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PUBLIC INFRASTRUCTURE MAINTENANCE AND THE DISTRIBUTION OF WEALTH

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When considering how to allocate scarce resources for the development of public infrastructure, many countries have a tendency to neglect maintenance in favor of new infrastructure investment projects. We examine the role of maintenance expenditures on output and on the distribution of wealth in a heterogeneous agents model. In our model, maintenance affects the quality of existing infrastructure and thus the flow of services derived from it. Furthermore, maintenance expenditures also affect the depreciation rates of both public infrastructure and private capital. We calibrate our model to Mexico and consider several policies that increase the flow of resources to infrastructure and find that a policy that allocates all additional resources to new investment is dominated by policies that allocate at least some of the additional resources to maintenance. Specifically, focusing all additional resources on maintenance is shown to generate the largest reduction in inequality, while a more balanced policy that increases both investment and maintenance maximizes output growth. (*JEL* E00, E62, H54)

I. INTRODUCTION

A country's roads, railways, airports, water systems, and electricity networks are the base of economic activity. This stock of public infrastructure is typically provided by a country's government. While the insufficient provision of public infrastructure is an issue in many countries, the quality and condition of existing infrastructure deteriorate over time unless adequate and timely maintenance is undertaken. Infrastructure in bad condition has been a concern even in some industrial countries like the United States in recent years. Yet, governments have often prioritized building new infrastructure over spending on adequate maintenance. Neglecting maintenance can lead to infrastructure deterioration and hence to a reduction in infrastructure services received by firms and households. For example, transportation costs to firms may increase due to roads in bad condition; production costs may also rise to frequent water outages or electricity outages that are due to badly maintained distribution networks. Using a heterogenous agents model, we study the effects of various infrastructure funding policies. Specifically, we compare the growth and distributional effects that arise when additional resources are devoted to the development of new infrastructure to that found when some of these resources are allocated to maintaining the existing stock of infrastructure.

There is a large empirical literature on how public infrastructure affects economic growth going back to Aschauer's (1989) seminal paper that found large effects of public infrastructure on U.S. total factor productivity. Subsequent empirical studies covering many countries have generally supported Aschauer's finding, reporting that public infrastructure investment positively affects economic growth (see literature survey papers by Bom and Ligthart 2014 and Romp and De Haan 2007). Among the empirical literature on the distributional effects of infrastructure, cross-country empirical studies by Calderon and Serven (2004) and Calderon and Chong (2004) find some evidence that infrastructure can help reduce inequality. At a more micro level, Khandker, Bakht,

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ABBREVIATIONS

CRRA: Constant Relative Risk Aversion
GDP: Gross Domestic Product
INEGI: Mexico's National Institute of Statistics and Geography

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and Koolwal (2009) find that the poorest households benefited the most from road improvement projects in Bangladesh.

In the theoretical literature, the effects of public infrastructure on economic growth were analyzed by Barro (1990), Glomm and Ravikumar (1994a, 1994b), and others.[1] Rioja (2003a) introduced the role of maintenance expenditures and how they can affect the depreciation rate of infrastructure. Rioja (2003b) added how maintenance expenditures affect the quality or effectiveness of existing infrastructure. Both of these two latter papers find that spending more on maintenance rather than new infrastructure investment can have a positive impact on output. Agenor (2009) and Kalaitzidakis and Kalyvitis (2004) analyze the issue in an endogenous growth framework and study optimal spending in infrastructure and its optimal allocation between new investment and maintenance. Yet all of the papers cited above use a representative agent framework; they cannot analyze how these various policies may influence the distribution of wealth and the degree of inequality present in the economy.

Several papers have studied how infrastructure influences the distribution of wealth (see Chatterjee and Turnovsky 2012, Ferreira 1995, Getachew and Turnovsky 2015, Gibson and Rioja 2015, and Klenert et al. 2014). However, these papers have focused on infrastructure investment and have ignored the issue of maintenance and its impact on the quality of infrastructure. In this article, we develop a model that can be used to determine the effects of infrastructure investment and maintenance on both the level of total output and the distribution of wealth (inequality) observed in an economy. Our framework extends Aiyagari's (1994) heterogenous agents model by including an endogenous labor supply decision and allowing the quality-adjusted infrastructure stock to impact the economy-wide production function.[2] The government must allocate resources to the development of new infrastructure and the maintenance of the existing stock. Both the quality of infrastructure and the rate at which it depreciates will depend on the amount of resources allocated to maintenance.

We calibrate our model to the economy of Mexico. We choose Mexico because it is an emerging market in the top third in Latin America and the Caribbean in income per capita, yet according to enterprise surveys by the World Bank (2010), the quality of its infrastructure ranks about average within Latin America. Firms in the World Bank (2010) survey have ranked public infrastructure as one of the important barriers for doing business, thus it is an important issue. In addition, the type of heterogeneous agents model that we use requires information on household surveys with longitudinal data on income and employment. In this regard, Mexico's National Institute of Statistics and Geography (INEGI) provides an easily accessible household survey with all of the relevant information. After calibrating our benchmark model to Mexico, we consider several policies that increase the flow of resources to infrastructure and find that a policy that allocates all additional resources to new investment is dominated by policies that allocate at least some of the additional resources to maintenance. Specifically, focusing all additional resources on maintenance is shown to generate the largest reduction in inequality, while a more balanced policy that increases both investment and maintenance maximizes output growth.

