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An Analysis of the Optimal Provision of Public Infrastructure:  
A Computational Model Using Mexican Data

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Abstract

An intertemporal general equilibrium model is used to examine infrastructure effects on the Mexican national income. Production functions are estimated for the major sectors of the economy in which sectoral output depends on inputs of capital and labor, as well as the stocks of the public infrastructure. The analysis indicates that despite high estimated output elasticities with respect to public infrastructure, increased expenditure on infrastructure has rapidly decreasing benefits. Some benefits could be achieved by modest increases in capital expenditures, although at the cost of significantly higher inflation and real interest rates. The increase in real interest rates causes these benefits to be greatly reduced.

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H54, H62

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Summary

This paper presents a simple intertemporal general equilibrium model used to examine the impact of public expenditure on infrastructure in the Mexican economy. It considers three types of infrastructure: electricity, transportation, and communication. It then estimates production functions for the 16 major sectors of the economy in which sectoral output depends on inputs of capital and labor, as well as the stocks of the three types of infrastructure.

Three separate numerical simulations of the estimated model are carried out, designed to analyze the effect of increasing expenditure on infrastructure. The paper concludes that relatively small increases in real spending on public infrastructure may be beneficial to the real economy, but at the cost of increased inflation. Also, the welfare benefits are not uniformly distributed, since income derived from the enhanced productivity of private capital is not uniformly distributed. A large increase in infrastructure spending, on the other hand, has generally negative implications for the economy, primarily because of its impact on real interest rates. This conclusion might be different in an economy with significant infrastructure shortages, such as some economies in South East Asia. The results of the analysis suggest that any increases in public capital spending must be carried out with considerable care.

1. The first part of the paper discusses the importance of the study of the history of the United States. It is argued that the study of the history of the United States is essential for a full understanding of the country and its people. The paper then discusses the various methods used by historians to study the past, including the use of primary and secondary sources, and the importance of critical thinking in the study of history.

2. The second part of the paper discusses the role of the federal government in the development of the United States. It is argued that the federal government has played a central role in the development of the country, and that its actions have shaped the course of American history. The paper then discusses the various policies and programs of the federal government, and the impact of these policies on the country.

3. The third part of the paper discusses the role of the states in the development of the United States. It is argued that the states have played a central role in the development of the country, and that their actions have shaped the course of American history. The paper then discusses the various policies and programs of the states, and the impact of these policies on the country.

4. The fourth part of the paper discusses the role of the people in the development of the United States. It is argued that the people have played a central role in the development of the country, and that their actions have shaped the course of American history. The paper then discusses the various policies and programs of the people, and the impact of these policies on the country.

5. The fifth part of the paper discusses the role of the economy in the development of the United States. It is argued that the economy has played a central role in the development of the country, and that its actions have shaped the course of American history. The paper then discusses the various policies and programs of the economy, and the impact of these policies on the country.

## Introduction

How much infrastructure should a government provide? This question is clearly of considerable interest at present in the United States. It has, in reverse, been of concern to policy makers in a variety of countries undergoing stabilization programs. It is often determined that the easiest way to reduce public expenditure is to cut capital spending. There is no need to drastically cut public payrolls, as would be the case if civil service employment or wages were reduced. Indeed, the costs, if any, of reduced formation of infrastructure are usually not felt for some time.

Mexico is an extreme case of government reduction in public investment. As indicated by Table 1, public investment fell from 12.1 percent of GDP in 1981 to 4.2 percent of GDP in 1989. At the same time we observe a marked slowdown in economic growth. Real GDP, which grew by 8.8 percent in 1981 grew by only 1.1 percent in 1988, all while private investment remained approximately constant as a percentage of GDP. Is it possible that there is a connection between the stagnation of Mexican income and the decline in investment in public infrastructure?

Table 1. Mexico: Real Economic Indicators

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Real GDP <u>1/</u>	8.4	8.8	-0.6	-0.4	3.6	2.6	-3.8	1.5	1.1	3.2	3.9
Public Capital formation <u>2/</u>	10.6	12.1	10.2	6.6	6.6	6.5	6.5	5.5	4.4	4.2	5.2
Private Capital formation <u>2/</u>	14.1	14.3	12.8	11.0	11.3	12.6	12.9	13.1	13.1	13.3	13.5

Source: IMF and World Bank.

1/ Annual percentage change.

2/ As a percent of GDP.

It is, of course, difficult to draw conclusions from a category as broad as public capital formation. Table 2 shows the stock of capital in three key types of infrastructure, electricity and gas, transportation, and communications. We see that there have been dramatic changes in rates of growth of all three over the past 20 years. Thus, for example, from 1970 to 1980 the stock of capital in electricity and gas grew by 12.8 percent per year. From 1980 to 1990 the corresponding rate of growth was only 0.3 percent annually. In fact, the stock of electricity and gas infrastructure has declined from 1981 to 1990. The stock of capital in transportation grew by 8.7 percent from 1970 to 1980 and by only 3.5 percent from 1980 to 1990. Similarly, communications capital grew by 49.8 percent annually from 1970 to 1980 and by 4.1 percent from 1980 to 1990.

