The Potential Economic Impacts of the Proposed Development Corridor in Egypt: An Interregional CGE Model

Author: Dina N. Elshahawany

PhD Student, Economic Department, Faculty of Commerce, Zagazig University, P.O Box 44519 Zagazig, Sharkia, Egypt. Research Student, Center for Urban Policy Research, EJB School of Planning and Public Policy, Rutgers University, New Brunswick, NJ 08901-1982, USA, (732)318-7562, dina.elshahawany@rutgers.edu, dina_elshahawany@hotmail.com.

Sponsor: Michael L. Lahr

Research Professor, Rutgers Economic Advisory Service (R/ECON™), Edward J. Bloustein School of Planning & Public Policy, Rutgers, The State University of New Jersey, 33 Livingston Avenue, New Brunswick, NJ 08901-1982, (848) 932-2372, lahr@rutgers.edu

Abstract

Egypt has proposed a new development corridor. A main component is a desert-based expansion of the current highway network. This network is founded on a 1200-kilometer north-south route that starts at a proposed new port near El-Alemein and runs parallel to the Nile Valley to the border of Sudan. It also includes 21 east-west branches that connect the main axis to densely populated cities on the Nile. The paper is a first attempt at an economic assessment of the impact of this proposed corridor. It uses an interregional computable general equilibrium (CGE) model developed and reported in a prior paper. Here, that model is integrated for the first time with a stylized geo-coded transportation network model to help quantify the spatial effects of transportation cost change due specifically to the efficiencies induced by the corridor. The paper focuses on the likely structural economic impacts that such a large investment in transportation could enable through a series of simulations, including some sensitivity analyses of the model's strongest assumptions.

1. Introduction

Even before civilizations arose, the Nile served as a mechanism to transport people, news, and products. It has also enabled better mobilization of armies and tax collections—key aspects of a unified, sustainable state. Similarly, Greek, Roman, and Arab empires assured the ease and security of travel within the boundaries of their vast territories (El-Baz, 2007). More recently, transportation access assisted development in Europe and the Americas, leading to the rise of Western Civilization (Bairoch 1988). It is also clear that superb transportation systems allowed the United States to better utilize its vast natural resources to reach its present position of prominence (Glaab and Brown, 1967).

Currently, Egypt's population is confined to a fine strip of arable land along the Nile River: deserts account for 96% of Egyptian land. Its deserts represent a national wealth that should be used to benefit future generations. The western desert hides energy sources, underground water, and vast spaces for settlement. To alleviate overcrowding and chronic urban problems, it is necessary to move into the deserts, and there to implement some urban development projects that use available local resources.

The transportation is important for enabling economic development. It provides market accessibility by linking producers and consumers. An efficient transport system with modern infrastructure favors many economic changes, most of them positive. Transportation networks are the circulatory systems through which economic and social activities flow. All sectors of an economy depend on the services and facilities of this sector to link supply to demand, thereby enabling markets. They give access to raw materials, services, and factory loading docks.

Economic opportunities are enabled through the mobility of people, goods, and information. A relation between the quantity and quality of transport infrastructure and the level of economic development is apparent. High density transport infrastructure and highly connected networks are commonly associated with high levels of development. When transport systems are efficient, they provide economic and social opportunities and benefits that result in positive multipliers effects such as better accessibility to markets, employment and additional investments. When transport systems are deficient in terms of capacity or reliability, they can have an economic cost such as reduced or missed opportunities and lower quality of life (Rodrigue et.al, 2009).

Investments in transportation infrastructure allow efficiencies, which in turn permit regional and national economic growth. They reduce firms' transaction costs and thereby expand the economic opportunities in a region/country. In this way, such investments can potentially help increase incomes and standards of living for resident populations (Haddad et.al, 2011).

Transportation cost plays a significant role not only in forming urban hierarchies, but also in forming the shapes of traditional cities. The spatial organization of land uses determines the plan and characteristics of transport networks and at the same time transport route determine land uses. Decreased commuting costs flatten the population density and land-rent gradients for housing. Reduced commuting costs result in a larger periurban area. If the cost of commuting were zero, the population, employment, and land rent would be uniformly distributed (Edwards, 2007).

