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U.S. Affiliates, Infrastructure and Growth: A Simultaneous Investigation of Critical Mass

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Abstract: An empirical model that allows for the endogeneity of growth, multinational activity and wages is developed that permits for the decomposition of the impact of infrastructure into *direct* and *indirect* general equilibrium effects. It is found that, like previous studies, schools and telecommunications have a positive and significant *direct* contribution to domestic growth and there are greater marginal returns for countries with higher investment levels in schools and telecommunications; a result that is suggestive of a critical mass story. However, once spurious correlation of firm location and the *indirect* effects through wages and multinational activity are accounted for, the *total* effects of telecommunications and schools on growth are lower than direct estimates would suggest.

Key Words: Infrastructure, Growth, Multinational Corporations, Development

JEL Classification: F2; O4; H4

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I. Introduction

The importance of infrastructure for the growth of economies is a subject that has been extensively examined over the course of the past 15 years, but with little attention paid empirically to the exact mechanisms by which infrastructure influences markets and factors of production. Theoretical models (see for example Martin and Rogers [1995], Martin [1999] , Baldwin et. al. [2003], and Kellenberg [2003]) have shown that public inputs such as infrastructure can have significant impacts on the marginal productivity of factors of production, create agglomerative externalities, lower the costs of production, facilitate knowledge spillovers, and attract foreign investment. The vast majority of these models have been written in a general equilibrium context, yet the empirical literature to date has not made a serious effort to control for the simultaneity and feedback effects on factor prices and foreign producers suggested by the theory. This paper develops a simple general equilibrium model to estimate the impact of various types of infrastructure while controlling for the simultaneity of GDP, multinational activity, and wages. The advantage of this approach is that it allows for the deconstruction of the impacts of infrastructure on GDP, multinational activity and wages into their *direct* and *indirect* general equilibrium feedback effects. Doing so permits us to more fully capture the intricacies of the general equilibrium theory models and provide a richer structure for analysis. It is found that the *indirect* effects of infrastructure can have significant impacts on infrastructures *total* effect on GDP, wages, and multinational activity; especially with respect to telecommunications and schools.

The contributions of this paper are threefold. First, it is shown that by developing a simple and theoretically consistent model that allows for the endogeneity of GDP, multinational activity, and wages, we can decompose the *total* effect of infrastructure into *direct* and *indirect* general equilibrium effects. Second, using this theoretical framework we can construct an empirical model to obtain estimates of the direct and indirect marginal effects of infrastructure development and test for issues of critical mass. Third, it is shown that like previous findings regarding infrastructures impact on aggregate production functions, spurious correlation is a potential problem when estimating infrastructures marginal effects on multinational location decisions. Country specific fixed-effects can correct the problem and lead to more reasonable estimates than previously found.

The rest of the paper is laid out as follows: Section II discusses prior work on infrastructures impacts on growth and issues regarding the link between empirics and theory; Section III presents the theoretical model; Section IV describes the empirical model and the data used for estimation; Section V presents the results and analysis; and Section VI concludes.

II. Prior Literature and Issues

The general approach to estimating the impact of infrastructure on growth has been to regress aggregate output against some measure of a country or states level of infrastructure. The first to do this was Aschauer [1989], where he estimated an aggregate production function for the U.S. and found that the stock of public infrastructure has a significant positive impact on total factor productivity growth. Another approach (used by Shah [1992], Lynde et. al. [1992], Nadiri et. al. [1994] and Morrison et. al. [1996]) has been to invoke duality and estimate the cost function rather than the production function. This approach has yielded positive and significant roles for infrastructure in explaining productivity growth, albeit with much lower estimates than were initially found by Aschauer.

Two main criticisms stemmed directly from the initial work by Aschauer. The first is the risk of spurious correlation of the explanatory variables whereby the infrastructure measure picks up the effects of other variables that are state specific or simply correlated with growth, such as education, government regime, or R&D spending. Subsequent work by T. Garcia-Mila et. al. (1992), Holtz-Eakin (1993, 1994), and Canning (1999) show that estimation of aggregate production functions when accounting for state-level fixed effects significantly reduces or negates the impact of infrastructure on GDP.

The second criticism is simultaneity, and has only recently been explored in the infrastructure and growth literature. Röller and Waverman [2001] (referred to as R&W from here on) show that growth and investment in telecommunications infrastructure may suffer from two-way causality and if this simultaneity is not taken into account, the effect of telecommunications infrastructure on GDP growth may be biased upward. They argue that telecommunications is different than other forms of infrastructure because of the positive external spillovers associated with the “information super-highway” and knowledge dissemination, and find that telecommunications do have a positive and significant effect on growth when country specific fixed-effects and simultaneity of growth and telecommunications are accounted for. Further, they find that telecommunications exhibit nonlinear effects, such that larger marginal growth effects are obtained after reaching a threshold level of investment. The explanation being that before a country reaches the critical mass level of telecommunications[1], the country is unable to fully realize the external benefits associated with the information superhighway and rapid knowledge dissemination.

The R&W paper was not the first to explore issues of critical mass in infrastructure. Fernald [1999] found that the relationship between roads and productivity was positive and significant for the U.S. in the 1950's and 1960's, but since then roads have not provided the same high rate of return. The explanation being that road construction provided a one-time boost to the U.S. economy as it passed a threshold level of road networks. Borensztein, De Gregorio, and Lee [1998] found that FDI has positive effects on growth only after passing a threshold level of human capital stock. The story is that without enough educated workers to absorb knowledge and technical spillovers, the marginal returns of FDI on growth will not be as great. These results shed light on an important aspect associated with public infrastructure and are a subject of investigation in this paper, namely, that there may be a critical mass of investment necessary before public inputs such as infrastructure become productive.

Kellenberg [2003] develops a theoretical model of how these threshold effects might arise, while incorporating multinational location decisions and their effects on wages and national output. In the model, infrastructure development can attract foreign firms by lowering fixed and marginal costs of production and allow a host country to "jump" out of a 'low level production trap' to a higher national income equilibrium. The idea is that until a country has achieved a threshold, or critical mass, of developed

[1] R&W find a critical mass level of 40 mainlines per 100 people, which is approximately 1 mainline per household.

infrastructure, they will not be able to attract enough firms to generate positive external spillovers from agglomeration in intermediate input markets.

Lowering fixed and marginal production costs is not the only way that infrastructure has been shown to affect firm location and market size. Infrastructure can also impact transportation costs. Martin and Rogers [1995] and Martin [1999] show in a two country general equilibrium context, infrastructure development that lowers international transportation costs and facilitates access to markets can decrease the number firms that locate in a country. If the cost of accessing markets is low, due to a developed international infrastructure, it can be more profitable for firms to stay in their larger home market and simply export to smaller, less developed markets.

The general equilibrium nature of the Kellenberg, Martin and Rogers, and Martin papers reveal an important characteristic associated with infrastructure and its impacts; that infrastructure can have direct and indirect effects in an economy. However, the empirical literature to date has not accounted for the indirect feedback effects of infrastructure on factors of production and multinational location decisions. In fact there has been very little investigation of even the direct impacts of infrastructure on multinational firms and wages, or the potential problem of simultaneity of wages and multinational firm location decisions. For example, Wheeler and Mody [1992] found that labor factor prices are a significant determinant of multinational location decisions while Aitken, Harrison and Lipsey [1996] found that FDI has positive effects on wages. This suggests that if labor receives spillover benefits in terms of higher productivity from increased multinational activity *and* multinationals are basing location decisions on the marginal productivity of labor, then a simultaneity issue must be present[2]. Prior work has captured the direct effect of infrastructure on multinational activity and but reveals nothing about the indirect effects of infrastructure through wages or national output.

Each of the empirical studies described in this section focus on specific parts of the general equilibrium story related to infrastructure. Some studies find direct contributions of infrastructure to growth. Some find positive contributions of infrastructure to multinational location decisions. Numerous other studies have found that MNE's have positive productivity spillovers on host countries GDP[3]. Yet others, in an effort to explain multinational location decisions, have put GDP on the right hand side as an explanatory variable for foreign direct investment or multinational affiliate sales and also found positive results[4]. Some of these studies recognized the simultaneity of domestic growth and multinational activity and attempted to instrument for the problem. However, none of the studies model the problem as a simultaneous system, and thus, do not report the effects in both directions. This raises concerns about the relative magnitudes of the true effects of MNEs on growth, and market size on MNE's. Further, if infrastructure directly affects either multinationals or the marginal product of labor, we should expect indirect feedback effects.

[2] Aitken, Harrison, and Lipsey do instrument to control for endogeneity of FDI and wages, but dismiss the results in favor of a model that does not control for simultineity.

[3] For example, see Caves [1974], Globerman [1979], Blomstrom et. al. [1983], Blomstrom [1986], Aitken, Hanson, and Harrison [1997], Borensztein et. al. [1998], or Aitken and Harrison [1999].

[4] See Kravis and Lipsey [1982], Wheeler and Mody [1992], or Carr, Markusen, and Maskus [2001].

III. The Theoretical Model

This section develops a simple general equilibrium model in a small open economy context that allows for the examination of: (*i*) spillover effects on domestic production from multinational activity in a host country; (*ii*) real wage effects of increasing multinational production; (*iii*) host country market size on multinational production; and (*iv*), the effects of exogenously supplied infrastructure. Using this framework, it is shown that exogenous changes in stocks of infrastructure have direct and indirect effects on domestic output, wages, and multinational production in a host country. The small open economy model consists of two productive sectors, domestic and multinational, which are described below.