The article proceeds as follows: Section II describes the model. Section III describes the calibration and computational procedure. Section IV discusses the results and Section V concludes.

II. MODEL

To investigate the differential impact of investing in new infrastructure versus spending on preventative maintenance, we use a modified version of Aiyagari (1994) where an endogenous labor supply decision and productive public infrastructure have been added. The additional detail included in this article is that the government can now choose to allocate resources to maintaining the existing stock of infrastructure in the economy. As more resources are allocated to maintenance, the efficiency of infrastructure will rise and the rate of depreciation will fall. The following subsections provide a detailed description of our model.

A. The Firm

Aggregate output is produced by a representative firm that combines the economy-wide supply of capital and labor, K and N, and public infrastructure, K_G. The stock of public infrastructure enters the production function in a

1. These papers include Fisher and Turnovsky (1998); Glomm and Ravikumar (1997); Turnovsky (1997).

2. See Gibson and Rioja (2015) for a discussion on the advantages of our incomplete markets approach to heterogeneity relative to that used by Chatterjee and Turnovsky (2012) and Getachew and Turnovsky (2015).

way similar to that found in the literature (see Glomm and Ravikumar 1994a; Rioja 2003a, 2003b among others). However, the condition or effectiveness of the infrastructure stock, $\Omega \in (0, 1)$, will affect the service-flow private producers can derive from using a given stock of infrastructure. For example, given an existing power distribution network, producers derive more electricity services from a network in good condition versus the same network in bad condition which has frequent outages. Hence, it is the efficiency-adjusted infrastructure stock, ΩK_G, which enters the aggregate production function:

$$(1) \qquad Y = \left(\Omega K_G\right)^{\phi} K^{\alpha} N^{1-\alpha}$$

where $0 < \alpha < 1$, $\phi < 1$, and the value of $\Omega \in (0, 1)$ depends on how well the government maintains the infrastructure stock. This relationship between maintenance and effectiveness is described fully in the next subsection.

The firm chooses aggregate capital and labor in order to solve the following profit maximization problem:

$$(2) \qquad \max_{K,N} (1-\tau)\left(\Omega K_G\right)^{\phi} K^{\alpha} N^{1-\alpha} - wN - (r+\delta) K$$

where τ is the output tax rate, w is the market clearing wage rate, r is the market clearing rental rate on capital, and δ is the depreciation rate of private capital. Solving the firm's problem yields the standard result that the gross return on capital, $r + \delta$, and the wage rate, w, are both equal to their respective factor's marginal products.

B. Government

The government raises revenue by levying a tax, τ, on aggregate output. This revenue is used to provide government consumption, G, lump-sum transfers, T, and public infrastructure (both new construction and maintenance). We assume that the government allocates τ_G to government consumption, τ_T to lump-sum transfers, and τ_{K_G} to overall infrastructure spending, where $\tau_G + \tau_T + \tau_{K_G} = \tau$.

Infrastructure-related expenditures are allocated further, with λ going to new infrastructure investment and μ going to preventative maintenance (where $\lambda + \mu = \tau_{K_G}$). Maintenance expenditures affect the condition of infrastructure, therefore $\Omega(\mu)$. Higher expenditures on maintenance improve the condition of infrastructure, so $\Omega'(\mu) > 0$. Furthermore, maintenance expenditures affect the rate of depreciation of public infrastructure, so $\delta_G(\mu)$. The less the government spends on maintenance, the higher the depreciation rate of infrastructure and vice versa, so then $\delta_G(\mu)' < 0$.[3]

The depreciation rate of private capital, δ, can also be thought to depend on the level of infrastructure maintenance. For example, roads in bad condition wear out private capital such as trucks and other transportation vehicles much faster since they suffer more wear and tear. Furthermore, disruptions in power services such as black-outs and brown-outs can lead to the premature failure of electronic equipment such computers. Therefore following Agenor (2009), we model private capital's depreciation rate as a function of maintenance expenditure, so $\delta(\mu)$, where $\delta(\mu)' < 0$.

The government is assumed to invest in new infrastructure at a rate that keeps up with depreciation, implying that the stock of infrastructure is constant in steady state. Therefore, new infrastructure investment is given by:

$$(3) \qquad \delta_G(\mu) K_G = \lambda Y.$$

The government's total spending is given by:

$$(4) \qquad TS = G + T + \delta_G K_G + \mu Y$$

while their total revenue is given by:

$$(5) \qquad TR = \tau Y.$$

We require that the government balance its budget every period, so the government's budget constraint is given by:

$$(6) \qquad TS = TR.$$

C. The Household's Problem

The economy is populated by a large number of agents who derive utility from consumption, c, and leisure, l. The agents' period utility function is a standard constant relative risk aversion (CRRA) function given by:

$$(7) \qquad u(c, l) = \left(1/_{1-\sigma}\right) c^{1-\sigma} + \eta \left(1/_{1-\sigma}\right) l^{1-\sigma}.$$

While the agents' preferences are identical, they differ in terms of their wealth and labor productivity. Specifically, all agents start with the same level of wealth, but they receive idiosyncratic shocks to their labor productivity, z,

3. Our use of endogenous depreciation is similar to that of Greenwood, Hercowitz, and Huffman (1988), Smith (1970), and Taubman and Wilkinson (1970), except we focus on maintenance expenditures while they focus on utilization rates or capital.

at the start of each period. While agents lack the ability to perfectly insure against fluctuations in z, they have the ability to save by accumulating assets, a, that pay a market determined return, r (i.e., accumulate wealth). Standard precautionary savings motives apply, and agents will accumulate assets while their productivity is higher in order to partially insure themselves against the risk of becoming less productive in the future. Over time, these differences in productivity translate into large differences in individual asset holdings, giving rise to an endogenous wealth distribution.