Table 2. Stocks of Infrastructure, 1970-1990

(In millions of pesos at constant prices)

	Electricity	Transportation	Communications
1970	19,013.1	9,062.5	147.8
1971	22,285.4	9,562.9	153.6
1972	26,091.1	9,863.7	180.7
1973	30,141.8	10,066.8	218.2
1974	33,986.5	10,045.8	248.3
1975	37,846.9	12,244.8	1,398.7
1976	44,798.6	17,055.9	3,658.4
1977	46,669.3	18,495.8	5,524.5
1978	51,148.1	19,536.6	7,458.9
1979	55,761.8	20,368.6	9,137.7
1980	63,419.0	20,921.4	8,436.3
1981	70,175.4	22,809.5	10,342.3
1982	73,962.6	23,875.1	11,124.0
1983	73,587.9	24,511.5	11,276.7
1984	71,613.8	24,630.4	11,818.7
1985	69,216.9	25,213.3	12,471.3
1986	66,555.8	25,096.4	11,689.6
1987	64,195.5	26,583.0	11,975.3
1988	65,630.1	31,746.4	13,409.7
1989	65,340.5	30,763.4	12,769.1
1990	65,110.6	29,372.1	12,564.5

Source: *La Encuesta de Acervos, Depreciación y Formación de Capital del Banco de México*, (1992).

Our aim in this paper will be to develop a model that will permit us to analyze the extent to which inadequate levels of public infrastructure have contributed to slow economic growth. Feltenstein and Ha (1993, 1995) use a partial equilibrium model to estimate the income shortfall due to the decline in the stock of infrastructure. A key problem with the approaches taken in those papers is that prices are taken as given. Clearly prices should depend on the availability of infrastructure.

Infrastructure may either be publicly or privately provided. If the infrastructure is publicly provided, as was the case in Mexico until 1990, then changes in its rate of provision will have an effect on the government budget deficit. There will, accordingly, be corresponding changes in the domestic interest rate. Thus, for example, an increase in the public

provision of infrastructure may, initially, increase the productivity of private capital, leading to increases in output. The rise in interest rates caused by larger budget deficits may, however, damp private investment, leading to a less-than-expected eventual increase in private output.

Let us now turn to a model designed to analyze the connections between increased infrastructure and higher private output.

## 1. The model

In this section we will describe the formal structure of our model. It is intertemporal and with  $n$  discrete time periods, with an infinite time horizon future beyond the final period. There is disaggregation in production, as well as heterogeneous consumers. Infrastructure is provided by the public sector. We assume that the government intends for there to be a fixed exchange rate, but will allow the rate to vary depending upon its foreign reserve position. <sup>1/</sup>

All agents optimize in each period over a 2 period time horizon. That is, in period  $t$  they optimize given prices for periods  $t$  and  $t + 1$  and expectations for prices for the future after period  $t$ . When period  $t + 1$  arrives, agents reoptimize for period  $t + 1$  and  $t + 2$ , based on new information about period  $t + 1$ . Thus there may have been an unexpected change in the tax code, or an unanticipated financial insolvency, or a variety of other possible phenomena. Accordingly, only period  $t$  is actually realized if there is an unanticipated event in period  $t + 1$ . When the optimization is carried out for period  $t + 1$ ,  $t + 2$ , only period  $t + 1$  is actually realized, and so forth.

We will now describe the various components of our model. We will do so in a 2 period context, in order to simplify notation. Recall, however, that the model has  $n$  periods that are solved as a sequence of perfect foresight 2 period models.

### a. Production

We assume that intermediate and final production in period  $i$  is given by an  $N \times N$  input-output matrix,  $A_i$ . Value added in the  $j^{th}$  sector in time  $i$ ,  $va_{ji}$ , is given by a CES production function that uses inputs of capital and labor from that period, as well as the existing stocks of infrastructure. We will suppose that there are two types of labor, urban and rural. Rural labor is used in agriculture while urban labor is used in all other sectors of the economy. Sector-specific capital is used as the other factor input by each nonagricultural sector, while land is used by agriculture. Let  $y_{ki}^j$ ,

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<sup>1/</sup> This is similar to the specification of Feltenstein and Morris (1990) and Feltenstein (1992).

$y_{Li}^j$ , be the inputs of capital and labor to the  $j$ th sector in period  $i$ . Let  $Y_{Gni}$  be the outstanding stock of infrastructure of type  $n$  in period  $i$ .

