DISCUSSION PAPERS IN ECONOMICS

Working Paper No. 03-11

The Provision of Public Inputs and Foreign Direct Investment

Derek K. Kellenberg
Department of Economics, University of Colorado at Boulder
Boulder, Colorado

October 2003

Center for Economic Analysis
Department of Economics

University of Colorado at Boulder
Boulder, Colorado 80309

The Provision of Public Inputs and Foreign Direct Investment

Derek K. Kellenberg[*]
University of Colorado at Boulder
October 21, 2003

Abstract: A general equilibrium model of a small open economy is developed that incorporates *direct* and *indirect* effects on multinational location decisions associated with public input provision. It is shown that when agglomeration externalities are present, public input provision can affect firms directly by lowering the fixed costs of production and indirectly by decreasing the costs of intermediate inputs. It is further shown that a policy of public input provision that provides a threshold level of public inputs can generate greater increases in GNP for a host country than a policy of subsidies or tax incentives.

*Key Words***:** Public Infrastructure; Multinational corporations; Intermediate goods; Development

*JEL classification***:** F2**;** H4; O1

---

[*] Correspondence can be sent to Derek.Kellenberg@colorado.edu. Author's address: Department of Economics, University of Colorado at Boulder, Campus Box 256, Boulder, CO 80309-0256. Tel: 303-938-9390. Fax: 303-492-8960.

I. Introduction

Foreign direct investment by multinational corporations has played a significant role in the success of developing nations that have grown out of poverty and into developed economies. Since the 1950's, Taiwan, South Korea, Hong Kong and Singapore have been but a few that have actively pursued multinationals from the U.S., Japan, and Europe in an effort to create jobs and raise wages. Proximity to markets, subsidies, low wages, and tax incentives are common reasons cited for why multinationals choose to invest in these economies.

A critical link, often mentioned but given far less attention in theory, has been the role of public inputs[1]. It is no coincidence that multinational activity began to take place in South Korea after the 1953-56 Post War Reconstruction, or in Singapore after massive public investment in telecommunications, or Taiwan after government funded research institutes and industrial parks were built[2].

Recently, researchers have begun to examine linkages between multinational corporations and indigenous intermediate input suppliers in the context of the 'new trade theory.' This approach has helped to shed light on the welfare impacts of host countries that accept, or choose to compete for, multinational activity. Because the approach is new, many questions regarding upstream and downstream linkages have not yet been addressed in the literature, especially with respect to public inputs as factors of

[1] The statement here refers specifically to the role public inputs play in the context of the multinational location literature. Public inputs generally, and with respect to capital mobility, have received much more attention; see for example Clarida and Findlay [1994], Martin and Rogers [1995], Keen and Marchand [1996], Manning et. al. [1997], and Feehan and Matsumoto [2000].

[2] See Hobday [1995] and Li [2002].

production and the interaction they create between intermediate goods suppliers and final goods producers. This paper contributes to that literature by examining how the provision of public inputs affect multinational location decisions as well as the subsequent wage and domestic market effects associated with competing policy proscriptions.

Recent empirical research suggests that public inputs have a non-negligible impact on the productivity and cost structure of private firms (Aschauer [1989], Haughwout [2001], Morrison et. al. [1996], Nadiri et. al. [1994]). Cost elasticity estimates with respect to infrastructure capital in the Nadiri et. al. [1994] study range from –0.11 to –0.21 depending on the industry, while Morrison et. al. [1996] estimate an output elasticity of 0.11 for private firms with respect to public infrastructure[3]. In simple bivariate regressions found in the *Global Competitiveness Report 2000*, strong and significant correlations exist between GDP growth and a wide range of public infrastructure measures.

Despite this evidence, universal agreement regarding the contribution of public investment to private sector productivity does not exist. Conflicting studies have found that public investment does not have a statistically significant *direct* impact on productivity in the private sector (Holtz-Eakin [1994], Holtz-Eakin et. al. [1995]). Even if such infrastructure has no *direct* role in the cost structure and productivity of private firms, ample evidence suggests that the *indirect* spillovers from agglomeration and clustering created by public infrastructure lower the costs of firms (Houghwout [2001]).

[3] See also Röller and Waverman [2001] for the effects of telecommunications infrastructure on growth.

The model developed in this paper incorporates both the *direct* and *indirect* aspects of cost savings for multinationals created by the provision of public inputs.

The approach here is different from other papers that look at the impact of public inputs on firm location decisions (such as Martin and Rogers [1995] or Baldwin et. al. [2003]). Prior work has focused on two-country models with agglomeration externalities, where public inputs (infrastructure) are modeled as iceberg trade costs that affect firms' ability to get their products to consumers. In this paper, public inputs are modeled as factors of production for intermediate as well as final goods producers in the host country rather than as iceberg trade costs. This approach sheds light on two important aspects of infrastructure development that are not explicitly captured by previous models. First, infrastructure can have both direct effects on multinational firms by lowering the fixed costs of production as well as indirect effects on marginal costs through agglomeration in intermediate goods markets. Second, by incorporating intermediate goods markets we allow for new firms to be created as suppliers to final goods producers, rather than final goods producers simply relocating from one country to another (as found in the two-country models).

The paper builds on the partial equilibrium model first developed by Markusen and Venables [1999] and extended to a general equilibrium framework by Haaland and Wooton [1999]. The model is theoretically similar to Markusen and Venables in that *linkage effects* create positive agglomeration externalities in domestic markets. However, like Haaland and Wooton the tension between the *linkage* and *competition effects* associated with Markusen and Venables is replaced by the opposing forces of positive

agglomeration externalities in intermediate goods markets (*linkage effects*) and rising labor costs.

Another contribution of this model is that allows for the identification of a threshold level of public inputs, which is the minimum public input level necessary to induce the first MNE to invest in the economy. Once the first MNE invests, it is more attractive for more MNE's to invest as the cost of intermediate inputs is falling in the number of multinational firms located in the host country. If the government invests in a public input level that is lower than the threshold level of public inputs, the possibility of a *low-level production trap* is present. Without enough government assistance, no multinational firms will choose to invest and the intermediate goods market will never get off the ground. A public input level higher than the threshold will result in a stable equilibrium. It is shown that because of the direct and indirect effects that public inputs have on multinational and indigenous intermediate producers, public input provision can yield greater returns for a host country than expenditure neutral policies of direct subsidization or tax relief.

In Section II, a model is developed that incorporates public inputs into the cost functions of multinational and indigenous firms. Section III presents the equilibrium conditions and compares alternative policies for attracting multinational corporations in the presence of agglomeration externalities. Section IV compares national income under the alternative policies, Section V reports sensitivity analysis, and Section VI concludes.