An agent's individual state consists of their asset holdings, a, and their labor productivity, z. Given their current state, each agent chooses consumption, c, labor, n, leisure, l, and their next period asset level, a', to maximize the present discounted value of their expected utility. We can set up the household's problem as the following dynamic program:

(8)

$$V(a,z) = \max_{c,n,l,a'} \left[u(c,l) + \beta \sum_{z'} \pi\left(z'|z\right) V\left(a',z'\right) \right]$$

s.t.

$$c + a' \leq \begin{Bmatrix} (1+r)a + T + wn\theta & \text{if employed} \\ (1+r)a + T & \text{if unemployed} \end{Bmatrix}$$

(9) $$n + l \leq 1$$

(10) $$a' \geq 0.$$

Equation (8) is the household's budget constraint. It simply states that a household's spending on consumption and investment cannot exceed their current resources. This equation differs depending on the employment status of the agent. The distinction between employed and unemployed is handled through z. Specifically, the lowest realization of z is an unemployed state with $z = 0$. Equation (9) is a standard time constraint and Equation (10) is a no-borrowing constraint, which prevents any household from carrying a negative asset balance.

D. Equilibrium

A stationary equilibrium for this economy is a value function, $v(a,z)$, individual decision rules, $a'(a,z)$, $n(a,z)$, $l(a,z)$, and $c(a,z)$, a time-invariant distribution of individual states, $F(a,z)$ (with associated density, $f(a,z)$), time invariant factor prices, w and r, time-invariant government taxes and transfers, τ, τ_G, τ_T, τ_{K_G}, μ, and λ, and a vector of aggregates, K, N, C, K_G, G, T, TS, and TR such that:

1. Given the factor prices, government taxes and transfers, and the level of infrastructure in the economy, the value function solves the household's problem and the individual decision rules are the optimal decision rules.
2. Factor prices, w and r, satisfy the firm's first order conditions.
3. The values of K, N, and C are obtained by aggregating over individual decisions:
   (a) $K = \int \sum_z a'(a,z) f(a,z) da$
   (b) $N = \int \sum_z z n(a,z) f(a,z) da$
   (c) $C = \int \sum_z c(a,z) f(a,z) da$.
4. The values of K_G, G, T, TS, and TR are consistent with the government's problem.
5. Goods market clears: $C + \delta K + \delta_G K_G + G + \mu Y = (\Omega K_G)^{\phi} K^{\alpha} N^{1-\alpha}$.
6. Government balances its budget: $TS = TR$.
7. Distribution of individual states is stationary: $F(a',z') = \sum_z \pi(z'|z) F(a'^{-1}(a',z),z)$.

III. CALIBRATION AND SOLUTION

Our model is calibrated to an annual frequency and set to match several basic properties of the Mexican economy. As described in the introduction, we choose to calibrate the model to Mexico due to two main reasons. First, Mexico is in the top third of Latin American and Caribbean countries in income per capita, yet it is only about average on infrastructure quality. Infrastructure and its quality are important issues according to the firm surveys undertaken by the World Bank (2010). Second, calibrating our model requires a reliable longitudinal household survey with data on income and employment. INEGI provides an easily accessible household survey with all of the relevant information. In this section, we will provide details regarding our calibration procedure as well as the numerical methods that were employed to approximate a solution to our model.

A. Government Policy Parameters

INEGI collects data on various government expenditures. According to INEGI (2012), investment in new infrastructure has averaged about 2% of gross domestic product (GDP) between 2006 and 2011, which is also confirmed as the average infrastructure investment in Mexico in the last three decades by Calderon and Serven (2010). Therefore, we set the parameter

$\lambda = 0.02$ in the model benchmark. Maintenance expenditures have averaged 0.25% of GDP according to INEGI (2012), so we set $\mu = 0.0025$ in the benchmark. This implies that total infrastructure spending is 2.25% of GDP, so that $\tau_{K_G} = 0.0225 = \lambda + \mu$. Public expenditures for government consumption average about 10% of GDP according OECD Stats, while government transfers average about 6% of GDP according to INEGI (2012). Thus, we set $\tau_G = 0.10$ and $\tau_T = 0.06$.