The production of value added is then given by:

$$va_{ji} = va_{ji}(y_{Ki}^j, y_{Li}^j, Y_{G1i}, \dots, Y_{Gmi}) \quad (1)$$

Here we are supposing that there are  $m$  types of infrastructure. In our application to Mexico, we will use three types of infrastructure, transportation, electricity, and communications. It is assumed that sector  $j$  cost-minimizes with respect to capital and labor. Each sector pays value-added tax rates on inputs of capital and labor, given by  $t_{Ki}^j$ ,  $t_{Li}^j$ , respectively, in period  $i$ . Let  $P_{Ki}$  and  $P_{Li}$  be the prices of capital and labor in period  $i$ . 1/ The prices charged by enterprises,  $P_i$ , are given by

$$(P_i) = va(P, Y_{G1i}, \dots, Y_{Gmi}) (1 + t) (I - A_i)^{-1} \quad (2)$$

where  $va(P, Y_{G1i}, \dots, Y_{Gmi})$  is the vector of cost-minimizing nominal value added per unit of output, subject to  $P = (P_{Ki}, P_{Li})$  and  $Y_{Gi}$ , and  $t = (t_{Ki}^j, t_{Li}^j)$ . Hence  $va(P, Y_{G1i}, \dots, Y_{Gmi})(1+t)$  represents the vector of total cost of value added for each sector.

The private sector invests in capital, which is sector specific. Private investment is assumed to respond to anticipated future returns on each type of capital, as well as future interest rates. Suppose that  $H_i = H_i(y_{Ki}, y_{Li})$  is a neoclassical production function that produces capital using inputs of sectoral capital and labor, and which exhibits decreasing returns to scale. Let  $C_{Hi}$  be the cost minimizing cost of producing the quantity  $H_i$  of capital. It is assumed that this capital does not begin to yield a return until the period after which it is produced. Accordingly, if  $P_{Ki}$  is the price of capital in period  $i$  in the sector in question, and  $r_i$  the nominal domestic interest rate, then we must have:

$$C_{Hi} = \frac{P_{K(i+1)} H_i}{1+r_i} \quad (3)$$

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1/ Capital is sector specific and hence the price of capital will differ across sectors. We have not indicated the differing prices for different types of capital in order to avoid unreadable subscripts.



where  $r_i$  is the interest rate in period  $i$ , given by:

$$r_i = \frac{1}{P_{Bi}} \quad (4)$$

where  $P_{Bi}$  is the price of a bond in period  $i$ . Hence the level of private investment depends on both the current interest rate and the perfectly anticipated future return on capital. Government and private bonds are viewed as being identical. <sup>1/</sup>

The final productive agent in our model is the government. The government carries out current spending, which has no productive purpose. It also produces public infrastructure which enters private production as a productivity increase. This infrastructure is  $Y_{Gi}$ , given in the private sector value added function in equation (3.1). Infrastructure is produced via neoclassical production functions,  $g_i(y_{Ki}, y_{Li})$ , in period  $i$  which use inputs of capital and labor. The government thus competes directly with the private sector in the absorption of capital. In particular, it is not apparent whether the cost to the private sector of the government's absorption for infrastructure output will be outweighed by the productivity improvement generated by the infrastructure. We will suppose that the government sets the real value of expenditure on infrastructure exogenously. Hence no attempt is made to model optimizing behavior.

#### b. Consumption

There are two types of consumers, representing rural and urban labor. We suppose that both consumer classes have the same demand patterns for goods, and that their demands for the different types of goods are given by constant fractions of their incomes. The consumers differ, however, in their initial allocations of scarce resources and financial assets.

The consumers maximize intertemporal utility functions, which have as arguments the levels of consumption and leisure in each of the two periods. As in Feltenstein (1992), we permit rural-urban migration which depends upon the relative rural and urban wage rate. <sup>2/</sup> The consumers maximize these utility functions subject to intertemporal budget constraints. The consumer saves by holding money, domestic bonds, and possibly foreign currency. He

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<sup>1/</sup> In order to incorporate a distinction between public and private bonds it would be necessary to have a notion of risk. Otherwise our model would always generate corner solutions in which one or the other, but never both, of the two assets were held in the consumer's portfolio.

<sup>2/</sup> This approach is motivated by the Harris and Todaro (1970) model of rural-urban migration, in which movement to the city depends upon relative urban/rural wage rates, as well as the probability of finding work in the city. Feltenstein (1992) estimates such a migration model for Mexico.

requires money for transactions purposes, but his demand for money is sensitive to changes in the interest rate. The consumer receives income from his labor, from the rental on any capital or land that he owns, and from the interest payments on bonds that he has purchased.

