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The Regional Impact of Infrastructure Investment in Mexico

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LOONEY R. and FREDERIKSEN P. (1981) The regional impact of infrastructure investment in Mexico, *Reg. Studies* **15,** 285–296. Using multiple regression analysis, production functions are estimated for Mexico to examine whether infrastructure's impact on GDP differs depending on the type of investment (economic or social overhead capital) or the type of recipient region (intermediate or lagging). This possibility has been suggested by Hansen. The states were grouped by means of cluster analysis. The results tend to confirm the Hansen thesis: economic overhead capital has had its greatest impact on GDP in intermediate regions while social overhead capital has had its greatest impact in lagging regions. A test for causality indicates that investment precedes income growth. Several policy recommendations are offered on the basis of these results.

Intermediate and lagging regions
Economic and social overhead capital
Policy implications
Regional development
Cluster analysis
Mexico

LOONEY R. and FREDERIKSEN P. (1981) L'impact de l'investissement en infrastructure au Mexique, *Reg. Studies* **15,** 285–296. A partir d'une régression multiple, on évalue les fonctions de production pour le Mexique afin d'approfondir si l'impact de l'infrastructure sur le PIB varie ou selon la catégorie d'investissement (infrastructure économique ou sociale), ou selon la région destinataire (région intermédiaire ou défavorisée). Cette possibilité remonte à Hansen. On a regroupé les états à partir d'un sondage en grappes. Les résultats ont tendance à corroborer la thèse de Hansen: à savoir, l'infrastructure économique influe le plus sur le PIB dans les régions intermédiaires, tandis que l'infrastructure sociale a influé le plus sur les régions défavorisées. A partir d'un test de causalité, on constate que l'investissement précède la croissance des revenus. Par suite de ces résultats-ci, on propose plusieurs recommandations de politique.

Régions intermédiaires et défavorisées
Infrastructure économique et sociale
Implications de politique
Développement régional
Sondage en grappes
Mexique

LOONEY R. and FREDERIKSEN P. (1981) Die regionale Wirkung von Investierung in die Infrastruktur in Mexiko, *Reg. Studies* **15,** 285–296. Mit Hilfe der Partialregressionsanalyse werden Produktionsfunktionen für Mexiko abgeschätzt, um zu prüfen, ob die Wirkung der Infrastruktur auf das Gesamtsozialprodukt nach Investierungstyp (wirtschaftliches oder soziales Unkostenkapital) oder nach Typ der Empfängerregion (zwischen- oder zurückgebliebene) verschieden ist. Diese Möglichkeit wurde von Hansen vorgeschlagen. Die Staaten werden mittels Klusteranalyse in Gruppen zusammengefasst. Die Ergebnisse neigen dazu, die Hansensche These zu bestätigen: wirtschaftliches Unkostenkapital übt seine grösste Wirkung auf das Gesamtsozialprodukt in Zwischenregionen aus, während soziales Unkostenkapital die grösste Wirkung in zurückgebliebenen

Regionen hervorruft. Eine Prüfung der Ursachen weist darauf hin, dass Investierung dem Einkommenswachstum vorausgeht. Auf der Grundlage dieser Ergebnisse werden verschiedene politische Empfehlungen gemacht.

Zurückgebliebene und Zwischenregionen
Wirtschaftliches und soziales Unkostenkapital
Politische Folgerungen
Regionale Entwicklung
Klusteranalyse
Mexiko

INTRODUCTION

THE POSSIBILITY that infrastructure investment can alter existing patterns of regional income has long intrigued economists. This possibility is clearly suggested by infrastructure's key role in HIRSCHMAN's (1958, Chap. 4) unbalanced development strategy and in the theory of interregional comparative advantage. If a stable relationship between infrastructure and regional income exists, the public sector would have a powerful tool at its disposal to implement regional development decisions.

The fundamental importance of the relationship between changes in the regional stock of infrastructure and the spatial pattern of socio-economic development has led to considerable research activity, most of which, however, has been undertaken for the more developed countries. In addition, and almost without exception, the case studies published to date (KRAFT *et al.*, 1971) have been undertaken without any general theory as a basis, and have produced no tenable theories of their own. ALDER (1965, p. 189) commenting on the state of transportation economics has noted that "it is frequently assumed that all transport improvements stimulated economic development. The sad truth is that some do, some do not and that even some of those that do may not be economically justified in the sense that there may be better investment opportunities."

The most comprehensive theory on the effect of infrastructure investment on income levels in developing countries is that of HANSEN (1965a). While a more detailed description of his theory appears below, Hansen has hypothesized that the impact of infrastructure investment on income levels can be significant but will depend on: (a) the economic characteristics of the region in which the investment takes place, and on (b) the type of infrastructure investment. The objective of this paper is to empirically test the Hansen hypothesis for one developing country. Following a discussion of the role of infrastructure in the development process and the Hansen thesis, the reasons for selecting Mexico as the country for study are discussed. The states of Mexico are then classified into two groups by means of cluster and discriminant analysis, and production functions are estimated by use of multiple regression analysis to statistically examine the *within-group relationship* between the Gross Domestic Product (GDP) and selected types of infrastructure investment. The final section statistically examines causality between infrastructure and GDP, i.e. is infrastructure the initiating factor in the development process or is it merely a passive or accommodating factor.