II. The Model

Imagine a small open economy with four distinct sectors: (i) a *traditional* sector, which can be thought of as a composite good consisting of food, housing, clothing and

other domestic essential goods whose product is consumed exclusively by the home country, (ii) a *public inputs* sector where the government produces public goods as inputs in the production of intermediate and final goods, (iii) an *intermediate goods* sector that supplies inputs for the modern sector, and (iv) a *multinational* sector, which consists of assembly operations of final goods for export.

The Traditional Sector

The traditional sector consists of M perfectly competitive firms that produce a homogenous good (Y), using a primary factor of production (L_Y)[4] with a decreasing returns-to-scale technology[5]:

$$Y = \frac{L_Y^{\gamma}}{\gamma} \text{ for } \gamma < 1. \quad (1)$$

Y is not traded and is consumed entirely in the home country. The Y good is the numeraire good at home and the wage rate of the primary factor is equal to its marginal product:

$$L_Y = w^{-\varepsilon} , \quad (2)$$

[4] A primary factor of production is defined here as a composite of labor, capital and resources; but for the purposes of this discussion, the primary factor can be thought of as labor.

[5] The decreasing returns technology implies that there is a fixed factor of production, such as land, that receives rents. Decreasing returns is not necessary for the results of the model but does add convexity which makes the model more tractable. Further, given that countries have a fixed proportion of land, this is not an unreasonable assumption for an aggregate production function.

where $\varepsilon = -1/(\gamma - 1)$ is the elasticity of the primary factor of production with respect to the traditional good.

The Public Inputs Sector

Public inputs are produced by the government using tax revenues obtained by taxation of traditional sector output[6]. For simplicity, the amount of public inputs provided is equal to the tax revenue collected such that:

$$P = tY \quad , \tag{3}$$

where *P* are new public inputs provided and *t* is the per unit tax rate. Public inputs are assumed to be non-rival and non-congestible in production such that once the government produces the public good (*P)*, multinational and intermediate goods sectors are both able to use the public input as a factor of production.

The Intermediate Goods Sector

The intermediate goods sector consists of *J* identical monopolistically competitive firms where each firm uses the primary factor (L_Z) and the public input (*P*) to produce output (*z).* Intermediate goods are assumed to be non-traded goods and are demanded solely by multinational firms that set up assembly operations in the home country. Each firm uses an identical technology and cost function in conjunction with the primary factor (L_Z) and the public input (*P*) to create one variety of the intermediate good. The initial fixed cost of entering the market is *a* units of the primary factor. Additionally, the firms must use *b* units of the primary factor for each unit of *z* produced. The cost function of the representative firm is:

[6] As will become apparent in Section IV, when a country has a low level of public inputs the traditional sector is the only sector operating in the country. Therefore, the choice of taxation reflects that real output in the Y sector will have to be used up to invest in public inputs.

$$c(z) = (a + bz)w, \tag{4}$$

where *z* is output per firm and *w* can be thought of as the national wage or rental rate paid to the primary factor of production. As is standard in models of monopolistic competition we get the result that the price charged for each variety of intermediate good will be a fixed mark-up over marginal cost:

$$q = \lambda w, \tag{5}$$

where $\lambda \equiv \sigma b/(\sigma - 1)$ and σ represents the elasticity of demand for each variety. Monopolistic competition requires there be a zero profit condition. Free entry and exit will ensure that

$$z = \frac{a}{b}(\sigma - 1). \tag{6}$$

I make two assumptions here regarding the nature of the intermediate goods market. The first is identical to the assumption made by Haaland and Wooton; the second is new. First, I assume external economies of scale associated with the number of firms in the intermediate goods market[7]. Second, I assume that greater investment in the public input reduces demand for the primary factor necessary to begin production,

[7] Economies of scale occur through learning by doing or other economies of scale associated with local agglomeration effects, such as found in Aitken, Hanson, and Harrison [1997], or the division of labor discussed in Markusen [1990].

lowering fixed costs for each intermediate firm[8]. These two assumptions are incorporated into equation[9] (7):

$$a = \frac{A}{R^{\eta} n^{\theta}} \ , \tag{7}$$

where $\theta > 0$, $0<\eta<1$, and R is the sum of endowed public inputs (i.e. from past infrastructure projects), $\underline{P}$, and new investment in public inputs, P: $R = \underline{P} + P$. Each firm's fixed cost is a declining function of both the level of public inputs provided and the number of varieties offered in the domestic market. The parameter η can be thought of as the degree to which public inputs substitute for private fixed costs. For example, $\eta=1$ would correspond to public inputs that substitute perfectly for private fixed costs. Small levels of η would correspond to public inputs that were less substitutable and would substitute imperfectly for private fixed costs. Output per firm is found by substituting equation (7) into equation (6) to get

$$z = \frac{A(\sigma - 1)}{R^{\eta} n^{\theta} b} . \tag{8}$$

Total demand for the primary factor of production in the intermediate goods market will be a function of the total number of firms operating there and the output of each firm:

---

[8] For example, government investment in a power plant would lower the fixed costs for each intermediate firm of hiring the primary factor to build their own power generators.

[9] Notice that the modeling of R and n in equation (7) assumes a form of complementarity between agglomeration and public inputs. This assumption seems plausible. Think of a port that has a number of exporting firms that experience local agglomeration externalities. Upgrading that port, through more technological loading docks, will increase the productivity of the existing firms and induce more agglomeration. Similarly, the marginal product for a public input increase in the port will be higher if there are agglomeration externalities than if agglomeration is not present.

$$L_Z = n(a + bz). \tag{9}$$

Substituting (7) and (8) into (9) gives

$$L_Z = \frac{\sigma A n^{1-\theta}}{R^{\eta}}. \tag{10}$$

The Multinational Sector

The multinational sector consists entirely of multinational enterprises that choose whether or not to set up assembly facilities in the host country. These firms sell their product, *X*, on the world market and make investment decisions based on their costs of production. There are *F* multinational firms operating in the home country, each of which uses the primary factor, intermediate goods, and the public input to produce a fixed level of output, X[10]. The cost function for each multinational is

$$C = \frac{B}{R^{\eta}} + \left(Q^{a}\ w^{1-\alpha}\ \right)X \quad \text{where } 0 \le \alpha\ \le 1, \tag{11}$$

where *B* are fixed costs that are necessary to open operations in the host country[11]. Notice that fixed costs are falling as the level of public inputs rises. This is a departure from the Haaland and Wooton model and captures the idea that if public inputs are provided by the government then the multinational won't have to use resources to build

[10] The idea that X is fixed is based on the assumption that multinational firms have production facilities all over the world and have, exogenous to the model, determined optimal plant size for any production facility regardless of where they build it. For example, a semiconductor firm may have assembly plants in many different locations with a blueprint for the optimal size of a production facility. Once it chooses a plant location, it is choosing the location where it will build a plant of optimal size and produce X units per year.