Here, and in what follows, we will use  $x$  to denote a demand variable and  $y$  to denote a supply variable. We suppose that the consumer receives utility from consumption of goods and leisure. His utility function is time separable, and in our applications will have constant consumption shares in each period, with the intertemporal allocation of consumption being determined by a nonzero rate of time preference. The consumer's maximization problem is thus:

$$\max U(x), \quad x = (x_1, x_{Lu1}, x_{Lr1}, x_2, x_{Lu2}, x_{Lr2}) \quad (5)$$

such that:

$$(1+t_i) P_i x_i + P_{Lui} x_{Lui} + P_{Lri} x_{Lri} + P_{Mi} x_{Mi} + P_{Bi} x_{Bi} + e_i P_{Bfi} x_{Bfi} = C_i \quad (5a)$$

$$P_{K1} K_0 + P_{A1} A_0 + P_{Lu1} L_{u1} + P_{Lr1} L_{r1} + P_{M1} M_0 + r_0 B_0 + P_{B1} B_0 + e_1 P_{Bf1} B_{f0} + TR_1 = N_1$$

$$P_{K2} (1-\delta) K_0 + P_{A2} A_0 + P_{Lu2} L_{u2} + P_{Lr2} L_{r2} + P_{M2} x_{M1} + r_1 x_{B1} + P_{B2} x_{B1} + e_2 P_{Bf2} x_{Bf1} + TR_2 = N_2$$

$$C_i = N_i$$

$$\log P_{Mi} x_{Mi} = a + b \log (1+t_i) P_i x_i - c \log r_i \quad (5b)$$

$$\log P_{Bi} x_{Bi} - \log e_i P_{Bfi} x_{Bfi} = \alpha + \beta (\log r_i - \log \frac{e_{i+1}}{e_i} r_{fi}) \quad (5c)$$

$$\log (L_{ui}/L_{ri}) = a_1 + a_2 \log \frac{P_{Lui} - P_{Lri}}{P_{Lui} + P_{Lri}} \quad (5d)$$

$$\text{if } P_{Lui} \geq P_{Lri}; \text{ otherwise } \log (L_{ui}/L_{ri}) = 0$$

(if the representative household is rural, otherwise labor holdings are constant)

$$P_{B2}X_{B2} = s(1+t_2)P_2X_2 \quad (5e)$$

where:

- $P_i$  = price vector of consumption goods in period  $i$ .
- $x_i$  = vector of consumption in period  $i$ .
- $C_i$  = value of aggregate consumption in period  $i$  (including purchases of financial assets).
- $N_i$  = aggregate income in period  $i$  (including potential income from the sale of real and financial assets).
- $t_i$  = vector of sales tax rates in period  $i$ .
- $P_{Lui}$  = price of urban labor in period  $i$ .
- $L_{ui}$  = allocation of total labor to urban labor in period  $i$ .
- $x_{Lui}$  = demand for urban leisure in period  $i$ .
- $P_{Lri}$  = price of rural labor in period  $i$ .
- $L_{ri}$  = allocation of total labor to rural labor in period  $i$ .
- $x_{Lri}$  = demand for rural leisure in period  $i$ .
- $a_2$  = elasticity of rural/urban migration.
- $P_{Ki}$  = price of capital in period  $i$ .
- $K_0$  = initial holding of capital (incorporating each type of capital).
- $P_{Ai}$  = price of land in period  $i$ .
- $A_0$  = initial holding of land.
- $\delta$  = rate of depreciation of capital.
- $P_{Mi}$  = price of money in period  $i$ . Money in period 1 is the numeraire and hence has a price of 1. A decline in the relative price of money from one period to the next represents inflation.
- $x_{Mi}$  = holdings of money in period  $i$ .
- $P_{Bi}$  = discount price of a domestic bond in period  $i$ .
- $r_i$  = domestic interest rate in period  $i$ .
- $x_{Bi}$  = quantity of domestic bonds purchased in period  $i$ .
- $e_i$  = the exchange rate in terms of units of domestic currency per unit of foreign currency in period  $i$ .
- $P_{BFi}$  = foreign currency price of foreign bonds in period  $i$ .
- $x_{BFi}$  = quantity of foreign bonds purchased in period  $i$ .
- $TR_i$  = transfer payments from the government in period  $i$ .
- $a, b, c, \alpha, \beta$  = estimated constants.

Thus the left hand side of equation (5a) represents the value of consumption of goods and leisure, as well as of financial assets. The next two equations contain the value of the consumer's holdings of capital and labor, as well as the principal and interest that he receives from the domestic and foreign financial assets that he held at the end of the previous period. The equation  $C_i = N_i$  then imposes a budget constraint in each period. Equation (5b) is a standard money demand equation in which the demand for cash balances depends upon the domestic interest rate and the value of intended consumption. Equation (5c) says that the proportion of savings made up of domestic and foreign interest bearing assets depends upon relative domestic

and foreign interest rates, deflated by the change in the exchange rate. Finally, equation (5d) is a migration equation that says that the change in the consumer's relative holdings of urban and rural labor depends on the relative wage rates.