THE ROLE OF INFRASTRUCTURE IN DEVELOPMENT

Among economists there is a broad spectrum of viewpoints, some of them diametrically opposed to one another, concerning the role of infrastructure in the development process. There is consensus, however, as to the need for basic infrastructure facilities in potential development areas since ultimately infrastructure must be a limiting factor without which no development process could take place even if other development-inducing factors were present. However, opinions as to infrastructure's precise role in socio-economic development beyond this point differ greatly.

Some economists (GLOVER and SIMON, 1975) take the view that the role of infrastructure is simply to relieve "tensions" generated by supply and demand patterns as well as bottleneck pressures scattered throughout the region. Another (smaller) group of economists[1] maintain that alterations in infrastructure exert a follow-on influence on regional macroeconomic and social processes. Thus autonomous or induced changes in the stock of infrastructure produce external effects in the area serviced.

The majority of economists seem to take a middle position between these two more or less diametrically opposed views. Some of them consider infrastructure to be a function of the level of socio-economic development;

in other words, the more economically and socially backward a potential development region, the stronger the impulses emanating from improvements in the stock of infrastructure. Others feel that the reciprocal relationship between changes in infrastructure and socio-economic development is such that the problem of cause and effect is not open to solution.

However, most economists agree that if infrastructure investments, labour market planning, and educational planning are unconnected they are likely to yield conflicting results or, at any rate, outcomes that could eventually lead to undesirable situations. Much of the confusion as to the role of infrastructure in regional development occurs because infrastructure itself is not homogeneous. In addition, it is quite likely that within any one country the contribution to output from infrastructure investment will be dependent on the stock of supporting factors—the composition and level of which are likely to vary considerably from region to region.

A balanced approach toward the role of infrastructure in regional development must be more disaggregated than the usual capital/output approaches, and yet at the same time be more aggregative than the micro-cost–benefit analysis often championed by some of the leading lending agencies. An approach that seems to fit these requirements was developed several years ago by HANSEN (1965a) but as yet remains untested.

THE HANSEN THESIS

Hansen suggests two alternative approaches that the government might take to promote economic development. On the one hand is a policy of balanced growth whereby many interdependent public investment projects are started simultaneously. As HANSEN (1965a, p. 3) notes "the principal justification for such action is based on the phenomenon of external economies". On the other hand, the government can pursue a policy of unbalanced growth where only a few projects are initiated, and "the key sectors would be determined by measuring the backward-linkage and forward-linkage effects in terms of input–output maxima" (HANSEN, 1965a, p. 4). As HIRSCHMAN (1958, pp. 62–63) noted development occurs:

> "... with growth being communicated from the leading sectors of the economy to the followers, from one firm to another.... The advantage of this kind of... advance over 'balanced growth,' where every activity expands perfectly in step with every other, is that it leaves considerable scope to *induced* investment decisions and therefore economizes our principal scarce resource, namely genuine decision-making."

By and large, Hansen favours economic development by means of the latter approach. In the first place, lesser developed countries can rarely afford the vast outlay of resources called for under the "big-push" programme. In addition unbalanced growth has been:

> "... the characteristic pattern of development which mature economies have in fact followed and because it is generally the most feasible approach from an institutional point of view. More important, it is also the most rational from a purely economic point of view" (HANSEN, 1965a, p. 5).

In order to implement such a policy, Hansen diaggregates infrastructure investment into two types: economic overhead capital (EOC) and social overhead capital (SOC). The former is "primarily oriented toward the support of directly productive activities or toward the movement of economic goods" (HANSEN, 1965b, p. 15). EOC consists of, for example, roads and other transportation systems, electricity and water supply, bridges, harbours, drainage and sewer systems, and irrigation systems. On the other hand SOC is designed to enhance human capital and consists of such things as education, public health facilities, fire and police protection, and homes for the aged.

To help eliminate regional economic imbalances, Hansen suggests that the appropriate investment—either EOC or SOC or both—will depend on the economic characteristics of recipient regions. Regions are classified into three broad categories: congested, intermediate and lagging. Congested regions are "characterized by very high concentrations of population, industrial and commercial activities, and public overhead capital" (HANSEN 1965a, p. 5). While standards of living are relatively high in congested regions, any marginal social benefits which might accrue from further investment would be less than the marginal social costs of pollution and congestion. Intermediate regions are characterized by an environment conductive to further economic activity—an abundance of well-trained labour, cheap power and raw materials. It is presumed that economic activity located in the area would lead to marginal social benefits greater than marginal social costs.

The economic situation of lagging regions offers little to attract new firms. Standards of living are low and current economic activity is either in small-scale agriculture or in stagnant or declining industries.