[11] Fixed costs B are measured in units of Y but incurred by a multinational parent in its home country.

its own infrastructure to support its operations. Q is the intermediate goods price index such that

$$Q = \left[\sum_{j=1}^{J} q_j^{1-\sigma} \right]^{\frac{1}{1-\sigma}}, \tag{12}$$

where q_j is the price of variety j of the intermediate goods. Since it is assumed in the previous section that all intermediate goods have identical technology and costs, it follows that q_j will be the same for all varieties, and we can rewrite (12) as:

$$Q = n^{\frac{1}{1-\sigma}} q . \tag{13}$$

Using equations (11), (12) and (13) we can solve for each multinational's demand for each variety of intermediate input, z as:

$$z = \alpha n^{\frac{\alpha+\sigma-1}{1-\sigma}} \left(\frac{w}{q} \right)^{1-\alpha} X . \tag{14}$$

Taking the price for each intermediate that we established earlier in equation (5), plugging it into equation (14), and multiplying by the number of multinationals operating in the home country yields the total demand for each variety of intermediate good produced:

$$Z = \alpha \lambda^{\alpha-1} n^{\frac{\alpha+\sigma-1}{1-\sigma}} FX . \tag{15}$$

In a similar fashion, we can determine the total demand for the primary factor of production in the X sector using equations (11), (13), and (5), and multiplying by the number of multinational firms, F:

$$L_F = (1-\alpha) n^{\frac{\alpha}{1-\sigma}} \lambda^{\alpha} FX . \tag{16}$$

III. Equilibrium

Three conditions ensure equilibrium in the home country: primary factor market clearing, intermediate goods market clearing, and an iso-cost condition such that the multinational faces the same costs in the home market as if it chose to locate its facility in another country.

The primary factor (L) is supplied inelastically and is demanded by each of the three productive sectors. Setting the supply of the primary factor (L) equal to the demand for the primary factor (the sum of equations 2, 10, and 16) we get:

$$L = L_Z + L_F + L_Y = \frac{\sigma A n^{1-\theta}}{R^{\eta}} + (1-\alpha) n^{\frac{\alpha}{1-\sigma}} \lambda^{\alpha} FX + w^{-\varepsilon} \quad . \tag{17}$$

Equilibrium in the primary factor market is a function of the number of intermediate and multinational sector firms that are operational (n and F), the scale of multinational operations (X), and the level of public inputs provided (R).

Equilibrium in the intermediate goods sector is obtained by setting the supply of intermediate goods in equation (8) equal to the demand for intermediate goods in equation (15). After some rearranging, the equilibrium condition implies that the number of intermediate goods producers in operation will be:

$$n = \left[\frac{\lambda^{\alpha} R^{\eta} FX}{\delta} \right]^{\frac{\sigma-1}{\alpha+\beta}}, \tag{18}$$

where $\delta \equiv \sigma A / \alpha$ and $\beta \equiv (\sigma - 1)(1 - \vartheta)$. Equation (18) implies that the number of firms operating in the intermediate goods sector increases in the number of multinational firms in the country, the scale of modern sector operations, and the level of public inputs.

The final equilibrium condition is the multinational's iso-cost condition. It is assumed that each multinational has the option of opening its facility in an alternative country at cost $\overline{C}$. For the multinational to locate in the host economy, its costs minus any subsidies offered by the host country must be less than or equal to the costs of opening a facility in a competing country[12]. The equilibrium condition is

$$C - Xs = \overline{C}. \tag{19}$$

The firms' equilibrium iso-cost condition is derived using the cost function in (11), the pricing equation in (5), and (19) to obtain:

$$w = \lambda^{-\alpha} n^{\frac{\alpha}{\sigma-1}} \left(\overline{C} + sX - \frac{B}{R^{\eta}} \right). \tag{20}$$

Equation (20) reflects the fact that multinational's average costs of production decrease in the number of intermediate firms and the level of public inputs. The wage that the multinational is willing to pay increases in the number of intermediate firms and the public inputs available for its use.

Solving the system yields two equations that describe the wage rate as function of the number of multinational firms operating in the country. The first of these is the iso-cost condition and describes the wage multinationals are willing to pay the primary factor of production as the number of multinationals in the country increases. This equation is obtained by substituting equations (5) and (18) into (20) to get:

$$w = \left[\overline{C} + sX - \frac{B}{R^{\eta}} \right] \left[\lambda^{-\alpha\beta} \left(R^{\eta} \right)^{\alpha} F^{\alpha} X^{\alpha} \delta^{-\alpha} \right]^{\frac{1}{\alpha+\beta}}. \tag{21}$$

[12] The discussion focuses on production subsidies but the analysis can equally be thought of as a lowering of taxes on output.

The second equation describes the wage necessary to maintain equilibrium in the primary factor market as a function of the number of multinational firms[13]. It is found by substituting equation (18) into (17) to yield:

$$w = \left\{ \left[L - \left[\left(R^{\eta} \right)^{-\alpha} \lambda^{\alpha\beta} \left(FX \right)^{\beta} \delta^{\alpha} \right]^{\frac{1}{\alpha+\beta}} \right] \right\}^{-\frac{1}{\varepsilon}} . \qquad (22)$$

Graphing the Equilibria

Equations (21) and (22) are graphed in Figure 1. Equation (21) is labeled "*Iso*", signifying the wage that firms would be willing to pay in equilibrium as a function of the number of multinationals that are operating in the country. Equation (22) is represented by "*Mwage*", indicating the market clearing wage rate for the primary factor of production as a function of the number of multinational firms. In Figure 1, for exogenously given parameters of the model ($\alpha, \beta, L, \gamma, \varepsilon, \vartheta, X, \delta, \lambda$, *s,* η and $\underline{P}$), the level of public inputs is too low for any multinationals to enter the country. That is, given the level of public inputs in the host country, the wage that firms are willing to pay (*Iso*) will always be less than the market wage (*Mwage*), and the only equilibrium is zero multinational investment.[14] Notice that the *Iso* curve is upward sloping. This reflects the fact that as more multinational firms enter the country and bid up demand for intermediate goods, intermediate goods become cheaper as agglomeration externalities

[13] An important point regarding $\overline{C}$ is that it is a function of the level of public inputs in other countries. From a policy perspective this is important because it means that it's the *relative* rather than *absolute* level of public inputs that matters for a host country.

[14] The model is calibrated for s=0, α=0.8, β=1.8, γ=0.5, λ=1, ε=2, X=8, φ=0.1, σ=3, δ=0.95, $\overline{C}$ =0.29, B=0.2, L=30, P=0, η=0.5 and $\underline{P}$ =0.9.

increase. Thus for a fixed output and cost level, multinationals are willing to pay more for the primary factor because intermediate goods are becoming less expensive.