The Domestic Sector

The domestic sector consists of an aggregate production function, *Y*, that represents all goods produced domestically and sold on a world market. The production function for the domestic sector is given as:

$$Y = \Omega f(L, K), \tag{1}$$

where $f(\cdot)$ is a twice differentiable, non-increasing returns production function, $f_i > 0, f_{ii} < 0$ for $i = K, L$, and $\Omega = \Omega(\mathbf{P}, X)$. The endogenously determined productivity variable, Ω, is a function of a vector of various types of exogenous variables (**P**) such as infrastructure, as well as an endogenously determined level of multinational activity in the domestic economy (X). Allowing multinational production to enter into the productivity variable Ω is intended to capture the idea that local multinational production potentially confers knowledge or technological spillovers onto domestic producers. For simplicity, Ω is assumed to be Hicks neutral in the domestic production function with respect to labor (*L*) and capital (*K*).

The two factors of production, labor and capital, are assumed to be inelastically supplied to the domestic sector. Perfect competition in factor markets ensures that wage and rental rates are equal to their marginal products:

$$w = \Omega \frac{\partial f(L,K)}{\partial L}, \tag{2}$$

and

$$r = \Omega \frac{\partial f(L,K)}{\partial K}. \tag{3}$$

For the model to be consistent with profit-maximization, the sum of the marginal products of labor and capital, multiplied by their respective supplies, must be less than or equal to total output. The assumption of non-increasing returns with respect to *f(·)* and Hicks neutrality of the productivity variable Ω are sufficient conditions to ensure that labor and capitals contribution to output is not greater than total product[5].

The Multinational Sector

The multinational sector consists of a representative multinational affiliate that sells output, X, on a competitive world market and has the option of opening operations in the host country. No assumptions are made about the exact composition of competition for the international good on the world market, but it is assumed that the representative multinational takes the world price p_w as given, and then makes location

[5] If the production function *f(·)* exhibits constant returns to scale then the marginal products multiplied by their respective endowments must equal total product. If *f(·)* exhibits decreasing returns to scale, then it implies that there is some fixed factor that is receiving rents.

and output decisions. The multinational uses labor to produce *X*, which can be augmented by an endogenously determined productivity variable Φ. The multinationals production function for the international good is:

$$X = \Phi g(L_X) \tag{4}$$

where *g(·)* is a twice differentiable, decreasing returns production function, $g_{Lx}>0$, $g_{LxLx}<0$, and $\Phi = \Phi(\mathbf{P}, Z)$[6]. Like Ω in the domestic sector, Φ is a Hicks neutral productivity variable, where productivity depends on a vector of exogenous variables (**P**), which include measures of infrastructure.

The international sector is assumed to be small relative to the domestic sector. This implies that the multinational is a price taker in the labor market, where the wage rate is determined by the marginal productivity of labor in the domestic sector. The multinational firms problem with respect to production in the host country is to:

$$\max_{L_x} \ \Pi = p_x t(\boldsymbol{\tau}) m(\mathbf{P_I}, Y) \Phi g(L_x) - wL_x - F \ \text{ s.t. } \Phi g(L_X) \geq X \tag{5}$$

where *F* is the fixed cost of operations in the host country[7]. The functions $t(\boldsymbol{\tau}) \in (0,1)$ and $m(\mathbf{P_I}, Y) \in (0,1)$ represent a form of iceberg trade cost. Here, iceberg trade costs reflect the fact that real resources are used up when there are trade and

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[6] One might argue that capital should be included in the multinationals production function. It is left out because capital markets are more complete (especially for large multinationals) internationally than labor markets, such that MNE's are likely to finance capital operations on world capital market rather than in a specific host country. Thus, the focus here is on labor, which is constrained from moving across countries to seek higher returns.

[7] *F* can be thought of as the fixed cost of capital purchased on world markets in units of the numeraire good X.

investment barriers (**τ**), poor international infrastructure ($\mathbf{P_I}$)[8], or the size of the domestic economy (Y) is large. For example, one of the elements of **τ** might represent a tariff on good *X*, which would effectively raise *t(·)* for the multinational. The reason being that it is cheaper to locate in the host country and avoid the tariff charges than to locate in an alternative country and export into the host market[9]. Another example might be protection of intellectual or physical property rights. If the host country has a poor administration of justice or access to legal recourse then the effective costs of doing business in that country will be higher (i.e. a lower *t(·)*).

Including domestic output (*Y)* in the *m(·)* function is intended to capture the idea that market size matters. A simple way to think about this is that multinational firms must make their products "visible" to customers. By not being visible and accessible to their markets, there is a cost of losing market share to world competitors. In this sense there is an opportunity cost to multinational firms associated with not being located in larger markets and implies that *m(·)* is increasing in *Y*[10]. However, if international infrastructure ($\mathbf{P_I}$), such as telecommunications, allow firms to access markets, via the telephone or internet, this will mitigate access losses associated with not physically locating in the country. The idea is similar to the iceberg trade costs associated with

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[8] International infrastructure $\mathbf{P_I}$ can be thought of as a subset of the **P** vector. International infrastructure are those forms of infrastructure that have effects on international access to markets such as telecommunications and the internet.

[9] A tariff on good X raises *t(·)* because by locating in the host country the multinational firm forgoes tariff charges, and thus fewer resources are lost.

[10] The idea here is that not being visible in the larger markets imposes real costs on multinational firms in terms of lost market share and access to customers.

international infrastructure found in Martin and Rogers [1995] and Martin [1999]. The expectation with respect to Y and $\mathbf{P_I}$ can be summarized as $\frac{\partial m(\cdot)}{\partial Y} > 0$ and $\frac{\partial m(\cdot)}{\partial \mathbf{P_I}} < 0$.

The first order condition for equation (5) implies that the marginal product of labor must be equal to the prevailing wage rate in the country

$$p_x \Phi \frac{\partial g(L_x)}{\partial L_x}[t(\boldsymbol{\tau})m(\mathbf{P_I}, Y)]^{-1} = w. \tag{6}$$

Solving equation (6) for labor demand (L_X) and plugging it into equation (4) yields multinational supply in the host country

$$X = X(p_x, w, \Phi, t(\boldsymbol{\tau}), m(\mathbf{P_I}, Y)), \tag{7}$$

as a function of trade and investment costs, *t(·)*, market access, *m(·)*, and the productivity variable in the multinational sector, Φ.

To close the model and ensure that the multinational enters the host country, one more assumption must be made. It is assumed that profits in the host country (Π) are greater than or equal to the profits that could be obtained by opening operations in an alternative country (Π_A), that is, $\Pi \geq \Pi_A$.

Normalizing p_w to 1, the equilibrium values of domestic output, wage rate, and multinational production in the small open economy are determined by equations (1), (2), and (7)[11].

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[11] The two factor market clearing equations are implicitly satisfied here since the assumption is that both K and L are inelastically supplied to the domestic sector. That is, $\overline{K} = K_Y$ and $\overline{L} = L_Y$ where $\overline{K}$ and $\overline{L}$ are the supply of capital and labor available in the country and K_Y and L_Y are the demands from the Y sector. Now, this is not exactly correct because the multinational sector is also demanding labor, which

Decomposing direct and indirect effects

It has been pointed out in Haughwout [2003] and Kellenberg [2003] that investment in public inputs such as infrastructure can have direct as well and indirect effects on the endogenous variables (i.e. domestic output, factor prices, firm location) in a system. To see how the direct and indirect effects arise in the small open economy model above, we can solve each of the three endogenous variables in the system (*Y*, *w*, and *X*) as functions of the exogenous variables and use comparative statics to decompose infrastructures impacts.

First, examining the impact of infrastructure on domestic output, plug equation (2) and (7) into equation (1) and solve for *Y* to get:

$$Y = Y(\Omega(\mathbf{P}, X(\Phi(\mathbf{P}), t(\boldsymbol{\tau}), m(\mathbf{P_I}), w(\mathbf{P}, f(L,K)), f(L,K)) = Y(\mathbf{P}, L, K) . \tag{8}$$

Equation (8) gives output as a function of the exogenous variables in the model (**P**, *L*, and *K*).

To solve for the marginal effect on domestic output of a change in infrastructure type P_j, take the partial derivative of (8) with respect to P_j to obtain:

$$\frac{\partial Y}{\partial P_j} = \frac{\partial Y}{\partial \Omega}\frac{\partial \Omega}{\partial P_j} + \left[\frac{\partial Y}{\partial \Omega}\frac{\partial \Omega}{\partial X}\frac{\partial X}{\partial \Phi}\frac{\partial \Phi}{\partial P_j} + \frac{\partial Y}{\partial \Omega}\frac{\partial \Omega}{\partial X}\frac{\partial X}{\partial m}\frac{\partial m}{\partial P_j}\right] + \frac{\partial Y}{\partial \Omega}\frac{\partial \Omega}{\partial X}\frac{\partial X}{\partial w}\frac{\partial w}{\partial P_j} . \tag{9}$$

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means that the labor market clearing condition is really $\bar{L} = L_Y + L_X$. However, for simplicity we assume away multinational firm demand side effects on the wage rate by assuming L_X is excessively small relative to L_Y. While there is reason to believe that in some circumstances this assumption may be too strong, in many countries less than 1% of overall employment is with foreign multinational firms. In this respect, any affects that multinational production has on domestic productivity and wage rates will be interpreted as knowledge or technological spillovers.

Infrastructure type P_j has a direct effect on domestic output through the first term in equation (9) by impacting the productivity variable Ω. However, it also has indirect effects on output by: (i) impacting multinational productivity, Φ, which affects multinational production in the host country, X, and thus affects the spillover effects on domestic production through Ω; (ii) increasing market access for multinational firms, which ultimately effects spillovers to production in the domestic sector[12]; and (iii) by changing the marginal product of labor, w, which again affects firm output, X, and thus, domestic output though Ω.

