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# Valuing the Economic Cost of Remoteness: A Case Study of the Tiznit-Dakhla Expressway in Morocco

By Eduardo A. Haddad, Mahmoud Arbouch, Ademir A. Rocha and Vinicius A. Vale

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There is a long tradition in transportation planning research in quantifying remoteness in the context of accessibility indicators. Considering an existing system's network structure and its components' performance, it is possible to assess the socio-economic impacts of changes in the physical characteristics of specific links that affect critical locations. Nonetheless, the connection between changes in accessibility and their socio-economic consequences frequently relies on using parameters estimated econometrically under partial equilibrium frameworks. More recently, modeling integration based on links between transportation networks and computable general equilibrium (CGE) models has been gaining attention from the research community. In this paper, we add to this research trend by examining the case of remote regions in Morocco. The physical transportation network in the country is particularly interesting for understanding the economic costs of isolation. We calibrate a spatial CGE model for Morocco and integrate existing interregional trade flows into the transportation infrastructure to simulate the potential higher-order economic impacts of a road project improving the access of regions in the Southern part of the country.

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**RESEARCH PAPER**

# Valuing the Economic Cost of Remoteness: A Case Study of the Tiznit-Dakhla Expressway in Morocco*

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# 1. Introduction

Since its independence, Morocco has attached great importance to road infrastructure, given its impact on the country's economic and social development, its significant contribution to territorial development and the opening of rural populations, and improving accessibility and transportation across regions. In this regard, several large-scale infrastructure projects were launched to enable Morocco to become a major transport corridor and integrate a wider global trade network by linking its major industrial hubs and ensuring the fluidity of its port activity. These infrastructure projects have been translated into sectoral plans that offer significant growth opportunities, including the Roads Plan 2035, the National Strategy for the Development of Logistics Competitiveness 2030, the liberalization of the various transportation means, the Rail Plan 2040, and the National Port Strategy 2030.

The road network in Morocco ensures 90% of the movement of people and 75% of the transport of goods[1]. The paved road network has evolved during the last years to reach 45,240 km in 2021, knowing that right after independence, Morocco had only 10,348 km of paved roads.[2] The road network in Morocco comprises 1,800km of highways and 1,100km of expressways, representing 4.0% and 2.5% of the global paved road network. The road network is divided between national, regional, and provincial roads with respective shares of 27%, 20%, and 53%.

Highways and expressways play a crucial role in the country's development. Currently, 60% of the population is directly connected to this network, and 85% resides within an hour of a highway or an expressway[3]. Similarly, all cities with more than 400,000 people are connected to the highway network, and new sections are regularly put into service. Regarding the prospects, the country has put in place a Roads Plan for 2035 with the launch of an ambitious program to expand and modernize the road network. This project consists of constructing 7,000 km of national roads, 2,000 km of expressways, 45,000 km of rural roads, and 2,000 km/year of rehabilitated roads. Concerning the highway network, this project includes the realization of 1,700 km of highways to reach a network of 3,500 km by 2035. The objective is to double the current capacity.

One of these projects aims to improve the accessibility of the remote Moroccan Sahara to the economic core of the country. The project of the Tiznit-Dakhla expressway is particularly important as part of a new development model for the southern provinces of Morocco and consists of the doubling and widening of the national road linking these two cities on 1,055 km; the overall cost of the project is 850 million dollars, with a period of implementation initially planned between 2016 and 2021. To date, the work execution rate exceeds 80%, but the project is on track to be completed by 2023. This expressway is expected to reduce the time and cost of transport for people and goods while positively and directly impacting a population of more than 2.2 million inhabitants spread over ten provinces in 4 regions. Traffic flow, safety, and comfort are also expected to be improved. According to Morocco's government, the expressway abides by international standards while ensuring high safety. It is expected to allow greater accessibility to the southern regions of Morocco and sub-Saharan Africa. In what follows, we look closer at the potential impacts of the Tiznit-Dakhla expressway project using a spatial computable general equilibrium (SCGE) model integrated with a GIS network for Morocco.

1. Moroccan Ministry of Equipment

2. Between 2010 and 2020, Morocco's public investment in transport infrastructure amounted to over 32 billion dollars.

3. Moroccan Ministry of Equipment

# 2. Related Literature

There is a long tradition in transportation planning research in quantifying remoteness in the context of accessibility indicators. Furthermore, some studies have focused on the potential relationship between accessibility level and regional economic development. In this sense, some authors have used computable general equilibrium (CGE) models to approach issues related to transportation networks. Bröcker (1998), Bröcker (2000), Kim et al. (2004), Haddad and Hewings (2005), Bröcker et al. (2010), Almeida et al. (2010), Haddad et al. (2011), Elshahawany et al. (2017) and Rokicki et al. (2021) are some of them that contribute to the literature.

Bröcker (1998) has developed a prototype spatial computable general equilibrium (SCGE) model that considers transportation technology. The model has been extended and used by Bröcker (2000), Bröcker et al. (2010), and others. Furthermore, Almeida et al. (2010) have used a similar methodology. Bröcker et al. (2010), for example, used an SCGE model to evaluate the EU initiative of enforcing transport infrastructure development. Almeida et al. (2010) used an SCGE model to analyze the relationship between transport and regional equity in Minas Gerais, Brazil.

Haddad and Hewings (2005) and Haddad et al. (2011) have also presented some theoretical and empirical contributions using CGE models calibrated to the Brazilian economy. Haddad and Hewings (2005) used the Brazilian Multisectoral and Regional/Interregional Analysis Model (B-MARIA) to evaluate the short-run and long-run effects of reductions in transportation costs. As addressed by the authors, the model has added two new features to standard spatial CGE models: (i) the system is integrated with a transportation network, and (ii) firms in some regions are assumed to exploit increasing returns to scale. Haddad et al. (2011), otherwise, have applied a fully operational inter-regional CGE model to assess the effects of road transportation policy changes in Brazil. The inter-regional CGE model explicitly considers the modeling of transportation costs based on origin-destination flows, which considers the spatial structure of the Brazilian economy. Thus, it allowed the integration of the inter-regional CGE model with a geo-coded transportation network model, which increases the framework's potential in understanding the infrastructure's role in regional development.

Studies were also carried out for other countries, such as Korea (Kim et al., 2004), Egypt (Elshahawany et al., 2017), and Poland (Rokicki et al., 2021). Kim et al. (2004) used a transport model and a multiregional CGE model to estimate the economic effects of a highway project on economic growth and regional disparity in Korea. They measured changes in interregional distance and accessibility due to the highway project by the transport model. Then, they estimated the spatial economic effects through a CGE model, including effects on GDP, prices, exports, regional distribution of wages, and population. Elshahawany et al. (2017) used an SCGE model to estimate the economic impacts of changes in transportation costs due to a desert-based expansion of the highway network in Egypt. The simulation results have shown positive effects in all Egyptian governorates. Furthermore, the authors highlight the substantial gains in efficiency for those regions most isolated. Rokicki et al. (2021) used a regional dynamic CGE model to measure the effects of large transport infrastructure investments in Polish NUTS2 regions. They used data on investment spending and accessibility improvement (expressed as a reduction in transport margins) to distinguish between possible short and long-term impacts.

Thus, although there are other relevant studies, these contributions show the potential of SCGE models to evaluate investment in transport infrastructure, accessibility level, and regional economic development.

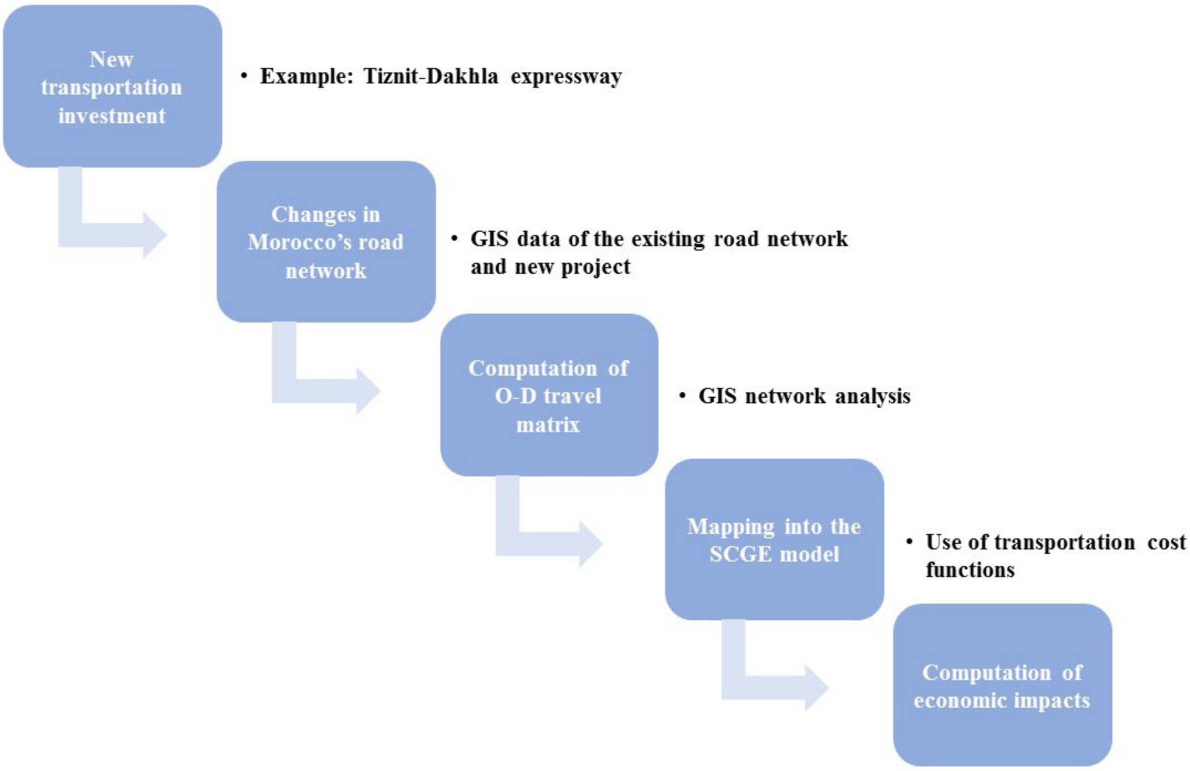
# 3. Modelling of Transportation Costs in the SCGE model