[Insert Fig. 1 Here]

To attract firms, the host country has two policy options available. It can subsidize multinationals directly[15] or it can increase the level of public inputs in the home country. Both policies will lower the average cost of multinationals and create incentives for inward investment. However, the impacts and potential costs and benefits associated with each policy are different. The static impacts of the direct subsidy and public inputs policy will be discussed before turning to an analysis of national income.

Direct Subsidy

The minimum subsidy necessary to get the first multinational to invest in the home country is found by setting *F=1*, *P=0*, equations (21) and (22) equal to each other, and solving for *s*. The expression is similar to the threshold subsidy identified by Haaland and Wooton and is represented as

$$\tilde{s} = \frac{1}{X}\left[\delta^{\alpha} X^{-\alpha}\left(\underline{P}^{\eta}\right)^{-\alpha}\lambda^{\alpha}\right]^{\frac{1}{\alpha+\beta}}\left[L-\left(\lambda^{\alpha\beta}\left(\underline{P}^{\eta}\right)^{-\alpha}X^{\beta}\delta^{\alpha}\right)^{\frac{1}{\alpha+\beta}}\right]^{-\frac{1}{\varepsilon}}+\frac{1}{X}\left[\frac{B}{\underline{P}^{\eta}}-\overline{C}\right], \quad (23)$$

where $\tilde{s}$ is the minimum subsidy that a government can offer and still get the first multinational firm to profitably enter the country. Plugging equation (23) into (21) we plot the new *Iso(sub)* curve in Figure 2. An increase in the subsidy has no effect on the primary factor market equation (*Mwage*) as the subsidy does not directly effect labor supply decisions. Three equilibria emerge. The first is at *eL* where exactly one multinational firm enters the home country. This equilibrium is unstable, because for any

[15] Again, the discussion here is on subsidies but we can equally think of subsidies as a net lowering of a production tax.

epsilon decrease in the number of firms, the wage firms are willing to pay is less than the market clearing wage and firms will leave the country. Firms will continue to leave the country until there are zero firms operating at home. This *is* a stable equilibrium and is what Haaland and Wooton describe as a '*low- level production trap'*.

[Insert Figure 2]

Conversely, for any small increase in the number of firms above *F=1*, the wage that firms are willing to pay is greater than the market clearing wage and multinational firms will enter the home country until the market clearing wage is just equal to the wage that firms are willing to pay at *eH*. The equilibrium *eH* is also stable, as any number of firms above *eH* will cause firms to exit the country because the wage they are willing to pay is lower than the market wage[16].

Public Inputs

The second policy option available to the home country is to finance the production of public goods that serve as inputs to production for firms in the economy[17]. Like the direct subsidy option above, we can solve for a threshold level of public inputs necessary to induce the first multinational to enter the country. Setting *s=0*, *F=1*, and equations (21) and (22) equal to each other we can solve for the minimum level of public inputs necessary to induce the first multinational to enter the country. Plugging this level of *P* back into equations (21) and (22) we get the *Iso(pub)* and *mwage(pub)* curves found in Figure 3. The first thing to notice is that the *mwage(pub)* curve has shifted down. At first glance this may seem counter intuitive, as the government's decision to provide

[16] For the calibration here, e*H* in Fig. 2 corresponds to 9.64 firms and a wage rate of 0.28.

[17] Public inputs are financed via equation (3).

more public inputs will increase the marginal productivity of the primary factor in both the public inputs and traditional markets, and bid *up* the wage rate[18]. The subtlety lies in the intermediate and modern goods sectors. Increasing public inputs reduces the amount of the primary factor necessary for start up costs in the intermediate goods sector (equation 5), increases the number of intermediate firms (equation 18), lowers the price index of intermediate goods, and places *downward* pressure on the wage rate as multinationals substitute intermediate goods for the primary factor. For low levels of public inputs, the second effect dominates.

Again, three equilibria exist; two that are stable (0, *eH*), one that is not (*eL*). The point at which the two curves cross for the first time (*eL*) is not a stable equilibrium. For any epsilon decrease in the number of firms, it will not be profitable for the multinationals to operate in the host country. The wage they would be willing to pay would be less than the market wage; firms would exit the country and the

[Insert Figure 3]

equilibrium would be zero multinational firms (i.e. the *low-level production trap*). Any increase in the number of firms above *eL* will cause more firms to enter the country. Once the first firm enters, agglomeration effects in the intermediate goods markets and decreasing fixed costs for the multinationals both act to decrease the multinationals' average costs, making it cheaper for other firms to enter. In turn, multinationals are willing to pay a higher wage in the primary factor market. Multinationals will continue to enter until the wage they are willing to pay is again equal to the primary factor market

[18] The government imposes a lump-sum tax on the primary factor and uses the revenue to hire the primary factor away from the traditional sector and into the public inputs sector.

wage. In Fig. 3, this corresponds to *eH*[19] and is a stable equilibrium. Above *eH*, the market wage is higher than what firms are willing to pay and firms will exit.

IV. National Income

Direct subsidies to multinationals and investment in public inputs can attract multinational activity and raise wages in the home country. The pertinent question faced by decision makers is which policy will yield the greatest benefits at least cost. To analyze this question we examine national income measures under each policy prescription for a given government expenditure level. Define gross domestic product, *D(F, P)*, as the sum of the traditional sector output and wages paid to the primary factor of production from multinational and intermediate goods sectors, minus the value of public inputs provided by the government[20]:

$$D(F,P) = Y(L_Y) + (\bar{L} - L_Y)w - P\,. \tag{25}$$

Substituting equations (1), (4), and (22) into (25) and rearranging we obtain an expression for gross domestic product:

$$D(F,P) = \left\{\bar{L} - \left[(R)^{-\alpha\eta}\lambda^{\alpha\beta}(Fx)^{\beta}\delta^{\alpha}\right]^{\frac{1}{\alpha+\beta}}\right\}^{-\frac{1}{\varepsilon}} \times$$

$$\left\{\varepsilon\bar{L} - \left[(R)^{-\alpha\eta}\lambda^{\alpha\beta}(Fx)^{\beta}\delta^{\alpha}\right]^{\frac{1}{\alpha+\beta}}\right\}\left(\frac{1}{\varepsilon - 1}\right) - P\,. \tag{26}$$

[19] In Fig. 3, *eH* corresponds to 12.06 firms and a wage rate of 0.29.

[20] Writing national income in this way includes the value of output in the traditional sector, rents to the fixed factor of production, and payments to the primary factors employed in the intermediate and modern sectors.

Gross national product will be defined as gross domestic product minus any subsidy payments to multinational firms[21]:

$$G(F,P,s) = D(F,P) - sFx \ . \tag{27}$$

National income increases occur in the home country if the ratio of GNP after a policy prescription to GNP in the baseline is greater than 1. Define growth of GNP as:

$$g(F,P,s) = \frac{G(F,P,s)}{G(F,P^0,s^0)}, \tag{28}$$

where P^o and s^o represent the initial levels of public inputs and subsidy payments.