In a similar fashion, we can solve for w as a function of the exogenous variables in the system by substituting equation (1) into (7) to get an expression for X. Then, substitute the new expression for X into equation (2) and solve for w to get:

$$w = w(\Omega(\mathbf{P}, X(\mathbf{P}, t(\tau), m(\mathbf{P_I}, Y(\Omega(\mathbf{P}), f(L,K)), f(L,K)) = w(\mathbf{P}, L, K) \qquad (10)$$

Taking the partial derivative of (10) with respect to infrastructure type P_j we can decompose the impacts into their direct and indirect effects on wages:

$$\frac{\partial w}{\partial P_j} = \frac{\partial w}{\partial \Omega}\frac{\partial \Omega}{\partial P_j} + \left[\frac{\partial w}{\partial \Omega}\frac{\partial \Omega}{\partial X}\frac{\partial X}{\partial P_j} + \frac{\partial w}{\partial \Omega}\frac{\partial \Omega}{\partial X}\frac{\partial X}{\partial m}\frac{\partial m}{\partial P_j}\right] + \frac{\partial w}{\partial \Omega}\frac{\partial \Omega}{\partial X}\frac{\partial X}{\partial m}\frac{\partial m}{\partial Y}\frac{\partial Y}{\partial P_j}, \qquad (11)$$

where the first term represents the direct effect on the marginal productivity of labor and the last three terms represent the indirect effects through affiliate production, market access (again, this term is only present if P_j is in the subset of $\mathbf{P_I}$), and market size.

[12] The term in brackets represents the combined productive and market access indirect effect through multinational firms. Note that the third term in equation (9) will only appear when infrastructure type P_j is in the subset of infrastructure types that affect market access ($\mathbf{P_I}$).

Finally, the decomposition of the marginal effect of infrastructure type P_j on multinational sector output can be solved in the same fashion as above by substituting equations (1) and (2) into (7) and solving for *X*. Multinational output can be represented as:

$$X = X(\Phi(\mathbf{P}), m(\mathbf{P_I}, Y(\Omega(\mathbf{P})), w(\Omega(\mathbf{P}), f(L,K)), t(\boldsymbol{\tau})) . \quad (12)$$

The marginal effect of a change in infrastructure type P_j on multinational production is:

$$\frac{\partial X}{\partial P_j} = \left[\frac{\partial X}{\partial \Phi}\frac{\partial \Phi}{\partial P_j} + \frac{\partial X}{\partial m}\frac{\partial m}{\partial P_j} \right] + \frac{\partial X}{\partial m}\frac{\partial m}{\partial Y}\frac{\partial Y}{\partial \Omega}\frac{\partial \Omega}{\partial P_j} + \frac{\partial X}{\partial w}\frac{\partial w}{\partial \Omega}\frac{\partial \Omega}{\partial P_j} , \quad (13)$$

where again, the first term in brackets in equation (13) is the combined direct effect of infrastructure type P_j on multinational production (the productive effect and the market access effect) and the last two terms represent the indirect effects through domestic output and wages.

IV. The Empirical Model

Maintaining the assumptions of the theoretical model and specifying simple functional forms, it is possible to obtain consistent estimates of the parameters by estimating the model using a systems approach. Let equation (1) of the theoretical model be defined as:

$$Y = \Omega(L^{\alpha_2} K^{\alpha_3}) \quad (1')$$

where $\Omega = C_Y^{\alpha_0} X^{\alpha_1} \prod_{j=4}^{J} P_j^{\alpha_j} e^{\alpha_t t} e^{\varepsilon_Y}$ and $\alpha_2 + \alpha_3 = 1$. C_Y is a constant productivity parameter specific to the host economy, *X* is production from multinational corporations, P_j are exogenous productivity effects such as infrastructure, *L* and *K* are the exogenous and inelastically supplied stocks of labor and capital, t is a systematic growth trend, and ε_Y is a mean-zero normally distributed random productivity parameter.

Taking the partial derivative of (1) with respect to L and K and setting them equal to the wage (w) and rental (r) rates we get:

$$w = \alpha_2 L^{\alpha_2 - 1} K^{\alpha_3} \Omega \qquad (2')$$

and

$$r = \alpha_3 L^{\alpha_2} K^{\alpha_3 - 1} \Omega \ . \qquad (3')$$

The production function for the multinational good sector is:

$$X = \Phi\left(\frac{L_X^{\delta_1}}{\delta_1}\right), \qquad (4')$$

where $\Phi = C_X^{\delta_0} \prod_{j=3}^{J} P_j^{\delta_j} e^{\delta_t t} e^{\varepsilon_X}$, and $\delta_1 < 1$. Productivity depends on the size of the domestic economy (Y), exogenous productivity variables (P_j), a time trend (t), and a mean-zero normally distributed random productivity shock (ε_X).

The multinational firms problem is to maximize the profit function in equation (5), where the functional forms for trade and investment barriers and market access are given as $T = t(\tau) = \prod_{m=J+1}^{M} \tau_m^{\delta_m}$ and $M = m(P_I, Y) = Y^{\delta_3} \prod_{g=M+1}^{G} P_I^{\delta_g}$. Solving for the multinationals labor demand and plugging it back into the production function gives the multinationals supply function:

$$X = \delta_1^{-1} \left[\Phi T^{-\delta_1} M^{-\delta_1} w^{-\delta_1}\right]^{\frac{1}{1-\delta_1}} . \qquad (7')$$

To estimate the system, take the log of equations (1’), (2’) and (7’) to obtain:

$$Y_{it}^{*} = \alpha_{i0} + \alpha_1 X_{it}^{*} + \sum_{s=2}^{3} \alpha_s V_{sit}^{*} + \sum_{j=4}^{J} (\alpha_j + D_{jit}^{M} \alpha_j^{M} + D_{jit}^{H} \alpha_j^{H}) P_{jit}^{*} + \alpha_{J+1} Den^{*} + \varepsilon_Y , \qquad (1")$$

$$w_{it}^{*} = \alpha_0^{w} + \alpha_1^{w} X_{it}^{*} + \sum_{s=2}^{3} \alpha_s^{w} V_{sit}^{*} + \sum_{j=4}^{J} (\alpha_j^{w} + D_{jit}^{M} \alpha_j^{wM} + D_{jit}^{H} \alpha_j^{wH}) P_{jit}^{*} + \alpha_{J+1}^{w} Den^{*} + \varepsilon_w , \qquad (2")$$

and

$$X_{it}^{*} = \beta_{i0} + \beta_1 w_{it}^{*} + \beta_2 Y_{it}^{*} + \sum_{j=3}^{J} (\beta_j + D_{jit}^{M} \beta_j^{M} + D_{jit}^{H} \beta_j^{H}) P_{jit}^{*} + \beta_{J+1} Den^{*} + \sum_{m=J+2}^{M} \beta_m \tau_{mt}^{*} + \varepsilon_X , \qquad (7")$$

where $\beta_1 = -\delta_1 \rho, \beta_2 = \delta_2 \rho, \beta_j = \delta_j \rho, \beta_g = \delta_g \rho, \beta_m = -\delta_m \rho$, $\rho = \left[\frac{1}{1-\delta_1} \right]$, (*'s) indicate logged variables, and the *V*'s now represent the two primary factors of production (labor and capital). The variables D_{jit}^{M} and D_{jit}^{H} are dummy variables indicating whether country *i* has a medium or high level of infrastructure type *j* in year *t*, the classification of which is described in the next section. In equation (1") α_j, represents the direct effect of U.S. affiliate sales on GDP for countries with low levels of infrastructure, while α_j^{M} and α_j^{H} represent the difference in the direct effects of countries with medium and high levels of infrastructure type *j*. Likewise, in equation (7") the parameter β_j represents the direct effect of low infrastructure type *j* on U.S. affiliate sales, while β_j^{M} and β_j^{H} are interpreted as the difference in the direct effects of medium and high infrastructure type *j* on U.S. affiliate sales.

The system (1"), (2") and (7") constitute an equilibrium for the small open economy[13]. Constant returns to scale in the domestic sector combined with the assumptions of Hicks neutrality and competitive factor markets imply the following restrictions:

$$(R1)\quad \alpha_2 + \alpha_3 = 1,$$

$$(R2)\quad \alpha_2^w = \alpha_2 - 1,$$

and

$$(R3)\quad \alpha_h^w = \alpha_h \text{ for all } \alpha_h \neq \alpha_2 .$$

From the above specification we can obtain estimates of the structural parameters for domestic output and wages as well as estimates of the reduced form variables in the multinational sector.

Data and Descriptive Statistics

Data for the model include 31 countries over a 16-year time span covering the years 1983-1998[14]. Starting with equation (1"), *Y* is GDP net of U.S. Affiliate Sales[15]. Multinational production, *X*, is manufacturing sales by majority-owned U.S. foreign affiliates. Actual production figures for U.S. foreign affiliates are not available, so

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[13] Notice that we do not need to estimate the capital return equation (3) because the return to capital has no feedback effects on domestic or international production or the marginal productivity of labor. That is, with the exception of the mean zero random shock, the capital rate in the host country is deterministic.

[14] To put the sample into context, in 1983 these 31 countries accounted for 90% of total U.S. manufacturing affiliate sales in the world.

[15] All monetary figures have been converted to real 1995 international dollars using the appropriate PPP investment, consumption or GDP exchange rates from the Penn World Tables V6.1.

affiliate sales are used as a proxy for production in the host country[16]. Labor (*L)* is measured as total labor force, while the capital stock (*K)* is constructed using the perpetual inventory method on gross fixed capital investment over the previous 14-year time period and a discount rate of 10%. Wages are measured as the average hourly wage paid to manufacturing workers. The *Den* variable is an exogenous productivity parameter that is measured as the percentage of the population living in an urban area. It is included to capture the net effects of agglomeration and congestion externalities that are not specifically attributable to infrastructure in an economy, but are rather the result of a population's geographic location.