In the model, we use $\Omega \in (0, 1)$ to capture the effectiveness of the current stock of infrastructure. The empirical counterpart of this measure is a proxy index of infrastructure quality developed by the World Bank. This index tracks the quality of roads, ports, railroads, and information technology which are reported as one component of the Logistics Performance Index (World Bank). Using data for this index from 2007 to 2014, we compare Mexico's index to that of an average of the nine infrastructure-quality leading countries (Netherlands, Singapore, Germany, Switzerland, Sweden, Japan, United States, Austria, and Hong Kong). We find that, on average, Mexico's infrastructure effectiveness is approximately 70% that of the average for the leading countries. Hence, our model should yield an $\Omega = 0.70$ in our benchmark case.[4]

As we described earlier, Ω is a function of maintenance, μ. We use the following simple functional form, $\Omega = a\mu^b$, and we choose the parameters a and b based on data on maintenance expenditures and the effectiveness of infrastructure observed in Mexico. While we have data on maintenance expenditures and the efficiency of infrastructure for several years, we only observe their values in the same year twice, in 2007 and in 2010. In 2007, maintenance expenditures were 0.117% of GDP and effectiveness was 0.65, implying $\mu = 0.00117$ and $\Omega = 0.65$. In 2010, maintenance expenditures were 0.0043% of GDP and effectiveness was 0.72, implying $\mu = 0.0043$ and $\Omega = 0.72$. We use these two data points to solve for the values of a and b in the function listed above. With the values of a and b pinned down, we verify that our function replicates the data well on average. We do this by feeding the function the long-run average maintenance expenditure of 0.0025. With $\mu = 0.0025$, our function returns $\Omega = 0.69$, which is remarkably close to the average effectiveness of 0.7, found in the data for Mexico.

The depreciation rate of public infrastructure is also a function of maintenance spending. We use the following functional form: $\delta_G = 1 - \mu^d$, with $d > 0$. In the limit, if nothing is spent on maintenance, infrastructure would depreciate fully. We pin down the value d by requiring δ_G to equal 0.075 when μ equals 0.0025. This value for δ_G represents an average of estimates of annual depreciation rates which range from 0.04 to 0.10 (see Inklaar and Timmer 2014; Krusell and Smith 2015)[5] As described in the model section, we follow Agenor (2009) and treat the depreciation rate of private capital, $\delta(\mu)$, as a function of maintenance expenditures. For example, private capital like machinery and vehicles will depreciate faster if public infrastructure is not maintained properly. However, it is unrealistic to think that public expenditures on infrastructure maintenance will impact the depreciation rate of private capital to the extent that it impacts the depreciation of public capital. Therefore, we restrict the depreciation rate of private capital to a weighted average as follows: $\delta = 0.075^{\Phi}\delta_G^{1-\Phi}$, where $\Phi = 0.5$.[6] Thus, increasing the amount of resources going to maintenance will reduce both δ and δ_G, but δ_G will be more responsive.

B. *Production and Utility Parameters*

The discount rate, β, is set to 0.92 to target the annual rental rate on capital for Mexico, which is approximately 4% (Esteban-Pretel and Kitao 2014). Capital's share of output, α, and the elasticity of output with respect to the efficient stock of infrastructure, ϕ, are set to 0.36 and 0.15, respectively (see Bom and Ligthart 2014 and Gollin 2002). The utility parameters, σ and η, are set to target a reasonable value for the Arrow-Pratt measure of relative risk aversion and to ensure that aggregate labor for our baseline calibration is 0.36 in steady state ($\sigma = 2.5$ and $\eta = 5.25$). See Table 1 for a list of model parameters and targets.

C. *Income Shock Process*

INEGI collects household surveys that include data on employment status, income, and worker

4. This efficiency value is similar to the one used by Rioja (2003b) for an average of Latin American countries which was obtained from infrastructure loss indicators reported by the World Bank.

5. This procedure is similar to that followed by Greenwood, Hercowitz, and Huffman (1988).

6. Using values of Φ different from 0.5 yields similar results.

TABLE 1
Model Parameters

Parameter	Value	Target
λ	0.02	Infrastructure investment-GDP ratio
μ	0.0025	Infrastructure maintenance-GDP ratio
τ_G	0.10	Gov't consumption-GDP ratio
τ_G	0.06	Transfers-GDP ratio
Ω	0.69	Average efficiency for Mexico
η	5.25	Aggregate labor ≊ 0.36
β	0.92	Capital rental rate ≊ 4%
σ	2.50	Std. Arrow-Pratt CRRA
α	0.36	Capital's income share
ϕ	0.15	Elasticity of Y w.r.t. infrastructure

TABLE 2
Productivity Shock Process

$z_1 = 0.000$	$z_2 = 0.331$	$z_3 = 0.588$	$z_4 = 0.878$	$z_5 = 2.203$	
	z_1	z_2	z_3	z_4	z_5
z_1	0.200	0.800	0.000	0.000	0.000
z_2	0.032	0.551	0.247	0.115	0.055
z_3	0.032	0.240	0.397	0.244	0.087
z_4	0.032	0.113	0.235	0.402	0.218
z_5	0.032	0.056	0.085	0.207	0.620

Source: Income data from the Mexican National Survey of Occupation and Employment (ENOE) from 2005 to 2010.