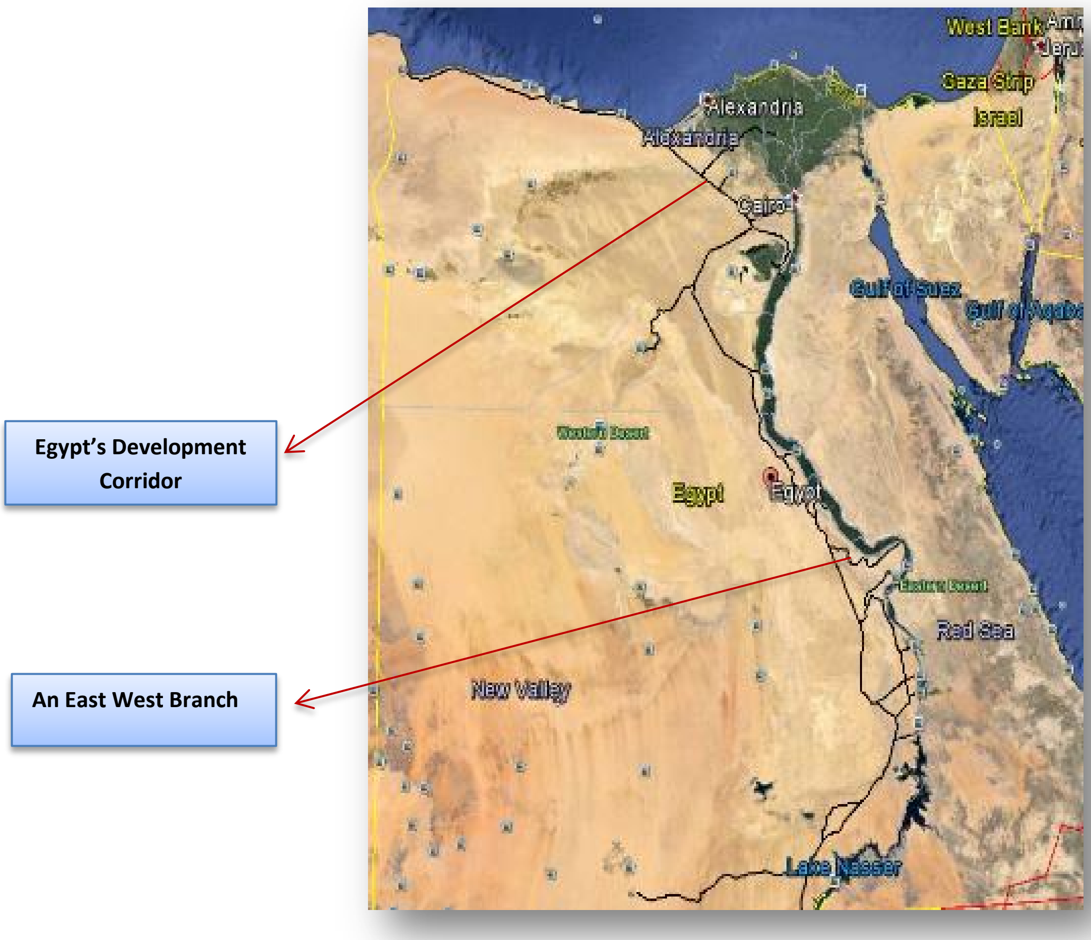
Egypt has 23,619 kilometers of roads—from single lane “dirt” roads, to two-way surfaced streets, to multi-lane highways. Car ownership is rising rapidly in Egypt. Plus Egypt's roads carry the lion’s share of freight–53% of the total. Logistics providers in Egypt have expressed a need for a more consistent distribution infrastructure, as there remains a severe lack of services around road-based transportation. That is, accessibility varies tremendously across Egyptian regions. Thus, interregional transportation infrastructure is often lacking to link small centers to large urban areas. This lack disables efficient location decisions. Consequently, while the road network is important to Egypt's economy, the country could stand more road investment, particularly in its underdeveloped south. In any case, it is clear that highway expansion and improved freight corridors will be vital in relieving congestion and boosting economic development.

A major highway investment proposal is the “Development Corridor.” The Corridor, proposed by Farouk El-Baz (2007) of Boston University, was conceived to provide solutions to numerous problems that Egypt faces. While facilitating transportation, it was designed to limit urban encroachment into the nation's prime agricultural lands along the Nile and to encourage the deconcentration of congested, overpopulated areas. Meanwhile, it opens up vast areas for industrial zones, trade centers and other developments. It is one of the most promising proposals to date, if not the best, for opening up use of the western desert.

The corridor approach to development uses transport corridors as a backbone or spatial focus for regional cooperation projects and activities (Srivastave, 2013). The idea behind the approach is to cluster such activities along corridors or at nodal centers on the corridors, where certain agglomeration economies naturally arise and are hopefully nurtured. Such agglomerations are expected to facilitate growth in surrounding areas by catalyzing further investment from both within and outside of the region. The spatial focus can also facilitate prioritization of regional projects, and coordination of national projects among neighboring countries. The corridor development approach is thus potentially a very practical way to get the most from limited government resources available for regional development projects.

A main component of the Corridor in Egypt is a super highway network in the western desert. It is to consist of a 1,200 km of eight-lane highway in a north-south direction with 21 east-west spurs that connect the main highway to densely populated river cities along its path. Parallel to it are included a railway to enable low-cost transport of people and products, a pipeline to supply fresh water to corridor developments, and a grid-connected electricity transmission line that could eventually supply energy from desert-based solar farms.

Figure 1: Egypt’s Development Corridor.