Three forms of physical infrastructure are examined, telecommunications, schools, and electrical capacity[17]. To measure whether there are differences in the effects of the specific types of infrastructure, each country is classified in each year as having a low, medium, or high level of the three types of infrastructure[18]. These categorizations are used as dummy variables (D_{jit}^{M} and D_{jit}^{H}) on the infrastructure variables in the system. The reason for doing so is to determine whether countries with medium or high levels of

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[16] To the extent that sales overstate actual production taking place in the host country, the use of sales figures instead of production figures will tend to understate the effects of affiliate production on the domestic sector and factor productivity.

[17] Schools and electrical capacity can be thought of as domestic infrastructure types in the set **P** of Section III, while telecommunications are in the subset $\mathbf{P_I}$ that have both direct productive effects but also market access effects through *m(·).*

[18] For each classification of the three infrastructure variables (low, medium, high), each classification contains at least 23% of the observations in the sample.

infrastructure experience the same marginal effects as countries with low levels of infrastructure.

Telecommunications data are measured as the total stock of telephone mainlines in a country. Distinguishing between low, medium and high telecommunications countries, we use the same classification as R&W such that an observation with less than 20 mainlines per 100 people is classified as ‘low’ telecommunications; an observation with greater than 20 but less than 40 mainlines per 100 people is classified as ‘medium’ telecommunications; and an observation with 40 or greater mainlines per 100 people is classified as ‘high’ telecommunications.

Educational infrastructure in the country, *School*, is proxied by the average years of schooling of people aged 25 years or older. Observations are only available for the years 1980, 1985, 1990, 1995, and 2000 so the non-observation years are interpolated to obtain a complete time-series. Countries with populations that have less than 7 years of average schooling are classified as ‘low’ school countries. Those with between 7 and 9 years of average schooling are classified as ‘medium’ school countries; and those with greater than 9 years of average schooling were classified as ‘high’ school countries

Total installed electrical capacity is the third form of infrastructure examined and is measured as the total electrical capacity from fossil fuel, nuclear, hydroelectric and wind generating sources. Country observations with a capacity of 1 or less kilowatts per person are classified as ‘low’ electrical capacity; observations with capacity that is greater than 1 but less than 2 kilowatts per person are classified as ‘medium’ electrical capacity; and observations with capacity of 2 or greater kilowatts per person are classified as ‘high’ electrical capacity.

An important assumption in the approach taken in this paper is that measures of infrastructure are exogenous. In this regard, a few caveats are in order. First, with the exception of the R&W paper, previous literature has assumed measures of infrastructure to be exogenous to growth. This is not an adequate justification for doing it here, but Röller and Waverman concede in a footnote that for many specifications, simultaneity of growth and telecommunications infrastructure is not significant. Second, one of the arguments of this paper is that investments in infrastructure have marginal effects on factor productivity, and subsequently on factor prices. However, there may be simultaneity issues between infrastructure variables and wage rates. A common reason cited for why governments spend money on large infrastructure projects is as a solution to problems of unemployment and job creation. That is, low labor demand, which is reflected in low wage rates, could be the impetus for government spending on infrastructure in the first place.

Third, the empirical question of whether infrastructure and foreign direct investment are endogenously related has not been addressed previously in the literature. Do governments actively build infrastructure projects to attract multinationals or does infrastructure improve *because* of multinationals? The issue is not immediately clear. However, specific case studies [outlined in Hobday (1995) and Li (2002)] of such East Asian countries as Singapore, South Korea, and Taiwan that strategically invested ex-ante in various research parks, educational institutes, and telecommunications projects in order to attract foreign companies, seem to suggest that causality runs from infrastructure to multinational activity.

Caveats aside, the point of this paper is to address the effects of various forms of infrastructure while controlling for the potentially more problematic simultaneity issues between GDP growth, multinational activity, and wages. Since not all variables in the model can be endogenized, a second best effort to control for the potential problem of simultaneity of infrastructure with the endogenous variables (Y, w, and X) in the system is handled by using one year lagged, or predetermined, values for all infrastructure variables.

[Insert Table 1]

The theoretical model allows for the effects of various forms of trade and/or investment barriers (T) on multinational activity. The variables included in T for the empirical specification are *INVC* and *TCI*, which are indexes of investment barriers and trade protection in a host country. The *INVC* index contains information on perceived barriers to foreign investment such as market dominance by small numbers of enterprises, lack of intellectual property rights, controls on hiring and firing practices, difficulty in securing local bank credit, restraints on local and foreign capital markets, restrictions on joint ventures or ability to acquire control in domestic firms, and the fair administration of justice. The *TCI* index measures the relative strength of protectionist policies in the host country and is intended to account for trade barriers such as tariffs or domestic subsidies[19]. The sign of *INVC* is expected to be negative, as larger barriers to investment increase the effective costs of production (i.e. a lower value of $t(\cdot)$) in the host economy. If U.S. MNE's are jumping tariffs we expect the coefficient on *TCI* to be positive; the greater the level of protection, the greater the incentive to produce in a host country rather

[19] See Carr, Markusen, and Maskus [2001] for details about the construction of the *INVC* and *TCI* indexes.

than export to it. A complete list of the variables in the model and their sources are described Table 1.

[Insert Table 2]

Table 2 gives the 1983 and 1998 values of GDP[20], U.S. affiliate sales, wages, and stocks of infrastructure (telecommunications, electrical capacity and schools), as well as the average annual growth rate (AAGR) of each. Note first the AAGR of output, factor prices and infrastructure. Over the period sample, the average AAGR of GDP and U.S. affiliate sales for the 31 countries was 3.76% and 6.84%, respectively . At the same time, the average real wage was growing by 1.66% per year. Note however that not all countries were sharing in these growth rates equally. While countries like Singapore and Korea saw exceptional growth in real manufacturing wage rates, other countries such as Mexico and Indonesia actually saw a decline in the real value of their wages. Average GDP growth was as high as 8.2% for Chile and as low as –0.05% in Germany, while average growth in U.S affiliate sales ranged from 19.77% in Indonesia to –3.97% in Norway. All of this was taking place at a time when the average annual growth rate of infrastructure in all 31 countries was positive. Between 1983 and 1998, the average AAGR of telecommunications, electrical, and school infrastructures was 5.30%, 3.47%,

[20] GDP is calculated as net GDP, that is, GDP minus U.S. affiliate sales. The reason for this calculation is that any manufacturing affiliates that produce in the host country will be counted in domestic product; and we are trying to make a distinction between domestic and U.S. affiliate produced goods. U.S. affiliate sales are *not* measures of production, but are a proxy for production in the host country. To the extent that value added comes from intermediate goods shipped from abroad, U.S. affiliate sales will tend to overstate U.S. affiliate production.

and 1.45%, respectively. In the following section, we report the effects of infrastructure on the endogenously determined variables of GDP, U.S. affiliate sales and wages.

V. Results and Extensions

The system (1”), (2”) & (7”) is estimated in columns (A) and (B) of Table 3 using equation-by-equation 2SLS and 3SLS, respectively, while controlling for country specific fixed-effects in the *Y* equation. Of the three types of infrastructure estimated, only telecommunications and schools have significant productivity enhancing effects on GDP and wages.

[Insert Table 3]

The estimates of telecommunications on GDP and wages are positive and significant for countries with less than 20 mainlines per 100 people in the 2SLS estimation but insignificant in the 3SLS estimation. However, medium and high telecommunications countries have positive and significant coefficients on growth and labor productivity under both estimation strategies[21]. In fact, medium and high infrastructure countries (those with greater than 20 mainlines per 100 people) get a 0.012 to 0.017 greater marginal effect on productivity and wages than low telecommunications countries. This represents an 18% to 29% greater marginal effect for medium and high telecommunications countries than for low telecommunications countries and is consistent with a critical mass story[22].

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[21] Joint tests of the significance of (*Tele+Telemed*) and (*Tele+Telehi*) are significant at the 10% level.

[22] The results here indicate that the threshold level is 20 mainlines per 100 people, whereas R&W find a threshold level of 40 mainlines per 100 people. There are many things that could account for this. One is that the R&W study did not account for the effects of multinational activity or other forms of infrastructure, a second is that the sample periods are different (1970-1990 vs. 1983-1998). Ideally we would like to test

Like telecommunications, there are increasing marginal returns to GDP and wages for greater investment in schools. Countries with 'high' levels of school infrastructure receive 0.047% to 0.068% greater marginal increases in domestic output and wages than countries with 'low' levels of schools. In fact, in the 2SLS estimation of column (A), schools do not have a statistically significant effect on domestic output or wages while countries with 'high' levels of schools get a 0.19% increase in GDP and wages from a 1% increase in schools[23]. Under the 3SLS estimation, 'low' school countries get a 0.168% increase in GDP and wages from a 1% increase in schools while 'medium' and 'high' school countries get marginal increases of 0.196% and 0.236%, respectively.

The negative coefficient on *Density* in the GDP and wage equations at first appears surprising, as one expects greater concentration to potentially facilitate knowledge spillovers and decrease transaction costs associated with distance. However, greater concentration can also mean greater congestion, creating negative spillovers that hamper productivity. Another explanation concerns the composition of the labor market. In this model, it is assumed that all factors of production are at full employment. If unemployment is prevalent, then the *Density* variable could be picking up the effects of unemployment. For example, if people move from low paying, but productive, rural jobs in hopes of finding higher paying work in cities but are unable to, concentration will rise but overall productivity will decline.

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the results here against the same time period as used by Röller and Waverman, however BEA data on U.S. affiliates are only available from 1983 on.

[23] Joint tests that *Sch+Schhi=0* and *Sch+Schmed=0* for the *Y* and *w* equations are rejected at the 5% and 10% significance levels, respectively, for columns (A)-(D) of Table 3.