An essential feature of the spatial computable general equilibrium (SCGE) model for Morocco is its ability to explicitly estimate the costs of moving products based on origin-destination pairs according to transportation margins.[4] The model accounts for the specific cost structure of the flow of each traded commodity. Furthermore, it physically constraints this structure by the available transportation network modeled in a geo-coded transportation module, as introduced in Haddad and Hewings (2005).

The model's integration with a GIS network[5] helps quantify the spatial effects of transportation cost change. Moreover, it explicitly enables us to model commodity-based transportation costs within the SCGE model. Thus, the model intrinsically accounts for the spatial structure of the Moroccan economy. Including the transportation network within the SCGE model 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 SCGE model estimates the higher-order economic impacts caused by expected changes in regional accessibility. Figure 1 summarizes the main methodological aspects of our modeling strategy.

Figure 1

Sequential Modeling Integration Strategy




4. The complete specification of the spatial computable general equilibrium model for Morocco is presented in Haddad (2022).

5. See Annex.

The set of equations that specify purchasers' prices in the SCGE model imposes zero pure profits in the distribution of commodities to different users. Prices paid for commodity i from source s in region q by each user equate to the sum of its basic value, indirect taxes, and the transportation costs associated with the use of the relevant margin-commodity.

The role of the margin-commodity is to facilitate flows of commodities from points of production or points of entry to either domestic users or ports of exit. The margin-commodity, or simply margin, includes transportation services. Combined, they take account of transfer costs in a broad sense.[6] The model's margin demand equations show that the margins' demands are proportional to the commodity flows with which the margins are associated; moreover, a technology change component allows changes in the implicit transportation rate.[7]

The model uses a general functional form for the equations of margin demand for different users. Let x be a flow of good i from region s to region r, and m the quantity of the required transportation margin.[8] Assumin g $m=A\eta x$, with parameter $\eta$ specific to *i*, s and r; and *A* specific to *i*, *s* and *r,* being a shift variable used to rescale the reference estimates of $\eta$. Thus, an integration scenario that reduces transportation costs from region *s* to region *r* by 10%, for example, is modeled by reducing *A* by 10% for all goods *i*.[9]

In integrating the network and the SCGE model, we assume that each region's locus of production and consumption is its central city; moreover, for tractability, it is assumed that international trade transpires only through Casablanca. 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 restricted to a matrix of travel times among Morocco's regional capitals. Moreover, to account for intra-regional transportation costs, the model lets trade within each region take place at a "distance" that is time-wise half that of the one other capital city most readily accessed. The transportation module then calculates the minimum interregional (path) times, considering the road network as connected. Travel times are then associated via a gravity model formulation to the transportation costs implicit in the transactions of the SCGE database and tariff functions using data on general cargo prices (for domestic trade flows) and container prices (for international trade flows).

General equilibrium effects occur within a stable and relatively well-understood system of market relationships. According to the model structure, this may represent a margin-saving change, i.e., the use of transportation services per unit of output is reduced, implying a direct reduction in the output of the transportation sector, which frees resources for the economy (technical change channel).

The reduction in transport cost also decreases the price of composite commodities, with positive implications for real regional income (price change channel): in this cost-competitiveness approach, firms become more competitive – as production costs go down (inputs are less costly); investors foresee potential higher returns – as the cost of producing capital also declines; and households increase their real income, envisaging higher consumption possibilities. The higher income generates higher domestic demand, while increases in the competitiveness of national products

6. Hereafter, transportation services and margins will be used interchangeably.

7. In the case of international imported goods, the implicit transportation margin is interpreted as the costs at the port of entry plus land transportation costs to the consuming region, while for foreign exports it includes transportation costs from the producing region and the costs at the port of exit.

8. Similarly, one can think about flows of exports from the producing region to the port or flows of imports from the port to the consuming region.

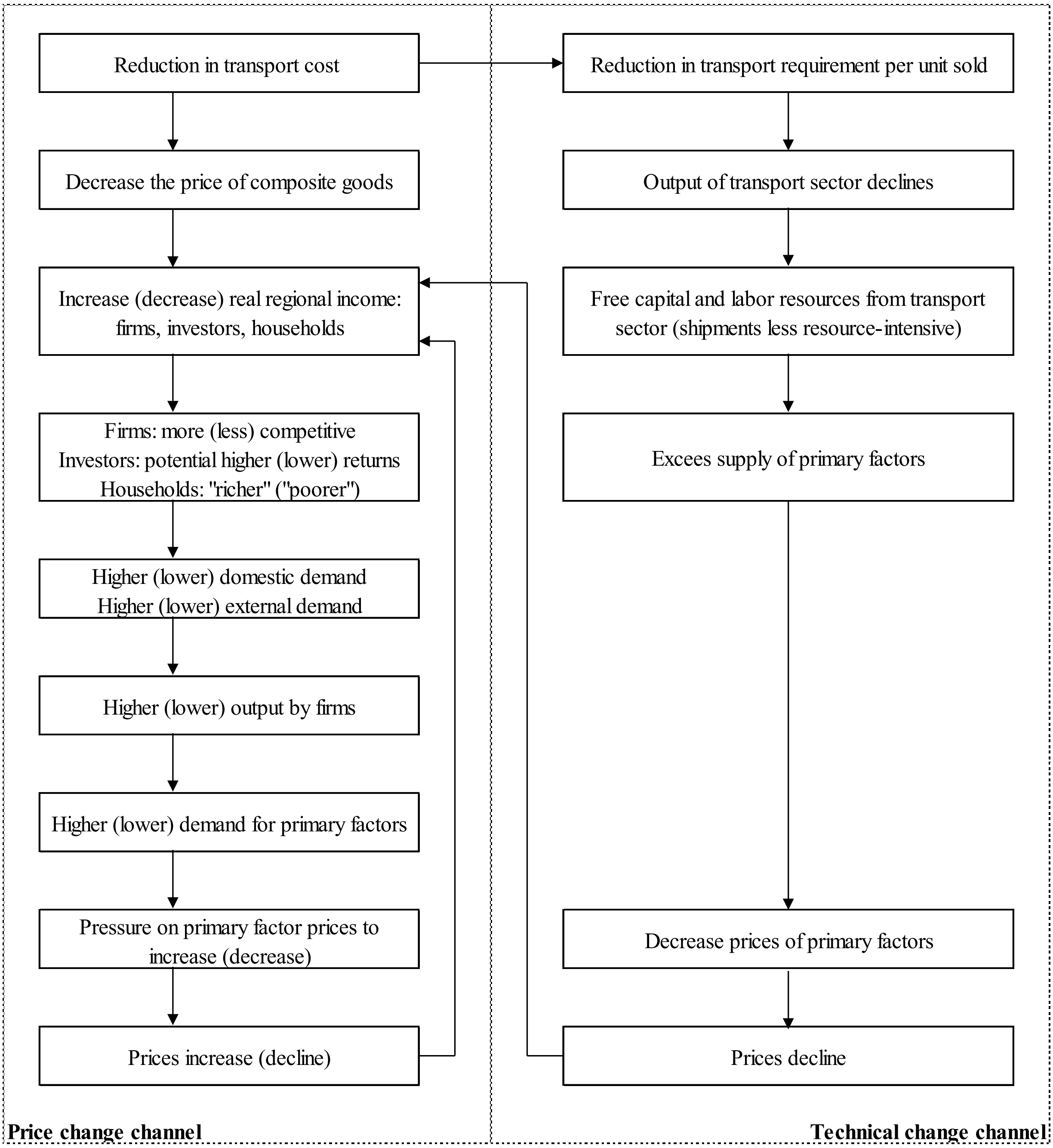
9. The process of calibration of transportation costs assumes $A = 1$ for all *i*, *s* and *r* in the benchmark year. Thus, $\eta$ can be calibrated by calculating the relationship between *m* and *x* directly from the interregional input-output database.

stimulate external demand, creating room for increasing firms' output – directed for both domestic and international markets – which requires more inputs and primary factors. Increasing demand puts pressure on the factor markets for price increases, with a concomitant expectation that the prices of domestic goods would increase.