In the final period of the model we impose an exogenous savings rate on the consumers, as in equation (5e). Thus savings rates are endogenously determined by intertemporal maximization in period 1, but are fixed in period 2.

c. The government

The government collects income, profit, and value-added taxes, as well as import duties. It pays for the production of public goods, as well as for subsidies. In addition, the government must cover both domestic and foreign interest obligations on public debt. The deficit of the central government in period 1,  $D_1$ , is then given by:

$$D_1 = G_1 + S_1 + r_1 B_0 + r_{F1} e_1 B_{F0} - T_1 \quad (6)$$

where  $S_1$  represents subsidies given in period 1,  $G_1$  is spending on goods and services, while the next two terms reflect domestic and foreign interest obligations of the government, based on its initial stocks of debt.  $T_1$  represents tax revenues. Tax revenues include sales taxes, as well as the personal and corporate income taxes.

The resulting deficit is financed by a combination of monetization and domestic and foreign borrowing. If  $\Delta y_{BG1}$  represents the face value of domestic bonds sold by the government in period 1, and  $C_{F1}$  represents the dollar value of its foreign borrowing, then its budget deficit in period 2 is given by:

$$D_2 = G_2 + S_2 + r_2 (\Delta y_{BG1} + B_0) + e_2 r_{F2} (C_{F1} + B_{F0}) - T_2 \quad (7)$$

where  $r_2(\Delta y_{BG1} + B_0)$  represents the interest obligations on its initial domestic debt plus borrowing from period 1, and  $e_2 r_{F2}(C_{F1} + B_{F0})$  is the interest payment on the initial stock of foreign debt plus period 1 foreign borrowing.

The government finances its budget deficit by a combination of monetization, domestic borrowing, and foreign borrowing. As in Feltenstein (1992), we assume that foreign borrowing in period  $i$ ,  $C_{Fi}$ , is exogenously

determined by the lender. The government then determines the face value of its bond sales in period  $i$ ,  $\Delta y_{BGi}$ , and finances the remainder of the budget deficit by monetization. Hence:

$$D_i = P_{Bi}\Delta y_{BGi} + P_{Mi}\Delta y_{Mi} + e_i C_{Fi} \quad (8)$$

d. The foreign sector and exchange rate determination

The foreign sector is represented by a simple export equation in which aggregate demand for non-oil exports is determined by domestic and foreign price indices, as well as world income. We take the dollar value of oil exports to be exogenous. The specific form of the non-oil export equation is:

$$\Delta X_{no} = \sigma_1 \left[ \frac{\pi_i}{\Delta e_i \pi_{Fi}} \right] + \sigma_2 \Delta y_{wi}$$

where the left hand side of the equation represents the change in the dollar value of Mexican non-oil exports in period  $i$ ,  $\pi_i$  is inflation in the domestic price index,  $\Delta e_i$  is the percentage change in the exchange rate, and  $\Delta_i$  is the foreign rate of inflation. Also,  $\Delta y_{wi}$  represents the percentage change in world income, denominated in dollars. Finally,  $\sigma_1$  and  $\sigma_2$  are corresponding elasticities.

The combination of the export equation and domestic supply responses then determines aggregate exports. Demand for imports is endogenous and is derived from the domestic consumers' maximization problems. Foreign lending has not been modelled, but has been taken to be exogenous. Thus gross capital inflows are exogenous, but the overall change in reserves is endogenous.

The government also attempts to adjust the exchange rate. The supply of foreign reserves  $y_{FGi}$ , available to the government in period  $i$  is given by:

$$y_{FGi} = y_{FG(i-1)} + X_i - M_i + x_{F(i-1)} - x_{Fi} + C_{Fi} \quad (9)$$

Here  $x_{Fi}$  represents the demand for foreign assets by citizens of the home country, so  $x_{F(i-1)} - x_{Fi}$  represents private capital flows.  $C_{Fi}$  represents exogenous foreign borrowing by the home government.

The government has a demand for foreign assets which, we suppose, is determined by an exchange rate rule. Let  $y_{Fi}$  represent whatever the

government feels to be the critical level of foreign reserves in period  $i$ . 1/ The government wishes to peg the exchange rate in period  $i$ ,  $e_i$ , at its level of the previous period,  $e_{i-1}$ . It will, however, adjust the exchange rate if its stock of reserves,  $y_{FGi}$ , deviates from its target,  $y_{Fi}$ . When reserves exceed the government's target, the government leaves the exchange rate as is or revalues it only slightly. When reserves are below the government's target, the government devalues the exchange rate substantially. 2/

Finally, changes in the money supply in period  $i$ ,  $\Delta M_{Si}$ , are now given by:

$$\Delta M_{Si} = \Delta y_{Mi} + e_i y_{FGi} - e_{i-1} y_{FG(i-1)}$$

where  $\Delta M_{Mi}$  is determined in equation (7) from the government's financing its budget deficit, while the remainder of the right hand side represents the domestic currency value of the balance of payments, determined by equation (8).