U.S affiliate sales have a positive and significant effect on domestic output and wages, supporting the notion that multinationals have non-negligible spillover effects on host economies. From column (*B*) in Table 3 we see that a 1% increase in U.S. affiliate sales will contribute to an increase in domestic output of 0.18%. The elasticity estimates of 0.12 and 0.18 are similar to the estimates obtained by Aitken, Harrison, and Lipsey (1996) in their study of Mexico, Venezuela, and the U.S. They obtain estimates of wage elasticities with respect to foreign direct investment that range from 0.03 to 0.28.

The coefficients related to trade and investment costs (*INVC* and *TCI*) in the *X* equation are of the expected sign. The results indicate that U.S. affiliates are negatively influenced by barriers to investment (a lower *t(·)* function in equation (5)), and more likely to locate in countries with high degrees of protection (again, a lower *t(·)* function).

Higher levels of GDP have strong and significant positive effects on the output of U.S. affiliates; a result that is in line with the work by Carr, Markusen and Maskus [2001] and Chakraborty and Basu [2002]. All else equal, a 1% increase in domestic sector output will increase U.S. multinational sales by 1.13% to 1.30%.

Contrary to what we would expect from the theoretical model, wages have a positive and significant impact on affiliate sales. U.S. affiliate sales actually increase between 0.84% to 1.07% for every 1% increase in wage rates. Despite this counterintuitive result, it is consistent with the previous findings of Kravis and Lipsey [1982] and Wheeler and Mody [1992]. Additionally, telecommunications, schools and electrical capacity have strong negative marginal effects on affiliate sales[24]. The negative

[24] The coefficient for 'low' telecommunications countries is positive but insignificant while *Tele+Telemed* and *Tele+Telehi* are both negative and significant.

effect of telecommunications is reasonable if the market access effect (second term in equation (13)) is stronger than the productive effect (first term in equation (13)). However, unless we believe that electrical capacity somehow improves market access, then the strong and significant negative effect of electrical capacity on affiliate sales is a bit puzzling. Further, given that Markusen and Venables [1998] have shown theoretically, and Carr, Markusen, and Maskus [2001] have shown empirically, that MNE's are attracted to countries with more skilled workforces, the negative coefficient on schools is cause for concern.

One reason for the unexpected results may have to do with spurious correlation of multinational firm location and unobserved country-specific characteristics. This is a problem that has been well established in the growth literature, but has not been adequately accounted for in the multinational location literature[25]. To control for the problem, country specific fixed-effects are included in equation (7") and the system is run again. The results of the 2SLS and 3SLS estimations are reported in columns (C) and (D) of Table 3, respectively.

Note that the estimates in the GDP and wage equations remain almost identical to the estimates in columns (A) and (B). However, there are significant changes in the parameter estimates in the U.S. affiliate equation. Wages now have a statistically significant negative effect on U.S. affiliate sales. All else equal, a 1% rise in the market wage will decrease U.S. affiliate sales in a host country by 0.77% to 0.85%. Market size remains a positive and significant influence on U.S. affiliate sales and the sign on schools

[25] Neither Kravis and Lipsey [1982] nor Wheeler and Mody [1992] control for country specific fixed-effects.

is positive and significant. However, unlike the effects on GDP and wages, countries with ‘medium’ and ‘high’ levels of school do not have statistically different marginal effects on attracting U.S. affiliates than ‘low’ school countries.

A 1% increase in telecommunications decrease U.S. affiliate sales by 0.37% to 0.42%, supporting the hypothesis that infrastructure that facilitates access to markets can decrease the incentives for multinational firms to physically locate affiliates in foreign markets. The effect of electrical capacity on U.S. affiliates is still negative, but the coefficient has fallen substantially and is not significant for any of the three levels of infrastructure.

Comparative Static Analysis

Estimation of the system (1”), (2”) and (7”) allows us to recover estimates of the structural parameters of (1’) and (2’) and reduced form estimates of (7’). However, as pointed out in Section III, in order to fully answer the question of whether various measures of infrastructure have a role in attracting affiliate sales, and further, whether countries with relatively high infrastructure experience different effects than countries with relatively low levels of infrastructure, we must take into account the *direct* as well as the *indirect* effects of infrastructure development. To do so we must solve for the comparative static effects of infrastructure on the endogenous variables (*Y*, *w*, and *X*).

The empirical analogs of equations (9), (11), and (13) of Section III are given as:

$$\frac{\partial Y^*}{dP_j^*} = \left[\frac{1}{1-\beta_2\alpha_1}\right]\left[\alpha_1\beta_1\alpha_j^{wq} + \alpha_1\beta_j^q + (1-\alpha_1\beta_1)\alpha_j^q\right], \qquad (9')$$

$$\frac{\partial w^*}{dP_j^*} = \left[\frac{1}{1-\beta_1\alpha_1}\right]\left[\alpha_1\beta_2\alpha_j + \alpha_1\beta_j + (1-\alpha_1\beta_2)\alpha_j^{wq}\right], \qquad (11')$$

$$\frac{\partial X^*}{\partial P_j^*} = \left[\frac{1}{1-\beta_1\alpha_1^w - \beta_2\alpha_1}\right]\left[\beta_1\alpha_j^{wq} + \beta_2\alpha_j^q + \beta_j^q\right], \tag{13'}$$

where *q = low, medium, high*. For example, when *q = low*, $\alpha_j^{wq} = \alpha_j^w$ but when *q = high*, α_j^{wq} is equal to $(\alpha_j^w + \alpha_j^{wH})$, α_j^{rq} is equal to $(\alpha_j^r + \alpha_j^{rH})$, and so forth[26]. In equation (9'), the first term in brackets represents the indirect effect of infrastructure type P_j on output Y through wages; the second term is the indirect effect of infrastructure type P_j's impact on affiliate sales X; and the third term represents the weighted direct effect of infrastructure P_j on output Y. The sum of the two indirect effects and the direct effect gives the total effect of a change in a measure of infrastructure P_j on domestic output. Equations (11') and (13') can be interpreted in the same fashion, where the first two terms in the second set of square brackets are the indirect effects of infrastructure type P_j through the other endogenous variables in the system and the third term is the direct effect on the endogenous variable in question.

Looking at the effects of the three forms of infrastructure in Table 4(a)-(c), we see that by using the parameter estimates from the structural equations in columns (C) and (D) of Table 3, we can recover the *indirect*, *direct* and *total* effects of a change in a particular form of infrastructure on the endogenous variables of the model.

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[26] It is possible simply to solve for the reduced form of the model and then estimate it using OLS to obtain the total effect of exogenous increases in infrastructure. There are two reasons for not taking that approach; first, as pointed out by Wooldridge [2002], deriving the estimates of the reduced form parameters from the estimates of the structural parameters is asymptotically more efficient than estimating the reduced form parameters directly (provided the model is not misspecified). Second, estimating the structural model allows us to see exactly how the infrastructure measures are influencing the endogenous variables in the model.

[Insert Table 4(a)]

In Table 4(a), the effects of telecommunications on output (*Y*), wages (*w*), and U.S. affiliate sales (*X*), are reported for low, medium and high levels of infrastructure. When we account for the indirect effects of telecommunications on the other endogenous variables in the system, we find that the *total* effect of telecommunications on GDP and wages is much smaller than the direct effects would suggest. As telecommunications infrastructure increases there is a positive and increasing marginal direct effect on GDP through increased domestic productivity. However, the indirect effects through wages and U.S. affiliates tend to partially negate the positive direct effects. As telecommunications increase, workers become more productive and wages rise. U.S. affiliates subsequently exit the country because of rising wages and their increased ability access markets from abroad, which negatively affects GDP due to lost productivity spillovers. The *total* effect is a smaller but still positive contribution to GDP from telecommunications infrastructure and is suggestive of a critical mass story. The total marginal effect of telecommunications on GDP is 22% to 27% larger for countries that have passed the 20 mainlines per 100 person threshold.

The total effect of telecommunications on wages is similar to the effect on GDP. The negative indirect effect associated with lost productivity spillovers to labor when U.S. affiliates exit, partially negate the positive direct effects associated with increased telecommunications development. With respect to telecommunications effects on U.S. affiliates, it is the negative indirect effect through wages and the negative direct market access effect that dominate the positive indirect effect through GDP.

[Insert Table 4(b)]

Table 4(b) and 4(c) present the comparative static effects of schools and electrical capacity on GDP, wages and U.S. affiliates, respectively. Schools have positive and increasing marginal total effects on all three endogenous variables. Looking at the comparative static effects of schools on domestic output and wages, the total effects are greater than the direct effects alone. The reason is that greater investment in schools has the additional positive indirect effect of generating more spillovers to labor productivity by attracting U.S. affiliates. With respect to schools effects on U.S. affiliates, it is the direct positive effect combined with the indirect effect through GDP that outweigh the indirect effect of rising wages. Schools effects on GDP, wages and U.S. affiliates might at first appear to be best described as a 'mass' effect rather than one of critical mass, as marginal returns are increasing as we move from countries with 'low' to 'high' levels of school. However, the marginal effects for 'high' school countries over 'medium' school countries tend to be proportionately larger than the marginal effects of 'medium' school countries over 'low' school countries. For example, in row (D) of Table 4(b), the marginal total effect for 'medium' school countries is 8% larger than the marginal total effect for 'low' school countries, but the marginal total effect for 'high' school countries is 14% greater than the marginal total effect for 'medium' school countries.

[Insert Table 4(c)]

The total effect of electrical capacity on the three endogenous variables is positive with increasing marginal returns for countries with greater capacity. Countries with a capacity of greater than 2 kilowatts per person get marginal total effects on GDP and wages that are nearly twice as big as countries with capacities of less than 2 kilowatts per person. However, given the statistical insignificance of electrical capacity in any of the three equations in columns (C) and (D) of Table 3, caution should be taken in drawing conclusions with respect to issues of critical mass in electrical capacity.