Continued development of a modern network of transportation systems within the confines of the Nile Valley and its Delta would reduce agricultural land. The fertile soil within the inhabited strip of Egypt has been deposited by the Nile River over millions of year; it is a very limited and irreplaceable resource that facilitates national food security. In the meantime, the country's pace of population expansion counteracts its ability to live on just that narrow green strip, which represents 5% of its land. If we must grow, it is imperative that we expand outside of the inhabited strip. The Corridor a solution these numerous problems (El-Baz, 2011).

The paper develops a framework for analyzing the economic analysis of the highway network of the proposed Development Corridor for Egypt. The analysis is based on the multiregional computable general equilibrium model (MCGE) model for Egypt's economy that was developed by Haddad et al., (2015). An important feature of our MCGE model is its ability to explicit estimate costs of moving products based on origin-destination pairs according to transportation margins. That is, the model accounts for the specific cost structure of the flow of each traded commodity. This paper innovates, by physically constrained that structure by the available transportation network, which is modeled in a stylized geo-coded transportation module. We examine the trade flows with and without the proposed Development Corridor. The model's integration with a GIS network helps quantify the spatial effects of transportation cost change. Moreover it enables us to explicit model commodity-based transportation costs within the MCGE model, which are based on origin-destination flows. Thus, the model intrinsically accounts for the spatial structure of the Egyptian economy. That is, inclusion of the transportation network within the MCGE augments the general model framework for understanding the equilibrating role of transportation (and hence transportation investments) in regional economic development.

The transport module measures minimum travel times between regions using actual road routes. The MCGE model estimates the long-run spatial spread of national Gross Domestic Production (GDP) (and/or other measures of economic activity) caused by expected changes in regional economic activity. Combined it is possible to examine the spatial effects of transportation cost reductions in Egypt induced by transportation infrastructure improvements. We adopt a cost-competitiveness approach that reviews possible relative changes in the regional costs and on different demand structures.

2. Literature Review

Public agencies are increasingly under fire to justify major spending items. Proposed transportation projects are no exception, and demonstrations of the magnitude of expected consequent economic development impacts are typically employed to justify them. Indeed, such cost/benefit analysis, which include economic impact statements, are often used to compare the relative potential economic development effects of spending alternatives. They are thus often used to support planning design decisions and/or investment decisions. In most cases, the focus of economic impact studies is on estimating how projects are likely to affect economic development of the specific populations or regions within which they are placed. A wide range of methods have been deployed to measure economic impacts. There are qualitative surveys, detailed market studies, and comprehensive economic simulation models to list just a few. The primary economic assessment methods considered include: Social Cost Benefit Analysis (SCBA), Input-Output Analysis (I-O), and Computable General Equilibrium (CGE). SCBA is most effective for determining the value of project objectives and outcomes from a social welfare perspective. I-O and CGE take macroeconomic perspectives of system wide effects of transport investment including employment, GDP, and taxes (Wallis, 2009). In many cases, the analysis compares a no-build or base case scenario to one or more transportation investment scenarios. Examinations of such impacts often cover the expected life cycle of the investment, which can be 30 or more years. Some even assume the infrastructure costs and benefits are elicited in perpetuity.

If the stream of national and regional economics literature is a reasonable measure, infrastructure continues to play a strong role in development. A number of alternative approaches appear. Martin and Helpman and Krugman (1985) and Vickerman (1990) present an extensive collection of papers addressing the relationship between infrastructure and regional economic development. Rogers (1995) show infrastructure plays a key role in industry location. More recent literature explores the role of government transportation-investment initiatives as a major means of reducing inter-regional disparities (World Bank, 2008).

During the last 20 years, applied computable general equilibrium (CGE) models have become standard tools of quantitative policy assessment. Their appeal is built on their rigorous grounding in economic theory: individual agent's decision-making behaviors are derived from explicit optimization under strictly specified technological or budget constraints, given markets signals that ensure global consistency. These theoretical foundations have made CGE models appear particularly useful for *ex ante* evaluations of policy reforms (De Palma et al., 2011).

The initial research linking CGE models to transportation networks—so-called spatial CGE models--was Roson's (1994), which was followed by Bröcker (1998a) and Bröcker and Schneider (2002). Buckley (1992) earlier considered the impacts of transportation systems on the spatial economy, but he did not represent transportation costs via a network. Kim and Hewings (2003) and Kim et al. (2004) have explored ways in which a multiregional CGE model could be linked with a transportation network model to examine the welfare implications of a massive highway construction program in South Korea (World Bank, 2008).

The advantage of a general equilibrium approach is that it treats an economy as a system of many interrelated markets in which the equilibrium of all variables must be determined simultaneously. Any perturbation to the economic environment can be re-evaluated through the new set of endogenous variables values in the economy (Haddad, 2009).