In addition, the appropriate investment strategy in each region depends on a time factor (Table 1). In phase 1, congested regions are characterized by too much EOC and SOC, and concomitant DPA. In phases 2 and 3, controls are placed on further expansion of economic activity in the region. Furthermore, the government can actively encourage decentralization by locating its own agencies in intermediate or lagging regions.

In phase 1, intermediate and lagging regions are deficient in EOC and SOC, respectively. With regard to the intermediate region, HANSEN (1965a, p. 11) notes that "... it is reasonable to assume unbalanced growth will be generated by excess EOC capacity". This will induce DPA and in turn further EOC. As optimal levels of EOC and DPA are reached, SOC is induced (phase 3). For the lagging regions, initial excess EOC capacity is not justified as more profitable alternatives exist in the intermediate regions. As HANSEN (1965a, p. 12) notes moreover:

> "The SOC needs of lagging regions are relatively great and their SOC equipment is the least well developed; thus marginal productivity considerations would favor concentrating SOC in lagging regions rather than in areas well equipped in this regard. Insofar as possible, public outlays should aim at adapting the population for employment in activities with substantial prospects for future expansion."

However, after the initial SOC investments, Hansen suggests a policy of balanced growth (phase 3), primarily designed to stem large out-migration of persons who benefited from the initial SOC. Such policy measures include balanced growth of EOC, SOC and DPA, the stimulation of saving and its investment locally, and the transfer of government agencies to these areas.

PREVIOUS STUDIES

Empirical research on the use of EOC and SOC investments to promote regional growth is scant.[2] Most of the work in this area has been concerned with identifying the determinants of infrastructure investment, and not the effects of the investment on regional income. In other words, infrastructure has been considered the dependent rather than the independent variable in the statistical analyses. HANSEN (1965b) found that for the communities of East Flanders, Belgium, variations in *per capita* EOC expenditures were explained by differences in various growth factors such as changes in housing density. Variations in SOC investments among the communities were explained by several static factors, such as population density. In a cross-country study of 113 countries, GLOVER and SIMON (1975) established that population density and *per capita* income were significant determinants of road building. SIMON (1975) found in a further cross-country study the positive

Table 1. Regional growth under conditions of induced public investment (phase 1) and excess capacity of public overhead capital (phases 2 and 3)

Phase	Type of region	Nature of public and private investment activity
1	Congested	Overexpanded OC* and DPA
	Intermediate	Deficient EOC
	Lagging	Deficient SOC
2	Congested	Public controls on expansion of DPA and concomitant OC
	Intermediate	Excess EOC capacity
	Lagging	Excess SOC capacity
3	Congested	Public controls on expansion of DPA and concomitant OC
	Intermediate	EOC and DPA approach optimal levels, inducing SOC expansion
	Lagging	Balanced growth of SOC, EOC and DPA

Source: HANSEN (1965a, p. 13).
*Overhead capital.

effect population density had on agricultural savings in irrigation systems. FREDERIKSEN (forthcoming) confirmed the findings of these cross-country studies for a single country in a cross-province analysis of the Philippines. Population density and *per capita* income were both found to be significant determinants of electrification.

While these studies have undoubtedly contributed to the literature, the major policy implication of Hansen's hypothesis remains untested, i.e. can deliberate changes in various types of infrastructure have significant regional effects on income levels within a developing country. The design of any test to examine this point should thus concentrate on the following questions:

(1) Are the current disparities in regional income within a developing country attributable to differences in the stock of infrastructure?
(2) Can altering the stock of infrastructure serve as a permanent means of reducing regional disparities?
(3) Can one be relatively certain as to the cause and effect relationship between infrastructure and regional income, and is this relationship likely to hold for the foreseeable future?

The remainder of this paper examines these questions in the context of Mexico.

SELECTION OF MEXICO

To test statistically for the regional impact of infrastructure on income levels and to test the further question of causality, the 32 states of Mexico were examined. Several reasons exist for the selection of Mexico.

In the first place, an examination of Mexico's spatial pattern of development indicates that not only do levels of regional income differ greatly but also that during the 1960s (and presumably the 1970s) the gap between the richer and poorer regions has been increasing.[3] It is the goal of the Mexican government to reduce these income disparities. Thus, Mexico presents an interesting case study in the context of the three questions posed earlier to examine whether part of the existing income differentials between the states can be attributed to different levels of infrastructure, and to examine the possibilities of using infrastructure investments in the future to narrow the gap between the states.

Second, in many cases the uncertainty over the contribution of infrastructure to regional growth stems from the absence of data required for econometric analysis. Even where data are available, the number of regions or states distinguished is either insufficient to allow the required sample size necessary for the appropriate statistical tests, or the data exist for only one point in time. This is not the case for Mexico. Not only does the required regional detail exist for 32 states, but it is available in Census form for several points in time.

Third, following an examination of several economic indicators for each state in 1970, it appears that in 1970 Mexico was in Hansen's phase 1. If this is the case, we should then expect to find that the impacts of EOC and SOC investments to have been different between the states. Finally the states of Mexico appear to fall into the three groups as suggested by Hansen. This is in contrast with many other countries of the world (for example, Peru, Chile and Thailand) where practically no intermediate regions exist. The capital city is the congested region, and the remainder of the country can be considered as lagging.