VI. Conclusion

This paper makes three important contributions to the existing literature with respect to the impacts of infrastructure on growth. First, it has shown that by developing a simple theoretical model that allows for the endogeneity of growth, multinational activity, and wages, we can decompose the total effect of infrastructure into *direct* and *indirect* general equilibrium effects. Empirically, it is found that the total effects of telecommunications and schools on GDP, wages, and U.S. affiliate activity are significantly influenced by both direct productivity impacts as well as indirect general equilibrium feed back effects.

Second, using this framework we test for issues of critical mass in three types of infrastructure. It is found that telecommunications, schools and electrical capacity all have increasing marginal total effects. That is, greater investments in infrastructure result in greater marginal returns to domestic output, wages, and U.S. affiliate sales. This fact should be an important consideration for anyone thinking about growth and development policy, because the returns to any type of infrastructure investment are going to be determined by a countries current stage of infrastructure development.

Finally, it is shown that spurious correlation is a potential problem when estimating infrastructures marginal effects on multinational firm location decisions. Country specific fixed-effects can correct the problem and lead to more reasonable estimates than previously found.

References

Aitken, Brian J., Gordon H. Hanson, and Ann E. Harrison. "Spillovers, foreign investment, and export behavior." *Journal of International Economics*, 43, 1997.

Aitken, Brian J. and Ann E. Harrison. "Do Domestic Firms Benefit from Direct Foreign Investment? Evidence from Venezuela." *American Economic Review*, Vol. 89, No. 3, 1999.

Aitken, Brian J., Ann E. Harrison, and Robert E. Lipsey. "Wages and foreign ownership: A comparative study of Mexico, Venezuela, and the United States." *Journal of International Economics*, 40, 1996.

Aschauer, David Alan. "Is Public Expenditure Productive?" *Journal of Monetary Economics*, March 1989, 23(2), pp. 177-200.

Baldwin, Richard, Rikard Forslid, Philippe Martin, Gianmarco Ottaviano and Frederic Robert-Nicoud. Economic Geography and Public Policy. Princeton University Press, 2003.

Belderbos, René, and Giovanni Capannelli. "Backward Vertical Linkages of Foreign Manufacturing Affiliates: Evidence from Japanese Multinationals." *World Development*, Vol. 29, No. 1, 2001.

Berman, E., J. Bound and Z. Griliches. "Changes in the demand for skilled labor within U.S. manufacturing: evidence from the annual survey of manufactures." *Quarterly Journal of Economics*, 109, 1994.

Blomstrom, Magnus. "Foreign Investment and Productive Efficiency: The Case of Mexico." *Journal of Industrial Economics*, 35(1), September 1986.

Blomstrom, Magnus, Gunnar Fors, and Robert E. Lipsey. "Foreign Direct Investment and Employment: Home Country Experience in the United States and Sweden." *The Economic Journal*, Vol. 107, 1997.

Blomstrom, Magnus, and Robert E. Lipsey. "Firm Size and Foreign Operation of Multinationals." *Scandinavian Journal of Economics*, Vol. 93, No. 1, 1991.

Blomstrom, Magnus and Hakan Persson. "Foreign Investment and Spillover Efficiency in an Underdeveloped Economy: Evidence from the Mexican Manufacturing Industry." *World Development*, 11(6), June 1983.

Blonigen, Bruce A. "Firm-Specific Assets and the Link between Exchange Rates and Foreign Direct Investment." *American Economic Review*, Vol. 87, No. 3, 1997.

Borensztein, E., J. De Gregorio, and J-W. Lee. "How does foreign direct investment affect economic growth?" *Journal of International Economics,* 45, 1998.

Bound, J. and G. Johnson. "Changes in the structure of wages in the 1980's: an evaluation of alternative explanations." *American Economic Review,* 82, 1992.

Brainard, Lael S. "An Empirical Assessment of the Proximity-Concentration Trade-off Between Multinational Sales and Trade." *American Economic Review,* Vol. 87, No. 4, 1997.

Canning, David. "A Database of World Infrastructure Stocks, 1950-1995." *The World Bank Economic Review*, Vol. 12, No. 3, 1998.

Canning, David. "Infrastructure's Contribution to Aggregate Output." Policy Research Working Paper 2246, World Bank, 1999.

Carlton, Dennis W. "The Location and Employment Choices of New Firms: An Econometric Model with Discrete and Continuous Endogenous Variables." *The Review of Economics and Statistics,* Vol. 65, Issue 3, 1983.

Carr, David L., James R. Markusen, and Keith E. Maskus. "Estimating The Knowledge-Capital Model of the Multinational Enterprise." *American Economic Review,* Vol. 91, No. 3, 2001.

Caves, Richard E. "Multinational Firms, Competition, and Productivity in Host-Country Markets." *Economica*, 41(162), May 1974.

Chakraborty, Chandana and Parantap Basu. "Foreign Direct Investment and growth in India: a cointegration approach." *Applied Economics*, 34, 2002.

Cushman, David O. "The Effects of Real Wages and Labor Productivity on Foreign Direct Investment." *Southern Economic Journal,* Vol. 54, 1987.

Davis, S.J. and J. Haltiwanger. "Wage dispersion between and within U.S. manufacturing plants, 1963-86." Brookings Papers on Economic Activity: Microeconomics, 1991.

Eaton, Jonathan and Akiko Tamura. "Bilateralism and Regionalism in Japanese and U.S. Trade and Direct Foreign Investment Patterns." *Journal of the Japanese and International Economies,* 8(4), 1994.

Feenstra, Robert C., and Gordon H. Hanson. "Foreign direct investment and relative wages: Evidence from Mexico's maquiladoras." *Journal of International Economics,* 42, 1997.

Fernald, John G. "Roads to Prosperity? Assessing the Link Between Public Capital and Productivity." *American Economic Review*, Vol. 89, No. 3, 1999.

Garcia-Mila, T. and T.J. McGuire. "The Contribution of Publicly Provided Inputs to States' Economies." *Regional Science and Urban Economics*, June, 22(2), 1992.

Globerman, Steven. "Foreign Direct Investment and 'Spillover' Efficiency Benefits in Canadian Manufacturing Industries." *Canadian Journal of Economics*, 12(1), February 1979.

Gramlich, Edward M. "Infrastructure Investment: A Review Essay." *Journal of Economic Literature*, Vol. 32, Issue 3, 1994.

Haaland, Jan I. And Ian Wooton. "International Competition for Multinational Investment". *Scandinavian Journal of Economics* 101(4), 1999.

Helpman, Elhanan. "A Simple Theory of International Trade with Multinational Corporations." *Journal of Political Economy*, 93(3), June 1984.

Heston, Alan, Robert Summers and Bettina Aten, Penn World Table Version 6.1, Center for International Comparisons at the University of Pennsylvania (CICUP), October 2002.

Hobday, Michael. Innovation in East Asia: The Challenge to Japan. Edward Elgar Publishing Ltd., U.K., 1995.

Holtz-Eakin, Douglas. "State-Specific Estimates of State and Local Government Capital." *Regional Science and Urban Economics*, April, 23(2), 1993.

Holtz-Eakin, Douglas. "Public-Sector Capital and the Productivity Puzzle." *Review of Economics and Statistics*, February, 76(1), 1994.

Kellenberg, Derek K. "The Provision of Public Inputs and Foreign Direct Investment." Working Paper, University of Colorado, 2003.

Kravis, Irving B. and Robert E. Lipsey. "The Location of Overseas Production and Production For Export By U.S. Multinational Firms." *Journal of International Economics*, 12, 1982.

Li, Ku-Wai. Capitalist Development and Economism in East Asia: The rise of Hong Kong, Singapore, Taiwan, and South Korea. Routledge, 2002.

Limão, Nuno and Anthony J. Venebles. "Infrastructure, Geographical Disadvantage, Transport Costs, and Trade." *The World Bank Economic Review*, Vol. 15, No. 3, 2001.

Lynde, Catherine, and James Richmond. "The Role of Public Capital in Production." *The Review of Economics and Statistics*, Volume 74, Issue 1, 1992.

Markusen, James R. "The Boundaries of Multinational Enterprises and the Theory of International Trade." *Journal of Economic Perspectives*, Spring , 9(2), 1995.

Markusen, James R., and Anthony J. Venables. "The Role of Multinational Firms in the Wage-Gap Depate." *Review of International Economics*, November, 5(4), 1997.

Markusen, James R., and Anthony J. Venables. "Multinational Firms and the New Trade Theory." *Journal of International Economics*, December, 46(2), 1998.

Markusen, James R. and Anthony J. Venables. "Foreign Direct Investment as a Catalyst for Industrial Development". *European Economic Review* 43, 1999.

Martin, Philippe. "Public Policies, regional inequalities, and growth." *Journal of Public Economics*, 73, pg. 85-105, 1999.

Martin, Philippe and Carol Ann Rogers. "Industrial Location and Public Infrastructure." *Journal of International Economics*, 39, pg. 335-351, 1995.

Mátyás, László and Patrick Sevestre (Editors). The Econometrics of Panel Data: A Handbook of the Theory and Applications. 2nd Ed. Kluwer Academic Publishers, 1996.

Morrison, Catherine J. and Amy Ellen Schwartz. "State Infrastructure and Productive Performance." *American Economic Review*, Vol. 86, No. 5, 1996.

Röller, Lars-Hendrik, and Leonard Waverman. "Telecommunications Infrastructure and Economic Development: A Simultaneous Approach." *American Economic Review*, Vol. 91, No. 4, 2001.

Shah, Anwar. "Dynamics of Public Infrastructure, Industrial Productivity and Profitability." *The Review of Economics and Statistics*, Volume 74, Issue 1, 1992.

Wheeler, David and Ashoka Mody. "International investment location decisions: The case of U.S. firms." *Journal of International Economics*, 33, 1992.