In Figure 4, equation (28) is graphed for the threshold subsidy found in equation (23)[22]. Assuming that firms are continuous, then 9.64 modern sector firms will enter the country and there is an increase in national income of 6.68% associated with a subsidy. If firms are discrete then 9 is the maximum number of firms that will enter the country and national income increases by 4.47%. Although not obvious, an examination of equation (26) reveals that even though the subsidy leads to a national income gain, for different exogenous parameters, it is possible for the subsidy to yield a national income loss.

[Insert Figure 4]

A policy of financing the provision of public inputs has a different impact on national income. To compare the effects of the two policy proposals, solve for the expenditure level under the subsidy proposal above and set it equal to the level of public

[21] Again, s in equation (27) can be thought of as a per unit subsidy payment or as a reduction in a production tax.

[22] In Figure 4, *s=0.02* and *P=0*. In Figure 5, *P=1.08* and *s=0*.

inputs such that: $\tilde{s}\tilde{F}x = \tilde{P}(L_p)$, where $\tilde{s}$ and $\tilde{F}$ are the stable equilibrium values at *eH* in Figure 4 (i.e. under the minimum subsidy policy). Setting $P = \tilde{P}$ in equations (21), (22), and (28) gives the equilibrium number of firms, wage level, and national income change under a policy of public input provision when expenditures are the same as a policy of direct subsidization.

[Insert Figure 5]

In Figure 5, notice that using the same level of expenditure on the provision of public inputs ensures that the first firm enters and a stronger positive effect is created on national income. Depending on whether firms are continuous or discrete, increases in national income are 32.5% and 25.33% respectively. This is a significant improvement over a policy of direct subsidization of multinational firms. Given a fixed expenditure level, a policy of financing public inputs dominates a policy of direct subsidization for a broad range of parameter values.

There are two important influences that lead to this result. First, as represented in equations (7) and (11), the *direct effect* of the public input decreases the average cost of multinational and intermediate goods firms by lowering the fixed costs of production. Second, the *indirect effect*, attributable to agglomeration, lowers the marginal cost for multinationals by increasing the number of intermediate firms, making intermediate goods cheaper. Direct subsidization of multinationals triggers the *indirect effect* associated with agglomeration, but at a cost, as resources leave the country in the form of subsidy payments to foreign firms. Public input provision generates the *indirect effect* as well as the *direct effect* to multinationals and intermediate goods producers and underscores a significant policy point. When there are local agglomeration externalities

and fixed costs to production, host countries can address both issues with a single policy of public input provision.

V. Sensitivity Analysis

Tables 1(a)-1(d) report sensitivity analysis when we change a few of the key parameters of the model. The four parameters under investigation are the share of intermediate goods in multinational affiliate costs (α), the elasticity of substitution between intermediate inputs (σ), the strength of agglomeration externalities (θ), and the substitution parameter between public and private fixed inputs (η). In all four tables, column (2) reports the baseline parameter values used in the analysis of the previous sections.

[Insert Table 1]

The analysis proceeds as follows. First, for each new set of parameter values the threshold subsidy in equation (24) is calculated. This is reported as the "Threshold Subsidy" in Tables 1(a)-1(d). Second, the minimum expenditure necessary to achieve the high equilibrium (such as *eH* in Figure 2) is obtained by multiplying the threshold subsidy by the number of firms that enter at the high equilibrium and output per firm, such that *Expenditure* = $\tilde{s}\tilde{F}x$. The "# of firms (subsidy)" and "Growth (subsidy)" in Tables 1(a)-1(d) report the respective number of modern sector firms that enter the host country at the high equilibrium and the resulting growth in GNP over the initial equilibrium of having no modern sector firms[23]. The "# of firms (public)" and "Growth (public)" rows report the total number of modern sector firms that present at the high

[23] For simplicity, the table reports the highest discrete number of firms rather than reporting the firms as a continuous variable.

equilibrium, such as *eH* in Figure 3, when the same expenditure spent under a subsidy policy is spent on the provision of the public input; the "Growth (public)" row gives the growth in gross national product under the public provision policy.

In Table 1(a) the share of intermediate inputs in the modern sector cost function (α) is altered holding the other parameters in the model constant. As the share of intermediates in the modern cost function rises, the benefits associated with GNP growth from a policy of public input provision is far greater than an expenditure neutral subsidy policy. This is due to the fact that public inputs create a *direct* effect on modern sector cost structures by lowering fixed cost requirements and an *indirect* effect by facilitating agglomerative externalities in the intermediate goods sector. The subsidy policy only creates the *indirect* effect. As intermediates become less important in the modern sector cost structure (smaller α), a policy of subsidy provision may be preferable to a policy of public input provision, all else equal. This statement needs qualification because it is contingent on having a fixed expenditure level. Notice in columns (3) and (4) of Table 1(a) that the number of modern sector firms under the provision of public inputs policy is zero. Since the share of intermediates in modern sector costs are declining, so too is the importance of agglomerative externalities in that sector. Therefore, the threshold level of public inputs to attract the first modern sector firm to the country is rising. Zero firms means that the total expenditure under the subsidy policy would not be enough to attract the first firm to the country if the money were instead spent on public inputs. The result

is a loss in GNP from public input provision (-6.47%) because money would be taxed out of the domestic sector to pay for a public good that is not useful[24].

In Table 1(b), sensitivity to the elasticity of substitution between intermediate inputs (σ) is examined. The results are similar to those in Table 1(a), with an expenditure neutral policy of public input provision providing greater increases in GNP than a subsidy policy for a broad range of parameter values. As the elasticity of substitution between intermediate inputs rises, market power for each intermediate producer falls, thus fewer intermediate goods producers will enter the market in equilibrium [see equation (19)]. This has two important effects, it acts to dampen agglomerative externalities and reduces the number of modern sector firms that choose to enter the country. As a result, there are fewer intermediate and modern sector firms to benefit from lower fixed costs due to the provision of the public input. With an elasticity of substitution of $\sigma = 4$, the threshold subsidy expenditure would not be enough to attract the first modern sector firm to the country and so GNP would fall if it were spent on a policy of public input provision[25].

Tables 1(c) and 1(d) allow for changes in the strength of agglomeration (θ), and the substitution parameter between public and private fixed inputs (η), respectively. The results remain the same, the expenditure neutral policy of public input provision dominates the policy of direct subsidies. The exception being column 4 in Table 1(d)

[24] Modern sector firms would not be using the public input because none of them have entered the country and intermediate goods firms would not be using the public input because without modern sector firms then an intermediate goods sector cannot exist.