flows. The National Survey of Occupation and Employment (ENOE) surveys over 100,000 households in 48 metropolitan and rural areas in Mexico every quarter. Since ENOE started in 2005, we focus on the period 2005–2010.[7] Individuals are surveyed for five consecutive quarters, so we assemble a longitudinal panel to determine transition probabilities among income quintiles. The average productivities,

$$[z_2, z_3, z_4, z_5] \tag{11}$$

are estimated from the data for the average income of each quartile. We normalize the average productivity across all four quartiles to 1 following Heer and Trede (2003). These are presented in Table 2 along with the transition probability matrix. The first row and first column of this matrix tell us about the transition from unemployment to working and vice versa. Following Heer and Trede (2003), we assume that agents' skills erode while in the unemployment state, so that agents may only transition from unemployment to the lowest productivity employment state. The exact values in the first row and column of the transition matrix are set to match the average rate and duration of unemployment observed in the data. During the period that we study, the average unemployment rate in Mexico was 3.99%, while the average duration of unemployment was approximately 10 months (OECD 2015).[8] The lower 4 × 4 of the transition matrix is obtained as the average transition probability between two consecutive years in our sample period. The results have been renormalized to ensure that each row sums to 1.

D. Solution Method and Methodology

To solve the model, we employ standard methods for computing the stationary distribution of an incomplete markets model with idiosyncratic shocks. Specifically, we start by guessing values for aggregate capital, K, and labor, N, and we use these values to compute r, w, and K_G. We discretize private assets, restricting assets to 1,000 unevenly spaced grid points on the interval (0, 4) and use value function iteration with golden section search and parabolic interpolation to solve for the agents' decisions rules. Next, these decision rules are used to solve for the invariant density, $f(a, z)$. Because we are interested in how this wealth density changes across specification, we approximate it on a much finer grid than we used to compute the decision rules (2,000 grid points). Once we have the invariant density, we update our values of K and N and repeat the process until K and N no longer change.[9]

Once we have approximated the stationary distribution for our baseline specification, we change the amount of resources that are allocated to infrastructure investment and maintenance and recompute the stationary distribution. This process is repeated for all policies considered. These stationary solutions are compared, both in terms of aggregate output and the distribution of wealth, in the next several sections. By comparing the stationary solutions, we are implicitly focusing on the long-run impact of the policy change and ignoring the short-run effects that occur over

7. The household survey prior to ENOE's creation was ENEU which had somewhat different coverage and methodology.

8. Given that our model is calibrated to an annual frequency, it is impossible for us to exactly match the duration of unemployment found in the data. However, we set the probability of remaining unemployed to a low value, which allows to come close to the empirical estimate.

9. See Heer and Maussner (2009) for a detailed discussion of these methods. Also, a technical appendix is available from the authors upon request.

TABLE 3
Model versus Data

Aggregate Variables			Wealth Distribution		
	Data[a]	Model		Data[b]	Model
Rental rate	0.04	0.04	Quintile 1	7.76	2.74
G/Y ratio	0.10	0.10	Quintile 2	10.78	8.65
T/Y ratio	0.06	0.06	Quintile 3	14.18	16.71
C/Y ratio	0.67	0.69	Quintile 4	20.85	27.18
$\widetilde{K}/Y$ ratio	2.50	2.80	Quintile 5	44.70	44.72

[a]While our model is calibrated to be consistent with the capital rental rate and the G/Y and T/Y ratios observed in the data, the C/Y and $\widetilde{K}/Y$ ratios ($\widetilde{K} = K_G + K$) where not explicitly targeted.

Sources: K/Y (Penn World Tables 8.1, Feenstra, Inklaar, and Timmer 2015); C/Y (World Development Indicators, The World Bank 2015); G/Y (OECD Stats); T/Y (INEGI 2012).

[b]Wealth distribution data for Mexico at the quintile and decile level was obtained from De la Torre and Moreno (2004). Their wealth measure is constructed from the INEGI household survey data in Mexico. The data are defined as net total wealth, so it includes financial wealth and real estate wealth.

the transition path. While others (see Chatterjee and Turnovsky 2012 and Turnovsky 2004) have demonstrated that the short-run effects along the transition path may differ considerably from the long-run results, we are ultimately interested in how allocating resources between infrastructure investment and maintenance influence aggregate output and the distribution of wealth in a country. These effects will likely accumulate over the course of many years, and as such, an approach that focuses on the long-run impact is appropriate here. We leave the exploration of the transitional dynamic effects in our model for future research.

IV. RESULTS

Prior to studying the results of infrastructure policies, we examine how well our baseline model replicates key features of the Mexican economy. Table 3 presents evidence that our model does a reasonably good job replicating both average values (such as the ratio of capital and consumption to output) and the aggregate wealth distribution (the share of wealth held by each quintile) that is observed in the Mexican data. While the first panel of Table 3 indicates that our model matches the rental rate on capital, the government consumption-output ratio, and the government transfers-output ratio, this stems from our calibration strategy which targets those values. However, we do not calibrate our model to target the consumption-output ratio or the capital-output ratio,[10] yet our model matches these values well. Inspection of the second panel of Table 3 indicates that our model also does a reasonable job replicating the degree of wealth concentration observed in the data, especially in quintiles 2, 3, and 5. However, our baseline model underestimates the share of wealth held by the poorest agents (quintile 1). The fact that our model incorrectly estimates the share of wealth held in the lower tail of the asset distribution is a common shortcoming of incomplete markets models that are calibrated using income data. Alternatively, one could calibrate the labor productivity shocks so that the baseline model's wealth distribution matches the data as close as possible (see Castaneda, Diaz-Giminenez, and Rios-Rull 1998). However, as our focus is on the change in wealth that follows various policies, not the level of wealth at a specific point in time, we choose to match labor productivities and transition probabilities accurately rather than adjusting them to target a baseline wealth distribution.