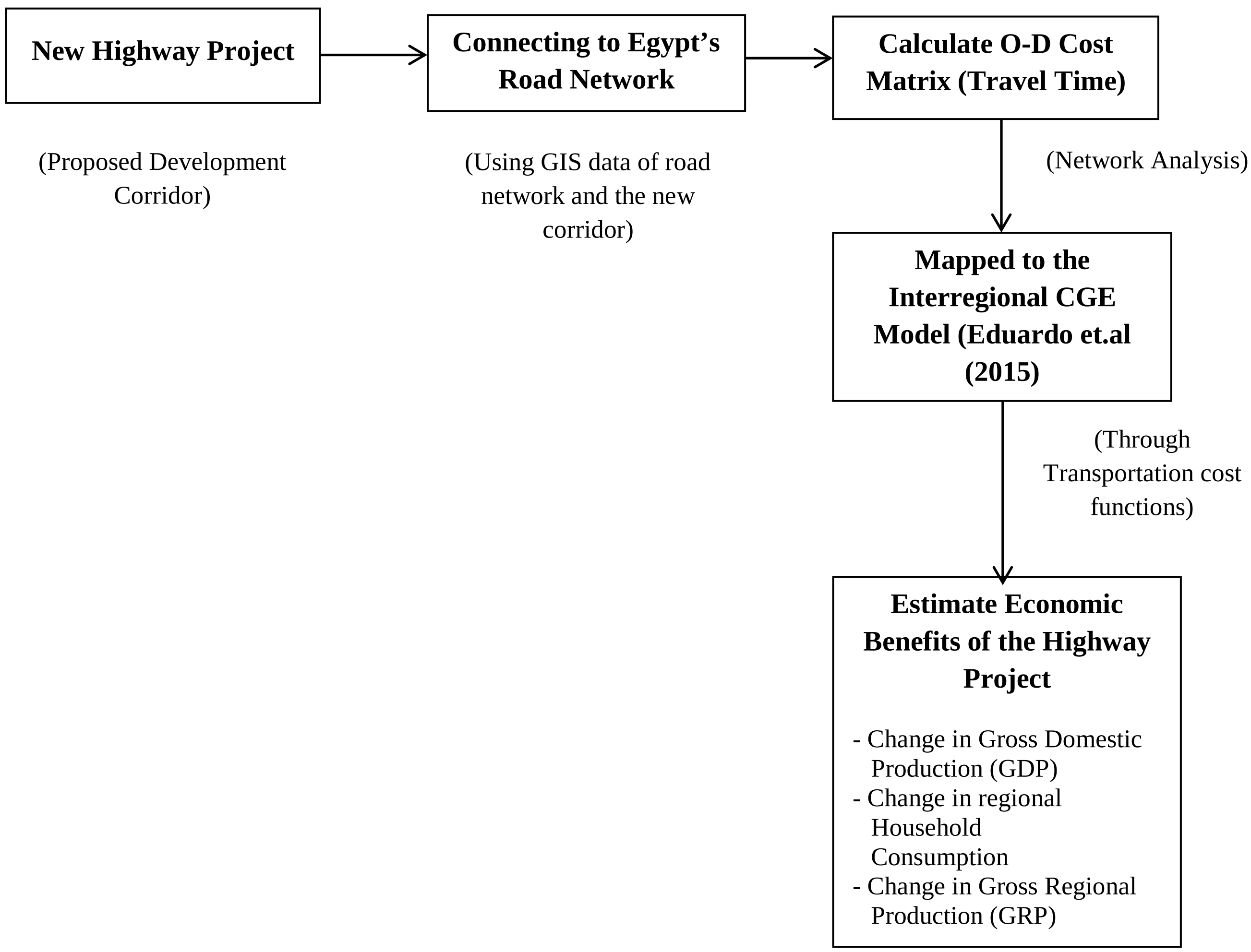
The CGE model is a model that can estimate likely changes in jobs, income, value added and output by industry, given some stimulus. When made multiregional it has a spatial component through which transportation costs affect trade by commodity or industry across regions. As a spatial CGE, the multiregional aspect tracks transportation connections to re-estimate travel times based on road capacities and concordant speeds (based on trip-generation intensities) to estimate trade among regions. Thus spatial CGE model estimates the economic impact of transportation projects and policies through a process that first calculate the impacts on interregional freight transport cost, effective labor supply, value of capital stock and overall factor productivity. This can include effects of changing travel time, congestion levels, reliability, accident rates (and hence, potentially the value of injuries, lost work time, and lives lost), and operating costs (NCFRP, 2011). As a result, spatial CGE models are notable for estimating impacts of proposed projects on business activity levels and interregional trade (freight shipment) patterns both by industry and by region.

But MCGE models also can examine changes in income per capita and interregional economic disparities attendant to infrastructure projects or programs. In this vein, findings from Kim and Hewings (2002, 2003), who made an initial attempts to link a transportation network model with a spatial CGE model, are encouraging for regional planners. Haddad and Hewings (2005), who also use a spatial CGE model, explore how economies of scale and transportation combine to affect national and regional social welfare impacts and find they are much more sensitive to changes in transportation costs than are standard measures of economic activity like jobs, wages and salaries, and GDP.