## 2. Numerical examples

Since our model does not permit an analytical solution, we will use a numerical solution method to derive certain qualitative conclusions about government policies. We derive a fixed-point that corresponds to an intertemporal equilibrium. This equilibrium thus represents a set of prices in each period at which all factor and financial markets clear. Recall that we solve the model as a sequence of 2 period perfect foresight problems. Hence our reported solution reflects the first period in each 2 period segment.

### a. Calibration

In order to simulate our model we have used parameter estimates reported in Feltenstein and Shah (1995), Feltenstein (1992), and Feltenstein and Ha (1993, 1995). 3/ These represent behavioral equations for consumption parameters, money demand and portfolio allocation, as well as production

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1/ Thus, for example, the government might desire a stock of foreign reserves equal to three months of exports. We let this level be a policy parameter and do not derive it from optimizing behavior.

2/ This may thus be interpreted as a "leaning against the wind" exchange rate policy in which the government changes the rate to compensate for movements in reserves. The speed of adjustment is a policy parameter set by the government.

3/ These parameter estimates are, in turn, derived from Alberro (1989a,b), Jarque (1988), Jung (1988), and Zedillo (1986).

coefficients and non-oil export elasticities. In addition, parameters estimates representing the migration equation are also used. For our purposes, however, we need to estimate one further set of equations, namely, the sectoral production of value added as a function of inputs of capital and the three types of infrastructure.

We therefore estimate for each of the 16 major sectors of the economy a constant-returns-to-scale Cobb-Douglas production function augmented by public infrastructure. 1/ The form of this function is:

$$\log Y = \alpha + \beta \log K + (1 - \beta) \log L + \gamma_E \log GE + \gamma_T \log GT + \gamma_C \log GC$$

where  $Y$  = sectoral output,  $K$  = sectoral capital inputs,  $L$  = sectoral labor inputs,  $GE$  = stock of electricity infrastructure,  $GT$  = stock of transportation infrastructure, and  $GC$  = stock of communication infrastructure.

This equation can be rewritten as:

$$\log(Y/L) = \alpha + \beta \log(K/L) + \gamma_E \log GE + \gamma_T \log GT + \gamma_C \log GC.$$

Under the assumption of constant returns to scale,  $\beta$  is referred to as the share of capital. We thus calculate the value of  $\beta$  as the mean over the sample period of the share of capital, an approach also employed by Jarque (1988) in estimating a production function for Mexico. 2/ Let  $\hat{\beta}$  denote the estimate of  $\beta$ . We run the regression over the sample 1970-90 for the following equation:

$$\log(Y/L) - \hat{\beta} \log(K/L) = \alpha + \gamma_E \log GE + \gamma_T \log GT + \gamma_C \log GC.$$

Table 3 shows that  $\gamma_E$  and  $\gamma_C$  are positive but  $\gamma_T$  is negative in most sectors, a result consistent with our estimation of translog cost functions.

In order to simulate the estimated form of our model, we have taken initial allocations, for our first simulation, to be the stocks at the end of 1988. We then carry out a simulation for a three year period in which all exogenous parameters take on values approximately equal to their corresponding Mexican values over the period 1989-91. In particular, we take public expenditure on the three types of infrastructure to be equal to actual expenditure. 3/

We have carried out this first simulation with several constraints designed to make our benchmark results policy-neutral. First, there is no monetary expansion other than that caused by financing a budget deficit. Second, we suppose that the real exchange rate is indexed, so that the nominal rate follows the inflation rate. Finally, we have adjusted government spending, and hence the

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1/ See Table 2 for a listing of these sectors.

2/ Directly estimating  $\beta$  together with  $\gamma$ 's may lead to biased results because of the multicollinearity between private and public capitals.

3/ We do not wish to claim that we are way replicating the actual economy, so these parameters should be viewed as having only illustrative value.

budget deficit, so as to have a close to 0 inflation rate. Because prices are endogenous and relative prices change, it is not possible to achieve precisely 0 inflation. We are not attempting to replicate actual outcomes for the 3 years of our simulation. Rather, we wish to use this benchmark case as a reference point for alternative policy simulations. The resulting outcomes are as follows.