Second-order price changes go in both directions – decrease and increase. The relative strength of the countervailing forces determines the net effect. Figure 2 summarizes the transmission mechanisms associated with significant first-order and second-order effects in the adjustment process underlying the model's aggregate results.

Figure 2

Functioning Mechanisms of the Model's Simulation

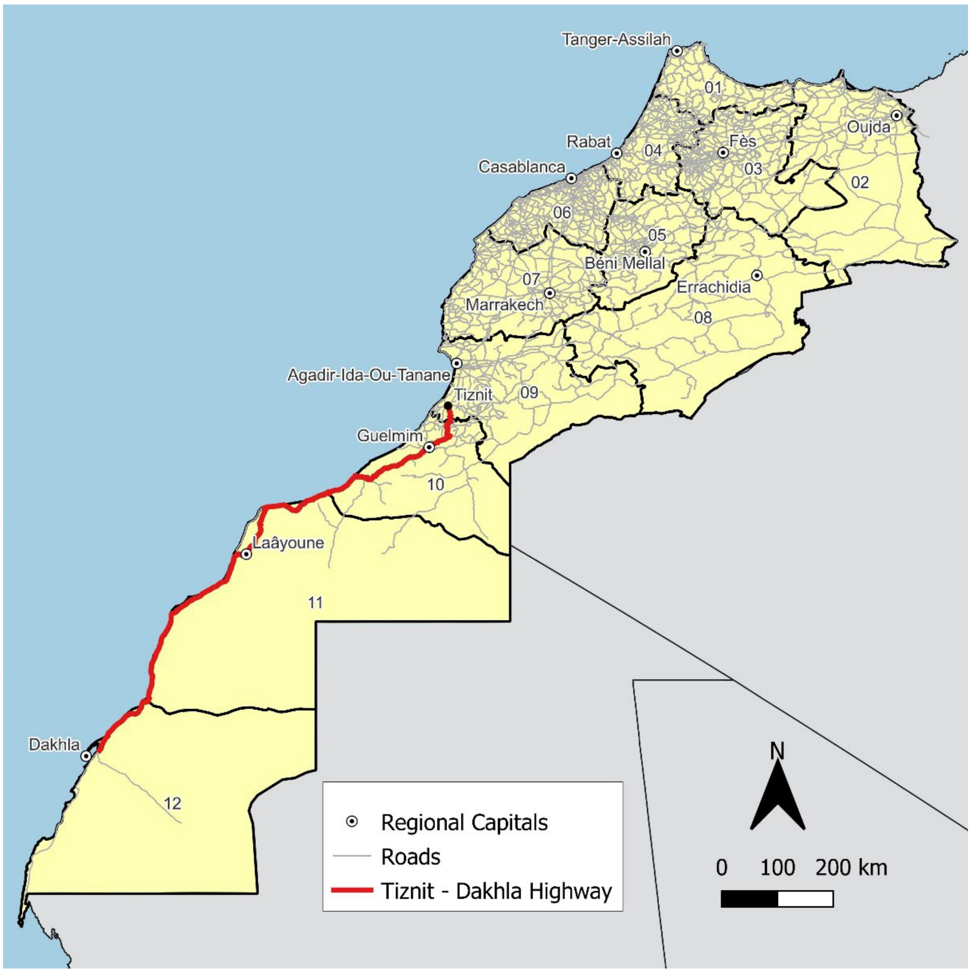


# 4. Simulation Strategy

The simulation shows the short and long-run effects of a project duplicating the existing road link between Tiznit and Dakhla (Figure 3). Investment in transportation is an important element of the range of regional policies available for the Moroccan government. To explore the effects of such policies, the SCGE model for Morocco is used to simulate the impacts of a specific intervention in the southern part of the country.

Figure 3

The Tiznit-Dakhla Expressway




We start by calculating the project's effect on the travel times among regions. We record the minimum impedance paths in minutes among the prime cities of Morocco's regions. Table 1 presents the specific travel time changes for every pair of origin-destination. They reflect the reduction in travel time that the duplication of the corridor between Tiznit and Dakhla engenders in the accessibility of a region to/from all other regions. We have changed the speed limit in the corridor from 80 km/h to 100 km/h. Notice that regions that face higher reductions in travel time are Laâyoune-Sakia El Hamra and Dakhla-Oued Ed-Dahab, since they are in the direct area of influence of the project. However, network effects spread the benefits of higher accessibility to other regions in the country. The change in the travel-time matrix associated with the operation of the new transport infrastructure project provides the basis for integrating the transport module into the SCGE model.

**Table 1**

## Change in Travel Time to/from Regions due to the Project (in % change)

| | | | DESTINATION | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 | R9 | R10 | R11 | R12 |
| ORIGIN | Tanger | R1 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -2,26 | -7,87 | -10,86 |
| | Oujda | R2 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -1,74 | -6,58 | -9,53 |
| | Fès | R3 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -2,12 | -7,53 | -10,53 |
| | Rabat | R4 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -3,06 | -9,52 | -12,39 |
| | Béni Mellal | R5 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -3,34 | -10,02 | -12,82 |
| | Casablanca | R6 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -3,42 | -10,16 | -12,93 |
| | Marrakech | R7 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -4,32 | -11,51 | -14,01 |
| | Errachidia | R8 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -2,17 | -7,67 | -10,66 |
| | Agadir | R9 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -9,43 | -15,90 | -16,95 |
| | Guelmim | R10 | -2,26 | -1,74 | -2,12 | -3,06 | -3,34 | -3,42 | -4,32 | -2,17 | -9,43 | -9,43 | -23,40 | -20,58 |
| | Laâyoune | R11 | -7,87 | -6,58 | -7,53 | -9,52 | -10,02 | -10,16 | -11,51 | -7,67 | -15,90 | -23,40 | -24,86 | -37,66 |
| | Dakhla | R12 | -10,86 | -9,53 | -10,53 | -12,39 | -12,82 | -12,93 | -14,01 | -10,66 | -16,95 | -20,58 | -37,66 | -37,66 |

We then calculate the change in transportation cost dependent on the change in travel time. The change in transportation costs among regions is considered the immediate direct impact of the improvement in the Tiznit-Dakhla corridor, which should be followed by other economic impacts on the economy, as discussed above. We use the change in travel time to calculate the change in cost for domestic and international trade flows using the following two estimated functions for the calibration stage:

$$Tariff_i = 3.79998 * Time^{0.85257}{}_i \quad \text{(Domestic trade cost function)}$$

$$Tariff_i = 3.55169 * Time^{0.88635}{}_i \quad \text{(International trade cost function)}$$

where *Tariff* is the change in transportation cost, *Time* is the change in travel time due to the project.

Table 2 presents the changes in transportation costs to/from all Moroccan regions and the rest of the world (Foreign – IMP and EXP). These changes are the shocks (changes in margins) used in the simulations with the SCGE model for Morocco.

Table 2

## Change in Transportation Cost to/from Regions due to the Project (in % change)

| | | | DESTINATION | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 | R9 | R10 | R11 | R12 | EXP |
| ORIGIN | Tanger | R1 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -0,84 | -2,99 | -4,17 | 0,00 |
| | Oujda | R2 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -0,65 | -2,49 | -3,64 | 0,00 |
| | Fès | R3 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -0,79 | -2,86 | -4,03 | 0,00 |
| | Rabat | R4 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -1,14 | -3,64 | -4,78 | 0,00 |
| | Béni Mellal | R5 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -1,25 | -3,83 | -4,95 | 0,00 |
| | Casablanca | R6 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -1,28 | -3,89 | -5,00 | 0,00 |
| | Marrakech | R7 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -1,62 | -4,43 | -5,44 | 0,00 |
| | Errachidia | R8 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -0,81 | -2,91 | -4,09 | 0,00 |
| | Agadir | R9 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -3,60 | -6,21 | -6,65 | 0,00 |
| | Guelmim | R10 | -0,84 | -0,65 | -0,79 | -1,14 | -1,25 | -1,28 | -1,62 | -0,81 | -3,60 | -3,60 | -9,40 | -8,18 | -1,33 |
| | Laâyoune | R11 | -2,99 | -2,49 | -2,86 | -3,64 | -3,83 | -3,89 | -4,43 | -2,91 | -6,21 | -9,40 | -10,04 | -16,05 | -4,04 |
| | Dakhla | R12 | -4,17 | -3,64 | -4,03 | -4,78 | -4,95 | -5,00 | -5,44 | -4,09 | -6,65 | -8,18 | -16,05 | -16,05 | -5,19 |
| | Foreign | IMP | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | -1,33 | -4,04 | -5,19 | |

In other words, we use the SCGE model to estimate the project's short and long-run impacts on national and regional variables. A distinguishing feature of short-run versus long-run simulations is the treatment of capital stock. Short-run simulations assume having a fixed capital stock. That is, industries' capital stocks are held at their pre-shock level, while policy changes are allowed to affect capital stocks in the long run. Moreover, we also allow for interregional labor mobility in the long run.