[25] Again, resources would be taxed away from the primary factor and spent on an unproductive public input that failed to attract any firms.

where the threshold subsidy expenditure is not enough to attract the first modern sector firm under a policy of public input provision.

An interesting result has emerged that cannot be solved for analytically (since the threshold level of public inputs can only be solved for computationally) but is strongly suggested by the sensitivity analysis. An observational sufficient condition for a policy of public input provision to dominate a subsidy policy is that $\tilde{s}\tilde{F}x$ be greater than or equal to the threshold level of public inputs necessary to attract the first modern sector firm into the country. That is, if the resources spent on providing production subsidies to modern sector firms could instead be spent on the provision of public inputs *and* are large enough to get the first modern sector firm to enter the country, then the country will get greater benefits in terms of higher GNP levels from a policy of public input provision than by offering subsidies. This is attributed to the fact that the multinational firms will experience both *direct* and *indirect* effects on their cost structures.

It is important to reiterate though, that a policy of public input provision may not, however, always be the best policy option. Take Table 1(a) column (3) for example. In this case, a country can benefit from offering a subsidy of 0.022 per unit of output and attract 6 modern sector firms to the country. The result is an increase in GNP of 1.26%. An expenditure neutral policy of public input provision would fail to attract the first modern sector firm and the country would have wasted resources on a public input that was not productive.

VI. Conclusions

This paper has demonstrated two important aspects regarding public inputs, multinational location decisions and the linkage to endogenously arising intermediate

input markets. The first is that public inputs can influence firm cost structures in two ways: the *direct effect*, that acts to lower fixed costs of production, and the *indirect effect*, which acts to lower the marginal costs of intermediate goods. Public inputs decrease the fixed cost requirements for multinational and intermediate goods producers while at the same time facilitate agglomeration externalities in the intermediate goods sector. This is an important point to keep in mind in thinking about the effects of public input provision on multinational investment decisions and subsequent domestic growth effects.

Second, it is shown that small developing economies must achieve a threshold level of public inputs if they hope to be successful in attracting foreign direct investment. By providing the threshold level of public inputs, countries can jump from a 'low-level production trap' to a higher level of national income as intermediate goods producers arise to supply multinational firms for final goods production. Tax incentives, access to markets, and tariff jumping are but a few well documented and important influences on multinational location decisions, but as the analysis in this paper shows, adequate levels of public inputs have a significant role to play; and in many cases provide a better policy option than expenditure neutral subsidy or tax alternatives.

References

Aitken, Brian, Gordon H. Hanson, Ann E. Harrison, 1997, Spillovers, foreign investment, and export behavior, Journal of International Economics, 43, 103-132.

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

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

Clarida, Richard and Ronald Findlay, 1994, After Maastricht: Public Investment, Economic Integration and International Mobility, Economica, 61(243), 319-329.

Feehan, James P. and Mutsiumi Matsumoto, 2000, Productivity-enhancing public investment and benefit taxation: the case of factor-augmenting public inputs, Canadian Journal of Economics, 33(1), 114-121.

The Global Competitiveness Report 2000, 2000, (Oxford University Press, Geneva).

Haaland, Jan I. And Ian Wooton, 1999, International Competition for Multinational Investment, Scandinavian Journal of Economics, 101(4), 631-49.

Haufler, Andreas and Guttorm Schjelderup, 1999, Corporate Taxation, Profit Shifting, and the Efficiciency of Public Input Provision, Finanzarchiv 56, 481-489.

Haughwout, Andrew, 2001, Infrastructure and Social Welfare in Metropolitan America, Federal Reserve Bank of New York Economic Policy Review, 7(3), 1-16.

Hines Jr., James R. Ed., 2001, International Taxation and Multinational Activity (University of Chicago Press).

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

Hoffmann, Anders N., 2003, Education, Trade and Investment Liberalizations, Journal of International Economics, 60(2), 433-453.

Holtz-Eakin, Douglas, 1994, Public-Sector Capital and the Productivity Puzzle, Review of Economics and Statistics, 76(1), 12-21.

Holtz-Eakin, Douglas and Amy Ellen Schwartz, 1995, Spatial Productivity Spillovers from Public Infrastructure: Evidence from State Highways, International Tax and Public Finance, 2(3), 459-468 .

Keen, Michael and Maurice Marchand, 1997, Fiscal competition and the pattern of public spending, Journal of Public Economics, 66, 33-53 .

Kind, Hans Jarle, Karen Helene Midelfart Knarvik, and Guttorm Schjelderup, 2000, Competing for capital in a 'lumpy' world, Journal of Public Economics, 78(3), 253-274.

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

Manning, Richard, James Markusen, and John McMillan, 1985, Paying for public inputs, American Economic Review, 75(1), 235-238.

Markusen, James R., 1990, Micro-foundations of external economies, Canadian Journal of Economics, 23(3), 495-508.

Markusen, James R., 1995, The Boundaries of Multinational Enterprises and the Theory of International Trade, Journal of Economic Perspectives, 9(2), 169-189.

Markusen, James R. and Anthony J. Venables, 1999, Foreign Direct Investment as a Catalyst for Industrial Development, European Economic Review, 43(2), 335-356.

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

McMillan, John, 1979, A Note on the Economics of Public Intermediate Goods, Public Finance, 34(2), 293-299.

Morrison, Catherine J. and Amy Ellen Schwartz, 1996, State Infrastructure and Productive Performance, American Economic Review, 86, Issue 5, 1095-1111.

Nadiri, Ishaq M. and Theofanis P. Mamuneas, 1994, The Effects of Public Infrastructure and R&D Capital on the Cost Structure and Performance of U.S. Manufacturing Industries, Review of Economics and Statistics 76(1), 22-37.

Röller, Lars-Hendrik, and Leonard Waverman, 2001, Telecommunications Infrastructure and Economic Development: A Simultaneous Approach, American Economic Review, 91(4), 909-923.