While a more detailed examination of our statistical procedure for grouping the states appears later, we have considered the Distritio Federal (Mexico City) to be typical of a congested region. As TORRES (1976, p. 131) notes:

> "Some 60 percent of all manufacturing is centered in this area, and more than 70 percent of certain branches: textiles, publishing, rubber goods, chemical products, metallic products, electrical and non-electrical machinery, and transportation equipment. . . . Additionally, its role as supplier of services, encompassing the major part of public administration and enterprises providing special services, and as center of higher education and research, financial activities and tourism, is of paramount importance."

At the other end of the spectrum are the depressed, or lagging, regions. These regions are located in the south (as typified by Oaxaca, Guerrero, Chiapas, Yucatan, Campeche and Quintana Roo), the overflow zone of Mexico City (such as Tlaxcala and Hidalgo) and the north-central part of Mexico (for example Zacatecas, San Luis Potosi and Durango). These states are characterized by low levels of income, and very little growth of income since 1940. In addition, agriculture in these regions is generally at subsistence levels, unemployment and underemployment are high, the terrain to a large extent is inhospitable for economic activity, and the urban structure is incipient.

Typical of the intermediate regions are the largest industrial centres outside Mexico City (Nuevo Leon and Jalisco) and the commercial, agricultural and U.S. border regions in the north and north-west part of the country (Baja California Norte, Sonora, Sinaloa and Chihuahua, for example). Characteristic of these regions are large industrial bases, large urban service sectors, well-advanced education and health levels, and large positive migration flows over time in response to increased employment opportunities.

EMPIRICAL METHODOLOGY AND RESULTS

The methodology used to examine the quantitative impact of infrastructural investment on patterns of Mexican regional income consisted of three steps. First, the states of Mexico were statistically grouped into an intermediate group and a lagging group using cluster analysis and discriminant analysis. Second, linear equations were estimated using regression analysis to test whether the stocks of different kinds of infrastructure were statistically significant in explaining differences in income within each group. Third, a two-stage least-squares procedure was employed to examine the question of causality between infrastructure and income. In other words does infrastructure cause income differentials, or do income differentials prompt the government expenditure on infrastructure?

The Hansen thesis is not completely specific as to its operational application. For example, using *per capita* income to group the states, no clear delineation emerges between an intermediate and lagging group. Certain states, such as Veracruz and Mexico, could logically be classified in either group. When different measures of development are used, other than *per capita* income, the ranking of states will often change. For example, MENDOZA-BUERRUETO (1968) constructed an index of development for the Mexican states based on a set of social variables including urban population, population using shoes or sandals, population regularly eating wheat bread, literacy, and population living in houses with sewage disposal. He then compared the ranking by this index with the ranking by *per capita* GDP. Not only does the ranking change between measures, but the constructed index also fails to delineate between intermediate and lagging groups. To avoid a purely judgemental grouping, a statistical decision rule based on cluster analysis was applied as the basis of a regional classification.

Regional grouping by cluster analysis

Through an examination of the characteristics of each state, cluster analysis groups states on the basis of their similarity or "closeness" with one another. The regional attributes used in the cluster analysis were to a large degree selected on the basis of availability in the Census and to conform with descriptions given by Hansen of intermediate and lagging regions. Data were for 1970 and included: (1) per cent of population in urban areas (cities over 20,000); (2) per cent of population regularly consuming milk; (3) value of sales per worker in industry; (4) per cent of work force classified as non-labourers; (5) per cent of houses with electricity; (6) per cent of houses with piped water; and (7) per cent of population with six or more years of education.

The results of the cluster analysis (Table 2) are intuitively satisfactory, and generally conform to the findings of others (TORRES, 1976; JAMES, 1978). the sharp delineation between the groups is indicated by the differences in the mean values of the seven factors. With the cluster analysis grouping used as the initial classification of regions, a discriminate analysis was employed to determine the probability of correct grouping. The probability of correct grouping (last column of Table 2) was over 90% for every state except Mexico which was 63.98%. When the GDP of each state was added as an eighth variable, the groupings remained unchanged.

A three-group cluster analysis was also conducted. In this case the lagging group remained the same, but the intermediate group split into: (1) Baja California Norte, Baja California Sur, Sonora, Coahuila, Tamaulipas and Nuevo Leon; and (2) Aguascalientes, Jalisco, Mexico, Chihuahua and Sinaloa. The means between these groups were quite close, which indicated a division of the intermediate group into relatively more affluent and less affluent groups. Both of these groups appeared to fall within the Hansen intermediate classification, and therefore the intial two-group classification was adopted for the regression analysis.