Kim and Hewings (2003) and Kim et al. (2004) follow a somewhat different line of argument for identifying regional impacts of transport infrastructure improvements. Perhaps unrealistically, they let firms use transport infrastructure as a production input that is provided for free. The level of service of the transport infrastructure is measured a Harris-type potential indicator of accessibility. Interestingly, the authors find a positive network effect of infrastructure policy, meaning that the welfare gain of an entire network of new projects exceeds the sum of the effects, if all projects are evaluated separately.

Sakamoto (2012) develops a spatial interregional CGE (ICGE) model to analyze the influence on a regional economy of a reduction in the transportation cost. The study analyzes the economic effect on surrounding regions of the cost reduction caused by the logistics policies instituted by Northern Kyushu. He shows that the policies have a net positive effect, including an increase in the number of establishments in the Northern Kyushu. He further shows that the positive effects spillover to the neighboring regions as well. In short the robustness and strength of the simulation results suggest that authorities should introduce such cost-reducing policies as soon as possible so the regions can exploit and enjoy the stream of generous benefits early and often.

Figure 2: Study Framework



3. Overview of the ICGE Model[1]

We use an MCGE model for Egypt.[2] Drawing on recent experience reported in Haddad (2014a,b) in the development of an ICGE model for Lebanon under

[1] This section draws on Haddad et al. (2015).

conditions of limited information, Haddad et al. (2015) developed the interregional structure of the Egyptian model used in this paper.[3] Incorporating the ability to model transportation costs changes that explicitly affect interregional relationships enables investigations into important issues related to integrated regional systems. The model developed in this paper is designed for analyzing policies related to changes in Egypt's existing transportation infrastructure.

The model has R endogenous regions, $r = 1, ..., R$, and one exogenous region (the rest of the world), *ROW*, that exhaust Egypt's space economy. Economic interactions take place inside (intraregional trade) and outside the endogenous regions (interregional and international trade). The regional setting of the model recognizes the economies of R = 27 Egyptian governorates (*mohaafazaat*).

Agents' behavior is modeled at the regional level, accommodating variations in the structure of regional economies. An important feature of the model is the detailed treatment of interregional trade flows in the Egyptian economy, in which interregional commodity flows are fully specified by origin and destination. The building blocks of the "structural" components of the ICGE model are very standard in their specifications.[4] Results are based on a bottom-up approach—i.e., national results are aggregates (sums) of the individual regional results. The model identifies nine production/investment sectors in each region producing nine

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[2] To our knowledge, this is the first fully operational ICGE for Egypt.
[3] See also Peter et al. (1996), Haddad (1999), and Haddad and Hewings (2005).
[4] Peter et al. (1996) and Haddad (1999).

commodities (Table 1), one representative household in each region, one government in each region, and a single foreign area that trades with each domestic region.[5] Each industry uses two local primary factors (capital and labor) to produce along with regional material endowments. Special groups of equations define capital accumulation relations.

The model is structurally calibrated for 2011. A rather complete data set for Egypt is available for 2011—the year of the national input-output accounts used to the estimate of the multiregional input-output database. Additional structural data for 2007-2011 complement that database.

Table 1. Sectors/products in the MCGE Model

1. Agriculture, forestry and fishing
2. Mining and quarrying
3. Manufacturing
4. Electricity, gas, steam and air conditioning supply
5. Construction
6. Wholesale and retail trade; repair of motor vehicles and motorcycles
7. Transportation and storage
8. Other services
9. Public services

The model is a Johansen-type model. That is, solutions are obtained by solving the system of linearized equations of the model following Australian traditions. A typical result shows the percentage change in the set of endogenous variables,

[5] The domination in Egypt of Mediterranean ports makes the latter a fairly realistic assumption.

after a policy is carried out, compared to their values in the absence of such policy, in a given environment. The schematic presentation of Johansen solutions for such models is standard in the literature. More details can be found in Dixon and Parmenter (1996).

To capture the effects of the new corridor in its operational phase, the simulations are carried out using a long-run closure. The model has no dynamic attributes. Thus, any simulations run using the MCGE model capture the effects associated with a static impact-effect question, i.e., given the structure of the economy, what-if questions are addressed in a comparative-static framework. Short- and long-run considerations differ in the way the equilibrating mechanisms are set through specified closure rules. Structural changes are captured *only* by evaluating the re-allocation of resources.

Policy changes can affect the capital stock in the long run. Interregional mobility assumptions for capital and labor are flexible. A steady-state-type of solution is achieved in which regional "natural" unemployment rates and regional aggregate rates of return are reestablished (they do not change). Moreover, the equilibrium for the balance of payment is reflected in the hypothesis of fixed share of trade balance in GDP. Also the government deficit is set exogenously, so that government expenditures can change. In the model's treatment of savings and investment, the long-run closure is similar to that of the Johansen school (Dixon and Rimmer, 2002). It assumes independent determination of investment (functions relating investment to rates in return), and the deficit is identified as the gap between domestic investment and savings.