In the SCGE model, the general functional form used for the margin demand equations is the following:

$$XMARG(i,s,q,r) = AMARG(i,s,q,r) * \left[\eta(i,s,q,r) * X(i,s,q)^{\theta(i,s,q,r)}\right]$$

where $XMARG(i,s,q,r)$ is the margin *r* on the flow of commodity *i*, produced in region r and consumed in region *q*; $AMARG(i,s,q,r)$ is a technology variable related to commodity-specific origin-destination flows; $\eta(i,s,q,r)$ is the margin rate on specific basic flows; $X(i,s,q)$ is the flow of commodity *i*, produced in region *r* and consumed in region *q*; and $\theta(i,s,q,r)$ is a parameter reflecting scale economies to (bulk) transportation. In the calibration of the model $\theta(i,s,q,r)$ is set to one for every flow.

In the database of the model, information on transport rates is available. With that in hand, changes in transport rates can be estimated and incorporated into the SCGE model as follows. Rearranging the margin demand equation, we have

$$\frac{XMARG(i,s,q,r)}{X(i,s,q)^{\theta(i,s,q,r)}} = AMARG(i,s,q,r) * \eta(i,s,q,r)$$

with $\theta(i,s,q,r)$ = 1 implying that the left-hand side becomes the specific transport rate. A percentage change in the transport rate can then be mapped into the technology variable, $AMARG(i,s,q,r)$. Thus, in percentage-change form, $AMARG(i,s,q,r)$ becomes the relevant linkage variable

$$xmarg(i,s,q,r) - x(i,s,q) = amarg(i,s,q,r)$$

# 5. Results

## 5.1. Accessibility Impacts

The accessibility index developed in this study is based on Hansen's formulation (Hansen, 1959), which defines accessibility as the potential of opportunities for interaction. Hansen gravity-based accessibility measures combine the effects of transport and land use. We have computed a simple province-level value-added-based accessibility indicator considering pairwise travel time between provincial capitals. We applied a systematic time-distance discount in evaluating markets by calculating an index of market access potential for each Moroccan province (Hoover and Giarratani, 1985). Thus, to compute the potential index $A_i$ for any specific production location *i*, we divide the value added of each province *j* ($VA_j$) by the time from *i* to *j* ($time_{ij}$) and then add up all the resulting quotients so that

$$A_i = \sum_j (VA_j / time_{ij})$$

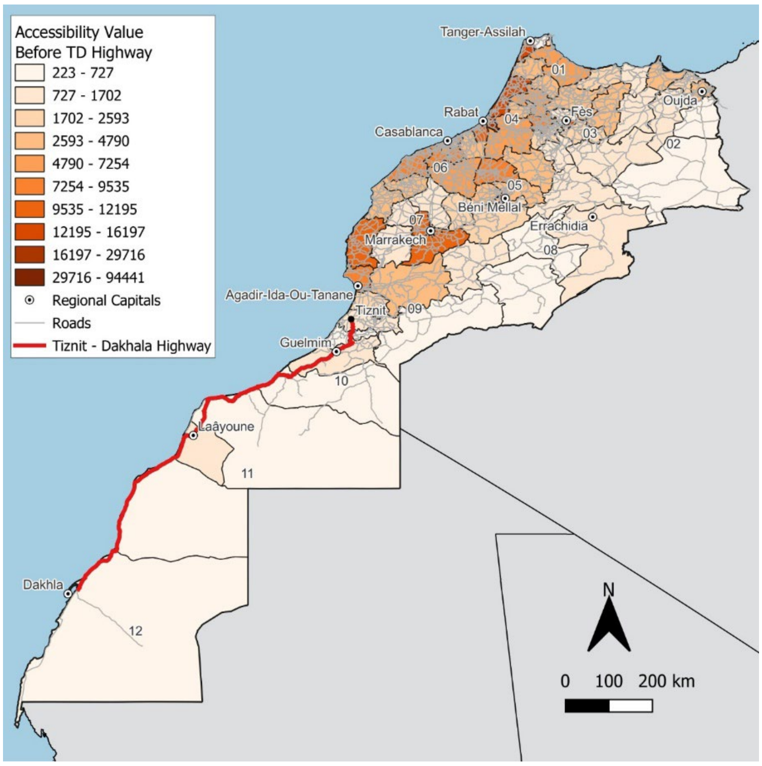
Figure 4 presents the accessibility indicator for the benchmark values and the change in accessibility due to the road improvement, comparing values based on time matrices computed before and after the implementation of the expressway. In the first map (Figure 4a), it is clear the pattern of higher accessibility concentrated in the core regions of the country, where you find better transportation connectivity and denser economic spaces. Remoteness is associated with very low accessibility indicators prevailing in southern Moroccan provinces. As observed by Haddad *et al*. (2020, p. 569), Grand Casablanca-Settat concentrates approximately 20% of the population and 30% of the national GDP. Higher productivity levels are perceived mainly in the two largest urban agglomerations of the country, which present higher GDP shares than population shares. In a broader territorial context, the presence of other relevant industrial areas outside Casablanca reveals the economic core of the Moroccan economy comprising six of the twelve regions, namely, Tanger-Tetouan-Al Hoceima (R1), Fès-Meknès (R3), Rabat-Salé-Kénitra (R4), Béni Mellal-Khénifra (R5), Grand Casablanca-Settat (R6) and Marrakech-Safi (R7), which, together, are responsible for over 80% of the GDP. Given the fish-shaped-like cartographical representation of the territorial limits of this cluster, this set of regions is referred to as the "Fish".

Despite some minor impacts around the "Fish", Figure 4b shows that improved accessibility due to the Tiznit-Dakhla Expressway benefits mainly provinces in the more remote Moroccan Sahara, as the region improves its connection with the more developed and denser economic spaces of the national economy. In some cases, in the extreme south, accessibility improves by more than 60% (Laâyoune and Es-Semara/Tarfaya provinces).

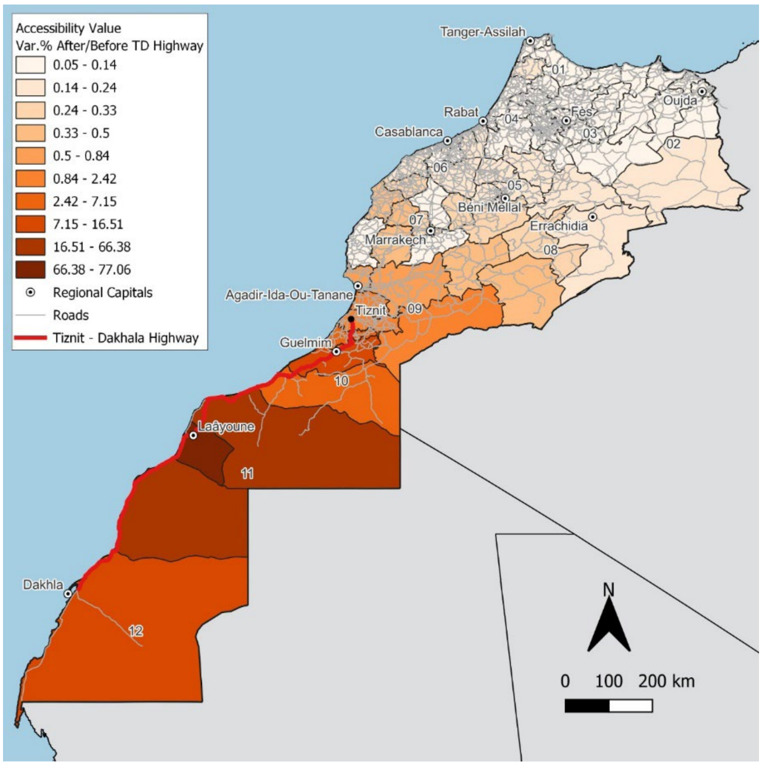
Figure 4

## Accessibility Indicator: Benchmark Level and Changes due to the Project

**(a) Benchmark (million MAD)**




**(b) Impact (% change in the benchmark)**



## 5.2. Macroeconomic Impacts

As mentioned earlier, the SCGE model allows us to estimate the project's impacts on regional and national variables, both in the short and long run. The selected variables of interest are the real GDP (GRP in the regional case) and real household consumption. The project's impact on these two variables can be broken down into three dimensions: domestic integration, access to foreign suppliers, and access to foreign markets.

In the short run, considering a fixed capital stock, the simulations indicate that the project's impact on real GDP and real household consumption at the national level will not exceed 0.0027% and 0.0009%, respectively (Table 3).

In the long-run, allowing changes in the capital stock, the impacts of the project on the variables of interest become larger and spread to the rest of the country beyond the Moroccan Sahara. Hence, the construction of the Tiznit-Dakhla expressway may increase real GDP by 0.0322% and real household consumption by 0.0908% at the national level (Table 3).

In order to address the issue of identification of the analytically most important transportation links in generating the SCGE model outcomes (Haddad and Hewings, 2007), we proceed with a thorough decomposition of the results of the simulations considering the role played by the changes in specific transportation costs, shown in Table 2. For each transportation link, we calculate its contribution to specific outcomes, considering different dimensions of the transportation project. It is possible to aggregate this information in such a way that we obtain three summary measures reflecting the isolated effects of increasing the region's direct access to foreign markets, increasing direct access to foreign suppliers, and the effects associated with transportation cost reductions promoting domestic integration. We first look at the effects on national GDP growth and welfare (Table 3). In both cases, national results are driven by integrating the remote south with domestic markets, followed by better access to foreign markets, especially in the long run.