Regression analysis results

Using the two groups as delineated by the cluster analysis, the impact of infrastructure

Table 2. Regional grouping (two-group specification) based on socio-economic indicators, 1970

	Per cent population in urban areas over 20,000	Per cent regularly consuming milk	Value of sales per worker in industry (millions of pesos)	Per cent work force non-labourers	Per cent houses with electricity	Per cent houses with piped water	Per cent population with 6 yr or more education	Probability of correct grouping
Intermediate group								
Aguascalientes	53.6	69.9	113.0	22.0	65.0	78.0	15.0	0.9665
Chihuahua	52.4	73.1	122.0	23.5	62.0	66.0	16.0	0.9882
Jalisco	45.8	75.3	135.0	23.4	64.0	66.0	12.0	0.9725
Mexico	21.0	59.7	126.0	21.7	62.0	63.0	12.0	0.6398
Sinaloa	30.1	70.5	145.0	19.9	53.0	51.0	12.0	0.9946
Baja California Norte	76.8	81.7	205.0	31.7	79.0	67.0	17.0	1.0000
Baja California Sur	35.9	76.7	181.0	24.6	47.0	62.0	15.0	1.0000
Sonora	51.0	73.4	201.1	26.7	64.0	68.0	16.0	1.0000
Coahuila	57.5	71.9	149.0	25.0	73.0	73.0	18.0	0.9999
Tamaulipas	59.6	72.8	148.0	25.6	64.0	66.0	16.0	0.9987
Nuevo Leon	58.1	82.6	175.0	30.9	78.0	81.0	21.0	1.0000
Mean	49.3	73.4	154.5	25.0	64.6	67.4	15.5	0.9600
Lagging group								
Campeche	41.4	55.9	73.0	19.1	55.0	48.0	11.0	0.9998
Michoacan	22.6	53.4	70.0	13.9	49.0	52.0	6.0	1.0000
Quintana Roo	26.9	62.1	66.0	16.6	47.0	40.0	7.0	1.0000
Durango	24.5	57.3	83.0	16.1	47.0	53.0	12.0	0.9789
Nayarit	23.2	60.2	80.0	16.0	58.0	47.0	9.0	0.9975
Coliña	46.0	69.5	87.0	20.5	58.0	78.0	12.0	0.8986
Morelos	21.8	57.7	90.0	19.8	65.0	67.0	11.0	0.9858
Chiapas	12.6	42.4	83.0	10.7	30.0	38.0	5.0	1.0000
Zacatecas	12.1	46.0	90.0	12.5	33.0	43.0	7.0	0.9997
Hidalgo	10.0	37.8	89.0	12.7	38.0	48.0	7.0	0.9999
Queretaro	23.3	39.3	89.0	15.9	37.0	51.0	7.0	1.0000
San Luis Potosi	23.9	47.8	86.0	15.5	41.0	45.0	9.0	0.9997
Guerrero	17.7	48.7	95.0	12.5	37.0	38.0	5.0	0.9998
Tabasco	13.0	49.9	105.0	15.0	32.0	34.0	8.0	0.9984
Quanajuato	32.7	53.3	101.0	15.9	51.0	56.0	8.0	0.9947
Veracruz	25.6	58.2	105.0	17.1	49.0	51.0	10.0	0.9494
Puebla	22.3	39.1	99.0	15.6	48.0	48.0	10.0	0.9988
Yucatan	28.0	47.2	99.0	17.6	53.0	42.0	7.0	0.9999
Oaxaca	7.5	31.7	56.0	9.3	28.0	35.0	5.0	1.0000
Tlaxcala	5.0	35.9	42.0	12.2	64.0	48.0	12.0	1.0000
Mean	22.0	49.7	84.4	15.2	46.0	48.1	8.4	0.9900

Sources: Secretaria de Industria y Comercio (1975) and Secretaria de Industria y Comercio (1973).

on regional income was tested by means of multiple regression analysis. A production function was estimated for the intermediate and lagging groups in the following form:

$$GDP = a + b_1 POP_i + b_2 AGCAP_i + b_3 FIRMS_i + b_4 INFRA_i + E_i;\ b_1, b_2, b_3, b_4 > 0; \qquad (1)$$

where i represents the individual state, *GDP* the Gross Domestic Product, *POP* the economically active population, *AGCAP* the capital (in 1950 pesos) in agriculture, *FIRMS* the number of large firms (employing six or more workers), *INFRA* the measure of infrastructure, and E_i the error term having the traditional statistical assumptions.[4] The equations are estimated for 1970. Ideally, the specification of the production function for the two groups should have included a measure for the total private capital stock in each state. Unfortunately no such measure is reported. *AGCAP* is included in the equation to capture part of the total capital stock, and *FIRMS* is included as a proxy measure for the remaining part of private capital stock. Based on Hansen's work, it is hypothesized that EOC infrastructure will have a statistically significant and positive effect on GDP in those states which comprise the intermediate region. On the other hand, it is hypothesized that SOC infrastructure will have a statistically significant and positive effect on GDP in those states which are classified as lagging. Furthermore, we should expect SOC to have little or no impact on GDP in intermediate regions.