A. Adding 1% of GDP to Infrastructure Spending

As a first policy experiment reported in Table 4, we increase overall infrastructure spending by 1% of GDP, then we allocate all of it to either new investment, maintenance, or half to each expenditure ("All Investment," "All Maintenance," and "Half-and-Half," respectively). The first two rows of Table 4 show how the allocation of expenditures change μ and λ from their baseline values. The next two rows show how the depreciation rate of infrastructure, δ_G, and the efficiency of infrastructure, Ω, are affected. For example, under the "All Investment" policy, neither the depreciation rate nor the condition of the infrastructure are affected since the additional funds go to new investment in infrastructure. However, under the "All Maintenance" policy, δ_G falls from 0.075 to 0.055 and Ω rises from 0.69 to 0.78. Therefore, as can be seen in the Aggregate Effects panel of Table 4, increasing maintenance raises both the raw stock of infrastructure, K_G, as well as the efficiency-adjusted stock of infrastructure, ΩK_G. Aggregate private capital, K, is also higher after the policy change, due in part to the fact that its depreciation rate,

10. Here we define capital as $\tilde{K} = K_G + K$, or the sum of private and public capital. This is done because capital values observed in the Mexican data do not distinguish between public and private capital.

TABLE 4
Increasing Infrastructure-Related Spending by 1% of GDP

	Baseline	All Investment	All Maintenance	Half-and-Half
Infrastructure spending allocation parameters				
μ	0.0025	0.0025	0.0125	0.0075
λ	0.0200	0.0300	0.0200	0.0250
Infrastructure effectiveness parameters				
Ω	0.690	0.690	0.783	0.752
δ_G	0.075	0.075	0.055	0.062
δ	0.075	0.075	0.065	0.068
Aggregate effects				
K_G	0.084	0.136	0.125	0.141
ΩK_G	0.058	0.094	0.098	0.106
K	0.803	0.854	0.927	0.915
N	0.365	0.353	0.342	0.343
Y	0.317	0.340	0.346	0.349
w	0.454	0.498	0.522	0.526
r	0.041	0.041	0.044	0.043
Distributional effects				
Gini	0.426	0.427	0.421	0.423
$Q1$	2.745	2.715	2.784	2.751
$Q2$	8.647	8.574	8.779	8.740
$Q3$	16.710	16.740	17.006	16.922
$Q4$	27.181	27.271	27.228	27.289
$Q5$	44.717	44.700	44.204	44.298
$Q5/Q1$	16.292	16.462	15.878	16.101

δ, is reduced when more resources are devoted to maintaining infrastructure. Most importantly, GDP rises by 9.15% (from 0.317 to 0.346) following the "All Maintenance" policy. This effect is large, even after noting that these steady state changes represent the long-run policy response. After further inspection of Table 4, we see that all three policies yield similar increases in GDP, but the "Half-and-Half" allocation yields the largest increase. Therefore, if we base our decision on how to allocate additional resources between infrastructure investment and maintenance solely on the response of aggregate output, we would prefer the balanced policy, "Half-and-Half." Will this policy still be preferred after we consider the distributional effects? We proceed to that discussion next.

The bottom panel of Table 4 shows the effects of the policy changes on the share of wealth held by each quintile. For instance, the poorest quintile, Q1, gains wealth share following both the "All Maintenance" and "Half-and-Half" policies, but loses wealth share following the "All Investment" policy. Furthermore, the largest gains in wealth shares for the bottom three quintiles occur for the "All Maintenance" policy change, while the bottom two quintiles see reduced wealth share following the "All Investment" policy. These results clearly indicated that middle- and low-wealth individuals benefit more from maintenance spending than new investment.

To get a precise measure of the policies' effect on wealth inequality, we turn to changes in the Gini coefficient and wealth concentration measure, ($Q5/Q1$), reported in Table 4. Inspection of these values indicate that the "All Investment" policy actually leads to a slight increase in inequality, with the Gini rising from 0.426 to 0.427 and wealth concentration increasing from 16.292 to 16.462. This is in stark contrast with the "All Maintenance" policy which leads to a significant reduction in wealth inequality, with the Gini falling to 0.421 and wealth concentration falling to 15.88. While the "Half-and-Half" policy also leads to a reduction in inequality, it does not reduce inequality as much as "All Maintenance." Therefore, if we select our policy based on its ability to reduce wealth inequality, the "All Maintenance" policy, not the "Half-and-Half" policy, would be preferred.