Woolridge, Jeffrey M. Econometric Analysis of Cross Section and Panel Data. MIT Press, Cambridge, Massachusetts, 2002.

TABLE 1[a]

Variable Descriptions

Y	Real GDP net of U.S. affiliate manufacturing sales (1995 international $).
X	Real U.S. affiliate manufacturing sales (1995 international $).
w	Average manufacturing hourly wage (1995 international $).
Tele	1 year lagged stock of telephone mainlines.
Telemed	*Tele* interacted with a dummy variable for observations with between 20 and 40 telephone mainlines per 1000 people.
Telehi	*Tele* interacted with a dummy variable for observations with greater than 40 telephone mainlines per 1000 people.
School	Average years of schooling of those in the population aged 25 and over.
Schmed	*School* interacted with a dummy variable for observations with greater than 7 but fewer than 9 years of average schooling.
Schhi	*School* interacted with a dummy variable for observations with greater than 9 years of average schooling.
Elec	1 year lagged value of total electrical capacity.
Elecmed	*Elec* interacted with a dummy variable for observations with electrical capacity of greater than 1 but fewer than 2 kilowatts per person .
Elechi	*Elec* interacted with a dummy variable for observations with electrical capacity of 2 or greater kilowatts per person .
INVC	Index of investment costs.
TCI	Index of trade costs.
K	Capital stock.
L	Total labor force.
Density	% of the population living in an urban area.
t	Time trend.

[a] Data on *Y, Tele, Dist, K, L,* and *Density* are obtained from the World Bank Development Indicatiors (2002). Data on *X* is obtained from the BEA; *School* is constructed from the Barro-Lee (2000) dataset; *w* is from the ILO LABORSTA database; *Elec* is from the U.S. Department of Energy; and *TCI* and *INVC* are from Carr, Markusen, and Maskus [2001].

TABLE 2[a]

Data and Average Annual Growth Rates for Output, Factor Prices and Infrastructure

Country	Output						Factor prices			Infrastructure								
	GDP (billion)			*U.S Affiliate Sales (billion)*			*Wage (hourly rate)*			*Telephone Mainlines (mil)*			*Electrical Capacity (mil kilowatts)*			*Schools (Ave. Years)*		
	1983	**1998**	**AAGR**	**1983**	**1998**	**AAGR**	**1983**	**1998**	**AAGR**	**1983**	**1998**	**AAGR**	**1983**	**1998**	**AAGR**	**1983**	**1998**	**AAGR**
Country																		
Australia	258	566	5.71	15.1	30.1	5.40	11.51	13.64	1.20	5.42	9.61	2.53	28.20	40.94	2.57	10.04	10.47	0.28
Austria	242	230	0.28	4.5	6.6	5.56	10.49	14.38	2.15	2.43	3.97	2.86	14.24	14.54	0.27	8.33	8.65	0.26
Belgium	305	318	2.60	27.5	24.3	0.47	10.36	10.70	0.25	2.72	4.97	3.86	10.73	13.54	1.70	8.04	8.66	0.50
Canada	483	961	4.79	77.3	171.8	6.00	12.76	14.86	1.03	10.44	18.82	2.86	85.05	116.76	2.16	10.33	11.33	0.62
Chile	45	144	8.21	0.1	0.3	12.45	0.19	0.31	3.74	0.44	2.73	12.44	3.36	7.36	5.65	6.00	7.75	1.71
Colombia	69	150	5.57	3.4	5.8	4.77	3.12	4.01	1.85	1.07	5.49	9.59	4.86	13.51	7.32	4.06	4.88	1.23
Denmark	179	175	0.49	1.9	2.0	1.66	11.95	19.54	3.70	2.35	3.36	2.17	7.67	11.11	2.53	9.32	10.00	0.47
Egypt	36	49	6.85	0.1	0.9	13.17	1.42	1.19	-1.12	0.46	3.52	12.29	5.17	13.33	7.22	2.65	4.73	3.95
Finland	127	145	3.13	0.3	2.2	15.90	7.55	12.76	3.76	1.94	2.86	2.24	10.86	14.57	2.00	8.10	10.01	1.42
France	1,780	1,763	0.51	51.0	66.9	2.68	10.36	16.01	3.91	19.56	33.81	3.28	69.71	105.41	2.83	7.09	8.20	0.97
Germany	2,595	2,323	-0.05	112.3	126.3	1.95	10.46	12.64	1.28	28.60	45.19	2.80	106.82	110.28	0.24	8.75	9.68	0.67
Greece	165	159	0.12	1.4	2.0	2.83	6.89	6.38	-0.46	2.55	5.43	4.72	5.96	8.81	2.69	6.79	8.33	1.37
Indonesia	154	1,304	10.17	0.8	9.9	19.77	1.35	0.87	-2.19	0.47	5.03	15.45	5.89	17.12	7.47	3.42	4.44	1.74
Ireland	51	78	5.37	8.7	34.3	11.61	7.92	9.38	1.15	0.58	1.52	6.20	3.04	3.90	1.79	7.76	8.92	0.93
Isreal	72	124	4.41	0.7	2.3	10.29	9.78	11.19	1.01	1.00	2.68	4.21	3.48	7.74	5.91	9.05	9.16	0.08
Italy	1,275	1,292	2.14	30.0	32.3	1.73	19.58	18.44	-0.35	14.67	25.79	3.72	48.85	61.40	1.57	5.58	6.84	1.36
Japan	4,579	4,893	3.03	24.1	32.7	3.51	14.77	14.86	1.41	41.72	65.88	2.70	143.33	210.55	2.60	8.40	9.61	0.90
Korea	409	1,203	7.99	2.3	11.3	11.91	4.73	9.03	4.55	4.15	20.61	10.26	10.11	37.64	9.40	7.54	10.31	2.11
Malaysia	54	205	9.58	2.2	33.9	15.38	2.74	4.22	3.25	0.60	4.32	11.12	3.14	12.50	9.95	4.72	7.79	3.39
Mexico	362	532	2.95	10.7	34.5	10.39	2.01	1.34	-2.45	3.21	9.23	5.43	19.92	37.61	4.36	4.30	6.58	2.89
Netherlands	402	437	3.20	28.5	43.7	5.55	10.85	15.28	2.38	5.31	8.88	2.88	17.72	20.44	0.99	8.19	9.13	0.73
New Zealand	67	83	3.36	2.1	4.4	1.93	10.40	10.73	0.24	1.21	1.84	1.72	5.82	7.69	1.94	11.43	11.44	0.01
Norway	111	145	3.67	2.9	1.5	-3.97	8.11	14.22	3.90	1.43	2.48	3.29	22.37	27.77	1.46	8.35	11.84	2.35
Philippines	159	215	2.48	1.8	4.1	7.20	0.66	0.74	1.05	0.49	2.08	8.22	5.06	11.19	5.54	6.34	7.50	1.13
Portugal	139	154	3.53	4.1	4.0	1.34	5.52	5.47	0.21	1.21	4.01	8.34	4.87	9.40	4.54	3.45	4.76	2.17
Singapore	57	151	6.91	4.9	35.5	14.84	2.00	5.98	8.04	0.65	1.77	4.22	2.11	5.26	6.59	4.16	8.00	4.45
South Africa	155	181	2.20	10.4	9.4	2.26	10.81	10.42	-0.22	1.85	4.66	4.08	22.86	35.18	3.04	5.06	7.95	3.06
Spain	839	780	0.12	29.7	40.3	3.06	10.26	13.26	1.74	8.05	15.87	4.42	31.78	41.83	1.87	5.25	7.00	1.94
Sweden	230	248	2.42	4.5	6.1	6.69	9.26	10.07	0.69	4.97	6.01	0.88	29.66	33.73	0.88	9.32	11.31	1.30
Switzerland	279	297	2.59	4.1	7.2	8.93	9.46	13.79	2.99	2.99	4.70	2.37	14.11	14.39	0.18	9.97	10.31	0.22
U.K.	1,087	1,242	2.15	50.2	133.3	6.85	8.85	13.23	2.75	19.26	32.00	3.10	69.10	70.46	0.19	8.33	9.22	0.68
Averages	**541**	**663**	**3.76**	**16.7**	**29.7**	**6.84**	**7.94**	**9.97**	**1.66**	**6.19**	**11.59**	**5.30**	**26.32**	**36.64**	**3.47**	**7.10**	**8.54**	**1.45**

[a] Due to data constraints, 1983 telephone data for Chile is from 1984; 1998 capital return data for Columbia and Indonesia is from 1996; 1998 U.S. Affiliate Sales data for Denmark is from 1997; 1983 wage data for Egypt is from 1985; 1998 wage data for Malaysia is from 1997; and 1998 capital return data for Mexico is from 1993.