The various EOC measures examined are the length of public telephone lines (*PTL*), the electrical generating capacity (*ELEC*), surfaced road density (*SURF*), and surfaced and earth road density (*RDS*).[5] The various SOC measures examined are the number of doctor's offices (*DOCOFF*), the number of medical emergency facilities (*MEDEMER*), the number of kindergartens (*KINDER*), the number of hospitals (*HOSP*), and the number of primary schools (*PRIM*).[6]

The results of the regression analyses for the intermediate and lagging groups appear as Tables 3 and 4, respectively. As indicated earlier, the infrastructure variable was entered into the regression as the last variable. This was done to determine, at the margin, whether infrastructure contributed significantly to the improvement of the R^2-value given that *POP*, *AGCAP* and *FIRMS* had already been taken into account. The value which appears in parentheses under the estimated coefficient is the square root of the partial *F*-value, or the "*t*"-statistic.[7]

Table 3. Regression results of the impact of infrastructure investment on GDP, intermediate group, 1970

	a	*POP*	*AGCAP*	*FIRMS*	*INFRA*	R^2
Economic overhead capital						
Public telephone	−0.9	0.08	0.06	0.03	0.02	0.99
lines (*PTL*)		(17.5)‡	(2.3)*	(5.5)‡	(9.4)‡	
Electrical generating	0.4	0.04	0.02	0.04	2.81	
capacity (*ELEC*)		(12.7)‡	(1.3)	(3.9)‡	(7.8)‡	0.98
Surfaced road	−3.6	0.004	0.05	0.01	148.97	
density (*SURF*)		(5.8)‡	(0.8)	(1.8)	(2.1)*	
Surfaced and earth road	−4.1	−0.003	0.06	0.13	129.49	0.88
density (*RDS*)		(6.0)‡	(0.8)	(1.9)	(2.3)*	
Social overhead capital						
Doctor's offices (*DOCOFF*)	0.02	0.1	0.03	0.01	7.56	0.79
		(4.5)‡	(0.6)	(1.4)	(0.5)	
Medical emergency	1.0	0.09	0.03	−0.01	0.06	0.84
facilities (*MEDEMER*)		(5.1)‡	(0.7)	(1.6)	(1.4)	
Kindergartens (*KINDER*)	−1.5	0.06	0.03	0.05	0.03	0.82
		(4.8)‡	(0.6)	(1.5)	(1.0)	
Hospitals (*HOSP*)	−0.3	0.15	0.12	0.09	−0.03	0.80
		(4.6)‡	(0.6)	(1.4)	(0.7)	
Primary schools (*PRIM*)	0.4	0.25	−0.001	0.08	−6.19	0.94
		(8.3)‡	(1.1)	(2.6)†	(3.9)‡	

*Significant at the 90% level of confidence.
†Significant at the 95% level of confidence.
‡Significant at the 99% level of confidence.

Table 4. Regression results of the impact of infrastructure investment on GDP, lagging group, 1970

	a	*POP*	*AGCAP*	*FIRMS*	*INFRA*	R^2
Economic overhead capital						
Public telephone lines (*PTL*)	−1.5	0.01 (10.7)‡	0.09 (2.6)†	0.14 (3.7)‡	−0.003 (0.6)	0.90
Electrical generating capacity (*ELEC*)	−1.5	0.02 (10.7)‡	0.08 (2.6)†	0.13 (3.7)‡	−0.12 (0.4)	0.90
Surfaced road density (*SURF*)	−1.7	0.01 (10.9)‡	0.06 (2.6)†	0.14 (3.7)‡	16.3 (0.9)	
Surfaced and earth road density (*RDS*)	−1.7	0.004 (10.9)‡	0.06 (2.6)†	0.15 (3.7)‡	10.28 (0.9)	0.90
Social overhead capital						
Doctor's offices (*DOCOFF*)	−1.3	0.005 (12.9)‡	0.02 (3.1)‡	0.01 (4.4)‡	18.7 (2.7)†	0.93
Medical emergency facilities (*MEDEMER*)	−1.8	0.02 (12.7)‡	0.12 (3.1)†	0.03 (4.4)‡	0.10 (2.6)†	0.93
Kindergartens (*KINDER*)	−1.4	−0.01 (12.2)‡	0.04 (2.9)†	0.13 (4.2)‡	0.01 (2.2)†	0.92
Hospitals (*HOSP*)	−2.5	−0.01 (13.5)‡	0.11 (3.2)‡	0.09 (4.6)‡	0.02 (3.0)‡	0.94
Primary schools (*PRIM*)	−1.2	−0.08 (14.1)‡	0.05 (3.4)‡	0.13 (4.8)‡	2.19 (3.4)‡	0.94

†Significant at the 95% level of confidence.
‡Significant at the 99% level of confidence.

The results which appear in Tables 3 and 4 are quite satisfactory, and go a long way to support the Hansen hypothesis. The coefficients of each EOC measure examined in Table 3 are statistically significant (at the 90% level or above) in explaining the within-group variation in GDP in the intermediate group of states. At the same time, none of the SOC measures examined are statistically significant in explaining differences in income. In the case of primary schools, the estimated coefficient is negative and highly significant. In each equation in Table 3 (and Table 4) the population variable is statistically significant at the 99% level of confidence.[8] In all cases but one, the *AGCAP* variable is not statistically significant for the intermediate group, and the *FIRMS* variable is statistically significant only in the *PTL*, *ELEC* and *PRIM* equations.