Figure 1
"Initial State of the Economy"

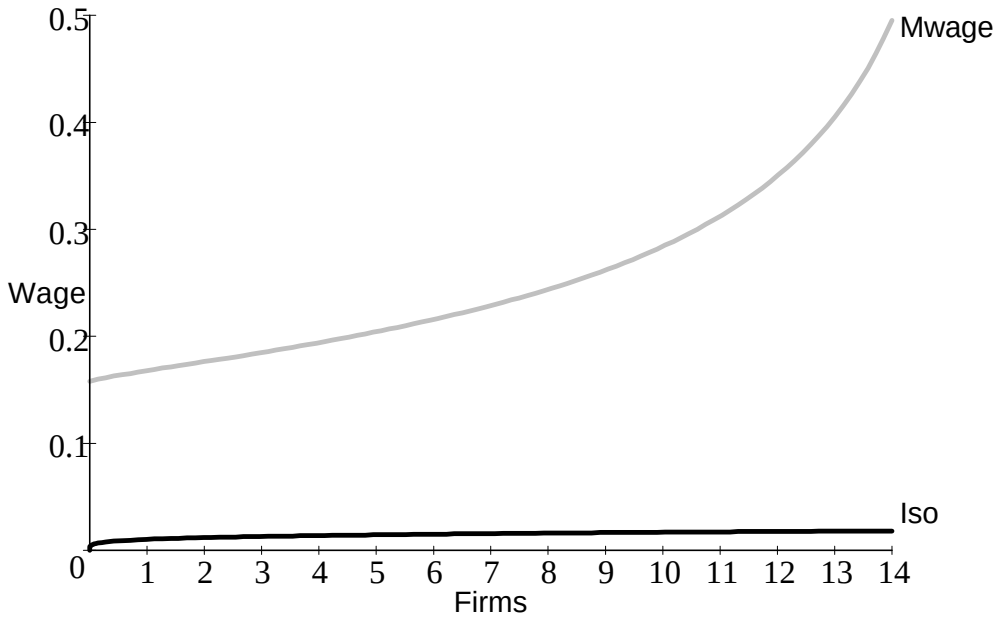

Figure 2
"State of the Economy with a subsidy policy"

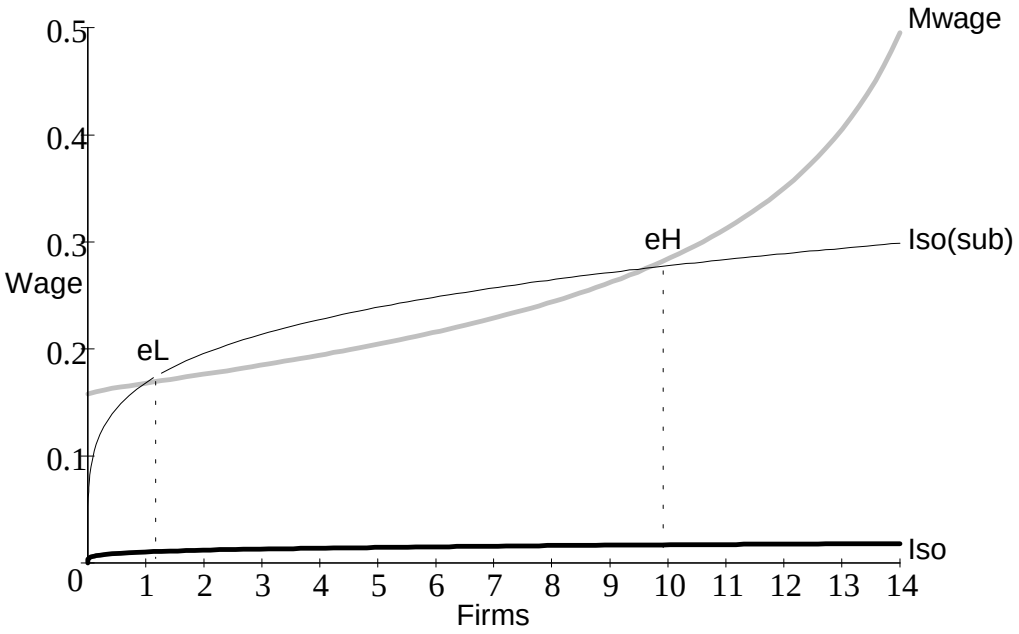

Figure 3
"State of the Economy with public input provision"

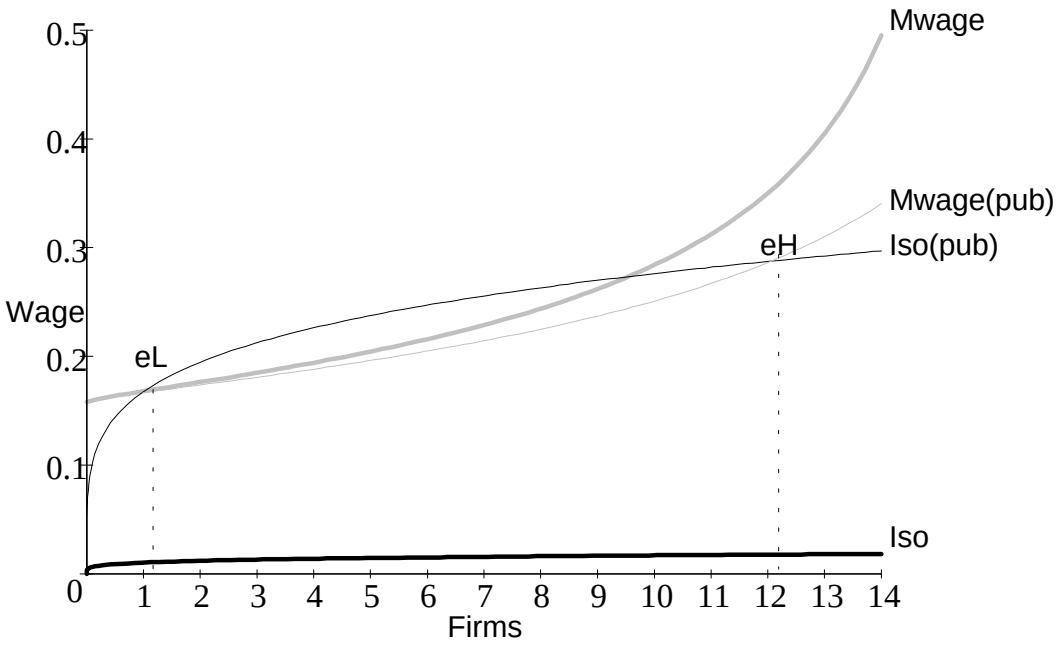

Figure 4
"GNP with a subsidy policy"