Table 3. Estimates of the Production Function 1/

Sector	$\beta$	$\gamma_E$	$\gamma_T$	$\gamma_C$	$R^2$
1. Mining	10.160	-0.048	0.097	-0.039	0.822
2. Food Products	20.035	0.026	-0.053	0.047	0.946
3. Textiles	30.057	0.027	-0.077	0.059	0.917
4. Wood Products	40.088	0.214	-0.184	0.020	0.980
5. Paper and Print	50.226	0.133	-0.128	0.047	0.940
6. Chemicals and Petroleum	60.103	0.130	-0.177	0.099	0.972
7. Nonmetallic Minerals	70.165	0.024	-0.066	0.061	0.900
8. Basic Metals	80.398	0.030	0.134	-0.086	0.536
9. Machinery and Equipment	90.052	-0.038	0.018	0.044	0.722
10. Other Manu- facturing	100.233	-0.047	-0.057	0.066	0.686
11. Construction	110.034	-0.057	-0.001	0.005	0.900
12. Electricity	120.704	-0.059	0.192	-0.075	0.840
13. Commerce and Hotels	130.109	0.068	-0.135	0.076	0.809
14. Transport and Communications	140.216	0.206	-0.240	0.037	0.320
15. Financial Services	150.227	0.074	-0.142	0.041	0.604
16. Medicine	160.008	0.060	-0.041	-0.001	0.829

1/ We interpret  $\gamma_E$ ,  $\gamma_T$ , and  $\gamma_C$  as elasticities of sectoral output with respect to the corresponding stock of infrastructure.



Table 4. Base Case: Low Inflation

	1989	1990	1991
Nominal GDP <u>2/</u>	100.0	102.1	103.6
Real GDP <u>2/</u>	100.0	101.8	98.6
Price level <u>2/</u>	100.0	100.3	105.1
Budget Deficit (in percent of GDP)	0.5	1.3	1.6
Exchange Rate (US\$/peso)	2.46	2.47	2.59
Interest rate			
(real interest rate) <u>3/</u>	44.9 (0.0)	70.5 (25.1)	71.4 (18.7)
Trade balance (US\$)	7.3	3.1	1.5
Net capital stock at <u>4/</u> at end of period 3		<u>Utility index 1/</u>	
Sector 1 100.0		Consumer 1	100.0
Sector 2 100.0		Consumer 2	100.0
Sector 3 100.0			
Sector 4 100.0			
Sector 5 100.0			

1/ Consumer 1 is the urban consumer. Consumer 2 is the rural consumer. The utility index is calculated as the value of the consumer's intertemporal utility function over the 3 periods, normalized by its value in this benchmark simulation.

2/ These are index numbers based on 1989.

3/ Here and in subsequent simulations the real interest rate is normalized based on the 1989 price level of Table 1.

4/ The capital stocks are normalized to their net period 3 values in this simulation.

We see that there is a sharp increase in both the real and nominal interest rates, primarily because of the tight money policy employed by the central bank. We also observe that it is necessary to reduce the budget deficit to less than 2 percent of GDP if the model is to generate near 0 inflation. The reduction in government spending required for this tightened deficit has also caused real GDP to decline slightly over the 3 years in question, although historical GDP rose over the same time period.

#### b. Policy simulations

Let us now turn to some alternative examples. We will suppose that the government attempts to stimulate the economy by increasing spending on infrastructure. We will carry out our exercises in the following way. First, the government decides on an exogenous increase in spending, as a percentage of GDP. Thus, for example, if the government previously spent 20 percent of GDP and decides to increase spending by 10 percent, it now will spend 22 percent of GDP.

We also assume that the entire increase goes to infrastructure and is divided equally among the three types of infrastructure. Given the production functions estimated in Table 3, we then determine the cost-minimizing quantity of new infrastructure of each type produced for these levels of spending.

As a first example, let us suppose that the government increases spending by 10 percent in each of the 3 periods, with the increase going entirely to the construction of infrastructure. The resulting outcomes are given in Table 5.

Table 5. Increase of 10 Percent in Public Spending 1/

	Period 1	Period 2	Period 3
Nominal GDP <u>2/</u>	113.1	124.1	125.9
Real GDP <u>2/</u>	101.5	104.6	100.5
Price level <u>2/</u>	111.4	118.6	125.3
Budget Deficit (percent of GDP)	1.7	2.1	2.3
Exchange Rate (US\$/peso)	2.61	2.78	2.94
Interest rate	55.4 (-5.4)	107.0 (49.5)	99.3 (43.7)
(real interest rate) <u>3/</u>			
Trade balance (US\$)	6.2	2.7	0.8
Net capital stock <u>4/</u> at end of period 3	<u>Utility index 1/</u>		
Sector 1 101.3	Consumer 1	103.1	
Sector 2 99.9	Consumer 2	91.9	
Sector 3 99.6			
Sector 4 99.3			
Sector 5 99.5			

1/ Consumer 1 is the urban consumer. Consumer 2 is the rural consumer. The utility index is calculated as the value of the consumer's intertemporal utility function over the 3 periods, normalized by its value in this benchmark simulation.

2/ These are index numbers based on 1989.