With respect to the infrastructure variables in the lagging regions (Table 4), the results are the opposite—once again lending support to the Hansen thesis. None of the coefficients of the EOC variables are statistically significant in explaining variations in regional income, while all the coefficients of the SOC variables are statistically significant at the 95% level or above. In this group, the coefficients of *AGCAP*. and *FIRMS* are statistically significant in each case.[9]

Several other measures of infrastructure—earth road density and length of telegraph lines (EOC), and the number of hospital beds (SOC)—were tested but were found not to be statistically significant in either group. Despite this however, we feel that the earlier results lend credence to the thesis that regional differences in income can be lessened (or that regional growth can be enhanced) if policy makers consider the specific type of public investment applicable to each region. Naturally, more research needs to be devoted to the topic especially in the way in which the infrastructure variables are specified.[10]

TEST FOR CAUSALITY

As noted earlier, there has been continuing controversy in the literature over the causation between infrastructure and income levels. Simply for convenience, but also based on our interpretation of the process of Mexico's regional development patterns, infrastructure was treated earlier as an exogenous variable. To examine this assumption additional regressions were estimated with 1970 infrastructure as the dependent variable in the following form:

$$INFRA_{i,1970} = a + b_1 POPDEN_{i,1960} + b_2 OUT_{i,1960} + b_3 INFRA_{i,1960} + E_i, \quad (2)$$

where *POPDEN* is the population density, *OUT* is the output *per capita*, and *INFRA* is the respective infrastructure variable (all for 1960).[11] The equations were estimated for the EOC variable for the intermediate group and the SOC variables for the lagging group. Using these equations, an estimated value for each infrastructure measure was calculated for 1970. This instrumental variable was then included in equation (1) in place of the actual 1970 value. The results of this two-stage procedure appear as Table 5. These results tentatively confirm the direction of causality assumed by Hansen, and do not, other than slightly lowering the "*t*"-statistics, deviate from the original equations as presented in Tables 3 and 4.

SUMMARY AND CONCLUSIONS

The primary purpose of this paper has been to evaluate the hypothesis that regional impacts on income will differ depending on the type of infrastructure investment. It has been hypothesized by Hansen that EOC investment will have a significant impact on income levels in regions classified as intermediate, while SOC investment will have a significant impact on income levels in lagging or underdeveloped regions. As an initial step, the states of Mexico were classified into these two groups by means of cluster analysis. A discriminant analysis lent support to this classification. The Federal District was assumed to fall into Hansen's third category of a congested region. Production functions were estimated to test the earlier hypothesis that within-group differences in income could be attributed to selected types of infrastructure investment. The infrastructure variable was included as the fourth independent variable following population, agricultural capital, and the number of large firms. The results of this analysis tentatively confirm the application of the Hansen hypothesis to Mexico. Each measure of EOC examined was statistically significant in explaining variations in GDP in the intermediate group of states, but was not significant in the lagging group. On the other hand, each SOC measure was statistically significant in explaining differences in income among the lagging group, but not significant in the intermediate group. There were several measures of EOC and SOC that were not statistically significant in either group.

As an additional step, the direction of causality between infrastructure and income

Table 5. Regression results, two-stage procedure, of the impact of infrastructure on GDP, intermediate and lagging groups, 1970

	a	*POP*	*AGCAP*	*FIRMS*	*INFRA*	R^2
Intermediate group (EOC)						
Public telephone lines (*PTL*)	−0.5	+0.08	+0.05	+0.03	+0.02	0.95
		(9.3)‡	(1.2)	(2.9)†	(4.6)‡	
Electrical generating capacity (*ELEC*)	−0.3	+0.04	+0.01	+0.05	+2.64	0.96
		(9.7)‡	(0.96)	(3.0)†	(5.8)‡	
Surfaced and earth road density (*RDS*)	−3.9	+0.008	+0.07	+0.12	+120.9	0.88
		(5.9)‡	(0.8)	(1.8)	(2.2)*	
Surfaced road density (*SURF*)	−2.6	+0.04	+0.06	+0.10	+110.92	0.85
		(5.3)‡	(0.7)	(1.7)	(1.6)	
Lagging group (SOC)						
Doctor's offices (*DOCOFF*)	−1.9	−0.0007	+0.11	+0.10	+8.01	0.92
		(11.9)‡	(2.9)†	(4.1)‡	(1.9)*	
Medical emergency facilities (*MEDEMER*)	−1.8	+0.03	+0.11	+0.09	+0.06	0.92
		(12.2)‡	(2.9)†	(4.2)‡	(2.2)†	
Kindergartens (*KINDER*)	−1.5	−0.004	+0.06	+0.13	+0.01	0.91
		(11.4)‡	(2.8)†	(3.9)‡	(1.5)	
Hospitals (*HOSP*)	2.82	−0.005	+0.13	+0.10	+0.02	0.92
		(12.1)‡	(2.9)†	(4.1)‡	(2.1)*	
Primary schools (*PRIM*)	−1.3	−0.07	+0.05	+0.13	+1.93	0.94
		(14.0)‡	(3.4)‡	(4.8)‡	(3.3)‡	

*Significant at the 90% level of confidence.
†Significant at the 95% level of confidence.
‡Significant at the 99% level of confidence.

levels was tested by means of a two-stage procedure. This procedure indicated that infrastructure appears to be the initiating factor in the development process, rather than the passive or accomodating factor. This result is in accord with Hansen. It is also consistent with numerous statements and reports issued by the Mexican authorities.