Table 3

Decomposition of the Impacts on Real GDP and Real Household Consumption at the National Level (in % change)

| | Short run | Long run |
|---|---|---|
| Real GDP | 0,0027 | 0,0322 |
| *Access to foreign markets* | 0,0005 | 0,0097 |
| *Access to foreign suppliers* | 0,0005 | 0,0028 |
| *Domestic integration* | 0,0017 | 0,0197 |
| | | |
| Real Household Consumption | 0,0009 | 0,0908 |
| *Access to foreign markets* | 0,0004 | 0,0283 |
| *Access to foreign suppliers* | 0,0000 | 0,0074 |
| *Domestic integration* | 0,0005 | 0,0551 |

## 5.3. Regional impacts

The regions most affected in the short run are the southern ones where the project is located. The project may increase real GRP by 0.1516% in the Dakhla-Oued Eddahab region, 0.0462% in the Laayoune-Sakia El Hamra region, and 0.0121% in the Guelmim-Oued Noun region. The impacts on real household consumption in the three regions are 0.0656%, 0.0307%, and 0.0076%, respectively (Table 4).

In the long run, the highest impacts continue to be observed in the southern regions, with a real GRP increase of 0.1479% in Dakhla-Oued Eddahab, 0.0937% in Laayoune-Sakia El Hamra, and 0.0346% in Guelmim-Oued Noun. Meanwhile, real household consumption increases due to the project would be 0.1216%, 0.1068%, and 0.0899% in the three regions, respectively. The GRP impact of the road project on the remaining regions ranges from 0.0158% in Béni Mellal-Khénifra to 0.0634% in Souss-Massa; in terms of real household consumption, the impacts outside the Moroccan Sahara range from 0.0727% in Tanger-Tetouan-Al Hoceima to 0.1151% in Souss-Massa (Table 4).

The spatial effects on GDP reveal, both in the short run and in the long run, positive impacts in regions directly influenced by the project. Noteworthy is that these positive impacts spread over space in the long run. Moreover, re-location effects tend to be directed to the regions in the eastern fringe of the "Fish" (Souss-Massa, Marrakech-Safi, and Drâa-Tafilalet), closer to the connected South, as well as to the areas directly linked to the project itself within the borders of the Moroccan Sahara. However, despite the project's clear relative regional de-concentration impact, regions outside the South tend to benefit proportionally more in the long run, compared to their short-run performance, both in terms of growth and welfare gains.

To obtain a finer perspective on the analytically most important transportation links for optimizing a given policy target, we look further at the decomposition of the results into region-to-region links. Key links based on their influence on each policy strategy (regional GDP growth) are highlighted in Figure 5. Notice that the set of most influential transportation links varies according to different (regional) policy targets. For instance, growth in the South associated with the project seems to be influenced somehow more equally by improved access to foreign markets and foreign suppliers, and to better connections with other regions of the country, especially with Casablanca (R6) and within the South involving Laayoune-Sakia El Hamra (R11). Direct and indirect connections between the South and Casablanca dominate the effects on the "Fish". Table 5 summarizes this information.

Table 4

### Impacts on Real GRP and Real Household Consumption at the Regional Level (in % change)

| Region | | Real GRP | | Real HH Consumption | |
|---|---|---|---|---|---|
| | | Short run | Long run | Short run | Long run |
| R1 | Tanger-Tetouan-Al Hoceima | 0,0002 | 0,0171 | -0,0011 | 0,0727 |
| R2 | Oriental | 0,0004 | 0,0385 | -0,0003 | 0,0905 |
| R3 | Fès-Meknès | 0,0004 | 0,0500 | -0,0004 | 0,1038 |
| R4 | Rabat-Salé-Kénitra | 0,0006 | 0,0284 | -0,0001 | 0,0872 |
| R5 | Béni Mellal-Khénifra | 0,0004 | 0,0158 | -0,0003 | 0,0827 |
| R6 | Grand Casablanca-Settat | 0,0016 | 0,0179 | -0,0002 | 0,0789 |
| R7 | Marrakech-Safi | 0,0004 | 0,0519 | -0,0004 | 0,1029 |
| R8 | Drâa-Tafilalet | 0,0004 | 0,0516 | -0,0004 | 0,1005 |
| R9 | Souss-Massa | 0,0005 | 0,0634 | -0,0019 | 0,1151 |
| R10 | Guelmim-Oued Noun | 0,0121 | 0,0346 | 0,0076 | 0,0899 |
| R11 | Laayoune-Sakia El Hamra | 0,0462 | 0,0937 | 0,0307 | 0,1068 |
| R12 | Dakhla-Oued Eddahab | 0,1516 | 0,1479 | 0,0656 | 0,1216 |

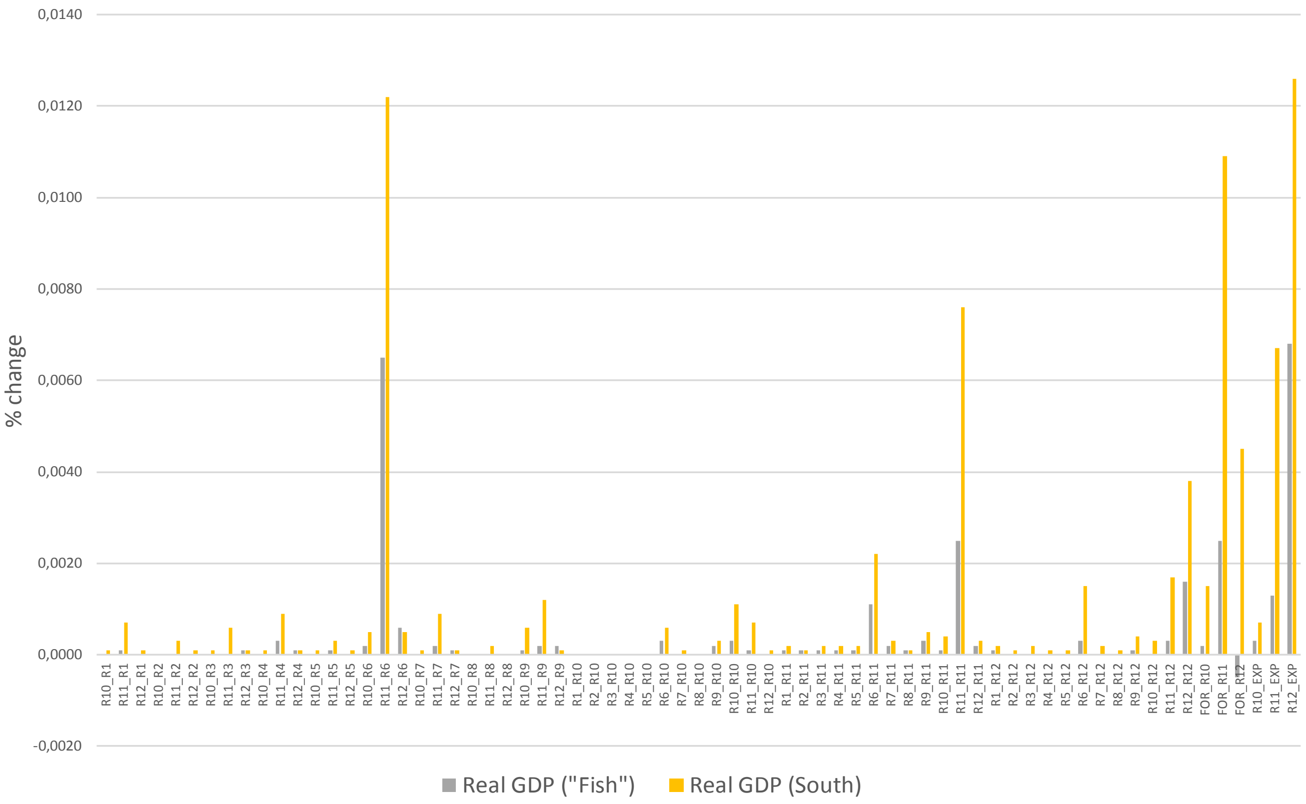
Table 5

### Decomposition of the Impacts on Real GDP and Real Household Consumption at the Regional Level (in % change)

| | Short run | Long run |
|---|---|---|
| Real GDP (South) | 0,0507 | 0,0812 |
| *Access to foreign markets* | 0,0150 | 0,0200 |
| *Access to foreign suppliers* | 0,0128 | 0,0169 |
| *Domestic integration* | 0,0229 | 0,0443 |
| | | |
| Real GDP ("Fish") | 0,0009 | 0,0282 |
| *Access to foreign markets* | 0,0000 | 0,0084 |
| *Access to foreign suppliers* | 0,0000 | 0,0022 |
| *Domestic integration* | 0,0009 | 0,0176 |

Figure 5

Analytically-important Transportation Links: Decomposition of the Impacts on Real GDP and Real Household Consumption at the Regional Level (in % change)




