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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

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,

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] 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. Fi7448i on0004 T0.8usoacts

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 $\Omega = \Omega(\mathbf{P}, X)$

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:

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

where *F* is the fixed cost of operations in the host country[7]. The functions

( ) (0,1) and (,)) ∈ [(0,1)

investment barriers (τ

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

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

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

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

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].

[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:

$$Y = Y(\Omega(\mathbf{P}, X(\Phi(\mathbf{P}), t(!), m(\mathbf{P}_{\mathrm{I}}), w(\mathbf{P}, f(L,K)), f(L,K)) = Y(\mathbf{P}, L, K)\,. \tag{8}$$

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 $\overline{L} = L_Y + L_X$. However, for simplicity we assume away multinational firm demand side effects on the wage rate by assuming L_X

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:

$$(\quad (\quad , \quad (\quad , (\quad), \quad (\quad , \quad (\quad (\quad), \quad (\quad ,K)), f(L,K)) \quad w(\quad ,L,K)$$

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:

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

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

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:

$$= \quad {}^{2-} \quad {}^{3}\Omega$$

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

$$w_{it}^{*} = \alpha_{0}^{w} + \alpha_{1}^{w} X_{it}^{*} + \sum_{s=2}^{3} \alpha_{s}^{w} V_{sit}^{*} + \sum_{j=4}^{J} (\alpha_{j}^{w} + D_{jit}^{M} \alpha_{j}^{wM} + D_{jit}^{H} \alpha_{j}^{wH}) P_{jit}^{*} + \alpha_{J+1}^{w} Den^{*} + \varepsilon_{w} , \qquad (2")$$

and

$$X_{it} = \beta_{i0} + \beta_{1} w_{it}^{*} + \beta_{2} Y_{it}^{*} + \sum_{j=3}^{J} \ \beta_{j} + D_{jit}^{M} \beta_{j}^{M} + D_{jit}^{H} \beta_{j}^{H} \ P_{jit}^{*} + \beta_{J+1} Den^{*}$$
$$+ \sum_{m=J+2}^{M} \beta_{m} \tau_{mt}^{*} + \varepsilon_{X}$$

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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*) $\alpha_2 + \alpha_3 = 1$,

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

and

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

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.

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

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].

[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

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

$$\text{———} \quad \text{—————} \left[\qquad\qquad\qquad\qquad {}^{q}_{j} \right]$$

[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

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Y

X

w

Tele

Country	"983	"998	AAGR	"983	"998	AAGR	"983	"998	AAGR	"983	"998	AAGR	"983	"998	AAGR	"983	"998	AAGR
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

	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								

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
	Low	-0.016	0.101	0.189	0.274 **
(C)	**Medium**	-0.018	0.106	0.210	0.298 *
	High	-0.021	0.115	0.251	0.344 *
	Low	-0.017	0.101	0.190	0.273 **
(D)	**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
	Low	0.023	0.076	0.108	0.207 **
(C)	**Medium**	0.025	0.080	0.120	0.226 *
	High	0.030	0.087	0.143	0.260 *
	Low	0.023	0.075	0.106	0.204 **
(D)	**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
	Low	-0.120	0.230	0.769	0.878 **
(C)	**Medium**	-0.134	0.257	0.806	0.928 *
	High	-0.160	0.306	0.874	1.020 *
	Low	-0.131	0.233	0.764	0.866 *
(D)	**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
(C)	Low	-0.003	-0.002	0.034	0.029
	Medium	-0.003	0.001	0.031	0.030
	High	-0.005	0.000	0.062	0.057
(D)	Low	-0.003	-0.006	0.036	0.027
	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
(C)	Low	0.004	-0.002	0.019	0.022
	Medium	0.004	0.001	0.018	0.022
	High	0.008	0.000	0.036	0.043
(D)	Low	0.004	-0.004	0.020	0.020
	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
(C)	Low	-0.022	0.041	-0.017	0.003
	Medium	-0.020	0.038	0.007	0.025
	High	-0.040	0.076	-0.003	0.034
(D)	Low	-0.025	0.044	-0.043	-0.024
	Medium	-0.023	0.041	-0.017	0.001
	High	-0.044	0.078	-0.034	0.000