In the long run, industry and household “re-location” becomes relevant; as factors of production are free to move among the regions. Thus investment decisions define the marginal re-location of activities, guiding the spatial distribution of capital stocks and population. Thus main differences from the short run are encountered in labor and capital markets (naturally enough, land remains immobile). In the first case, aggregate employment is determined by population change, labor force participation rates, and the “natural” unemployment rate (the unemployment rate at the start of the simulation). The distribution of labor across regions and sectors is subsequently endogenously determined. Labor is attracted to more competitive industries and regions. In essence, population movements keep overall household utility differentials constant. Similarly, capital is pulled towards more-profitable industries, which causes interregional rates of return to converge.

3. The Network Analysis

A main feature of the model used in this paper is the manner in which we have integrated a geo-coded transportation network for Egypt with the MCGE model. Thus, if one wants to simulate changes in the network, which might affect relative accessibility (e.g., the Corridor), a transportation cost matrix can be calculated *ex ante* and *ex post*, and mapped to the MCGE model through transportation cost functions. This mapping includes two stages—one for model calibration and another for the simulations.[6]

A detailed national-level GIS road network data was generously provided by the Egyptian Central Agency for Public Mobilization and Statistics (CAPMAS). We merged this database with information on specific technical road attributes, particularly important was an estimate of the maximum speed of each road in the network so that, when combined with road length information, we could estimate travel times of every single road and, hence, network link and path. In addition, we obtained GIS data for the highway aspect of the Development Corridor and with a bit of effort and consternation connected it to the network (see Figure 3). We next calculated the Corridor's effect on the travel times among regions.[7] We then recorded the minimum impedance paths in hours among the prime cities of Egypt's governorates. Figure 4 shows aggregate time savings by governorate. That is it reflects the percentage reduction in travel time that the Corridor effects on the average accessibility of a governorate to the people and goods of all other governorates. The change in the travel-time matrix from before the Corridor is connected to after it is connected to Egypt's road network is the basis for integrating the transport model to the multiregional CGE model.

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[6] Details can be found in Haddad et al. (2015)

[7] We used the origin-destination (O-D) cost matrix function within ArcGIS's Network Analyst software extension.

Figure 3: Egypt's Transportation Network after Connecting the Proposed Corridor.

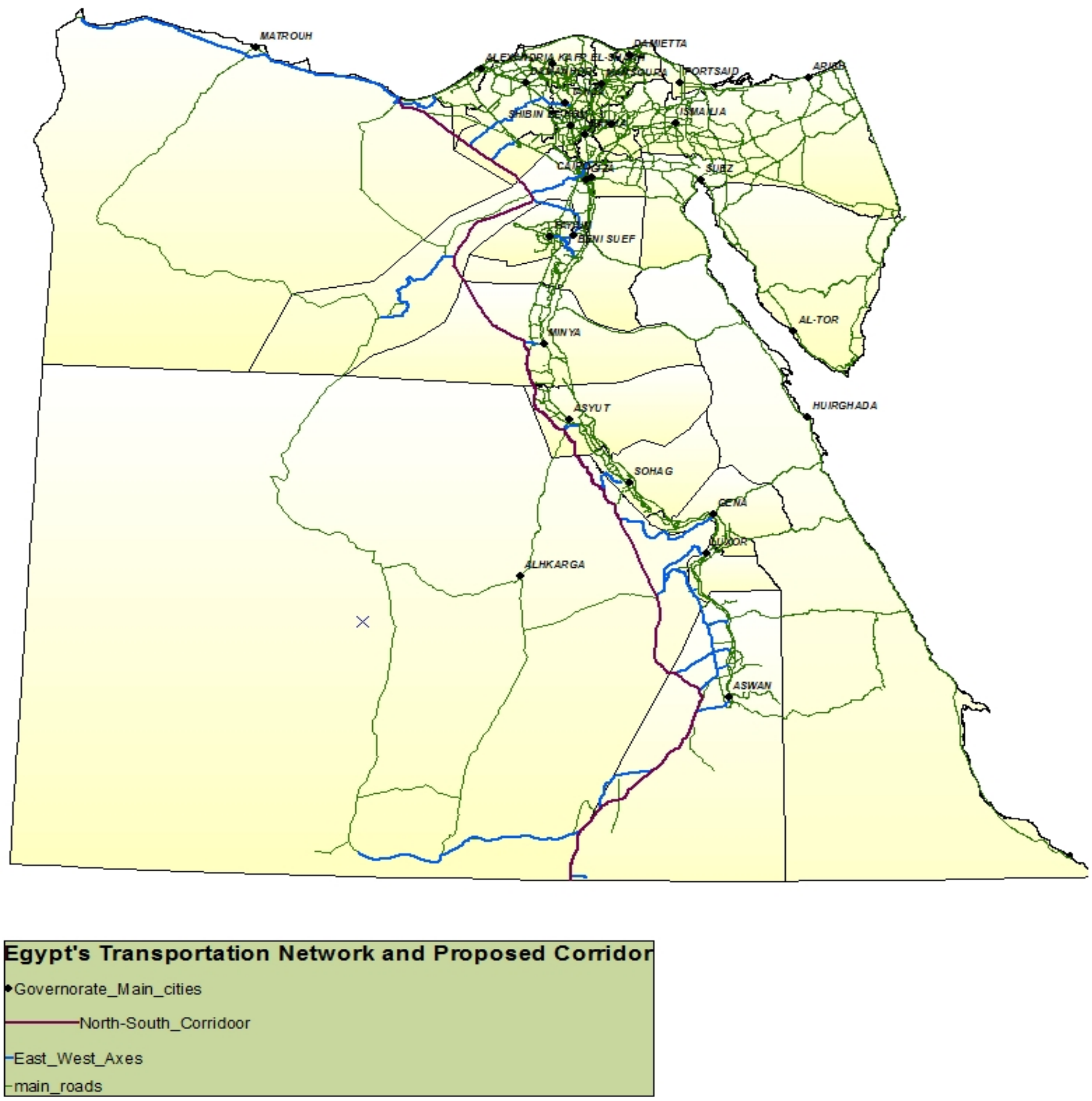
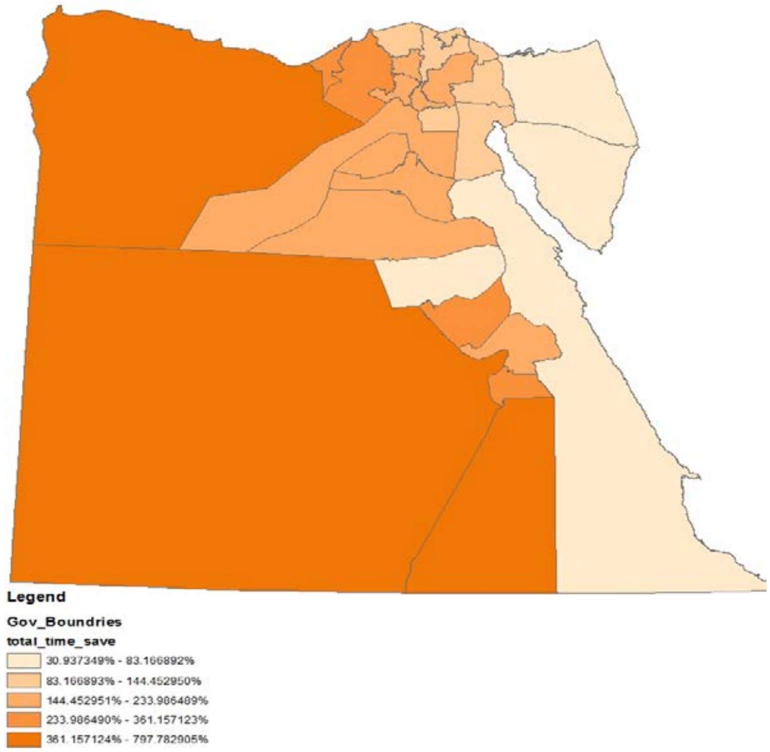