These results have several policy implications. First, a major objective of the Mexican government in the last 30 yr has been to maximize economic growth. This policy has led to increased regional disparities of income. To a certain extent this was inevitable, as the productivity of private-sector investment increased more rapidly in the modern sectors of the economy than in the more traditional sectors. In addition, the modern sectors are regionally concentrated. Our results indicate that, contrary to popular belief in Mexico, the country need not necessarily accept a lower rate of national growth in order to minimize regional disparities. Rather, the results suggest that by concentrating EOC expenditures in intermediate regions and SOC expenditures in lagging regions, the implicit trade-off between growth and minimizing differences in income need not exist.

Second, the indicated appropriate regional expenditure policy might possibly be a more practical—and politically feasible—way to redistribute income than alternative ways such as land reform or tax reform. Third, as oil revenues to Mexico increase in the future, it is quite likely that the number of requests and proposals for public investment projects will increase dramatically. Thus, the Mexican government will need to adopt different and more efficient criteria to allocate revenues. At a minimum, the results obtained in this paper could conceivably be used as the initial screening device for these competing public-sector projects.

The generality of these conclusions—especially in light of the small sample size—can only be determined by further research. This research should be directed to an examination of the experience of other developing countries, at all phases in Hansen's thesis, and at the same time to other measures of infrastructure.

NOTES

1. VOIGH (1974) is the leading advocate of this view.
2. [illegible]
3. Specifically, median monthly earnings in Baja California (803 pesos) which was the nation's highest in 1960 were four times as great as median monthly earnings in Queretaro (197 pesos) which was the nation's lowest. By 1970, the range from the state with the highest earnings (Baja California) to that of the lowest (Oaxaca) had increased to a factor of almost seven (1333 compared to 188 pesos). Measured across the nation's 32 states, the Gini coefficient of median earnings increased from 0.40 in 1960 to 0.48 in 1970. See GREENWOOD (1978, p. 18). 1960 state median earnings were calculated from data presented in SECRETARIA DE INDUSTRIA Y COMERCIO (1972).
4. *GDP* (1969) from INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT (1973, p. 100), *POP* from SECRETARIA DE INDUSTRIA Y COMERCIO (1973, Table 226), *AGCAP* from UNIKEL (1972, Table VI-A2), and *FIRMS* from SECRETARIA DE INDUSTRIA Y COMERCIO (1975, pp. 89–90). All data sheets can be obtained from authors on request.
5. *PTL*, *ELECT* and *SURF/RDS* from SECRETARIA DE INDUSTRIA Y COMERCIO (1973, pp. 572, 506 and 574, respectively). The specification of the two road density variables was suggested by research in FREDERIKSEN and LOONEY (1980).
6. *DOCOFF*, *MEDEMER*, *KINDER*, *HOSP* and *PRIM* from SECRETARIA DE INDUSTRIA Y COMERCIO (1973, pp. 189, 189, 220, 186 and 224, respectively).
7. The partial *F*-test is a test for the statistical significance of the additional contribution in explaining the variation of the dependent variable that is gained by adding the particular variable to the model. See POLSTER (1978, p. 540).
8. However the sign of the *POP* coefficient in several of the equations in Tables 3 and 4 is negative, despite the "*t*"-statistic always having a value greater than 4.0. This is because the "*t*"-statistic (computed as the square root of the partial *F*-value) is calculated incrementally, i.e. *POP* is the only independent variable in the regression equation at that time. The correlation coefficient between *POP* and *GNP* is 0.82 and 0.86 for the intermediate and the lagging groups, respectively. Thus the negative sign indicates some multicollinearity between independent variables. As mentioned earlier however, our interest lies primarily in the partial *F*-value of the infrastructure variable when entered into the equation as the last independent variable.
9. While not shown the overall *F*-value in every equation in both tables is statistically significant at the 99% level.
10. For example, Hansen specifically mentions such things as harbours and playgrounds. Even if the data were available, we are unsure as to how to specify the variable in any statistical analysis.
11. *POPDEN* calculated from SECRETARIA DE INDUSTRIA Y COMERCIO (1963), *OUT* from UNIKEL (1972, Table 7-83), and the respective 1960 infrastructure measures from SECRETARIA DE INDUSTRIA Y COMERCIO (1963). Because 1960 measures of *HOSP*, *MEDEMER* and *DOCOFF* were unavailable, a proxy measure—the number

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