## 5.4. Marginal productivity of the investment

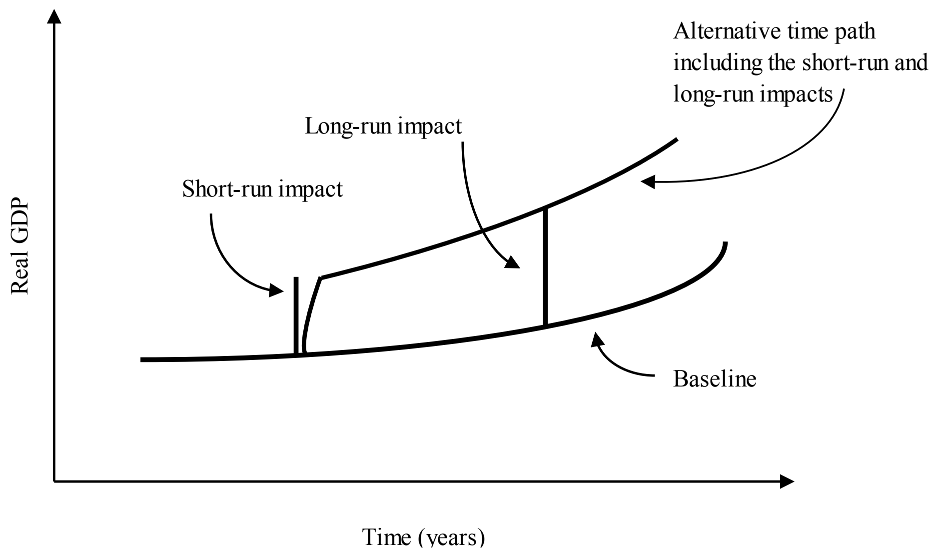
Impact analysis helps put "hard numbers" on political strategies to test their veracity. Different partial criteria are used to analyze and assess the potential for an investment policy. The marginal productivity of investment, one of such criteria, focuses on the real rate of return that the economy's marginal investment projects yield. By "real" it is meant the market value of the outputs and net of all the inputs of the project, both appropriately discounted for time (Sassone and Schaffer, 1978). Invariably, a project subjected to CBA will have its costs and benefits spread over several years. From an economic perspective, the present value of the investments could be compared to the present value of the higher-order marginal economic flows projected during the project's lifespan. Nonetheless, given the inextricable difficulty in systemically quantifying the marginal product, this approach is rarely used.

To circumvent this obstacle, Haddad (2004) proposed using CGE models as an alternative methodology to fill this gap in the context of transportation infrastructure projects. Accordingly, marginal economic flows are the annual differences in the economic variables, in relation to a baseline or control path, due to the changes associated with the investments, both in the construction and operation phases. While the effects of the investment spending concentrate in the short run, accessibility improvements (expressed as an estimated reduction in travel time) start generating impacts right after the project is finished and tend to magnify its impacts as the project matures in the long run (Rokicki et al., 2020). The main differences, as shown in the previous section, refer to the different adjustment mechanisms in different time spans; the longer the period, the more flexible the operation of such mechanisms.

In aggregate terms, the investment in the Tiznit-Dakhla Expressway has the potential to generate real GDP growth in the short run, which is magnified in the long run, with heterogeneous regional effects. In essence, what a typical simulation does is depart from an equilibrium of the circular flow of income of the economy, depicted in the benchmark database, and reach another equilibrium – an updated version of the original flow of income. Results are drawn from the comparison of the two equilibria. An alternative "temporal" interpretation of the comparative-static simulation results is based on the intrinsic characteristics of our exercise.
As in the SCGE model we work with flows, we can interpret the differences that result from the adjustments to the shocks in the different closures as changes in the flow of income/output of the economy in a typical year of operation of the improved road, representing deviations from a control path – in our case hypothetical or unrealistic given the lack of the dynamics in the model (Figure 6). The issue at stake, thus, refers to the relevant adjustment mechanisms for such interpretation. In our simulations, we adopted two closures that mimic different mechanisms associated with different hypotheses on factor mobility. On the one hand, we can consider the more restrictive short-run closure as a likely environment prevailing during the first years of operation of the project. On the other hand, the more flexible adjustment mechanisms embodied in the long-run closure mimic the economic environment that relates to future years.[10]

Figure 6

Alternative Interpretation of the Results of Comparative-Static Simulations: Unrealistic Control Path (Baseline)




We can use the comparative-static results to project the marginal output flows in the Moroccan economy. We would additionally need to gather information about the lifespan of the project. In

10. Peter et al. (1996) report econometric studies that reinforce this suggestion

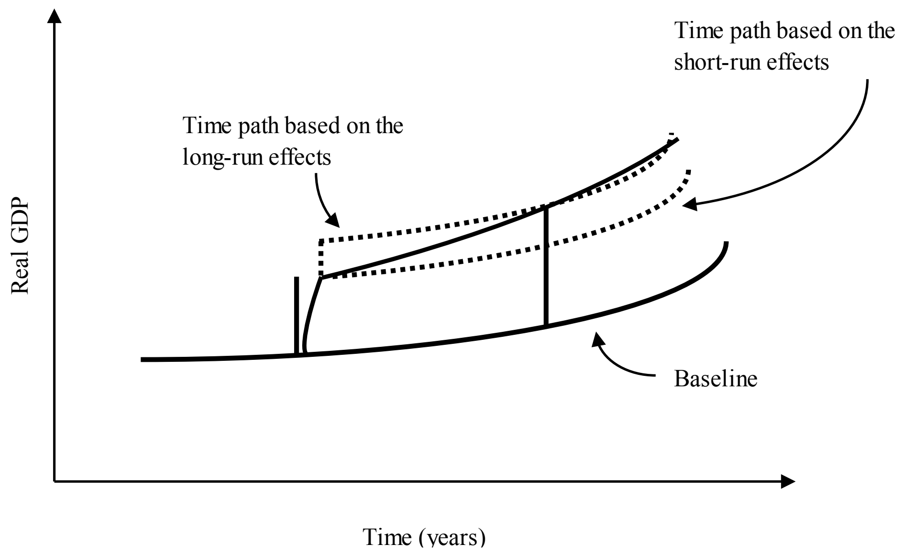
this project, the pavement was projected to last 15-20 years[11] with proper maintenance.[12] Using this parameter, we calculated the present value (PV) of the marginal flows of GDP, constant over 20 years (Figure 7), under different annual discount rates (3%, 5%, and 8%). The reported values refer to the effects of the short-run and long-run simulations in 2021 USD million. Tables 6 and 7 include estimates of the PV of the marginal flows of GDP, and an indicator of the marginal productivity of the investment (MPI)[13], calculated as the relationship between the present value (PV) of the marginal flows of GDP and the PV of the investments (both in 2021, considering different discount rates).

Results show that the marginal productivity of the investments is magnified in the long run. As the project maturates, productivity gains are bigger, as there is a potential complementarity between the investments in road improvement and the attraction of increasing investments, captured in the model through the long-run adjustment of regional and sectoral capital stocks. In our context, the concept of marginal indicators of the investments, brought to a given point in time, mixes with the concept of static multipliers. It means that the other sectors of the Moroccan economy would generate, in addition to the USD 850 million initial investments in the project, between USD 486 and 713 million in different productive chains that benefit from improved accessibility of/to the Moroccan Sahara in the 20 years following the start of the operations of the improved transport links.

To summarize the GDP effects, we calculated the internal rate of return (IRR) for the project (as GDP considers the value added to the economy, it represents a better measure to assess the economic effects of the project; moreover, it enables comparisons with other experiences): results reveal a very low IRR, equivalent to 0.96%.

Figure 7

## Alternative Time Paths to Real GDP




11. Moroccan Ministry of Equipment

12. In the SCGE model, maintenance costs are included in the production function of the transportation sector, including depreciation.

13. The inverse of this relationship refers to the incremental capital-output ratio, which informs about the level of investment necessary to generate one additional unit of output (GDP).

Table 6

Partial Criteria to Assess the Tiznit-Dakhla Expressway Project: PV of the Marginal Flows of GDP in the Operation Phase (USD million of 2021)

| | Short run | Long run |
|---|---|---|
| PV (3%) | 56,62 | 712,71 |
| PV (5%) | 48,01 | 604,29 |
| PV (8%) | 38,58 | 485,61 |

Observation: Investment cost = USD 850 million; operation period = 20 years

Table 7

Partial Criteria to Assess the Tiznit-Dakhla Expressway Project: PV of the Marginal Productivity of the Investments in the Operation Phase (USD million of 2021)

| | Short run | Long run |
|---|---|---|
| MPI (3%) | 0,067 | 0,838 |
| MPI (5%) | 0,056 | 0,711 |
| MPI (8%) | 0,045 | 0,571 |

Observation: Investment cost = USD 850 million; operation period = 20 years

# 6. Final Considerations

While improving accessibility, the Tiznit-Dakhla expressway will represent a step forward in promoting territorial integration and accelerating the economic development of the southern regions. The construction of this expressway and the realization of the new Dakhla Atlantic port, for an investment of 1.3 billion dollars, will allow the development of new special economic zones oriented towards exports. Thus, Morocco will be able to replicate its successful experiences in the creation of integrated industrial zones like the Tangier Free Zone and the Kenitra Atlantic Free Zone, to develop further its major industrial sectors, such as automotive, textiles, and aeronautics, and be able to access new markets, particularly in sub-Saharan Africa. Moroccan industrial zones would not have been successful in attracting FDI from large foreign companies (e.g., Renault, Stellantis, Boeing, and Airbus Ecosystems) without the presence of high-quality road and port infrastructure. The Moroccan experience in industrialization has shown that the development of road infrastructure and the improvement of accessibility remain prerequisites for any regional industrial development.