Figure 4: Total Travel Time (percentage change) due to the corridor.



4. Integration of the MCGE and the Transportation Network Module

Recall that a main goal of the research reported here is to develop a framework that enables assessments of the socio-economic impacts of domestic integration policies in Egypt. Following Haddad and Hewings (2005), we next integrate the afore-discussed geo-coded transportation network with the pre-existing MCGE model for Egypt. This enables us to simulate changes in the network, which have the potential to affect relative accessibility (e.g. road improvements, investments in new highways, etc.), which triggers estimation of a new transportation cost matrix, which in turn is mapped to the MCGE model through transportation cost functions to alter commutation and freight transport patterns and, thereby, interregional flows of commodities and labor income. This mapping includes two stages—calibration and simulation.

As alluded to earlier, in integrating the network and MCGE models we assumed that the locus of production and consumption in each governorate is its capital; moreover, for tractability we assumed international trade transpires only through Alexandria. Thus, travel times associated with the flows of commodities from points of production (or port of entry) to points of consumption (or port of exit) are, again for the sake of model tractability, restricted to a matrix of travel times among Egypt's governorate capitals. Moreover, to account for *intra*-regional transportation costs, we let trade within each governorate take place at a "distance" that is time-wise half that to the one other capital city that is most readily accessed. The transportation module then calculates the minimum interregional (path) times, considering the road network as connected.[8] Travel times are then associated via a gravity model formulation to the transportation costs implicit in the transactions of the MCGE social accounting matrix and tariff functions using data on general cargo prices (for domestic trade flows) and

[8] According to the Ministry of Transport of Egypt, 94% of the nation's freight is transported by road (http://www.comcec.org/).

container prices (for international trade flows) based on survey work by Felkner et al. (2012).

