focused on the improvement of the interregional transportation infrastructure. However, a public expenditure whose goal is improving the quality of intraregional infrastructure can decrease the household welfare in both concentration and dispersion equilibriums. In other words, residents in Jeddah, Makkah, Medina and Taif MAs will not profit from this policy if the expenditure is financed exclusively by regional taxes. Like Martin and Rogers (1995), this model suggests that if the improvement of domestic infrastructure could be financed by a third party (e.g. another region or the private sector), the negative effect on regional incomes would be null; thus, long-term household welfare would be improved without incurring direct costs.
APPENDIX
Appendix 1

Asymmetric stability

In region 1, we have the following equations at equilibrium:

\[ w_1 = \frac{2}{2 - \gamma \lambda L_t} \]
\[ p_1 = \frac{\sigma}{(\sigma-1)} \beta \lambda L_t \]
\[ E_{4,0} = (1-g)(1+F_1/L_t) \]
\[ F_1 = (1-g) \frac{\lambda L_t^2}{2(2 - \gamma \lambda L_t)} \]
\[ n_1 = \frac{\lambda L_t^2(4 - \gamma \lambda L_t + 2g_\gamma \gamma_1) - 4g_\gamma}{4\sigma} \]
\[ q_1 = q_1 = \frac{\mu L_t E_{4,0} P_2^\sigma}{n_1 (\tau p_1)^\sigma} + \frac{\mu L_t E_{4,0} (\tau p_1)^\sigma}{n_1 (\tau p_1)^\sigma} \]

By replacing \( E_{4,0} \) and \( E_{2,0} \), we find:

\[ q_1 = \frac{\mu (1-g)(L_t + F_1) + \mu L_t (1-g)}{n_1 \tau p_1} \]

By replacing \( F_1, p_1, n_1 \) and \( w_1 \), we find the total demand for manufacturing goods in region 1:

\[ q_1 = \frac{\mu (1-g)(L_t + (1-g) \frac{\gamma_1 (\lambda L_t)^2}{2(2 - \gamma \lambda L_t)} + L_t)}{2\beta\sigma \lambda (2 - \gamma \lambda L_t) (4 - \gamma \lambda L_t + 2g_\gamma \gamma_1) - 4g_\gamma} \]

In region 2, we have the following equations at equilibrium:

\[ w_2 = 1 \]

\[ p_2 = \frac{\sigma}{(\sigma-1)} \beta \]
\[ E_{2,0} = (1-g) \]
\[ q_2 = \frac{\mu L_t E_{2,0} P_2^\sigma}{n_1 (\tau p_1)^\sigma} + \frac{\mu L_t E_{2,0} (\tau p_1)^\sigma}{n_1 (\tau p_1)^\sigma} \]

By replacing \( E_{4,0} \) and \( E_{2,0} \), we get:

\[ q_2 = \frac{\mu L_t (1-g) P_2^\sigma + \mu (1-g)(L_t + F_1)(\tau p_1)^\sigma}{n_1 (\tau p_1)^\sigma} \]

By replacing \( F_1, n_1, p_1, p_2 \) and \( w_2 \), we find this final expression for total manufacturing demand:

\[ q_2 = \frac{\mu (1-g)(L_t + (1-g) \frac{\gamma_1 (\lambda L_t)^2}{2(2 - \gamma \lambda L_t)} + L_t)}{2\beta\sigma \lambda (2 - \gamma \lambda L_t) (4 - \gamma \lambda L_t + 2g_\gamma \gamma_1) - 4g_\gamma} \]

Finally, we find the profitability expression:

\[ \frac{q_2}{q_1} = \left( \frac{L_t + (L_t + \Omega) \tau^{-2\sigma}}{2(2 - \gamma \lambda L_t)} \right)^\gamma \]

with

\[ \Omega = (1-g) \frac{\gamma_1 (\lambda L_t)^2}{2(2 - \gamma \lambda L_t)} \]
Appendix 2

The asymmetric stability without regional taxes

Fig. 14. Asymmetric stability with higher intra transport cost in the MA of Jeddah

Fig. 15. Asymmetric stability with lower intra transport cost in the MA of Jeddah

Table 5. Parameter values for the asymmetric stability

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References


سياسات النقل العام و النمو الحضري في المملكة العربية السعودية:

دروس من نموذج التوازن العام

تكرى شجعان أبا العلا
وليد عبدالوهاب شطي

المستخلص: في أواخر القرن العشرين شهدت المملكة العربية السعودية تحولا سريعا من مجتمع بديوي إلى مجتمع حضري متطور. وقد أثارت هذه النقلة السريعة العديد من التحديات الاجتماعية والاقتصادية والديموغرافية، بما فيها النمو الحضري والفوارق الجهوية. تحاول هذه الورقة البحثية تقييم بعض هذه التحديات باستخدام نموذج تطبيقي من الاقتصاد الحضري والجغرافيا الاقتصادية الجديدة لدراسة آثار سياسات النقل الجهوية على النمو الحضري ورفاهية المواطنين. ومع الأخذ بعين الاعتبار التكاليف الحضرية أوجدت المحاكاة الرقمية نتائج رائعة: (1) يمكن استخدام سياسات النقل العام كأداة استراتيجية للتخطيط الجهوي، (2) يكون التوزيع العادل في الأنشطة الاقتصادية على المستوى الجهوي أفضل من تمركزها المفرط لأجل مزيد من رفاهية المواطنين.

الكلمات المفتاحية: المملكة العربية السعودية, النمو الحضري, النقل, السياسات الحكومية, الرفاهية