TABLE 3

2SLS and 3SLS Regression Results

	(A)		(B)		(C)		(D)	
	Coef.	*St. Err.*	*Coef.*	*St. Err.*	*Coef.*	*St. Err.*	*Coef.*	*St. Err.*
Y								
X	**0.118** *	0.020	**0.183** *	0.019	**0.118** *	0.020	**0.118** *	0.020
Tele	**0.092** ***	0.047	**0.063**	0.045	**0.092** ***	0.047	**0.091** **	0.046
Telemed	**0.013** *	0.003	**0.017** *	0.003	**0.013** *	0.003	**0.012** *	0.003
Telehi	**0.012** *	0.003	**0.017** *	0.003	**0.012** *	0.003	**0.011** *	0.003
Sch	**0.143**	0.101	**0.168** ***	0.095	**0.143**	0.101	**0.142**	0.097
Schmed	**0.016**	0.019	**0.028**	0.018	**0.016**	0.019	**0.014**	0.018
Schhi	**0.047** ***	0.025	**0.068** *	0.023	**0.047** ***	0.025	**0.042** ***	0.023
Elec	**0.026**	0.053	**0.003**	0.050	**0.026**	0.053	**0.027**	0.051
Elecmed	**-0.002**	0.013	**-0.012**	0.012	**-0.002**	0.013	**-0.002**	0.013
Elechi	**0.022**	0.018	**0.007**	0.017	**0.022**	0.018	**0.021**	0.017
K	**0.684** *	0.032	**0.623** *	0.030	**0.684** *	0.032	**0.696** *	0.031
L	**0.316** *	0.032	**0.377** *	0.030	**0.316** *	0.032	**0.304** *	0.031
Density	**-0.765** *	0.105	**-0.757** *	0.100	**-0.765** *	0.105	**-0.755** *	0.102
t	**-0.015** *	0.002	**-0.017** *	0.002	**-0.015** *	0.002	**-0.015** *	0.002
_cons	**--**	--	**--**	--	**--**	--	**--**	--
w								
X	**0.118** *	0.020	**0.183** *	0.019	**0.118** *	0.020	**0.118** *	0.020
Tele	**0.092** ***	0.047	**0.063**	0.045	**0.092** ***	0.047	**0.091** **	0.046
Telemed	**0.013** *	0.003	**0.017** *	0.003	**0.013** *	0.003	**0.012** *	0.003
Telehi	**0.012** *	0.003	**0.017** *	0.003	**0.012** *	0.003	**0.011** *	0.003
Sch	**0.143**	0.101	**0.168** ***	0.095	**0.143**	0.101	**0.142**	0.097
Schmed	**0.016**	0.019	**0.028**	0.018	**0.016**	0.019	**0.014**	0.018
Schhi	**0.047** ***	0.025	**0.068** *	0.023	**0.047** ***	0.025	**0.042** ***	0.023
Elec	**0.026**	0.053	**0.003**	0.050	**0.026**	0.053	**0.027**	0.051
Elecmed	**-0.002**	0.013	**-0.012**	0.012	**-0.002**	0.013	**-0.002**	0.013
Elechi	**0.022**	0.018	**0.007**	0.017	**0.022**	0.018	**0.021**	0.017
K	**0.684** *	0.032	**0.623** *	0.030	**0.684** *	0.032	**0.696** *	0.031
L	**-0.684** *	0.032	**-0.623** *	0.030	**-0.684** *	0.032	**-0.696** *	0.031
Density	**-0.765** *	0.105	**-0.757** *	0.100	**-0.765** *	0.105	**-0.755** *	0.102
t	**-0.015** *	0.002	**-0.017** *	0.002	**-0.015** *	0.002	**-0.015** *	0.002
_cons	**4.284** *	0.678	**3.924** *	0.642	**4.284** *	0.678	**4.310** *	0.657
X								
w	**0.838** *	0.072	**1.065** *	0.070	**-0.774** **	0.317	**-0.850** *	0.298
Y	**1.301** *	0.110	**1.131** *	0.107	**1.479** *	0.096	**1.512** *	0.090
Tele	**0.044**	0.149	**0.043**	0.145	**-0.371** *	0.125	**-0.421** *	0.117
Telemed	**-0.081** *	0.012	**-0.095** *	0.012	**0.001**	0.006	**-0.002**	0.006
Telehi	**-0.101** *	0.014	**-0.117** *	0.014	**-0.007**	0.007	**-0.010**	0.007
Sch	**-0.154**	0.371	**-0.313**	0.362	**0.705** *	0.258	**0.704** *	0.244
Schmed	**-0.349** *	0.096	**-0.331** *	0.094	**0.034**	0.047	**0.035**	0.044
Schhi	**-0.723** *	0.114	**-0.680** *	0.111	**0.097**	0.064	**0.088**	0.060
Elec	**-0.460** *	0.154	**-0.333** **	0.150	**-0.015**	0.157	**-0.040**	0.148
Elecmed	**0.140** **	0.059	**0.134** **	0.057	**0.021**	0.031	**0.024**	0.029
Elechi	**0.304** *	0.073	**0.259** *	0.071	**0.013**	0.043	**0.008**	0.041
INVC	**-1.628** *	0.292	**-1.551** *	0.276	**-0.114**	0.142	**-0.142**	0.132
TCI	**0.312** **	0.146	**0.249** ***	0.135	**0.019**	0.055	**0.016**	0.051
Density	**1.626** *	0.268	**1.631** *	0.261	**-0.612** ***	0.321	**-0.433**	0.301
t	**0.030** *	0.012	**0.033** *	0.012	**0.045** *	0.009	**0.048** *	0.009
_cons	**-8.940** *	2.025	**-7.226** *	1.955	**--**	--	**--**	--

* denotes significance at the 1% level
** denotes significance at the 5% level
*** denotes significance at the 10% level
Columns (A) and (B) are run using equation by equation 2SLS and 3SLS with country specific fixed-effects in the GDP equation, respectively. Columns (C) and (D) are again run using 2SLS and 3SLS

TABLE 4(a)

Comparative Static Effects of Telecommunications on Y

Regression (from table 3)	Infrastructure Classification	Indirect Effect (w)	Indirect Effect (X)	Direct Effect	Total Effect
	Low	-0.010	-0.053	0.122	0.059
(C)	**Medium**	-0.012	-0.053	0.139	0.075
	High	-0.012	-0.054	0.138	0.072
	Low	-0.011	-0.060	0.122	0.051
(D)	**Medium**	-0.013	-0.061	0.138	0.065
	High	-0.012	-0.062	0.137	0.063

Comparative Static Effects of Telecommunications on w

Regression (from table 3)	Infrastructure Classification	Indirect Effect (w)	Indirect Effect (X)	Direct Effect	Total Effect
	Low	0.015	-0.040	0.070	0.044
(C)	**Medium**	0.017	-0.040	0.080	0.056
	High	0.017	-0.041	0.079	0.055
	Low	0.015	-0.045	0.068	0.038
(D)	**Medium**	0.017	-0.045	0.077	0.049
	High	0.017	-0.046	0.077	0.047

Comparative Static Effects of Telecommunications on X

Regression (from table 3)	Infrastructure Classification	Indirect Effect (w)	Indirect Effect (Y)	Direct Effect	Total Effect
	Low	-0.078	0.149	-0.404	-0.333 **
(C)	**Medium**	-0.089	0.170	-0.403	-0.323 **
	High	-0.088	0.168	-0.412	-0.332 **
	Low	-0.084	0.149	-0.457	-0.391 **
(D)	**Medium**	-0.095	0.170	-0.459	-0.384 **
	High	-0.094	0.168	-0.468	-0.394 **

** denotes joint significance at the 5% level

TABLE 4(b)

Comparative Static Effects of Schools on Y

Regression (from table 3)	Infrastructure Classification	Indirect Effect (w)	Indirect Effect (X)	Direct Effect	Total Effect
(C)	Low	-0.016	0.101	0.189	0.274 **
	Medium	-0.018	0.106	0.210	0.298 *
	High	-0.021	0.115	0.251	0.344 *
(D)	Low	-0.017	0.101	0.190	0.273 **
	Medium	-0.019	0.106	0.208	0.295 *
	High	-0.022	0.113	0.245	0.336 *

Comparative Static Effects of Schools on w

Regression (from table 3)	Infrastructure Classification	Indirect Effect (w)	Indirect Effect (X)	Direct Effect	Total Effect
(C)	Low	0.023	0.076	0.108	0.207 **
	Medium	0.025	0.080	0.120	0.226 *
	High	0.030	0.087	0.143	0.260 *
(D)	Low	0.023	0.075	0.106	0.204 **
	Medium	0.025	0.079	0.116	0.221 *
	High	0.030	0.085	0.137	0.251 **

Comparative Static Effects of Schools on X

Regression (from table 3)	Infrastructure Classification	Indirect Effect (w)	Indirect Effect (Y)	Direct Effect	Total Effect
(C)	Low	-0.120	0.230	0.769	0.878 **
	Medium	-0.134	0.257	0.806	0.928 *
	High	-0.160	0.306	0.874	1.020 *
(D)	Low	-0.131	0.233	0.764	0.866 *
	Medium	-0.144	0.255	0.802	0.914 *
	High	-0.169	0.301	0.860	0.991 *

* denotes joint significance at the 1% level

** denotes joint significance at the 5% level

TABLE 4(c)

Comparative Static Effects of Electrical Capacity on Y

Regression (from table 3)	Infrastructure Classification	Indirect Effect (w)	Indirect Effect (X)	Direct Effect	Total Effect
	Low	-0.003	-0.002	0.034	0.029
(C)	Medium	-0.003	0.001	0.031	0.030
	High	-0.005	0.000	0.062	0.057
	Low	-0.003	-0.006	0.036	0.027
(D)	Medium	-0.003	-0.002	0.033	0.028
	High	-0.006	-0.004	0.064	0.053

Comparative Static Effects of Electrical Capacity on w

Regression (from table 3)	Infrastructure Classification	Indirect Effect (w)	Indirect Effect (X)	Direct Effect	Total Effect
	Low	0.004	-0.002	0.019	0.022
(C)	Medium	0.004	0.001	0.018	0.022
	High	0.008	0.000	0.036	0.043
	Low	0.004	-0.004	0.020	0.020
(D)	Medium	0.004	-0.002	0.019	0.021
	High	0.008	-0.003	0.036	0.040

Comparative Static Effects of Electrical Capacity on X

Regression (from table 3)	Infrastructure Classification	Indirect Effect (w)	Indirect Effect (Y)	Direct Effect	Total Effect
	Low	-0.022	0.041	-0.017	0.003
(C)	Medium	-0.020	0.038	0.007	0.025
	High	-0.040	0.076	-0.003	0.034
	Low	-0.025	0.044	-0.043	-0.024
(D)	Medium	-0.023	0.041	-0.017	0.001
	High	-0.044	0.078	-0.034	0.000