5. Economic Impacts of the Proposed Development Corridor

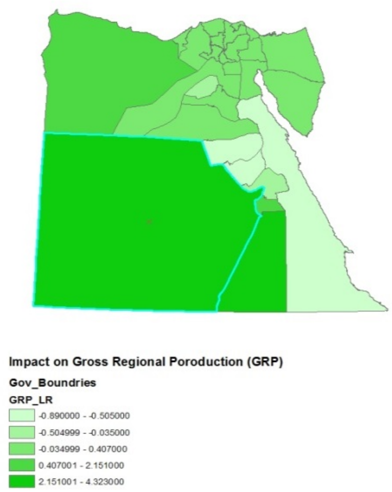
We used the MCGE model to estimate the long-run impacts of the project on both national and regional variables. We would examine short-run impacts for the investment/construction phase of the project, which is being ignored in the present paper. The main results are discussed below.

National results: Table 2 presents simulation results for national aggregates in the long run. When growth in gross domestic production (GDP) is positive, efficiency gains are realized from the Corridor. GDP is positive for Real Household Consumption, Real Government Expenditures, international exports, and international imports. However the Corridor's impact on aggregate investment is negative.

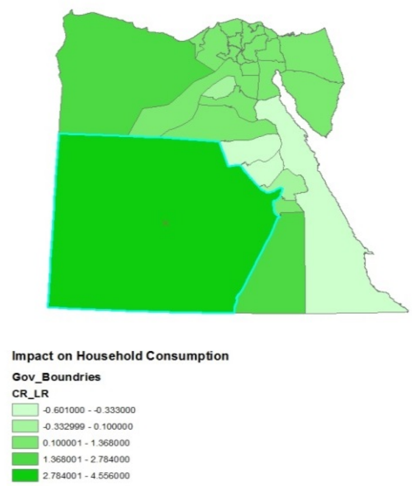
Table . 2 National results in the Long Run (Percentage change).

Real GDP	0.241
Real Household Consumption	0.435
Real aggregate investment	(0.404)
Real government Expenditures	0.450
International Export Volume	0.240
International Import Volume	0.425

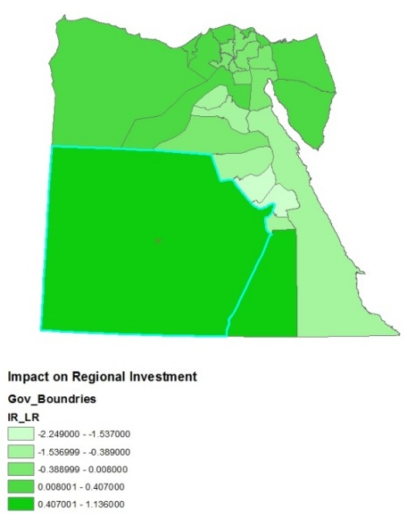
Figure 5: Spatial Regional Results in the Long Run.



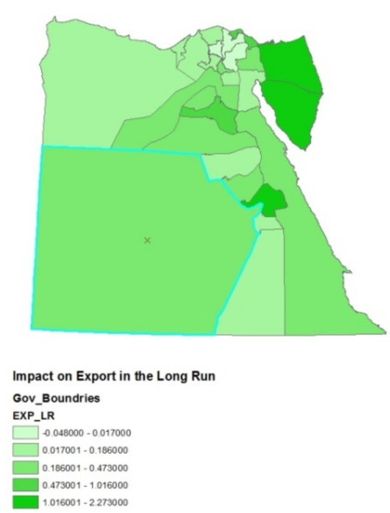
(a)



(b)



(c)



(d)

Regional Results: The analysis now focuses on the Corridor's effects upon the allocation of economic activity, looking at the model results for changes in GDP. Figure 5 is a map of the distribution of the results across regions. GDP (part a) and household consumption (part b) impacts across governorates show those governorates that win travel time savings via the Corridor's existence tend to gain the most efficiency benefits, while governorates in the Delta region tend to gain less.

Impacts on regional investment is some different. Figure 5c shows positive impacts on investment around the Corridor especially in the southern governorates and Western Desert, but the Sinai Desert also gains more benefits. According to Figure 5d, gains in regional exports concentrate in the Sinai. The immediate area around the Corridor gains fewer export benefits.

Summary and Conclusion

In this paper, we used an integrated spatial CGE model to assess the interregional economic effects of a new highway network proposed for Egypt as a main component of the Development Corridor project on national economic growth and regional activates. The Corridor is connected to Egypt's current highway network so as to calculate its impacts on travel time among Egypt's main cities (changes in the macro O-D matrix). We map network changes via a gravity model to the MCGE model in order to estimate some economic impacts of the corridor.

Results show the Corridor's presence yields string positive effects on Egypt's economy. Both nationally and regionally, the measured impacts are positive, reflecting net gains in efficiency. The governorates located in south Egypt and west of the Nile River tend to obtain the most efficiency gains. Hence, It appears the project should lessen regional disparities among governorates.

This paper is a first cut at estimating the economic benefits of the Development Corridor project. We did not consider the construction phase of the project in the analysis, however. This certainly should be considered in a final analysis as should the costs of the Corridor, including the manner by which Egypt will pay for it. Still it is clear an integrated spatial CGE model can be useful in estimating the potential economic impacts of transportation projects in Egypt. In this vein, this or similar models should support government decisions on such projects.

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