3/ Here and in subsequent simulations the real interest rate is normalized based on the 1989 price level of Table 1.

4/ The capital stocks are normalized to their net period 3 values in this simulation. Capital stocks are normalized by the corresponding stocks from Table 4.

We notice several important differences from the benchmark case. As might be expected, the increase in spending has increased the budget deficit of the government, and there have been significant increases in both the inflation rate and the nominal interest rate. The real interest rate increases after the first year, in response to the increase in the budget deficit. Also, the trade balance deteriorates as a result of the monetary expansion.

Real income rises, as compared to the benchmark case. Real income declines, however, in period 3, as the rising cost of capital, induced by the government's increased demands, has reduced output in spite of the increase in infrastructure. There have been slight declines in net capital formation in 4 of 5 sectors, as increased factor costs have tended to outweigh the enhanced productivity of capital brought about by the increase in infrastructure. Finally, the utility index of the urban consumer has risen, while that of the rural consumer has fallen, due to the fact that the returns to capital have risen, benefiting the urban capital owner.

We thus see that the increase in infrastructure spending has had benefits in terms of higher real income. On the other hand, there have been costs in terms of higher inflation rates, reduced investment, and a deteriorating trade balance. What will happen if we carry out another experiment, increasing spending on infrastructure further? As an example, we will now increase government spending by 27.5 percent, the increase spent uniformly on the three types of infrastructure. <sup>1/</sup> The outcomes are given in Table 6.

Table 6. Increase of 27.5 Percent in Public Spending

	Period 1	Period 2	Period 3
Nominal GDP	155.5	190.2	173.6
Real GDP	106.4	108.3	98.5
Price level	146.2	75.7	176.3
Budget Deficit (percent of GDP)	3.4	3.4	5.5
Exchange Rate (US\$/peso)	109.7	131.8	132.3
Interest rate (real interest rate)	95.6 (-11.1)	144.7 (58.7)	161.2 (84.7)
Trade balance (US\$)	4.2	1.4	0.6
Net capital stock at end of period 3	<u>Utility index <sup>1/</sup></u>		
Sector 1	101.2	Consumer 1	106.1
Sector 2	87.8	Consumer 2	75.4
Sector 3	96.6		
Sector 4	96.2		
Sector 5	96.7		

<sup>1/</sup> Consumer 1 is the urban consumer. Consumer 2 is the rural consumer. The utility index is calculated as the value of the consumer's intertemporal utility function over the 3 periods, normalized by its value in this benchmark simulation.

<sup>1/</sup> The percentage increase is, of course, arbitrary and serves only for illustrative purposes.

We observe an acceleration of the trends seen in the previous example. If we compare the results with the benchmark case, we see that the price index is now almost 70 percent higher after 3 periods. In addition, we now observe a significant decline in capital formation, caused by the government-induced increase in the cost of factor inputs, in particular capital, as reflected in the dramatic increase in the real interest rate. The trade balance continues to deteriorate and there continues to be a welfare improvement for the urban consumer, caused by the increased returns to capital, and a loss for the rural consumer who does not own capital. We thus conclude that large increases in spending on public infrastructure may well be counterproductive.

### 3. Summary and conclusion

We have constructed a simple intertemporal general equilibrium model and have used it to examine the impact of public expenditure on infrastructure on the Mexican economy. We consider three types of infrastructure, electricity, transportation, and communications. We have then estimated production functions for the 16 major sectors of the economy in which sectoral output depends upon inputs of capital and labor, as well as the stocks of the three types of infrastructure.

We carry out three separate numerical simulations of our estimated model, designed to analyze the effect of increasing expenditure on infrastructure. We conclude that relatively small increases in real spending on public infrastructure may be beneficial to the real economy, but at the cost of increased inflation. Also, the welfare benefits are not uniformly distributed. A large increase in infrastructure spending, on the other hand, has generally negative implications for the economy. We conclude that any increases in public capital spending must be carried out with considerable care.

We should add several qualifying remarks. First, there are a variety of ways of financing the increased expenditure on infrastructure that we have not considered. An increase in taxation might avoid the observed rise in real interest rates as well as the negative impact on income distribution. Similarly, the government could reduce current spending or spending on other types of infrastructure to compensate for the increased expenditure on the three targeted types of infrastructure. Finally, financing the increased budget deficit by access to foreign borrowing might also avoid the rise in interest rates. In all of these cases, other than foreign borrowing, the alternative policies might well generate a decline in real income. Foreign borrowing of course presents problems of future debt repayment.

Finally, our results depend to some extent on the fact that there is not a severe capital shortage in Mexico. If there were, then an increase in public expenditure on infrastructure might yield a larger boost in output than we simulate. Accordingly, applying our methodology to certain countries in, for example, South East Asia, where there are serious infrastructure shortages, might lead to qualitatively different outcomes.

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