We have just seen that if we base our policy decision on output growth, then the "Half-and-Half" policy is preferred, but if we base our policy decision on inequality reduction, then the "All Maintenance" policy is preferred. The first thing to notice here is that regardless of our objective, the "All Investment" policy is dominated by an alternative policy involving some level of increased maintenance spending. Therefore, the current level of maintenance spending is less than optimal, and if additional resources are channeled to infrastructure spending, at least some of these resources should be allocated to infrastructure maintenance. Second, we face a basic growth-inequality trade-off in deciding how much to increase maintenance. Making this choice requires further understanding of the scale of the growth and inequality effects. First, we can look back at Table 4 and see that the growth effects are very similar with Y increasing to 0.346 following the "All Maintenance" policy and to 0.349 following the "Half-and-Half" policy. Therefore, little growth must be given up to gain the reduction in inequality that accompanies the "All Maintenance" policy. However, inspection of the last panel of Table 4 indicates that the distributional effects are also similar between these two policies. Therefore, while we cannot conclude which policy is the best, "All Maintenance" or "Half-and-Half," we can conclude that allocating additional resources to maintenance is preferred to the case where all additional resources go to new infrastructure investment.

TABLE 5
Allocating 5% of GDP to Infrastructure

	Baseline	All Investment	1% to Maintenance	2% to Maintenance	All Maintenance
		Infrastructure spending allocation parameters			
μ	0.0025	0.0025	0.0125	0.0225	0.0300
λ	0.0200	0.0475	0.0375	0.0275	0.0200
		Infrastructure effectiveness parameters			
Ω	0.690	0.690	0.783	0.820	0.839
δ_G	0.075	0.075	0.055	0.048	0.045
δ	0.075	0.075	0.065	0.060	0.058
		Aggregate effects			
K_G	0.084	0.233	0.260	0.216	0.164
ΩK_G	0.058	0.161	0.204	0.177	0.137
K	0.803	0.906	1.013	1.024	1.002
N	0.365	0.340	0.324	0.324	0.330
Y	0.317	0.368	0.385	0.378	0.365
w	0.454	0.547	0.601	0.590	0.560
r	0.041	0.041	0.044	0.045	0.046
		Distributional effects			
Gini	0.426	0.427	0.421	0.418	0.417
$Q1$	2.745	2.692	2.740	2.785	2.807
$Q2$	8.647	8.529	8.730	8.835	8.933
$Q3$	16.710	16.784	17.006	17.102	17.161
$Q4$	27.181	27.316	27.415	27.486	27.334
$Q5$	44.717	44.680	44.110	43.793	43.764
$Q5/Q1$	16.292	16.598	16.100	15.727	15.592

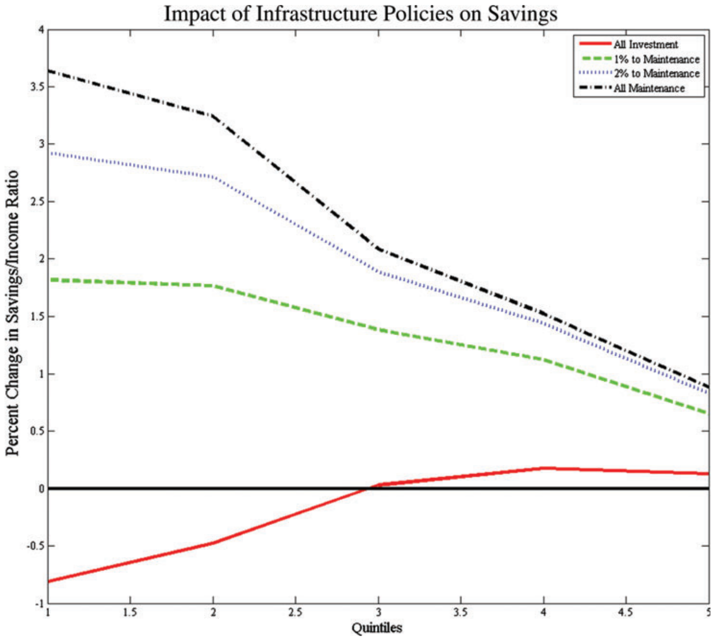
B. Increasing Infrastructure Spending to Its Optimal Level

As a second policy experiment, we consider the optimal infrastructure spending needs for Latin America that were reported in Fay and Morrison (2007). The authors estimate that Latin America needs to spend about 5% of GDP on overall infrastructure to be able to catch up to the infrastructure stock of East Asian countries. We start with the benchmark allocation of 2% to new investment and 0.25% to maintenance for an overall infrastructure-related spending of 2.25% of GDP. Then we raise the overall expenditure by 2.75% of GDP bringing the total to the 5% level suggested by Fay and Morrison (2007). We consider four alternative policies for allocating this extra 2.75% between new investment and maintenance. Two of these policies are the extreme cases, where all of the additional resources are allocated to either investment or maintenance ("All Investment" and "All Maintenance," respectively) while the other two policies are balanced, allocating some to investment and some to maintenance ("1%-to-Maintenance" and "2%-to-Maintenance"). See Table 5 for the results of all four policies.

Inspection of Table 5 indicates that the "1%-to-Maintenance" policy yields the highest increase in GDP, with aggregate output increasing by 21.5% (increasing from 0.317 to 0.385). Furthermore, the "All Maintenance" policy is found to yield the largest reduction in wealth inequality, with the Gini falling from 0.426 to 0.418 and wealth concentration falling from 16.292 to 15.727. Therefore, just as in Section IV.A, a more balanced policy that allocates additional resources to both maintenance and investment is preferred if maximizing output is the sole objective, while a policy that focuses all new resources on maintenance is preferred if reducing inequality is the sole objective. However, unlike before, there is a more pronounced growth-inequality trade-off present between policies. Specifically, in Table 5, the output level found after the "1%-to-Maintenance" policy is 5.5% larger than the output level found after the "All Maintenance" policy. The distributional effects also differ, with the "1%-to-Maintenance" policy yielding a Gini of 0.421 and a wealth concentration of 16.1 versus the values of 0.417 and 15.592 found following the "All Maintenance" policy. Therefore, one must be willing to give up a sizable amount of growth (or equality) in order to choose the equality (growth) maximizing policy.