Beyond its role in improving accessibility in the southern regions of Morocco, the construction of such a big infrastructure project has other objectives, not only economic but also social and political. In this regard, the Tiznit-Dakhla road represents a bridge between the northern part of Morocco and its southern regions. Hence, this road will allow an opening up for the southern populations for whom travel to the rest of the country will become quicker and easier. Besides, historical facts testify of the great attachment of Morocco to its Sahara since the period of the Spanish protectorate. In 1975, 350.000 Moroccan civilian volunteers advanced thousands of kilometers from all over Moroccan regions, peacefully reclaiming the return of the Sahara to Moroccan sovereignty in what is called "The Green March".

Finally, regarding its impact on African regional integration, the Tiznit-Dakhla expressway can be considered a first step in developing African transnational infrastructure projects to enhance intra-African trade in relation to the establishment of the African Continental Free Trade Area (AfCFTA) and the creation of the African common market. In such a way, this infrastructure project will strengthen Morocco's African and Atlantic dimensions and reinforce Morocco's strategic choice to contribute to the emergence of an African economic hub in the service of sharing prosperity in the African continent.

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# ANNEX. GIS Road Network

The road network data were taken from OpenStreetMap (http://www.openstreetmap.org/), a free and editable map built by volunteers and released with an open-content license. The data from OpenStreetMap were downloaded from Geofabrik's free download server. (http://download.geofabrik.de/index.html).

The road network in OpenStreetMap is classified by a tag named "highway" which is any road, route, way, or thoroughfare on land which connects one location to another and has been paved or otherwise improved to allow travel by some conveyance, including motorized vehicles, cyclists, pedestrians, horse riders, and others (but not trains). Table A.1, extracted from http://wiki.openstreetmap.org/wiki/Map_Features, describes how *OpenStreetMap* classifies the road network.

We considered only the country's main highways for this project, so we applied a filter and used the key "highway" classified as a motorway, motorway_link, trunk, trunk_link, primary, primary_link, secondary, secondary _link, tertiary, and tertiary_link (Table A.2).

The geographic coordinate system used is the "Merchich_Sahara_Nord". Using the Calculate Geometry tool from ArcGis, we created and calculated a new table field with the length of the roads. We also created a new table field of the free-flow average speed by road classification; for this, we used the conditions shown in Table A.3.

With these two fields, we were able to create a new field that contains the time in minutes necessary to drive the whole road length using the following formula:

*Time (Minutes) = Length (km)/Avg speed (km/h)*60.*

Table A.1

## Main Tags for the Road Network

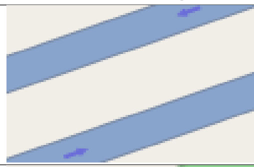
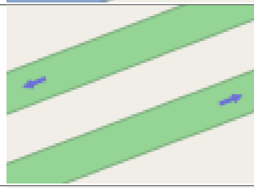
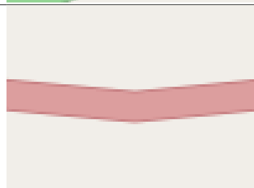
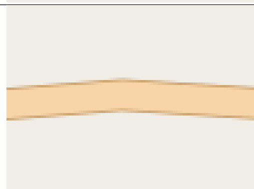
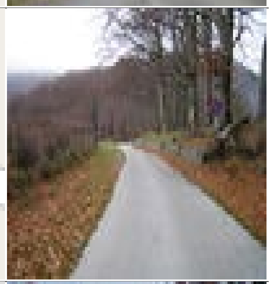
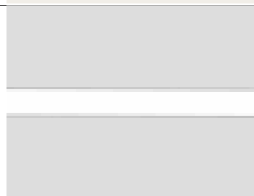
| Key | Value | Comment | Rendering | Photo |
|---|---|---|---|---|
| **highway** | **motorway** | A restricted access major divided highway, normally with 2 or more running lanes plus emergency hard shoulder. Equivalent to the Freeway, Autobahn, etc.. |  |  |
| **highway** | **trunk** | The most important roads in a country's system that aren't motorways. (Need not necessarily be a divided highway). |  |  |
| **highway** | **primary** | The next most important roads in a country's system. (Often link larger towns). |  |  |
| **highway** | **secondary** | The next most important roads in a country's system. (Often link towns). |  |  |
| **highway** | **tertiary** | The next most important roads in a country's system. (Often link smaller towns and villages). |  |  |
| **highway** | **unclassified** | The least most important through roads in a country's system – i.e. minor roads of a lower classification than tertiary, but which serve a purpose other than access to properties. Often link villages and hamlets. (The word 'unclassified' is a historical artefact of the UK road system and does not mean that the classification is unknown; you can use highway=road for that). |  |  |
| **highway** | **residential** | Roads which serve as an access to housing, without function of connecting settlements. Often lined with housing. |  |  |
| **highway** | **service** | For access roads to, or within an industrial estate, camp site, business park, car park etc. Can be used in conjunction with service=* to indicate the type of usage and with access=* to indicate who can use it and in what circumstances. |  |  |

Table A.2

## Link Roads

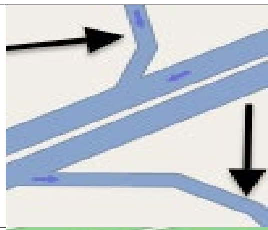
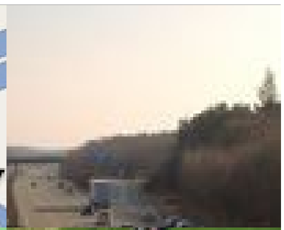
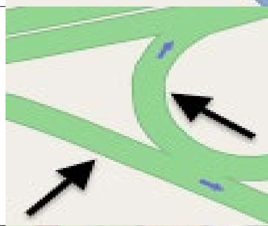
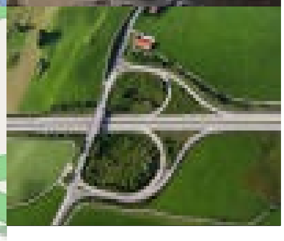
| | | | | |
|---|---|---|---|---|
| **highway** | **motorway_link** | The link roads (sliproads/ramps) leading to/from a motorway from/to a motorway or lower class highway. Generally with the same motorway restrictions. |  |  |
| **highway** | **trunk_link** | The link roads (sliproads/ramps) leading to/from a trunk road from/to a trunk road or lower class highway. |  |  |
| **highway** | **primary_link** | The link roads (sliproads/ramps) leading to/from a primary road from/to a primary road or lower class highway. |  | |
| **highway** | **secondary_link** | The link roads (sliproads/ramps) leading to/from a secondary road from/to a secondary road or lower class highway. | same rendering as highway=secondary in mapnik | |
| **highway** | **tertiary_link** | The link roads (sliproads/ramps) leading to/from a tertiary road from/to a tertiary road or lower class highway. | same rendering as highway=tertiary in mapnik | |

Table A.3

## Average Free-Flow Speed by Road Type

| ***Road type*** | ***avg speed (km/h)*** |
|---|---|
| motorway/motorway_link | 100 |
| trunk/trunk_link | 90 |
| primary/primary_link | 80 |
| secondary/secondary _link | 60 |
| tertiary/tertiary_link | 60 |

## A.1. Provinces – Point Map

The point shape file for the Provinces was created using Table A.4. The Longitude and Latitude coordinates from the Provinces were taken from the website http://www.getamap.org/.