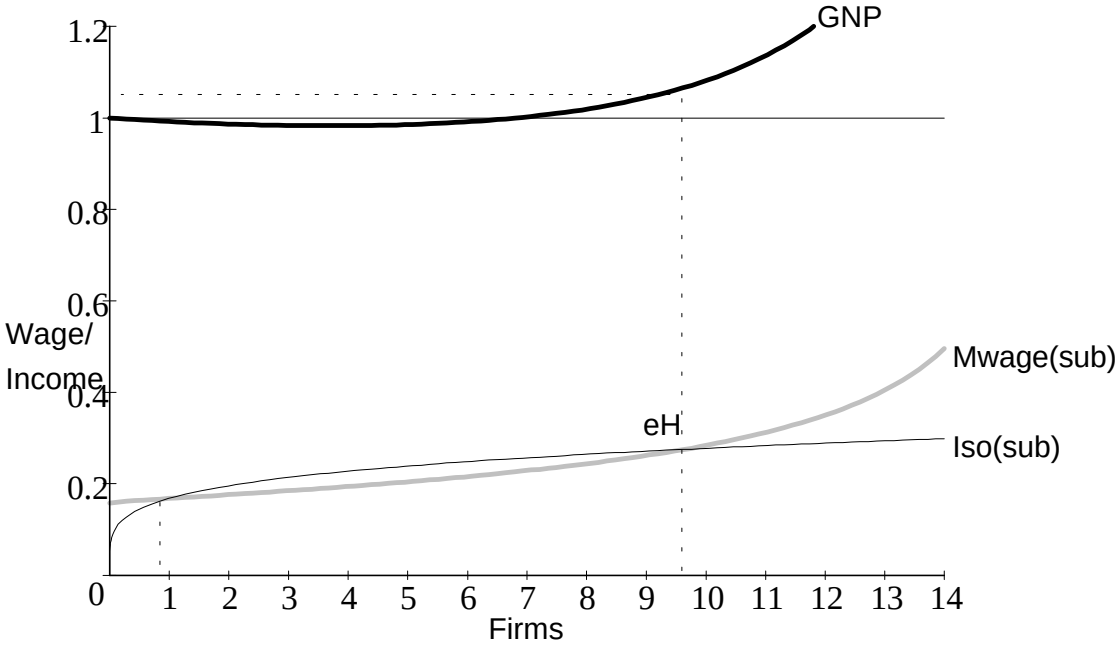

Figure 5
"GNP with public input provision"

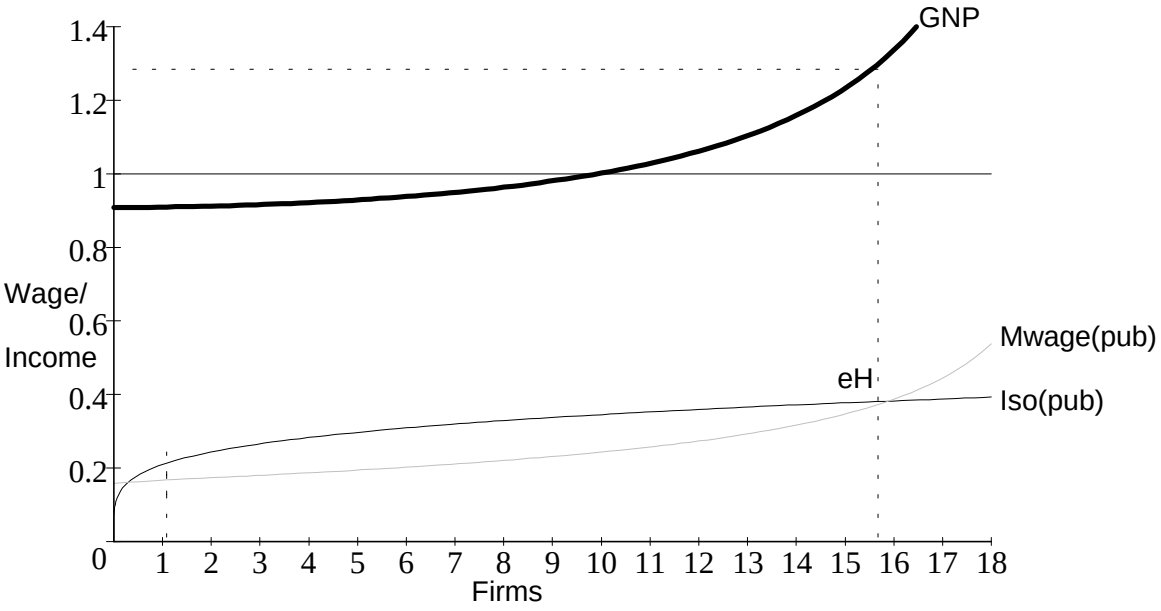

Table 1
"Sensitivity analysis"

TABLE 1(a)

Changing the share of intermediate inputs in multinational costs

	(1)	**(2)**	(3)	(4)
	α=0.8, η=1, σ=3, θ=0.1	**α=0.5, η=1, σ=3, θ=0.1**	α=0.4, η=1, σ=3, θ=0.1	α=0.3, η=1, σ=3, θ=0.1
Threshold subsidy	0.015	**0.02**	0.022	0.024
Expenditure	2.53	**1.08**	0.82	0.43
# of firms (subsidy)	28	**9**	6	3
Growth (subsidy)	43.12%	**4.47%**	1.26%	-1.17%
# of firms (public)	59	**15**	0	0
Growth (public)	237.43%	**25.33%**	-6.47%	-17.38%

TABLE 1(b)

Changing the elasticity of substitution between intermediate inputs

	(1)	**(2)**	(3)	(4)
	α=0.5, η=1, σ=1.8, θ=0.1	**α=0.5, η=1, σ=3, θ=0.1**	α=0.5, η=1, σ=3.3, θ=0.1	α=0.5, η=1, σ=4, θ=0.1
Threshold subsidy	0.014	**0.02**	0.021	0.022
Expenditure	5.54	**1.08**	0.882	0.66
# of firms (subsidy)	66	**9**	7	5
Growth (subsidy)	136.26%	**4.47%**	1.72%	0.00%
# of firms (public)	274	**15**	9	0
Growth (public)	142.05%	**25.33%**	3.92%	-5.22%

TABLE 1(c)

Changing the strength of agglomeration externalites

	(1)	**(2)**	(3)	(4)
	α=0.5, η=1, σ=3, θ=0.01	**α=0.5, η=1, σ=3, θ=0.1**	α=0.5, η=1, σ=3, θ=0.2	α=0.5, η=1, σ=3, θ=0.3
Threshold subsidy	0.02	**0.02**	0.019	0.019
Expenditure	0.84	**1.08**	1.254	1.71
# of firms (subsidy)	7	**9**	11	15
Growth (subsidy)	1.34%	**4.47%**	7.45%	18.03%
# of firms (public)	10	**15**	20	28
Growth (public)	6.52%	**25.33%**	52.16%	107.46%

TABLE 1(d)

Changing the substitution parameter between public and private fixed inputs

	(1)	**(2)**	(3)	(4)
	α=0.5, η=1.1, σ=3, θ=0.1	**α=0.5, η=1, σ=3, θ=0.1**	α=0.5, η=0.8, σ=3, θ=0.1	α=0.5, η=0.5, σ=3, θ=0.3
Threshold subsidy	0.02	**0.02**	0.019	0.018
Expenditure	1.08	**1.08**	1.03	1.08
# of firms (subsidy)	9	**9**	9	10
Growth (subsidy)	4.45%	**4.47%**	4.56%	8.17%
# of firms (public)	16	**15**	12	0
Growth (public)	31.99%	**25.33%**	9.70%	-8.39%