Given the larger differences between the growth-maximizing "1%-to-Maintenance" policy and the equality-maximizing "All

FIGURE 1
Savings Effects of Optimal Infrastructure Spending (5% of GDP)



Maintenance" policy that we just observed, it might be preferable for a government to choose the "2%-to-Maintenance" policy instead. Policies like the "2%-to-Maintenance" policy do not maximize growth or equality, but they lie in-between the policies that do. Notice that following the "2%-to-Maintenance" policy yields an output level that is only 1.82% lower than that found under the output-maximizing policy. Furthermore, following this policy rather than the equality-maximizing policy only causes the Gini and wealth concentration to rise by 0.001 and 0.135, respectively. While the exact amount of additional maintenance depends on the specific objectives of the government, what remains clear is that the current amount of maintenance is suboptimal and if additional resources are allocated to infrastructure, at least some of these resources should go to maintenance.

C. Explanation of Results

While we have demonstrated that channeling additional resources to maintenance generates more growth in output and yields a more equitable wealth distribution than channeling all additional resources to new infrastructure investment, we must explain the mechanism underlying these results. Understanding this aggregate outcome requires an understanding of how each policy impacts the savings behavior of the individual agents. Figure 1 summarizes this effect at the quintile level. Specifically, Figure 1 presents the percentage change in savings, as a share of income (savings/income ratio), following the four policies described in the previous subsection.[11] The three policies which raise maintenance expenditures in some degree ("1%-to-Maintenance," "2%-to-Maintenance," and "All Maintenance") increase the savings rate of all agents, but the magnitude of this increase declines with wealth. Therefore, these policies cause a reduction in inequality as poor agents increase their savings rate more rapidly than rich agents. Furthermore, we see that the "All Maintenance" policy generates the largest response to savings for poor agents, which explains why it was found to generate the largest reduction in inequality in the previous subsection. Conversely, the "All Investment" policy causes poorer agents, those in the bottom two quintiles, to reduce savings, while it causes richer agents, those in the top

11. We focus attention on the optimal case, but the same intuition holds for the 1% policies as well.

two quintiles, to increase savings. Therefore, the "All Investment" policy increases inequality as it causes poor agents to reduce their savings rate and richer agents to increase their savings rate.

Why do the savings responses vary for different agents? The differential effect on savings generated by the policies stems from the fact that the policies influence factor prices, w and r, in different ways. In our model, agents face both an intratemporal trade-off (allocate time between working and taking leisure) and an intertemporal trade-off (allocate current resources between current consumption and future consumption, which is facilitated through the accumulation of assets), and changes in factor prices will alter agent behavior through these channels. For example, inspection of Table 5 indicates that the wage rate, w, is increased following each policy, yet, the "All Investment" policy leads to the smallest increase. Furthermore, we see that this increase in w is accompanied by a reduction in aggregate labor, N, indicating a dominating substitution effect. Further inspection of Table 5 indicates that while the rental rate on capital, r, remains unchanged following the "All Investment" policy, it increases substantially following the three other policies and reaches its maximum value of 0.046 following the "All Maintenance" policy. This increase in r alters the agents' intertemporal trade-off problem and increases the benefit of future consumption. Therefore, savings rises by more under these policies, which can be seen by the larger increase in K relative to the "All Infrastructure" policy. At an individual level, the "All Investment" policy increases the income of all agents but as poor agents faced very low levels of consumption in the baseline case, they choose to allocate a majority of this increase to consumption rather than savings. On the other hand, increased maintenance expenditures are shown to increase wages and the rental rate by more than the "All Investment" policy and these larger factor price changes alter the intra- and intertemporal trade-offs faced by agents. As a consequence, poorer agents now see the value in accumulating assets and begin to do so at a rate that exceeds richer agents, leading to a reduction in inequality.

V. CONCLUSIONS

While the aggregate and distributional effects of public infrastructure investment have been studied, we examine the role of an important aspect of spending: maintenance expenditures. Maintenance in our model can affect the quality of existing infrastructure and thus the flow of services derived from it. Maintenance expenditures can also affect the depreciation rates of both public infrastructure and private capital. Oftentimes, however, governments neglect maintenance in favor of building new infrastructure. Our first key finding is that given the recent allocation of public expenditures in Mexico, which is not too dissimilar from other Latin American countries, spending more on maintenance rather than on new investment can increase aggregate GDP and improve the distribution of wealth. That is, poorer segments benefit more than richer ones. Poorer households increase their savings rate comparatively more than richer agents as factor prices rise with the increase in effective infrastructure services. Another finding is that spending more on both maintenance and new investment also yields an improvement in the distribution and may increase aggregate output the most. In sum, policymakers need to pay much more attention to maintenance within their spending priorities.

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