Table A.4

Coordinates used for Locating Provinces

| Region | Province | Longitude | Latitude |
|---|---|---|---|
| Béni Mellal-Khénifra | Béni Mellal | -6.3533 | 32.3341 |
| Béni Mellal-Khénifra | Azilal | -6.5709 | 31.9592 |
| Béni Mellal-Khénifra | Khénifra | -5.6695 | 32.9357 |
| Casablanca-Settat | Settat | -7.6198 | 33.0023 |
| Casablanca-Settat | Khouribga | -6.9092 | 32.8855 |
| Casablanca-Settat | Benslimane | -7.1267 | 33.6228 |
| Casablanca-Settat | Casablanca | -7.6176 | 33.5939 |
| Casablanca-Settat | Mohammadia | -7.3893 | 33.6958 |
| Casablanca-Settat | Nouaceur | -7.6301 | 33.4302 |
| Casablanca-Settat | Médiouna | -7.5194 | 33.4562 |
| Casablanca-Settat | El Jadida | -8.4988 | 33.2429 |
| Dakhla-Oued Ed-Dahab | Oued Ed-Dahab | -13.508 | 23.3225 |
| Draâ-Tafilalet | Zagora | -5.8371 | 30.328 |
| Draâ-Tafilalet | Ouarzazate | -6.9018 | 30.9206 |
| Draâ-Tafilalet | Errachidia | -4.4335 | 31.9292 |
| Fès-Meknès | El Hajeb | -5.3719 | 33.6901 |
| Fès-Meknès | Ifrane | -5.1074 | 33.5276 |
| Fès-Meknès | Meknès | -5.5678 | 33.885 |
| Fès-Meknès | Fès | -5.0133 | 34.0341 |
| Fès-Meknès | Sefrou | -4.8333 | 33.8248 |
| Fès-Meknès | Boulemane | -4.73 | 33.3659 |
| Fès-Meknès | Moulay Yacoub | -5.1794 | 34.0874 |
| Fès-Meknès | Taza | -4.0101 | 34.2301 |
| Fès-Meknès | Taounate | -4.6359 | 34.5384 |
| Guélmim-oued Noun | Guélmim | -10.057 | 28.9863 |
| Guélmim-oued Noun | Tan Tan | -11.098 | 28.4375 |
| Laâyoune-Sakia El Hamra | Laayoune | -13.195 | 27.1545 |
| Laâyoune-Sakia El Hamra | Boujdour | -14.484 | 26.1272 |
| Laâyoune-Sakia El Hamra | Es Semara | -11.664 | 26.7435 |

| | | | |
|---|---|---|---|
| Marrakech-Safi | Al Haouz | -7.9245 | 31.2806 |
| Marrakech-Safi | El Kelaa Des Sraghna | -7.4067 | 32.0543 |
| Marrakech-Safi | Marrakech | -7.9886 | 31.6259 |
| Marrakech-Safi | Chichaoua | -8.7595 | 31.5469 |
| Marrakech-Safi | Essaouira | -9.7621 | 31.5117 |
| Marrakech-Safi | Safi | -9.2395 | 32.2994 |
| Oriental | Berkane | -2.3294 | 34.9266 |
| Oriental | Nador | -2.9282 | 35.1792 |
| Oriental | Oujda-Angad | -2.0358 | 34.6694 |
| Oriental | Taourirt | -2.8938 | 34.4134 |
| Oriental | Figuig | -1.2304 | 32.115 |
| Oriental | Jerada | -2.1599 | 34.3105 |
| Rabat-Salé-Kénitra | Kénitra | -6.5701 | 34.2645 |
| Rabat-Salé-Kénitra | Sidi Kacem | -5.7114 | 34.2264 |
| Rabat-Salé-Kénitra | Rabat | -6.839 | 34.0223 |
| Rabat-Salé-Kénitra | Salé | -6.814 | 34.0448 |
| Rabat-Salé-Kénitra | Skhirate-Témara | -6.8822 | 33.7538 |
| Rabat-Salé-Kénitra | Khémisset | -6.2648 | 33.6657 |
| Souss-Massa | Tata | -7.9696 | 29.7463 |
| Souss-Massa | Chtouka Ait Baha | -9.3383 | 30.0085 |
| Souss-Massa | Agadir Ida Ou Tanane | -9.585 | 30.4218 |
| Souss-Massa | Inezgane Ait Melloul | -9.5032 | 30.3486 |
| Souss-Massa | Taroudannt | -8.8779 | 30.4706 |
| Souss-Massa | Tiznit | -9.7312 | 29.6986 |
| Tanger-Tétouan-Al Hoceima | Al Hoceima | -3.9301 | 35.2451 |
| Tanger-Tétouan-Al Hoceima | Larache | -6.1529 | 35.1952 |
| Tanger-Tétouan-Al Hoceima | Tanger-Assilah | -5.8038 | 35.7769 |
| Tanger-Tétouan-Al Hoceima | Chefchaouen | -5.2683 | 35.1687 |
| Tanger-Tétouan-Al Hoceima | Tétouan | -5.3743 | 35.5705 |
| Tanger-Tétouan-Al Hoceima | Fahs Anjra | -5.6032 | 35.7514 |

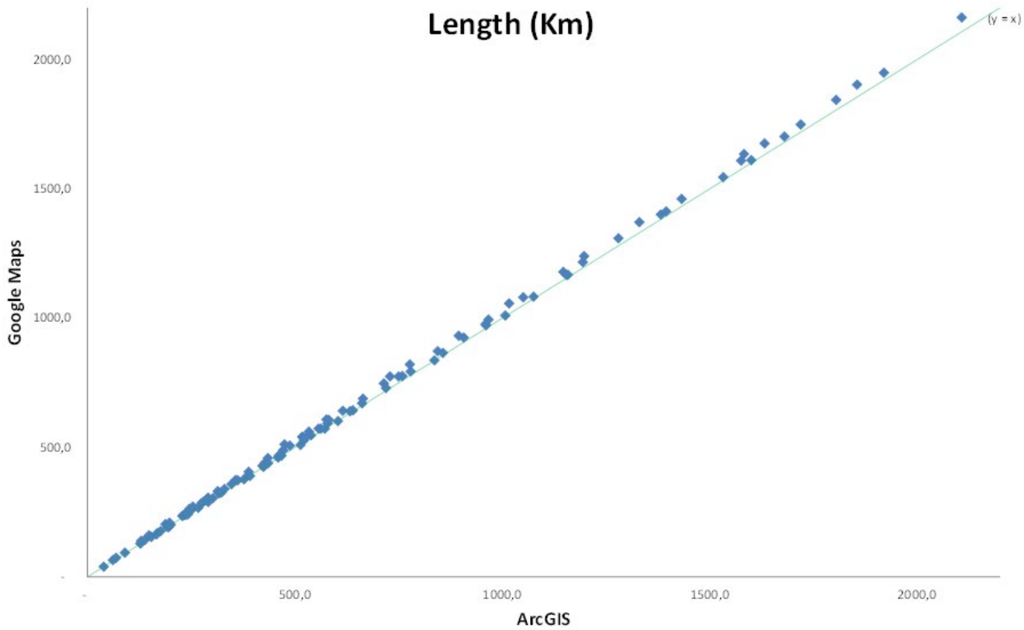
## A.2. OD Cost Matrix

We used the Network Analyst extension from the software ArcGIS to create an Origin-Destination (OD) cost matrix.[14] The parameter used to build the OD cost matrix were route length (kilometers) and time (minutes). On the software, we can choose the shortest or the fastest route. We opted for the latter in our simulations. We used all the provinces as the origin and destination points. We considered that the vehicles could drive in both directions (two-way) on the roads, so the same distance and time will be found from point A to B and from B to A.

Figures A.1 and A.2 present the estimates of distance and minimum travel time between origin-destination pairs (we have considered, for illustrative purposes, only the regional capitals). We compare the estimates based on our calibrated network and those calculated using Google Maps. Notice that our distance estimates are very close to those obtained using Google Maps (Figure A.1). There is a slight difference when we compare travel time between regional capitals (Figure A.2).

Figure A.1

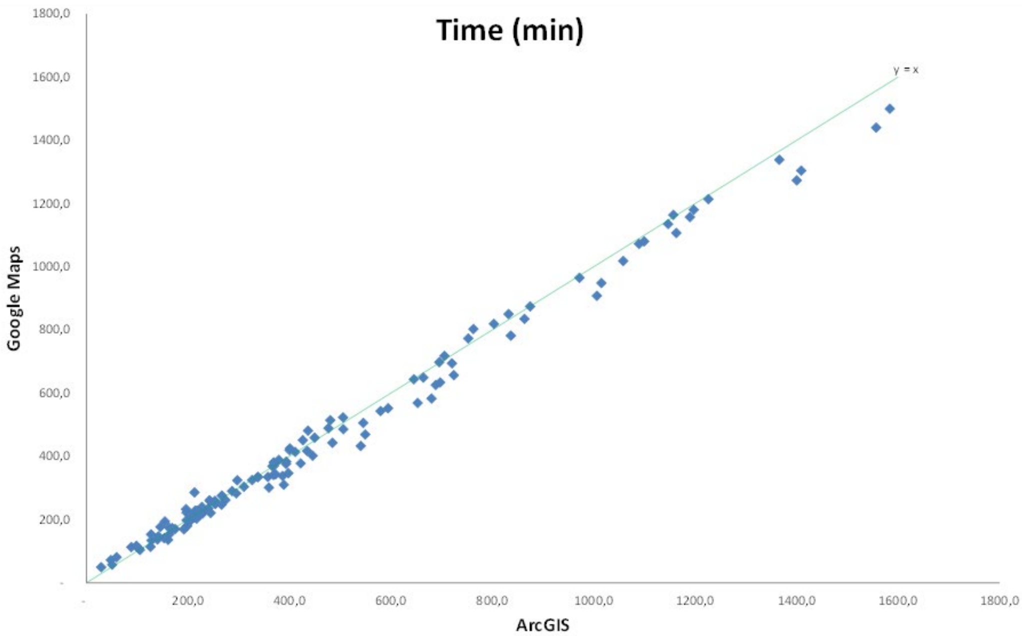
Comparison between Length Estimates based on the Calibrated Network and Google Maps




14. The "Network Analyst Tutorial" by ESRI is available on: http://help.arcgis.com/en/arcgisdesktop/10.0/pdf/network-analyst-tutorial.pdf.

Figure A.2

## Comparison between Time Estimates based on the Calibrated Network and Google Maps



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